



Less noise • More sound

RT-2X

***Expandable Audio Test System
For Analog & Digital Signals***

Reference Manual

Refers to firmware revision 7.10 or higher

NOTE	Firmware version 5.20 or higher runs only on <i>RT-2X</i> units with S/N > 75. Older <i>RT-2X</i> units must be upgraded – please contact NTI.

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V 2.2.2 / Dec. 2007 / MBe



CE Declaration of Conformity

We, the manufacturer

NTI AG
Im alten Riet 102
FL-9494 Schaan

hereby declare that the product

Product Name Rapid-Test

Model Number RT-2X

Year of Construction 1998

conforms to the following standards or other normative documents

Harmonized Standards EN 61326-1
FCC Part 15, according to ANSI C63.4-1992

This declaration becomes void in case of any changes on the product without written authorization by **NTI**.

Date Schaan, 14. December 1999

Signature

Position of Signatory Technical Director



Samples of this instrument have been tested and found to conform to the statutory protective requirements. Instruments of this type thus meet all requirements to be given the CE mark.

Installation

Unpacking

RT-2X has been carefully packed by **NTI** to avoid damages during transportation. Should the box show severe damages, please immediately check the instrument inside for external impacts. In case of any visible damage, please do not send the instrument back but contact your local **NTI** dealer or the carrier to avoid loss of claims for replacement.

Rack Mount

RT-2X is designed to mount in a 19" Rack and occupies only two units of height or rack space (3.5"). Please allow at least 2" additional depth at the back for all necessary connectors.

Make sure there is enough fresh air circulation through the cooling slots and around the unit, and do not place **RT-2X** besides high temperature devices such as power amplifiers to avoid overheating. The specified temperature range is 5° C – 45° C (40° F – 110° F), whereby the humidity must not exceed 90 % R.H. non-condensing.

AC Power Connection

Before connecting the instrument to mains power make sure that the selected voltage matches the one of your area. *RT-2X* can operate from 100 VAC, 120 VAC and 230 VAC sources.

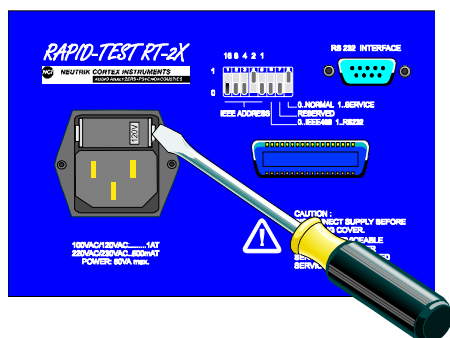


Fig 1 Voltage Selector

To change the mains voltage of *RT-2X*, remove the power cable and open the flap of the fuse holder at the rear side of *RT-2X*. Press a small screwdriver into the slot to open the flap as shown in **Fig 1** or ruin your fingernails.

Take out the drum and insert it in the new position, so that the proper voltage indicator points towards you. At the same time, replace the mains fuse with the proper current rating:

- 1 A slow for 100 / 120 VAC
- 500 mA slow for 230 VAC

After selection of the correct mains voltage, close the flap and insert the power cable.



RT-2X is connected with earth through the ground wire of the mains power cable. This connection is essential for safe operation and must not be interrupted.

Mains Power Cable

The mains power cable that is included to the unit has an unconnected end with three colored leads. Connect these leads to an appropriate mains plug as follows:

- Brown → Live (AC)
- Blue → Ground
- Yellow-Green → Earth

Warranty

Limited Warranty

NTI guarantees the *RT-2X* system and its components against defects in material or workmanship, for a period of one year from the date of original purchase, and agrees to repair or replace any defective unit at no cost for parts or labor.

Important

This warranty does not cover damage resulting from accident, misuse or abuse, lack of reasonable care, the affixing of any attachment not provided with the product, loss of parts or connecting the product to another but the specified receptacles. This warranty is void unless service or repairs are performed by an authorized **NTI** service center.

In case of a damage, pack your *RT-2X* system in the original box and take or ship prepaid the unit to your nearest **NTI** service center. Transport damages are not covered by this warranty. Be sure to include your sales invoice as proof of purchase date.

Note

No other warranty, written or verbal, is authorized by **NTI**. Except as otherwise stated in this warranty, **NTI** makes no representation or warranty of any kind, expressed or implied in law or in fact, including, without limitation, implied merchantability or fitness for any particular purpose and assumes no liability, either in tort, strict liability, contract or warranty for products.

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WARNING	Read this manual and especially chapter <i>Installation</i> (p. 3) carefully before operating the instrument. Important information about the proper mains voltage selection and fuse rating are given therein. Never open, modify or try to repair this instrument unless properly instructed by an authorized service technician.



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AC Coupling

NOTE This feature is only available if the LCL/RL option is installed.

The input section of *RT-2X* can be AC coupled (i.e. DC de-coupled) for applications where the test signal is superposed with a DC voltage. If this feature is activated, it applies for all available *RT-2X* measurement functions, regardless whether the test signal is a multitone burst, a stepped sweep or a chirp (i.e. gliding sweep).

Commands **OUTPut[1|2]:ACCOupling [OFF|ON]** and **INPut[1|2]:ACCOupling [OFF|ON]** switch the AC coupling circuit of the *RT-2X* output and input ON and OFF.

The status of the AC coupling is stored in the non-volatile memory, i.e. *RT-2X* re-activates the last active status after switching the unit OFF and ON.

Block Diagrams

Generator

RT-2X contains a completely independent two-channel arbitrary generator. The digital section has its own high level microprocessor enabling the system to react flexibly to external events, communicate with various interfaces and reprogram the sample counter for the arbitrary generator

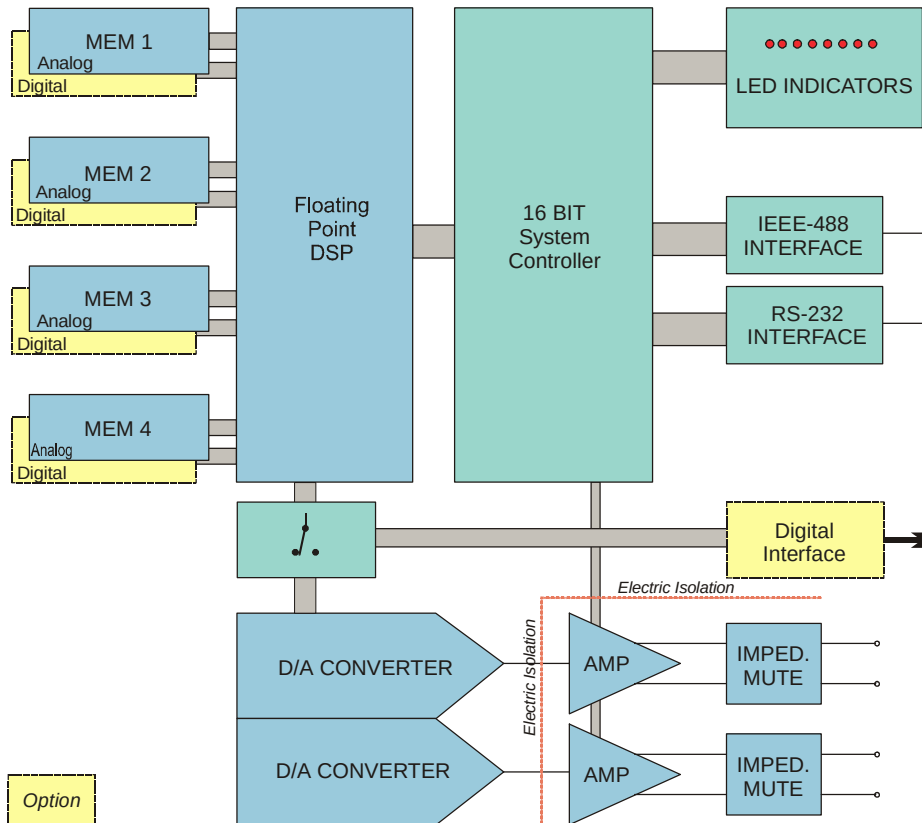


Fig 2 Block Diagram Generator

Digital Section

The CPU reads the samples out of a non-volatile memory. The memory block provides capacity for eight independent test signals, each with 16 bit resolution and any length as defined in **Table 16**. Space is also provided for the header of each signal. The master clock is derived from a high precision crystal. The digital interface (ISDN or T1) is connected directly with the arbitrary logic module.

Analog Section

The two-channel analog output signal after the D/A converters is fed into a reconstruction filter, cutting off all frequencies above 20 kHz. On its way the signal also passes through an electrical isolation to keep the complete analog output section floating. The programmable output amplifier offers a balanced signal with 150 Ω output impedance (unbalanced 75 Ω) at any level in steps of 0.1 dB between -60 dBVp to +29 dBVp.

Analyzer

The *RT-2X* analyzer consists of a two channel analog input stage that converts the input signals into digital data. Next, the DSP calculates a FFT with twice the blocklength of the defined multitone signal and provides the required test result according to the individual demands of the user.

The analyzer also allows weighting the measurement results according to different standards.

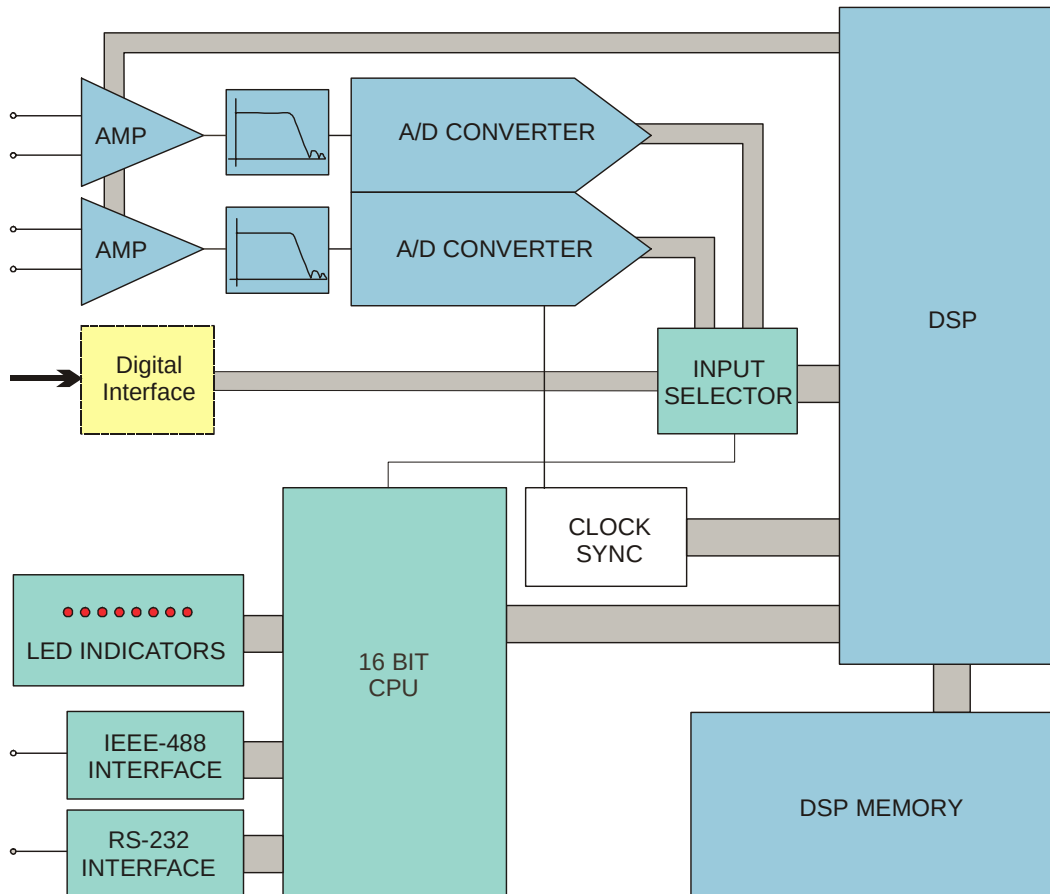


Fig 3 Block Diagram Analyzer

Digital Section

The digital section mainly consists of the DSP and a logic circuitry programmed into a FPGA. A demultiplexer, controlled by the CPU, either directs the A/D converted analog input signal or the ISDN signal to the DSP. The DSP is used for all calculations - especially the FFT - and to control the range setting of the analog input amplifiers. The DSP is connected via a bus to the central processing unit, which manages all communication to the PC and controls the system bus.

Analog Section

RT-2X features two independent analog input stages with completely independent ranging facilities. At the rear panel, balanced 4 mm 'banana' and BNC connectors provide access to the input section with input impedance of 100 k Ω . Levels can be handled from -60 dBVp to +40 dBVp with full dynamic range.

Commands

Command Structure

To control *RT-2X*, send the commands to the unit in ASCII format, either through the IEEE-488 or RS232 interface (verify the DIP-switch setting as shown on p. **182, 254**).

Under RS232 control, every command transmission from the PC to *RT-2X* has to be terminated with a "CR LF" (Carriage Return Line Feed), whereby the answers of *RT-2X* are terminated with "LF" (Line Feed).

The full IEEE-488.1 function set is implemented, but not all IEEE-488.2 commands.

Function	Implemented	Note
Source handshake	SH1	Complete capability
Acceptor handshake	AH1	Complete capability
Talker	T6	No talk-only mode
Talker (extended)	TE0	No capability
Listener	L4	No listen-only mode
Listener (extended)	LE0	No capability
Service request	SR1	Complete capability
Remote local	RLO	Only local lockout
Parallel poll	PP0	No capability
Device clear	DC1	Complete capability
Device trigger	DT0	No capability
Controller	C0	No capability

Table 1 IEEE 488.1 Compatibility

The control commands are divided into six groups (i.e. "subsystems").

Subsystem	Function
SYSTem	System status commands
INOUT	Interface & operation mode status
OUTPut	Generator control commands
INPut	Analyzer control commands
MEASurement	Measurement result query commands
*	Device status commands

Table 2 Subsystem Definition

- *RT-2X* accepts only the *short* or the *exact full* form of the commands. Sending a command in another form will generate an error.
- In the command list, the CAPITAL letters indicate the *short* form. However, *RT-2X* accepts either lowercase *and* UPPERCASE letters, i.e. it is not case sensitive.
- If several commands shall be transmitted to the unit together, they must be separated by semi-colons (";")

Command Notation & Descriptive Symbols

The *RT-2X* command descriptions use headings to divide the syntax information into easily readable parts. These headings and their meaning are listed below. If a heading does not apply to a command, it does not appear in the command syntax description.

Usage	What the command does.
Availability	The mode and system settings that must be active to execute the command.
Parameter	The parameters to be set and their types (<i>integer</i> , <i>float</i> ¹ or <i>string</i>).
Answer	The possible answer(s) to a query command.
Default	The default value(s) of the parameter(s) that will be applied after a system RESET.
Unit	The available units of the parameters.
Query	The query instruction that returns the parameter value(s) of the corresponding command.
Examples	Command examples are provided here. Short form and lowercase characters randomly to remind the reader that both forms are allowed.
Explanation	Additional explanations, hints and note.

Table 3 Command Headings

The subsequent table lists the symbols that are used for the command description.

Symbol	Description
:	Colons separate elements of a RT-2X command.
[]	Square brackets enclose the <i>list of available parameters</i> , out of which 1 parameter must be selected.
!	A vertical line reads as an "OR", i.e. this sign separates <i>alternative</i> parameters.
< >	Triangle brackets enclose the <i>variable parameters</i> that must be set to a user-defined value.
{ }	Braces have the same meaning as triangle brackets ("< >"), except that the enclosed parameters can be included <i>several</i> times.
,	Commas separate arguments in an arguments list.
?	The question mark indicates a <i>query</i> command.
;	Semi-colons must be used to separate commands in a command list.
()	Round brackets enclose comments.
 →	The string is sent from the PC to RT-2X.
→ 	The string is returned from RT-2X to the PC.

Table 4 Descriptive Symbols

¹ Examples for float numbers: 1.23E-03 = 0.00123; 0.10E00 = 0.1; 0.3E+02 = 30;



SYSTem Subsystem

SYSTem:ERRors?

Usage Queries the error message numbers that occurred since the last query, PowerUp or RESET.

Availability Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed).

Answer {Error_No}, integer (error number)

Command errors:

- 100 No subsystem separator found (':')
- 101 No subsystem found
- 102 No command separator found (':')
- 110 No SYSTem command found (e.g. RESET)
- 120 No INPut command found (e.g. LINK)
- 121 No INPut[1|2] command found (e.g. RANGE)
- 130 No OUTPut command found (e.g. FLOAT)
- 131 No OUTPut[1|2] command found (e.g. LEVEL)
- 132 No MTONE command found (e.g. START)
- 133 No TRIGger command found (e.g. ARMED)
- 134 No THREShold command found (e.g. DELAY)
- 140 No MEASurement command found (e.g. LEVEL)
- 141 No MEASurement[1|2] command found (e.g. DIST)
- 142 No NOISe command found (e.g. UNIT)
- 143 No FREQuency command found (e.g. SElective)
- 144 No WINDows command found (e.g. SElective)
- 145 No device status command found (e.g. *OPC)
- 146 No RETurnloss command found (e.g. COMPLex)
- 147 No EchoReturnLoss command found (e.g. COMPLex)
- 148 Return loss measurement status parameter string expected (e.g. BALANCED)
- 149 Trigger configuration parameter expected (e.g. LOOSE)
- 150 No parameter expected
- 151 Float parameter expected
- 152 Float parameter out of range (e.g. INP:RANG -5E3)
- 153 Integer parameter expected
- 154 Integer parameter out of range (e.g. OUTP:MTON:START 0)
- 155 String parameter expected (e.g. "ON")
- 156 "ON" or "OFF" string expected
- 157 Filter parameter expected (e.g. "CCIT")
- 158 Location parameter expected (e.g. "FRONT")
- 159 Sync parameter expected (e.g. "EXTERNAL")
- 160 String too long
- 161 Wrong No. of samples (512, 1024, 2048, 4096, 8192 or 128, 256, 512, 1024, 2048)
- 162 Corresponding frequency or binnumber out of range
- 163 Phase value out of range
- 164 Wrong number of multitone parameters
- 165 IEEE bus error
- 166 Output Buffer overflow
- 167 Bins must be in increasing order
- 168 Too many parameters
- 169 Integer parameter must be in increasing order
- 170 Illegal unit
- 171 Binlevel weighting parameter out of range (-60 dB to 0 dB)
- 172 Missing BinLevel reference: minimum 1 weighting factor per chn. must be set to 0 dB
- 173 No valid signal identifier (e.g. "OUTPUT:MTONE:ACTIVE 5" in 48 kHz mode)
- 174 No channel selection allowed (e.g. "INPUT:TRIGGER:TIMEOUT ")
- 175 No valid string or float & unit parameter (e.g. MEAS:PURE:STE:REF:LIMIT1 10)
- 176 No valid string or float+integer parameter (e.g. OUTPut:ARBSIN 1000.0,350.0)



- 179 Command is only available in 48 kHz mode
- 180 Option not installed
- 181 Command not executable in LCTL mode
- 182 Command not executable after command INPut:TRIGger:ARMed
- 183 Command not executable in LCL mode
- 184 Command not executable in RL mode
- 185 Command not executable, change to OFF mode first
- 186 Caps board not installed
- 187 Command not executable while unit is generating an arbitrary sine signal
- 190 Not available with this HW Version
- 191 Not available with this SW Version
- 192 Not available with RS232 interface
- 193 Command not available
- 194 Stepped Sweep license required – please contact NTI
- 199 Unexpected error occurred – please report to NTI

Device errors:

- 203 No trigger detected.
- 204 No stereo trigger detected. (e.g. phase measurement)
- 205 Measurement function needs ≥ 1 same bin on both channels
- 206 Measurement function needs ≥ 1 different bin on both channels
- 207 Measurement function needs same set bins on both channels
- 208 No signal exceeded threshold
- 209 No signal sampled
- 210 Analyzer overload
- 211 The queried measurement doesn't support filtering – turn off active input filter
- 212 Measurement function needs same weighting factors on both channels
- 213 Measurement function needs same phase values on both channels
- 214 Wrong stepped sweep acquisition mode – activate mode DISTORTION
- 215 Measurement function needs valid steepness reference – active reference is not valid
- 216 Measurement function needs same reference & measurement signal length
- 217 Acquired stepped sweep signal is not compatible with measurement function
- 218 Acquired multitone signal is not compatible with measurement function
- 219 Acquired steepness signal is not compatible with measurement function
- 220 Replace backup-battery
- 230 Hardware and software version do not match
- 240 Minimum one external measurement required (e.g. SYNC EXTNoheader)
- 241 No external measurement with digital input source
- 242 Internal Link not allowed with digital input sources – internal link was turned off
- 243 Measurement function only available in analog operation
- 245 No valid frequency within selected bandwidth
- 246 Measurement not possible – signal bins defined too close to each other (choose higher blocklength or change signal bins)
- 250 DTMF receive buffer overflow
- 255 RS232/GPIB interface output buffer overflow
- 256 RS232/GPIB interface input buffer overflow
- 261 Channel 2 must be looped for complex return loss measurement on channel 1
- 262 Channel 1 must be looped for complex return loss measurement on channel 2
- 263 Wrong impedance setting on channel 2 for complex return loss measurement on channel 1 – set 50 Ω output impedance and 100 k Ω input impedance on channel 2
- 264 Wrong impedance setting on channel 1 for complex return loss measurement on channel 2 – set 50 Ω output impedance and 100 k Ω input impedance on channel 1
- 265 Measurement function requests same range setting on both channels
- 266 Measurement function requests same output level setting on both channels
- 267 No filter allowed with this measurement
- 268 Wrong external balanced connection – swap HI and LO input of active channel
- 269 Overtemperature detected – disconnect external voltage source
- 280 Entered license code not accepted
- 281 No valid license installed
- 290 No different digital sources for Input and Output allowed

*RT-2X ISDN interface command interpretation errors:*

- 301 Mode parameter expected (e.g. 48KSAMPLINGRATE)
- 302 Valid source parameter expected (e.g. ANALOG)
- 303 ISDN parameter expected (e.g. LAW)
- 304 Law parameter expected (e.g. OFF)
- 305 S0 bus was not activated during the last signal acquisition
- 306 No range setting at ISDN input source
- 307 No ISDN source available in 48 kHz mode
- 308 No INOUT command
- 309 No S0BUS parameter
- 310 No continuous output in ISDN mode

RT-2X impedance errors:

- 311 Invalid impedance value
- 312 Selected impedance hardware not installed
- 313 Required reference impedance hardware not installed
- 321 Input voltage on Chn1 too high – input section switched to loop & high impedance
- 322 Input voltage on Chn2 too high – input section switched to loop & high impedance
- 325 Customer impedance reference values lost. Invalid dBm output or measurement with customer impedance
- 326 ZREF query expected e.g. CUST1?
- 330 PLL unlocked occurred during signal output
- 340 Modification of weighting factors of ERL,SRL-Lo or SRL-Hi signal not allowed

RT-2X E1/T1 errors:

- 350 Frame error detected – 2 out of 6 framing bits [Ft(D4) or FPS(ESF)] received in error
- 354 Last re-sync caused a change of frame or multiframe alignment
- 356 Receive data stream violates pulse density requirement (according to ANSI T1.403)
- 357 Transmit data stream violates pulse density requirement (according to ANSI T1.403)
- 360 Signaling buffer overflow
- 361 Signaling buffer empty
- 370 T1: Blue Alarm (AIS)
 - SET condition: if 5 or fewer zeros are received over a 3 ms window
 - CLR condition: if 6 or more zeros are received over a 3 ms windowE1: AIS
 - SET condition: fewer than 3 zeros in two frames (512 bits)
 - CLR condition: more than 2 zeros in two frames (512 bits)
- 371 T1: Red Alarm (RCL)
 - SET condition: if 192 consecutive zeros are received
 - CLR condition: if 14 or more ones out of 112 possible bit positions are receivedE1: RCL (Receive Carrier Loss)
 - SET condition: 255 consecutive zeros received
 - CLR condition: at least 32 ones in 255-bit times are received
- 372 T1: Yellow Alarm (RAI)
 - SET condition D4 T1: if bit 2 of 256 consecutive channels is set to 0 for ≥ 254 times
 - SET condition D4 J1: if the 12th framing bit is set to 1 for two consecutive times
 - SET condition ESF: if 16 consecutive patterns of 00FF appear in the FDL
 - CLR condition D4 T1: if bit 2 of 256 consecutive channels is set to 0 for ≤ 254 times
 - CLR condition D4 J1: if the 12th framing bit is set to 0 for two consecutive times
 - CLR condition ESF: if ≤ 14 patterns of 00FF out of 16 possible appear in the FDLE1: NONE
- 373 T1: NONE
 - E1: RRA (Receive Remote Alarm)
 - SET condition: bit 3 of nonalign frame set to 1 for three consecutive times
 - CLR condition: bit 3 of nonalign frame set to 0 for three consecutive times
- 374 T1: NONE
 - E1: RDMA (Receive Distant Alarm)
 - SET condition: bit 6 of time slot 16 in frame 0 set for two consecutive multiframes
 - CLR condition: -



- 375 E1/T1: Loss Of Sync – input is not synchronized to the receive data stream
- 391 PCM: TX-FS LOSS occurred – no valid FrameSync signal detected at TX-FS
- 392 PCM: RX-FS LOSS occurred – no valid FrameSync signal detected at RX-FS
- 393 PCM: BCLK frequency out of range – no valid clock freq. detected at BCLK Master

System errors:

- 400 RS232 parity error
- 401 RS232 overrun error – character in input buffer overwritten
- 402 RS232 framing error – no valid stop bit detected (e.g. wrong Baudrate, no stopbit...)
- 410 RS232 transmitting timeout /* OUT OF ORDER */
- 420 IEEE bus error
- 430 Analog output & input calibration values lost – recalibrate device
- 431 LCL calibration values lost – recalibrate device
- 438 Steepness reference values lost – please report to NTI
- 439 Amplitude shaping values lost – please report to NTI
- 440 All installed licenses lost – please report to NTI
- 450 Unexpected interrupt occurred – please report to NTI
- 451 Unexpected command occurred – please report to NTI
- 452 DSP memory failure – please report to NTI
- 453 DSP not running – please report to NTI
- 455 E1/T1/PCM FPGA configuration failed – please report to NTI
- 456 E1/T1 framer not found – please report to NTI
- 460 RT-1M command that can not be executed with RT-2X
- 499 The current firmware version does not work on this hardware – please contact NTI

PureSound errors:

- 501 No valid chirp parameter (e.g. FSTART)
- 502 No valid PureSound™ command
- 503 No valid STEepness command
- 504 No valid REFeRence command
- 505 Illegal reference selection (A or B)
- 506 Correlation steepness reference not valid
- 507 No valid clicks command
- 508 No valid varlimit Command
- 509 No valid RMS level command
- 510 No valid PureSound™ mode
- 515 Not valid in PureSound™ mode RNB or CORRelation
- 516 Not valid in PureSound™ mode RNB
- 517 Not valid in PureSound™ mode CORRelation
- 518 Not valid in PureSound™ mode OFF
- 520 Not valid in PureSound™ mode RNB or CORRelation – specific channel required (e.g. INPut[1|2]:TRIGger:ARMed)
- 521 Not valid in PureSound™ mode OFF – specific channel not allowed (e.g. INPut[1|2]:TRIGger:ARMed)
- 530 Number of reference values does not match with previous band
- 531 Transmitted bands are not consecutive
- 532 Parsing error in reference values
- 533 Number of reference values does not match with set length
- 535 Chirp start- or stop-frequency too high
- 536 "EXTENDED" or "NORMAL" string parameter expected
- 540 No valid steepness varlimit parameter (e.g. ENABLE)
- 541 xValues for variable steepness limits must be in an increasing order
- 542 Wrong number of variable steepness limits
- 543 Not valid with variable steepness limits set – disable variable steepness limit of this band first
- 544 Not valid with constant steepness limits set – disable constant steepness limit of this band first

*Stepped sweep command errors:*

- 550 No valid STEPped sweep command (e.g. RMSLEVEL)
- 551 No valid settling command (e.g. ACTIVE)
- 552 No valid RMS level command found (e.g. UNIT)
- 553 No valid PHASe command found (e.g. UNIT)
- 555 Stepped sweep start/stop frequencies too close
- 556 No valid smoothing command (e.g. RESOLUTION)
- 557 No valid distortion command (e.g. HARMONIC?)
- 558 No valid THDN / HARMONIC command (e.g. UNIT)
- 562 Wrong number of stepped sweep parameters
- 563 No valid acquisition mode parameter (e.g. RMSLEVEL)
- 565 No valid settling mode parameter (e.g. NORMAL)
- 566 No valid settling active parameter (e.g. CHANNEL1)
- 567 No valid settling algorithm parameter (e.g. EXPONENTIAL)
- 568 No valid settling type parameter (e.g. RMSLEVEL)
- 569 Settling type not valid in acquisition mode RMSLEVEL
- 570 No valid amplitude shape paramter (e.g. ENABLE)
- 571 Amplitude shaping parameters are not valid for the actual system settings (e.g. wrong number of #Steps)

Loudness command errors:

- 580 No valid Loudness command (e.g. SLR, RLR)
- 581 Acoustical loudness measurement not available in D-D operation

Internal errors:

- 600..799 Service required – please report to NTI

RT-2X E1/T1 command errors:

- 801 T1 command expected
- 809 Slotnumber 16 is reservated for signaling only
- 810 Slotnumber out of range (0..23)
- 811 Slotnumbers Chn1 & Chn2 equal
- 812 No T1 source in 48kHz mode
- 813 START or STOP expected
- 814 No T1 mode (D4|ESF)
- 815 No T1 linecode
- 816 No link parameter (e.g. LOCAL)
- 817 No LoopBack parameter
- 818 No Signaling parameter
- 819 No T1 clocksource
- 820 TX signaling timestamps not increasing
- 821 TX signaling must be enabled
- 822 Only even counts in D4 framing mode
- 825 Clksource INTernal not allowed in oopback mode payload or remote

RT-2X E1 command errors:

- 830 No E1 source in 48k mode
- 840 E1 command expected
- 841 No valid E1 mode parameter (e.g. CAS|CAS&CRC4)

RT-2X PCM command errors:

- 850 PCM command expected (e.g. SLOTNUMBER)
- 851 No PCM source in 48k mode
- 855 PCM wordlength not possible for actual BCLK mode
- 856 PCM slotnumber out of range
- 857 PCM wordlength not allowed in actual PCM mode
- 858 PCM comand Law not allowed for actual DataWordlength

*RT-2X E1 T1 PCM command errors:*

- 880 T1 command not allowed with actual active digital interface type (E1 or PCM)
- 881 E1 command not allowed with actual active digital interface type (T1 or PCM)
- 882 PCM command not allowed with actual active digital interface type (E1 or T1)

RT-2X LCL/RL command errors:

- 915 Command not valid outside RL mode
- 920 No valid LCL status parameter
- 925 Command only executable in LCL mode
- 926 Command not executable if LCL mode OFF
- 927 Command only executable in LCTL mode
- 930 No valid LCL parameter
- 931 LCL/LCTL/RL mode change not permitted with external voltage divider ratio $\neq 1.0$
- 935 No valid RL parameter
- 937 Wrong signal selected for ERL or SRL (hi/lo) measurement
- 938 Can not overwrite an ERL or a SRL signal

RT-2X LCL/RL device errors:

- 940 An error occurred during calibration. Please report to NTI
- 970 Command is only available for channel 1
- 975 Wrong INPut:SOURce or OUTPut:SOURce selected

Example  → System:Errors?
 →  130, 203, 204

Explanation If no error(s) have occurred, a "0" is returned. In any other case, the buffered list of error numbers is returned. The error buffer is cleared after each query.

SYSTem:INformation?

Usage Queries the manufacturer, hardware version, serial number and firmware revision of the system. Compatible with SCPI <*IDN?> command.

Availability Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed).

Answer NEUTRIK, string (manufacturer)
 RT2X, string (instrument type)
 <S_No>, integer (serial number)
 <FW_Rev> float (firmware revision)

Example  → System:Information?
 →  NEUTRIK, RT2X, 0123, 6.11

SYSTem:LiCense?

Usage	Queries the type of license and its status on RT-2X.
Availability	Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed).
Answer	<License> [n DAYS PERMANENT] string [integer&string string] (n = 1 – 8190)
Examples	 → System:License?  → PURESOUND 30 DAYS  → SYST:LIC?  → RTATS PERMANENT
Explanation	NTI provides several PC-software packages for turnkey test solutions with RT-2X, whereby the latter must be activated with an individual license key. Ask you NTI agent for further information.

SYSTem:MODE [8Ksamplingrate|48Ksamplingrate]

Usage	Sets the sampling rate (fs) to either 8 kHz or 48 kHz.
Availability	Normal mode (<u>not</u> available if the analyzer is armed), whereby the 48Ksamplingrate is only available in A-A operation.
Parameter	[8Ksamplingrate 48Ksamplingrate] string (8 kHz 48 kHz)
Default	(the last active state; factory default = 48KSAMPLINGRATE)
Query	SYSTem:MODE?
Examples	 → SYST:MODE 8k  → System:Mode 48Ksamplingrate
Explanation	Analysis in A-A operation is available with either 8K or 48K, whereby analysis in A-D, D-A or D-D operation (with ISDN or E1/T1/PCM option) is only available with 8k. The max bandwidth in the 8K mode is 20 Hz – 4 kHz *, and 20 Hz – 20 kHz in 48k mode. The status of the SYSTem:MODE is kept in the non-volatile memory of RT-2X.

* See filter characteristic shown on p. 179

SYSTem:MODE?

- Usage** Queries the actual sampling rate of the unit.
- Availability** Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed).
- Answer** [8KSAMPLINGRATE | 48KSAMPLINGRATE] *string* (8 kHz | 48 kHz)
- Example**  → SYSTem:MODE?
→  48KSAMPLINGRATE
- Explanation** 8Ksamplingrate is available for A-A, A-D, D-A and D-D operation (with ISDN or E1/T1 /PCM option), whereby 48Ksamplingrate is only available for A-A operation.

SYSTem:RESet

- Usage** Executes a system RESET. All previously changed command parameters are re-set to their default values. Error queue is cleared.
- Availability** Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed).
- Examples**  → SYST:RES
 → SYSTEM:RESET
- Explanation** The RESET command initializes the complete instrument including the IEEE interface. Commands that are in the command buffer, or those that are entered shortly after the RESET can be deleted by the RESET command and are therefore not executed.

INOUT Subsystem

INOUT:E1:ALARM?

Usage	Queries the E1 alarm messages that have occurred since the last query or PowerUp (p. 175).		
Availability	Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed), whereby the E1/T1 interface must be installed.		
Answer	[RCL AIS RRA RDMA LOS FRAME ERROR CRC4 ERROR NONE]	<i>string</i>	(chronologic list of all E1 alarms that have occurred or "NONE")
Examples	<pre> PC → INOUT:E1:ALARM? PC → AIS,LOS,CRC4 ERROR PC → inout:e1:alarm? PC → NONE </pre>		
Explanation	If an alarm occurs during a measurement, RT-2X generates the corresponding error message. The returned vector lists all alarms, separated by "," (commas). If no alarm has occurred, "NONE" is returned. Refer to chapter E1/T1 Settings (p. 175) for further details.		

INOUT:E1:FORMAT [CAS|CAS&CRC4]

Usage	Selects between the two available E1 formats CAS or CAS&CRC4.		
Availability	Normal, LCL, RL and PureSound™ mode (<u>not</u> available if the analyzer is armed), whereby the E1/T1 interface must be installed.		
Parameter	[CAS CAS&CRC4]	<i>string</i>	
Default	CAS		
Query	<i>INOUT:E1:STATUS?</i>		
Example	<pre> PC → INOUT:E1:FORMAT CAS&CRC4 </pre>		
Explanation	CAS and CRC 4 have an independent multiframing. - CAS = Channel Associated Signaling multiframing. - CAS&CRC4 = Channel Associated Signaling multiframing and CRC 4 multiframing (i.e. includes CRC check every 16 frames).		

INOUT:E1:LINEcode [AMI|HDB3]

Usage	Selects between the two available E1 linecodes (p. 175).
Availability	Normal, LCL, RL and PureSound™ mode (<u>not</u> available if the analyzer is armed), whereby the E1/T1 interface must be installed.
Parameter	[AMI HDB3] <i>string</i> (Alternate Mark Inversion High Density Bipolar order 3 encoding)
Default	AMI
Query	INOUT:E1:STATUS?
Example	 → INOUT:E1:LIN HDB3
Explanation	The two modes AMI and HDB3 are transmission protocols embedded in the E1 bit stream.

INOUT:E1:LINK [LOCAL|OFF]

Usage	Selects between the two available E1 link modes (p. 175).
Availability	Normal, LCL, RL and PureSound™ mode (<u>not</u> available if the analyzer is armed), whereby the E1/T1 interface must be installed.
Parameter	[LOCAL OFF] <i>string</i>
Default	OFF
Query	INOUT:E1:STATUS?
Example	 → INOUT:E1:LINK LOCAL
Explanation	In the LOCAL mode, the TX-bitstream is sent out <u>and</u> linked to the E1 receive (RX) section. D-D measurements can be executed without any DUT connected.

INOUT:E1:LOOPback [REMote;PAYLoad;OFF]

Usage Selects one of the three available E1 loopback settings (p. 175).

Availability Normal, LCL, RL and PureSound™ mode (not available if the analyzer is armed), whereby the E1/T1 interface must be installed.

Range [REMOte|PAYLoad|OFF] *string*

Default OFF

Query *INOUT:E1:STATUS?*

Example $\rightarrow$ INOUT:E1:LOOP PAY

Explanation *REMote* loops the incoming voice data and the signaling (the complete RX-bitstream) back to the E1 output. Thus, the RX-bitstream becomes the TX-bitstream of RT-2X, whereby the unit can monitor the bitstream.

In the **PAYload** mode, in a PLB situation, the DS2155 loops the 248 bits of payload data (with BPVs corrected) from the receive section back to the transmit section. Consequently, the incoming voice data of the RX-bitstream is looped back to the E1 outputs. The transmit section modifies the payload. The FAS word, Si, Sa, and E bits as well as the CRC4 are not looped back, but re-inserted by the RT-2X.

INOUT:E1:STATUS?

Usage Queries the actual E1 state.

Availability Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed), whereby the E1/T1 interface must be installed.

Answer

FORMAT [CAS CAS&CRC4],	string
LINECODE [AMI HDB3],	string
RXLEVEL [HIGH MEDIUM LOW TOOLOW],	string
LOOPBACK [REMOTE PAYLOAD OFF],	string
LINK [LOCAL OFF]	string

Example

```
🖥️ → INOUT:E1:STATUS?  
→ 🖥️ FORMAT CAS,LINECODE AMI,RXLEVEL HIGH,LOOPBACK OFF,  
LINK LOCAL
```

Explanation The returned string reflects the current RT-2X status as defined with the corresponding commands.

The RX LEVEL indicates the physical voltage level at the E1 interface connectors. It can have four different levels.

- HIGH → > -7.5 dB
- MEDIUM → -7.5 dB to -15.0 dB
- LOW → -15.0 dB to -22.5 dB
- TOOLOW → < -22.5 dB

INOUT:ISDn:S0Bus [ACTivate|DEACTivate]

Usage	Activates or deactivates the ISDN S ₀ bus.
Availability	Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed), whereby the ISDN interface must be installed.
Parameter	[ACTivate DEACTivate] <i>string</i>
Default	DEACTivate
Query	<i>INOUT:ISDn:S0Busstatus?</i>
Example	 → INOUT:ISDN:S0BUS ACTIVATE
Explanation	As soon as RT-2X is physically connected to an ISDN S₀ bus and switched ON, it is automatically DEACTivated. It can be ACTivated either by an external access from the NT (network terminator) or, if a signal shall be sent out, through command <i>INOUT:ISDn:S0Bus ACTivate</i>. Deactivate RT-2X with command <i>INOUT:ISDn:S0Bus DEACTivate</i> if required.

INOUT:ISDn:S0Busstatus?

Usage	Queries the actual status of the ISDN S ₀ bus.
Availability	Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed), whereby the ISDN interface must be installed.
Answer	[ACTIVATED DEACTIVATED SYNCHRONIZED ACTIVATIONREQUEST] <i>string</i>
Example	 → INOUT:ISDN:S0BUSSTATUS? →  ACTIVATED
Explanation	SYNCHRONIZED and ACTIVATIONREQUEST are states between DEACTIVATED and ACTIVATED. If they appear, a problem with the S ₀ bus is occurring.

INOUT:LCLBridge:LCLCompensation [START|ENABLE|DISable]

Usage Executes a LCL circuit compensation that eliminates the effect of parasitic capacitance and resistance of the external wiring (chapter **LCL Wiring Compensation**, p. 193).

Availability LCL mode (not available if the analyzer is armed):

- The LCL Bridge must be switched to LCL (**INOUT:LCLBridge:MODE LCL**).
- The RL Bridge must be switched OFF (**INOUT:RLBridge:MODE OFF**).

Parameter [START|ENABLE|DISable] *string*

Default DISable

Query **INOUT:LCLBridge:STATus?**

Examples  → INOUT:LCLCOMPENSATION START

 → INOUT:LCLB:LCLC ENABLE

Explanation

- **INOUT:LCLB:LCLC START** calculates a compensation factor for the actual setup.
- **INOUT:LCLB:LCLC ENABLE** applies the previously acquired compensation factor for the following LCL measurements.
- **INOUT:LCLB:LCLC DISABLE** discontinues the application of the compensation.

NOTE Before executing the command **INOUT:LCLB:LCLC START**, connect the RT-2X to the LCL-Calibration Box (available as accessory) with the same wiring as for the DUT measurements.
If no proper calibration has been executed, enabling the LCL compensation mode will result in inaccurate results.

INOUT:LCLBridge:MODE [LCL|LCTL|OFF]

Usage Activates the LCL or LCTL mode (p. 192).

Availability Normal and LCL mode (not available if the analyzer is armed), whereby the RL Bridge must be switched OFF (**INOUT:RLBridge:MODE OFF**).

a) LCL measurements: RT-2X must be in A-A operation.
b) LCTL measurements: RT-2X must be in A-A, A-D or D-A operation.

Parameter [LCL|LCTL|OFF] *string*

Default OFF

Query **INOUT:LCLBridge:STATus?**

Examples  → INOUT:LCLBRIDGE:MODE LCL

 → INOUT:LCLB:MODE LCTL

Explanation Switch OFF the LCL Bridge before toggling from the LCL to the LCTL mode and vice versa.

NOTE The LCLBridge mode LCL or LCTL only allows querying LCL and LCTL.

INOUT:LCLBridge:RANGe [HIGHer40|LOWer40]

Usage	Adjusts the input range of the LCL measurement.
Availability	Normal and LCL mode (<u>not</u> available if the analyzer is armed), whereby the RL Bridge must be switched OFF (INOUT:RLBridge:MODE OFF). a) LCL measurements: RT-2X must be in A-A operation. b) LCTL measurements: RT-2X must be in A-A, A-D or D-A operation.
Parameter	[HIGHer40 LOWer40] <i>string</i>
Default	LOWer40
Query	INOUT:LCLBridge:STATus?
Examples	→ INOUT:LCLBRIDGE:RANGE HIGHER40 → INOUT:LCLB:RANG LOW
Explanation	Select the parameter HIGHer40 LOWer40 according to the expected LCL result. Proper selection of the parameter provides the optimum measuring accuracy. - If the expected LCL result is ≥ 40 dB, apply the parameter HIGHer40. - If the expected LCL result is < 40 dB, apply the parameter LOWer40.

NOTE If the LCL range is set to HIGHer40, but the acquired result is < 40 dB, an overflow occurs (error 210).

INOUT:LCLBridge:REFimplctl <Impedance>

Usage	Defines the reference impedance for the LCTL measurement that has to be identical to the DUT impedance.
Availability	LCL mode (<u>not</u> available if the analyzer is armed): - The RL Bridge must be switched OFF (INOUT:RLBridge:MODE OFF). - The LCL Bridge must be switched to LCTL (INOUT:LCLBridge:MODE LCTL).
Parameter	<Impedance> <i>integer</i> 1 to 2000 (ref. impedance expressed in Ohm; resolution = 1)
Default	736 (Ohm)
Query	INOUT:LCLBridge:STATus?
Examples	→ INOUT:LCLBRIDGE:REFIMPLCTL 600 → INOUT:LCLB:REF 850
Explanation	The reference impedance value is required for the proper calculation of the LCTL result under half-channel operation.



INOUT:LCLBridge:STATus?

Usage

Queries the LCL mode parameters.

Availability

Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed), whereby the RL Bridge must be switched OFF (**INOUT:RLBridge:MODE OFF**).

a) LCL measurements: RT-2X must be in A-A operation.

b) LCTL measurements: RT-2X must be in A-A, A-D or D-A operation.

Answer

A) LCL Bridge switched **OFF** or to **LCL**

MODE [LCL|LCTL|OFF], *string*
TERMINATION [ON|REFGROUND|REFFLOAT], *string*
RANGE [HIGHER40|LOWER40], *string*
LCLCOMPENSATION [ENABLE|DISABLE] *string*

B) LCL Bridge switched to **LCTL**

MODE [LCL|LCTL|OFF], *string*
TERMINATION [ON|REFGROUND|REFFLOAT], *string*
RANGE [HIGHER40|LOWER40], *string*
REFIMPLCTL <Impedance> *string & integer*

Examples

 → INOUT:LCLBridge:STATus?
→  MODE OFF,TERMINATION OFF,RANGE HIGHER40,
LCLCOMPENSATION DISABLE

 → INOUT:LCLBRIDGE:STATus?
→  MODE LCL,TERMINATION REFGROUND,RANGE LOWER40,
LCLCOMPENSATION ENABLE

 → INOUT:LCLB:STAT?
→  MODE LCTL,TERMINATION OFF,RANGE HIGHER40,REFIMPLCTL 736

Explanation The returned status format depends on the LCLBridge mode (**OFF**, **LCL** or **LCTL**).

INOUT:LCLBridge:TERMination [OFF|REFGround|REFFloat]

Usage	Controls the status of the LCL/LCTL termination.
Availability	Normal and LCL mode (<u>not</u> available if the analyzer is armed), whereby the RL Bridge must be switched OFF (INOUT:RLBridge:MODE OFF). a) LCL measurements: RT-2X must be in A-A operation. b) LCTL measurements: RT-2X must be in A-A, A-D or D-A operation.
Parameter	[OFF REFGROUND REFFLOAT] <i>string</i>
Default	OFF
Query	INOUT:LCLBridge:STATus?
Examples	 → INOUT:LCLBRIDGE:TERMINATION REFGROUND  → INOUT:LCLBridge:TERMination REFFloat  → INOUT:LCLB:TERM OFF
Explanation	This command connects the internal LCL/LCTL termination of RT-2X to input channel 1 (Fig 38, p. 209). OFF: The termination of the LCL/RL option is disconnected from input chn1. REFGround: The termination of the LCL/RL option is connected to input chn1 <u>and</u> to ground. ⇒ Required for <i>Series Imbalance</i> measurements of a 2-port DUT. REFFloat: The termination of the LCL/RL option is connected to input chn1 but <u>not</u> to ground. ⇒ Required for <i>Shunt Imbalance</i> measurements of a 2-port DUT.

INOUT:PCM:ALARM?

Usage	Queries the PCM Alarm messages that occurred since the last query or PowerUp.
Availability	Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed), whereby the E1/T1/PCM interface must be installed.
Answer	[FS OUT LOSS FS IN LOSS BCLK FREQ OUT OF RANGE PLL UNLOCKED NONE] <i>string</i> (chronologic list of all PCM alarms that have occurred or "NONE")
Examples	 → INOUT:PCM:ALARM? →  FS OUT LOSS,FS IN LOSS,BCLK FREQ OUT OF RANGE  → inout:PCM:alarm? →  NONE
Explanation	The command queries all Alarm messages that have been generated by RT-2X during a measurement. The returned vector lists all Alarm messages, separated by "," (commas). If no alarm has occurred, "NONE" is returned. Refer to chapter PCM Alarm Table (p. 242) for further details.

INOUT:PCM:BCLK:EDGE [POSitive|NEGative]

Use	Defines the BCLK signal sampling edge (connector BCLK Master / Slave) for the DataWord (connector Data In, Data Out) and FrameSync (connector FS In, FS Out).
Availability	Normal, LCL, RL and PureSound™ mode (<u>not</u> available if the analyzer is armed), whereby the E1/T1/PCM interface must be installed.
Parameter	[POSitive NEGative] <i>string</i> Selects the rising falling edge for transmit data and FrameSync sampling
Default	POSitive
Query	INOUT:PCM:STATUS?
Examples	 → INOUT:PCM:BCLK:EDGE NEG
Explanation	The BCLK Master clock signal defines the change & sampling of the DataWord and the FrameSync signals. DataWords and FrameSync signals can be sampled on either the rising or falling edges of the BCLK Master clock signal. DataWords and FrameSync signals change their state on the clock edge that is <u>not</u> selected.

INOUT:PCM:BCLK:FREQuency <Frequency>

Use	Defines the BCLK Master clock frequency (connector BCLK Master / Slave).
Availability	Normal, LCL, RL and PureSound™ mode (<u>not</u> available if the analyzer is armed), whereby the E1/T1/PCM interface must be installed.
Parameter	[64kHz 104kHz 128kHz 256kHz 512kHz 1024kHz 1544kHz 2048kHz] <i>string</i> The DataWord length and slot assignments are restricted by the selected BCLK (refer to Table 17).
Default	64kHz
Query	INOUT:PCM:STATUS?
Examples	 → INOUT:PCM:BCLK:FREQ 2048kHz
Explanation	The BCLK Master clock signal defines the change and sampling of the DataWord and the FrameSync signal. Furthermore, the BCLK Master is the source of the RT-2X houseclock. DataWords and FrameSync signals can be sampled on either the rising or falling edges of the BCLK Master clock signal (command INOUT:PCM:BCLK:EDGE [POSitive NEGative]).

NOTE The DataWord length and slot assignments are restricted by the selected BCLK (refer to **Table 17**).

Take special care if the BCLK Master clock source is external. The RT-2X houseclock is internally synchronized to the incoming clock at the BCLK Master signal. For accurate measurements, the clock has to fulfill the specified jitter definitions. Please refer to the RT-2X specification.

INOUT:PCM:BCLK:SLAVE [DISable|ENAbLe]

Use	Enables or disables the BCLK Slave signal, i.e. loops the BCLK Master to the BCLK Slave.
Availability	Normal, LCL, RL and PureSound™ mode (<u>not</u> available if the analyzer is armed), whereby the E1/T1/PCM interface must be installed.
Parameter	[DISable ENAbLe] <i>string</i>
Default	ENAbLe
Query	INOUT:PCM:STATUS?
Examples	 → INOUT:PCM:BCLK:SLAV DIS
Explanation	The BCLK slave signal can be used for D-D measurement applications, where the data stream of the DUT's output section must be synchronized to the BCLK Master (p. 239).

INOUT:PCM:BCLK:SYNC [EXTeRnal|!NTErnal]

Use	Defines, whether the master BCLK signal is generated internally (by RT-2X) or externally (by the DUT).
Availability	Normal, LCL, RL and PureSound™ mode (<u>not</u> available if the analyzer is armed), whereby the E1/T1/PCM interface must be installed.
Parameter	[EXTeRnal !NTErnal] <i>string</i>
Default	!NTErnal
Query	INOUT:PCM:STATUS?
Examples	 → INOUT:PCM:BCLK:SYNC EXTERNAL
Explanation	The master BCLK signal serves as RT-2X houseclock.

DataWord and FrameSync signals can be sampled either on the rising or falling edges of the BCLK Master clock (refer to command **INOUT:PCM:BCLK:EDGE [POSitive|NEGative]**).

NOTE Take special care if the master BCLK is created by an external source, since the RT-2X houseclock is internally synchronized to this clock signal. For accurate measurements, the master BCLK signal has to fulfill the specified jitter limits.

INOUT:PCM:DATA:WLENgth [8|13|14|16]

Use	Defines the DataWord length for the RT-2X generator (TX-data) & analyzer (RX-data).
Availability	Normal, LCL, RL and PureSound™ mode (<u>not</u> available if the analyzer is armed), whereby the E1/T1/PCM interface must be installed.
Parameter	[8 13 14 16] <i>integer</i> The DataWord length.
Default	8
Query	INOUT:PCM:STATUS?
Examples	 → INOUT:PCM:DATA:WLENGTH 8  → INOUT:PCM:DATA:WLEN 14
Explanation	The DataWord length represents the resolution of the transmitted / received signal.

NOTE With A-law or μ -law active, the DataWord length must be 8 bit. If another DataWord length is selected, the output and input law will be automatically switched OFF.

Selection of the DataWord length and slot assignments are restricted by the active BCLK (refer to Table 17).

INOUT:PCM:FRAMESync:LOGic [POSitive|NEGative]

Use	Defines the active logic of the FrameSync signal.
Availability	Normal, LCL, RL and PureSound™ mode (<u>not</u> available if the analyzer is armed), whereby the E1/T1/PCM interface must be installed.
Parameter	[POSitive NEGative] <i>string</i>
Default	POSitive
Query	INOUT:PCM:STATUS?
Examples	 → INOUT:PCM:FRAMESYNC:LOGIC POSITIVE
Explanation	This command defines the active FrameSync logic. The FrameSync pulse can either be POSitive (i.e. active low) or NEGative (i.e. active high). The FrameSync signal is either sampled on the rising or falling edge of BCLK (refer to the command INOUT:PCM:BCLK:EDGE [POSitive NEGative]).

INOUT:PCM:FRAMESync:MODE [EARLy|LATE]

- Use** Defines the synchronization between the FrameSync signal and the DataWord.
- Availability** Normal, LCL, RL and PureSound™ mode (not available if the analyzer is armed), whereby the E1/T1/PCM interface must be installed.
- Parameter** [EarLy|Late] *string*
- Default** EARLy
- Query** INOUT:PCM:STATus?
- Examples**  → INOUT:PCM:FRAMESYNC:MODE FSLATE
- Explanation** The the first bit of the DataWord in slot #0 can be synchronized to the first edge of the FrameSync signal (“EARLy”) or to its second edge (“LATE”).
- **EARLy FrameSyncs (default mode):** the first bit of the transmit DataWord (TX-data) and the first bit of the receive DataWord (RX-data) are latched with the first master BCLK cycle *after* the FrameSync signal.
 - **LATE FrameSyncs (alternate mode):** the first bit of the transmit DataWord (TX-data) and the first bit of the receive DataWord (RX-data) are latched with the master BCLK cycle *parallel* to the FrameSync signal.

NOTE Internally generated FrameSyncs always have the same duration as one master BCLK cycle.

INOUT:PCM:LINK [LOCAl|OFF]

- Usage** Activates the internal link from the PCM generator to the analyzer of RT-2X.
- Availability** Normal, LCL, RL and PureSound™ mode (not available if the analyzer is armed), whereby the E1/T1/PCM interface must be installed.
- Parameter** [LOCAl|OFF] *string*
- Default** OFF
- Query** INOUT:PCM:STATus?
- Example**  → INOUT:PCM:LINK LOCAL
- Explanation** In the LOCAl mode, the TX-bitstream is sent out and linked to the internal PCM receive (RX) section of RT-2X.

INOUT:PCM:LOGiclevel <LogicLevel>

- Use** Defines the level of the PCM interface logic signals. All PCM signals (BCLK, FrameSync, DataWord) have the same logic level reference.
- Availability** Normal, LCL, RL and PureSound™ mode (not available if the analyzer is armed), whereby the E1/T1/PCM interface must be installed.
- Parameter** [2.5V|3.3V|5.0V] *string* 2.5V → TTL | 3.3V → LVTTTL | 5.0V → CMOS, TTL
- Default** 2.5V
- Query** INOUT:PCM:STATUS?
- Examples**  → INOUT:PCM:LOGICLEVEL 5.0V
 → INOUT:PCM:LOG 3.3V
- Explanation** Refer to the PCM specification for more details.

INOUT:PCM:STATus?

- Usage** Queries the actual status of the PCM interface.
- Availability** Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed), whereby the E1/T1/PCM interface must be installed.
- Answer** LOGICLEVEL [5.0V|3.3V|2.5V], *string*
BCLK:SYNC [INTERNAL|EXTERNAL], *string*
BCLK:SLAVE [ENABLE|DISABLE], *string*
BCLK:FREQUENCY [64kHz|104kHz|128kHz|256kHz|
512kHz|1024kHz|1544kHz|2048kHz], *string*
BCLK:EDGE [POSITIVE|NEGATIVE], *string*
FRAMESYNC:LOGIC [POSITIVE|NEGATIVE], *string*
FRAMESYNC:MODE [EARLY|LATE], *string*
DATA:WLENGTH [8|13|14|16], *string & integer*
LINK [LOCAL|OFF] *string*
- Example**  → INOUT:PCM:STATUS?
→  LOGICLEVEL 3.3V, BCLK:SYNC INTERNAL, BCLK:SLAVE ENABLE,
BCLK:FREQUENCY 64kHz, BCLK:EDGE POSITIVE,
FRAMESYNC:LOGIC POSITIVE, FRAMESYNC:MODE EARLY,
DATA:WLENGTH 8, LINK OFF
- Explanation** The returned string reflects the current status of the PCM interface module as defined with the corresponding commands.

INOUT:PUResound:MODE [OFF|RNB|CORRelation]

Usage	Activates the PureSound™ mode.
Availability	Normal and PureSound™ mode (<u>not</u> available if the analyzer is armed), whereby the sampling rate must be switched to 48 kHz (SYSTem:MODE 48Ksamplingrate).
Parameter	[OFF RNB CORRELATION] <i>string</i> (inactive steepness measurement correlation analysis)
Default	OFF
Query	INOUT:PUResound:MODE?
Examples	 → INOUT:PUResound:MODE RNB  → INOUT:PUResound:MODE CORRelation
Explanation	INOUT:PUResound:MODE RNB enables the Rub & Buzz measurement functions. INOUT:PUResound:MODE CORRELATION allows measuring the sound correlation.

NOTE To enable the PureSound™ license please contact NTI.

INOUT:PUResound:MODE?

Usage	Queries the PureSound™ status.
Availability	Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed), whereby the PureSound™ license must be enabled.
Answer	[OFF RNB CORRELATION] <i>string</i> (inactive steepness measurement correlation analysis)
Example	 → INOUT:PUResound:MODE? →  RNB

INOUT:RLBRidge:MODE [ON|OFF]

- Usage** Activates the RL mode (p. 253).
- Availability** Normal and RL mode (not available if the analyzer is armed), whereby the LCL Bridge must be switched OFF (**INOUT:LCLBridge:MODE OFF**).
- Range** [ON|OFF] *string*
- Default** OFF
- Query** **INOUT:RLBRidge:STATus?**
- Examples**
-  → INOUT:RLBRIDGE:MODE ON
-  → INOUT:RLBR:MODE OFF
- Explanation** **INOUT:RLBRidge:MODE ON** puts the instrument to the RL mode, wherein RL, ERL and SRL HI/LO measurements can be executed.

NOTE If the RLBridge mode is ON, only RL, ERL and SRL can be queried.

INOUT:RLBRidge:STATus?

- Usage** Queries the RL bridge status.
- Availability** Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed).
- Answer** MODE [ON|OFF] *string*
- Example**
-  → INOUT:RLBRIDGE:STATUS?
-  MODE OFF

INOUT:T1:ALARM?

Usage	Queries the T1 alarm messages that have occurred since the last query or PowerUp.	
Availability	Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed), whereby the E1/T1 interface must be installed.	
Answer	[RED BLUE YELLOW LOS FRAME ERROR CHANGED FRAME ALIGNMENT RX PULSE VIOLATION TX PULSE VIOLATION NONE]	<i>string</i> (chronologic list of all T1 alarms that have occurred or "NONE")
Examples	<pre> → INOUT:T1:ALARM? → YELLOW,LOS,RX PULSE VIOLATION → inout:t1:alarm? → NONE </pre>	
Explanation	The command queries all alarm messages that have been generated by RT-2X during a measurement. The returned vector lists all alarm messages, separated by "," (commas). If no alarm has occurred, "NONE" is returned.	
	Refer to chapter E1/T1 Settings (p. 175) for further details.	

INOUT:T1:FORMat [D4|ESF]

Usage	Selects between the two available T1 formats D4 and ESF (p. 175).	
Availability	Normal, LCL, RL and PureSound™ mode (<u>not</u> available if the analyzer is armed), whereby the E1/T1 interface must be installed.	
Parameter	[D4 ESF]	<i>string</i>
Default	D4	
Query	INOUT:T1:STATUS?	
Example	<pre>→ INOUT:T1:FORMAT ESF</pre>	

INOUT:T1:LINecode [AMI|B8ZS]

Usage	Selects between the two available T1 linecodes (p. 175).	
Availability	Normal, LCL, RL and PureSound™ mode (<u>not</u> available if the analyzer is armed), whereby the E1/T1 interface must be installed.	
Parameter	[AMI B8ZS]	<i>string</i> (Alternate Mark Inversion Bipolar with 8 Zero Substitution)
Default	AMI	
Query	INOUT:T1:STATUS?	
Example	<pre>→ INOUT:T1:LIN B8ZS</pre>	
Explanation	The two modes AMI and B8ZS refer to the carrier signal format.	

INOUT:T1:LINK [LOCAL|OFF]

Usage	Selects between the two available T1 link modes (p. 175).
Availability	Normal, LCL, RL and PureSound™ mode (<u>not</u> available if the analyzer is armed), whereby the E1/T1 interface must be installed.
Parameter	[LOCAL OFF] <i>string</i>
Default	OFF
Query	INOUT:T1:STATUS?
Example	 → INOUT:T1:LINK LOCAL
Explanation	In the LOCAL mode, the TX-bitstream is sent out <u>and</u> linked to the T1 receive (RX) section.

INOUT:T1:LOOPback [REMOTE|PAYLoad|OFF]

Usage	Selects one of the three available T1 loopback settings (p. 175).
Availability	Normal, LCL, RL and PureSound™ mode (<u>not</u> available if the analyzer is armed), whereby the E1/T1 interface must be installed.
Range	[REMOTE PAYLoad OFF] <i>string</i>
Default	OFF
Query	INOUT:T1:STATUS?
Example	 → INOUT:T1:LOOP REM
Explanation	REMOTE loops the incoming voice data <u>and</u> the signaling (the complete RX-bitstream) back to the T1 outputs. Thus, the RX-bitstream becomes the TX-bitstream of RT-2X, whereby the unit can monitor the bitstream. In the PAYLoad mode, RT-2X loops the 192 bits of payload data from the receive section back to the transmit section. The FPS framing pattern, CRC6 calculation and the FDL bits are not looped back, but re-inserted by RT-2X. The incoming <u>voice data</u> of the RX-bitstream is looped back to the T1 outputs. Consequently, the incoming RX-signaling & voice data can be monitored, whereby the user can define the TX-signaling.

INOUT:T1:STATUS?

Usage Queries the actual T1 state.

Availability Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed), whereby the E1/T1 interface must be installed.

Answer

FORMAT [D4 ESF],	string
LINECODE [AMI B8ZS],	string
RXLEVEL [HIGH MEDIUM LOW TOOLOW],	string
LOOPBACK [REMOTE PAYLOAD OFF],	string
LINK [LOCAL OFF]	string

Example

```

→ INOUT:T1:STATUS?
→ FORMAT ESF,LINECODE AMI,RXLEVEL MEDIUM,LOOPBACK OFF,
  LINK FRAMER
  
```

Explanation The returned string reflects the current RT-2X status as defined with the corresponding commands.

The RX LEVEL indicates the physical voltage level at the T1 interface connectors. It can have four different levels.

- HIGH → +2.0 dB to −7.5 dB
- MEDIUM → −7.5 dB to −15.0 dB
- LOW → −15.0 dB to −22.5 dB
- TOOLOW → < −22.5 dB

OUTPut Subsystem

OUTPut[1|2]:ACCOupling [OFF|ON]

- Usage** Activates the output AC coupling of RT-2X.
- Availability** Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed), whereby the LCL/RL option must be installed and the generator must be in analog operation (**OUTPut:SOURce ANALog**).
- Parameter** [OFF|ON] *string*
- Default** (the last active state; factory default = OFF)
- Query** **OUTPut[1|2]:STATus?**
- Examples**
- OUTPut1:ACCOupling ON
- OUTP:ACCO ON (links both channels)
- Explanation** If ACCOupling is ON, a maximum of +60 VDC can be applied to the output connectors.

NOTE If no channel-number is indicated, the command applies to both channels simultaneously.

OUTPut:ARBitrarysine [<Frequency>,<Time>|BREAK]

OUTPut:ARBSIN [<Frequency>,<Time>|BREAK]

- Usage** Generates a sine signal with user-defined frequency & duration (p. 255).
- Availability** Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed).
- Parameter**
- | | | | |
|---------------|----------------|--|---|
| [<Frequency>, | <i>float</i> | 1.00 to 22000.00 | (signal frequency in 48k 8k mode, expressed in Hz, resolution = 0.01) |
| | | 4000.00 | |
| <Time> | <i>integer</i> | 0 to 30000 | (time in ms, resolution = 1) |
| BREAK] | <i>string</i> | (immediately stops the arbitrary sine output signal) | |
- Examples**
- Outp:Arb 1.23456E+02,500 (123.456 Hz, 500 ms)
- OUTPUT:ARBSIN 2.150E+03,1200 (2150 Hz, 1200 ms)
- OUTP:ARB BREAK (stop the current signal generation)

Explanation The command allows using RT-2X as arbitrary sine wave generator, whereby the output level is defined by command **OUTPut[1|2]:LEVel ...** or **OUTPut[1|2]:SINelevel ...**

Re-send the **OUTP:ARB ...** command with a new frequency or duration parameter to amend the signal generation without interruption.

NOTE The actual output level is attenuated below 20 Hz and above 20 kHz as follows (refer to p. 255):

- -4 dB to 0 dB from 1 Hz to 20 Hz
- 0 dB to -0.5 dB from 20 kHz to 22 kHz.

OUTPut[1;2]:BINlevel <BinLevel> **[V|VP|DBV|DBVP|DBM|DBFSP|%FSP|DBFS|%FS|DBM0]**

Usage Defines the BinLevel of the active multitone signal, i.e. its (reference) signal bin level.

Availability Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed).

Parameter

A) A-A, A-D operation	
[0 to xxV	(Volt _{RMS})
0.001 to xx VP	(Volt Peak)
+0.001 to xx DBV	<i>float & string</i> (Decibel Volt _{RMS})
-60.00 to xx DBVP	(Decibel Volt Peak)
xx DBM]	(Analog RMS level, p. 281)
B) D-A, D-D operation	
[-72.25 to yy DBFSP	(Decibel FullScale peak)
0.0244 to yy %FSP	(Percent of FullScale Peak)
-75.30 to yy DBFS	<i>float & string</i> (Decibel FullScale)
0.0244 to yy %FS	(Percent of FullScale)
yy DBM0]	(Digital RMS level, p. 282)

Default [0 DBVP|0 DBFSP] (A-A, A-D | D-A, D-D operation)

Query **OUTPut[1;2]:BINlevel?** [V|VP|DBV|DBVP|DBM|DBFSP|%FSP|DBFS|%FS|DBM0]

Examples

```

→ Outp1:Binlevel -0.62E+01 dBVp
→ OUTPUT2:BINLEVEL 1.00E-01 V
→ outp2:bin 0.96e+02 %fs

```

Explanation The command defines the actually generated signal bin level of the active multitone signal.

- If no BinLevel weighting is active, the <BinLevel> applies for all signal bins.
- Alternatively, i.e. if the BinLevels of the multitone signal bins are weighted individually with command **OUTPut:MTONE:PARAMeter ...**, <BinLevel> defines only the BinLevel of the reference signal bin, i.e. the unweighted signal bin (refer to p. 236).

The maximum possible BinLevel depends on the Crest factor of the test signal (p. 199).

NOTE REFER TO CHAPTER *Output Level* (p. 234) FOR DETAILS ABOUT THE CORRELATION BETWEEN BINLEVEL, MT LEVEL AND SINELEVEL.

Using command **OUTPut[1;2]:BINlevel <Level> ...** is only recommended for advanced customers. Better apply **OUTPut[1;2]:LEVel <Level> ...** to adjust the output level (i.e. MT Level) of a multitone signal.

[dBm] is a power unit that refers to 600 Ω output impedance. Thus, if another output impedance is selected, the actual RMS output level changes.

OUTPut[1'2]:BINlevel? [V|VP|DBV|DBVP|DBM|DBFSP|%FSP|DBFS|%FS|DBM0]

Usage Queries the (reference) BinLevel of the active test signal, expressed in the selected unit.

Availability Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed).

Parameter

A) A-A, A-D operation

[V		(Volt _{RMS})
VP		(Volt Peak)
DBV	string	(Decibel Volt _{RMS})
DBVP		(Decibel Volt Peak)
DBM]		(Analog RMS level, p. 281)

B) D-A, D-D operation

[DBFSP		(Decibel FullScale peak)
%FSP		(Percent of FullScale Peak)
DBFS	string	(Decibel FullScale)
%FS		(Percent of FullScale)
DBM0]		(Digital RMS level, p. 282)

Answer

A) A-A, A-D operation

<BinLevel> [V|VP|DBV|DBVP|DBM] float & string

B) D-A, D-D operation

<BinLevel> [DBFSP|%FSP|DBFS|FS|DBM0] float & string

Examples

→ Output2:Binlevel? Vp
→ -1.23456E-01 VP

→ OUTP1:BIN? DBM0
→ 0.03E00 DBM0

Explanation The reference BinLevel represents the level of the unweighted signals bin(s). Refer to chapter **Multitone Binlevel Weighting (Individual Binlevel)** for further details (p. 236).

The command is very helpful for the conversion of the BinLevel into different units. For instance, if the BinLevel has been defined in V, it can be queried directly in another unit.

Even if the generator level has been defined with command **OUTPut[1'2]:LEVel ...** or **OUTPut[1'2]:SINlevel ...** the query returns directly the BinLevel.

NOTE REFER TO CHAPTER *Output Level* (p. 234) FOR DETAILS ABOUT THE CORRELATION BETWEEN SINELEVEL, MT LEVEL AND BINLEVEL.

[dBm] is a power unit that refers to 600 Ω output impedance. Thus, if another output impedance is selected, the actual RMS output level changes.

**OUTPut:DTMF****[1|2|3|4],[1|2|3|4],<Time>,<RowFrqDev>,<ColFrqDev>,<AmpRatio>**

Usage Generates a DTMF tone, whereby the user must define the key-number, signal duration, frequency deviation and amplitude ratio of the two signal components (p. 169).

Availability Normal and PureSound™ mode (also if the analyzer is armed).

Parameter

[1 2 3 4],	integer	(x-coordinate of the 4x4 keypad)
[1 2 3 4],	integer	(y-coordinate of the 4x4 keypad)
1 to 5000,	integer	(DTMF signal duration in milliseconds; resolution = 1)
-5.00 to +5.00,	float	(row-frequency deviation in %; resolution = 0.01)
-5.00 to +5.00,	float	(column-frequency deviation in %; resolution = 0.01)
0.10 to 10.00	float	(amplitude ratio LowFreq : HighFreq; resolution = 0.01)

Examples

→	OUTP:DTMF 2,3,100,0,0,1	(standard DTMF tone of key #6)
→	outp:dtmf 1,1,50,0.50E00,-0.50E00,3.00E00	(key 1, 50 ms, frequencies de-tuned to 700.5 / 1203.0 Hz, amplitude ratio 3:1)

Explanation The standard 4x4 keypad coding is:

↓ row	1	2	3	4	→ column
	1	2	3	a	
	2	4	5	6	b
	3	7	8	9	c
	4	*	0	#	d

(the meaning of the characters a, b, c, d is user-defined)

The frequencies associated to the rows and columns are:	row	frequency	column	frequency
	1	697	1	1209
	2	770	2	1336
	3	852	3	1477
	4	941	4	1633

OUTPut:E1:CLKSource [INTernal|RECovered]

Usage	Selects, whether the clock of the TX-bitstream shall be synchronized either to the internal oscillator of RT-2X, or recovered from the incoming RX-bitstream (p. 173).
Availability	Normal, LCL and RL mode (<u>not</u> available if the analyzer is armed), whereby the E1/T1 interface must be installed.
Parameter	[INTernal RECovered] <i>string</i> (internal oscillator synchronized to RX-bitstream)
Default	RECovered
Query	OUTPut[1 2]:STATus?
Examples	 → Outp:E1:CLKS Internal
Explanation	In the OUTPut:E1:CLKSource RECovered update link mode, the 'carrier level' must be high enough to allow the RT-2X analyzer synchronizing properly.

OUTPut:E1:LAW [ALAW|ULAW|OFF]

Usage	Selects the E1 LAW output voice encoding.
Availability	Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed), whereby the E1/T1 interface must be installed.
Parameter	[ALAW ULAW OFF] <i>string</i>
Default	ALAW
Query	OUTPut[1 2]:STATus?
Example	 → OUTP:E1:LAW ULAW
Explanation	Select the RT-2X output voice encoding according to your DUT decoding requirements.

OUTPut:E1:SIGnaling [ENABLE|DISAbLe|SINGLe|CYCLe|STOP|<Parameter>]

Usage

- Enable / disable the E1 CAS signaling of RT-2X.
- Send out a pattern sequence of the TX-signaling buffer as a single shot or in cycles.
- Stop the cyclic sending of the TX-signaling buffer.
- Modify the contents of the TX-signaling buffer.

Availability

Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed), whereby the E1/T1 option must be installed and RT-2X under GPIB IEEE-488 control (i.e. not RS232).

Parameter

[ENABLE| string (enables the CAS signaling, p. 170)
DISAbLe| string (disables the CAS signaling, p. 170)
SINGLe| string (must be preceded by **OUTPut:E1:SIGnaling ENABLE**. Sends out the signaling buffer sequence once [= single shot] and keeps the last pattern in the TX signaling buffer active for all slots)
CYCLe| string (must be preceded by **OUTPut:E1:SIGnaling ENABLE**; Starts the cyclic sending of the signaling buffer sequence)
STOP| string (must be preceded by **OUTPut:E1:SIGnaling CYCLe**; Forces the unit to freeze the cyclic sending of the TX-signaling buffer at the actual pattern, i.e. to continuously send out only the pattern that was active when the command was received)
<Parameter>| string (defines or appends a new signaling buffer sample; the definition parameter = 30 hex numbers, each corresponding to one slot, followed by count)

Default

DISAbLe

Query

OUTPut[1|2]:STATus?

Examples

→ OUTP:E1:SIG ENABLE (enables - i.e. activates - the E1 signaling and
OUTP:E1:SIG SINGLE sends out once the contents of the TX-signaling buffer)
→ OUTP:E1:SIG ENABLE (enables the E1 signaling and starts to send out the
OUTP:E1:SIG CYCLE contents of the TX-signaling buffer in cycles, i.e. again and again)
→ Outp:E1:Sig Enab (as soon as the **Outp:E1:Sig Stop** command is
Outp:E1:Sig Cyc transmitted, the RT-2X analyzer 'freezes' the
Outp:E1:Sig Stop cyclical sending procedure at the current pattern, i.e. continuously sends out this pattern).
→ Outp:E1:Sig 810000000000000099000 (the sample is appended to the
0000000000F,0 signaling buffer at count 50)

Explanation

The format of each signaling pattern is "xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx,ct", whereby each "x" stands for 4 bits (i.e. one Hex number) and corresponds to one slot (the first "x" represents slot 1 etc. – refer to p. 170). "ct" stands for the count (i.e. multiframe No.), where the pattern is located (Example: count = 13 ⇒ timestamp = 13 x 2ms = 26 ms).

If the first count is "0" (zero), the TX-signaling buffer is initialized (cleared) and filled with the new pattern. If the first count ≠ 0, the pattern is appended to the actual TX-signaling buffer contents. **In the latter case, the count must be larger than all the other counts in the TX-signaling buffer.**

The TX-signaling buffer allows saving up to 100 patterns. If more patterns are defined or appended, an error message will be generated.

OUTPut:E1:SLOTnumber <Chn1> <Chn2>

- Usage** Assigns an individual slot-number to each of the two RT-2X output channels 1, 2.
- Availability** Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed), whereby the E1/T1 interface must be installed.
- Parameter**
- | | | | |
|--------|----------------|---------|---|
| <Chn1> | <i>integer</i> | 1 to 31 | (Except 0, 16: slot 0 is reserved for frame alignment, slot |
| <Chn2> | <i>integer</i> | 1 to 31 | 16 for CAS signaling) |
- Query** ***OUTPut[1|2]:STATus?***
- Examples**
-  → Outp:E1:Slot 1 2
-  → INPUT:E1:SLOTNUMBER 17 11
- Explanation** Please refer to chapter ***E1/T1 Interface*** (p. 170) for further information.

OUTPut:FLOAT [OFF|ON]

Usage	Switches the generator output connectors to grounded (OFF) or floating (ON).
Availability	Normal and PureSound™ mode (also if the analyzer is armed), whereby the generator must be switched to analog operation (OUTPut:SOURce ANALog).
Range	[OFF ON] <i>string</i>
Default	OFF
Query	OUTPut[1 2]:STATus?
Example	 → Output:Float ON
Explanation	Please refer to chapters Ground Connections and Analog Output Connections , (p. 181, 287) for application details.

OUTPut[1|2]:IMPedance [150|600|200|850|900|COMPLEX|CUSTOMER1|CUSTOMER2|CUSTOMER3|CUSTOMER4]

Usage	Activates the impedance of the analog generator output (p. 183).
Availability	Normal, RL and PureSound™ mode (also if the analyzer is armed), whereby the generator must be switched to analog operation (OUTPut:SOURce ANALog).
Range	[150 600 200 850 900 COMPLEX CUSTOMER1 CUSTOMER2 CUSTOMER3 CUSTOMER4] <i>integer string</i>
Default	150 (Ohm)
Query	OUTPut[1 2]:STATus? and OUTPut[1 2]:ZREF:CUSTomer[1 2 3 4]?
Examples	 → Output:Imp 150 (output impedance of <u>both</u> channels = 150 Ω)  → OUTP1:IMPED 600 (output impedance of channel 1 = 600 Ω)
Explanation	The RT-2X output impedance is only active in status INPut[1 2]:LINK OFF. - Numerical values refer to the output impedance expressed in Ω (Ohm). - The COMPLEX output impedance equals 220 Ω + (820 Ω // 115 nF) and is included on the RT-2X impedance option. - The CUSTOMERx output impedance are user-defined and must be ordered separately and assembled by NTI on the RT-2X impedance option.

NOTE If no channel-number is indicated, the **OUTPut[1|2]:IMPedance ...** command applies on **both** channels simultaneously.

OUTPut:ISDn:LAW [ALAW|ULAW|OFF]

Usage	Activates the ISDN LAW output signal coding.
Availability	Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed), whereby the ISDN interface must be installed.
Range	[ALAW ULAW OFF] <i>string</i>
Default	ALAW
Query	OUTPut[1 2]:STATus?
Example	 → OUTP:ISD:LAW ULAW
Explanation	If the LAW-encoding of the RT-2X output is active, the analyzer of the receiving RT-2X unit must be adjusted accordingly (use command INPut:ISDn:LAW [ALAW ULAW OFF]).

OUTPut[1;2]:LEVel <Level> **[V;VP;DBV;DBVP;DBM;DBFSP;%FSP;DBFS;%FS;DBM0]**

Usage Defines the MT Level, i.e. the overall output level of the active test signal (refer to p. 234).

Availability Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed).

Parameter

A) A-A, A-D operation		
[xx V]		(Volt _{RMS})
0.001 to 28.20 VP		(Volt Peak)
xx DBV	float & string	(Decibel Volt _{RMS})
-60.00 to +29.00 DBVP		(Decibel Volt Peak)
xx DBM		(Analog RMS level, p. 281)
B) D-A, D-D operation		
[-72.25 to +6.00 DBFSP]		(Decibel FullScale peak)
0.0244 to 200.00 %FSP		(Percent of FullScale Peak)
-72.25 to +yy DBFS	float & string	(Decibel FullScale)
0.0244 to yy %FS		(Percent of FullScale)
yy DBM0		(Digital RMS level, p. 282)

Default [0 DBVP;0 DBFSP] (A-A, A-D | D-A, D-D operation)

Query **OUTPut[1;2]:LEVel?** [V;VP;DBV;DBVP;DBM;DBFSP;%FSP;DBFS;%FS;DBM0]

Examples  → output2:level 0.50E-01 dbm

 → Outp1:Level -6.2 dBVp

 → OUTPUT2:LEVEL 0.35e2 V

Explanation The MT Level represents the actual RMS level of the complete multitone signal, regardless whether some of its signal bins are weighted or not.

The absolute maximum analog MT Level is +29 dBVp. If the MT Level is expressed in dBV, V, dBm, dBFS, %FS or dBm0, its range depends on the Crest factor of the test signal.

Command **OUTPut:MTONE:PARAMeter ...** allows individually weighting the multitone signal bins (chapter **Multitone Binlevel Weighting (Individual Binlevel)**, p. 236).

NOTE REFER TO CHAPTER **Output Level** (p. 234) FOR DETAILS ABOUT THE CORRELATION BETWEEN MT LEVEL, BINLEVEL AND SINELEVEL.

[dBm] is a power unit that refers to 600 Ω output impedance. Thus, if another output impedance is selected, the actual RMS output level changes.

OUTPut[1'2]:LEVeL? [V|VP|DBV|DBVP|DBM|DBFSP|%FSP|DBFS|%FS|DBM0]

Usage Queries the MT Level of the active test signal, expressed in the indicated unit.

Availability Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed).

Parameter

A) A-A, A-D operation

[V		(Volt _{RMS})
VP		(Volt Peak)
DBV	string	(Decibel Volt _{RMS})
DBVP		(Decibel Volt Peak)
DBM]		(Analog RMS level, p. 281)

B) D-A, D-D operation

[DBFSP		(Decibel FullScale peak)
%FSP		(Percent of FullScale Peak)
DBFS	string	(Decibel FullScale)
%FS		(Percent of FullScale)
DBM0]		(Digital RMS level, p. 282)

Answer

A) A-A, A-D operation

<MTLeveL> [DBVP|VP|DBV|V|DBM] float & string

B) D-A, D-D operation

<MTLeveL> [DBFSP|%FSP|DBFS|FS|DBM0] float & string

Examples

→ Output1:Level? dBVp
→ 6.80888E+00 DBVP

→ OUTP2:LEV? DBFS
→ 0.2103E-01 DBFS

Explanation The MT Level represents the actual RMS level of the complete multitone signal, regardless whether some of its signal bins are weighted or not.

The command is very helpful for the conversion of the MT Level into different units. For instance, if the MT Level has been defined in V, it can be queried directly in another unit.

Even if the generator level has been defined with command **OUTPut[1'2]:BINlevel ...** or **OUTPut[1'2]:SINlevel ...** the query returns directly the MT Level.

NOTE REFER TO CHAPTER *Output Level* (p. 234) FOR DETAILS ABOUT THE CORRELATION BETWEEN SINELEVEL, MT LEVEL AND BINLEVEL.

[dBm] is a power unit that refers to 600 Ω output impedance. Thus, if another output impedance is selected, the actual RMS output level changes.

OUTPut:MTONe:ACTive [1|2|3|4|5|6|7|8|LOUDNESS|ERL|SRLHI|SRLLO]

Usage Selects the active multitone signal for the next signal transmission. All commands with no signal number refer by default to this selection.

Availability Normal, LCL, RL and PureSound™ mode (not available if the analyzer is armed), whereby ERL, SRLHI and SRLLO are only available if the LCL/RL option is installed and the RL Bridge active (**INOUT:RLBRidge:MODE ON**).

Parameter

A) SYSTem:MODE 48Ksamplingrate
[1|2|3|4|LOUDNESS|ERL|SRLHI|SRLLO] *integer|string*

B) SYSTem:MODE 8Ksamplingrate
[5|6|7|8|LOUDNESS|ERL|SRLHI|SRLLO] *integer|string*

Query OUTPut[1|2]:STATus?

Examples

→ OUTP:MTON:ACT 2

→ output:mtone:active loudness

Explanation

- Signals No. 1 – 4 (user-defined) are for A–A operation @ $f_s = 48$ kHz.
- Signals No. 5 – 8 (user-defined) are for A–A, A–D, D–A, D–D operation @ $f_s = 8$ kHz.
- Signal LOUDNESS is for SLR, RLR and STMR measurements (p. 213).
- Signals ERL, SRLHI and SRLLO are only available if the LCL/RL option is installed.

OUTPut:MTONe:BLOCKlength?

Usage Queries the blocklength (i.e. number of samples) of the active multitone signal (p. 197).

Availability Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed).

Answer

A) SYSTem:MODE 48Ksamplingrate
[512|1024|2048|4096|8192] *integer*

B) SYSTem:MODE 8Ksamplingrate
[128|256|512|1024|2048] *integer*

Example

→ OUTput:MTONe:BLOCKlength
→ 2048

OUTPut:MTONe:CLEarweightings

Usage Clears the individual BinLevel weighting of the active multitone signal.

Availability Normal mode (not available if the analyzer is armed).

Example

→ OUTP:MTONE:CLE

Explanation Refer to commands **OUTPut:MTONe:PARAMeter ...** and **OUTPut[1|2]:MTONe:EQUALize** as well as to the chapter **Multitone Binlevel Weighting (Individual Binlevel)** (p. 236).

OUTPut:MTONE:CONTinuous

Usage Starts RT-2X to continuously generate the active multitone signal.

Availability Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed).

Example  → OUTP:MTONE:CON

Explanation The multitone signal is sent out in a continuous loop without header.

Stop the continuous multitone signal generation by sending any command to RT-2X.

NOTE No measurement can be executed in this status.

OUTPut[1;2]:MTONE:CRESt?

Usage Queries the Crest factor of the active multitone signal (p. 199).

Availability Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed).

Answer <CrestFactor> float (any positive number $\geq \sqrt{2}$)

Example  → OUTP1:MTONE:CREST?
→  2.33433E00

Explanation The Crest factor can be used to calculate the correspondance between:

- RMS output level and peak level of a multitone signal (p. 234).
- MT Level, BinLevel and SineLevel (p. 235).

OUTPut[1;2]:MTONE:EQUalize

Usage Equalizes the active multitone signal with the inverse transfer function of the last successful multitone measurement (p. 236).

Availability Normal mode (not available if the analyzer is armed).

Example  → Outp2:Mton:Equ

Explanation The command amends the individual BinLevel weighting of the active multitone signal so that the new weighting compensates the frequency response of the DUT.

NOTE Use command *OUTPut:MTONE:CLEarweightings* to reset an equalized BinLevel weighting.

OUTPut:MTONe:MTONelength <Length>

- Usage** Prolongs the multitone signal duration of the active multitone signal (p. 201).
- Availability** Normal, LCL, RL and PureSound™ mode (not available if the analyzer is armed).
- Parameter** <Length> *integer* 0 to 30000 (multitone length in ms; resolution = 1)
- Default** 0 (ms)
- Example**  → Outp:Mton:Mton 500
- Explanation** The <Length> is rounded to the next possible integer multiple of 1 multitone block duration. 0 corresponds to the transmission of the minimum number of multitone blocks.
- The command allows the DUT stabilizing to the multitone signal before analysis is started.

OUTPut:MTONe:NAME?

- Usage** Queries the name of the active multitone signal.
- Availability** Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed).
- Answer** <Name> *string* (up to 8 characters)
- Example**  → Output:Mtone:Name?
→  23_BIN

OUTPut:MTONe:PARAmeter [1;2;3;4;5;6;7;8;LOUDNESS;ERL;SRLLO;SRLHI],
<SignalName>,[128;256;512;1024;2048;4096;8192],[WTD,]
<#SigBinsChn1>,<#SigBinsChn2>,{Bin_ID1},{Bin_ID2},
{ ϕ 1},{ ϕ 2},{Weighting1},{Weighting2}

Usage Defines the mandatory and the optional parameters of a multitone signal.

Availability Normal, LCL, RL and PureSound™ mode (not available if the analyzer is armed).

Parameter

A) SYSTem:MODE 48Ksamplingrate

[1;2;3;4;	integer string	(multitone signal number, p. 227)
LOUDNESS;ERL;		
SRLLO;SRLHI],		
<SignalName>,	string	(user-defined name, ≤ 8 characters, no spaces)
[512;1024;2048;	integer	(blocklength, p. 197)
4096;8192],		
[;WTD,]	string	(string 'WTD' activates BinLevel weighting, p. 236)
<#SigBinsChn1>,	integer	1 to 31 (number of signal bins that are defined for channel 1, channel 2)
<#SigBinsChn2>,	integer	
{Bin_ID1},	integer	Bin_Min to Bin_Max (individual signal bin Nos. of channel 1, channel 2, p. 226)
{Bin_ID2},	integer	
{ ϕ 1},	float	-3.1416 to + 3.1416 (individual phases of chn. 1, chn. 2 signal bins in radian, resolution = 0.001)
{ ϕ 2}	float	
{,0 to -60}	float	(individual BinLevel weightings of chn. 1, chn. 2 in dB, resolution = 0.00001 [apply only if WTD])
{,0 to -60}	float	

B) SYSTem:MODE 8Ksamplingrate

[5;6;7;8;	integer string	(multitone signal number, p. 227)
LOUDNESS;ERL;		
SRLLO;SRLHI],		
<SignalName>,	string	(user-defined name, ≤ 8 characters, no spaces)
[128;256;512;	integer	(blocklength, p. 197)
1024;2048],		
[;WTD,]	string	(string 'WTD' activates BinLevel weighting, p. 236)
<#SigBinsChn1>,	integer	1 to 31 (number of signal bins that are defined for channel 1, channel 2)
<#SigBinsChn2>,	integer	
{Bin_ID1},	integer	Bin_Min to Bin_Max (individual signal bin Nos. of channel 1, channel 2, p. 226)
{Bin_ID2},	integer	
{ ϕ 1},	float	-3.1416 to + 3.1416 (individual phases of chn. 1, chn. 2 signal bins in radian, resolution = 0.001)
{ ϕ 2}	float	
{,Weighting1}	float	0 to -60 (individual BinLevel weightings of chn.1, chn.2 in dB, resolution = 0.00001 [only if WTD])
{,Weighting2}	float	

Query **OUTPut:MTONe:PARAmeter?**

Examples

→ OUTP:MTON:PAR 3, '3TONEWTD', (signal # 3, signal name '3TONEWTD',
512,WTD,3,3,3,7,32,5,9,36, blocklength 512, individual BinLevel
-0.15254E+01,2.43579E+01, weighting active, 3 signal bins different
3.04434E+01,-0.15254E+01, on chn.1: 3, 7, 32 and chn.2: 5, 9, 36 with
2.43579E+01,3.04434E+01, identical phases: -1.5254, 2.43579,
0.00,-0.60E+02,-1.20E+02, 3.04434, individual BinLevel weighting
0.00,0.00,0.00 of chn.1 signal bins: 0,-6,-12 [dB])

→ OUTP:MTON:PAR 1, 'TELEFON', (signal No. 1, signal name 'TELEFON',
2048,3,3,25,85,256,25,85, blocklength 2048, no individual BinLevel
256,0,1.5708E00,3.1416E00, weighting, 3 identical signal bins on both
0,1.5708E00,3.1416E00 channels: 25, 85, 256 with identical
phases: 0, $\pi/2$, π [= 0°, 90°, 180°])

- Explanation** The command parameters comprise all information that define a multitone signal, except of the generator level (refer to **OUTPut[1|2]:LEVel ...** and **OUTPut[1|2]:BINlevel ...**).
- The parameters of the predefined signals (LOUDNESS, ERL, SRLLO, SRLHI) cannot be amended. The only exception is the BinLevel weighting of the "LOUDNESS" signal that can be equalized with command **OUTPut[1|2]:MTONE:EQualize** and cleared with **OUTPut:MTONE:CLEarweightings**.
 - $\langle \#SigBins1|2 \rangle$ equals the total number of signal bins for channel 1|2.
 - The available $\langle Blocklength \rangle$ range depends on the actual sampling frequency, defined with command **SYSTem:MODE [8Ksamplingrate|48Ksamplingrate]**
 - $\{BinID1|2\}$ indicates the bin numbers as calculated with **Equation 18** (p. 226).
 - $\{\phi1|2\}$ indicates the phases of the signal bins.
 - $\{Weightg1|2\}$ defines the attenuation of the corresponding signal bin, expressed in dB (0 dB = no attenuation). At least one signal bin must be left unweighted (p. 236).
 - Use command **OUTPut[1|2]:MTONE:EQualize** to let RT-2X automatically define a BinLevel weighting that compensates for the DUT's frequency response.
 - Use command **OUTPut:MTONE:CLEarweightings** to clear the BinLevel weighting.

NOTE	In case of BinLevel weighting, the reference bin has the highest BinLevel within the multitone signal, because it is not possible to apply a negative weighting (i.e. amplification).

OUTPut:MTONe:PARAmeter?

Usage Queries the parameters of the active multitone signal.

Availability Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed).

Answer

A) SYSTem:MODE 48Ksamplerate

[1 2 3 4	integer string	(multitone signal number, p. 227)
LOUDNESS ERL		
SRLLO SRLHI],		
<SignalName>,	string	(user-defined name)
[512 1024 2048	integer	(blocklength, p. 197)
4096 8192],		
[WTD,]	string	('WTD' = BinLevel weighting active, p. 236)
<#SigBinsChn1>,	integer	1 to 31 (number of signal bins that of channel 1,
<#SigBinsChn2>,	integer	channel 2)
{Bin_ID1},	integer	Bin_Min to Bin_Max (individual signal bin Nos.
{Bin_ID2},	integer	of channel 1, channel 2, p. 226)
{φ1},	float	−3.1416 to +3.1416 (individual phases of chn. 1,
{φ2}	float	chn. 2 signal bins in radiant)
{, 0 to −60}	float	(individual BinLevel weightings of chn. 1, chn. 2
{, 0 to −60}	float	in dB [only if WTD])

B) SYSTem:MODE 8Ksamplerate

[5 6 7 8	integer string	(multitone signal number, p. 227)
LOUDNESS ERL		
SRLLO SRLHI],		
<SignalName>,	string	(user-defined name)
[128 256 512	integer	(blocklength, p. 197)
1024 2048],		
[WTD,]	string	('WTD' = BinLevel weighting active, p. 236)
<#SigBinsChn1>,	integer	1 to 31 (number of signal bins that of channel 1,
<#SigBinsChn2>,	integer	channel 2)
{Bin_ID1},	integer	Bin_Min to Bin_Max (individual signal bin Nos.
{Bin_ID2},	integer	of channel 1, channel 2, p. 226)
{φ1},	float	−3.1416 to +3.1416 (individual phases of chn. 1,
{φ2}	float	chn. 2 signal bins in radiant)
{,Weighting1}	float	0 to −60 (individual BinLevel weightings of chn.
{,Weighting2}	float	1, chn. 2 in dB [only if WTD])

Examples

→ OUTP:MTON:PAR?
→ 4, 3TONE, 512, WTD, 3, 3, 3, 11, 32, (signal No. 4, signal name '3TONE',
3, 11, 32, −0.352E00, 2.435E00, blocklength 512, individual BinLevel
2.644E00, −0.352E00, 2.435E00, weighting active, 3 identical signal
2.644E00, 0.00E00, −0.60E+02, bins on both channels.2: 3, 11, 32 with
−1.20E+02, 0.00E00, 0.00E00, identical phases: −0.352, 2.435, 2.644,
0.00E00 individual BinLevel weighting of
chn.1 signal bins: 0, −6, −12 [dB])

→ OUTP:MTON:PAR?
→ 7, ISDN_1, 128, 4, 4, 1, 32, 48, 64, (signal No. 7, signal name 'ISDN_1',
1, 32, 48, 64, 1.23E00, 0.01E00, blocklength 128, no individual
−3.141E00, −1.65E00, 0.98E00, BinLevel weighting, 4 identical signal
2.99E00, 1.54E00, −0.55E00 bins on both channels: 1, 32, 48, 64,
phases chn.1: 1.23, 0.01, −3.14, −1.65,
phases chn.2: 0.98, 2.99, 1.54, −0.55)

Explanation The format of the returned string complies with **OUTPut:MTONe:PARAmeter ...**

OUTPut:MTONe:PRETriggerlength <Length>

Usage	Prolongs the duration of the multitone pretrigger for the active signal (p. 224).
Availability	Normal, LCL, RL and PureSound™ mode (<u>not</u> available if the analyzer is armed).
Parameter	<Length> <i>integer</i> 0 to 30000 (pretrigger duration expressed in ms; resolution = 1)
Default	0 (ms)
Example	 → Output:Mtone:Pret 12345

Explanation <Length> does not include the duration of the trigger, which always occupies some 42 ms.
<Length> = 0 defines the shortest possible pretrigger length = 0 ms.

This command allows the DUT stabilizing before the trigger signal is transmitted.

OUTPut:MTONe:START

Usage	Starts the transmission (i.e. generation and/or analysis) of the active multitone signal.
Availability	Normal, LCL and RL mode (<u>not</u> available if the analyzer is armed).
Example	 → OUTP:MTONE:START

Explanation Send this command to RT-2X to

- generate and analyze a multitone burst or
- only generate a multitone burst or
- only analyze a multitone burst.

Refer to command **INPut:SYNC ...** and chapter **Test Setups** (p. 264) for further information about the generation and analysis of multitone signals as well as test setup parameters

OUTPut[1|2]:MUTe [OFF|ON]

Usage	Mutes the generator output.
Availability	Normal and PureSound™ mode (also if the analyzer is armed).
Parameter	[OFF ON] <i>string</i>
Default	OFF
Query	OUTPut[1 2]:STATus?

Example  → Output1:Mute ON

Explanation In the **MUTe** state, the *output connectors* are not disconnected from the internal output impedance circuit, whereby the *generator circuit* is internally disconnected.

OUTPut:PCM:SLOTnumber <Channel1> <Channel2>

Use	Assigns an individual slot-number to each of the two output channels 1, 2.		
Availability	Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed), whereby the E1/T1/PCM interface must be installed. Table 17 describes the slot-availability depending on the number of channels, DataWord length and BCLK		
Parameter	<Chn1>	integer 0 to 31,X	See Table 17 for restrictions
	<Chn2>	integer 0 to 31,X	
Default	0 1		
Query	INPut[1 2]:STATus?		
Examples	 →	OUTP:PCM:Slot 1 2	
	 →	OUTPUT:PCM:Slot 0 X	
	 →	OUTPUT:PCM:Slotnumber X 0	
Explanation	The 2-channel architecture of RT-2X allows using two different slots independently. Please refer to p. 239 for further information.		

OUTPut:PCM:FRAMESync:SYNC [EXTeRnal|INTeRnal]

Use	Defines, whether the transmit FrameSync signal (connector TX-FS) is generated internally (by RT-2X) or externally (by the DUT).		
Availability	Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed), whereby the E1/T1/PCM interface must be installed.		
Parameter	[External Internal]	string	The FrameSync signal is generated externally by RT-2X, whereby the transmit FrameSync is configured as Input Output.
Default	INTERNAL		
Query	OUTPUT1:STATUS?		
Examples	 →	OUTPUT:PCM:FRAMESYNC:SYNC EXTERNAL	
Explanation	Framing signals indicate the beginning of each frame. Each frame contains the channels (or slots) to be received / transmitted. Both transmit & receive FrameSync signals can be generated independently by RT-2X or synchronized to an external source (e.g. DUT).		

OUTPut:PCM:DATA:DIRection [MSBFIRST|LSBFIRST]

Use	Determines, whether the serial DataWord is transmitted MSB-first or LSB-first.		
Availability	Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed), whereby the E1/T1/PCM interface must be installed.		
Parameter	[MSBFIRST LSBFIRST]	<i>string</i>	The serial words are transmitted with endian format MSB-first or LSB-first.
Default	MSBFIRST		
Query	OUTPUT1:STATUS? LINK		
Examples	 →	OUTPUT:PCM:FRAMESYNC:SYNC EXTERNAL	
Explanation	Refer to p. 239 for further details.		

OUTPut:PCM:LAW [ALAW|ULAW|OFF]

Usage	Defines the type of PCM signal decoding.
Availability	Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed), whereby the E1/T1/PCM interface must be installed.
Parameter	[ALAW ULAW OFF] <i>string</i>
Default	OFF
Query	INPut[1 2]:STATus?
Examples	 → OUTPUT:PCM:law Alaw
Explanation	If the LAW-encoding of the RT-2X output is active, the analyzer of the receiving RT-2X unit must be adjusted accordingly (use command INPut:PCM:LAW [ALAW ULAW OFF]).

OUTPut:PUResound:CHIRp:AMPLitudeshape <Frequency>,<Attenuate_HI>,<Attenuate_LO>

Usage Attenuates the generated chirp level above or below an user-defined frequency (p. 239).

Availability Normal and PureSound™ mode (not available if the analyzer is armed).

Parameter

<Frequency>,	float	5.0 to 750.0	(frequency in Hz; resolution = 0.01)
<Attenuate_HI>,	float	0.0 to -40.0	(attenuation in dB <u>above</u> the specified frequency; resolution = 0.1)
<Attenuate_LO>	float	0.0 to -40.0	(attenuation in dB <u>below</u> the specified frequency; resolution = 0.1)

Default 500, 0, 0 (Hz, dB, dB)

Query OUTPut:PUResound:CHIRp:AMPLitudeshape?

Examples

 →	outp:pur:chirp:ampl 100, -20	(transition frequency = 100 Hz, attenuation above = -20 dB)
 →	outp:pur:chirp:ampl 3000, 0, -12	(transition frequency = 3 kHz, attenuation below = -12 dB)

Explanation The command is mainly intended for woofer or compression tweeter testing. This application typically requires:

- a very high test signal level at low (or high) frequencies to detect all Rub&Buzz defects,
- a lower test signal level at higher (or lower) frequencies to protect the operator's ears.

The amplitude shape has no impact on the continuous frequency change nor the chirp duration. The transition time is fixed to 10.2 ms.

NOTE Either the <Attenuate_HI> or <Attenuate_LO> must be 0 (Zero).

OUTPut:PUResound:CHIRp:AMPLitudeshape?

Usage Queries the chirp level attenuation and the transition frequency (p. 239).

Availability Normal and PureSound™ mode (not available if the analyzer is armed).

Answer

<Frequency>,	float	5.0 – 750.0	(frequency in Hz; resolution = 0.01)
<Attenuate_HI>,	float	0.0 to -40.0	(attenuation in dB <u>above</u> the specified frequency; resolution = 0.1)
<Attenuate_LO>	float	0.0 to -40.0	(attenuation in dB <u>below</u> the specified frequency; resolution = 0.1)

Default 500, 0, 0 (Hz, dB, dB)

Example

 →	outp:pur:chirp:ampl?	
→ 	50, -15, 0	(transition frequency = 50 Hz, attenuation below = -15 dB)
 →	outp:pur:chirp:ampl?	
→ 	1500, 0, -40	(transition frequency = 1.5 kHz, attenuation above = -40 dB)

OUTPut:PUResound:CHIRp:FADEin <Duration>

- Usage** Defines the fade-in duration of the chirp (= gliding sweep, p. 239).
- Availability** Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed).
- Parameter** <Duration> *integer* 0 to 1000 (fade-in duration expressed in ms; resolution = 1)
- Default** 20 (ms)
- Example**  → outp:pur:chirp:fade 0.30E+02
- Explanation** During fade-in, RT-2X linearly increases the amplitude of the start frequency from 0 to the defined output level. This prevents an initial transient at the beginning of the chirp.
- Most applications require a fade-in that is shorter than the settling (refer to the command **OUTPut:PUResound:CHIRp:SETTling <Duration>**, p. 78).

OUTPut:PUResound:CHIRp:FRANge [NORMal|EXTended]

- Usage** Determines the frequency range (i.e. bandwidth) of the chirp (= gliding sweep, p. 239).
- Availability** Normal and PureSound™ mode (not available if the analyzer is armed)
- Parameter** [NORMal|EXTended] *string* (NORMal = 20–1500 Hz | EXTended = 5–6000 Hz)
- Default** NORMal
- Example**  → OUTPut:PUResound:CHIRp:FRANge EXT
- Explanation** Most drivers, speakers etc. can be tested properly in the NORMal range (20 – 1500 Hz). Only few woofers or tweeters need a stimulus 5–20 Hz or 1.5–6.0 kHz (EXTended).

NOTE The generated chirp level is attenuated in the range 5–20 Hz as follows:
 0 dB @ 20 Hz → -0.6 dB @ 10 Hz → -1.3 dB @ 5 Hz

OUTPut:PUResound:CHIRp:FSTArt <Frequency>

- Usage** Defines the start frequency of the chirp (= gliding sweep, p. 239).
- Availability** Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed).
- Parameter** <Frequency> *float* 20.0 to 1500.0 | 6000.0 (start frequency in Hz, resolution = 0.1; > 1500.0 Hz only with extended range)
- Default** 200.0 (Hz)
- Example**  → outp:pur:chirp:fsta 1.00E+03
- Explanation** Adjust the start frequency if RT-2X generates the chirp before transmitting the latter with the command **OUTPut[1|2]:PUResound:CHIRp:STArt**.

NOTE The generated chirp level is attenuated in the range 5–20 Hz as follows:
 0 dB @ 20 Hz → -0.6 dB @ 10 Hz → -1.3 dB @ 5 Hz

OUTPut:PUResound:CHIRp:FSTOp <Frequency>

- Usage** Defines the stop frequency of the chirp (= gliding sweep, p. 239).
- Availability** Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed).
- Parameter** <Frequency> *float* 20.0 to 1500.0 | 6000.0 (start frequency in Hz, resolution = 0.1; > 1500.0 Hz only with extended range)
- Default** 1000.0 (Hz)
- Example**  → outp:pur:chirp:fsto 0.25E+04
- Explanation** Adjust the stop frequency if RT-2X generates the chirp before transmitting the latter with the command **OUTPut[1|2]:PUResound:CHIRp:STARt**.

NOTE The generated chirp level is attenuated in the range 5–20 Hz as follows:
0 dB @ 20 Hz → -0.6 dB @ 10 Hz → -1.3 dB @ 5 Hz

OUTPut:PUResound:CHIRp:LENGth <Duration>

- Usage** Sets the duration of the chirp (= gliding sweep, p. 239).
- Availability** Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed).
- Parameter** <Duration> *integer* 100 to 10000 (chirp duration expressed in ms; resolution = 1)
- Default** 1000 (ms)
- Example**  → outp:pur:chirp:leng 1.5E+03
- Explanation** Adjust the stop frequency if RT-2X generates the chirp before transmitting the latter with the command **OUTPut[1|2]:PUResound:STARt**.

NOTE The chirp duration must always be higher or identical to the acquisition length defined by **MEASurement:PUResound:LENGth**.

OUTPut:PUResound:CHIRp:MAXRuns <Runs>

- Usage** Defines the number of cycles (i.e. repeated measurements) that are executed if the acquired steepness results exceed the user-defined individual limits. Thus, RT-2X can separate random noise from systematic DUT defects (p. 252).
- Availability** Normal, LCL, RL and PureSound™ mode (not available if the analyzer is armed).
- Parameter** <Runs> *integer* 1 to 20 (maximum number of runs; resolution = 1)
- Default** 1 (one RNB test per DUT)
- Example**  → outp:pur:chirp:maxr 5
- Explanation** In a noisy environment, adjust <Runs> to ≥ 2. Thus RT-2X re-measures every DUT that exceeds the given steepness limits and determines, whether the recorded transients are caused by a Rub & Buzz defect or random noise.

OUTPut:PUResound:CHIRp:SETTling <Duration>

- Usage** Defines the settling duration of the RNB chirp (refer to p. 239).
- Availability** Normal, LCL, RL and PureSound™ mode (not available if the analyzer is armed).
- Parameter** <Duration> *integer* 0 to 1000 (settling duration expressed in ms; resolution = 1)
- Default** 50 (ms)
- Example**  → outp:pur:chirp:settling 1.0E+02
- Explanation** Settling represents the time during which RT-2X generates the start frequency before it actually starts the chirp. This allows the test stand settling to the chirp's start frequency.

OUTPut[1|2]:PUResound:CHIRp:START

- Usage** Starts the RNB chirp generation and analysis.
- Availability** PureSound™ mode in status **INOUT:PUResound:MODE RNB** (not available if the analyzer is armed).
- Example**  → Outp1:pur:chirp:star
- Explanation** The command not only starts the chirp transmission but also the RNB analysis of the incoming signal (refer to chapter **Test Setups**, p. 264).
- Alternatively, it is possible to execute a RNB analysis on an externally generated signal with command **MEASurement[1|2]:PUResound:START**.

OUTPut:PUResound:STATus?

- Usage** Queries the status of the PureSound™ RNB chirp.
- Availability** Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed).
- Answer**
- | | | |
|---------------------------|-----------------------------|-----------------------------|
| FRANGE [NORMAL EXTENDED], | <i>string</i> | (1500 Hz 6000 Hz) |
| FSTART [20.0 to 6000.0], | <i>string & float</i> | (start frequency in Hz) |
| FSTOP [20.0 to 6000.0], | <i>string & float</i> | (stop frequency in Hz) |
| LENGTH [100 to 10000], | <i>string & integer</i> | (chirp duration in ms) |
| SETTLING [0 to 1000], | <i>string & integer</i> | (settling period in ms) |
| FADEIN [0 to 1000], | <i>string & integer</i> | (fade-in period in ms) |
| MAXRUNS [1 to 20] | <i>string & integer</i> | (# noise cancellation runs) |
- Example**  → OUTPUT:PUR:STAT?
 → FRANGE NORMAL, FSTART 2.00E+02, FSTOP 1.00E+03,
LENGTH 1000, SETTling 50, FADEIN 20, MAXRUNS 1

OUTPut[1;2]:SINelevel? **[V|VP|DBV|DBVP|DBM|DBFSP| %FSP|DBFS| %FS|DBM0]**

Usage Queries the SineLevel of the active test signal, expressed in the indicated unit.

Availability Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed).

Parameter

A) A-A, A-D operation

[V		(Volt _{RMS})
VP		(Volt Peak)
DBV	string	(Decibel Volt _{RMS})
DBVP		(Decibel Volt Peak)
DBM]		(Analog RMS level, p. 281)

B) D-A, D-D operation

[DBFSP		(Decibel FullScale peak)
%FSP		(Percent of FullScale Peak)
DBFS	string	(Decibel FullScale)
%FS		(Percent of FullScale)
DBM0]		(Digital RMS level, p. 282)

Answer

A) A-A, A-D operation

<MTLeve l> [DBVP|VP|DBV|V|DBM] float & string

B) D-A, D-D operation

<MTLeve l> [DBFSP|%FSP|DBFS|FS|DBM0] float & string

Example

```

→ Output1:sinelevel? dBVp
→ 6.80888E+00 DBVP

```

Explanation Similar to the MT Level, the SineLevel represents the RMS level of the test signal, regardless whether it is weighted (multitone) or shaped (stepped sweep).

The command is very helpful for the conversion of the SineLevel into different units. For instance, if the SineLevel has been defined in V, it can be queried directly in another unit.

Even if the generator level has been defined with command **OUTPut[1;2]:LEVel ...** or **OUTPut[1;2]:BINlevel ...**, the query returns directly the SineLevel.

NOTE REFER TO CHAPTER *Output Level* (p. 234) FOR DETAILS ABOUT THE CORRELATION BETWEEN SINELEVEL, MT LEVEL AND BINLEVEL.

[dBm] is a power unit that refers to 600 Ω output impedance. Thus, if another output impedance is selected, the actual RMS output level changes.

OUTPut:SOURce [ANALog|ISDn|E1|T1|PCM]

- Usage** Switches the RT-2X generator to ANALog, ISDn, E1, T1 or PCM operation.
- Availability** Normal mode (not available if the analyzer is armed), whereby the ISDN or E1/T1/PCM interface must be installed for D-A, D-D operation.
- Parameter** [ANALog|ISDn|E1|T1|PCM] *string*
- Default** ANALog
- Query** OUTPut[1|2]:STATus?
- Example**  → OUPt:SOUR ISD
- Explanation** The parameters **ISDn** or **E1**, **T1** and **PCM** are only available if the corresponding option is installed and the **SYSTem:MODE 8k** mode is active.

NOTE If you want to toggle the generator or analyzer from the E1 to the T1 mode (and vice versa), you must always switch the TX- and RX-section of RT-2X to the analog mode first.

OUTPut[1;2]:STATus?

Usage Queries the generator status.

Availability Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed).

Answer

A) A-A, A-D operation

MODE [8KSAMPLINGRATE 48KSAMPLINGRATE]	string
SOURCE ANALOG	string
ACTIVE [1 2 3 4 5 6 7 8 LOUDNESS ERL SRLLO SRLHI]	string & integer string
LEVEL [-60 to +29 dBVp 0.001 to 28.3 Vp]	string & float & string
BINLEVEL [-60 to +29 dBVp 0.001 to 28.3 Vp]	string & float & string
SINELEVEL [-60 to +29 dBVp 0.001 to 28.3 Vp]	string & float & string
MUTE [OFF ON]	string
IMPEDANCE [150 200 600 736 850 900 COMPLEX CUSTOMER1 CUSTOMER2 CUSTOMER3 CUSTOMER4]	string & integer string
FLOAT [OFF ON]	string
CLKSOURCE [INTERNAL RECOVERED]	string
SIGNALING [ENABLE DISABLE]	string
ACCOUPLING [OFF ON]	string

B) D-A, D-D operation with ISDN interface

MODE 8KSAMPLINGRATE	string
SOURCE ISDN	string
ACTIVE [5 6 7 8 LOUDNESS ERL SRLLO SRLHI]	string & integer string
LEVEL [-72.25 to 6 dBFSp 0.0244 to 200 %FSp]	string & float & string
BINLEVEL [-72.25 to 6 dBFSp 0.0244 to 200 %FSp]	string & float & string
SINELEVEL [-72.25 to 6 dBFSp 0.0244 to 200 %FSp]	string & float & string
MUTE [OFF ON]	string
LAW [ULAW ALAW OFF]	string

C) D-A, D-D operation with E1/T1 interface

MODE 8KSAMPLINGRATE	string
SOURCE [E1 T1 J1]	string
ACTIVE [5 6 7 8 LOUDNESS ERL SRLLO SRLHI]	string & integer string
LEVEL [-72.25 to 6 dBFSp 0.0244 to 200 %FSp]	string & float & string
BINLEVEL [-72.25 to 6 dBFSp 0.0244 to 200 %FSp]	string & float & string
SINELEVEL [-72.25 to 6 dBFSp 0.0244 to 200 %FSp]	string & float & string
MUTE [OFF ON]	string
LAW [ULAW ALAW OFF]	string
SLOTNUMBER [1 to 31 0 to 23]	string & integer
CLKSOURCE [INTERNAL RECOVERED]	string
SIGNALING [ENABLE DISABLE]	string

D) D-A, D-D operation with PCM interface

MODE 8KSAMPLINGRATE	string
SOURCE PCM	string
ACTIVE [5 6 7 8 LOUDNESS ERL SRLLO SRLHI]	string & integer string
LEVEL [-72.25 to 6 dBFSp 0.0244 to 200 %FSp]	string & float & string
BINLEVEL [-72.25 to 6 dBFSp 0.0244 to 200 %FSp]	string & float & string
SINELEVEL [-72.25 to 6 dBFSp 0.0244 to 200 %FSp]	string & float & string

MUTE [OFF|ON] *string*
LAW [ULAW|ALAW|OFF] *string*
SLOTNUMBER [0 to 1|2|4|8|16|31] *string & integer*
FRAMESYNC:SYNC [INTERNAL|EXTERNAL] *string*
DATA:DIRECTION [MSBFIRST|LSBFIRST] *string*

Examples

 → OUTPUT1:STATUS?
→  MODE 48KSAMPLINGRATE, SOURCE ANALOG, (A-A, A-D operation, Normal mode)
ACTIVE 2, LEVEL -4.59E+00 dBV,
BINLEVEL -9.35E+00 dBV, SINELEVEL
0.00E00 dBV, MUTE OFF, IMPEDANCE
150, FLOAT OFF

 → Output1:Status?
→  MODE 48KSAMPLINGRATE, SOURCE ANALOG, (A-A, A-D operation, LCL or RL mode)
ACTIVE ERL, LEVEL 0.00E00 dBVp,
BINLEVEL -1.90E-04 dBVp, SINELEVEL
0.00E00 dBVp, MUTE OFF, IMPEDANCE
736, FLOAT OFF, CLKSOURCE RECOVERED,
SIGNALING DISABLE

 → Output2:Status?
→  MODE 8KSAMPLINGRATE, SOURCE ISDN, (D-A, D-D operation with ISDN interface)
ACTIVE 5, LEVEL 1.00E-01 dBFsp,
BINLEVEL -1.65E-04 dBFsp, SINELEVEL
1.00E-01 dBFsp, MUTE OFF, LAW ALAW

 → Outp1:E1:Stat?
→  MODE 8KSAMPLINGRATE, SOURCE E1, (D-A, D-D operation in E1 mode)
ACTIVE 8, LEVEL -1.46E-04 dBm0,
BINLEVEL -3.14E+00 dBFsp, SINELEVEL -
1.74E-07 dBFsp, MUTE OFF, LAW ALAW,
SLOTNUMBER 1, CLKSOURCE INTERNAL,
SIGNALING DISABLE

 → Outp1:T1:Stat?
→  MODE 8KSAMPLINGRATE, SOURCE T1, (D-A, D-D operation in T1 mode)
ACTIVE 6, LEVEL 1.00E+00 dBFsp,
BINLEVEL -3.24E+00 dBFsp, SINELEVEL
1.00E+00 dBFsp, MUTE OFF, LAW ULAW,
SLOTNUMBER 0, CLKSOURCE RECOVERED,
SIGNALING DISABLE

 → Outp1:PCM:Stat?
→  MODE 8KSAMPLINGRATE, SOURCE PCM, (D-A, D-D operation in PCM mode)
ACTIVE 5, LEVEL 0.000E00 dBFsp,
BINLEVEL -1.64E-04 dBFsp, SINELEVEL
0.000E00 dBFsp, MUTE OFF, LAW OFF,
SLOTNUMBER 0, FRAMESYNC:SYNC INTERNAL,
DATA:DIRECTION MSBFIRST

Explanation

Please note the following restrictions:

- The signals No. 5–8 are only available if the ISDN or E1/T1/PCM interface is installed.
- The signals ERL, SRLLO and SRLHI are only available if the LCL/RL option is installed.
- In the LCL mode, the output impedance "736" of channel 1 is activated automatically.
- The strings CLKSOURCE and SIGNALING are only returned if the E1/T1 option is installed.
- The ACCOUPPLING status is only returned if the LCL/RL option is installed.

OUTPut:STEPpedswEEP:AMPLitudeSHAPE:SET ***<Shape₁>,<Shape₂>,...,<Shape_{#Steps+1}>***

Usage Defines the amplitude shape of the stepped sweep, i.e. the individual level attenuation of the sweep frequencies (p. 237).

Availability Normal, LCL, RL and PureSound™ mode (not available if the analyzer is armed).

Parameter <Shape_n>, float (attenuation of frequency #n, expressed in [dB])

Query ***OUTPut:STEPpedswEEP:AMPLitudeSHAPE:SET?***

Example  → **OUTP:STEP:AMPL:SET -4.57, -8.05, -3.25, 0**

Explanation The shaping (attenuation) becomes only effective if this feature is enabled (refer to command ***OUTPut:STEPpedswEEP:AMPLitudeSHAPE:ACTive [ENABle|DISABle]***).

"n", i.e. the number of <Shape_n> values must equal <#Steps+1> as defined with the command ***OUTPut:STEPpedswEEP:NStEPS <#Steps>***.

NOTE At least one frequency must not be attenuated (<Shape_x> = 0) to act as reference for the output level definition.

OUTPut:STEPpedswEEP:AMPLitudeSHAPE:ACTive [ENABle|DISABle]

Usage Enables or disables the amplitude shaping of the stepped sweep (p. 237).

Availability Normal, LCL, RL and PureSound™ mode (not available if the analyzer is armed).

Parameter [ENABle|DISABle] String

Default DISABLE

Example  → **OUTP:STEP:AMPL:ACT ENAB**

Explanation The amplitude shaping can only be enabled if the number of <Shape> values = <#Steps> + 1, whereby <Shape> and <#Steps> are defined by ***OUTPut:STEPpedswEEP:AMPLitude:SET <Shape₁>,...,<Shape_{#Steps+1}>*** and ***OUTPut:STEPpedswEEP:NStEPS <#Steps>*** respectively.

OUTPut:STEPpedswEEP:AMPLitudeSHAPE:SET?

Usage Queries the amplitude shape values of the stepped sweep (p. 237).

Availability Normal, LCL, RL and PureSound™ mode (not available if the analyzer is armed).

Answer {Shape_n}, float (amplitude shape values of all sweep frequencies, expressed in dB)

Example  → **OUTP:STEP:AMPL:SET?**
→  **-4.57E00, -8.05E00, -3.25E00, 0**

Explanation The number of returned {Shape_n} values = <#Steps> + 1, whereby <#Steps> is defined with the command ***OUTPut:STEPpedswEEP:NStEPS <#Steps>***.

OUTPut:STEPpedswEEP:FSTArt <StartFrequency>

- Usage** Defines the start frequency of the stepped sweep (generator & analyzer, p. 255).
- Availability** Normal, LCL, RL and PureSound™ mode (not available if the analyzer is armed).
- Parameter** <StartFrequency> *float* 20.00 to 20000.00 (start freq. in Hz; resolution = 0.0001)
- Default** 20.00 (Hz)
- Example**  → outp:step:fsta 1.50037e2
- Explanation** Define the start frequency before sending the command ***OUTPut:STEPpedswEEP:START***.

OUTPut:STEPpedswEEP:FSTOp <StopFrequency>

- Usage** Defines the stop frequency of the stepped sweep (generator & analyzer, p. 255).
- Availability** Normal, LCL, RL and PureSound™ mode (not available if the analyzer is armed).
- Parameter** <StopFrequency> *float* 20.00 to 20000.00 (stop freq. in Hz; resolution = 0.0001)
- Default** 20000.00 (Hz)
- Example**  → outp:step:fsto 1.20E+03
- Explanation** Define the stop frequency before sending the command ***OUTPut:STEPpedswEEP:START***.

OUTPut:STEPpedswEEP:NSTeps <#Steps>

- Usage** Defines the number of steps for the stepped sweep (p. 255).
- Availability** Normal, LCL, RL and PureSound™ mode (not available if the analyzer is armed).
- Parameter** <#Steps> *integer* 1 to 500 (number of steps; resolution = 1)
- Default** 100 (100 steps = 101 frequencies)
- Example**  → outp:step:nst 30
- Explanation** A sweep with n steps comprises of $n+1$ frequencies (if e.g. <#Steps> = 3, then the resulting stepped sweep comprises of 4 frequencies).
- The frequencies are placed with equal intervals on the logarithmic frequency axis.
- Define the number of steps before sending the command ***OUTPut:STEPpedswEEP:START***.

OUTPut:STEPpedswEEP:STARt

- Usage** Starts the stepped sweep generation & analysis (p. 265).
- Availability** Normal, LCL, RL and PureSound™ mode (not available if the analyzer is armed).
- Example**  → Outp:steppedswEEP:start
- Explanation** Command **OUTPut:STEPpedswEEP:STARt** not only starts the stepped sweep generation but also the simultaneous acquisition of the transmitted signal.
- The **INPut:SNYC ...** command has no effect on the analyzer triggering.

OUTPut:STEPpedswEEP:STATus?

- Usage** Queries the stepped sweep generator status.
- Availability** Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed).
- Answer**
- | | | |
|---------------------------------|---------|-------------------------------|
| FSTART [20.00 to 20000.00] | float | (start frequency in Hz) |
| FSTOP [20.00 to 20000.00] | float | (stop frequency in Hz) |
| NSTEPS [1 to 500] | integer | (number of sweep steps) |
| AMPLITUDESHAPE [ENABLE DISABLE] | string | (status of amplitude shaping) |
- Example**
-  → OUTPUT:STEPPEDSWEEP:STAT?
 →  FSTART 2.20E+01,FSTOP 2.00E+04,NSTEPS 3,
 AMPLITUDESHAPE ENABLE

OUTPut:T1:CLKSource [INTERNAL|RECOVERED]

Usage	Selects, whether the clock of the TX-bitstream shall be synchronized either to the internal oscillator of RT-2X, or recovered from the incoming RX-bitstream (p. 175).
Availability	Normal, LCL and RL mode (<u>not</u> available if the analyzer is armed), whereby the E1/T1 interface must be installed.
Parameter	[INTERNAL RECOVERED] <i>string</i> (internal oscillator synchronized to RX-bitstream)
Default	RECOVERED
Query	OUTPut[1 2]:STATUS?
Examples	 → Outp:T1:CLKS Internal
Explanation	In the OUTPut:T1:CLKSource RECOVERED mode, the 'carrier level' must be high enough to allow the RT-2X analyzer synchronizing properly.

OUTPut:T1:LAW [ALAW|ULAW|OFF]

Usage	Selects the T1 LAW output voice encoding.
Availability	Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed), whereby the E1/T1 interface must be installed.
Parameter	[ALAW ULAW OFF] <i>string</i>
Default	ULAW
Query	OUTPut[1 2]:STATUS?
Example	 → OUTP:T1:LAW ULAW
Explanation	Select the RT-2X output voice encoding according to your DUT decoding requirements.

OUTPut:T1:SIGnaling [ENABLE|DISAbLe|SINGLe|CYCLe|STOP|<Parameter>]

Usage

- Enable / disable the T1 signaling (D4 or ESF) of RT-2X.
- Send out the patterns of the TX-signaling buffer as a single shot or in cycles.
- Stop the cyclic sending of the TX-signaling buffer.
- Modify the contents of the TX-signaling buffer.

Availability

Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed), whereby the E1/T1 option must be installed & RT-2X under GPIB IEEE-488 control (i.e. not RS232).

Parameter

[ENABLE| string (enables the robbed bit signaling, p. 172)
DISAbLe| string (disables the robbed bit signaling, p. 172)
SINGLe| string (must be preceded by **OUTPut:T1:SIGnaling ENABLE**. Sends out the signaling buffer sequence once [= single shot])
CYCLe| string (must be preceded by **OUTPut:T1:SIGnaling ENABLE**; Starts the cyclic sending of the signaling buffer sequence)
STOP| string (must be preceded by **OUTPut:T1:SIGnaling CYCLe**; Forces the unit to freeze the cyclic sending of the TX-signaling buffer at the actual pattern, i.e. to continuously send out only the pattern that was active when the command was received)
<Parameter>;>] string (defines or appends a new signaling buffer sample)

Default

DISAbLe

Query

OUTPut[1|2]:STATus?

Examples

 → OUTP:T1:SIG ENABLE (enables - i.e. activates - the T1 signaling and
OUTP:T1:SIG SINGLE sends out once the contents of the TX-signaling
buffer)

 → OUTP:T1:SIG ENABLE (enables the T1 signaling and starts to send out the
OUTP:T1:SIG CYCLE contents of the TX-signaling buffer in cycles, i.e.
again and again)

 → Outp:T1:Sig Enab (as soon as the **Outp:T1:Sig Stop** command is
Outp:T1:Sig Cyc transmitted, the RT-2X analyzer 'freezes' the
Outp:T1:Sig Stop cyclical sending procedure at the current pattern,
i.e. continuously sends out this pattern).

 → Outp:T1:Sig 99999999999999999999 (the sample is appended to the
9999, 50 signaling buffer at count 50)

Explanation

The format of each signaling pattern is "xxxxxxxxxxxxxxxxxxxxxxxxct", whereby each "x" stands for 4 bits (i.e. one Hex number) and corresponds to one slot (the first "x" represents slot 0 etc.). "ct" stands for the count (i.e. multiframe No.), where the pattern is located (Examples: *ESF mode*, count = 13 ⇒ timestamp = 13 x 3 ms = 39 ms; *D4 mode*, count = 20 ⇒ timestamp = 13 x 1.5 ms = 30 ms).

OBSERVE: In the D4 mode, only even counts can be selected!

If the first count is "0" (zero), the TX-signaling buffer is initialized (cleared) and filled with the new pattern. If the first count ≠ 0, the pattern is appended to the actual TX-signaling buffer contents. **In the latter case, the count must be larger than all the other counts in the TX-signaling buffer.**

The TX-signaling buffer allows saving up to 100 patterns. If more patterns are defined or appended, an error message will be generated.

OUTPut:T1:SLOTnumber <Chn1> <Chn2>

- Usage** Assigns an individual slot-number to each of the two RT-2X output channels 1, 2.
- Availability** Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed), whereby the E1/T1 interface must be installed.
- Parameter** <Chn1> *integer* 0 to 23 (The two values for channel 1 and channel 2 must not be identical!)
<Chn2> *integer* 0 to 23
- Query** OUTPut[1|2]:STATus?
- Examples**  → Outp:T1:Slot 3 12
 → INPUT:T1:SLOTNUMBER 21 5
- Explanation** Please refer to chapter **E1/T1 Interface** (p. 170) for further information.

OUTPut[1|2]:ZREF:CUSTomer[1|2|3|4]?

- Usage** Queries the Z1020 reference value of an installed customer output impedance (p. 183).
- Availability** Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed).
- Parameter** [1|2|3|4] *integer* (number of active customer impedance)
- Example**  → Output2:ZREF:Customer1?
→  7.90876E+02 (equals 790.876 Ohm)
- Explanation** The Z1020 reference value is required for the dBm calculation. If no customer impedance is installed at the indicated location, "0" (zero) is returned.

INPut Subsystem

INPut[1|2]:ACCOupling [OFF|ON]

- Usage** Activates the input AC coupling of RT-2X.
- Availability** Normal, LCL, RL and PureSound™ mode (not available if the analyzer is armed), whereby the LCL/RL option must be installed and the RT-2X analyzer must be in analog operation (*INPut:SOURce ANALog*).
- Parameter** [OFF|ON] *string*
- Default** (the last active state; factory default = OFF)
- Query** *INPut[1|2]:STATus?*
- Examples**  → INPut1:ACCOupling ON
-  → INP:ACCO ON (links both channels)
- Explanation** If ACCOupling is ON; a maximum of +60 VDC can be applied to the input connectors.
- Activate the AC coupling de-couple DC voltages from the input connectors.

NOTE If no channel-number is indicated, the command applies on both channels simultaneously.

INPut:DEEMphasis [OFF|ON]

- Usage** Activates the 750μs deemphasis, which applies on both channels.
- Availability** Normal mode (not available if the analyzer is armed).
- Parameter** [OFF|ON] *string*
- Default** OFF
- Query** *INPut[1|2]:STATus?*
- Example**  → INP:DEEM ON
- Explanation** The DEEMphasis is applied on both channels simultaneously and can also be activated after execution of the signal transmission, thus providing the weighted & unweighted results. It can be activated independently of the status of other weightings (SWFilter, LAW).

INPut:E1:LAW [ALAW|ULAW|OFF]

Usage	Defines the type of E1 voice decoding.
Availability	Normal, LCL, RL and PureSound™ mode (<u>not</u> available if the analyzer is armed), whereby the E1/T1 interface must be installed.
Parameter	[ALAW ULAW OFF] <i>string</i>
Default	ALAW
Query	INPut[1 2]:STATus?
Examples	 → Input:E1:Law ulaw
Explanation	The LAW-decoding is applied on both channels. If a received multitone signal shall be LAW-decoded, the sending unit must encode the signal accordingly.

INPut:E1:RECSignaling [START|STOP]

Use	Starts / stops recording the input signaling.
Availability	Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed), whereby the E1/T1 interface must be installed and the RT-2X unit under IEEE-488 control (i.e. <u>not</u> RS232).
Parameter	[START STOP] <i>string</i>
Query	INPut:E1:RECSignaling?
Example	 → Inp:E1:Recs Start
Explanation	RT-2X records only signaling <u>changes</u>. The RX-signaling buffer of RT-2X allows storing up to 400 patterns.

INPut:E1:RECSignaling?

- Use** Queries the recorded CAS signaling patterns (i.e. changes that were formerly stored in the RX signaling buffer) with the corresponding counts.
- Availability** Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed), whereby the E1/T1 interface must be installed and the RT-2X unit under IEEE-488 control (i.e. not RS232).
- Answer** {Pattern}, CAS signaling patterns (30 Hex numbers, one for each slot) of a recorded
 {Count}, signaling change in Hex format (maximum 400 patterns), followed by the
 count of the corresponding pattern in Decimal format.
 ; (no patterns recorded)
- Examples**
- ```

PC → INPUT:E1:RECS?
→ PC 00000000000000000000000000000000, 0, 55555555555555555555555555555555
 5555555, 334, aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa, 666

PC → Input:T1:Recsignaling?
→ PC ; (no pattern has been recorded)

```

**Explanation** Start / stop the recording of signaling changes in the RX-signaling buffer with the command **INPut:E1:RECSignaling [START|STOP]**.

The returned vector is grouped in pairs,

- starting with the first pattern (30 Hex numbers) in the format "xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx,ct", whereby each "x" stands for 4 bits (i.e. one Hex number, corresponding to one slot – the first "x" represents slot 0 etc.), and "ct" stands for the count (i.e. multiframe No.), where the pattern is located
- followed by a comma "," and the corresponding count in Decimal format.
- Every further pair starts with a comma, followed by the next recorded pattern, another comma and the corresponding count. ";" indicates that no pattern was recorded.

Calculate the timestamp that corresponds to a count by applying **Equation 1** (p. 175).

RT-2X records only signaling changes.

**INPut:E1:SIGnaling?**

- Use** Queries the actually present signaling pattern (no recording of the signaling required).
- Availability** Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed), whereby the E1/T1 interface must be installed and the RT-2X unit under IEEE-488 control (i.e. not RS232).
- Answer** <Pattern> Pattern (30 numbers, one for each slot) of the currently received multiframe in Hex-format.
- Examples**
- ```

PC → INPUT:E1:SIG?
→ PC ffffffff45ffffffffffffffffffff
  
```

Explanation The returned vector indicates the pattern (30 Hex numbers) in the format "xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx,ct", whereby each "x" stands for 4 bits (i.e. one Hex number, corresponding to one slot – the first "x" represents slot 0 etc.).

Please refer to chapter **E1 Signaling Format** (p. 170) for further information.

INPut:E1:SLOTnumber <Chn1> <Chn2>

- Use** Assigns an individual slot-number to each of the two input channels 1, 2.
- Availability** Normal, LCL, RL and PureSound™ mode (not available if the analyzer is armed), whereby the E1/T1 interface must be installed.
- Parameter**
- | | | | |
|--------|---------|---------|---|
| <Chn1> | integer | 1 to 31 | (Except 0, 16: slot 0 is reserved for frame alignment, slot |
| <Chn2> | integer | 0 to 32 | 16 for CAS signaling) |
- Query** INPut[1|2]:STATus?
- Examples**
- Inp:E1:Slot 1 2
- INPUT:E1:SLOTNUMBER 17 11
- Explanation** The 2-channel architecture of RT-2X allows using two different slots independently.
- Please refer to chapter **E1 Signaling Format** (p. 170) for further information.

INPut[1'2]:IMPedance [100K'600'150'200'850'900'PHANTOM' COMPLEX'CUSTOMER1'CUSTOMER2'CUSTOMER3'CUSTOMER4]

Usage	Sets the input chn. impedance or activates the Phantom (i.e. microphone power) supply.
Availability	Normal and PureSound™ mode (<u>not</u> available if the analyzer is armed), whereby the RT-2X analyzer must be in analog operation (INPut:SOURce ANALog).
Parameter	[100K 600 150 200 850 900 PHANTOM COMPLEX CUSTOMER1 CUSTOMER2 CUSTOMER3 CUSTOMER4] <i>string</i>
Default	100k (Ohm)
Query	INPut[1'2]:STATus? and INPut[1'2]:ZREF:CUSTomer[1'2'3'4]?
Examples	→ Input : Imp 100k (set the input impd. of chn. 1 & 2 to 100 kΩ) → Inp1 : Impedance 600 (set the input impedance of chn. 1 to 600 Ω) → INPUT : IMP PHANTOM (activate Phantom power on <u>both</u> inputs)
Explanation	All input impedance as well as Phantom (i.e. microphone) power are available as standard in every RT-2X. - Numerical values refer to the input impedance expressed in Ω (Ohm). - The COMPLEX input impedance equals $220\ \Omega + (820\ \Omega // 115\ \text{nF})$ and is included on the RT-2X impedance option. - The CUSTOMERx input impedance are user-defined and must be ordered separately. - The Phantom voltage can be set to 15 V or 48 V (p. 195).

NOTE Make sure that Phantom power is never activated unless a microphone is connected to the inputs of RT-2X. Otherwise, the Phantom voltage could damage the connected device under test.

If no channel-number is indicated, the command applies on *both* channels simultaneously.

INPut:ISDn:LAW [ALAW'ULAW'OFF]

Usage	Defines the type of ISDN signal decoding.
Availability	Normal, LCL, RL and PureSound™ mode (<u>not</u> available if the analyzer is armed), whereby the ISDN interface must be installed.
Parameter	[ALAW ULAW OFF] <i>string</i>
Default	ALAW
Query	INPut[1'2]:STATus?
Examples	→ Input : Isdn : Law Ulaw
Explanation	If a received multitone signal shall be LAW-decoded, the sending unit must encode the signal accordingly (use command OUTPut:ISDn:LAW [ALAW'ULAW'OFF]).

INPut[1;2]:LINK [OFF;ON]

Usage	Links internally the generator output to the analyzer input. The external input connectors of the selected channel are physically disconnected.
Availability	Normal and PureSound™ mode (<u>not</u> available if the analyzer is armed), whereby the RT-2X generator and analyzer must be in analog operation (OUTPut:SOURce ANALog and INPut:SOURce ANALog).
Parameter	[OFF ON] <i>string</i>
Default	OFF (no internal link)
Query	INPut[1;2]:STATus?
Examples	 → Input2:Link OFF  → INP:LINK ON (links <u>both</u> channels internally)

Explanation

NOTE If no channel-number is indicated, the command applies on both channels simultaneously.

INPut[1;2]:MICSensitivity <Sensitivity>

Usage	Stores the entered microphone sensitivity in the non-volatile RT-2X memory (p. 195).
Availability	Normal, LCL, RL and PureSound™ mode (<u>not</u> available if the analyzer is armed).
Parameter	<Sensitivity> <i>float</i> 5.0 to 5000.0 (sensitivity in mV/Pa; resolution = 0.1)
Default	50 (mV/Pa)
Query	INPut[1;2]:STATus?
Example	 → INP1:MICS 45.2
Explanation	The command allows storing the sensitivity of the connected microphone on RT-2X. This is required for all measurements that are expressed in dBSPL as well as for the command MEASurement:PUREsound:STEEpness[1;2;3;4;5;6]?

INPut:PCM:DATA:DIRection [MSBFIRST|LSBFIRST]

Use	Determines, whether the serial word is transmitted MSB-first or LSB-first.		
Availability	Normal, LCL, RL and PureSound™ mode (<u>not</u> available if the analyzer is armed), whereby the E1/T1/PCM interface must be installed.		
Parameter	[MSBFIRST LSBFIRST]	<i>string</i>	The serial words are received with endian format MSB-first or LSB-first.
Default	MSBFIRST		
Query	<i>INPut[1 2]:STATus?</i>		
Examples	 →	INPUT:PCM:FRAMESYNC:SYNC EXTERNAL	
Explanation	Refer to p. 239 for further details.		

INPut:PCM:FRAMesync:SYNC [EXTeRnal|INTeRnal]

Use	Defines, whether the receive FrameSync signal is generated internally (by RT-2X) or externally (by the DUT).		
Availability	Normal, LCL, RL and PureSound™ mode (<u>not</u> available if the analyzer is armed), whereby the E1/T1/PCM interface must be installed.		
Parameter	[External Internal]	string	The FrameSync signal is generated externally by RT-2X, whereby the receive FrameSync is configured as Input Output.
Default	INTernal		
Query	INPut[1 2]:STATus?		
Examples	 →	INPUT:PCM:FRAMESYNC:SYNC EXTERNAL	
Explanation	The FrameSync signal indicates the beginning of each frame. Each frame contains the channels (or slots) to be received / transmitted. Both transmit and receive FrameSync signals can be independently generated by RT-2X or synchronized to an external source (e.g. DUT).		

INPut:PCM:LAW [ALAW|ULAW|OFF]

- Usage** Defines the type of PCM signal decoding.
- Availability** Normal, LCL, RL and PureSound™ mode (not available if the analyzer is armed), whereby the E1/T1/PCM interface must be installed.
- Parameter** [ALAW|ULAW|OFF] *string*
- Default** OFF
- Query** *INPut[1|2]:STATus?*
- Examples**  → Input:PCM:law Alaw
- Explanation** If the LAW-encoding of the RT-2X input is active, the generator of the sending RT-2X unit must must be adjusted accordingly (command **OUTPut:PCM:LAW [ALAW|ULAW|OFF]**).

INPut:PCM:SLOTnumber <Channel1> <Channel2>

- Use** Assigns an individual slot-number to each of the two input channels 1, 2.
- Availability** Normal, LCL, RL and PureSound™ mode (not available if the analyzer is armed), whereby the E1/T1/PCM interface must be installed.
- Table 17** contains slot-availability dependent on Nr. Of channels, Data Width and BCLK
- Parameter** <Chn1> *integer* 0 to 31,X See **Table 17** for restrictions
<Chn2> *integer* 0 to 31,X
- Default** 0 1
- Query** *INPut[1|2]:STATus?*
- Examples**  → Inp:PCM:Slot 1 2
 → Inp:PCM:Slot 0 X
 → Inp:PCM:Slot X 0
- Explanation** The 2-channel architecture of RT-2X allows using two different slots independently.
Please refer to p. 239 further information.

INPut[1|2]:RANGe <InputRange> [DBVP|VP]

Usage	Defines the input range (sensitivity) & unit (p. 189).
Availability	Normal and PureSound™ mode (<u>not</u> available if the analyzer is armed), whereby the RT-2X generator and analyzer must be in analog operation (OUTPut:SOURce ANALog and INPut:SOURce ANALog).
Parameter	<InputRange> [DBVP VP] <i>float & string</i> (–60 to +40 DBVP, resolution = 0.1 0.001 to 100 VP, resolution = 0.001)
Default	0 DBVP (both channels)
Query	INPut[1 2]:STATus?
Example	 → INPut1:RANGe 3 VP
Explanation	Adjust the input range properly to avoid clipping of the incoming signal, caused by the internal RT-2X attenuator. Identify the available headroom with command MEASurement[1 2]:HEADroom?

INPut:SOURce [ANALog|ISDn|E1|T1|PCM]

Usage	Switches the RT-2X analyzer to ANALog, ISDn, E1/T1 or PCM operation.
Availability	Normal mode (<u>not</u> available if the analyzer is armed), whereby the ISDN or E1/T1/PCM interface must be installed for A-D, D-D operation.
Parameter	[ANALog ISDn E1 T1 PCM] <i>string</i>
Default	ANALog
Query	INPut[1 2]:STATus?
Examples	 → Input:Source ISDN  → INP:SOUR T1
Explanation	ISDn or E1 , T1 and PCM are only available in the mode SYSTem:MODE 8Ksamplingrate .

NOTE If you want to toggle the generator or analyzer from the E1 to the T1 mode (and vice versa), you must always switch the TX- <u>and</u> RX-section of RT-2X to the analog mode first.

INPut[1;2]:STATus?

Usage

Queries the actual input status of the unit.

Availability

Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed).

Answer

A) A-A, D-A operation

MODE [8KSAMPLINGRATE 48KSAMPLINGRATE]	string
SOURCE ANALOG	string
RANGE -60 to +40 dBVp 0.001 to 100 Vp	string & float & string
IMPEDANCE [100k 600 150 850 900 PHANTOM COMPLEX CUSTOMER1 CUSTOMER2 CUSTOMER3 CUSTOMER4]	string & integer string
SWFILTER [OFF CWE CCIT]	string
LINK [OFF ON]	string
SYNC [INT INTN EXT EXTN THR]	string
DEEMPHASIS [OFF ON]	string
TRIGGER:CONFIGURATION [TIGHT LOOSE USER]	string
ACCOUPLING [ON OFF]	string
MICSENSITIVITY [5.0 TO 5000.0]	string & float
VOLTAGEDIVIDERRATIO [1.0 TO 100.0]	string & float

B) A-D, D-D operation with ISDN interface

MODE 8KSAMPLINGRATE	string
SOURCE ISDN	string
SWFILTER [OFF CWEighting CCIT]	string
SYNC [INT INTN THR]	string
DEEMPHASIS [OFF ON]	string
LAW [OFF ULAW ALAW]	string
TRIGGER:CONFIGURATION [TIGHT LOOSE USER]	string

C) A-D, D-D operation with E1/T1 interface

MODE 8KSAMPLINGRATE	string
SOURCE [E1 T1 J1]	string
SWFILTER [OFF CWEighting CCIT]	string
SYNC [INT INTN THR]	string
DEEMPHASIS [OFF ON]	string
LAW [OFF ULAW ALAW]	string
SLOTNUMBER [1 to 31 0 to 23]	string & integer
TRIGGER:CONFIGURATION [TIGHT LOOSE USER]	string

D) A-D, D-D operation with PCM interface

MODE 8KSAMPLINGRATE	string
SOURCE PCM	string
SWFILTER [OFF CWEighting CCIT]	string
SYNC [INT INTN THR]	string
DEEMPHASIS [OFF ON]	string
LAW [OFF ULAW ALAW]	string
SLOTNUMBER [0 to 1 2 4 8 16 32]	string & integer
TRIGGER:CONFIGURATION [TIGHT LOOSE USER]	string
FRAMESYNC:SYNC [INTERNAL EXTERNAL]	string
DATA:DIRECTION [MSBFIRST LSBFIRST]	string

Examples

```

→ Input2:Status?
→ MODE 48KSAMPLINGRATE,SOURCE ANALOG,RANGE 0.50E00
dBVp,IMPEDANCE 100K,SWFILTER CCIT,LINK OFF,SYNC
EXTN,DEEMPHASIS ON,TRIGGER:CONFIGURATION TIGHT,
ACCOUPLING ON,MICSENSITIVITY 1.350E+01,
VOLTAGEDIVIDERRATIO 1.00E+00

```



→ INP1:STAT?
→ MODE 8KSAMPLINGRATE, SOURCE ISDN, SWFILTER OFF, SYNC INT, DEEMPHASIS OFF, LAW ALAW, TRIGGER:CONFIGURATION USER

→ INPUT2:STATUS?
→ MODE 8KSAMPLINGRATE, SOURCE E1, SWFILTER OFF, SYNC INTN, DEEMPHASIS OFF, LAW ALAW, SLOTNUMBER 25, TRIGGER:CONFIGURATION LOOSE

→ INPUT2:STATUS?
→ MODE 8KSAMPLINGRATE, SOURCE T1, SWFILTER CCITT, SYNC INTN, DEEMPHASIS ON, LAW ULAW, SLOTNUMBER 15, TRIGGER:CONFIGURATION LOOSE

→ INPUT2:STATUS?
→ MODE 8KSAMPLINGRATE, SOURCE PCM, SWFILTER OFF, SYNC INTERNAL, DEEMPHASIS OFF, LAW OFF, SLOTNUMBER 0, TRIGGER:CONFIGURATION LOOSE, FRAMESYNC:SYNC EXTERNAL, DATA:DIRECTION MSBFIRST

Explanation The returned status format depends on the analyzer operation.

INPut:SWFilter [OFF|CWEighting|CCITT|AWEighting]

Usage Activates one of the software weighting filters (p. 179).

Availability Normal mode (not available if the analyzer is armed).

Parameter [OFF|CWEighting|CCITT|AWEighting] *string*

Default OFF

Query ***INPut[1|2]:STATus?***

Example → INPUT:SWFILTER CWEIGHTING

Explanation The SWFilter is applied on both channels simultaneously, and can also be activated *after* execution of the signal transmission, thus providing the weighted & unweighted results. It can be activated independently of the status of other weightings (DEEMphasis, LAW).

INPut:SYNC [INTernal|INTNoheader|EXTernal|EXTNoheader|THReshold]

Usage

Defines the trigger & synchronization mode (p. 270ff).

Availability

Normal and PureSound™ mode (not available if the analyzer is armed).

- INT: Only for multitone signals
- INTN: Multitone signals or chirp; mandatory default for stepped sweep
- EXT: Only for multitone signals
- EXTN: Only for multitone signals
- THR: Multitone signals or chirp

Parameter

A) A-A, A-D operation in Normal mode
[INT|INTN|EXT|EXTN|THR] *string*

B) D-A, D-D operation in Normal mode
[INT|INTN|THR] *string*

C) PureSound™ mode
[INTN|THR] *string*

INT The RT-2X generator and analyzer use the same sampling clock and the multitone signal is transmitted with the proprietary header.

- Command **OUTPut:MTONE:STARt** starts the signal transmission.
- The analyzer starts sampling as soon as it recognizes the proprietary header
- The maximum allowable time delay (timeout condition) between the start command and the detection of the proprietary header can be defined with command **INPut:TRIGger:TIMEout <Timeout>** (default = 500 ms).
- If command **INPut:TRIGger:ARMed** has been sent to RT-2X prior to the start command, no timeout condition is applied, i.e. the analyzer waits until it detects the proprietary header or until it is interrupted with **INPut:TRIGger:BRear**.

INTN The RT-2X generator and analyzer use the same sampling clock. The generator sends out the test signal without the proprietary header.

- Command **OUTPut:MTONE:STARt**, **OUTPut[1|2]:PUResound:CHIRp:STARt** or **OUTPut:STEPpedswEEP:STARt** start the signal transmission.
- The analyzer starts sampling simultaneously with the signal transmission.

EXT RT-2X sends out the multitone signal with the proprietary header. The analyzer synchronizes its sampling clock to the frequency of the 'clock synchronization' block in the header of the received multitone burst.

- Command **OUTPut:MTONE:STARt** starts the signal transmission.
- The analyzer starts sampling as soon as it recognizes the proprietary header.
- The maximum allowable time delay (timeout condition) between the start command and the detection of the proprietary header can be defined with command **INPut:TRIGger:TIMEout <Timeout>** (default = 500 ms).
- If command **INPut:TRIGger:ARMed** has been sent to RT-2X prior to the start command, no timeout condition is applied, i.e. the analyzer waits until it detects the proprietary header or until it is interrupted with **INPut:TRIGger:BRear**.

EXTN RT-2X sends out the multitone signal without the proprietary header. The analyzer applies the sampling clock that it has synchronized to the frequency of the 'clock synchronization' block in the header of the last multitone burst that was received in the "EXT" mode.

- Command **OUTPut:MTONE:STARt** starts the signal transmission.
- The analyzer starts sampling simultaneously with the signal transmission.

- THR The RT-2X generator and analyzer use the same sampling clock. The generator sends out the test signal without the proprietary header.
- Command **OUTPut:MTONE:START**, **OUTPut[1|2]:PUREsound:CHIRp:START** or **OUTPut:STEPpedswEEP:START** start the signal transmission.
 - The analyzer starts sampling as soon as it has triggered to a user-defined threshold level, defined by **INPut:TRIGger:THReshold:LEVel** **<ThreshLevel>**.
 - **INPut:TRIGger:THReshold:PREmeasdelay** **<PreMeasDelay>** allows introducing an additional delay between the trigger event and the beginning of the data acquisition.
 - The maximum allowable time delay (timeout condition) between the start command and the trigger event can be defined with command **INPut:TRIGger:TIMEout** **<Timeout>** (default = 500 ms).
 - If command **INPut:TRIGger:ARMed** has been sent to RT-2X prior to the start command, no timeout condition is applied, i.e. the analyzer waits until it detects the proprietary header or until it is interrupted with **INPut:TRIGger:BREak**.

Default INTERNAL|INTNoheader (multitone | PureSound™ or stepped sweep analysis)

Query INPut[1|2]:STATus?

Example  → Inp:Sync Intn

Explanation The trigger & synchronization mode command defines the operation of the RT-2X generator and analyzer.

- Multitone signal generation: with or without proprietary header (p. 198).
- Analyzer clock synchronization: generator clock or 'Clock synchronization' block (p. 198) of received multitone header.
- Start of analyzer sampling: simultaneous with start command, after detection of proprietary header or user-defined threshold level. If no trigger condition is met, the error message **203 No trigger detected** will be generated.

In addition to the **INPut:SYNC ...** command, the instructions **INPut:TRIGger:TIMEout** **<Timeout>**, **INPut:TRIGger:ARMed** etc. allow adapting the test signal acquisition to the specific requirements of the application.

NOTE In case of a dual-channel burst transmission, the RT-2X analyzer starts sampling on both channels simultaneously, as soon as the trigger condition has been met on either channel.

***INPut:T1:LAW [ALAW|ULAW|OFF]***

- Usage** Defines the type of T1 signal decoding.
- Availability** Normal, LCL, RL and PureSound™ mode (not available if the analyzer is armed), whereby the T1 interface must be installed.
- Parameter** [ALAW|ULAW|OFF] *string*
- Default** ULAW
- Query** ***INPut[1|2]:STATus?***
- Examples**  → Input:T1:Law u`law
- Explanation** The LAW-decoding is applied on both channels simultaneously.
- If a received multitone signal shall be LAW-decoded, the sending unit must encode the signal accordingly (use command ***OUTPut:E1:LAW [ALAW|ULAW|OFF]***).

INPut:T1:RECSignaling [START|STOP]

Use	Starts / stops the input signaling recording.
Availability	Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed), whereby the T1 interface must be installed and the RT-2X unit under IEEE-488 control (i.e. <u>not</u> RS232).
Parameter	[START STOP] <i>string</i>
Query	INPut:T1:RECSignaling?
Example	 → Inp:T1:Recs Start
Explanation	RT-2X records only signaling <u>changes</u> (i.e. patterns, p. 257). The RX-signaling buffer of RT-2X allows storing up to 495 patterns.

INPut:T1:RECSignaling?

Use	Queries the recorded robbed bit patterns (signaling changes) with the corresponding counts.
Availability	Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed), whereby the T1 interface must be installed and the RT-2X unit under IEEE-488 control (i.e. <u>not</u> RS232).
Answer	{Pattern}, Robbed bit patterns (24 numbers, one for each slot) of a recorded signaling {Count}, change in Hex format (maximum 495 patterns), followed by the count of the corresponding pattern in Decimal format. ; (no patterns recorded)
Examples	 → INPUT:T1:RECS? →  ffffffffffffffffffff345fff,0,000000000000000000200 (ESF mode) 000,40,555555555555555555555555,81,aaaaaaaaaaaa aaaaaaaaaaaa,121,ffffffffffffffffffffffffffff,161,0 000000000000000000000000,201  → Input:T1:Recsignaling? →  4444444444444444444444444444,0,000000000000000000080 (D4 mode) 0000,10,048c048c048c048c048c048c,16  → Input:T1:Recsignaling? →  ; (no pattern has been recorded)

Explanation Start / stop the recording of signaling changes in the RX-signaling buffer with the command **INPut:T1:RECSignaling [START|STOP]**.

The returned vector is grouped in pairs,

- starting with the first pattern (24 Hex numbers) in the format "xxxxxxxxxxxxxxxxxxxxxxxxxx,ct", whereby each "x" stands for 4 bits (i.e. one Hex number, corresponding to one slot – the first "x" represents slot 0 etc.), and "ct" stands for the count (i.e. multiframe No.), where the pattern is located
- followed by a comma ",", and the corresponding count in Decimal format.
- Every further pair starts with a comma, followed by the next recorded pattern, another comma and the corresponding count. ";" indicates that no pattern was recorded.

Calculate the timestamp that corresponds to a count by applying **Equation 1** (p. 175).

RT-2X records only signaling changes (i.e. patterns, p. 172).

**INPut:T1:SIGnaling?**

- Use** Queries the actually present signaling pattern (no recording of the signaling required).
- Availability** Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed), whereby the T1 interface must be installed and the RT-2X unit under IEEE-488 control (i.e. not RS232).
- Answer** <Pattern> Pattern (24 numbers, one for each slot) of the currently received multiframe in Hex-format.

Examples

```
→ INPUT:T1:SIG? (ESF mode)
→ ffffffff45fffffff

→ Input:T1:Signaling? (D4 mode)
→ 000000444444888888CCCCC
```

Explanation The returned vector indicates the pattern (24 Hex numbers) in the format "xxxxxxxxxxxxx
xxxxxxxxxx,ct", whereby each "x" stands for 4 bits (i.e. one Hex number, corresponding to one slot – the first "x" represents slot 0 etc.).

Please refer to chapter **E1/T1 Interface** (p. 170) for further information.

INPut:T1:SLOTnumber <Chn1> <Chn2>

- Use** Assigns an individual slot-number to each of the two input channels 1, 2.
- Availability** Normal, LCL, RL and PureSound™ mode (not available if the analyzer is armed), whereby the T1 interface must be installed.
- Parameter** <Chn1> integer 0 to 23 (The two values for channel 1 and channel 2 do not need to
<Chn2> integer 0 to 23 be identical!)

Query INPut[1|2]:STATus?

Examples

```
→ Inp:T1:Slot 0 1
→ INPUT:T1:SLOTNUMBER 17 11
```

Explanation The 2-channel architecture of RT-2X allows using two different slots independently.

Please refer to chapter **E1/T1 Interface** (p. 170) for further information.

INPut:TRIGger:ARMed

Use The command arms both input channels of the RT-2X analyzer in the Normal mode. Therein, the analyzer waits until the trigger condition is met before it starts sampling (p. 268).

Availability Normal mode (not available if the analyzer is already armed), whereby the **INPutSYNC ...** mode must be set to **INternal**, **EXternal** or **THReshold**.

Query **INPut:TRIGger:ARMed?**

Example  → Inp:Trig:Arm

Explanation The command allows e.g. triggering to an externally generated signal (p. 268).

Interrupt the armed operation with command **INPut:TRIGger:BR****EAk**.

In the armed status, the "Trigger" LED is flashing until the trigger condition is met or until the analyzer is reset.

As soon as the trigger condition is met, the RT-2X analyzer starts sampling on both input channels simultaneously.

NOTE	Not all commands are available after command <i>INPut:TRIGger:ARMed</i>. Please refer to the individual command descriptions for further details.

INPut[1;2]:TRIGger:ARMed

Use Arms the RT-2X analyzer input chn 1 or chn 2 in the PureSound™ mode. Therein, the analyzer waits until the trigger condition is met before it starts sampling (p. 269).

Availability PureSound™ mode (not available if the analyzer is already armed), whereby **INPutSYNC ...** must be set to **THReshold**.

Query **INPut:TRIGger:ARMed?**

Example  → Input2:Trigger:Armed

Explanation The command allows triggering to an externally generated chirp (p. 269).

Interrupt the armed operation with command **INPut:TRIGger:BR****EAk**.

In the armed status, the "Trigger" LED is flashing until the trigger condition is met or until the analyzer is reset.

NOTE	Not all commands are available after command <i>INPut:TRIGger:ARMed</i>. Please refer to the individual command descriptions for further details.

INPut:TRIGger:ARMed?

Use	Queries, whether the RT-2X analyzer is armed.		
Availability	Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed).		
Answer	[ARMED]	<i>string</i>	In the armed status, RT-2X waits until the trigger condition is met (p. 268ff) or until the unit is reset into the normal operation.
	STOPPED]	<i>string</i>	"STOPPED" indicates that RT-2X is in the normal mode (i.e. not armed). In this status, the "Trigger" LED remains dark.
Example	<pre> PC → Inp:Trigger:Armed? → PC ARMED </pre>		

INPut:TRIGger:BRear

Use	Resets the RT-2X analyzer if it is armed.		
Availability	Normal and PureSound™ mode (especially if the analyzer is armed).		
Query	INPut:TRIGger:ARMed?		
Example	<pre> PC → Inp:Trigger:Break </pre>		
Explanation	This command resets RT-2X to the normal operation, i.e. the analyzer is no longer armed. Consequently, the "Trigger" LED goes OFF.		

INPut:TRIGger:CONFiguration [LOOSE|TIGHT|USER]

Use Defines the trigger condition for the detection of the proprietary multitone header (p. 278).

Availability Normal, LCL, RL and PureSound™ mode (not available if the analyzer is armed).

Parameter [LOOSE|
TIGHT| *string*
USER]

Applies the normal trigger condition to an incoming multitone burst. This configuration is especially suited for industrial applications, where both multitone generator and analyzer are located in the same housing.

Applies the tight trigger condition to an incoming multitone burst. This configuration should be used for broadcast applications, where the signal is inserted into a shortly interrupted broadcast signal.

This configuration allows defining the trigger condition. However, since this requires a highly sophisticated fine-tuning, it is strongly recommended that this is only configured by very advanced users.

Default LOOSE

Query INPut[1|2]:STATus?

Example  → Inp:Trigger:Configuration Tight

Explanation It is recommended to change the trigger configuration only for transmission line tests and to select the TIGHT condition in such cases. As soon as RT-2X is used again for industrial applications, the trigger configuration should be set to LOOSE.

NOTE The use of the command is only recommended to very advanced users.

INPut:TRIGger:THReshold:LEVel <ThreshLevel>

Usage	Defines the threshold level for the INPut:SYNC THReshold trigger mode (p. 276).
Availability	Normal and PureSound™ mode (<u>not</u> available if the analyzer is armed).
Parameter	<ThreshLevel> <i>float</i> 1.0 to 99.9 (threshold in % of input range; resolution = 0.1)
Default	25.1 (%)
Query	INPut:TRIGger:THReshold:LEVel?
Example	 → INP:TRIG:THR:LEV 55.5
Explanation	The threshold level refers to the actual input range value. In the INPut:SOURce [ISDn'T1] operation, the threshold level value refers to 0 dBFSp, whereby 100 % equal 0 dBFSp. In the INPut:SYNC THReshold mode, the analyzer monitors the amplitude of the input signal, until it exceeds the threshold level. From that moment, it waits for a time defined by INPut:TRIGger:THReshold:PREmeasdelay <PreMeasDelay>, before the sampling starts.

INPut:TRIGger:THReshold:LEVel?

Usage	Queries the INPut:SYNC THReshold trigger level (p. 276).
Availability	Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed).
Answer	<ThreshLevel> <i>float</i> 1.0 to 99.9 (trigger threshold in % of current input range)
Example	 → Input:Trigger:Threshold:Level? →  75.00E+01
Explanation	The threshold level refers to the actual input range value. In the INPut:SOURce [ISDn'T1] operation, the threshold level value refers to 0 dBFSp, whereby 100 % equal 0 dBFSp.

INPut:TRIGger:THReshold:PREmeasdelay <PreMeasDelay>

Usage Defines the delay from the point when the input signal exceeds the threshold trigger level to when the analyzer starts sampling (p. 276).

Availability Normal and PureSound™ mode (not available if the analyzer is armed).

Parameter <PreMeasDe lay> *integer* 5 to 30000 (PreMeasdelay in ms; resolution = 1)

Default

<i>fs</i>	<i>Blocklength</i>	<i>Default Delay</i>
8k	128	128
	256	256
	512	256
	1024	640
	2048	512

<i>fs</i>	<i>Blocklength</i>	<i>Default Delay</i>
48k	512	74
	1024	170
	2048	170
	4096	426
	8192	341

Query INPut:TRIGger:THReshold:PREmeasdelay?

Example → inp:trig:thr:del 1000

Explanation This command allows the DUT settling to the input signal, i.e. letting possible transient responses disappear, before the sampling process (i.e. signal acquisition) is executed.

INPut:TRIGger:THReshold:PREmeasdelay?

Usage Queries the PREmeas trigger delay time (p. 276).

Availability Normal, LCL, RL and PureSound™ mode (not available if the analyzer is armed).

Answer <PreMeasDe lay> *integer* 5 to 30000 (PreMeasdelay expressed in ms)

Example → INPut:TRIGger:THReshold:PREmeasde lay?
→ 200

INPut:TRIGger:THReshold:POSTmeasdelay <PostMeasDelay>

- Usage** Prevents the RT-2X analyzer for a user-defined period from re-triggering after it has once triggered and completed the data acquisition (p. 276).
- Availability** Normal, LCL, RL and PureSound™ mode (not available if the analyzer is armed).
- Parameter** <PostMeasDelay> *integer* 0 to 30000 (PostMeasdelay in ms; resolution = 1)
- Default** 0 (ms)
- Query** **INPut:TRIGger:THReshold:POSTmeasdelay?**
- Example**  → INP1:TRIG:thr:post 3000
- Explanation** The command allows blocking the RT-2X analyzer from retriggering after it has triggered to a threshold (trigger mode **INPut:SYNC THReshold**). This may be necessary e.g. if RT-2X shall trigger to repeatedly incoming bursts that last longer than the data acquisition period.

INPut:TRIGger:THReshold:POSTmeasdelay?

- Usage** Queries the **POSTmeasdelay**, i.e. the time during which RT-2X is blocked from re-triggering after it has once triggered and completed the data acquisition (p. 276).
- Availability** Normal, LCL, RL and PureSound™ mode (not available if the analyzer is armed).
- Answer** <PostMeasDelay> *integer* 0 to 30000 (PostMeasdelay expressed in ms)
- Example**  → INP1:TRIG:thr:post?
→  500

INPut:TRIGger:TIMEout <Timeout>

- Usage** Defines the time period during which RT-2X waits that the trigger condition is met after it has received a start command. If this period expires, i.e. if the analyzer does not trigger during the **Timeout**, it returns error **203 (No trigger detected)**.
- Availability** Normal, LCL, RL and PureSound™ mode (not available if the analyzer is armed), whereby the **INPut:SYNC** command must be set to **INternal**, **EXternal** or **THreshold**.
- Parameter** <Timeout> *integer* 50 to 10000 (trigger timeout in ms; resolution = 1)
- Default** 500 (ms)
- Query** **INPut:TRIGger:TIMEout?**
- Example**  → INP:TRIG:TIME 1500
- Explanation** As soon as the RT-2X unit has received the start command **OUTPut:MTONE:START** or **MEASurement[1|2]:PUREsound:START**, its analyzer waits during the <Timeout> period for an incoming signal. If the trigger condition is met during this period, the analyzer starts sampling. Otherwise the error message **203 No trigger detected** is generated.

INPut:TRIGger:TIMEout?

- Usage** Queries the analyzer **Timeout**.
- Availability** Normal and PureSound™ mode (also if the analyzer is armed).
- Answer** <Timeout> *integer* 50 to 10000 (trigger timeout expressed in ms)
- Example**  → INP:TRIG:TIME?
→  1500

INPut:TRIGger:USRConfiguration <bin1>,<bin2>,<emptybin>

Use Defines a custom-specific proprietary multitone trigger (i.e. trigger bin levels, p. 278).

Availability Normal, LCL, RL and PureSound™ mode (not available if the analyzer is armed).

Parameter

<bin1>,	float	-10 to -50 dB
<bin2>,	float	-10 to -50 dB
<emptybin>	float	0 to -80 dB

Query *INPut:TRIGger:USRConfiguration?*

Example  → Inp:Trig:Usrc -2.00E+01, -4.00E+01, -8.00E+01

Explanation

NOTE	This command requires highly sophisticated handling for proper operation and should only be applied by very advanced users!

INPut:TRIGger:USRConfiguration?

Use Queries the user-defined multitone trigger (p. 278).

Availability Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed).

Answer

<setbin1>,	float	-10 to -50 dB
<setbin2>,	float	-10 to -50 dB
<emptybin>	float	0 to -80 dB

Example  → Inp:Trigger:Usrcconfiguration?
→  -4.00E+01, -3.00E+01, -4.50E+01

Explanation Refer to chapter *Trigger Configuration* (p. 278).

INPut[1;2]:VOLTagedividerratio <Ratio>

Usage	Applies a correction factor to the input range and all absolute measurement results (p. 284).
Availability	Normal, PureSound™ mode (<u>not</u> available if the analyzer is armed, LCL,RL,LCTL mode).
Parameter	<Ratio> <i>float</i> 1.00 to 100.0 (voltage divider ratio defined by 1:<Ratio>)
Default	1.0
Query	INPut[1;2]:STATus?
Example	 → INPUT1:VOLTAGEDIVIDERRATIO 2
Explanation	This feature supports applications where voltages higher than 100 Vp have to be measured (e.g. 100 V PA-systems) by connecting a voltage divider to the RT-2X input (p. 284). The command compensates the effect of an externally connected voltage divider. It corrects the input range and measurement result with the entered voltage divider <Ratio>.

INPut[1;2]:ZREF:CUSTomer[1;2;3;4]?

Usage	Queries the Z1020 reference value of the installed customer input impedance (p. 183).
Availability	Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed).
Parameter	[1 2 3 4] <i>integer</i> (number of customer impedance)
Answer	<Z1020> <i>float</i> (reference impedance @ 1020 Hz, expressed in Ohm)
Examples	 → INP1:ZREF:CUST3? →  1.234E+03 (1234 Ohm)
Explanation	If no customer impedance is installed at the indicated location, a "0" (zero) is returned. The Z1020 reference value is required for the dBm calculation of the RT-2X analyzer. Please refer to chapter dBm (p. 281) for further details.

MEASurement Subsystem

MEASurement[1|2]:CROSstalk:UNIT [%|DB]

Usage	Defines the unit, in which the crosstalk measurement is expressed.
Availability	Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed).
Parameter	[% DB] <i>string</i> (percent decibel)
Default	%
Example	 → MEAS1:CROS:UNIT dB

MEASurement[1|2]:CROSstalk?

Usage	Queries the measured crosstalk of the alternate channel to the active channel. The crosstalk result can be only evaluated if at least one signal bin of each channel in the transmitted multitone signal is set at an exclusive frequency (chapter Crosstalk , p. 202).
Availability	Normal mode (<u>not</u> available if the analyzer is armed).
Answer	{SignalBin _n }/ <i>integer</i> (signal bin number, p. 226) {Xtalk _n Unit}, <i>float NaN & string</i> (corresponding crosstalk result & unit)
Unit	(defined by command MEASurement[1 2]:CROSstalk:UNIT [% DB])
Example	 → MEAS1:CROS? →  13/-1.35764E+02 DB, 121/-0.54340E+01 DB, 235/NaN
Explanation	The returned vector is composed of pairs, indicating the crosstalk result at each signal bin. Every pair starts with the number of the signal bin, followed by a "/", the corresponding crosstalk value, a white space, the unit in which the result is expressed, and a comma (","). If the crosstalk value is too small to be measured, 'NaN' (not a number) will be returned.

NOTE In the 8 kHz mode the measuring bandwidth is limited to 20 Hz – 3.4 kHz.

MEASurement[1;2]:DISTortion:UNIT [DBV;V;DBM;DBFS;%FS;DBM0]

- Usage** Defines the unit, in which the distortion result shall be expressed.
- Availability** Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed).
- Parameter**
- A)** A-A, D-A operation
 [DBV; string (V_{RMS} in logarithmic scale, referred to 1 V_{RMS})
 V; string (V_{RMS} in linear scale)
 DBM] (RMS power in logarithmic scale, p. 281)
- B)** A-D, D-D operation (with ISDN or T1 option)
 [DBFS; string (V_{RMS} in logarithmic scale, referred to fullscale)
 %FS; string (V_{RMS} in linear scale, referred to fullscale)
 DBM0] (RMS level in logarithmic scale, p. 282)
- Default** DBV;DBFS (A-A, D-A | A-D, D-D operation)
- Example** → MEAS1:DIST:UNIT V
- Explanation** The availability of the units depends on the actual operation (A-A, A-D, D-A or D-D).

NOTE [dBm] is a **power** unit that refers to 600 Ω input impedance. Thus, if another input impedance is selected, the dBm level result changes.

MEASurement[1;2]:DISTortion?

- Usage** Queries the distortion values of all bands between 20 Hz → Bin_Min, Bin_Min → Bin_1, etc., Bin_n → Bin_Max (chapter **Distortion**, p. 204).
- Availability** Normal mode (not available if the analyzer is armed).
- Answer** {SignalBin_n}/ integer (signal bin number, p. 226)
 {Dist_n Unit}, float|NaN & string (corresponding distortion result & unit)
- Unit** (defined by MEASurement[1;2]:DISTortion:UNIT [DBV;V;DBM;DBFS;%FS;DBM0])
- Example** → Measurement1:Dist?
 → 3/-1.07006E+02 dBV, 11/-0.98914E+02 dBV, 32/
 -0.86325E+02 dBV, 48/-0.72354E+02 dBV, 214/NaN
- Explanation** The returned distortion vector starts with Bin_Min (i.e. the first possible bin number ≥20 Hz) followed by the distortion result between Bin_Min and the first signal bin. The second pair is the bin number of the first signal bin and the distortion result between this first signal bin and the second signal bin, etc. The last pair is the last signal bin with the distortion result between this last signal bin and Bin_Max (i.e. the last possible bin ≤ 20 kHz; **Fig 33**, p. 205)

If a band between two signal bins is too narrow to measure a distortion, 'NaN' is returned.

NOTE In the 8 kHz mode the measuring bandwidth is limited to 20 Hz – 3.4 kHz.
 [dBm] is a **power** unit that refers to 600 Ω input impedance. Thus, if another input impedance is selected, the dBm level result changes.

MEASurement[1|2]:DTMF:START

- Usage** Resets the DTMF tone receiver buffer (32 keys wide) of channel 1 or 2 (p. 169).
- Availability** Normal and PureSound™ mode (also if the analyzer is armed), whereby the RT-2X analyzer must be in analog operation (**INPut:SOURce ANALog**).
- Example**  → Meas1:Dtmf:Start
- Explanation** RT-2X continuously stores the incoming DTMF tones in its buffer after this command.

MEASurement[1|2]:DTMF?

- Usage** Queries the DTMF tone receiver buffer (32 keys wide) of channel 1 or 2 (p. 169).
- Availability** Normal and PureSound™ mode (also if the analyzer is armed).
- Answer** {Row}/ integer 1 to 4 (row number)
{Column}, integer 1 to 4 (column number)
; string (no DTMF signal received)
- Examples**  → MEAS1:DTMF?
→  1/2, 3/2, 2/2 (3 keys detected: 2,8,5)
-  → Meas2:Dtmf?
→  ; (empty buffer - no keys received since last reset)
- Explanation** RT-2X returns pairs of row / column numbers that identify the DTMF signals in the order as they have been received. The decoding of these numbers is described in **Table 7** (p. 169).
- Use the command **MEASurement[1|2]:FREQuency:SElective? <binstart> <binstop>** to measure the exact frequencies of an incoming DTMF signal.



MEASurement1:ERL?

- Usage** Queries the Echo Return Loss (ERL) according to recommendation IEEE 743-1995, measured at input channel 1 (p. 206).
- Availability** RL mode (not available if the analyzer is armed), whereby the RL Bridge must be switched **ON** (**INOUT:RLBridge:MODE ON**) and the predefined **ERL** test signal must be the active signal (**OUTPut:MTONe:ACTive ERL**).
- Answer** <LastSignalBin>/ *integer* (No. of the signal's last signal bin, p. 226)
<ERL_result> DB *float|NaN & string* (measured ERL value, expressed in dB)
- Example** → Meas1:erl?
→ 25/5.85075E+01 DB
- Explanation** The measurement result is returned in a string. The number of the last signal bin is separated from the result by a "/", and a white space is inserted between the result and its unit. NaN (Not a Number) indicates that the acquired result is not valid.

NOTE In the 8 kHz mode the measuring bandwidth is limited to 20 Hz – 3.4 kHz.

MEASurement[1|2]:FREQuency:FULLband?

Usage Queries the frequency of the sine component with the highest amplitude within the frequency band from 23 Hz to 20 kHz | 4 kHz (p. 180).

Availability Normal mode (not available if the analyzer is armed).

Answer <Bin_Max>/ integer (Bin_Max of current blocklength, p. 230)
<Frequency> Hz float|NaN & string (measured frequency, expressed in Hz)

Example  → MEAS1:FREQ:FULL?
→  213/1.23456E+03 Hz (dominant frequency = 1234.56 Hz)

Explanation This command allows measuring the exact frequency of a sine component generated by an external device that does not need to be synchronous to the RT-2X analyzer. If no dominant frequency can be measured, an error message will be returned.

Before a frequency measurement is executed, a signal has to be acquired, i.e. the analyzer has to be triggered to sample the incoming signal. This can be done in different ways as described in chapter **Test Setups** (p. 264).

NOTE In the 8 kHz mode the measuring bandwidth is limited to 20 Hz – 3.4 kHz.

MEASurement[1|2]:FREQuency:SElective? <binstart> <binstop>

Usage Queries the frequency of the dominant signal component in a user-defined band (p. 180).

Availability Normal mode (not available if the analyzer is armed).

Parameter <binstart> integer 1 to 3413 (<binstart> = upper, <binstop> = lower limit of
<binstop> integer 1 to 3413 the frequency band; refer to p. 180, 226)

Answer <binstop>/ integer (binstop)
<Frequency> Hz float|NaN & string (measured frequency, expressed in Hz)

Example  → MEAS1:FREQ:SEL? 23 34
→  34/1.03132E+03 Hz

Explanation The command measures the frequency of the sine signal with the highest amplitude in the selected frequency band.

Before the measurement, the signal has to be acquired (i.e. the analyzer has to trigger and to sample the incoming signal). This can be done in several different ways as described in chapter **Test Setups** (p. 264).

If no dominant signal can be detected, an error is returned.

The investigated input signal can have been generated by an external device, whereby the external generator does not need to be synchronous to the RT-2X analyzer.

The available range of <binstart> and <binstop> depends on the current blocklength (p. 230).

NOTE In the 8 kHz mode the measuring bandwidth is limited to 20 Hz – 3.4 kHz.

MEASurement[1|2]:GAIN?

Usage Queries the gain of every signal bin, i.e. output level [dB] – the input level [dB] (p. 207).

Availability Normal mode (not available if the analyzer is armed).

Answer {SignalBin_n}/ integer (signal bin number, p. 226)
 {Gain_n DB}, float|NaN & string (gain @ SignalBin_n, expressed in dB)

Example  → Measurement1:Gain?
 →  3/1.55E-02 DB, 11/1.36E-02 DB, (signal bin #3 → gain 155 dB,
 32/2.13E-02 DB #11 → 136 dB, #32 → 213 dB)

Explanation The result vector starts with the first signal bin No., /, the corresponding gain and 'dB', followed by the second signal bin No., /, gain and 'dB' etc.

Please note that all gain values are expressed in dB.

NOTE In the 8 kHz mode the measuring bandwidth is limited to 20 Hz – 3.4 kHz.

MEASurement[1|2]:HEADroom?

Usage Queries the headroom of the last received test signal (p. 189), i.e. the difference:
 "current *input range* of RT-2X – received *input level* of the test signal"
 (the first as defined by command **INPut[1|2]:RANGe <InputRange> [DBVP|VP]**, p. 97).

Availability Normal and PureSound™ mode (also if the analyzer is armed), whereby the RT-2X analyzer must be in analog operation (**INPut:SOURce ANALog**).

Answer <Headroom> DB float & string (headroom, expressed in dB)

Example  → MEAS1:HEAD?
 →  3.43200E+01 DB (received level = 34.4 dB below the input range)

Explanation This command is very helpful to optimize the input range of RT-2X. In practice, it is recommended to proceed as follows:

1. Adjust the initial input range IR_{Init} to a value that is high enough (e.g. +40 dBVp).
2. Start the test (**OUTPut:MTONe:STARt**, **OUTPut[1|2]:PUREsound:CHIRp:STARt** or **OUTPut:STEPpedswEEP:STARt**).
3. Query the headroom result HR [dB].
4. Adjust the new input range to $IR_{New} = IR_{Init} - HR + 6$ (6 dB = security margin).

MEASurement1:LCL?

- Usage** Queries the Longitudinal Conversion Loss (LCL) according to recommendation G.117, measured at input channel 1.
- Availability** LCL mode (not available if the analyzer is armed):
- RT-2X must be in A-A operation (**OUTPut:SOURce ANALog, INPut:SOURce ANALog**)
 - The RL Bridge must be switched OFF (**INOUT:RLBridge:MODE OFF**)
 - The LCL Bridge must be switched to LCL (**INOUT:LCLBridge:MODE LCL**).
- Answer** {SignalBin_n}/ integer (signal bin number, p. 226)
{LCL_n DB}, float|NaN & string (LCL result, expressed in dB)
- Example** → MEAS1:LCL?
→ 21/5.536310E+01 DB, 113/5.298542E+01 DB
- Explanation** The returned vector is grouped in pairs, starting with the first signal bin number, a "/", the respective LCL result, a white space and the unit in which the result is expressed. Pairs are separated by commas (","). If a received level is too low to be measured, 'NaN' (not a number) is returned.

Please refer to chapter **LCL Measurements** (p. 209) for further details.

NOTE In the 8 kHz mode the measuring bandwidth is limited to 20 Hz – 3.4 kHz.

MEASurement1:LCTL?

- Usage** Queries the Longitudinal Conversion Transfer Loss (LCTL) according to recommendation G.117, measured at input channel 1.
- Availability** LCL mode (not available if the analyzer is armed):
- The RL Bridge must be switched OFF (**INOUT:RLBridge:MODE OFF**)
 - The LCL Bridge must be switched to LCTL (**INOUT:LCLBridge:MODE LCTL**).
- Answer** {SignalBin_n}/ integer (signal bin number, p. 226)
{LCTL_n DB}, float|NaN & string (LCTL result, expressed in dB)
- Example** → MEAS1:LCTL?
→ 21/5.53630E+01 DB, 113/5.29842E+01 DB
- Explanation** The returned vector is grouped in pairs, starting with the first signal bin number, a "/", the respective LCTL result, a white space and the unit in which the result is expressed. Pairs are separated by commas (","). If a received level is too low to be measured, 'NaN' (not a number) is returned.

Please refer to chapter **Longitudinal Conversion Transfer Loss** (p. 211) for further details.

NOTE In the 8 kHz mode the measuring bandwidth is limited to 20 Hz – 3.4 kHz.



MEASurement[1;2]:LOUDnessrating:SLR?

Usage Queries the measured SLR (Send Loudness Rating, p. 215).

Availability Normal mode (not available if the analyzer is armed).

Answer <LastSignalBin>/ integer (No. of the highest signal bin)
<SLR_Result> DB float|NaN & string (SLR result, expressed in dB)

Example → MEAS1:LOUD:SLR?
→ 170/9.22375E+00 DB (bin No. 170 = 3984 Hz; SLR = 9.224 dB)

Explanation Use the "LOUDNESS" signal for SLR analysis (**OUTPut:MTONe:ACTive:LOUDNESS**).

NOTE Calibrate the setup prior to SLR measurements (p. 214).

MEASurement[1;2]:LOUDnessrating:STMR?

Usage Queries the measured STMR (Sidetone Masking Loudness Rating, p. 217).

Availability Normal mode (not available if the analyzer is armed).

Answer <LastSignalBin>/ integer (No. of the highest signal bin)
<STMR_Result> DB float|NaN & string (STMR result, expressed in dB)

Example → MEAS1:LOUD:STMR?
→ 170/1.9760E+01 DB (bin No. 170 = 3984 Hz; STMR = 19.76 dB)

Explanation Use the "LOUDNESS" signal for STMR analysis (**OUTPut:MTONe:ACTive:LOUDNESS**).

NOTE Calibrate the setup prior to STMR measurements (p. 214).

MEASurement[1;2]:LOUDnessrating:RLR?

Usage Queries the measured RLR (Receive Loudness Rating, p. 216).

Availability Normal mode (not available if the analyzer is armed).

Answer <LastSignalBin>/ integer (No. of the highest signal bin)
<RLR_Result> DB float|NaN & string (RLR result, expressed in dB)

Example → MEAS1:LOUD:RLR?
→ 170/2.25365E+00 DB (bin No. 170 = 3984 Hz; RLR = 2.254 dB)

Explanation Use the "LOUDNESS" signal for RLR analysis (**OUTPut:MTONe:ACTive:LOUDNESS**).

MEASurement[1|2]:MTTDan:UNIT [DB|%]

Use	Defines the unit, in which the TD+N result (Total Distortion + Noise, refer to p. 205) shall be expressed.
Availability	Normal or PureSound™ mode (also if the analyzer is armed).
Parameter	[DB %] <i>string</i> (decibel percent)
Default	DB
Example	→ MEAS1:MTTD:UNIT %

MEASurement[1|2]:MTTDan?

Use	Queries the TD+N result (Total Distortion + Noise, refer to p. 205) of a transmitted multitone signal in the frequency band from 23 Hz to 20 kHz.
Availability	Normal mode (<u>not</u> available if the analyzer is armed).
Answer	<Bin_Max>/ <i>integer</i> (Bin_Max, p. 226) <TD+N Unit> <i>float NaN & string</i> (TD+N result & unit)
Example	→ Measurement1:MTTDAN? → 854/-6.40217E+01 DB
Explanation	The result string starts with Bin_Max, followed by a slash "/", the TD+N result and the unit. The measurement considers the frequency band from the first bin ≥ 20 Hz (Bin_Min) to the last bin ≤ 20 kHz (i.e. Bin_Max), whereby the TD+N result is calculated out of the noise, distortion and signal levels according to Equation 8 .

MEASurement[1|2]:MTSinad?

Use	Queries the MT-SINAD result (p. 213) of a transmitted multitone signal in the frequency band from 23 Hz to 20 kHz.
Availability	Normal mode (<u>not</u> available if the analyzer is armed).
Answer	<Bin_Max>/ <i>integer</i> (Bin_Max, p. 226) <MT_Sinad> DB <i>float NaN & string</i> (MT-SINAD result, expressed in dB)
Example	→ Measurement1:MTSinad? → 213/5.22350E+01 DB
Explanation	The result string starts with Bin_Max, followed by a slash "/", the MT-SINAD result and the unit dB. The measurement considers all signal components from the first bin ≥ 20 Hz (Bin_Min) to the last bin ≤ 20 kHz (i.e. Bin_Max), whereby the MT-SINAD result is calculated out of the noise, distortion and signal levels according to Equation 13 . If two signal bins are too narrow to measure the distortion energy of the band in between, error 246 Measurement not possible is returned.

NOTE In the 8 kHz mode the measuring bandwidth is limited to 20 Hz – 3.4 kHz.

MEASurement[1;2]:NOISe:UNIT [DBV|V|DBM|DBFS|%FS|DBM0]

Usage Defines the unit, in which the noise measurement result is expressed (p. 219).

Availability Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed).

Parameter

A) A-A, D-A operation
 [DBV| V| DBM] *string* (V_{RMS} in logarithmic scale, referred to 1 V_{RMS})
 (V_{RMS} in linear scale)
 (RMS power in logarithmic scale, p. 281)

B) A-D, D-D operation (with ISDN or T1 option)
 [DBFS| %FS| DBM0] *string* (V_{RMS} in logarithmic scale, referred to fullscale)
 (V_{RMS} in linear scale, referred to fullscale)
 (RMS level in logarithmic scale, p. 282)

Default DBV|DBFS (A-A, D-A | A-D, D-D operation)

Example → MEAS1:NOISE:UNIT V

Explanation

NOTE	[dBm] is a <u>power</u> unit that refers to 600 Ω input impedance. Thus, if another input impedance is selected, the dBm level result changes.

MEASurement[1;2]:NOISe?

Usage Queries the noise values of the bands between Bin_Min → SignalBin_1, SignalBin1 → SignalBin2, etc., SignalBin_n → Bin_Max (chapter **Noise**, p. 219).

Availability Normal mode (not available if the analyzer is armed).

Answer {SignalBin_n}/ *integer* (signal bin number, p. 226)
 {Noise_n Unit}, *float|NaN & string* (measured noise result & unit)

Unit (defined by MEASurement[1;2]:NOISe:UNIT [DBV|V|DBM|DBFS|%FS|DBM0])

Example → Measurement1:Noise?
 → 3/-1.22176E+02 dBV, 11/-1.08494E+02 dBV, 32/
 -1.03108E+02 dBV, 48/-1.03342E+02 dBV, 214/NaN

Explanation The returned noise vector starts with Bin_Min, followed by the noise result between this bin and the first signal bin. The second pair is the bin number of SignalBin_1 and the noise value between SignalBin_1 and SignalBin_2, etc. The last pair is the last signal bin with the noise result between this signal bin and Bin_Max. Refer also to **Fig 48**.

If a band between two signal bins is too narrow to measure a noise value, 'NaN' (not a number) is returned.

NOTE	In the 8 kHz mode the measuring bandwidth is limited to 20 Hz – 3.4 kHz. [dBm] is a <u>power</u> unit that refers to 600 Ω input impedance. Thus, if another input impedance is selected, the dBm level result changes.



MEASurement[1;2]:NOISe:FULLband?

Usage Queries the full band noise from 20 Hz to 20 kHz | 4 kHz (**Full Band Noise**, p. 220).

Availability Normal mode (not available if the analyzer is armed).

Answer <Bin_Max>/ *integer* (Bin_Max, p. 226)
<FullBandNoise Unit> *float|NaN & string* (full band noise result & unit)

Unit (defined by **MEASurement[1;2]:NOISe:UNIT [DBV|V|DBM|DBFS|%FS|DBM0]**)

Example → Measurement1:Fullband?
→ 213/1.23456E-02 dBV

Explanation The returned result string starts with the highest possible bin (Bin_Max), followed by a "/", the fullband noise result and the unit.

The fullband noise result is calculated according to **Equation 15** (p. 220).

If two or more signal bins are set directly besides each other (with no bin in between), an error message is returned.

NOTE	In the 8 kHz mode the measuring bandwidth is limited to 20 Hz – 3.4 kHz. [dBm] is a <u>power</u> unit that refers to 600 Ω input impedance. Thus, if another input impedance is selected, the dBm level result changes.

MEASurement:PHASe:SCALe <Scale> [RAD|DEG]

Usage Defines the lower scaling end of the multitone and stepped sweep phase-plot (p. 220).

Availability Normal, LCL, RL and PureSound™ mode (not available if the analyzer is armed).

Parameter -6.28318E+00 to 0 RAD | -360.000E+00 to 0 DEG *float & string* (-6.28318 = -2π)

Default 0

Examples  → MEAS:PHASE:SCALE -2.70E-02 DEG (-270° to +90°)

 → Meas:Phas:Scal -3.14159E+00 RAD ($-\pi$ to $+\pi$)

Explanation The complete phase scale encompasses a full circle, i.e. 2π [rad] or 360° [deg].

The scale applies on multitone as well as stepped sweep measurements, i.e. regardless whether the measurement is executed with command **MEASurement[1|2]:PHASe?** or **MEASurement[1|2]:STEPpedswEEP:PHASe? <MeasFrequency>**.

MEASurement:PHASe:UNIT [RAD|DEG]

Usage Defines the unit (radian or degree) of the multitone phase measurement result (p. 220).

Availability Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed).

Parameter [RAD|DEG] *string* (radian: 0 to 2π @ degree: 0° to 360°)

Default RAD

Example  → MEAS:PHASE:UNIT DEG

Explanation The command defines the phase unit for multitone measurements.

Please note that phase measurements can also be executed with a stepped sweep (p. 263).

MEASurement[1|2]:PHASe?

Usage Queries the phase-difference between identical signal bins of a two-channel multitone signal (p. 220).

Availability Normal mode (not available if the analyzer is armed).

Answer {SignalBin_n}/ integer (signal bin number, p. 226)
{Phase_n Unit}, float|NaN & string (phase result & unit)
; (no trigger detected, i.e. no phase measurement possible)

Unit (defined by command **MEASurement:PHASe:UNIT [RAD|DEG]**)

Examples

```

PC → MEAS1:PHASE?
→ PC 13/1.24001E00 DEG,123/9.27300E-01 DEG

PC → MEAS1:PHASE?
→ PC ; (phase measurement not successful)

```

Explanation The multitone phase measurement is only available:

- If at least one identical signal bin is set in both channels of the multitone signal (p. 221).
- If the RT-2X analyzer has triggered on both channels to the incoming signal.

The returned vector is composed of blocks, indicating the measured phase value at a signal bin. Each block starts with the number of the signal bin, followed by a "/", the corresponding phase value, a white space, the unit in which the result is expressed, and a comma (",").

';' indicates that the analyzer did not trigger.

Please note that phase measurements can also be acquired with a stepped sweep (p. 263).

NOTE Set the input range of both channels to the same value to get accurate phase results.

In the 8 kHz mode the measuring bandwidth is limited to 20 Hz – 3.4 kHz.

MEASurement:PUResound:LENGth <Duration>

- Usage** Defines the acquisition length of the steepness analysis (p. 250).
- Availability** Normal and PureSound™ mode (not available if the analyzer is armed).
- Parameter** A) INOUT:PUResound:MODE RNB
 <Duration> *integer* 100 to 10000 (sampling duration in ms; resolution = 1)
 B) INOUT:PUResound:MODE CORrelation
 <Duration> *integer* 300 to 180000 (sampling duration in ms; resolution = 1)
- Default** 1000 (ms)
- Query** *MEASurement:PUResound:STATus?*
- Example**  → meas:pur:leng 1500
- Explanation** If the internal stimulus signal (chirp) is used for a RNB measurement, <Duration> should be equal to the value defined by *OUTPut:PUResound:CHIRp:LENGth <Duration>*

MEASurement:PUResound:NRESults <#Results>

- Usage** Defines the number of results for the steepness calculation (p. 250).
- Availability** Normal and PureSound™ mode (not available if the analyzer is armed).
- Parameter** <#Results> *integer* 1 to 1000 (number of results; resolution = 1)
- Default** 100
- Query** *MEASurement:PUResound:STATus?*
- Example**  → MEAS:PUR:NRES 500
- Explanation** <#Results> defines the resolution of the returned result vector, but not of the RNB test.

MEASurement[1|2]:PUResound:STARt

- Usage** Starts the PureSound™ analysis (RNB or CORRELATION) of an incoming signal (p. 267).
- Availability** PureSound™ mode (not available if the analyzer is armed).
- Example**  → MEAS1:PUR:STAR
- Explanation** The command starts only the analysis of an incoming signal, regardless whether it was generated by RT-2X or by an external signal generator.

NOTE	Select an appropriate trigger mode with command <i>INPut:SYNC INTN</i> or <i>THR</i> before starting the PureSound™ data acquisition.

MEASurement:PUREsound:STATus?

Usage Queries the measurement status of the PureSound™ option.

Availability Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed).

Answer

A) INOUT:PUREsound:MODE OFF
; *string* (not applicable)

B) INOUT:PUREsound:MODE RNB
NRESULTS [1 to 1000], *string & integer* (number of results)
LENGTH [100 to 10000], *string & integer* (chirp duration)
LIMIT1 [ENABLE|DISABLE], *string & float*
LIMIT2 [ENABLE|DISABLE], *string & float*
LIMIT3 [ENABLE|DISABLE], *string & float*
LIMIT4 [ENABLE|DISABLE], *string & float* (status of the individual steepness limits for band No. 1 – 6)
LIMIT5 [ENABLE|DISABLE], *string & float*
LIMIT6 [ENABLE|DISABLE] *string & float*

C) INOUT:PUREsound:MODE CORrelation
NRESULTS [1 to 1000], *string & integer* (number of results)
LENGTH [100|300 to 10000], *string & integer* (test signal duration)
ACTIVEREFERENCE [A|B], *string* (reference signal)
REFERENCELENGTH [300 to 10000], *string & integer* (duration of the reference signal)
REFERENCEVALIDITY [VALID|INVALID], *string* (validity of the reference signal)
NAME <RefName> *string* (name of the reference signal)

Examples

→ INOUT:PURESOUND:MODE OFF
MEASUREMENT:PURESOUND:STAT?
→ ;

→ INOUT:PUR:MODE RNB
MEASUREMENT:PUR:STAT?
→ NRESULTS 100,LENGTH 1000,LIMIT1 ENABLE,LIMIT2
ENABLE,LIMIT3 DISABLE,LIMIT4 ENABLE,LIMIT5 ENABLE,
LIMIT6 DISABLE

→ INOUT:PUR:MODE CORRELATION
MEASUREMENT:PUR:STAT?
→ NRESULTS 134,LENGTH 500,ACTIVEREFERENCE B,
REFERENCELENGTH 500,REFERENCEVALIDITY VALID,
NAME MOZART

Explanation The syntax of the returned string depends on the status of the PureSound™ mode as defined by **INOUT:PUREsound:MODE [OFF|RNB|CORrelation]**.

If the test signal length (PureSound™ mode CORrelation) is invalid, "0" will be returned.

MEASurement:PUResound:STEEpness[1'2'3'4'5'6]?

Usage Queries the measured steepness results of the selected band (#1–6) for the last signal that was acquired through the active channel (p. 250).

Availability PureSound™ mode (not available if the analyzer is armed).

Answer {TimeStamp_n}/ float (time since the start of the chirp, expressed in ms)
{Steepness_n}, float|NaN (steepness result, expressed in the active unit)

Unit (defined by **MEASurement:PUResound:STEEpness:UNIT [PA|S|V|S]**)

Example → MEAS:PUR:STE1?
→ 1.00E+00/3.16E-02, 2.00E+00/3.13E-02, . . . , 1.0E+02/
5.30E-02

Explanation The returned vector is grouped in pairs, starting with the first timestamp, a slash "/" and the corresponding steepness result (without unit). Pairs are separated by commas (",").

Select the active channel with command **MEASurement[1'2]:PUResound:START**

Select the active unit with **MEASurement:PUResound:STEEpness:UNIT [PA|S|V|S]**

If required, query the number of returned pairs with **MEASurement:PUResound:STATus?**

MEASurement:PUResound:STEEpness:CORRelation?

Usage Queries the sound correlation between the active reference signal and the last acquired test signal (p. 244).

Availability PureSound™ mode in status **INOUT:PUResound:MODE CORRelation** (not available if the analyzer is armed).

Answer <Delay/> float (trigger delay reference → test signal, expressed in ms)
<Correl %> float & string (sound correlation: 0 % to 100 %)

Example → MEAS:PUR:STE:CORR?
→ -6.73E+01/8.96E+01 %

Explanation The sound correlation represents the similarity between the active reference signal and the test signal. 100 % correlation corresponds to identical signals, whereby 0 % correlation indicates that there is no similarity.

The returned vector starts with the delay, followed by a slash "/", the correlation result, a white space and the unit "%".

The active channel is defined by command **MEASurement[1'2]:PUResound:START**.

MEASurement:PUResound:STEEpness:LEVelcorrection?

Usage	Queries the level difference between the active reference signal and the test signal (p. 244).
Availability	PureSound™ mode in status INOUT:PUResound:MODE CORRelation (<u>not</u> available if the analyzer is armed).
Answer	<SignalDuration>/ <i>float</i> (test signal duration, expressed in ms) <LevelCorrection> % <i>float & string</i> (level correlation, expressed in %)
Example	 → MEAS:PUR:STE:LEV? →  5.00E+02/2.18E+03% (duration: 500 ms; level correction: reference signal level = 218 % of test signal level [ref./test = 2.18])
Explanation	The level correction result represents the RMS level difference between the active reference signal and the test signal: $\text{LevelCorrection [\%]} = (\text{RefSignalLevel} / \text{TestSignalLevel}) * 100$ The returned vector starts with the duration of the test signal, followed by a slash "/", the level correction result, a white space and the unit "%". The active channel is defined by command MEASurement[1'2]:PUResound:STARt.

MEASurement:PUResound:STEEpness:OK?

Usage	Queries for the last acquired signal, whether the results of <u>all</u> six bands are below the user-defined steepness limits (p. 250).
Availability	PureSound™ mode in status INOUT:PUResound:MODE RNB (<u>not</u> available if the analyzer is armed).
Answer	[PASSED FAILED] <i>string</i> (no steepness limit exceeded ≥ 1 steepness limit exceeded)
Example	 → MEAS:PUR:STE:OK? →  PASSED
Explanation	Refer to command MEASurement:PUResound:STEEpness:VARLimit:SET ... about the definition of individual steepness limits for the six bands.

MEASurement:PUResound:STEEpness:REFerence:ACTive [A|B]

Usage	Activates the reference signal (memory A or B) for sound correlation measurements (p. 244).
Availability	Normal, LCL, RL and PureSound™ mode (<u>not</u> available if the analyzer is armed).
Parameter	[A B] <i>string</i> (memory location of RT-2X)
Default	A
Query	MEASurement:PUResound:STATus?
Example	 → MEAS:PUR:STE:REF:ACT B
Explanation	The command activates a previously saved reference signal. Execute one of the following procedures to save a reference signal on the internal memory of RT-2X: a) Record a test signal (MEASurement[1 2]:PUResound:START) and make it the reference signal (MEASurement:PUResound:STEEpness:REFerence:USELastmeas) or b) Transfer a previously stored reference signal from the PC to the RT-2X unit with the command MEASurement:PUResound:STEEpness:REFerence:SET. Execute a sound correlation measurement with MEASurement[1 2]:PUResound:START and MEASurement:PUResound:STEEpness:CORRelation?

MEASurement:PUResound:STEEpness:REFerence:NAME <RefName>

Usage	Assigns a user-defined name to the active reference signal (memory A or B, p. 244).
Availability	Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed).
Parameter	<RefName> <i>string</i> (user-defined reference signal name, up to 8 characters)
Query	MEASurement:PUResound:STEEpness:REFerence:NAME?
Example	 → MEAS:PUR:STE:REF:NAME mozart
Explanation	The command overwrites the previous name of the currently active reference signal. The name remains stored in the non-volatile RT-2X memory even after power OFF. Use command MEASurement:PUResound:STEEpness:REFerence:ACTive [A B] to select the active reference signal.

MEASurement:PUResound:STEEpness:REFerence:NAME?

Usage	Queries the name of the active reference signal (memory A or B, p. 244).
Availability	Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed).
Answer	<RefName> string (user-defined reference signal name)
Default	[REF_A001 REF_B001] (default names of reference signals in memory A\B)
Example	 → MEAS:PUR:STE:REF:NAME? →  MOZART
Explanation	Use command MEASurement:PUResound:STEEpness:REFerence:NAME <RefName> to define the name of the active reference signal.

MEASurement:PUResound:STEEpness:REFerence:USELastmeas

Usage	Stores the last acquired test signal in the active reference memory (A or B), thus making it the reference signal (i.e. 'golden' sample, p. 244).
Availability	PureSound™ mode in status INOUT:PUResound:MODE CORRELATION (<u>not</u> available if the analyzer is armed).
Query	MEASurement:PUResound:STATUS?
Example	 → MEAS:PURESOUND:STEEPNESS:REFERENCE:USELASTMEAS
Explanation	The command overwrites the contents of the currently active reference memory (A or B) with the last acquired signal. Use command MEASurement[1'2]:PUResound:STARt to record a test signal. Stored reference signals remain in the non-volatile memory even after power OFF.

MEASurement:PUResound:STEEpnness:REFerence:GET?

- Usage** Transfers the contents of the currently active reference memory (i.e. the reference signal) to the controlling PC in the form of a compressed data string (p. 244).
- Availability** PureSound™ mode in status **INOUT:PUResound:MODE CORRELATION** (not available if the analyzer is armed).
- Answer**
- | | | |
|---------------|---------|---|
| 3, | integer | (compression type = correlation) |
| <NoOfChars> , | integer | (number of characters of the compressed string) |
| <RefLength> , | integer | (duration of the reference signal, expressed in ms) |
| <RefName> , | string | (user-defined name of the reference signal) |
| <NormFactor> | integer | (normalization factor) |
| #0<Data> | string | ("#0" + compressed data string) |
- Examples**
- | | | |
|---|---|--|
| → | MEAS: PUR: STE: REF: GET? | |
| → | 3, 109, 40, MUSIC, 171008#0...Ů...†, 1
...-^%ŽÉ„É, 'fñf~, Ñ, @, 1 Å, °, ùfž†
%ÎÊÔŽ, Šö<- ¨ ¨ << ŮÊÔ< ŮÊÔÊ«%Ů
†ö†Ê^p<Ç ¨ ìžœ ¨ ¨ â~«œž' ' ¨ ì ¨ „Êÿ<
¨ ¨ Ê' ¨ ¨ ÷ ¨ ¨ †' @' Å ¨ Ō | (compressed data string = 109 chars;
reference signal name = "MUSIC";
normalization factor = 171008;
109 ASCII characters, representing
the compressed reference signal) |

Explanation The command saves the active reference signal in a compressed form on the PC.

Thus, it can be downloaded back from the PC to the RT-2X unit at a later time by using the command **MEASurement:PUResound:STEEpnness:REFerence:SET 3,<NoOfChars>,<RefLength>,<RefName>,<NormFactor>#0<Data>**.

MEASurement:PUResound:STEEpnness:REFerence:SET 3,<NoOfChars>,<RefLength>,<RefName>,<NormFactor>#0<Data>

- Usage** Transfers the compressed data string that represents a reference signal from the PC to the active RT-2X memory (p. 244).
- Availability** PureSound™ mode in status **INOUT:PUResound:MODE CORRELATION** (not available if the analyzer is armed).
- Example**
- | | | |
|---|--|--|
| → | MEAS: PUR: STE: REF: SET 3, 109, 40, MUSIC,
171008#0...Ů...†, 1...-^%ŽÉ„É, 'fñf~, Ñ, @, 1 Å
, °, ùfž† %ÎÊÔŽ, Šö<- ¨ ¨ << ŮÊÔ< ŮÊÔÊ«%Ů
†ö†Ê^p<Ç ¨ ìžœ ¨ ¨ â~«œž' ' ¨ ì ¨ „Êÿ<
¨ ¨ Ê' ¨ ¨ ÷ ¨ ¨ †' @' Å ¨ Ō | (hyroglyphs represent
the compressed
reference data) |
|---|--|--|

Explanation The command downloads a previously stored reference signal from the PC to RT-2X.

NOTE The content of the active reference memory is overwritten as soon as this commands is sent to RT-2X.

MEASurement:PUResound:STEEpnness:RMSLevel:UNIT [DBV;V;DBSPL;DBPA;DBM]

Usage Defines the unit, in which the RMS level of a correlation analysis shall be expressed.

Availability Normal and PureSound™ mode (also if the analyzer is armed).

Parameter

[DBV;		(V _{RMS} in logarithmic scale, referred to 1 V _{RMS})
V;		(V _{RMS} in linear scale)
DBSPL;	string	(Sound Pressure Level in logarithmic scale, p. 223)
DBPA;		(air pressure in logarithmic scale, p. 283)
DBM]		(RMS power in logarithmic scale, p. 281)

Default DBV

Example  → MEAS:PUR:STE:RMSL:UNIT V

Explanation

NOTE	A level expressed in dBm always refers to the current input impedance, since [dBm] is a <u>power</u> unit. Thus, if the input level is measured in dBm, the result depends on the selected input impedance.

MEASurement:PUResound:STEEpnness:RMSLevel?

Usage Queries the RMS level of the last correlation analysis, expressed in the selected unit (p. 244).

Availability Normal mode (not available if the analyzer is armed).

Answer Signal_Level float;NaN & string (test signal RMS level & unit)

Unit (defined by command MEASurement:PUResound:STEEpnness:RMSLevel:UNIT ...)

Example  → MEAS:PUR:STE:RMSL?
→  -2.19404E+01 dBV

Explanation The returned result reflects the RMS level of the whole signal that has been acquired for a sound correlation analysis.

If a received level is too low to be measured, 'NaN' (not a number) is returned.

NOTE	A level expressed in dBm always refers to the current input impedance, since [dBm] is a <u>power</u> unit. Thus, if the input level is measured in dBm, the result depends on the selected input impedance.

MEASurement:PUREsound:STEEpness:UNIT [PA|S|V|S]

Usage	Defines the unit, in which the steepness results shall be expressed.
Availability	Normal, LCL, RL and PureSound™ mode (<u>not</u> available if the analyzer is armed).
Parameter	[PA S V S] ² <i>string</i> (Pascal per Second Volt per Second)
Default	PA S
Example	 → MEAS:PUR:STE:UNIT PA S
Explanation	In case of acoustical measurement with a microphone connected, the unit PA S should be used. In this case, RT-2X considers the stored microphone sensitivity as defined by the command INPut[1 2]:MICsensitivity <Sensitivity> Select the steepness unit PA S only if the signal has been acquired with a microphone.

MEASurement:PUREsound:STEEpness:VARLimit:ACTive[1|2|3|4|5|6] [ENABLE|DISABLE]

Usage	Activates the individual limit test defined by MEAS:PUR:STE:VARL:SET ... (p. 250).
Availability	Normal, LCL, RL and PureSound™ mode (<u>not</u> available if the analyzer is armed).
Parameter	[1 2 3 4 5 6] <i>integer</i> (number of the active transient steepness band) [ENABLE DISABLE] <i>string</i>
Default	DISABLE
Example	 → MEAS:PUR:STE:VARL3 ENABLE
Explanation	The command activates an user-defined, individual PASS/FAIL test for each steepness band. Refer to chapter Steepness Limits for PASS/FAIL Test (Rub & Buzz Detection) (p. 250) for further details.

² Enter the character "|" by pressing the keys <AltGr> + <7>

MEASurement:PUResound:STEEpness:VARLimit:SET[1|2|3|4|5|6]
<NoOfPoints> [PA|S|V|S] <X_Point₁>,<X_Point₂>,...
<X_Point_{NoOfPoints}>,<Y_Limit₁>,<Y_Limit₂>,...,<Y_Limit_{NoOfPoints}>

Usage	Defines individual limits for the transient steepness bands (refer to p. 250).		
Availability	Normal, LCL, RL and PureSound™ mode (<u>not</u> available if the analyzer is armed).		
Parameter	[1 2 3 4 5 6]	integer	(number of the steepness analysis band)
	<NoOfPoints>	integer	1 to 200 (number of points that build the individual limit)
	[PA S V S]	string	(Pascal per second Volt per second)
	<X_Point _n >	float	0.00 to 100.00 (location of point "n", expressed in percent of the X-axis; resolution = 0.01)
	<Y_Limit _n >	float	0.00 to 100000.00 (individual limit of point "n", expressed in the selected unit; resolution = 0.01)
Default	2 PA S 0, 100, 20, 20 (2 points, Pa/s, location 0% and 100%, limit value 20)		
Example	→ MEAS:PUR:STE:VARL:SET3 5 (Variable limit definition: PA S 0.00E00, 1.00E+01, 1.50E+01, 2.30E+01, 1.00E+02, 0.33E+01, 0.50E+01, 1.20E+02, 0.60E+01, 0.20E+01 • Band #3 • 5 points • Unit: Pascal per Second • Points at: 0%, 10%, 15%, 23%, 100% • Limits: 3.3, 5, 120, 6, 2 [Pa/S])		
Explanation	The command defines the individual PASS/FAIL limits for the steepness analysis (refer to chapter Steepness Limits for PASS/FAIL Test (Rub & Buzz Detection) , p. 250). Thereby, the user-defined points & limits represent a tolerance band that is split into intervals with individual steepness limits.		

MEASurement:PUResound:STEEpness:VARLimit:SET[1|2|3|4|5|6]?

Usage	Queries the individual limits of a transient steepness band (refer to p. 250).		
Availability	Normal, LCL, RL and PureSound™ mode (<u>not</u> available if the analyzer is armed).		
Parameter	[1 2 3 4 5 6]	integer	(number of the transient steepness band)
Answer	<NoOfPoints>,<X_Point ₁ >,<X_Point ₂ >,...	integer	(number of points that build the individual limit)
	[PA S V S],	string	(unit, in which the limit values are expressed)
	{Point _n },	float	(relative locations of the points on the X-axis)
	{Limit _n },	float	(individual limits of the points, expressed in the active unit)
Default	2, PA S, 0, 100, 20, 20 (2 points, Pa/S, 0 – 100%, 20 – 20 [Pa/S])		
Example	→ MEAS:PUR:STE:VARL:SET3? → 4, V S, 0, 25, 50, 100, 0.10E00, 0.50E00, 1.2E00, 0.75E00		
Explanation	The command queries variable PASS/FAIL limits for the steepness analysis (refer to chapter Steepness Limits for PASS/FAIL Test (Rub & Buzz Detection) , p. 250).		

MEASurement:RL?

Usage Queries the Return Loss (RL) according to recommendation IEEE 743-1995, measured on input channel 1 (p. 222f).

Availability RL mode (not available if the analyzer is armed):

- The LCL Bridge must be switched OFF (**INOUT:LCLBridge:MODE OFF**).
- The RL Bridge must be switched ON (**INOUT:RLBridge:MODE ON**).
- The generator and analyzer must be in analog operation (**OUTPut:SOURce ANALog, INPut:SOURce ANALog**).

Answer {SignalBin_n}/ *string* (signal bin number, p. 226)
{RL_Result_n} DB, *float|NaN & string* (corresponding RL result, expressed in dB)

Example  → Measurement:rl?
→  5/5.80332E+01 DB, 10/5.83691E+01 DB, 15/5.84737E+01 DB, 20/5.87734E+01 DB, 25/5.88322E+01 DB

Explanation Measurement results are returned in a string, grouped in pairs. Between each signal bin number and the RL result, a separator "/" is used. A white space separates the RL result from the unit. Pairs are separated by a comma (",").

"NaN" indicates that the acquired result is not valid.

Please refer to chapter **Return Loss (RL)** (p. 222) for further details.

NOTE In the 8 kHz mode the measuring bandwidth is limited to 20 Hz – 3.4 kHz.

MEASurement[1;2]:SElectiverss:UNIT [DBV;V;DBSPL;DBPA;DBM;DBFS;%FS;DBM0]

Use	Defines the unit, in which the RSS selective result is expressed (p. 223).
Availability	Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed).
Parameter	A) A-A, D-A operation [DBV; (V_{RMS} in logarithmic scale, referred to 1 V_{RMS}) V; (V_{RMS} in linear scale) DBSPL; string (Sound Pressure Level in logarithmic scale, p. 223) DBPA; (air pressure in logarithmic scale, p. 283) DBM] (RMS power in logarithmic scale, p. 281) B) A-D, D-D operation (with ISDN or T1 option) [DBFS; (V_{RMS} in logarithmic scale, referred to fullscale) %FS; string (V_{RMS} in linear scale, referred to fullscale) DBM0] (RMS level in logarithmic scale, p. 282)
Default	DBV;DBFS (A-A, D-A A-D, D-D operation)

Example  → Meas1:Sel:Unit V

Explanation **NOTE** [dBm] is a power unit that refers to 600 Ω input impedance. Thus, if another input impedance is selected, the dBm level result changes.

**MEASurement[1|2]:SElectiverss? <Binstart> <Binstop>**

Use	Queries the RSS Selective result for the frequency band from <binstart> to <binstop> including these two bins (chapter RSS Selective , p. 223).		
Availability	Normal mode (<u>not</u> available if the analyzer is armed).		
Parameter	<Binstart> <Binstop>	<i>integer</i>	(signal bin numbers that define the band, p. 226)
Answer	<Binstop>/ <RSS_Sel Unit>	<i>integer</i> <i>float NaN & string</i>	(the bin that represents the upper band limit) (measured RSS result & unit)
Unit	(defined by MEAS[1 2]:SEL:UNIT[DBV V DBSPL DBM DBFS %FS DBM0])		

Examples	 →	Meas1:Sel? 11 11	(RSS value of Bin #11)
	→ 	11/-1.283429E+02 dBV	
	 →	MEAS2:SEL? 11 32	(RSS value from Bin #11 to Bin #32,
	→ 	32/-1.013521E+02 dBV	including levels of Bins #11 and #32)
	 →	MEAS2:SEL? 1 213	(Sound Pressure Level in dB _{SPL} from
	→ 	213/0.176425E+01 dB SPL	94 Hz – 20 kHz [blocklength = 512])

Explanation The RSS selective measurement returns the overall input level + distortion + noise in a user-defined frequency band. <binstart> and <binstop> define the lower and the upper end of this band (**Equation 19** and **Equation 20**, p. 226).

"NaN" indicates that the acquired result is not valid.

To measure the sound pressure level (SPL), connect a microphone to RT-2X, activate the Phantom power if required (**INPut[1|2]:IMPedance PHANTOM**) and save the microphone sensitivity on RT-2X (**INPut[1|2]:MICSensitivity <Sensitivity>**).

NOTE	In the 8 kHz mode the measuring bandwidth is limited to 20 Hz – 3.4 kHz. [dBm] is a <u>power</u> unit that refers to 600 Ω input impedance. Thus, if another input impedance is selected, the dBm level result changes.

MEASurement:SRLHI?

Usage Queries the Singing Return Loss High (SRL-Hi) accord. to recommendation IEEE 743-1995, measured on input channel 1 (p. 206).

Availability RL mode (not available if the analyzer is armed), whereby the RL Bridge must be switched **ON** (**INOUT:RLBridge:MODE ON**) and the predefined **SRLHI** test signal must be the active signal (**OUTPut:MTONE:ACTive SRLHI**).

Answer <LastSignalBin>/ integer (number of the highest signal bin, p. 226)
<SRLHiResult> DB float|NaN & string (SRL Hi result, expressed in dB)

Example  → Meas:srlhi?
→  37/1.54325E+01 DB

Explanation The measurement result is returned in a string. The number of the last signal bin is separated from the result by a "/", and a white space is inserted between the result and its unit.

"NaN" indicates that the acquired result is not valid.

NOTE In the 8 kHz mode the measuring bandwidth is limited to 20 Hz – 3.4 kHz.

MEASurement:SRLLO?

Usage Queries the Singing Return Loss Low (SRL-Lo) accord. to recommendation IEEE 743-1995, measured on input channel 1 (p. 206).

Availability RL mode (not available if the analyzer is armed), whereby the RL Bridge must be switched **ON** (**INOUT:RLBridge:MODE ON**) and the predefined **SRLLO** test signal must be the active signal (**OUTPut:MTONE:ACTive SRLLO**).

Answer <LastSignalBin>/ integer (number of the highest signal bin, p. 226)
<SRLLoResult> DB float|NaN & string (SRL Lo result, expressed in dB)

Example  → Measurement:srllo?
→  110/3.86542E+01 DB

Explanation The measurement result is returned in a string. The number of the last signal bin is separated from the result by a "/", and a white space is inserted between the result and its unit.

"NaN" indicates that the acquired result is not valid.

NOTE In the 8 kHz mode the measuring bandwidth is limited to 20 Hz – 3.4 kHz.

MEASurement:STEPpedswEEP:ACQUisition [RMSLEVEL|DISTORTION]

Usage	Activates the acquisition mode of the stepped sweep analysis (p. 262).		
Availability	Normal and PureSound™ mode (<u>not</u> available if the analyzer is armed), whereby the settling mode must be NORMAL or SELECTIVE (p. 154).		
Parameter	[RMSLEVEL DISTORTION]	<i>string</i>	(required for stepped sweep level or phase measurements) (required for stepped sweep THD+N, k2 or k3 measurements)
Default	RMSLEVEL		
Query	MEASurement:STEPpedswEEP:STATus?		
Example	 →	MEAS:STEP:ACQU DISTORTION	
Explanation	The acquisition mode optimizes the RT-2X signal analysis (accuracy, speed) for the available stepped sweep measurements: • RMSLEVEL mode must be activated <u>prior</u> to stepped sweep Level or Phase measurements (MEAS[1 2]:STEP:RMSL? or MEAS[1 2]:STEP:PHAS? <MeasFreq>). The mode is identical to the default signal analysis of RT firmware ≤ V6.0. • DISTORTION mode is <u>mandatory</u> for stepped sweep THD+N, k2 or k3 measurements, but <u>can</u> be applied as well for Level or Phase measurements. The DISTORTION mode noticeably prolongs the measurement duration.		

NOTE As soon as the RMSLEVEL or DISTORTION mode is activated, all stepped sweep settling parameters are automatically switched to the corresponding default values.
In addition, the DISTORTION mode automatically activates the HIPrecision mode.

MEASurement:STEPpedswEEP:DISortion:ACQUisitionlength <Length>

- Usage** Adjusts the signal acquisition length during a stepped sweep distortion measurement.
- Availability** Normal and PureSound™ mode (not available if the analyzer is armed), whereby the settling mode must be NORMAL or SELECTIVE (p. 154).
- Parameter** <Length> *float* 0.0 to 200.0 (acquisition length in ms; resolution = 0.1 ms)
- Default** 10.7 (ms)
- Query** MEASurement:STEPpedswEEP:DISortion:ACQUisitionlength?
- Example**  → MEAS:STEP:DIST:ACQU 50.0
- Explanation** By adjusting the signal acquisition length, unwanted low-frequency components (e.g. 50 Hz hum) can be filtered out (e.g. by adjusting the acquisition length to > 20 ms).

NOTE Adjusting the acquisition length prolongs the measurement.

MEASurement:STEPpedswEEP:DISortion:ACQUisitionlength?

- Usage** Queries the user-defined acquisition length.
- Availability** Normal and PureSound™ mode (not available if the analyzer is armed), whereby the settling mode must be NORMAL or SELECTIVE (p. 154).
- Answer** <Length> *float* 0.0 to 200.0 (acquisition length in ms; resolution = 0.1 ms)
- Example**  → MEAS:STEP:DIST:ACQU?
→  5.000E+01
- Explanation** By adjusting the signal acquisition length, unwanted low-frequency components (e.g. 50 Hz hum) can be filtered out (e.g. by adjusting the acquisition length to > 20 ms).

MEASurement[1|2]:STEPpedswEEP:DISortion:HARMONIC:UNIT [DB|%|DBV|V|DBM]

Usage Defines the unit, in which the 2nd or 3rd harmonic distortion results shall be expressed.

Availability Normal and PureSound™ mode (also if the analyzer is armed).

Parameter [DB|
%|
DBV|
V|
DBSPL|
DBPA|
DBM] (harmonic distortion ratio in logarithmic scale)
(harmonic distortion ratio in linear scale)
(V_{RMS} in logarithmic scale, referred to 1 V_{RMS})
(V_{RMS} in linear scale)
(Sound Pressure Level in logarithmic scale)
(air pressure in logarithmic scale, p. 283)
(RMS power in logarithmic scale, p. 281)

Default DB

Example → MEAS1:STEP:DIST:HARM:UNIT V

Explanation **NOTE** [dBm] is a **power** unit that refers to 600 Ω input impedance. Thus, if another input impedance is selected, the dBm level result changes.

MEASurement[1|2]:STEPpedswEEP:DISortion:HARMonic? [2|3|4|5]

Usage Queries the 2nd, 3rd, 4th or 5th harmonics results after a stepped sweep transmission (p. 263).

Availability Normal mode (not available if the analyzer is armed).

Parameter [2|3|4|5] integer (2nd|3rd|4th|5th harmonic)

Answer {SweepFrequency_n}/ float (sweep frequency, expressed in Hz)
{Harmonic_n Unit}, float|NaN & string (harmonic distortion result & unit)

Unit (defined by command
MEASurement[1|2]:STEPpedswEEP:DISortion:HARMONIC:UNIT
[DB|%|DBV|V|DBM])

Examples → MEAS1:STEP:DIST:HARM? 2
→ 2.000E+01/-5.64063E+01 DB, 2.000E+02/-4.75937E+01 DB,
1.000E+03/-1.63773E+02 DB, 2.000E+04/NaN

 → MEAS2:STEP:DIST:HARM? 4
→ 2.000E+01/0.124E-02 %, 2.000E+02/0.880E-02 %, 2.000E+03/1.086E+02 %

Explanation The command measures 2nd, 3rd, 4th or 5th harmonics in the following frequency ranges:

- 20 Hz – 11 kHz (2nd harmonic measurement).
- 20 Hz – 7.33 kHz (3rd harmonic measurement).
- 20 Hz – 5.5 kHz (4th harmonic measurement).
- 20 Hz – 4.4 kHz (5th harmonic measurement).

The returned vector is grouped in pairs, starting with the first frequency in Hz, a "/", the respective level result, a white space, and the unit in which the result is expressed. Pairs are separated by commas (","). "NaN" indicates that the acquired result is not valid or that the fundamental frequency exceeds the limits of the 2nd, 3rd, 4th, 5th harmonic analysis.

NOTE Activate the **DISTORTION** acquisition mode and the **HARMONIC** settling type prior to a 2nd, 3rd, 4th or 5th harmonic measurement.

MEASurement[1|2]:STEPpedswEEP:DISTortion:THD:UNIT [DB|%]

Usage	Defines the unit, in which the THD result shall be expressed.
Availability	Normal and PureSound™ mode (also if the analyzer is armed).
Parameter	[DB %] <i>string</i> (harmonic distortion ratio in logarithmic linear scale)
Default	DB
Example	 → MEAS1:STEP:DIST:THD:UNIT %

MEASurement[1|2]:STEPpedswEEP:DISTortion:THD?

Usage	Queries the THD result after a stepped sweep transmission (p. 263).
Availability	Normal mode (<u>not</u> available if the analyzer is armed).
Answer	{SweepFrequency _n }/ <i>float</i> (sweep frequency, expressed in Hz) {THD _n Unit}, <i>float NaN & string</i> (THD result & unit)
Unit	(defined by MEASurement[1 2]:STEPpedswEEP:DISTortion:THD:UNIT [DB %])
Examples	 → MEAS1:STEP:DIST:THD? →  2.000E+01/-8.72321E+01 DB, 2.000E+02/-9.80808E+01 DB, 2.000E+03/-1.02866E+02 DB, 2.000E+04/-7.05641E+01 DB
Explanation	The returned vector is grouped in pairs, starting with the first frequency in Hz, a "/", the respective level result, a white space, and the unit in which the result is expressed. Pairs are separated by commas (","). "NaN" indicates that the acquired result is not valid.

NOTE Activate the DISTORTION acquisition mode and the proper settling type (p. 157) prior to a THD measurement.

MEASurement[1|2]:STEPpedswEEP:DISortion:THDN:UNIT [DB|%]

Usage	Defines the unit, in which the THD+N result shall be expressed.
Availability	Normal and PureSound™ mode (also if the analyzer is armed).
Parameter	[DB %] <i>string</i> (harmonic distortion ratio in logarithmic linear scale)
Default	DB
Example	 → MEAS1:STEP:DIST:THDN:UNIT %

MEASurement[1|2]:STEPpedswEEP:DISortion:THDN?

Usage	Queries the THD+N result after a stepped sweep transmission (p. 263).
Availability	Normal mode (<u>not</u> available if the analyzer is armed).
Answer	{SweepFrequency _n }/ <i>float</i> (sweep frequency, expressed in Hz) {THDN _n Unit}, <i>float NaN & string</i> (THD+N result & unit)
Unit	(defined by MEASurement[1 2]:STEPpedswEEP:DISortion:THDN:UNIT [DB %])
Examples	 → MEAS1:STEP:DIST:THDN? →  2.000E+01/-8.72321E+01 DB, 2.000E+02/-9.80808E+01 DB, 2.000E+03/-1.02866E+02 DB, 2.000E+04/-7.05641E+01 DB
Explanation	The returned vector is grouped in pairs, starting with the first frequency in Hz, a "/", the respective level result, a white space, and the unit in which the result is expressed. Pairs are separated by commas (","). "NaN" indicates that the acquired result is not valid.

NOTE Activate the DISTORTION acquisition mode and the proper settling type (p. 157) prior to a THD+N measurement.

MEASurement:STEPpedswEEP:HIPRecision [OFF|ON]

Usage	Activates the high precision mode of the stepped sweep analysis (p. 258).
Availability	Normal and PureSound™ mode (<u>not</u> available if the analyzer is armed).
Parameter	[OFF ON] <i>string</i>
Default	OFF
Query	MEASurement:STEPpedswEEP:STATus?
Example	 → MEAS:STEP:HIPR ON
Explanation	In the high precision mode, RT-2X acquires at least one full period for the signal analysis (otherwise it acquires only half a period). Activate the high precision mode if: • A high measurement resolution at low frequencies is required. • The DUT's resonance impedance is only slightly higher than its DC resistance. • Wideband high-end drivers (speakers, capsules etc.) have to be tested. Please note that the high precision mode prolongs the measurement duration and that it is activated automatically in the MEAS:STEP:ACQU DISTORTION mode. Refer to chapter High Precision Mode (p. 258) for further details.

MEASurement:STEPpedswEEP:NOISeimmunity [OFF|ON]

Usage	Activates the "Noise Immunity" algorithm for a stepped sweep analysis.
Availability	Normal, LCL, RL and PureSound™ mode (<u>not</u> available if the analyzer is armed).
Parameter	[OFF ON] <i>string</i>
Default	ON
Query	MEASurement:STEPpedswEEP:SMOothing:STATus?
Example	 → MEAS:STEP:NOIS OFF
Explanation	Activate the noise immunity algorithm if the system is located in a noisy environment. Please note that the noise immunity prolongs the measurement duration.

MEASurement:STEPpedswEEP:PHASe:UNIT [RAD|DEG]

Usage Defines the unit (radian or degree) of the stepped sweep phase measurement result (p. 263).

Availability Normal, LCL, RL and PureSound™ mode (not available if the analyzer is armed).

Parameter [RAD|DEG] *string* (radian: 0 to 2π | degree: 0° to 360°)

Default RAD

Example  → MEAS:STEP:PHAS:UNIT DEG

Explanation The command defines the phase unit for stepped sweep measurements. The phase scale is defined by **MEASurement:PHASe:SCALE <Scale> [RAD|DEG]**.

Please note that phase measurements can also be executed with a multitone test (p. 221).

MEASurement[1|2]:STEPpedswEEP:PHASe? <MeasFrequency>

Usage Queries the phase results from a stepped sweep transmission (p. 263).

Availability Normal mode (not available if the analyzer is armed).

Parameter <MeasFrequency> *float* (optional parameter; restricts the phase measurement to the corresponding sweep frequency)

Answer {SweepFrequency_n}/ *float* (sweep frequency)
{Phase_n Unit}, *float|NaN & string* (phase result & unit)

Unit (defined by command **MEASurement:STEPpedswEEP:PHASe:UNIT [RAD|DEG]**)

Examples  → MEAS1:STEP:PHASE?
→  2.00E+01/1.248E00 RAD, 2.00E+02/0.934E00 RAD,
2.00E+03/0.567E00 RAD, 2.00E+04/0.106E00 RAD

 → MEAS2:STEP:PHASE? 1000.0
→  1.00E+03/2.71E+02 DEG (phase @ 1000 Hz = 271 degree)

Explanation The command executes a phase measurement at a single all sweep frequencies:

- Appending the optional parameter <**Frequency**> to the command queries only the phase result of the corresponding frequency.
- Without the optional parameter the phase results of all sweep frequencies are returned.

Please note that phase measurements can also be executed with a multitone test (p. 221).

MEASurement[1|2]:STEPpedswEEP:RMSLevel:UNIT [DBV|V|DBSPL|DBPA]

Usage Defines the unit, in which the stepped Sweep RMS-level (i.e. frequency response) result shall be expressed (p. 263).

Availability Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed).

Parameter [DBV|
V|
DBSPL|
DBPA] *string* (RMS Voltage in logarithmic scale, referred to 1 V)
(RMS Voltage in linear scale)
(Sound Pressure Level in logarithmic scale)
(air pressure in logarithmic scale, p. 283)

Default DBV

Example  → MEAS1:STEP:RMSL:UNIT V

MEASurement[1|2]:STEPpedswEEP:RMSLevel?

Usage Queries the RMS level results of the last stepped sweep measurement (p. 263).

Availability Normal mode (not available if the analyzer is armed).

Answer {Frequency_n}/ *float* (sweep frequency, expressed in Hz)
{Level_n Unit}, *float|NaN & string* (corresponding level result & unit)

Unit (defined by command **MEASurement[1|2]:STEPpedswEEP:RMSLevel:UNIT ...**)

Example  → Meas:step:rmsl?
→  2.00E+01/-6.416E+01 dBV, 2.00E+02/-6.396E+01 dBV,
2.00E+03/-6.425E+01 dBV, 2.00E+04/-6.400E+01 dBV

Explanation The returned vector is grouped in pairs, starting with the first frequency in Hz, a "/", the respective level result, a white space, and the unit in which the result is expressed. Pairs are separated by commas (",").

"NaN" indicates that the acquired result is not valid.

MEASurement:STEPpedswEEP:SETTling:ACTive [CHANNEL1;CHANNEL2;BOTHCHANNELS]

Usage	Defines the active channel(s) for the stepped sweep settling (p. 257).
Availability	Normal, LCL, RL and PureSound™ mode (<u>not</u> available if the analyzer is armed), whereby the settling mode must be NORMAL (MEAS:STEP:SETT:MODE NORMAL).
Parameter	[CHANNEL1 CHANNEL2 BOTHCHANNELS] <i>string</i>
Default	CHANNEL1 (RMSLEVEL and DISTORTION mode)
Query	MEASurement:STEPpedswEEP:SETTling:STATus?
Example	 → Measurement:steppedswEEP:settling:active channel1
Explanation	In case of a 1-channel measurement, it is strongly recommended to activate the settling only for the corresponding channel. Refer to chapter Stepped Sweep (p. 257) for further details.

MEASurement:STEPpedswEEP:SETTling:ALGorithm [EXPONENTIAL;FLAT]

Usage	Defines the active algorithm for the stepped sweep settling (p. 257).
Availability	Normal, LCL, RL and PureSound™ mode (<u>not</u> available if the analyzer is armed), whereby the settling mode must be NORMAL (MEAS:STEP:SETT:MODE NORMAL).
Parameter	[EXPONENTIAL FLAT] <i>string</i> (the settling criterion is less strict for older samples) (the settling criterion is equally strict for all samples)
Default	EXPONENTIAL (RMSLEVEL and DISTORTION mode)
Query	MEASurement:STEPpedswEEP:SETTling:STATus?
Example	 → Measurement:steppedswEEP:settling:algorithm flat
Explanation	Refer to chapter Stepped Sweep (p. 257) for further details.

MEASurement:STEPpedswEEP:SETTling:CYCLes <Cycles>

Usage	Applies a frequency-dependent delay before every stepped sweep measurement (p. 257).
Availability	Normal, LCL, RL and PureSound™ mode (<u>not</u> available if the analyzer is armed), regardless whether the settling is active or not.
Parameter	<Cycles> <i>float</i> 0.00 to 1000.00 (No. of cycles; resolution = 0.25, i.e. ¼ of a period)
Default	0 8 (RMSLEVEL DISTORTION mode)
Query	MEASurement:STEPpedswEEP:SETTling:STATus?
Example	 → MEAS:STEP:SETT:CYCL 0.525E+01
Explanation	The delay is defined in cycles (periods) of the currently active sweep frequency. Thus, it is proportional to the sweep frequency. If a fixed delay is required, please refer to the command MEASurement:STEPpedswEEP:SETTling:DELaY <Delay> .

Typically, the <Cycles> delay is used to compensate for the transient behaviour of the DUT.

Refer to chapter **Stepped Sweep** (p. 257) for further details.

NOTE The <Cycles> delay is also applied if the settling mode is turned OFF.

MEASurement:STEPpedswEEP:SETTling:DELaY <Delay>

Usage	Applies a fixed delay that is applied before every stepped sweep measurement (p. 257).
Availability	Normal, LCL, RL and PureSound™ mode (<u>not</u> available if the analyzer is armed), regardless whether the settling is active or not.
Parameter	<De la y> <i>float</i> 0. to 10000.0 (settling delay in ms; resolution = 0.1)
Default	1 (RMSLEVEL and DISTORTION mode)
Query	MEASurement:STEPpedswEEP:SETTling:STATus?
Example	 → MEAS:STEP:SETT:DEL 0.50E+02
Explanation	The delay is defined in milliseconds, i.e. independent of the sweep frequency. A frequency dependent delay can be defined with MEASurement:STEPpedswEEP:SETTling:CYCLes <Cycles> .

Typically, this command is used to compensate for fixed time delays on the signal path, e.g.:

- The running time of the test signal from the RT-2X generator → amplifier → speaker → air → microphone → RT-2X analyzer.
- The internal delay of a Codec etc.

Refer to chapter **Stepped Sweep** (p. 257) for further details.

NOTE The <Delay> is also applied if the settling mode is turned OFF.

MEASurement:STEPpedswEEP:SETTling:FBEGin <Frequency1>

Usage	Defines one limit of the frequency band, wherein the selective settling is active.
Availability	Normal mode (<u>not</u> available if the analyzer is armed), whereby the settling mode must be SELECTIVE (<i>MEASurement:STEPpedswEEP:SETTling:MODE SELECTIVE</i>).
Parameter	<Frequency1> <i>float</i> (20.00 to 20000.00)
Default	3.00E+01 (RMSLEVEL and DISTORTION mode)
Query	<i>MEASurement:STEPpedswEEP:SETTling:STATus?</i>
Example	 → MEAS:STEP:SETT:FBEG 1.00E+02
Explanation	In combination with <i>MEASurement:STEPpedswEEP:SETTling:FENd <Frequency2></i> and <i>MEASurement:STEPpedswEEP:SETTling:MODE SELECTIVE</i> , the command allows applying the stepped sweep settling on a user-defined frequency band. Please refer to chapter Settling (p. 258) for further details.

MEASurement:STEPpedswEEP:SETTling:FENd <Frequency2>

Usage	Defines the other limit of the frequency band, wherein the selective settling is active.
Availability	Normal mode (<u>not</u> available if the analyzer is armed), whereby the settling mode must be SELECTIVE (<i>MEASurement:STEPpedswEEP:SETTling:MODE SELECTIVE</i>).
Parameter	<Frequency2> <i>float</i> (20.00 to 20000.00)
Default	2.00E+02 (RMSLEVEL and DISTORTION mode)
Query	<i>MEASurement:STEPpedswEEP:SETTling:STATus?</i>
Example	 → MEAS:STEP:SETT:FEN 3.00E+02
Explanation	In combination with <i>MEASurement:STEPpedswEEP:SETTling:FBEGin <Frequency1></i> and <i>MEASurement:STEPpedswEEP:SETTling:MODE SELECTIVE</i> , the command allows applying the stepped sweep settling on a user-defined frequency band. Please refer to chapter Settling (p. 258) for further details.

MEASurement:STEPpedswEEP:SETTling:FLOor <Floor> [V|DBV]

Usage	Defines the lowest input level that is considered for the stepped sweep settling (p. 257).
Availability	Normal mode (<u>not</u> available if the analyzer is armed), whereby the settling mode must be NORMAL (MEASurement:STEPpedswEEP:SETTling:MODE NORMAL).
Parameter	<Floor> [V DBV] <i>float & string</i> 0.000001 to 1.0 V -120 to 0 DBV
Default	-70 DBV -90 DBV (RMSLEVEL DISTORTION mode)
Query	MEASurement:STEPpedswEEP:SETTling:STATus?
Example	 → MEAS:STEP:SETT:FLO 1.000000e-3 V
Explanation	Any input signal level that is below the <Floor> is not considered for the settling. This has two advantages: • The measurement is speeded up by neglecting very low input signals (e.g. noise). • The system is prevented from "hanging itself up" if the input signal is very close to the lower limit of the measurable range.

Refer to chapter **Stepped Sweep** (p. 257) for further details.

MEASurement:STEPpedswEEP:SETTling:MODE [OFF|NORMAL|SELECTIVE]

Usage	Activates the settling mode for stepped sweep measurements (p. 257).
Availability	Normal, LCL, RL and PureSound™ mode (<u>not</u> available if the analyzer is armed).
Parameter	[OFF NORMAL SELECTIVE] <i>string</i>
Default	NORMAL (RMSLEVEL and DISTORTION mode)
Query	MEASurement:STEPpedswEEP:SETTling:STATus?
Example	 → Meas:step:sett:mode selective
Explanation	In the NORMAL mode, the settling applies on all stepped sweep measurement results. In the SELECTIVE mode, the settling applies only in the frequency band defined by the command MEASurement:STEPpedswEEP:SETTling:FBEGin <Frequency1> and the command MEASurement:STEPpedswEEP:SETTling:FENd <Frequency2> .

The command does not affect other measurements than the stepped sweep analysis.

Refer to chapter **Settling** (p. 258) for further details.

MEASurement:STEPpedswEEP:SETTling:NOISe <Level> [V;dBV;dB SPL;dBPa]

Usage	Defines a flat settling limit in addition to the exponential settling (refer to p. 258f).
Availability	Normal, LCL, RL and PureSound™ mode (<u>not</u> available if the analyzer is armed).
Parameter	0.0000001 to 1.0 V -120.0 to 0.0 dBV <i>float & string</i> (width of noise acceptance band) 0.0 to 120.0 dB SPL -94.0 to +26.0 dBPa
Default	-120 dBV -68 dBV (settling type RMSLEVEL distortion)
Query	MEASurement:STEPpedswEEP:SETTling:STATus?
Example	 → Meas:step:sett:noise 5.0E-02 V
Explanation	The command allows introducing an additional settling criterion for noisy environments, where the exponential settling is not met. In this case, the RT-2X provides the measurement result as soon as the user-defined number of samples (p. 155) has been acquired within the <Level> band, regardless whether the EXPONENTIAL condition (p. 154) is met or not. Refer to chapter Settling (p. 258) for further details.

MEASurement:STEPpedswEEP:SETTling:SAMple <Samples>

Usage	Defines the number of acquired samples that must meet the settling condition to get a valid sweep measurement result (p. 258).
Availability	Normal, LCL, RL and PureSound™ mode (<u>not</u> available if the analyzer is armed), whereby the settling mode must be NORMAL (MEAS:STEP:SETT:MODE NORMAL).
Parameter	<Samples> <i>integer</i> 2 to 20 (number of valid samples; resolution = 1)
Default	3 (RMSLEVEL and DISTORTION mode)
Query	MEASurement:STEPpedswEEP:SETTling:STATus?
Example	 → MEASUREMENT:STEPPEDSWEEP:SETTLING:SAMPLE 5
Explanation	Refer to chapter Settling (p. 258) for further details.

MEASurement:STEPpedSweep:SETTLing:STATus?

Usage Queries the status of the settling parameters (only for stepped sweep measurements, p. 257).

Availability Normal, LCL, RL and PureSound™ mode (also if the analyzer is armed).

Answer

MODE [OFF NORMAL SELECTIVE],	string
ACTIVE [CHANNEL1 CHANNEL2 BOTHCHANNELS],	string
TYPE [RMSLEVEL HARMONIC2 HARMONIC3 THDN],	string
DELAY [0.0 to 10000.0],	float
CYCLES [0.0 to 1000.0]	float
ALGORITHM [EXPONENTIAL FLAT],	string
SAMPLE [2 to 20],	integer
TOLERANCE [0.0 to 400.0 % 8.68E-3 to 12 DB],	float & string
FLOOR [1.0E-06 to 1.0 V -120.0 to 0.0 DBV],	float & string
NOISE [1.0E-06 to 1.0 V -120.0 to 0.0 DBV 0.0 to 120.0 DBSPL -94.0 to 26.0 DBPA]	float & string
TIMEOUT [0.1 to 5000.0]	float
FBEGIN [20.0 to 20000.0],	float
FEND [20.0 to 20000.0]	float

Example

```

→ MEASUREMENT:STEPPEDSWEEP:SETTLING:STATUS?
→ MODE NORMAL,ACTIVE CHANNEL1,TYPE THDN,DELAY 1.00E+00,
CYCLES 8.00E00,ALGORITHM EXPONENTIAL,SAMPLE 3,
TOLERANCE 3.00E-01 DB,FLOOR 9.00E-01 DBV,
TIMEOUT 3.00E+02,FBEGIN 3.00E+01,FEND 2.00E+02

```

Explanation Refer to chapter *Stepped Sweep* (p. 257) for further details.

MEASurement:STEPpedSweep:SETTLing:TIMEout <Timeout>

Usage Defines the settling timeout for a stepped sweep measurement (p. 257).

Availability Normal, LCL, RL and PureSound™ mode (not available if the analyzer is armed), whereby the settling mode must be NORMAL (**MEAS:STEP:SETT:MODE NORMAL**).

Parameter <Timeout> float 0.1 to 5000.0 (settling timeout in ms; resolution = 0.1 ms)

Default 600|3000 (RMSLEVEL|DISTORTION mode)

Example

```

→ MEAS:STEP:SETT:TIME 500

```

Explanation Every sweep measurement that exceeds the <Timeout> will be stopped, i.e. the corresponding measurement result will be marked with an asterisk ("*") and the RT-2X system proceeds to the next frequency. Thus, the system is prevented from "hanging itself up" if it cannot settle to a stable measurement result.

Refer to chapter *Stepped Sweep* (p. 257) for further details.

MEASurement:STEPpedswEEP:SETTling:TOLerance <Tolerance> [%;DB]

Usage	Defines the tolerance limit of the settling algorithm for the stepped sweep (p. 257).
Availability	Normal, LCL, RL and PureSound™ mode (<u>not</u> available if the analyzer is armed), whereby the settling mode must be NORMAL (MEAS:STEP:SETT:MODE NORMAL).
Parameter	<Tolerance> [%;DB] <i>float & string</i> 0.1 to 400.0 % 0.00868 to 12.0 dB
Default	1.0 % 3.0 % (RMSLEVEL DISTORTION mode)
Query	MEASurement:STEPpedswEEP:SETTling:STATus?
Examples	→ MEAS:STEP:SETT:TOL 10 %
Explanation	Refer to chapter <i>Stepped Sweep</i> (p. 257) for further details.

MEASurement:STEPpedswEEP:SETTling:TYPE [RMSLEVEL;HARMONIC2;HARMONIC3;HARMONIC4;HARMONIC5;THD;THDN]

Usage	Defines the settling type for the stepped sweep measurement (p. 257).
Availability	Normal, LCL, RL and PureSound™ mode (<u>not</u> available if the analyzer is armed), whereby the settling mode must be NORMAL or SELECTIVE.
Parameter	[RMSLEVEL HARMONIC2 HARMONIC3 <i>string</i> (settling tracks on acquired 3 rd Harmonic results) HARMONIC5 (settling tracks on acquired 4 th Harmonic results) HARMONIC5 (settling tracks on acquired 5 th Harmonic results) THD THDN] (settling tracks on acquired THD THD+N results)
Default	RMSLEVEL HARMONIC2 (RMSLEVEL DISTORTION mode)
Query	MEASurement:STEPpedswEEP:SETTling:STATus?
Examples	→ MEAS:STEP:SETT:TYPE HARMONIC3
Explanation	The settling types are optimized for the corresponding measurement function. Generally, it is recommended to apply the RMSLEVEL settling for Level and Phase measurements and the HARMONICx settling for any kind of Distortion analysis, but <u>not</u> the THDN settling.

MEASurement:STEPpedswEEP:SMOothing:ACTive [CHANNEL1;CHANNEL2;BOTHCHANNELS]

Usage	Defines the active channel(s) for the stepped sweep data smoothing (p. 261).
Availability	Normal, LCL, RL and PureSound™ mode (<u>not</u> available if the analyzer is armed).
Parameter	[CHANNEL1 CHANNEL2 BOTHCHANNELS] <i>string</i>
Default	BOTHCHANNELS
Query	MEASurement:STEPpedswEEP:SMOothing:STATus?
Example	 → MEAS:STEP:SMO CHANNEL2

MEASurement:STEPpedswEEP:SMOothing:MODE [OFF;AVERAGE]

Usage	Activates the data smoothing for the stepped sweep measurement (p. 261).
Availability	Normal, LCL, RL and PureSound™ mode (<u>not</u> available if the analyzer is armed).
Parameter	[OFF AVERAGE] <i>string</i>
Default	OFF
Query	MEASurement:STEPpedswEEP:SMOothing:STATus?
Example	 → MEASurement:STEPpedswEEP:MODE AVERAGE

MEASurement:STEPpedswEEP:SMOothing:RESolution <Percent>

Usage	Defines the frequency window of the stepped sweep data smoothing (p. 261).
Availability	Normal, LCL, RL and PureSound™ mode (<u>not</u> available if the analyzer is armed).
Parameter	<Percent> <i>float</i> 0.0 to 300.0 (percent of an octave)
Default	33.33 (33.33% = 1/3 rd octave)
Query	MEASurement:STEPpedswEEP:SMOothing:STATus?
Example	 → MEAS:STEP:SMO:RES 3.33E+01 (100% = full octave)
Explanation	Calculation of the lower and upper limit of the frequency window is described in chapter <i>Smoothing</i> (p. 261).

MEASurement:STEPpedswEEP:SMOothing:STATus?

Usage	Queries the stepped sweep data smoothing status (p. 261).		
Availability	Normal, LCL, RL and PureSound™ mode (<u>not</u> available if the analyzer is armed).		
Answer	MODE [OFF AVERAGE],	string	(data smoothing Off or On)
	ACTIVE [CHANNEL1	string	(active channel(s))
	CHANNEL2 BOTHCHANNELS],		
	RESOLUTION [0.00E00 to	string & float	(width of frequency window)
	3.00E+02]		
Example	 → MEAS:STEP:SMO:STAT? →  MODE OFF, ACTIVE BOTHCHANNELS, RESOLUTION 3.30E+01		
Explanation	Refer to chapter <i>Smoothing</i> (p. 261) for further details.		

MEASurement:STEPpedswEEP:STATus?

Usage	Queries the stepped sweep analyzer status (p. 257).		
Availability	Normal, LCL, RL and PureSound™ mode (<u>not</u> available if the analyzer is armed).		
Answer	ACQUISITION [RMSLEVEL DISTORTION],	string	
	NOISEIMMUNITY [OFF ON],	string	
	HIPRECISION [OFF ON]	string	
Example	 → MEAS:STEP:STAT? →  ACQUISITION RMSLEVEL, NOISEIMMUNITY ON, HIPRECISION OFF		
Explanation	Refer to chapters <i>Acquisition Mode</i> (p. 262), <i>Noise Immunity</i> (p. 257) and <i>High Precision Mode</i> (p. 258) for further details.		

Commands for Device Status

*CLS

Usage The CLear Status command clears the *standard event status register* and consequently also the ESB bit of the *status byte register*.

Availability All modes (also if the analyzer is armed).

Example  → *CLS

Explanation The *CLS command has the same effect as the *ESR? command.
Refer to chapter *IEEE Standard Status Data Structure* (p. 183).

*ESE <NRf>

Usage The Event Status Enable command sets the indicated bits of the *standard event status enable register*, thus enabling the corresponding bits of the *standard event status register*.

Availability All modes (also if the analyzer is armed).

Parameter <NRf> integer 0 – 255 (<NRf> = $n_7 + n_5 + n_3 + n_0$, refer to p. 184)

Query *ESE?

Example  → *ESE 160 (enable bit $n_7 + n_5$ {128 + 32}: Power ON & Command Error events)

Explanation The *standard event status enable register* defines, which messages of the *standard event status register* are forwarded to bit n_5 (ESB = Event Summary Bit) of the *status byte register*.
Refer also to chapter *IEEE Standard Status Data Structure* (p. 183).

*ESE?

Usage The standard Event Status Enable query reads the current contents of the *standard event status enable register*.

Availability All modes (also if the analyzer is armed).

Answer [0–255] *integer* (the sum of all active bits, refer to p. 184)

Example
 → *ESE?
 →  160 (160 = 128 + 32 → Power On & Command Error events enabled)

Explanation The contents of the *standard event status enable register* must be defined with the command *ESE <NRf>.

Refer to chapter *IEEE Standard Status Data Structure* (p. 183).

*ESR?

Usage The standard Event Status Register query reads and clears the current contents of the *standard event status register*.

Availability All modes (also if the analyzer is armed).

Answer [0–255] *integer* (the sum of all active bits, refer to p. 184)

Example
 → *ESR?
 →  32 (a Command Error has occurred)

Explanation The content of the *standard event status register* indicates the events that occurred since it has been cleared.

Refer to chapter *IEEE Standard Status Data Structure* (p. 183).

*IDN?

Usage The IDentificationN query reads the unique identification of RT-2X.

Availability All modes (also if the analyzer is armed).

Answer

NEUTRIK,	string	(manufacturer)
RT2M,	string	(instrument type)
<S_No>,	integer	(serial number: 4 characters)
<FW_Rev>	float	(firmware revision)

Example

```

PC → *IDN?
→ PC NEUTRIK, RT2X, 0123, 5.15

```

Explanation The command returns the same information as the **SYSTEM:INformation?** query.

Refer to chapter **IEEE Standard Status Data Structure** (p. 183).

*OPC

Usage The Operation Complete command sets bit n_0 (Operation Complete) of the *standard event status register* as soon as all pending operations have been finished.

Availability All modes (also if the analyzer is armed).

Example

```

PC → output:mtone:start;*opc

```

(RT-2X activates "Operation Complete" as soon as the measurement is completed)

Explanation The command allows synchronizing the controlling PC to RT-2X by using the ESB bit in the *status byte register* according to following procedure:

1. Enable the bit n_0 in the *standard event status register* and bit n_5 in the *status byte register* with the commands ***ESE 32** and ***SRE 1**.
2. Generate the event "Operation Complete" (bit n_0) in the *standard event status register* with command ***OPC** (the string ***opc?** must follow the RT command, separated by a ";").
3. Consequently, RT-2X transmits a Service Request through the IEEE interface as soon as all pending commands have been executed.

Refer to chapter **IEEE Standard Status Data Structure** (p. 183).

*OPC?

Usage

The Operation Complete query is used to let RT-2X generate a response message.

- First, the command ***OPC?** places a "1" in the RT-2X *output queue*.
- Consequently, as soon as all pending device operations have been completed, a service request (SRQ) is executed.

Availability

All modes (also if the analyzer is armed).

Answer

[0|1] integer (not completed | completed)

Example

 → ***OPC?** (the command places a "1" in the output queue)
 →  **1** (as soon as the pending commands are completed, the "1" causes a service request via the MAV bit of the status byte register)

Explanation

The command allows synchronizing the controlling PC to RT-2X by using the MAV bit in the *status byte register* according to following procedure:

- Enable the bit n_4 in the *status byte register* with the command and ***SRE 16**.
- Place a '1' in the *output queue* with the command ***OPC?**
- Consequently, RT-2X transmits a Service Request through the IEEE interface as soon as all pending commands have been executed.

Refer to chapter *IEEE Standard Status Data Structure* (p. 183).

*PSC [0|1]

Usage

The Power-on Status Clear command defines, whether the *standard event status enable register* and the *service request enable register* shall be cleared automatically after system power ON or not.

Availability

All modes (also if the analyzer is armed).

Parameter

[0|1] (0: enable registers are not cleared, i.e. their last status remains active |
1: enable registers are cleared, i.e. all bits are disabled by setting them to '0')

Default

0

Examples

 → ***PSC 0**

Explanation

If the enable registers are cleared (reset), it is necessary to enable the required bits every time after a power ON.

Refer also to chapter *IEEE Standard Status Data Structure* (p. 183).

*PSC?

Usage The Power-on Status Clear query reads the status of the RT-2X power-on status clear flag.

Availability All modes (also if the analyzer is armed).

Answer [0|1] integer (no clearing|clearing active)

Example  → *PSC?
→  0

Explanation If the enable registers are cleared (reset), it is necessary to enable the required bits every time after a power ON.

Refer also to chapter *IEEE Standard Status Data Structure* (p. 183).

*RST

Usage The ReSeT command executes a device reset. All parameters are set to their default values except of the *output queue* and the *command queue*.

Availability All modes (also if the analyzer is armed).

Example  → *RST

Explanation Refer also to chapter *IEEE Standard Status Data Structure* (p. 183).

*SRE <NRf>

Usage The Service Request Enable command sets bits of the *service request enable register*.

Availability All modes (also if the analyzer is armed).

Parameter <NRf> integer 0 to 255 (<NRf> = n₇ + n₅ + n₄, refer to p. 184)

Example  → *SRE 32 (enables standard event status bit ESB)

Explanation The *service request enable register* defines, which bits of the *status byte register* can generate a Service ReQuest (SRQ) to the controlling PC.

Refer also to chapter *IEEE Standard Status Data Structure* (p. 183).

*SRE?

Usage The Service Request Enable query reads the contents of the *service request enable register*.

Availability All modes (also if the analyzer is armed).

Answer [0-255] *integer* (the sum of all active bits, refer to p. 184)

Example  → *SRE?
→  32 (32 represents bit n₅ that enables bit ESB of the *status byte register*)

Explanation The contents of the *standard event status enable register* must be defined with the command *SRE <NRf>.

Refer to chapter *IEEE Standard Status Data Structure* (p. 183).

*STB?

Usage The SStatus Byte query reads the contents of the *status byte register*.

Availability All modes (also if the analyzer is armed).

Answer [0-255] *integer* (the sum of all active bits, refer to p. 184)

Example  → *STB?
→  48 (48 = 16 + 32, i.e. n₅ {ESB} and n₆ {MAV} are TRUE)

Explanation The contents of the *status byte register* are given by messages from the *standard event status register* and the *output queue*.

Refer to chapter *IEEE Standard Status Data Structure* (p. 183).

*TST?

Usage The TeST query starts an internal self-test and writes the result to the *output queue*.

Availability All modes (also if the analyzer is armed).

Answer [0|1] *integer* (at least one error has occurred | self-test OK)

Example  → *TST?
→  1



Compatibility of RT-1M, RT-2M and RT-2X Commands

RT-2X is able to properly handle most RT-1M and RT-2M commands with the few exceptions and incompatibilities that are listed below.

	RT-1M	RT-2M	RT-2X
SYSTEem:LiCense?	n/a	✓	✓
SYSTem:MODE 8K, SYSTEM:MODE?	n/a	n/a	✓
INOUT:ISDn ..., INOUT:LCLBridge ..., INOUT:PCM ..., INOUT:RLBridge ..., INOUT:T1 ...	n/a	n/a	✓
INOUT:PUResound ...	n/a	✓ (if licensed)	✓ (if licensed)
OUTPut:ACCOupling ...	n/a	n/a	✓ (with LCL/RL option)
OUTPut:ARBSIN ...	n/a	✓	✓
OUTPut:DTMF ...	n/a	✓	✓
OUTPut:IMPedance ...	n/a	✓ (range: [150;600])	✓ (full range)
OUTPut:ISDn ..., OUTPut:LCLBridge ..., OUTPut:PCM ..., OUTPut:RLBridge ..., OUTPut:T1 ...	n/a	n/a	✓ (with the corresponding option)
OUTPut:MTONe:ACTive ...	✓ (range: [1;2;3;4])	✓ (range: [1;2;3;4])	✓ (full range)
OUTPut:MTONe:PARAmeter ...	✓ (specific format)	✓ (specific format)	✓ (specific format)
OUTPut:PUResound ...	n/a	✓ (if licensed)	✓ (if licensed)
OUTPut:SOURce ...	n/a	n/a	✓ (with ISDN or T1 option)
OUTPut:STATus?	✓ (specific format)	✓ (specific format)	✓ (specific format)
OUTPut:STEPpedswEEP...	n/a	✓	✓
OUTPut:ZREF ...	n/a	n/a	✓



	<i>RT-1M</i>	<i>RT-2M</i>	<i>RT-2X</i>
INPut:ACCOupling ...	n/a	n/a	✓ (with LCL/RL option)
INPut:FRONt ON	✓	n/a	n/a
INPut:IMPedance ...	n/a	✓ (range: [100k;600])	✓ (full range)
INPut:ISDn ..., INPut:LCLBridge ..., INPut:PCM ..., INPut:RLBridge ..., INPut:T1 ...	n/a	n/a	✓ (with the corresponding option)
INPut:MICSensitivity ...	n/a	✓	✓
INPut:SOURce ...	n/a	n/a	✓ (with ISDN or T1 option)
INPut[1 2]:STATus?	✓ (specific format)	✓ (specific format)	✓ (specific format)
INPut:TRIGger:THReshold ...	n/a	✓	✓
INPut:VOLTagedividerratio...	n/a	✓	✓
INPut:ZREF ...	n/a	n/a	✓
MEAS:DTMF ...	✓ (with DTMF option)	✓	✓
MEAS:ERL?	n/a	n/a	✓ (with LCL/RL option)
MEAS:NOISe:FULLband?	n/a	✓	✓
MEAS:PUResound ...	n/a	✓ (if licensed)	✓ (if licensed)
MEAS:RL?	n/a	n/a	✓ (with LCL/RL option)
MEAS:SRLHI?	n/a	n/a	(with LCL/RL option)
MEAS:SRLLO?	n/a	n/a	(with LCL/RL option)
MEAS:STEPpedswEEP...	n/a	✓	✓

Table 5 Command Incompatibilities

Digital Circuits

ISDN S₀ Bus

RT-2X features two ISDN S₀ bus connectors (RJ45 jacks), both connected in parallel. Each of them can be used to connect the unit to an ISDN network or ISDN device. Internally, *RT-2X* provides of an S₀ bus termination that must be activated if the unit is located at the end of an ISDN bus. Please contact your local **NTI** representative for further details.

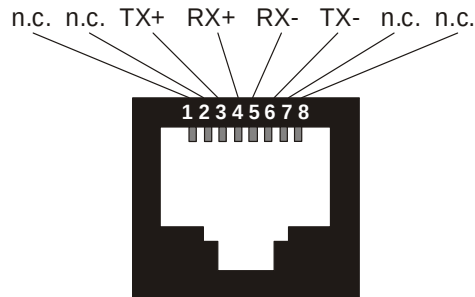


Fig 4 Pin Connection of ISDN RJ45 Jack (front view)

NOTE The ISDN interface of *RT-2X* is only available if the ISDN option is installed. Please refer to chapter *ISDN Interface* for further details.

Digital Raw Data Interface

These two D-Sub 15pin connectors are reserved for future applications.

T1 Interface

RT-2X features RX- and TX-Bantam connectors, located on the rear panel of the unit.

	<i>Tip</i>	<i>Ring</i>	<i>Sleeve</i>
<i>RX (Receive)</i>	RxTIP	RxRING	n.c.
<i>TX (Transmit)</i>	TxTIP	TxRING	n.c.

Table 6 Pin Connections of T1 Bantam Jacks

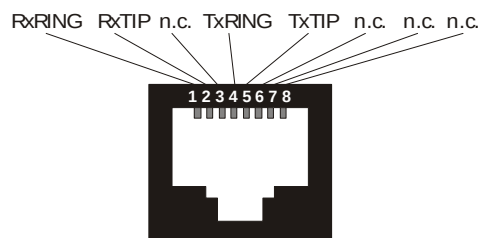


Fig 5 Pin Connection of T1 RJ45 Jack (front view)

NOTE The T1 interface of *RT-2X* is only available if the T1 option is installed. Please refer to chapter *E1/T1 Interface* for further details.

DTMF Analysis

RT-2X provides of a DTMF module that can generate & analyze DTMF tones completely independently of the other test functions (e.g. multitone or stepped sweep measurements).

		Row →	1	2	3	4
Column ↓			1209 Hz	1336 Hz	1477 Hz	1633 Hz
	1	697 Hz	1	2	3	<i>a</i>
	2	770 Hz	4	5	6	<i>b</i>
	3	852 Hz	7	8	9	<i>c</i>
	4	941 Hz	*	0	#	<i>d</i>

Table 7 Typical DTMF Signal Coding

Table 7 shows the definition of DTMF tones as well as their correspondence to a standard 4x4 keypad. Every key is represented by a dual tone comprising of the frequencies in the respective column & row. For instance, the DTMF tone for key #6 consists of 770 Hz & 1477 Hz. The meaning of the four 'empty' keys *a-d* in the last row is user-defined.

- **OUTPut:DTMF [1'2'3'4],[1'2'3'4],<Time>,<RowFrqDev>,<ColFrqDev>,<AmpRatio>** generates a DTMF tone – identified by its column & row – for a user-defined duration. In addition, the user can apply an independent frequency deviation for the dual tone and amend the amplitude ratio if required.
- **MEASurement[1'2]:DTMF:START** lets the DTMF module of RT-2X continuously monitor both input channels and store all received DTMF tones in the two internal buffers (in parallel to any other operation of RT-2X, except of the LCL and RL mode).
- **MEASurement[1'2]:DTMF?** queries the contents of the selected 32 keys wide DTMF signal buffer and resets it (i.e. deletes the stored contents).

Application Example

Typically, the complete analysis of an external DTMF device comprises of three topics:

- Stimulation of the device with standard and de-tuned DTMF tones.
- Decoding of the DTMF signals, generated by the device.
- Exact frequency & amplitude measurement of the DTMF tones, coming from the device.

First, use **OUTPut:DTMF [1'2'3'4],[1'2'3'4],<Time>,<RowFrqDev>,<ColFrqDev>,<AmpRatio>** to generate a DTMF signal with the required number, frequency deviation and amplitude ratio. After its transmission, check whether the device correctly decodes the transmitted DTMF signal. Next use commands **MEASurement[1'2]:DTMF:START** and **MEASurement[1'2]:DTMF?** to 'arm' the DTMF decoder of RT-2X and to query the received numbers. If the latter corresponds to the externally generated ones, the tested device complies to the DTMF standards.

The third point is more complex to verify since it requires the correct triggering of the RT-2X analyzer to the incoming DTMF signal. Please read the **NTI** Application Sheet '**DTMF Analysis**' (available as *.pdf file on the **NTI** homepage) for further details.

E1/T1 Interface

If the E1/T1 option is installed in *RT-2X*, the unit can be connected directly to an E1 or T1 line to measure the audio characteristics with multitone test signals in A-D, D-A or D-D mode (refer also to chapters *Normal Mode*, p. 231ff and *Test Setups*, p. 264ff).

E1/T1 Backgrounds

E1 Data Transmission Format

The E1 standard consists of 32 slots (i.e. channels), transmitted with 64 kbits/s (8 ksamples/s per channel, and 8 bit per sample). The data are organized in 'slots', 'frames' and 'multiframes' (refer to **Fig 6**):

- each *slot* (i.e. channel) contains 1 Byte (= 8 bit) of data
- each *frame* comprises 30 slots with voice data and 2 slots with admin data
- a *multiframe* is built by 16 frames.

Consequently, by taking into account the E1 data rate of 2.048 Mbit/s, the time duration of a multiframe is 2.0 ms.

E1 Signaling Format

Apart from the voice data, additional *admin* information is transmitted through a E1 line in slots #0 and #16 of every frame. Slot 16 carries telephony information as e.g. "ON-HOOK", "OFF-HOOK", "RING-ON or "RING-OFF" etc.

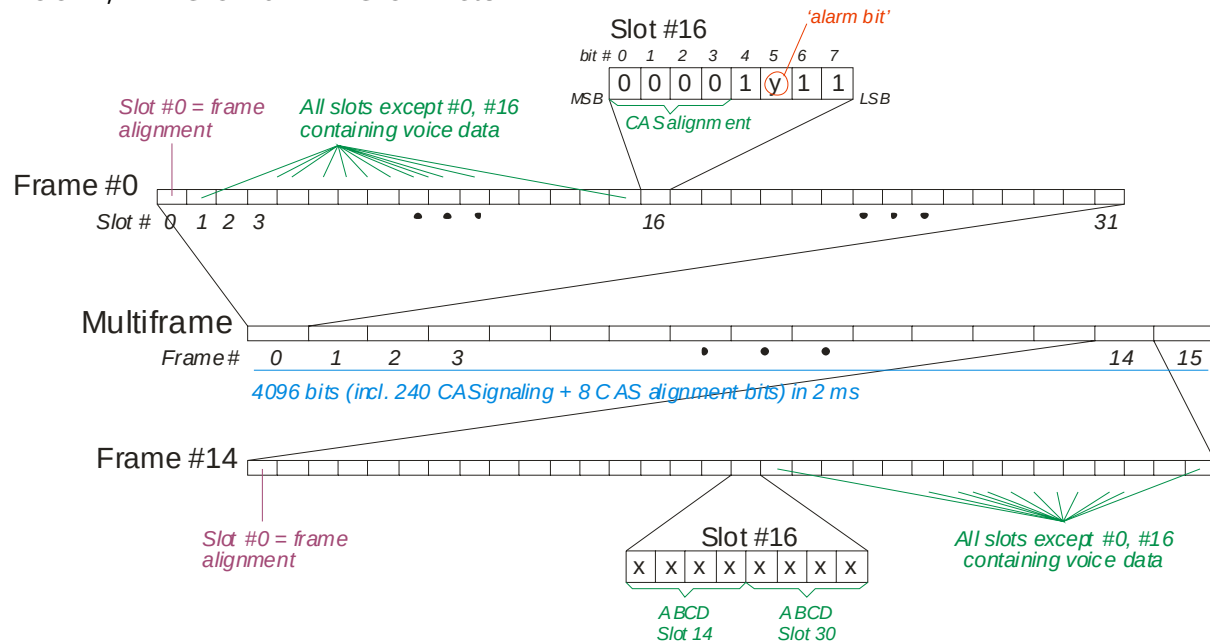


Fig 6 E1 Signaling Principle

The bit allocation of slot #16 in frame #0 is defined as follows (according to G.704) :

- 4* "0" → CAS alignment.
- "y" → alarm bit (0 = CAS received / 1 = no CAS received)

E1 CASignaling Pattern

RT-2X supports CASignaling, whereby four signaling bits are assigned per voice channel (slot), labeled A, B, C, D. For better clarity, they are listed in the table below.

Frame	Channel Slot #16	
0	0000	1y11
1	Chn1 (slot #1)	Chn16 (slot #17)
2	Chn2 (slot #2)	Chn17 (slot #18)
3	Chn3 (slot #3)	Chn18 (slot #19)
4	Chn4 (slot #4)	Chn19 (slot #20)
5	Chn5 (slot #5)	Chn20 (slot #21)
6	Chn6 (slot #6)	Chn21 (slot #22)
7	Chn7 (slot #7)	Chn22 (slot #23)
8	Chn8 (slot #8)	Chn23 (slot #24)
9	Chn9 (slot #9)	Chn24 (slot #25)
10	Chn10 (slot #10)	Chn25 (slot #26)
11	Chn11 (slot #11)	Chn26 (slot #27)
12	Chn12 (slot #12)	Chn27 (slot #28)
13	Chn13 (slot #13)	Chn28 (slot #29)
14	Chn14 (slot #14)	Chn29 (slot #30)
15	Chn15 (slot #15)	Chn30 (slot #31)

Table 8 CAS Pattern

Example

Establishing a phone call over an E1 line:

- 1) While we are waiting, the subscriber phone (i.e. DUT) is in the ON-HOOK state and it sends to the E1 interface a 0101. The *RT-2X* E1 interface sends back 0101 for IDLE, because we want to wait and don't want to place a call ourselves.
- 2) When the subscriber (i.e. DUT) receives a call, it cycles through a RING-ON (0000) and RING-OFF (0101) state, which it sends to the *RT-2X* E1 interface.
- 3) When we are ready, we have the interface send back an ANSWER (1111). The subscriber responds with its own ANSWER (1111).
- 4) Either the *RT-2X* E1 interface, or the phone calling the subscriber may terminate the call by sending a CLEAR FORWARD (0101).
- 5) The *RT-2X* E1 interface returns to the IDLE state (sends 0101) and the subscriber (i.e. DUT) to the ON-HOOK state (0101).

Hint The other ABCD sequences control or indicate other phone states, such as Reverse Battery, Coin Voltages, and others. All are used in both directions.

T1 Data Transmission Format

The T1 and J1 standards consist of 24 channels, transmitted with 64 kbits/s (8 ksamples/s per channel, and 8 bit per sample). The data are organized in 'slots', 'frames' and 'multiframes' (refer to **Fig 7**):

- each *slot* (i.e. channel) contains 1 Byte (= 8 bit) of data
- 24 slots build a *frame*
- 12 or 24 frames (depending on the T1 format 'D4' [4th generation Digital channel bank] or 'ESF' [Extended Super Frame]) build a *Multiframe*.

As the T1/J1 data rate equals 1.544 Mbit/s, the time duration of a multiframe is 1.5 ms in the D4 and 3.0 ms in the ESF format.

T1 Signaling Format

Apart from the voice data, additional *signaling* information can be transmitted through a T1 line by using the LSB (Least Significant Bit) of all slots in certain frames. These signaling bits are used e.g. for telephony information like "on hook" or "off hook" etc.

This principle – changing the purpose of certain voice bits in the T1 data stream – is called *robbed bit* signaling or *CAS* (Channel Associated Signaling).

- In the D4 format, the two frames #6 and #12 of each multiframe are used for this purpose (i.e. 2 robbed bits per channel), thus resulting in a signaling data rate of 1333 bits/s.
- In the ESF format, the robbed bits are placed in the frames #6, #12, #18, #24 of every multiframe (i.e. 4 robbed bits per channel), resulting in a signaling data rate of 1333 bits/s.

NOTE The robbed bit is present in every slot of the indicated frames.

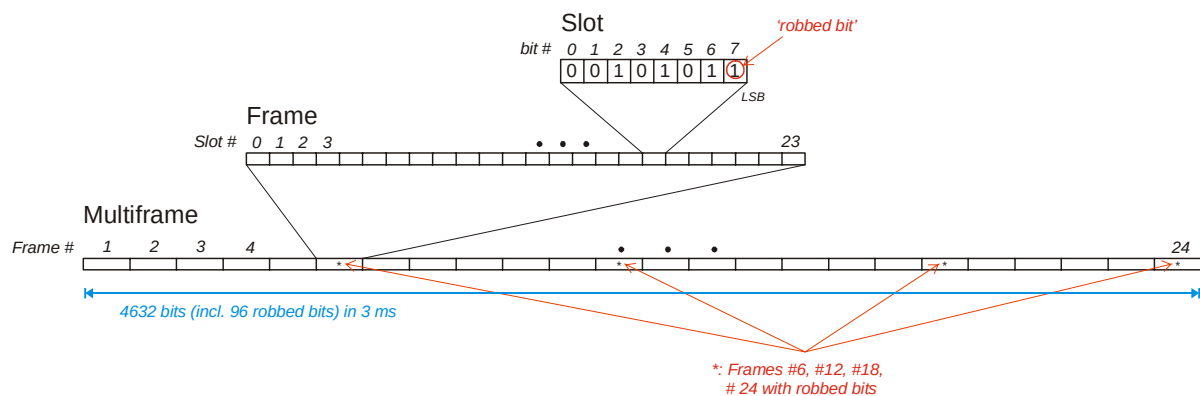


Fig 7 T1 Signaling Principle in ESF Format

Obviously, this 'misuse' of any voice bits for other purposes will decrease the audio quality of the transmitted signal. However, this temporary effect can be neglected in practice.

The states of the robbed bits in every multiframe are individual, i.e. that they can change from multiframe to multiframe.

T1 Signaling Patterns

The robbed bits in each frame are labeled *A*, *B*, *C*, *D* (ESF) or *A*, *B* (D4). Usually, they are listed in a table for better clarity. The states of the robbed bits in a multiframe are called *patterns* herein. In other words, each pattern ABCD is associated to the state of the robbed bits in a specific slot.

	ESF Format				D4 Format	
	Frame #6	Frame #12	Frame #18	Frame #24	Frame #6	Frame #12
Slot #0	A ₀	B ₀	C ₀	D ₀	A ₀	B ₀
Slot #1	A ₁	B ₁	C ₁	D ₁	A ₁	B ₁
...						
Slot #n	A _n	B _n	C _n	D _n	A _n	B _n
...						
Slot #23	A ₂₃	B ₂₃	C ₂₃	D ₂₃	A ₂₃	B ₂₃

Table 9 Robbed Bit Patterns

To further simplify the description of each pattern, the robbed bits of each frame are expressed as a Hex number.

- In the ESF format, the 4 robbed bits per slot can assume 16 different states, each representing a Hex number from 0 – F.
- In the D4 format, the 2 robbed bits per slot can have 4 different states, represented by the four Hex numbers 0, 4, 8, C.

Example

Binary	0000	0100	1000	1001	1010	1100	1111
= Hex	0	4	8	9	A	C	F

Consequently, 24 consecutive Hex numbers – representing the 24 consecutive slots of a frame – identify each pattern, as e.g.:

- *ESF or D4 format:* '000000000000000000000000', '000004444488888CCCCC' etc.
- *Only ESF format:* '0123456789ABCDEF0123456789' etc.

E1/T1 Device Testing with RT-2X

RT-2X supports the following analysis modes over an E1/T1 line:

1. *Transmission quality:* measuring e.g. Level, Distortion, Noise, Idle Channel Noise or Transmission Loss or Gain etc. by generating or receiving a multitone burst.
2. *Signaling pattern generation & recording:* sending out or recording signaling patterns (e.g. to set up a voice channel) over a E1/T1 line (supported E1 formats: CAS, CAS&CRC4 – supported T1 formats: D4, ESF).
3. *E1/T1 settings & messages:* adjust the standard E1/T1 settings and query the alarms.

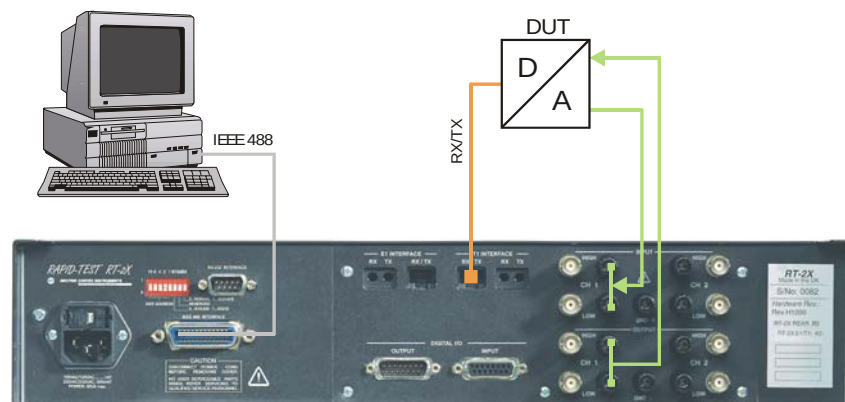


Fig 8 Example of E1/T1 Setup

E1/T1 Voice Transmission Analysis

RT-2X allows measuring the transmission quality of an E1/T1 digital-to-analog voice transmission. For instance, RT-2X generates a multitone signal in E1/T1 format, transmits it through the TX Bantam connectors and analyzes the analog signal that is returned via POTS interface.

- Adjust the sampling rate of RT-2X to 8 kHz (command **SYSTem:MODE 8Ksamplingrate**).
- Switch the RT-2X generator to the analog or E1/T1 mode (**OUTPut:SOURce ANALog, OUTPut:SOURce [E1|T1]**).
- Switch the RT-2X analyzer to the analog or the E1/T1 mode (**INPut:SOURce ANALog, INPut:SOURce [E1|T1]**).

NOTE To toggle the generator or analyzer from the E1 to the T1 mode (and vice versa), you must always switch the TX- and RX-section of *RT-2X* to the analog mode first.

- Select the clock source for the E1/T1 sender with command **OUTPut:E1:CLKSource** [INTernal'RECovered] or **OUTPut:T1:CLKSource** [INTernal'RECovered].

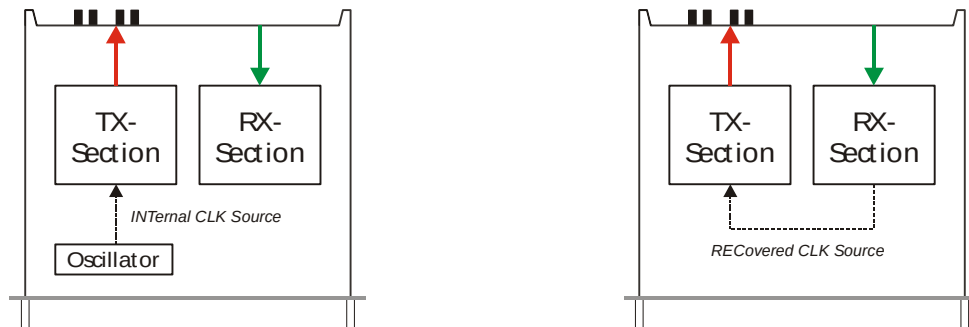


Fig 9 INTernal / RECovered Generator Clock Source

- Select the output slot, through which the measurement data shall be sent, with commands **OUTPut:E1:SLOTnumber** <Chn1> <Chn2> and **OUTPut:T1:SLOTnumber** <Chn1> <Chn2> (default after startup: <Chn1> = 0, <Chn2> = 1).
- Select the appropriate E1/T1 line format with **INOUT:E1:FORMat** [CAS'CAS&CRC4], **INOUT:T1:FORMat** [D4'ESF].
- Define the E1 or T1 signaling sequence with the command **OUTPut:E1:SIGnaling** <Parameter> or **OUTPut:T1:SIGnaling** <Parameter>.
- Enable or disable the signaling with command **OUTPut:E1:SIGnaling** [ENABLE'DISable] or **OUTPut:T1:SIGnaling** [ENABLE'DISable].
- Start the signaling transmission with **OUTPut:E1:SIGnaling** [SINGle'CYCLE'STOP] or **OUTPut:T1:SIGnaling** [SINGle'CYCLE'STOP].

Example

Command sequence to establish a call to a subscriber via E1:

```
OUTPut:E1:SIGnaling 55555... → all slots are ON-HOOK (i.e. idle)
OUTPut:E1:SIGnaling 05555... → slot #1 = RING-ON, other slots are ON-HOOK
OUTPut:E1:SIGnaling 55555... → all slots are ON-HOOK
OUTPut:E1:SIGnaling F5555... → slot # 1 = OFF-HOOK
```

- Activate the Law-encoding with **OUTPut:E1:LAW** [ALAW'ULAW'OFF], **OUTPut:T1:LAW** [ALAW'ULAW'OFF] (μLaw = typical for T1).
- Select the channels (slots) to be analyzed (**INPut:E1:SLOTnumber** <Chn1> <Chn2>, **INPut:T1:SLOTnumber** <Chn1> <Chn2>), with the default <Chn1> = 0 and <Chn2> = 1).
- Transmit the multitone signal with **OUTPut:MTONE:START**
- Query the required measurement results (e.g. level) with the corresponding commands (chapter **Multitone Measurements**, p. 202ff).

E1/T1 Signaling Pattern Generation & Analysis

Independent of the transmission quality, *RT-2X* allows generating & recording signaling patterns in an E1/T1 data stream.

- Set up the generator & analyzer as described in chapter **E1/T1 Voice Transmission Analysis**.
- TX-path: define, enable or disable the signaling pattern and send it out as single shot or in cycles with **OUTPut:E1:SIGnaling [ENABle'DISAbLe'SINGLe'CYCLe'STOP'<Parameter>]** or **OUTPut:T1:SIGnaling [ENABle'DISAbLe'SINGLe'CYCLe'STOP'<Parameter>]**.
- RX-path: start or stop recording the incoming signaling pattern(s). Thus, *RT-2X* permanently monitors the incoming data stream. If any signalling pattern changes in any slot, the analyzer automatically records all signalling patterns of all slots (refer to **INPut:E1:RECSignaling [STARt'STOP]**, **INPut:T1:RECSignaling [STARt'STOP]**).
- Query the actual signalling pattern(s) with **INPut:E1:SIGnaling?**, **INPut:T1:SIGnaling?**.
- Query the previously recorded and buffered signalling pattern(s) with the commands **INPut:E1:RECSignaling?**, **INPut:T1:RECSignaling?**.

HINT Since the signaling pattern can change with every multiframe, it is necessary to identify the multiframe number – the **count** – where such a change occurs. This information is also referred to as the **timestamp** of the corresponding pattern.

Obviously, the count and the multiframe duration $t_{\text{Multiframe}}$ (E1 mode = 2.0 ms; T1 mode D4 format³ = 1.5 ms; T1 mode ESF format 3.0 ms), define the timestamp:

$$\text{timestamp}[\text{ms}] = \text{count} * t_{\text{Multiframe}}[\text{ms}]$$

Equation 1 Timestamp Calculation

E1/T1 Settings

RT-2X allows adjusting the following settings in addition to the aforementioned voice band measurements and signaling pattern editing & analysis.

- The *E1 format*, CAS or CAS&CRC4 (**INOUT:E1:FORMat [CAS'CAS&CRC4]**) and the *T1 format*, D4 or ESF (**INOUT:T1:FORMat [D4'ESF]**).
- The *carrier signal format*, AMI (Alternate Mark Inversion), HDB3 (High-Density Bipolar 3) or B8ZS (Bipolar with 8 Zero Substitution) with commands **INOUT:E1:LINecode [AMI'HDB3]**, **INOUT:T1:LINecode [AMI'B8ZS]**.

³ In T1 mode and D4 format, the *RT-2X* generator only allows setting even counts in a 3 ms cycle.

E1/T1 Test Modes

- Sending out and linking the TX-bitstream to the RX-section by entering the *Local* mode (refer to **Fig 10**, **INOUT:E1:LINK [LOCAL'OFF]**, **INOUT:T1:LINK [LOCAL'OFF]**),
- The *loopback status* (**Fig 10**, commands **INOUT:E1:LOOPback [REMote'PAYLoad'OFF]**, **INOUT:T1:LOOPback [REMote'PAYLoad'OFF]**).

LOCAL mode (E1, T1)

The TX-bitstream is sent out and linked to the RX-section, whereby the E1/T1 input connectors are disabled (**Fig 10**).

REMote mode (E1, T1)

The RX-bitstream (i.e. incoming voice data & signaling) is looped back to the E1/T1 outputs, thus becoming the TX-bitstream. This way, **RT-2X** can only monitor the RX-bitstream (**Fig 10**).

PAYload mode (E1)

In a PLB situation, the DS2155 loops the 248 bits of payload voice data (with BPVs corrected) from the RX-section back to the TX-section. Consequently, the incoming voice data of the RX-bitstream is looped back to the E1 outputs. The TX-section modifies the payload. The FAS word, Si, Sa, and E bits as well as the CRC4 are not looped back, but re-inserted by the **RT-2X**.

PAYload mode (T1)

RT-2X loops the payload voice data (192 bits) from the RX-section back to the TX-section. The FPS framing pattern, CRC6 calculation and the FDL bits are not looped back, but re-inserted by **RT-2X**. The incoming voice data of the RX-bitstream are looped back to the E1/T1 outputs. Consequently, the incoming RX-signaling & voice data can be monitored, whereby the user can re-insert the TX-signaling (**Fig 10**).

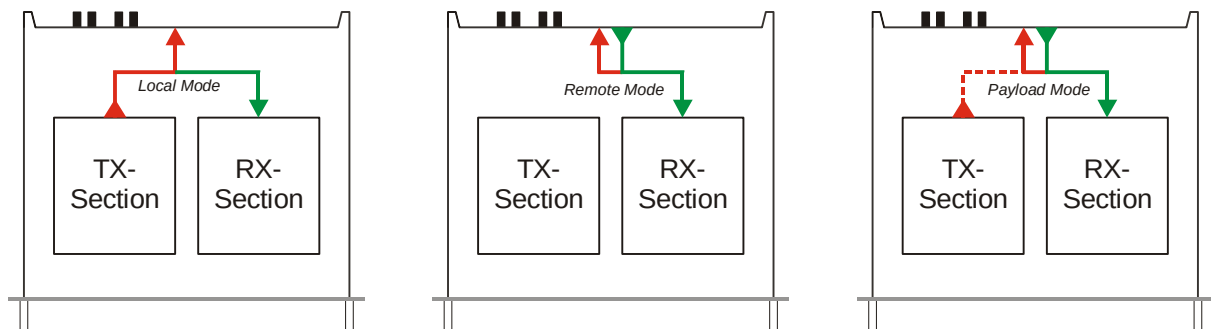


Fig 10 E1/T1 Local, Remote & Payload Mode



E1/T1 Messages

RT-2X allows querying the following information.

- The E1/T1 *alarms* by command **INOUT:E1:ALARM?**, **INOUT:T1:ALARM?** (Table 10).
- The complete *E1* or *T1* *status* of all related instrument settings (**INOUT:E1:STATUS?**, **INOUT:T1:STATUS?**).

Interf.	Alarm	Explanation
T1	Blue Alarm (AIS)	• SET condition: if 5 or fewer zeros are received over a 3ms window • CLR condition: if 6 or more zeros are received over a 3ms window
E1	AIS	• SET condition: fewer than 3 zeros in two frames (512 bits) • CLR condition: more than 2 zeros in two frames (512 bits)
T1	Red Alarm (RCL)	• SET condition: if 192 consecutive zeros are received • CLR condition: if ≥ 14 'ones' (1) out of 112 possible bit positions are received
E1	RCL (Receive Carrier Loss)	• SET condition: if 255 consecutive zeros (0) are received • CLR condition: if at least 32 'ones' (1) in 255-bit times are received
T1	Yellow Alarm (RAI)	• SET condition D4 T1: if bit 2 of 256 consecutive channels is set to '0' for at least 254 times • SET condition D4 J1: if the 12th framing bit is set to '1' for two consecutive times • SET condition ESF: if 16 consecutive patterns of 00FF (Hex) appear in the FDL • CLR condition D4 T1: if bit 2 of 256 consecutive channels is set to '0' for less than 254 times • CLR condition D4 J1: if the 12th framing bit is set to '0' for two consecutive times • CLR condition ESF: if ≤ 14 patterns of 00FF (Hex) out of 16 possible appear in the FDL
E1	RRA (Receive Remote Alarm)	• SET condition: bit 3 of nonalign frame set to 'one' (1) for three consecutive times • CLR condition: bit 3 of nonalign frame set to zero (0) for three consecutive times
E1	RDMA (Receive Distant MF Alarm)	Bit 6 of time slot #16 in frame #0 has been set for two consecutive multiframes
E1 / T1	LOS (Loss Of Sync)	RT-2X input is not synchronized to the receive data stream
E1	FRAME ERROR	Three consecutive incorrect FAS received <i>or</i> two consecutive Multiframe alignment words received in error
T1	FRAME ERROR	2 out of 4 framing bits (D4 = Ft pattern, ESF = FPS pattern) received in error
E1	CRC4 ERROR	Set if 915/1000 codewords are received in error
T1	RX PULSE VIOLATION	The receive data stream does not meet the ANSI T1.403 requirements for pulse density
T1	TX PULSE VIOLATION	The transmit data stream does not meet the ANSI T1.403 requirements for pulse density
T1	Changed Frame Alignment	The last ReSync resulted in a change of frame or multiframe alignment

Table 10 E1, T1 Alarms

External Signal Analysis

RT-2X supports several measurement functions for the analysis of externally generated signals.

Measurement function	Description	Page	Normal mode	PureSound™ mode
<i>DTMF</i>	• Decoding of DTMF key codes • DTMF frequency measurement • DTMF amplitude measurement	169	✓	✓
<i>Energy / signal level</i>	Measurement of the energy (signal level) in a user-defined band	223	✓	
<i>Frequency</i>	Measurement of the dominant frequency in a user-defined band	180	✓	
<i>Rub & Buzz defects</i>	Detection of defective electroacoustic transducers, drivers, speakers etc.	250		✓
<i>Sound correlation</i>	Comparison of a test signal against a previously recorded reference signal (i.e. "golden sample")	244		✓
<i>Sound pressure level (SPL)</i>	Calibrated SPL measurements in a user-defined band	223	✓	

Table 11 External Signal Analysis Functions

Please observe following chapters that refer to auxiliary settings that must be considered for an external signal analysis:

- **Test Setups** (p. 264)
- **Triggering & Signal Acquisition** (p. 270)
- **Multitone Signal Recording Duration** (p. 229)

Filtering

Selectable Filters

RT-2X provides of a standard set of three weighting and one Emphasis filter with a gain of 1 (= 0 dB) that are implemented in the internal firmware.

- C-message weighting according to ITU O.41
- CCITT Psophometric weighting according to North American Standard
- A-weighting according to IEC 651
- 750 μ s Emphasis

The filters can be activated independently of each other, and can be applied even *after* the signal transmission. Consequently, it is possible to query the unweighted *and* weighted measurement results after the transmission of the test signal.

- **INPut:SWFilter** [OFF'CWEighting'CCITT'AWeighting] disables the filter or selects the required weighting (C-message, CCITT Psophometric or A-weighting).
- **INPut:DEEmphasis** [OFF'ON] disables or activates the 750 μ s Emphasis.

Analog Lowpass Filtering @ $f_s = 8$ kHz

In *analog* operation @ $f_s = 8$ kHz, RT-2X automatically applies a 4 kHz lowpass filter (**Fig 11**), thus reducing the measuring bandwidth to 3.4 kHz.

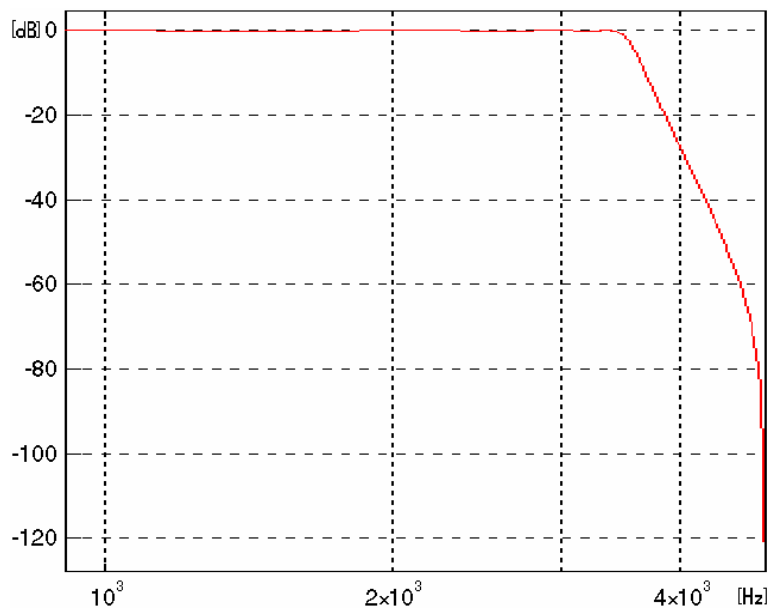


Fig 11 4 kHz Lowpass Filter Characteristic

NOTE The lowpass filter is only applied @ $f_s = 8$ kHz in *analog* operation, but not *digital* operation, where RT-2X has a flat frequency response.

Frequency Measurements

RT-2X provides two functions to measure the *frequency* of the input signal's dominant component, whereby the (e.g. external) signal generator does not need to be synchronous with the RT-2X analyzer.

- **OUTPut:MTONe:STARt** immediately starts the data acquisition (p. 264). Alternatively, the command **INPut:TRIGger:ARMed** lets the analyzer wait for the incoming signal (p. 268).
- **MEASurement[1|2]:FREQuency:FULLband?** queries the sine component with the highest amplitude in the full frequency band (20 Hz – 20 kHz @ 48 kHz sampling rate, 20 Hz – 4 kHz @ 8 kHz sampling rate).
- **MEASurement[1|2]:FREQuency:SElective? <binstart> <binstop>** queries the frequency of the sine component with the highest amplitude in an user-defined frequency band.

Fig 12 explains the selective frequency measurement.

The frequencies f_{sel} #1-3 represent the signals with the highest amplitude that occur in the three user-defined bands #1-3. Therefore, the returned results of the selective frequency measurement are these three frequency values.

The accuracy of a (full band or selective) frequency measurement depends on the actual sampling rate and of the blocklength of the active multitone signal. **Table 12** lists the corresponding values.

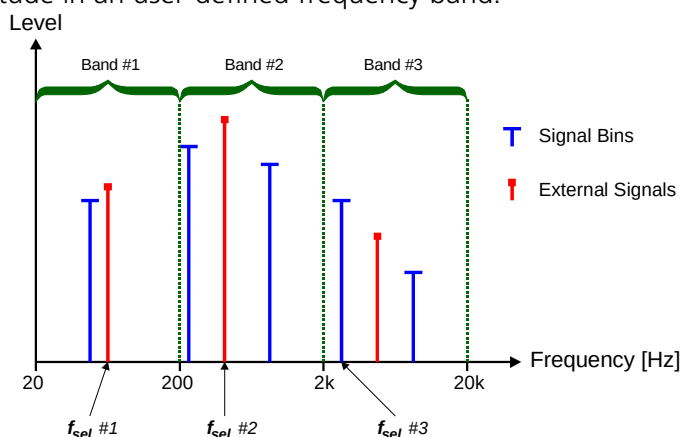


Fig 12 Selective Frequency Measurement

Sampling Rate	Blocklength	Measuring Accuracy	Lowest measurable Frequency	Bin_Min	Highest measurable Frequency	Bin_Max
8 kHz	128	0.28 Hz	115 Hz	2	3.5 kHz	56
	256	0.14 Hz	62.5 Hz	2	3.5 kHz	112
	512	0.07 Hz	31.25 Hz	2	3.5 kHz	224
	1024	0.035 Hz	23.43 Hz	3	3.5 kHz	448
	2048	0.0175 Hz	23.43 Hz	6	3.5 kHz	896
48 kHz	512	0.4 Hz	187.5 Hz	2	19968.8 Hz	213
	1024	0.2 Hz	93.8 Hz	2	19968.8 Hz	426
	2048	0.1 Hz	46.8 Hz	2	19992.2 Hz	853
	4096	0.05 Hz	23.45 Hz	2	19992.2 Hz	1706
	8192	0.025 Hz	23.43 Hz	4	19998.05 Hz	3413

Table 12 Frequency Measurement Parameters

Ground Connections

Every improper connection between *RT-2X* and a DUT can cause a ground loop. The subsequent rules help to avoid the unpleasant effects of such loops. However, each setup has to be considered individually, taking into account the actual connections between the reference grounds of the involved instrument to earth.

- Link the cable shield to GND only at one end and leave it open at the other end.
- Switch the *RT-2X* generator to FLOAT with the command **OUTPut:FLOAT ON** if the DUT's ground is connected to earth (chapter *Analog Output Connections*, p. 287).

NOTE	Remember to disassemble the ground bars from the <i>RT-2X</i> input connectors for a balanced connection.

IEEE-488 Parallel Interface

RT-2X provides of a GPIB IEEE-488 interface (standard design interface for programmable instrumentation) with a standard IEEE-488 connector on the rear panel as shown in **Fig 13**.

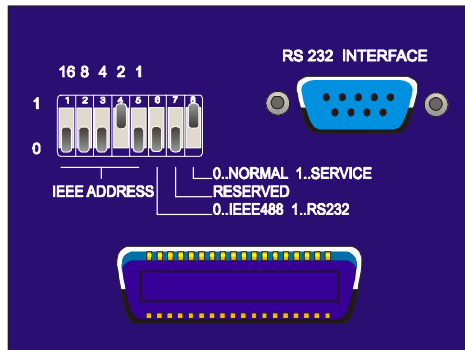


Fig 13 IEEE / RS232 Interfaces

The IEEE interface bus allows controlling up to 30 instruments from one PC. The IEEE cables have identical piggyback connectors on each end, so that they can be used to connect the controlled devices in virtually any configuration, as long as there is a path from the PC to every device.

As a practical matter, avoid stacking of more than three or four IEEE cables to a single connector. Otherwise, any force on the stack can damage the instrument's connector. Make sure that every cable connector is firmly fixed in its place.

Each IEEE device has at least one talk and listen address. The address of the RT-2X can be selected with the DIP-switch at the rear panel of the instrument. Each switch position has a number printed above. The resulting IEEE address is the sum of those numbers where the switch is in position "1". The available address range is 1 to 31.

Fig 13 shows an example with following status:

- DIP-switch #8: position "0" $\Rightarrow$ RT-2X is operated in the measuring mode.
- DIP-switch #6: position "0" $\Rightarrow$ IEEE interface active.
- DIP-switch #1–5: only switch #2 in position "1" $\Rightarrow$ IEEE address of this unit = 2.

IEEE Standard Status Data Structure

The standard IEEE 488.2–1992 specifies the IEEE Standard Status Device Structure, i.e. the standard codes, formats, protocols and common commands.

Overview

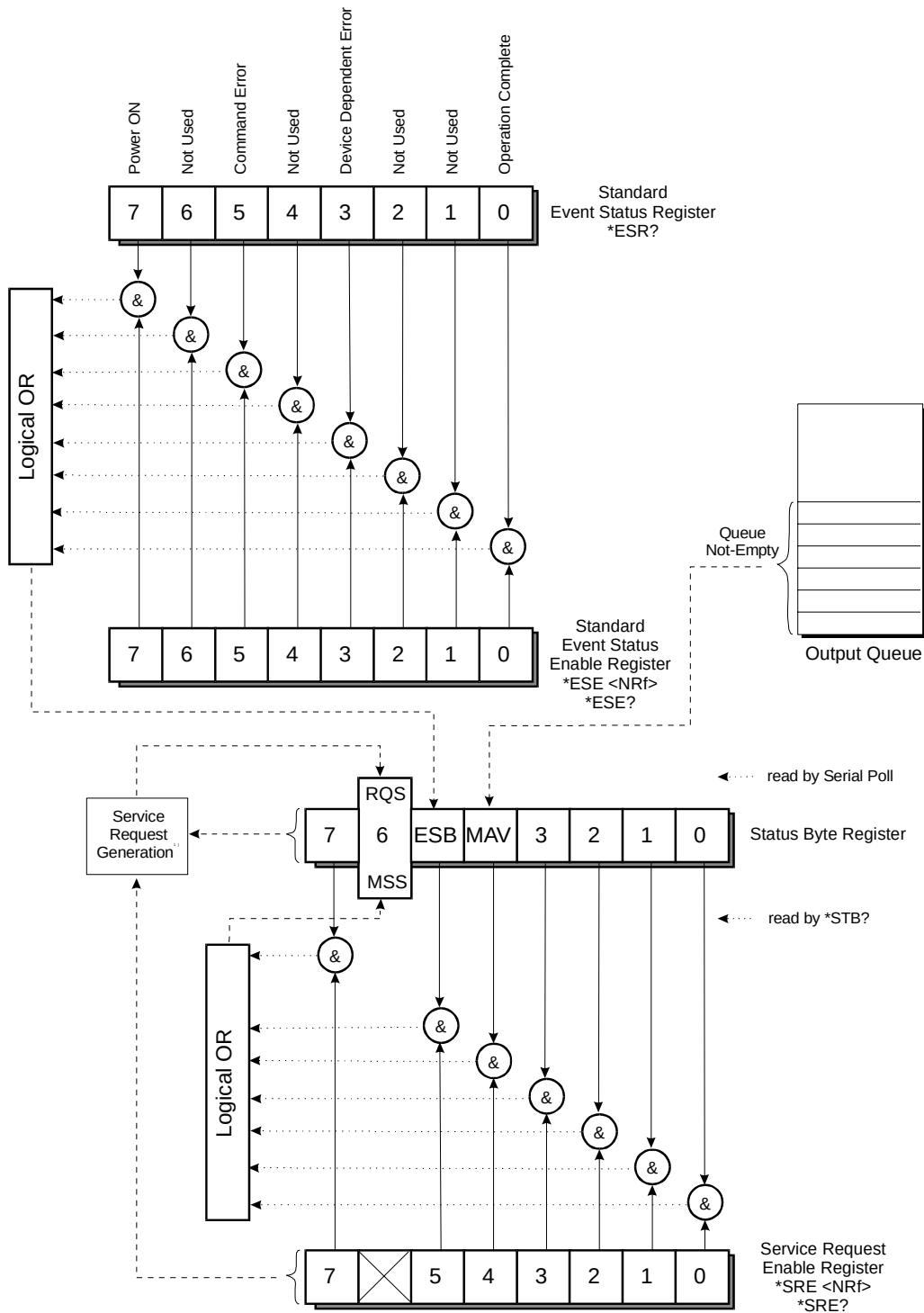


Fig 14 IEEE Device Status Registers

¹⁾ Service Request clears RQS but not MSS!

Registers

RT-2X has four internal registers, each comprising one Byte, i.e. 8 bits. The registers are grouped in two blocks, whereby the **Commands for Device Status** (refer to p. 160ff) allow accessing the registers:

- The *standard event status register* and the *status byte register* are status registers that indicate the *RT-2X* device status.
- The *standard event status enable register* and the *service request enable register* are enable registers that define, which messages of the status registers are forwarded.

Standard Event Status Register

This register records the events "Power ON" (n_7), "Command Error" (n_5), "Device Dependent Error" (n_3) and "Operation Complete" (n_0) and forwards these messages to the *status byte register*, supposed that the corresponding bits are enabled by the *standard event status enable register*. Thereby, the bits of the *standard event status register* are coded according to the following scheme:

$$\langle \text{Reg\_Status} \rangle = n_7 \cdot 128 + n_6 \cdot 64 + n_5 \cdot 32 + n_4 \cdot 16 + n_3 \cdot 8 + n_2 \cdot 4 + n_1 \cdot 2 + n_0$$

whereby

- n_7 = *Power ON event flag*. This event bit indicates that an Off-to-On transition has occurred in the power supply of RT-2X.
- n_6 = Not used
- n_5 = *Command error event flag*. This event bit indicates that either a syntax or a semantic error has been detected. The error-number can be read with the corresponding register query command.
- n_4 = Not used
- n_3 = *Device specific error event flag* (e.g. no trigger detected). The error-number can be read with the corresponding register query command.
- n_2 = Not used
- n_1 = Not used
- n_0 = *Operation complete event flag*. This event bit is generated in response to the *OPC command. It indicates that the device has completed all pending operations.

Standard Event Status Enable Register

This register enables the bits of the *standard event status register* according to the user settings defined with command ***ESE <Nrf>**. It thus defines, which messages are forwarded from the *standard event status register* to bit n_5 (ESB = Event Summary Bit) of the *status byte register*.

Status Byte Register

This register records the messages "RQS / MSS" (ReQuest Service / Master Summary Status, n_6), "ESB" (Event Status Summary, n_5) and "MAV" (Message AVailable, n_4) and creates a service request (SRQ) to the controlling PC, supposed that the corresponding bits are enabled by the *service request enable register*.

Service Request Enable Register

This register enables the bits of the *status byte register* according to the user settings defined with command ***SRE <Nrf>**. It thus defines, which events can create a service request (SRQ) at the controlling PC. In other words, the programmer can define the cases that result in a service request by altering the contents of the service request enable register.

Example: Use of an *OPC Command

The *OPC command and the *OPC? query allow synchronizing the controlling PC to the time when *RT-2X* has completed a command execution.

```

PC → *esr?                (clear previous events)
    *sre 32;*ese 1        (enable operation complete event)
    output:mtone:start;*opc (RT-2X starts the multitone transmission)
→ PC                      (as soon as the multitone measurement has been completed,
                           RT-2X sends a SRQ via serial polling to the controlling PC)

```

Example: Use of MAV Bit in the Status Byte Register

```

PC → *sre 16              (enable bit n5 = output queue not empty)
    output:mtone:start    (start the multitone transmission)
    meas1:distortion?     (read the distortion results)
→ PC                      (as soon as the output queue has the valid distortion results,
                           RT-2X sends a SRQ via serial polling to the controlling PC)

```

As soon as e.g. command ***SRE 16** has been sent, *RT-2X* is set to the service request mode. This means that *RT-2X* sends back a service request (SRQ) to the PC every time when a new message (e.g. measurement result) is ready. However, please note that the SRQ message can only be transferred to the PC by serial polling, since *RT-2X* cannot add any further information to the service request.

Impedance of Analog Output & Input

The standard version of *RT-2X* provides six output impedance as well as seven input impedance plus two microphone (Phantom) power voltages.

<i>Output</i>		<i>Input</i>
<i>Balanced</i>	<i>Unbalanced</i>	<i>Balanced or Unbalanced</i>
150 Ω	75 Ω	100 kΩ
900 Ω	450 Ω	900 Ω
850 Ω	425 Ω	850 Ω
600 Ω	300 Ω	600 Ω
200 Ω	100 Ω	200 Ω
		150 Ω
220 Ω + (820 Ω // 115 nF)	110 Ω + (410 Ω // 230 nF)	220 Ω + (820 Ω // 115 nF)
Customer1	½ Customer1	Customer1
Customer2	½ Customer2	Customer2
Customer3	½ Customer3	Customer3
Customer4	½ Customer4	Customer4
		15 V / 48 V Phantom

Table 13 Standard Output & Input Impedance ('//' means 'in parallel to')

Activate the required output and input impedance with **OUTPut[1-2]:IMPedance [...]** and **INPut[1-2]:IMPedance [...]**. **Fig 15** shows the detailed output & input circuits of *RT-2X* with activated complex impedance.

- The overall *output* impedance is built by two sub-circuits, each containing a fixed serial resistor of 75 Ω, followed by a circuit that can be activated optionally.
- The *input* impedance is defined by the internal amplifier (typ. > 100 kΩ), in parallel to an optional circuit.

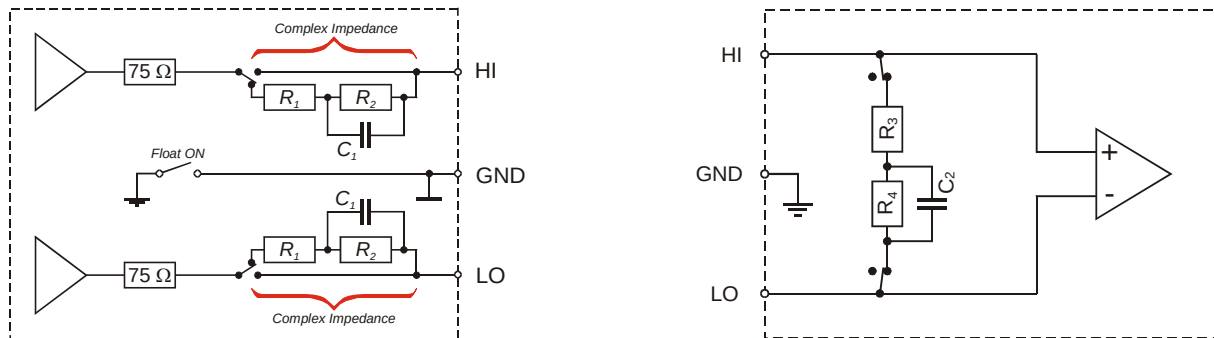


Fig 15 Complex Impedance Circuits

With *balanced* connections, the relation between the overall output impedance Z_{Out} and the values of the optional resistors and capacitors is the following (f = frequency of the output signal).

$$Z_{Out} = 75 \text{ Ohm} + R_1 + \frac{R_2}{1 + R_2 * 6.28 * f * C_1}$$

Equation 2 Overall Output Impedance

The minimum *balanced* output impedance is 150 Ω . For *unbalanced* connections, Z_{Out} can be reduced down to 75 Ω (the value of the non-removable output resistor). **Fig 16** shows how to connect *RT-2X* with a DUT to get the minimum output impedance of 75 Ω .

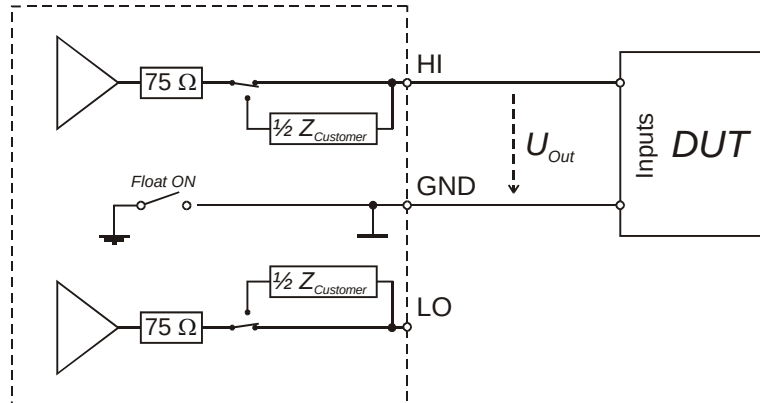


Fig 16 Low-Impedance Output Connection

NOTE With an unbalanced output connection, the actual output voltage equals only half of the selected output level: $U_{Out} = U_{Selected} - 6 \text{ dB}$.

Query the value of an installed Z1020 reference impedance with **OUTPut[1'2]:STATus?** and **OUTPut[1'2]:ZREF:CUSToMer[1'2'3'4]?**.

Example #1

Let's assume that in the case of a complex I/O impedance, as displayed in **Fig 15**, the values of the freely selectable resistors and capacitors are $R_1 = 35 \text{ } \Omega$, $R_2 = 410 \text{ } \Omega$, $C_1 = 230 \text{ nF}$ and $R_3 = 110 \text{ } \Omega$, $R_4 = 820 \text{ } \Omega$, $C_2 = 115 \text{ nF}$.

Thus, the output impedance Z_{Out} in the *balanced* operation equals

$$\begin{aligned} Z_{Out} &= (2 * 75 \text{ } \Omega + 2 * R_1) + (2 * R_2 // \frac{1}{2} C_1) \\ &= 220 \text{ } \Omega + (820 \text{ } \Omega // 115 \text{ nF}) \end{aligned}$$

which obviously is identical to the impedance Z_{In} of the input circuit.

Example #2

The actual output impedance equals the selected value in case of a balanced output connection.

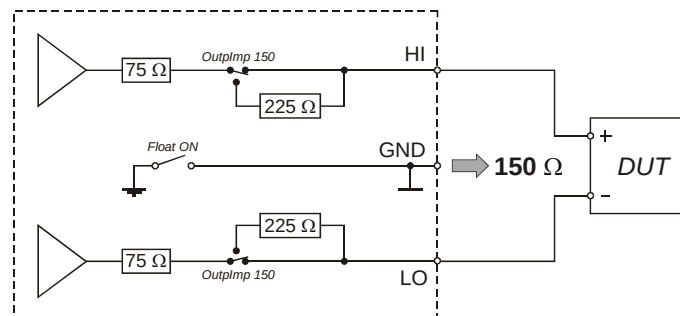


Fig 17 Balanced Output Impedance

Example #3

In case of an unbalanced output connection, the actual output impedance equals only half of the selected value.

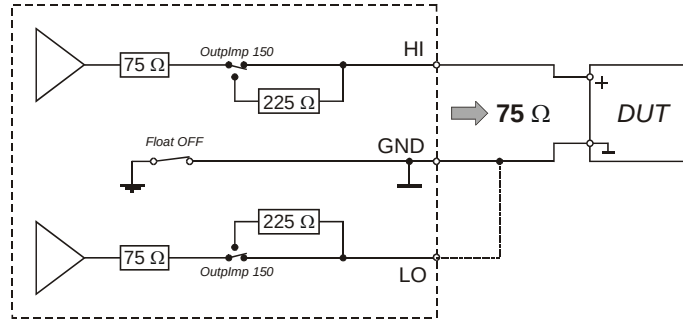


Fig 18 Unbalanced Output Impedance

Summary

The customer impedance can be required for applications, where the I/O impedance of the generator / analyzer must match the specific DUT impedance. This is e.g. always the case, if the generator output level or the measured input shall be expressed in dBm. Please refer to chapter (**dBm** p. 281) for further details.

NOTE The minimum possible *balanced* output impedance is 150 Ω, the minimum possible *unbalanced* output impedance is 75 Ω.

NOTE As soon as the input level exceeds 30 V_p, RT-2X automatically

- switches the input impedance to 100 kΩ,
- links the output connectors to the input connectors internally, and
- generates the error messages 321, 322.

Input Range

INPut[1|2]:RANGe <InputRange> [DBVP|VP] defines the *RT-2X* analyzer *sensitivity*, i.e. the maximum allowable input signal level. An input level that exceeds this value results in an overload of the *RT-2X* analyzer.

The input range should be set to a value that provides enough headroom (e.g. +6 dB) to the maximum input signal amplitude. It must be adjusted before the test execution and cannot be changed during the test signal transmission & sampling.

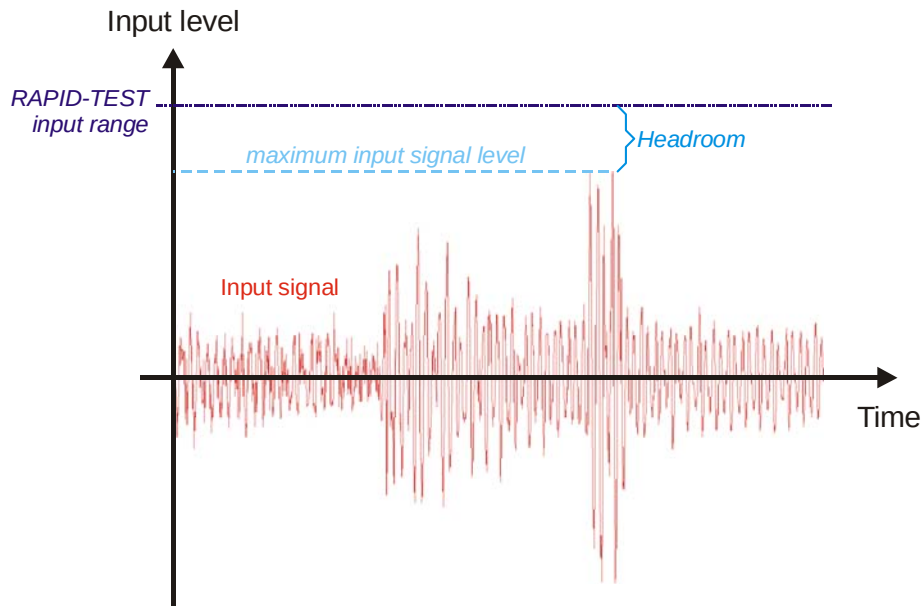


Fig 19 Input signal level, input range & headroom

Headroom

MEASurement[1|2]:HEADroom? queries the headroom of the last transmitted test signal. The returned result reflects the difference between the actual input range and the maximum level of the received signal.

HINT To optimize the headroom, proceed as follows:

- Adjust the input range to a value that is certainly high enough (e.g. +20 dBVp).
- Select the trigger mode **INPut:SYNC INTNoheader**.
- Start a signal acquisition (**OUTPut:MTONe:STARt**, **OUTPut:STEPpedswEEP:STARt**, **OUTPut[1|2]:PUResound:CHIRp:STARt** or **MEASurement[1|2]:PUResound:STARt**).
- Query the headroom of this transmission (**MEASurement[1|2]:HEADroom?**).
- Reduce the input range by considering the required headroom:

$$\text{InputRange}_{\text{New}} = \text{InputRange}_{\text{Previous}} - \text{HeadroomResult} + 6 \text{ dB}$$

ISDN Interface

The ISDN (Integrated Services Digital Network) option of *RT-2X* allows transmitting multitone bursts through an ISDN S_0 Bus, to measure its voice transmission quality. For the connection to the bus, *RT-2X* provides two RJ45 connectors (p. 168).

The ISDN option operates at a sampling rate of 8 kHz. Up to four multitone signals can be stored in the internal memory No. 5 – 8.

NOTE To operate *RT-2X* in an ISDN network, an external NT (Network Terminator) is required.

ISDN Data Transmission Format

BRI (Basic Rate Interface) is the basic ISDN service, through which the subscriber gets access to two 64 kbit/s *B-channels* and one 16 kbit/s *D-channel*, i.e. the S_0 bus.

- The two *B-channels* carry the data, e.g. of a telephone call (voice), a fax transmission or the communication between a PC and an internet server, whereby the two B-channels can be bundled together to increase the data throughput.
- The *D-channel* handles the routing of the calls and services to the appropriate ISDN devices that are connected to the subscriber's end of the ISDN BRI. Up to eight ISDN or analog devices can be linked & operated this way.
- A *NT* (Network Terminator) is required as interface both from the U-Interface to the S_0 bus, as well as between *RT-2X* and the devices that are connected to the S_0 bus.

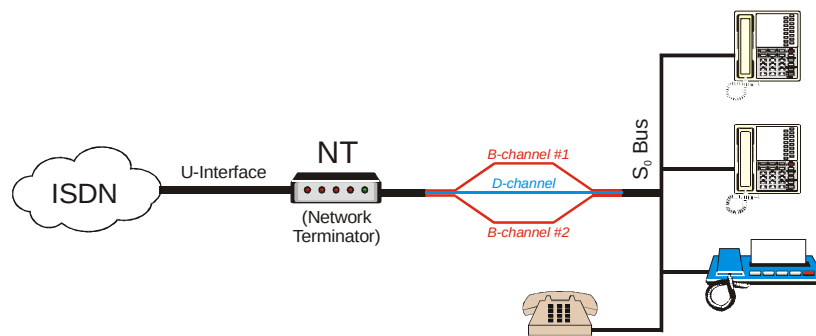


Fig 20 ISDN BRI Installation

ISDN Device Testing with RT-2X

The ISDN option of *RT-2X* comprises an ISDN S_0 bus interface. Typically, it is used for the analysis of the D-A or A-D voice transmission quality of an ISDN device. For this application, following restrictions have to be considered.

- *RT-2X* does not support D-channel signaling, i.e. the unit only operates as TE (terminal equipment).
- To transmit multitone signals between *RT-2X* and the DUT, a B-channel must be opened between these two devices. For this purpose, a specially programmed NT is required.
- By default, the *RT-2X* chn1 transmits the multitone signal through the ISDN B-channel #1, whereby the *RT-2X* chn2 uses the ISDN B-channel #2.

NOTE The ISDN option of *RT-2X* can neither be used to analyze nor to emulate the characteristics of the D-channel.

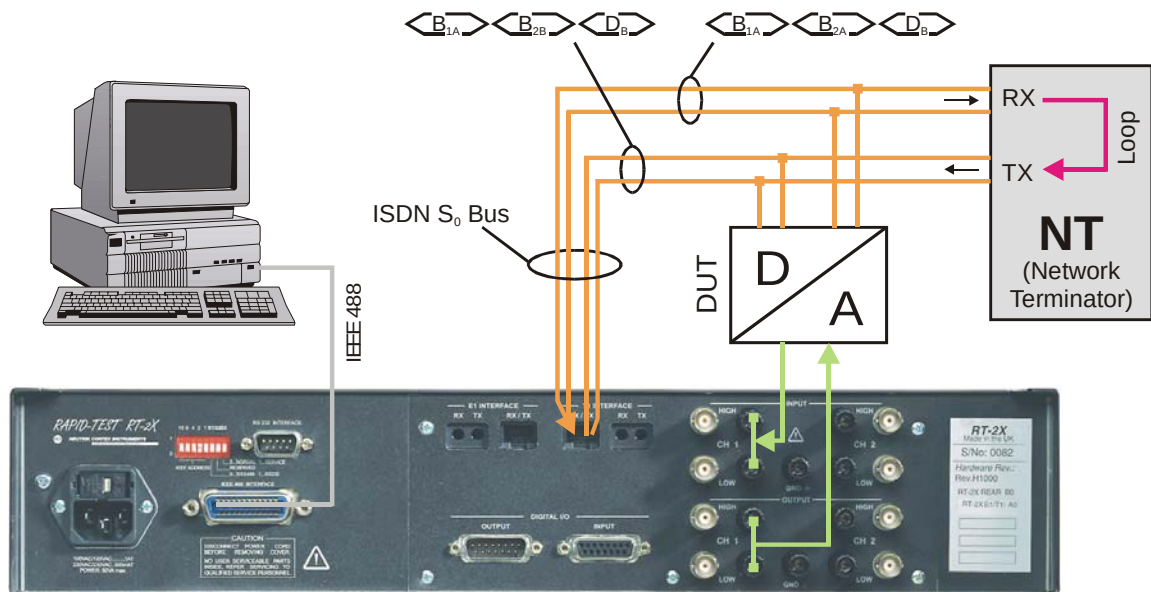


Fig 21 ISDN Setup

RT-2X supports half channel measurements as shown in **Fig 21**. This means that the multitone burst can be sent out e.g. on the ISDN S₀ bus, converted by the DUT into an analog signal, and analyzed by **RT-2X** (or vice versa).

The following example describes a typical test procedure of an ISDN device with **RT-2X** (please refer also to chapters **Half Channel Operation (A-D, D-A)** and **D-D Operation**, p. 232ff).

1. Connect **RT-2X** to a specially programmed NT that supports a loopback of the S₀ bus (**Fig 21**). In the NT, the RX of the B-channel has to be looped to the TX of either B-channel.
2. Switch the sampling rate to 8 kHz (**SYSTem:Mode 8Ksamplingrate**).
3. Select the active multitone signal (**OUTPut:MTONE:ACTivE [5'6'7'8]**).
4. Switch the **RT-2X** generator and analyzer to the ISDN or analog operation (commands **OUTPut:SOURce [ANALog'ISDN]** and **INPut:SOURce [ANALog'ISDN]**) according to the application (A-A, A-D or D-A operation).
5. Activate the Law-encoding if required (**OUTPut:ISDN:LAW [ALAW'ULAW'OFF]**).
6. Activate **RT-2X** with the NT that is connected to the S₀ bus or with command **INOUT:S0Bus ACTivate** (if the NT is passive).
7. Transmit the multitone burst (**OUTPut:MTONE:START**).
8. Query the required multitone measurement results.

LCL Mode

In the *LCL mode*, *RT-2X* supports multitone testing including the measurement of:

- Longitudinal Conversion Loss (LCL) *and*
- Longitudinal Conversion Transfer Loss (LCTL) measurements.

NOTE For LCL and LCTL measurements, the LCL/RL option must be installed.

In the LCL mode, not all *RT-2X* measurement functions are available. Please refer to the individual command descriptions.

Stepped sweep or PureSound™ testing is not supported in the LCL mode.

Enter the LCL mode as follows:

- Switch the *RT-2X* generator & analyzer to A-A (LCL or LCTL measurements) or to A-D, D-A operation (LCTL measurements).
- Disable the RL and the PureSound™ mode if they are active) with **INPut:TRIGger:BReak**, **INOUT:RLBridge:MODE OFF** and **INOUT:PUREsound:MODE OFF**.
- Activate the LCL Bridge (**INOUT:LCLBridge:MODE [LCL|LCTL]**).

As soon as *RT-2X* is in the LCL mode, it allows executing all LCL or LCTL related commands. The detailed operation instructions are described in chapters **Longitudinal Conversion Loss (LCL)** (p. 209) and **Longitudinal Conversion Transfer Loss (LCTL)** (p. 211).

LCL Wiring Compensation

In practice, every wiring between *RT-2X* and a DUT suffers under a parasitic capacitance and impedance that affects the measurement accuracy.

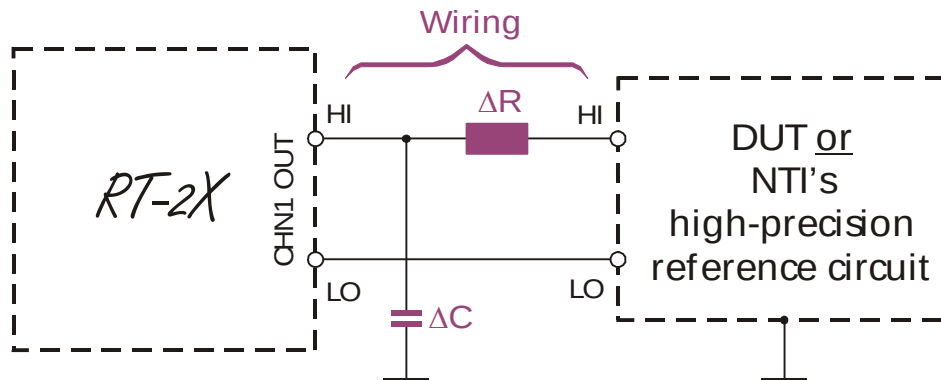


Fig 22 Parasitic Wiring Impedance

Execute the following compensation procedure to optimize the measurement accuracy:

1. Connect NTI's high-precision reference circuit ⁴ (LCL value = 120 dB) to *RT-2X* instead of the DUT. Make sure that the wiring between *RT-2X* and the reference circuit is exactly the same as if the DUT would be connected.
2. Switch the unit to $f_s = 48$ kHz (**SYSTem:MODE 48Ksamplingrate**).
3. Start the internal compensation procedure of *RT-2X* with the command **INOUT:LCLBridge:LCLCompensation START**
4. Enable the result of the completed compensation procedure with the command **INOUT:LCLBridge:LCLCompensation ENABLE**
5. Disconnect the high-precision reference circuit and re-connect the DUT to *RT-2X*.

The acquired compensation factor is stored in the non-volatile memory of *RT-2X*.

NOTE Optimize the LCL measuring accuracy by executing the compensation procedure.

⁴ Ask your NTI dealer for details.

LED Indicators

RT-2X has 15 LEDs on its front panel to display the current instrument status.

LED Name	RT-2X status if the LED is ON
COMMUNICATING	The RT-2X remote control interface (IEEE or RS232) is receiving a command. Under IEEE control, the LED remains lit after a query command until the host PC has read back the answer.
CALCULATING	An internal calculation is in progress.
TRIGGER	RT-2X has successfully triggered. The LED remains lit until the unit receives the next start command.
OVERLOAD	The input signal has overloaded one or both channels, i.e. the input voltage was higher than 40 dBVp (+70 Vp) or higher than the actual input range. The LED goes OFF as soon as a multitone burst has been transmitted without overload.
ERROR	One or more error(s) have occurred. The LED goes OFF as soon as the controlling PC queries the stored error message(s).
CARRIER SYNC	The analyzer section of RT-2X receives an ISDN or T1 signal <u>and</u> the internal PLL is synchronized to the clock of the incoming bitstream.
ISDN ACTIVATED	Layer 1 of an ISDN protocol is activated.
48 kHz SAMPLINGRATE	The current sampling rate is 48 kHz.
8 kHz SAMPLINGRATE	The current sampling rate is 8 kHz.
ANALOG INPUT	The RT-2X analyzer is switched to analog operation.
DIGITAL INPUT	The RT-2X analyzer is switched to digital operation.
ANALOG OUTPUT	The RT-2X generator is switched to analog operation.
DIGITAL OUTPUT	The RT-2X generator is switched to digital operation. The LED starts flashing if the output level is set to a value > 100 %FS / 0 dBFSp.
LOSS OF SYNC	This LED lights up if the analyzer cannot synchronize itself to the incoming T1 bitstream, i.e. cannot recognize it as T1 signal
FRAME ERROR	This LED is switched ON if the analyzer cannot recognize the frames of the incoming T1 bitstream

Table 14 LED Indicators

Microphone Power Supply, Sensitivity & Adapter

RT-2X features 15 V or 48 V Phantom power as a standard, thus allowing directly connecting measuring microphones.

INPut[1-2]:IMPedance PHANTOM activates the Phantom power. The default voltage is 15 V. Alternatively, if 48 V are required (e.g. for the NTI 3384 microphone) an internal switch has to be adjusted within the unit. Please contact your local **NTI** representative for detailed information.

Enter the microphone sensitivity, expressed in mV/Pa (millivolt per Pascal) with the command **INPut[1|2]:MICSensitivity <Sensitivity>**.

NTI provides an adapter as accessory that allows connecting XLR cables (e.g. of a microphone) to the RT-2X inputs.



Fig 23 XLR – Banana Adapter

Multitone Analysis (Overview)

Conventional audio test systems stimulate the device under test (DUT) with a single sinusoidal wave (**Fig 24**).

This method is relatively easy to handle, but slow & lacking the correlation to real-word signals as e.g. speech or music.

Other approaches like IMD (i.e. intermodulation distortion) tests stimulate the DUT with a pair of sinusoidal signals to come closer to a real audio signal transmission. Thus, the typically nonlinear characteristic of the DUT causes new harmonics and intermodulation products. However, real world signals such as music or speech are even more complex than the IMD stimulus, due to the much higher number of frequencies and their non-correlated phase relations.

Multitone testing comes much closer to the complex structure of natural sound and therefore is a much more realistic approach to audio testing. A multitone signal typically contains 2 to ~31 signal frequencies, all with individual phase relations, distributed over the frequency band of interest. Obviously, sophisticated test instruments are necessary to analyze such multitone signals.

Fig 25 shows how a typical multitone signal is composed of several sine waves with different frequencies, called *signal bins*. **Fig 26** shows the signal in the time & frequency domain.

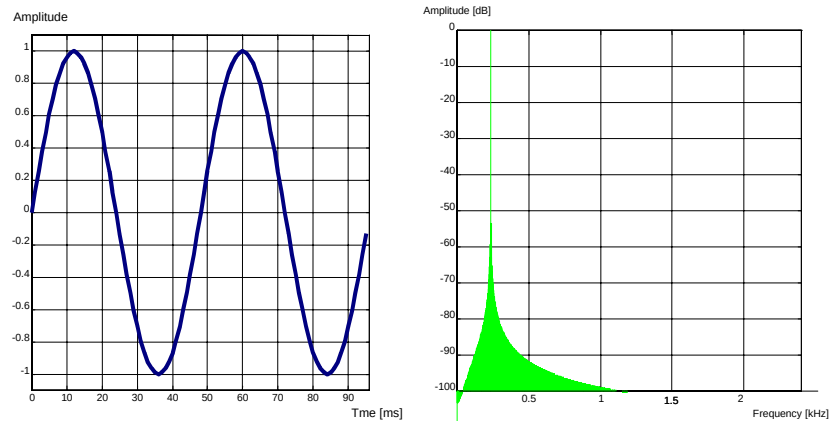


Fig 24 Time Plot & Spectrum of a Sinusoidal Signal

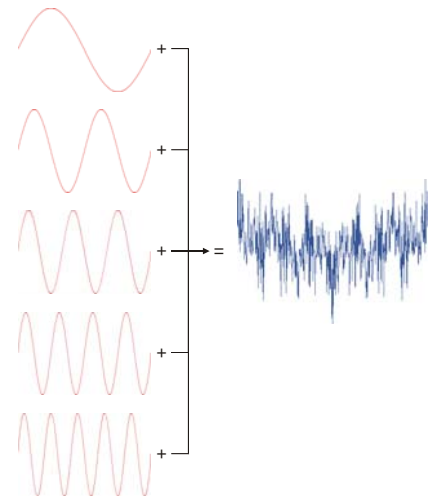


Fig 25 Multitone Signal Composition

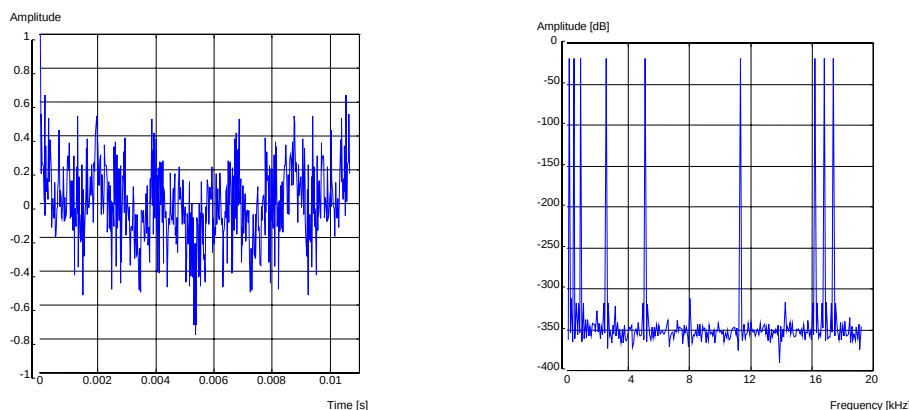


Fig 26 Time Plot & Spectrum of a Multitone Signal

Multitone Blocklength

RT-2X internally processes a multitone signal always as digitized data. This has the advantage of accuracy, speed and flexibility, as well as the possibility of post-processing a recorded signal. Depending on the operation mode (A-A, A-D, D-A or D-D, refer to p. 231) the internal signal processing comprises also of a D-A or A-D conversion.

A core characteristic of the multitone test signal is its *blocklength*, i.e. the *number of samples* that build the signal within RT-2X. Depending on the sampling rate (8 kHz or 48 kHz) following blocklengths are available:

- 128, 256, 512, 1024, 2048 ($f_s = 8$ kHz).
- 512, 1024, 2048, 4096, 8192 ($f_s = 48$ kHz).

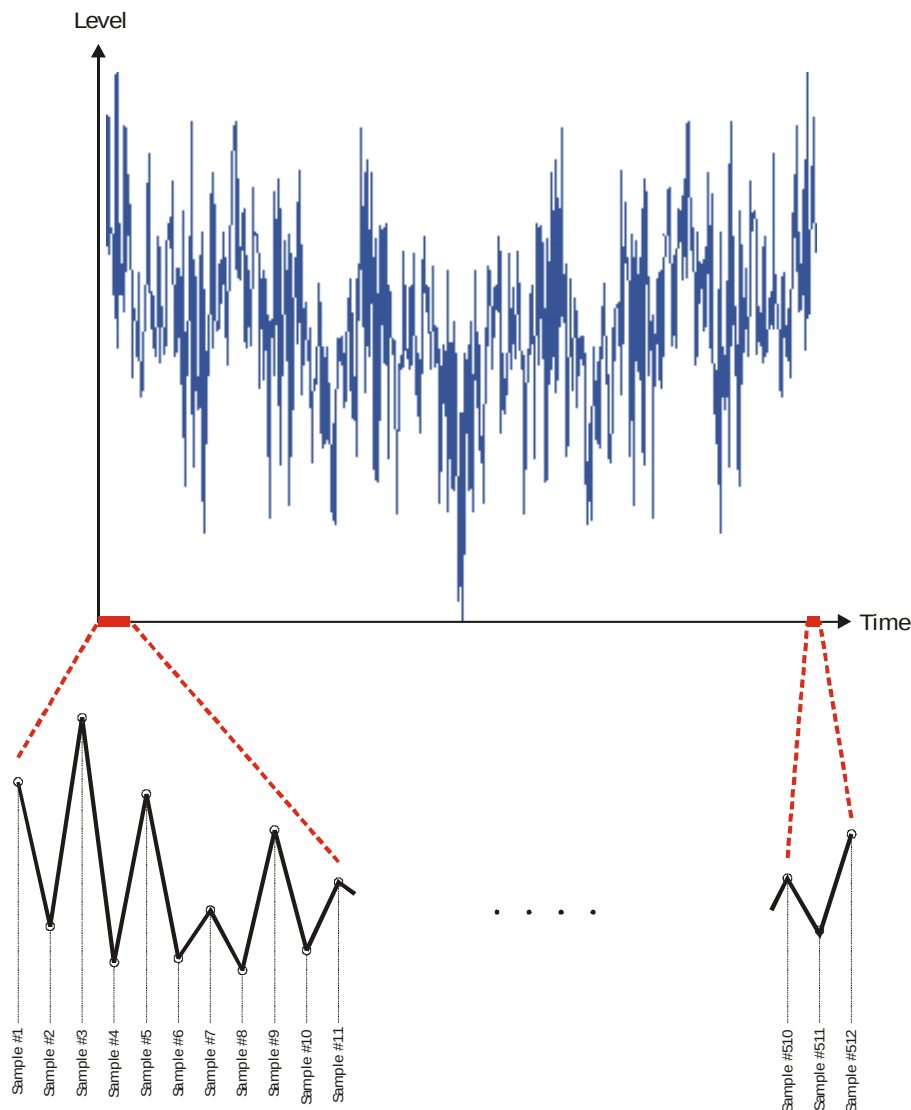


Fig 27 Multitone Signal and Blocklength

Fig 27 shows how a multitone signal is composed of a certain number of samples, given by the blocklength.

Apart from that, the blocklength also defines two other signal characteristics, the *multitone signal duration* and the *frequency spacing* (p. 228, 200).

Multitone Burst Structure

A *RT-2X* multitone burst comprises of two blocks:

1. The *proprietary header* with the *trigger* and the "Clock Sync" block.
 - The *trigger* allows the analyzer triggering to an incoming multitone burst that has been generated by a RAPID-TEST unit.
 - The "Clock Sync" block allows the analyzer synchronizing its internal sampling frequency to the one of the multitone burst.

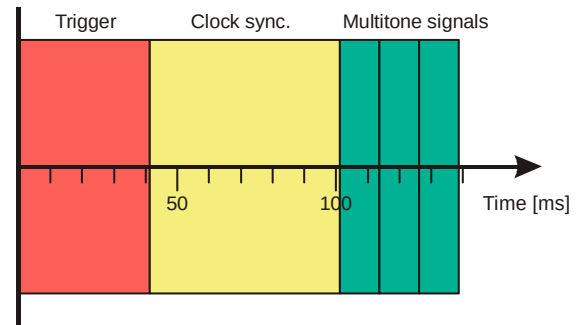


Fig 28 Multitone Burst

2. The *multitone signal* with the user-defined signal bins (i.e. frequencies). Every *RT-2X* multitone burst comprises of a 3 – 5 multitone signals (depending on the blocklength), of which the last two are sampled & processed for the measurement result calculation.

Trigger

The duration of the *trigger* is 42 ms. It comprises of 5 fixed frequencies in the voice band with predefined levels. The listening *RT-2X* analyzer recognizes this frequency & level pattern as the trigger of an incoming *RT-2X* multitone burst and immediately starts recording the signal. Please refer to chapter **Triggering & Signal Acquisition** (p. 270) for further details.

RT-2X detects the trigger down to –20 dB below the current input range. For instance, at an input range of –6 dBVp the trigger can be detected down to a level of –26 dBVp.

'Clock Sync' Block

The *Clock Sync* block has a fixed duration of 64 ms and consists of a 3 kHz single sine wave. Thus, the analyzer can synchronize its sampling frequency to the incoming multitone burst. This allows compensating for frequency shifts that have been caused by the DUT (e.g. modulators / demodulators or tape machines with speed differences) or slightly different clock frequencies of separated *RT-2X* units.

Multitone Signal

Right after the proprietary header follows the *multitone signal* with the user-defined signal bins (i.e. frequencies). Depending on the blocklength, the multitone signal is repeated at least 3 times within a burst, whereby the *RT-2X* analyzer samples the *last two* multitone signals to calculate the measurement results.

The reason to repeat the multitone signal ≥ 3 times is to eliminate the transient behavior of the DUT. Thus, it is assured that the signal transmission has settled to a stable status at the time when the analyzer starts sampling & calculating the measurement results.

Multitone Crest Factor & Signal Bin Phases

The shape of a given multitone signal – plotted in the time domain – strongly depends on the *phases* of its signal bins. If these phases are assigned in a 'good' way, the signal will show only few high 'peaks'. However, in case of a 'bad' signal bin phase selection, the resulting multitone signal comprises of high peaks (**Fig 29**).

The biggest disadvantage of a 'bad' signal definition is the large dynamic range that is required for its transmission without clipping the signal peaks.

Consequently, it is important to select the phases of the signal bins in a good way that results in a signal characteristic with as little & small peaks as possible. In mathematical words, the Crest factor Cf should be kept as low as possible:

$$Cf = \frac{PeakLevel}{RMSLevel}$$

Equation 3 Crest Factor

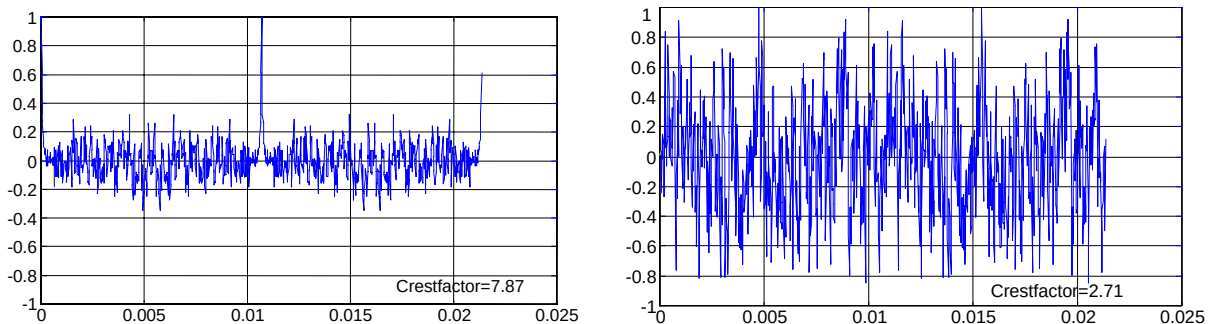


Fig 29 Multitone Signal with 'bad' and 'good' Signal Bin Phases Definition

Since the maximum signal amplitude directly determines the dynamic range of the DUT and of the analyzer, a low peak value is important & desirable. Therefore, the user should optimize the signal bin phases to get a low peak value of the time signal, i.e. a low Crest factor.

HINT *NTI's software package RT-EVAL automatically optimizes the phases of the multitone signal. Please contact your local **NTI** agent or visit our homepage <http://www.rapid-test.com> to get a free copy.*

Multitone Frequency Spacing

A multitone signal can only be composed of sine waves that fit with an integral number of time periods in the blocklength.

The simplest sine wave that fulfills this condition has a time period that equals the multitone signal duration. Consequently, the frequency of this signal is $f_1 = 1/t_{MT}$. The next allowed signal has a frequency of $2 * f_1$, the next $3 * f_1$ and so forth.

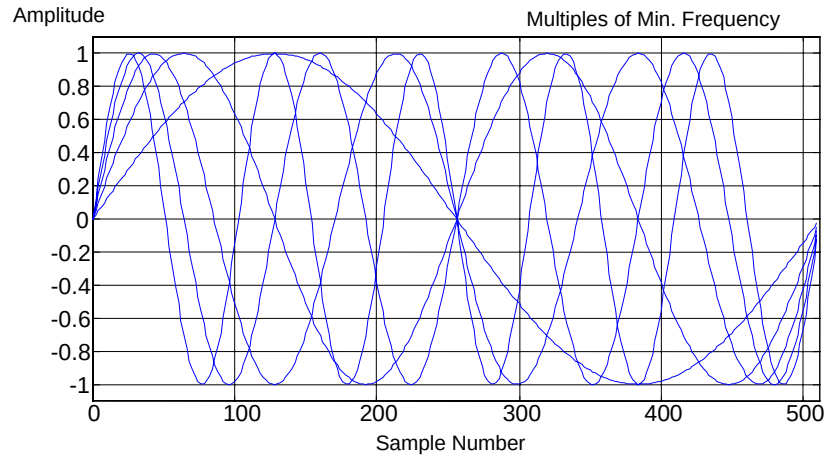


Fig 30 Time Plot of Sine Waves with f_1 , $2*f_1$, $3*f_1$, $4*f_1$ and $5*f_1$

f_1 is the smallest available frequency that can be part of a multitone signal. All the other available frequencies are multiples of f_1 . Therefore, this 'parent' frequency is called the *frequency spacing* (or *frequency resolution*) Δf of a multitone signal.

$$\Delta f = \frac{\text{SamplingRate}}{\text{Blocklength}}$$

Equation 4 Frequency Spacing

The frequency spacing depends on the actual blocklength and on the sampling rate (i.e. 8 kHz or 48 kHz) of the multitone signal. Please refer to **Table 16** (p. 230) for further details.

Multitone length

OUTPut:MTONE:MTONelength <Length> includes *additional* multitone signal blocks to the burst. For instance, this can be necessary to let the DUT stabilizing (e.g. to let transients disappear) before the analyzer starts sampling.

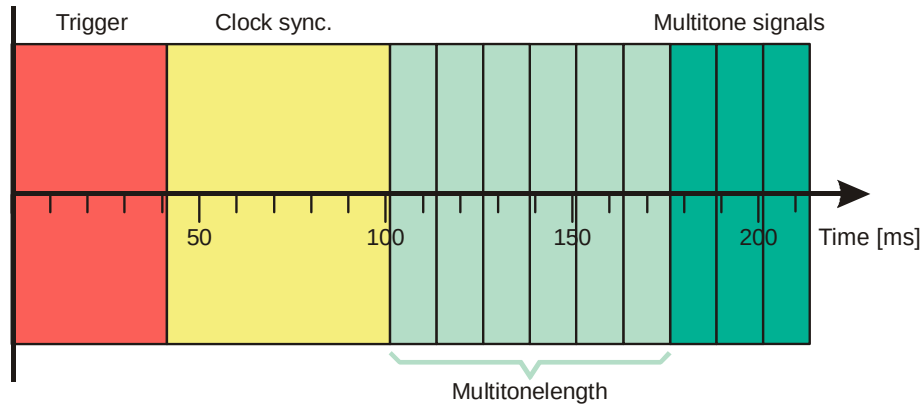


Fig 31 Multitone length (example)

HINT If the parameter <Length> is set to 0 (default), a minimum number of 3 – 5 multitone signal blocks is transmitted, depending on the actual blocklength.

Multitone Measurements

Crosstalk

NOTE At $f_s = 8$ kHz, the analog analyzer bandwidth is 20 Hz – 3.4 kHz, whereby the digital measuring bandwidth is 20 Hz – 4 kHz.

Crosstalk is the signal energy that is transferred from channel onto the other in a stereo transmission. For instance, if the DUT has a bad channel separation, the frequencies of channel A will 'talk' into channel B, i.e. they will appear in the received signal of channel B, and vice versa.

- The transmitted multitone test signal must have signal bins on *both* channels.
- The signal bins of the two channels must be defined at *different* frequencies.
- **MEASurement[1'2]:CROSstalk:UNIT [%'DB]** defines the unit, in which the result is expressed.
- **MEASurement[1'2]:CROSstalk?** queries the measurement results. The returned results of channel A are calculated as the ratio of the received BinLevels of channel A to the signal-BinLevels of channel B, as stated in **Equation 5** (n = the signal bin number of channel B):

$$\text{Crosstalk}(\text{ChA})_n[\%] = \frac{\text{ReceivedBinlevel\_ChA}_n}{\text{SignalBinlevel\_ChB}_n} * 100$$

$$\text{Crosstalk}(\text{ChA})_n[\text{dB}] = \text{ReceivedBinlevel\_ChA}_n[\text{dB}] - \text{SignalBinlevel\_ChB}_n[\text{dB}]$$

Equation 5 Crosstalk Calculation

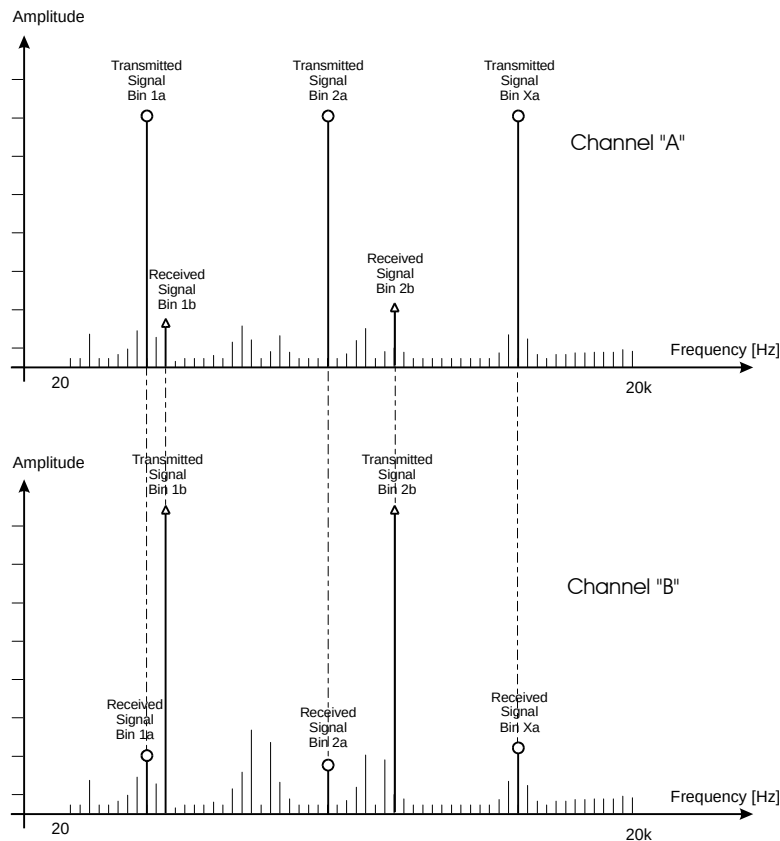


Fig 32 Crosstalk Plot

**Example**

Given Signal-BinLevel of channel A = 10 dBV @ 1 kHz

Measured Received BinLevel of channel B = -30 dBV @ 1 kHz

Result $\text{Crosstalk}_{B \rightarrow A} = 1 \% = -40 \text{ dB}$

NOTE	A noisy DUT will falsify the crosstalk results since the noise will be added to the 'pure' crosstalk level.

Distortion

NOTE At $f_s = 8$ kHz, the analog analyzer bandwidth is 20 Hz – 3.4 kHz, whereby the digital measuring bandwidth is 20 Hz – 4 kHz.

Distortion characterizes the nonlinear behavior of a DUT, i.e. the degree to which it generates new signal components at other frequencies than the stimulating signal.

- **MEASurement[1'2]:DISTortion:UNIT [DBV|V|DBM|DBFS|FS|DBM0]** defines the unit, in which the distortion results are expressed.
- **MEASurement[1'2]:DISTortion?** queries the *total distortion + noise energy* (TD+N) of every band between the signal bins of the transmitted multitone signal.

Watch **Equation 6** and **Equation 7** to understand the way, in which **RT-2X** calculates the TD+N values in the frequency bands of interest.

RMS and RSS Value

Conventional test instruments evaluate the distortion energy as *RMS* (Root Mean Square) voltage by summing up all received signal components V_i according to following equation.

$$V_{RMS} = \sqrt{\frac{\sum_{i=1..n} (V_i)^2}{n}} \quad \text{with } n = \text{number of signal components}$$

Equation 6 RMS Calculation

When applying this formula on the discrete spectrum of a FFT analysis, the result correlates in inverse proportion to the number of bins. Therefore, **RT-2X** calculates the *RSS* value (Root Sum Square) for the TD+N (i.e. distortion per band) result.

$$V_{RSS} = \sqrt{\sum_{i=1..n} (V_i)^2} \quad \text{with } i = \text{counter over all bins}$$

Equation 7 RSS Calculation

TD+N vs. THD+N

A conventional THD+N analysis stimulates the DUT with a *single* tone. This frequency component is subtracted from the received signal after transmission. The ratio of the remaining level to the total input level gives the THD+N or *SINAD* result respectively.

On the other hand, a multitone signal transmission creates not only harmonics but also intermodulation products that cannot be related backwards to the signal bins. Therefore, TD+N results differ slightly from a conventionally measured *THD+N* value.

Multitone Distortion Results

Fig 33 shows a typical distortion plot of a **RT-2X** measurement.

- The first value in the plot *D1* equals the RSS result (TD+N value) of the band between the first bin ≥ 20 Hz up to the last bin $< \text{SignalBin\#1}$.
- All further results *Dn* represent the bands between the first bin $> \text{SignalBin\#n}$ up to the last bin $< \text{SignalBin\#n+1}$.
- The last distortion result represents the band between the first bin above the highest signal bin up to the last bin ≤ 20 kHz.

Please note that the even as well as the odd bins of the received signal are considered for the TD+N calculation.

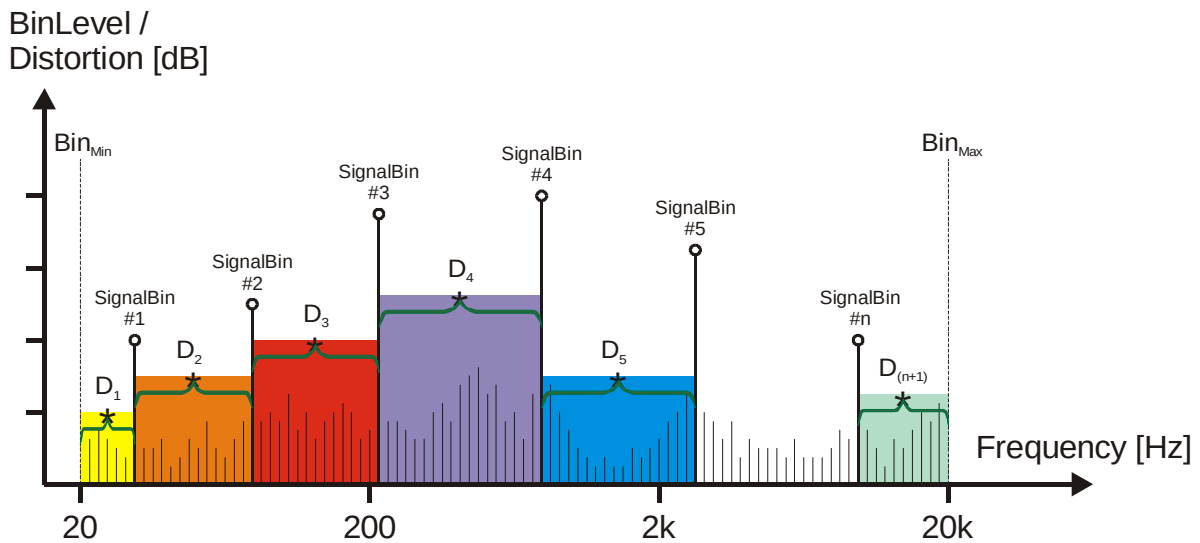


Fig 33 Multitone Distortion Measurement

Full Band TD+N

To evaluate the TD+N value in the full frequency band (20 Hz – 20 kHz), use the command **MEASurement[1|2]:MTTDan?** that is calculated according to the following equation:

$$TD + N_{FullBand} = \sqrt{D_1[V]^2 + D_2[V]^2 + \dots + D_n[V]^2}$$

Equation 8 Full Band TD+N

wherein D_1 - D_n are the returned distortion results, expressed in [V].

THD+N

To evaluate the true THD+N result of a DUT, the following requirements have to be met:

- Stimulation of the DUT with a single bin signal.
- Calculation of the THD+N value (expressed in %) according to

$$THD + N [\%] = \frac{\sqrt{D_1[V]^2 + D_2[V]^2}}{\sqrt{D_1[V]^2 + L_1[V]^2 + D_2[V]^2}} * 100$$

Equation 9 THD+N Calculation

with D_1 = distortion between 20 Hz and the signal bin, D_2 = distortion between the signal bin and 20 kHz and L_1 = received signal bin level.

NOTE RT-2X supports THD+N measurements in the stepped sweep mode (p. 263).

Echo Return Loss (ERL) and Singing Return Loss (SRL)

NOTE The ERL, SRL-Lo and SRL-Hi measurement functions are only available if the LCL/RL option is installed.
The specified ERL, SRL measuring accuracy requires that the DUT is not grounded.

Echo Return Loss (ERL) and Singing Return Loss (SRL-Lo, SRL-Hi) are averaged Return Loss measurements. The pre-defined **ERL**, **SRLHI** and **SRLLO** test signals of **RT-2X** have the characteristics as shown in **Fig 34**.

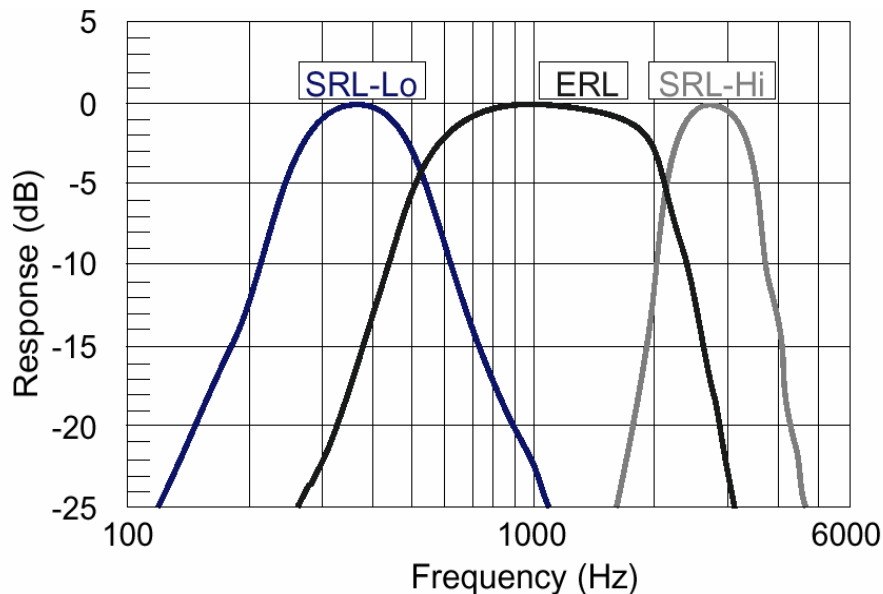


Fig 34 ERL, SRL-Lo & SRL-Hi Frequency Weighting, according to IEEE 743-1995

Execute an ERL or SRL measurement as follows:

- Switch **RT-2X** to A-A operation (**OUTPut:SOURce ANALog, INPut:SOURce ANALog**).
- Enter the RL mode (**INOUT:RLBRidge:MODE ON**).
- Connect the output channel 1 with the DUT as shown in **Fig 50** (p. 222).
- Select the required test signal (**OUTPut:MTONe:ACTivE ERL, SRLLO or SRLHI**).
- Select the output impedance of chn. 1 (**OUTPut1:IMPedance ...**) identical to the (expected) impedance of the DUT. This is the reference impedance of the RL measurement. If none of the available **RT-2X** output impedance matches the DUT's impedance, select the most similar impedance or install a customer impedance (custom-defined impedance options for **RT-2X** are available from **NTI**).
- Adjust the output level of channel 1 to the desired voltage (**OUTPut1:LEVel ...**). The most frequently used level is 0 dBm. In any case the multitone output level must be within the range from -20 dBVp to +14 dBVp.
- Start the signal transmission and measurement with **OUTPut:MTONe:STARt**
- Query the corresponding measurement result with the commands **MEASurement1:ERL?**, **MEASurement:SRLHI?** or **MEASurement:SRLLO?**

Gain

NOTE At $f_s = 8$ kHz, the analog analyzer bandwidth is 20 Hz – 3.4 kHz, whereby the digital measuring bandwidth is 20 Hz – 4 kHz.

Command **MEASurement[1'2]:GAIN?** queries the *gain* of the DUT. It is calculated for each signal bin n according to **Equation 10**.

$$Gain_n [dB] = 20 * \log_{10} \left(\frac{U_{In\_n} [V]}{U_{Out\_n} [V]} \right) = U_{In\_n} [dB] - U_{Out\_n} [dB]$$

Equation 10 Gain

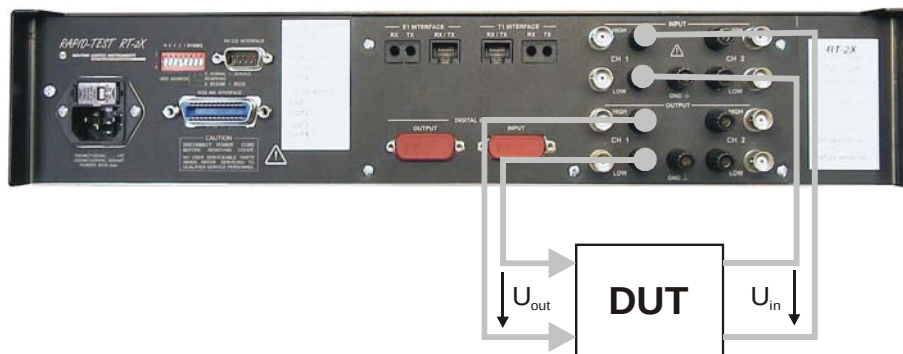


Fig 35 A-A Gain Measurement

The gain query returns the DUT's *gain vs. frequency* according to the signal bins of the transmitted multitone signal. The results are always expressed in dB, regardless of the selected output or input level unit.

A-A Setups

When measuring the gain in an A-A setup, it is important to be aware of the difference between *voltage* gain measurements and *power* gain measurements.

- For a *voltage gain* measurement, it is recommended to set the **RT-2X** output and input impedance to 150 Ω and 100 k Ω , whereby the generator level must be expressed in a voltage unit, i.e. V, Vp, dBV or dBVp. Regardless of which of these units is selected, the gain calculation refers to the output and input level in dBV.
- For a *power gain* measurement, the **RT-2X** output and input impedance should match the corresponding impedance of the DUT (e.g. 600 Ω output $\rightarrow$ 600 Ω input). Furthermore, the generator level must be expressed in the (power) unit dBm. Consequently, the gain calculation refers to the output / input level in dBm.

A-D, D-A Setups

In these two cases, the gain calculation is based on the *analog* level in dBm and on the *digital* level in dBm0.

D-D Setups

The gain calculation of purely digital setups is based on the output & input level in dBm0.

Level

NOTE At $f_s = 8$ kHz, the analog analyzer bandwidth is 20 Hz – 3.4 kHz, whereby the digital measuring bandwidth is 20 Hz – 4 kHz.

The level measurement provides the *frequency response* of the DUT.

- **MEASurement[1|2]:LEVel:UNIT** [DBVP|VP|DBV|V|DBM|DBFSP|%FSP|DBFS|%FS|DBM0] defines the unit, in which the level result shall be expressed.
- **MEASurement[1|2]:LEVel?** queries the level measurement results of the last multitone burst transmission.

The returned results correspond to the signal bin levels of the last received multitone signal. This analysis considers only the energies of the signal bins, and not the distortion + noise energy in the bands between the signal bins. Therefore, it is a very selective measurement that accurately reflects the DUT's frequency response.

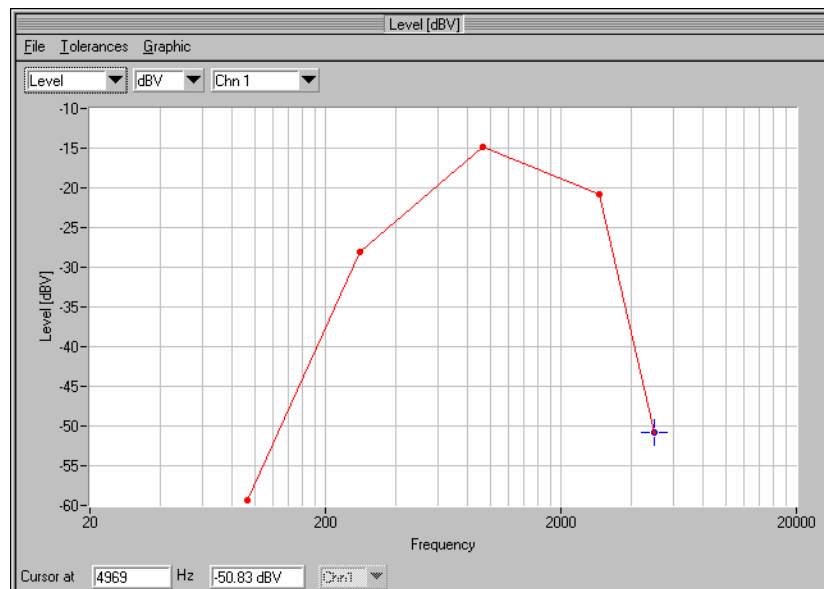


Fig 36 Level Plot

Please note that the *overall input level*, i.e. the total energy of all received *signal bin + (unused) bin levels* would correspond to the RMS level of the received multitone signal (signal bin levels + distortion + noise). However, this value is of almost no interest for the characterization of a DUT, since it only reflects its overall attenuation or amplification and not the frequency response.

Longitudinal Conversion Loss (LCL)

NOTE The LCL measurement function is only available if the LCL/RL option is installed on the RT-2X.

Recommendation G.117 (Annex A) states the following about the LCL measurement: "The balancing properties of an equipment can be expressed in many ways. The most commonly used parameter appears to be the 'Longitudinal Conversion Loss', LCL". According to ANSI/IEEE Standard 455-1985, LCL describes "the ratio of the disturbing longitudinal voltage V_l and the resulting metallic voltage V_m of the network under test expressed in dB, as follows: "

$$LCL [dB] = 20 * \log_{10} \left| \frac{V_l}{V_m} \right|$$

Equation 11 LCL Definition

RT-2X measures LCL according to ANSI/IEEE 455-1985 as referred in the Bellcore TR-57 and GR-303 standard. Depending whether the DUT is a 1-port or 2-port device, following wiring is required:

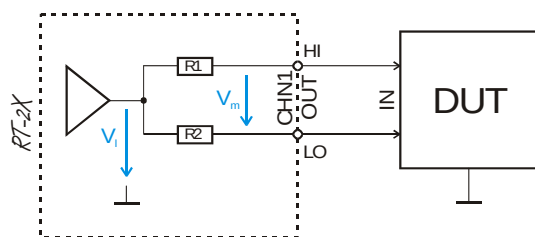


Fig 37 1-port Device Setup ($R1 = R2 = 368 \Omega^*$)

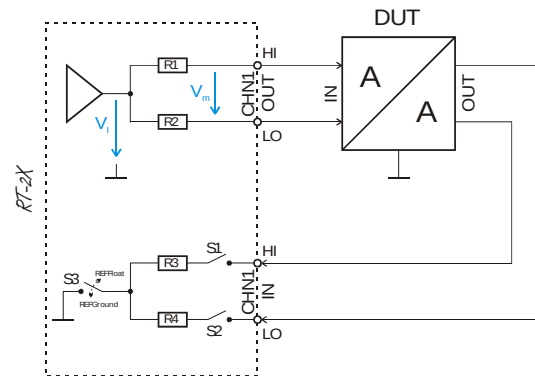


Fig 38 2-port Device Setup ($R3 = R4 = 368 \Omega^*$)

RT-2X generates the common mode voltage V_l at the two identical resistors $R1$, $R2$ and analyzes, whether the DUT creates an unbalance by measuring the voltage V_m .

Some 2-port devices need a termination for proper operation. The LCL/RL option comprises of such a termination. It consists of the two identical resistors $R3$, $R4$ that can be connected to the output of the DUT over the switches $S1$, $S2$. By closing or opening the switch $S3$, it becomes possible to find out, which of the DUT's *Series-* or *Shunt-Unbalance* is larger (chapter **2-Port DUT**, p. 210).

* This value was selected to provide a uniform circuit impedance for testing and is not intended to match specimen impedance (refer to ANSI/IEEE Std 455-1985).

LCL Measurements

1. Connect **RT-2X** to the DUT as shown in **Fig 37** (1-port DUT) or **Fig 38** (2-port DUT).
2. Choose the required sampling rate (**SYSTem:MODE [8Ksamplingrate|48Ksamplingrate]**)
3. Switch **RT-2X** to the A-A operation (**OUTPut:SOURce ANALog, INPut:SOURce ANALog**).
4. Activate the LCL mode with command **INOUT:LCLBridge:MODE LCL**.
5. Define the multitone test signal according to your requirements (p. 227).
6. Adjust the **RT-2X** output level (p. 234). The most frequently used level is 0 dBm. In any case the output level V_m must be $\leq 7.0 \text{ Vp} = 16.9 \text{ dBVp}$.
7. Adjust the **RT-2X** input range. If the expected LCL result is smaller than 40 dB, use the command **INOUT:LCLBridge:RANGE LOWEr40**. Otherwise, i.e. if the DUT has a very good LCL higher than 40 dB, use **INOUT:LCLBridge:RANGE HIGHer40**.

1-Port DUT

The setup is now ready for LCL measurements. Transmit the multitone signal with **OUTPut:MTONE:STARt** and query the results with **MEASurement1:LCL?**

2-Port DUT

When measuring a device with two ports (two metallic transmission ports), the driving test circuit is connected to one port. The remaining port is terminated with the internal termination of the LCL/RL option. Furthermore, this termination allows finding out whether the *Series* or the *Shunt Imbalance* of the DUT is higher.

Fig 39 shows the details behind this measurement.

Ideally, the two resistors R_A of the DUT have identical impedance. However, in practice there will always be a slight imbalance represented by ΔR_{Series} that is called the *Series Imbalance*.

The same applies for the imbalance between the two resistors R_C that is represented by ΔR_{Shunt} and is called the *Shunt Imbalance*.

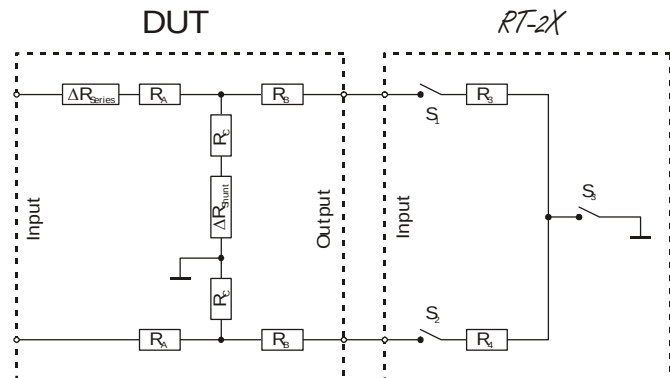


Fig 39 Series and Shunt Imbalance Measurement

To differentiate between the *Series* and *Shunt Imbalance* measurement it is necessary connecting the DUT with the appropriate termination. The LCL/RL option comprises of three different terminations, which can be activated as follows:

- **INOUT:LCLBridge:TERMination REFground** for *Series Imbalance* measurements.
- **INOUT:LCLBridge:TERMination REFFloat** for *Shunt Impedance* measurements.
- **INOUT:LCLBridge:TERMination OFF** disconnects the termination (default status).

As soon as these settings have been made, the setup is ready for LCL measurements. Transmit the multitone signal with **OUTPut:MTONE:STARt** and query the results with **MEASurement1:LCL?**

Longitudinal Conversion Transfer Loss (LCTL)

NOTE The LCTL measurement function is only available if the LCL/RL option is installed on the RT-2X.

§ 4.2.3. of Recommendation G.117 states the following about the LCTL measurement: "The LCTL is a measure (a ratio expressed in dB) of an unwanted transverse signal produced at the output of a two-port network due to the presence of a longitudinal signal on the connecting leads of the input port." It is calculated according to the following formula:

$$LCTL [dB] = 20 * \log_{10} \left(\frac{V_l}{V_m} \right)$$

Equation 12 LCTL Definition

LCTL test results can be acquired of three different device types, A-A, A-D and D-A. Consequently, the corresponding setups look differently.

A-A Device Testing

1. Connect RT-2X to the DUT (Fig 40).
2. Adjust the sampling rate: **SYSTem:MODE [8K|48K]** (48K recommended).
3. Switch RT-2X to the A-A operation (use commands **OUTPut:SOURce ANALog** and **INPut:SOURce ANALog**).
4. Activate the LCL mode with command **INOUT:LCLBridge:MODE LCL**.
5. Activate the termination (command **INOUT:LCLB:TERM REFG**).
6. Select the reference impedance value with **INOUT:LCLBridge:REFimplctl <Impedance>** identical to the analog impedance of the DUT.
7. Activate the multitone test signal (**OUTPut:MTONE:ACTive [1|2|3|4|5|6|7|8]**).
8. Adjust the RT-2X output level (p. 234). The most frequently used level is 0 dBm. In any case the output level V_m must be $\leq 7.0 \text{ Vp} = 16.9 \text{ dBVp}$.
9. Adjust the input range with the command **INOUT:LCLBridge:RANGE [HIGHer40|LOWer40]**. Choose **HIGHer40** for a high-quality DUT that has an expected LCL above 40 dB.
10. Start the measurement with the command **OUTPut:MTONE:STARt** and query the results with **MEASurement1:LCTL?**

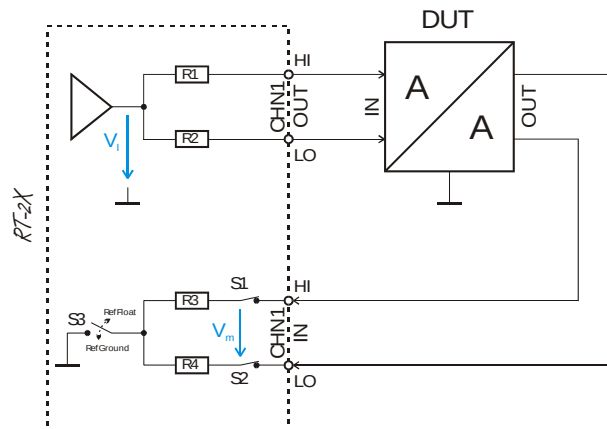


Fig 40 LCTL Measurement of an A-A Device

A-D Device Testing

1. Connect **RT-2X** as shown in **Fig 41**.
2. Adjust the sampling rate to 8 kHz (**SYSTem:MODE 8K**).
3. Switch **RT-2X** to the A-D operation (command **OUTPut:SOURce ANALog** and **INPut:SOURce ISDn** or **T1**).
4. Activate the LCL mode with command **INOUT:LCLBridge:MODE LCL**.
5. Adjust the operation of the **RT-2X** digital interface. In case of T1, the slot-number, signaling and ON-/OFF-hook must be defined (chapter **E1/T1 Interface**, p. 170). In case of ISDN, the channel must be activated (chapter **ISDN Interface**, p. 190).
6. Select the reference impedance value (**INOUT:LCLBridge:REFimplctl <Impedance>**) identical to the analog impedance of the DUT.
7. Activate the multitone test signal (**OUTPut:MTONE:ACTivE [5'6'7'8]**).
8. Adjust the **RT-2X** output level (p. 234). The most frequently used level is 0 dBm. In any case the output level V_m must be $\leq 7.0 \text{ Vp} = 16.9 \text{ dBVp}$.
9. Start the measurement with the command **OUTPut:MTONE:STARt** and query the results with **MEASurement1:LCTL?**

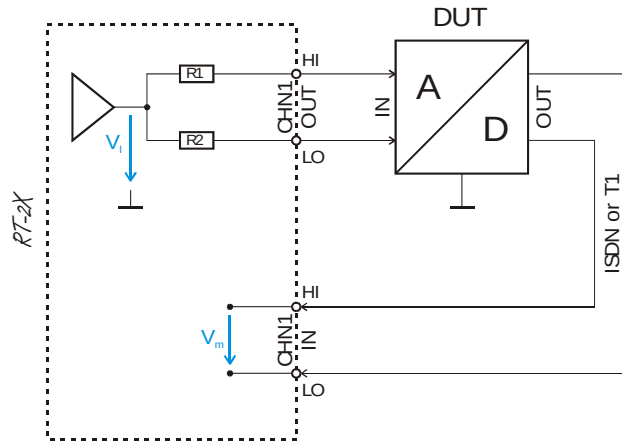


Fig 41 LCTL Measurement of an A-D Device

D-A Device Testing

1. Connect **RT-2X** as shown in **Fig 42**.
2. Adjust the sampling rate to 8 kHz (**SYSTem:MODE 8K**).
3. Switch **RT-2X** to the D-A operation (use **OUTPut:SOURce ISDn** or **T1** and **INPut:SOURce ANALog**).
4. Activate the LCL mode with command **INOUT:LCLBridge:MODE LCL**.
5. Adjust the operation of the **RT-2X** digital interface. In case of T1, the slot-number, signaling and ON-/OFF-hook must be defined (chapter **E1/T1 Interface**, p. 170). In case of ISDN, the channel must be activated (chapter **ISDN Interface**, p. 190).
6. Select the reference impedance value (**INOUT:LCLBridge:REFimplctl <Impedance>**) identical to the analog impedance of the DUT.
7. Activate the termination with command **INOUT:LCLB:TERM REFG**
8. Activate the multitone test signal (**OUTPut:MTONE:ACTivE [5'6'7'8]**).
9. Adjust the **RT-2X** output level (p. 234). The most frequently used level is 0 dBm. In any case the output level V_m must be $\leq 7.0 \text{ Vp} = 16.9 \text{ dBVp}$.
10. Adjust the input range with **INOUT:LCLBridge:RANGe [HIGHer40'LOWer40]**. Choose **HIGHer40** for high-quality DUTs with an expected LCL result $> 40 \text{ dB}$.
11. Start the measurement with the command **OUTPut:MTONE:STARt** and query the results with **MEASurement1:LCTL?**

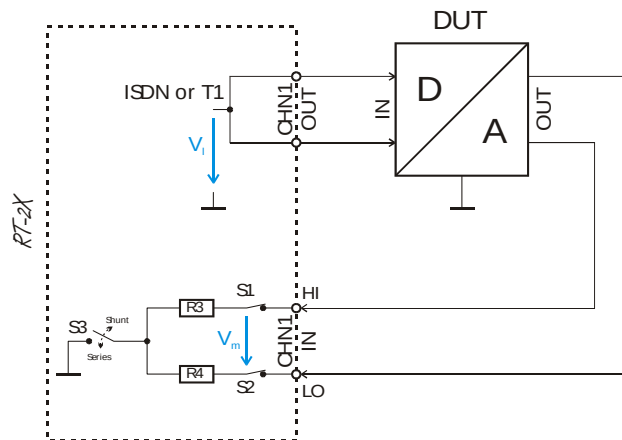


Fig 42 LCTL Measurement of a D-A Device

Loudness Rating (SLR, RLR, STMR according to ITU-T P.79)

Loudness Rating is a measure to indicate how loud the user perceives the speech transmission through a phone.

RT-2X supports the following measurements:

- SLR (Send Loudness Rating)
- RLR (Receive Loudness Rating)
- STMR (SideTone Masking Rating)

The standards that refer to Loudness Rating – e.g. ITU-T (CCITT) Recommendation P.79 or GSM 03.50 – specify the measurement setup through an artificial mouth and ear. Although the test could be executed without these items, it is recommended to comply with the standard in practice.

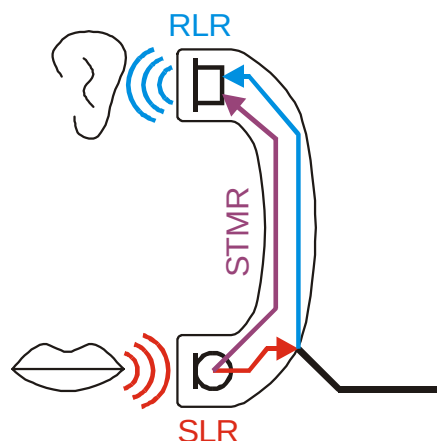


Fig 43 Loudness Rating Overview

Predefined Testsignal

RT-2X comprises a predefined loudness testsignal according to the ITU-T recommendation and GSM standard 03.50. Due to the multitone principle, the actual frequencies of the testsignal differ slightly from the standard. However, this does not compromise the accuracy of the measurement results.

ITU Rec.	48 kHz, blocklength 2048			8 kHz, blocklength 2048		
Frequency [Hz]	Frequency [Hz]	Frequency Error [%]	Signal Bin No.	Frequency [Hz]	Frequency Error [%]	Signal Bin No.
200	210.9	-5.45	9	203.1	1.54	13
250	257.8	-3.12	11	250.0	0.00	16
315	328.1	-4.16	14	312.5	-0.80	20
400	398.4	0.40	17	406.3	1.54	26
500	492.2	1.56	21	515.6	3.03	33
630	632.8	-0.44	27	640.6	1.66	41
800	796.9	0.39	34	796.9	-0.39	51
1000	1007.8	-0.78	43	1015.6	1.54	65
1250	1242.2	0.62	53	1265.6	1.23	81
1600	1593.8	0.39	68	1593.8	-0.39	102
2000	1992.2	0.39	85	2015.6	0.78	129
2500	2507.8	-0.31	107	2515.6	0.62	161
3150	3140.6	0.30	134	3156.3	0.20	202
4000	3984.4	0.39	170			

Table 15 Loudness Testsignal Frequencies

Activate the loudness testsignal with command **OUTPut:MTONe:ACTive LOUDNESS**, whereby the blocklength should be set to 2048 (command **OUTPut:MTONe:PARAmeter ...**). If a higher frequency resolution is required, copy the loudness signal to a standard multitone memory, chose a higher blocklength and amend the signal bins.

Setup Calibration for SLR, STMR Measurements

Prior to a SLR or STMR measurement, the setup – i.e. the artificial mouth – must be calibrated to make sure that the acoustic sound pressure level at the MRP is identical for all frequencies.

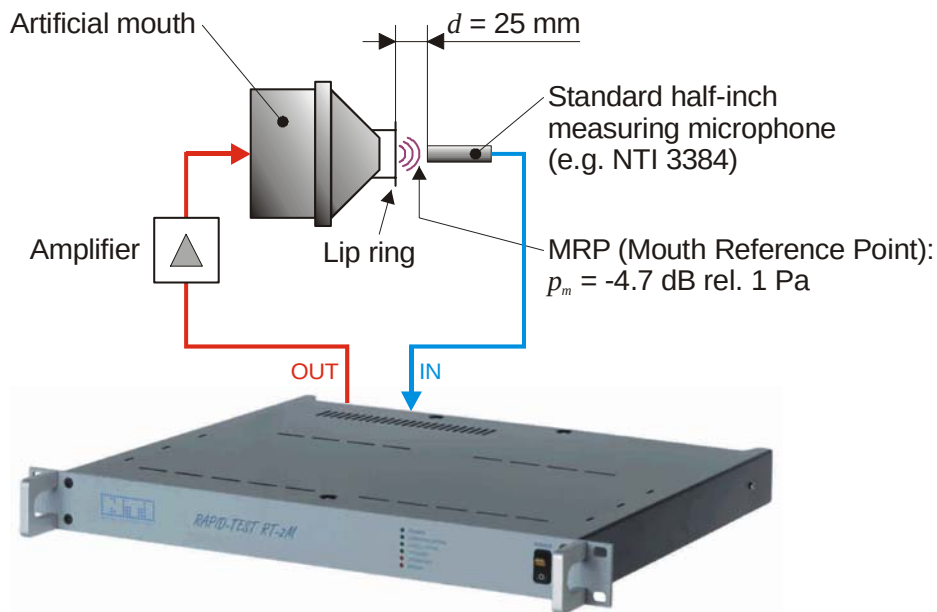


Fig 44 SLR, STMR Calibration Setup

The following list describes the calibration procedure.

1. Place a reference microphone 25 mm in front of the artificial mouth and connect it to the **RT-2X** input channel 1.
2. Select the predefined loudness multitone signal (**OUTPut:MTONe:ACTive LOUDNESS**).
3. Clear all binlevel weightings (**OUTPut:MTONe:CLearweightings**).
4. Activate the Phantom power on input channel 1 (**INPut1:IMPedance PHANTOM**).
5. Enter the sensitivity of the connected microphone (**INPut[1|2]:MICSensitivity <Sensitivity>**).
6. Set the output level to a very low voltage (e.g. -30 dBVp) to make sure that the artificial mouth will not be overdriven (**OUTPut1:LEVel -30 DBVP**).
7. Execute a measurement (**OUTPut:MTONe:STARt**).
8. Query the RSS Selective result, expressed in dBPA in the band from 20 Hz to 20 kHz (**MEASurement1:SElectiverss:UNIT dBPA, MEASurement1:SElectiverss? 1 853**).
9. Stepwise increase the **RT-2X** output level and repeat the RSS Selective measurement until the result reaches -4.7 dBPA.
10. Equalize the **RT-2X** output signal (**OUTPut[1|2]:MTONe:EQUalize**).
11. Repeat step 9. to make sure that the acquired RSS Selective is still -4.7 dBPA.
12. Note the current **RT-2X** output level (**OUTPut1:LEVel? DBVP**) and binlevel weighting (**OUTPut:MTONe:PARAmeter?**).

SLR Measurements

SLR reflects the signal loudness in sending direction, i.e. from the artificial mouth through the phone to the transmission line. A small SLR result indicates that the signal at the end of the transmission line is perceived as being loud. The SLR of a phone should be:

- 8 dB +6/-3 dB (acc. to ITU-T P.79)
- 8 dB $\pm$ 3 dB (acc. to GSM 03.50)

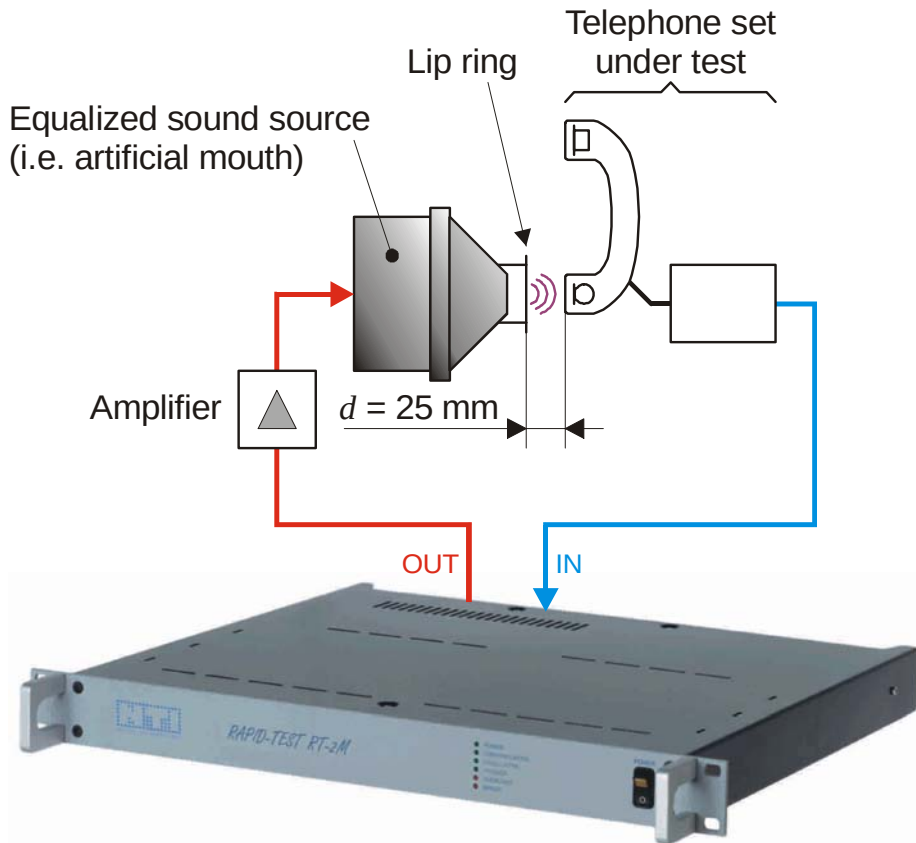


Fig 45 SLR Measurement Setup

NOTE Prior to SLR measurements, a calibration must be executed.

The following list describes the required steps for a SLR measurement:

1. Place the phone's mouthpiece 25 mm in front of the artificial mouth.
2. Select the *RT-2X* output level and binlevel weighting according to the values that have been acquired during calibration (**OUTPut1:LEVel ...**, **OUTPut:MTONe:PARAmeter ...**).
3. Activate the input AC Coupling (**INPut1:ACCOupling ON**; LCL/RL option required).
4. Select the input impedance that matches best the DUT, e.g. 600 Ω (**INPut1:IMPedance 600**; not required for A-D setups).
5. Query the headroom (**MEASurement[1|2]:HEADroom?**) and adjust the input range properly (**INPut[1|2]:RANGe <InputRange> [DBVP|VP]**).
6. Transmit the test signal (**OUTPut:MTONe:STARt**).
7. Query the SLR result (**MEASurement[1|2]:LOUDnessrating:SLR?**).

RLR Measurements

RLR reflects the signal loudness in receiving direction, i.e. from the transmission line through the phone to the artificial ear. A small RLR result indicates that the signal at the end of the artificial ear is perceived as being loud. The RLR of a phone should be in the range of 2 dB $\pm$ 3 dB (acc. to ITU-T P.79, GSM 03.50).

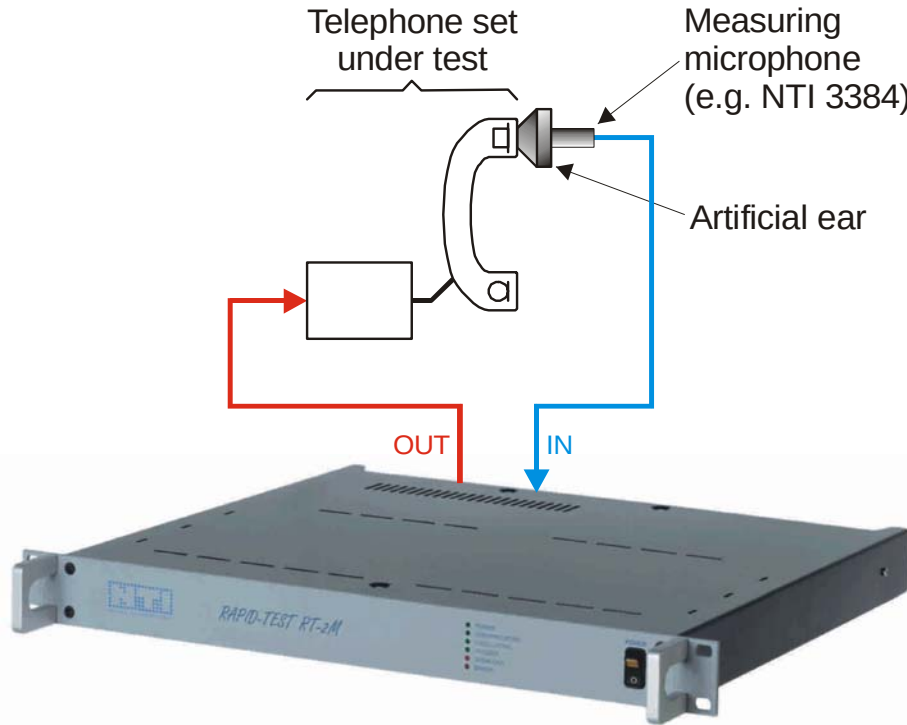


Fig 46 RLR Measurement Setup

Execute a RLR measurement as described below:

1. Activate the output AC Coupling (**OUTPut1:ACCOupling ON**; LCL/RL option required).
2. Press the earpiece of the telephone set onto the artificial ear.
3. Select the output impedance matching to the DUT, e.g. 600 Ω (**OUTPut1:IMPedance 600**; not required for D-A setups).
4. Activate the internal **RT-2X** Phantom power (**INPut1:IMPedance PHANTOM**; only if no external microphone power supply is used).
5. Enter the microphone sensitivity (**INPut[1|2]:MICSensitivity <Sensitivity>**).
6. Select the predefined loudness multitone signal (**OUTPut:MTONE:ACTive LOUDNESS**).
7. Clear all binlevel weightings (**OUTPut:MTONE:CLEarweightings**).
8. Adjust the **RT-2X** output SineLevel to -12 dBV (**OUTPut1:SINelevel -1.2E+01 DBV**) or to -15.8 dBm @ 600 Ω (**OUTPut1:SINelevel -1.58E+01 DBM**) or to -12 dBFS (D-A setups).
9. Query the headroom (**MEASurement[1|2]:HEADroom?**) and adjust the input range properly (**INPut[1|2]:RANGe <InputRange> [DBVP|VP]**).
8. Transmit the test signal (**OUTPut:MTONE:STARt**).
10. Query the RLR result (**MEASurement[1|2]:LOUDnessrating:RLR?**).

STMR Measurements

STMR reflects the loudness of the feedback signal, i.e. the sidetone from the mouthpiece of the phone to its earpiece. A small STMR result indicates that the signal at the earpiece is perceived as being loud. The STMR of a phone should be in the range of 15 dB $\pm$ 5 dB (acc. to ITU-T P.79).

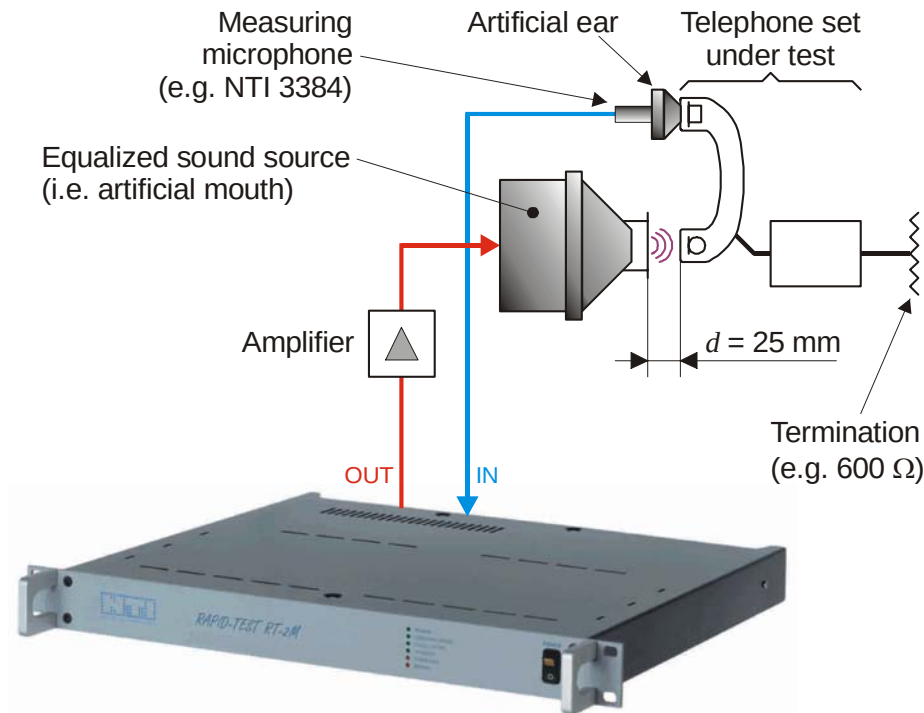


Fig 47 STMR Measurement Setup

NOTE Prior to STMR measurements, a calibration must be executed.

The following list describes the required steps for a STMR measurement:

1. Place the phone's mouthpiece 25 mm in front of the artificial mouth and press the earpiece onto the artificial ear.
2. Make sure that the telephone set is terminated properly (if you connect it to an unused *RT-2X* input or output, activate the AC-coupling and the corresponding output/input impedance).
3. Select the *RT-2X* output level and binlevel weighting according to the values that have been acquired during calibration (**OUTPut1:LEVel ...**, **OUTPut:MTONe:PARAmeter ...**).
4. Enter the microphone sensitivity (**INPut[1|2]:MICSensitivity <Sensitivity>**).
5. Activate the internal *RT-2X* Phantom power (**INPut1:IMPedance PHANTOM**; only if no external microphone power supply is used).
6. Query the headroom (**MEASurement[1|2]:HEADroom?**) and adjust the input range properly (**INPut[1|2]:RANGe <InputRange> [DBVP|VP]**).
7. Transmit the test signal (**OUTPut:MTONe:STARt**).
8. Query the STMR result (**MEASurement[1|2]:LOUDnessrating:STMR?**).

MT-SINAD

NOTE At $f_s = 8$ kHz, the analog analyzer bandwidth is 20 Hz – 3.4 kHz, whereby the digital measuring bandwidth is 20 Hz – 4 kHz.

SINAD is the reciprocal of THD+N:

$$SINAD = \frac{Signal + Noise + Distortion}{Noise + Distortion}$$

Equation 13 SINAD Definition

The command **MEASurement[1'2]:MTSinad?** allows querying the corresponding result after a multitone signal transmission.

HINT To get a true SINAD result it is necessary to stimulate the DUT only with a single sine wave. If a multitone signal is applied, intermodulation products appear that increase the Noise+Distortion value. Therefore, the RT-2X result is called MT-SINAD herein.

Noise

NOTE At $f_s = 8$ kHz, the analog analyzer bandwidth is 20 Hz – 3.4 kHz, whereby the digital measuring bandwidth is 20 Hz – 4 kHz.

The noise measurement divides the frequency band in sub-bands, split by the signal bins, and calculates the noise values of these sub-bands.

- **MEASurement[1'2]:NOISe:UNIT [DBV|V|DBM|DBFS|%FS|DBM0]** defines the unit, in which the noise results are expressed.
- **MEASurement[1'2]:NOISe?** queries the noise results after a multitone signal transmission.

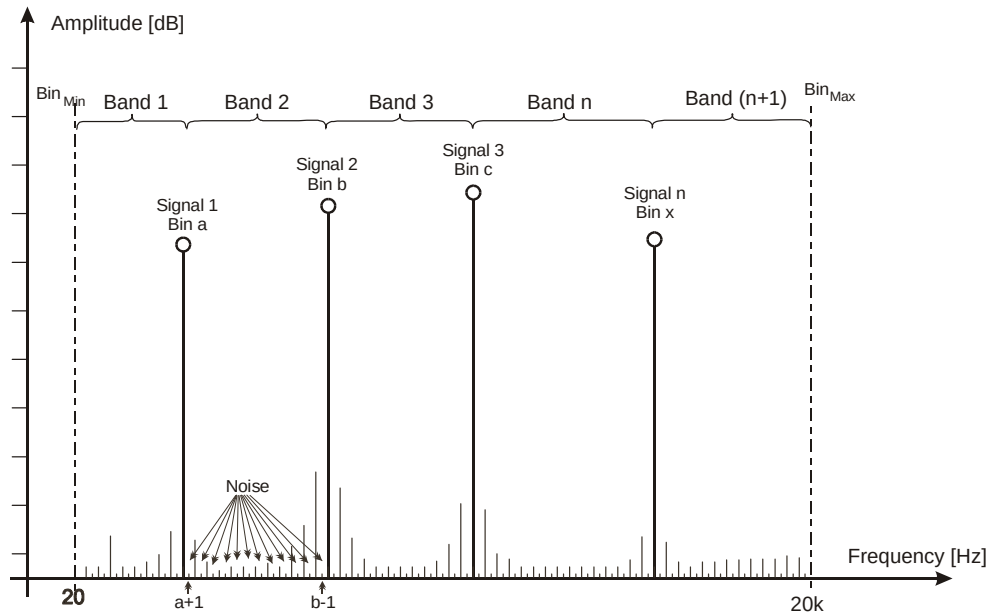


Fig 48 Multitone Noise Measurement

A noise measurement of a multitone signal with n signal bins results in $n+1$ noise values, each calculated internally by **RT-2X** according to the following formula.

$$Noise_i = \sqrt{2 * \sum_{i=a+1}^{b-1} (U_{2i-1})^2} = \text{RSS value of all odd bins in a band}$$

Equation 14 Internal Noise Calculation

wherein $a+1$ and $b-1$ = numbers of the odd bins above bin a and below bin b
 U_{2i-1} = level of odd bin No. $(2*i)-1$ with i = counter variable (integer)

NOTE Equation 14 describes the internal noise calculation of **RT-2X**, i.e. the actually returned noise results must not be re-calculated in any way.

Example

Let's assume that a multitone signal with 3 signal bins (300 Hz, 1 kHz and 3 kHz) has been transmitted through the DUT. By sending the command **MEASurement[1|2]:NOISe?** to **RT-2X**, the four noise results N_{300} , N_{1k} , N_{3k} and N_{20k} are calculated.

- N_{300} = noise energy from 20 Hz – 300 Hz
- N_{1k} = noise energy from 300 Hz – 1 kHz
- N_{3k} = noise energy from 1 kHz – 3 kHz
- N_{20k} = noise energy from 3 kHz – 20 kHz

Full Band Noise

Command **MEASurement[1|2]:NOISe:FULLband?** calculates the noise in the full frequency band (20 Hz – 20 kHz @ 48 kHz or 20 Hz – 4 kHz @ 8 kHz) according to the following equation.

$$N_{Fullband} = \sqrt{N_1[V]^2 + N_2[V]^2 + \dots + N_n[V]^2}$$

Equation 15 Full Band Noise

wherein $N_1-N_n [V]$ = the noise results of the bands between the signal bins.

*HINT The returned results of the individual and the fullband noise queries (**MEASurement[1|2]:NOISe?** and **MEASurement[1|2]:NOISe:FULLband?**) can be expressed in three different units, selected by **MEASurement[1|2]:NOISe:UNIT [DBV|V|DBM|DBFS|%FS|DBM0]**.*

Idle Channel Noise

To evaluate the *idle channel noise* of a DUT with **RT-2X**, proceed in the following way:

- Mute the generator output (**OUTPut[1|2]:MUTe ON**)
- Set the trigger mode to InternalNoHeader (**INPut:SYNC INTNoheader**)
- If required (e.g. for telecom applications), activate the C-message weighting filter (**INPut:SWFilter CWEighting**) and set the measurement unit to dBm (**MEASurement[1|2]:SElectiverss:UNIT DBM**)
- Transmit the multitone signal (**OUTPut:MTONe:START**)
- Query the measurement result with **MEASurement[1|2]:SElectiverss? <Binstart> <Binstop>**, where the values of **<binstart>** and **<binstop>** that define the frequency band of interest, must be selected by the user (p. 223).

Phase

NOTE At $f_s = 8$ kHz, the analog analyzer bandwidth is 20 Hz – 3.4 kHz, whereby the digital measuring bandwidth is 20 Hz – 4 kHz.

The *phase* measurement results reflect the *differences of the phase shifts* for the signal bins of a transmitted multitone signal. This measurement requires the transmission of a stereo signal with at least one identical signal bin on both channels.

- **MEASurement:PHASe:UNIT [RAD|DEG]** defines the unit, in which the result is expressed.
- **MEASurement:PHASe:SCALe <Scale>** defines the scaling of the result.
- **MEASurement[1|2]:PHASe?** queries the phase results after a multitone signal transmission.

RT-2X only calculates the phases φ_i of those signal bins i that are identical on both channels of the received multitone signal, according to

$$\varphi_i = \varphi(U_i^{Left}) - \varphi(U_i^{Right})$$

Equation 16 Phase Calculation

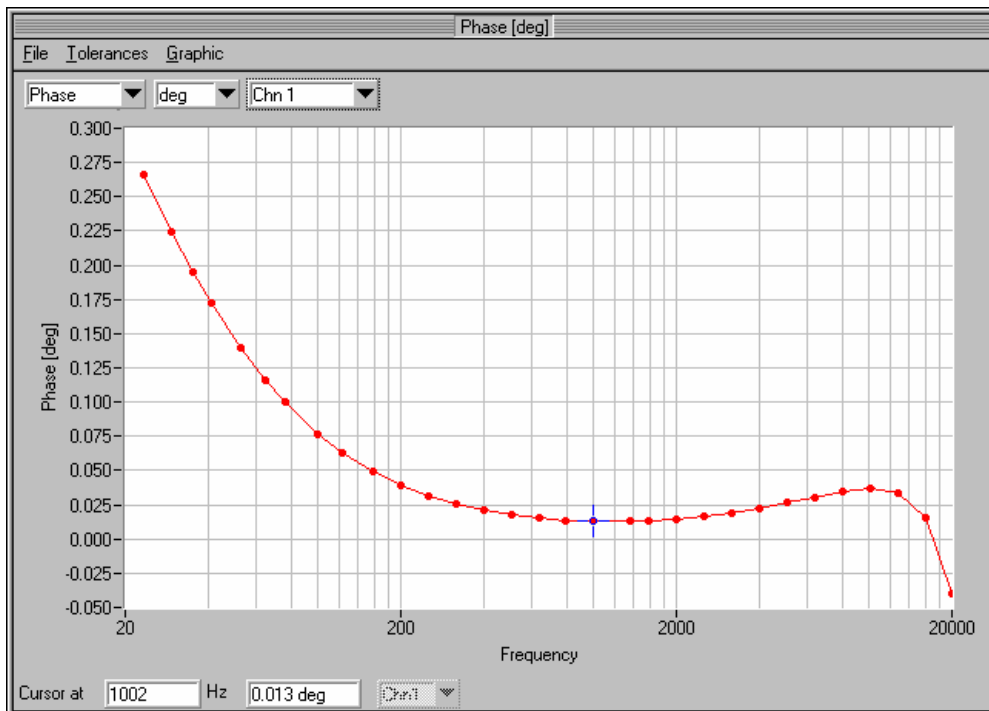


Fig 49 Phase Plot (RT-EVAL Screenshot)

The phase function can be used for two applications:

1. To measure the *phase difference* between the two channels of a multitone signal that has been transmitted e.g. through a stereo device or through two devices. For this application, both channels of RT-2X must be fed through the DUT(s).
2. To measure the *absolute phase shift* of a single-channel device. For this application, the output & input of one RT-2X channel must be connected directly (e.g. by using the command **INPUT[1|2]:LINK ON**), whereby the alternate channel is fed through the DUT. Keep in mind that this measurement is restricted to a maximum of 360° degrees (2π)

Return Loss (RL)

Note The RL measurement function is only available if the LCL/RL option is installed on the *RT-2X*.
The specified RL accuracy is only achievable if the DUT is not grounded.

Expressed in official terms (IEEE 743-1995), "*The **Return Loss** (RL) is a measure of the dissimilarity between two impedances, being equal to the number of decibels that corresponds to the scalar value of the reciprocal of the reflection coefficient, and hence being expressed by the following formula.*"

$$RL[dB] = 10 * \log_{10} \left(\frac{\text{transmittedPower}(f)}{\text{reflectedPower}(f)} \right)$$

$$= 10 * \log_{10} \left(\frac{S1}{S1 - S2} \right) = 20 * \log_{10} \left(\frac{Z_{Ref} + Z_{DUT}}{Z_{Ref} - Z_{DUT}} \right)$$

Equation 17 RL Definition

where **S1** = apparent power of transmitted signal at frequency *f*
 S2 = apparent power at DUT at frequency *f*
 S1-S2 = reflected apparent power at frequency *f*
 Z_{Ref} = *RT-2X* reference impedance
 Z_{DUT} = impedance of the DUT

In other words, RL is calculated as the ratio of the transmitted power to the reflected power that occurs due to the impedance mismatch between the output and input device. The RL measurement is executed as follows:

- Switch the *RT-2X* unit to A-A operation with **OUTPut:SOURCE ANALog, INPut:SOURCE ANALog**.
- Enter the RL mode (**INOUT:RLBridge:MODE ON**).
- Connect the *RT-2X* output channel 1 with the DUT as shown in **Fig 50**.
- Select the required multitone signal (command **OUTPut:MTONE:ACTive [1|2|3|4|5|6|7|8]**).
- Select the *RT-2X* output impedance of channel 1 by using command **OUTPut[1|2]:IMPedance ...** identical to the (expected) impedance of the DUT. This is the reference impedance of the RL measurement. If the available *RT-2X* output impedance do not match the DUT's impedance, select the most similar impedance or install an appropriate customer impedance (custom-defined impedance options for *RT-2X* are available from **NTI**).
- Adjust the *RT-2X* output level of channel 1 to the desired voltage (use the command **OUTPut1:LEVel ...**). The most frequently used level is 0 dBm. In any case the multitone output level must be within the range from -20 dBVp to +14 dBVp.
- Start the signal measurement with the command **OUTPut:MTONE:STARt**.
- Query the measurement results with the command **MEASurement:RL?**

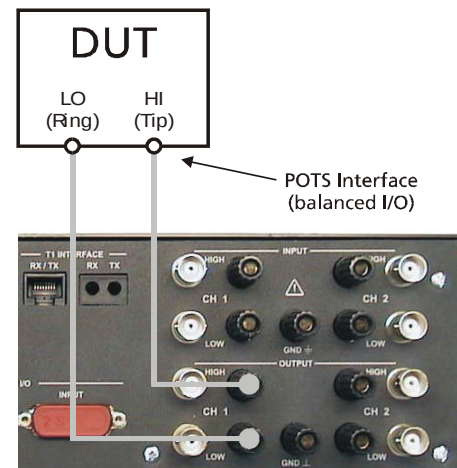


Fig 50 RL Setup

RSS Selective Level

NOTE At $f_s = 8$ kHz, the analog analyzer bandwidth is 20 Hz – 3.4 kHz, whereby the digital measuring bandwidth is 20 Hz – 4 kHz.

RT-2X allows measuring the total received energy (level + total distortion + noise) in a user-defined band (*Equation 7*, p. 204).

- **MEASurement[1'2]:SElectiverss:UNIT** [DBV|V|DBSPL|DBPA|DBM|DBFS|%FS|DBM0] sets the unit, in which the result is expressed.
- **MEASurement[1'2]:SElectiverss? <Binstart> <Binstop>** queries the total energy in the band between <binstart> and <binstop>. The two borders can be set freely and do not have to be identical to the signal bins of the transmitted multitone signal.

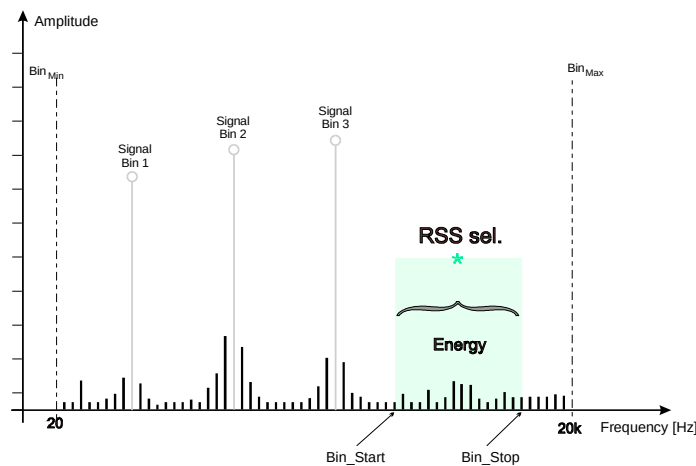


Fig 51 RSS Selective Measurement

NOTE The RSS selective measurement queries the total energy that was received in the specified band, i.e. *level + distortion + noise*.

The RSS selective analysis can also be executed on an *externally* generated signal. Thus, it becomes possible to measure specific signal components of any received signal.

Sound Pressure Level (SPL)

Proceed as follows to measure the sound pressure level in dB_{SPL}:

- Connect a microphone to the RT-2X input and activate the internal microphone power supply if required (**INPut[1'2]:IMPedance PHANTOM**). Make sure that RT-2X is switched to the correct Phantom power (15 V or 48 V).
- Enter the microphone sensitivity, expressed in [mV/Pa] with **INPut[1'2]:MICSensitivity <Sensitivity>**
- **MEASurement[1'2]:SElectiverss:UNIT DBSPL** selects the unit [dB_{SPL}] for the SPL query.
- **MEASurement[1'2]:SElectiverss? <binstart> <binstop>** queries the sound pressure level after the data acquisition. Normally, the band between <binstart> and <binstop> covers the frequency range from 20 Hz – 20 kHz @ $f_s = 48$ kHz and 20 Hz – 4 kHz @ $f_s = 8$ kHz. However, this range can also be limited to a narrower band, e.g. if the sound to be measured has a predictable, fixed frequency.

Multitone Pretrigger

Some devices (e.g. amplifiers with automated gain control, AGC) require a certain time to stabilize themselves to an incoming signal. This settling process can affect the *RT-2X* trigger in a way that the analyzing unit cannot recognize the trigger any more.

To overcome this effect, *RT-2X* allows inserting a neutral *pretrigger* signal in front of the proprietary trigger. Use the command **OUTPut:MTONe:PRETriggerlength <Length>** to let the DUT stabilize.

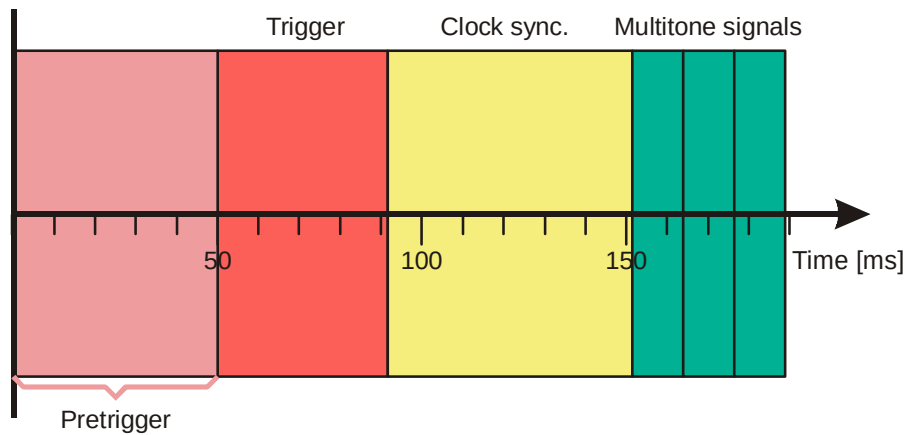


Fig 52 Pretrigger (example)

Multitone (Signal) Bins

The frequencies that are available for the multitone signal definition are called *bins*. For a better understanding, three types of bins are differentiated.

- *Signal bins* are those bins (frequencies) that are actually selected by the user to build the multitone signal.
- *Even bins* are the bins (frequencies) that emerge from **Equation 4** (p. 200), i.e. the frequencies that can be used as signal bins in a multitone signal.
- *Odd bins* are an effect of the internal FFT computation of RT-2X. They represent all bins halfway between the even bins, i.e. as if the frequency spacing would be $\Delta f/2$.

NOTE The RT-2X analyzer always samples 2 signal blocks, i.e. it operates at twice the blocklength of the defined multitone signal.
Thus, the frequency resolution of the RT-2X analyzer is $\Delta f/2$.

Example

Given Blocklength = 512 @ 48 kHz

- ⇒ Generator $\Delta f = 93.75$ Hz, i.e. available frequencies = $n * 93.75$ Hz ($n = \text{integer}$)
- ⇒ Analyzer frequency resolution = $\Delta f/2 = 46.88$ Hz

Number of Signal Bins

The maximum allowed number of signal bins (i.e. frequencies) in a RT-2X multitone signal is 31. All bins that are between **Bin_{Min}** and **Bin_{Max}** (**Equation 19** and **Equation 20**) can be made a signal bin. The distribution of the signal bins in a multitone signal is up to the user.

Multitone Signal Bin Number

For the definition of a multitone signal it is necessary to convert the required frequencies to the corresponding signal bin numbers as shown in **Equation 18**:

$$\text{SignalBin}_n = \text{Round}\left(\frac{f_n}{\Delta f}\right)$$

Equation 18 Calculation of Signal Bin Numbers

whereby f_n = required frequency
 Δf = frequency spacing (**Equation 4**, p. 200)

Example

Required Multitone signal with three signal bins $f_n = 300$ Hz, 1 kHz, 3 kHz

Given $f_s = 8$ kHz, blocklength = 128 ($\Rightarrow \Delta f = 62.5$ Hz)

Calculation $\text{Bin}_n = \text{Round}\left(\frac{f_n}{\Delta f}\right) = \frac{f_n [\text{Hz}]}{62.5 [\text{Hz}]}$ $\Rightarrow$ Signal bin numbers: 5, 16, 48

Bin_{Min} and Bin_{Max}

The minimum and the maximum available frequencies (Bin_{Min} and Bin_{Max}) of **RT-2X** are given by following formulas (whereby $\text{SamplingRate} = 8'000$ or $48'000$ and $f_{\text{max}} = 4'000$ or $20'000$ respectively):

$$f_{\text{Bin\_Min}} \geq 20 [\text{Hz}] \quad \text{thus} \quad \text{Bin}_{\text{Min}} = \text{ceil}\left(\frac{\text{Blocklength}}{\text{SamplingRate} [\text{Hz}]} * 20 [\text{Hz}]\right)$$

Equation 19 Bin_{min} : Minimum Signal Bin Frequency ⁵

$$f_{\text{Bin\_Max}} \leq f_{\text{max}} \quad \text{thus} \quad \text{Bin}_{\text{Max}} = \text{floor}\left(\frac{\text{Blocklength}}{\text{SamplingRate} [\text{Hz}]} * f_{\text{max}} [\text{Hz}]\right)$$

Equation 20 Bin_{max} : Maximum Signal Bin Frequencies ⁶

⁵ "ceil()" = round to the next higher integer

⁶ "floor()" = round to the next lower integer

Multitone Signal Definition

RT-2X can store up to 8 user-defined multitone signals in its non-volatile memory. Each signal comprises a fully independent signal bin (frequencies) definition for both channels, whereby a maximum of 31 signal bins can be defined per channel.

- Signals #1 – 4 are only available @ $f_s = 48$ kHz.
- Signals #5 – 8 are only available @ $f_s = 8$ kHz.
- The three specific signals "**ERL**", "**SRLLO**" and "**SRLHI**" are only available if the LCL/RL option is installed.

OUTPut:MTONe:PARAmeter ... (p. 69) defines a new multitone signal. This command comprises of the following information:

- *Memory location* of the signal: 1 to 4 ($f_s = 48$ kHz), 5 to 8 ($f_s = 8$ kHz) or ERL, SRLHI, SRLLO.
- *Name* of the signal, i.e. a user-defined ASCII string with up to 8 characters.
- *Blocklength* (number of samples). Available values are shown in **Table 16** (p. 230).
- *Number of signal bins* for channel 1 defines the number of frequencies that build the multitone signal of channel 1; the minimum is 1, the maximum is 31.
- *Number of signal bins* for channel 2 defines the number of frequencies that build the multitone signal of channel 2; the minimum is 1, the maximum is 31.
- *Signal bin numbers* of channel 1 (to be calculated according to the equation below).
- *Signal bin numbers* of channel 2 (to be calculated according to the equation below).
- *Phases* of the signal bins for channel 1
- *Phases* of the signal bins for channel 2

Example

Required Multitone signal parameters

Given Memory location #3
Signal name: 'Test'
blocklength = 1024
3 signal bins on channel 1: No. 6, 21, 64
5 signal bins on channel 2: No. 3, 12, 36, 48, 72
Signal bin phases of chn. 1: $-\pi$, 1.234, $1/\sqrt{2}$
Signal bin phases of chn. 2: 0, 2.456, 0.819, 1.414, 0.111

Result OUTP:MTON:PAR 3,"Test",1024,3,5,6,21,64,3,12,36,,48,72,
-3.141,1.234,0.707,0,2.456,0.819,1.414,0.111

HINT Optimize the signal bin phases with the Crest factor optimizer of RT-EVAL.

NOTE The multitone burst can be prolonged artificially with a pretrigger or the repeated transmission of the multitone signal (p. 204).

Multitone Signal Duration

The duration of the *multitone signal* depends on the current blocklength and sampling rate:

$$t_{MT}[\text{sec}] = \frac{\text{blocklength}}{\text{SamplingRate}[\text{Hz}]}$$

Equation 21 Multitone Signal Duration

However, as shown in chapter **Multitone Burst Structure** (p. 198) every *RT-2X* multitone burst comprises of several multitone signal blocks. Consequently, the actual multitone *burst* duration will always be longer than the multitone *signal* duration (**Table 16**, p. 230)).

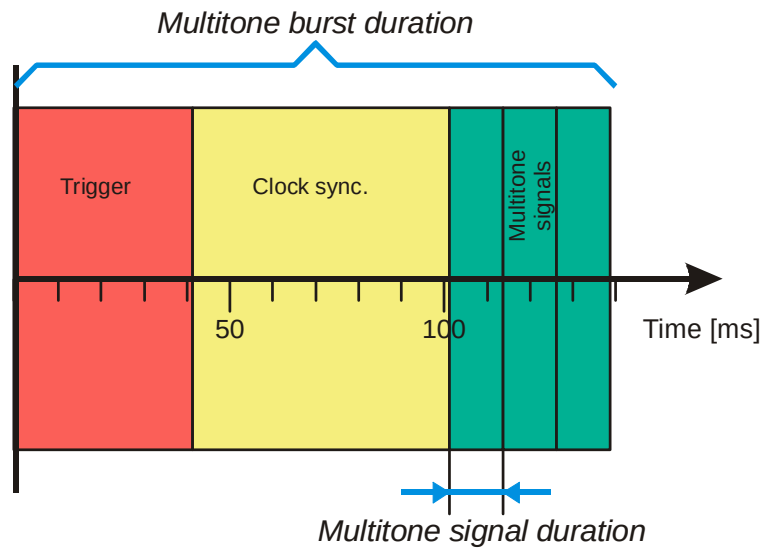


Fig 53 Multitone Signal Duration vs. Burst Duration

Multitone Signal Recording Duration

The signal acquisition time of **RT-2X** depends on the selected trigger mode and of the blocklength of the active multitone signal.

In the **INTernal**, **INTNoheader**, **EXTernal** and **EXTNoheader** trigger mode, the sampling time of the **RT-2X** analyzer is optimized to the transmitted multitone signal.

In the **THReshold** triggering mode, the signal acquisition time t_{Acq} is given by:

$$t_{Acq}[s] = \frac{Blocklength}{SamplingRate[Hz]} * 2$$

Equation 22 Acquisition Duration

Consequently, if an externally generated signal shall be analyzed by **RT-2X**, it must have a minimum duration of:

$$t_{ExtMin} = t_{Delay} + t_{Acq}$$

Equation 23 Minimum Signal Duration for External Signal Analysis

Multitone Signal Table

The following table provides an overview on the most important multitone signal parameters:

- Blocklength
- Multitone signal duration
- Frequency resolution (spacing)
- Bin_{Min} and Bin_{Max}

f_s	Generator Block-length	Analyzer Block-length	Min. Burst Duration (without Header)	Typical Burst Duration	Frequency Resolution Δf	Analyzer Resolution $\Delta f/2$	Bin_Min / f_{min}	Bin_Max / f_{max}
8 kHz	128	256	284 ms	390 ms	62.5 Hz	31.25 Hz	1 / 62.5 Hz	63 / 3.938 kHz
	256	512	484 ms	590 ms	31.25 Hz	15.63 Hz	1 / 31.3 Hz	127 / 3.969 kHz
	512	1024	574 ms	680 ms	15.63 Hz	7.81 Hz	2 / 31.3 Hz	255 / 3.984 kHz
	1024	2048	1084 ms	1190 ms	7.81 Hz	3.91 Hz	3 / 23.4 Hz	511 / 3.992 kHz
	2048	4096	1334 ms	1440 ms	3.91 Hz	1.95 Hz	6 / 23.4 Hz	1023 / 3.996 kHz
48 kHz	512	1024	154 ms	260 ms	93.75 Hz	46.88 Hz	1 / 93.8 Hz	213 / 19.97 kHz
	1024	2048	284 ms	390 ms	46.88 Hz	23.44 Hz	1 / 46.9 Hz	426 / 19.97 kHz
	2048	4096	344 ms	450 ms	23.44 Hz	11.72 Hz	1 / 23.4 Hz	853 / 19.99 kHz
	4096	8192	684 ms	790 ms	11.72 Hz	5.86 Hz	2 / 23.4 Hz	1706 / 19.99 kHz
	8192	16384	854 ms	960 ms	5.86 Hz	2.93 Hz	4 / 23.4 Hz	3413 / 19.99 kHz

Table 16 Blocklength and Multitone Burst Characteristics

Normal Mode

In the *Normal mode*, *RT-2X* supports analog multitone and stepped sweep testing. If a digital interface is installed (i.e. ISDN, E1/T1 or PCM), the unit supports in addition multitone testing on A-D, D-A (i.e. half channel) or D-D setups.

NOTE Some commands are not available if the analyzer has been armed, i.e. after the command **INPut:TRIGger:ARMed**.

The LCL/RL and PureSound™ measurement functions are not available in the Normal mode.

For half channel (A-D, D-A) or digital (D-D) operation, a digital interface (ISDN, E1/T1 or PCM) must be installed in *RT-2X*.

Stepped sweep analysis is not available in A-D, D-A and D-D operation.

A-A Operation

The A-A operation, i.e. the generation and analysis of analog multitone signals or a stepped sweep is available as standard on all *RT-2X* units.

- Connect the unit to the DUT as shown in **Fig 54**.

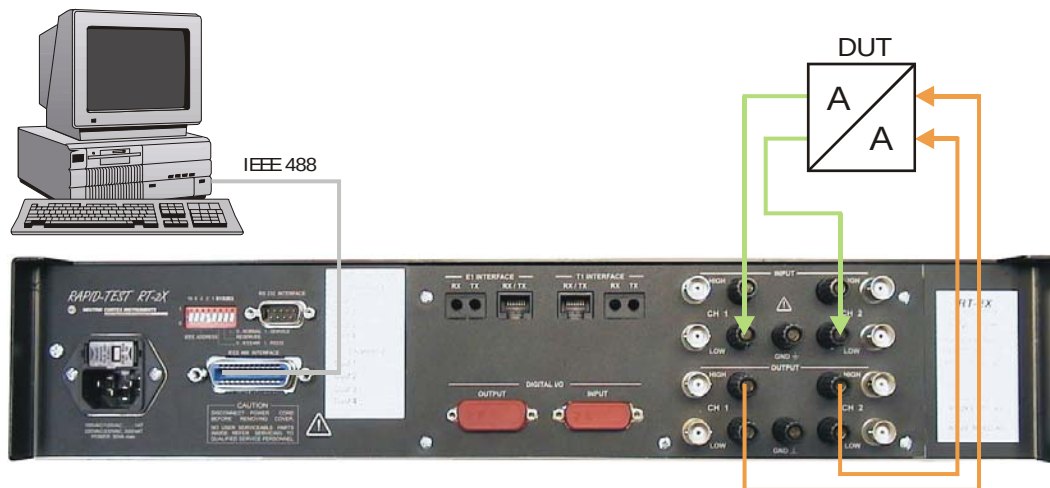


Fig 54 A-A Setup

- Activate the A-A operation with **OUTPut:SOURce ANALog** and **INPut:SOURce ANALog**.
- Adjust the *sampling rate* to 48 kHz with the command **SYSTem:MODE 48Ksamplingrate** (this frequency applies on the generator and analyzer).
- Activate one of the multitone signals that are stored in the internal memory with command **OUTPut:MTONe:ACTIve [1|2|3|4]**.
- Select the appropriate trigger mode (chapter **Triggering & Signal Acquisition**).
- Adjust the *RT-2X* output level (p. 234f) and the input range (p. 189).
- Transmit the multitone signal or the stepped sweep (commands **OUTPut:MTONe:STARt**, **OUTPut:STEPpedswEEP:STARt**).
- Query the required measurement results.

Half Channel Operation (A-D, D-A)

The A-D, D-A or "half channel" operation is typically used for applications where the DUT comprises an A/D or D/A converter, e.g. an ISDN telephone, E1/T1 linecard or PCM device. It is only available if *RT-2X* is equipped with a ISDN, E1/T1 or PCM interface.

Use the following commands to enter the half channel operation:

- Adjust the sampling rate to 8 kHz (**SYSTem:MODE 8Ksamplingrate**).
- Switch the *RT-2X* generator & analyzer to the respective operation mode (**OUTPut:SOURce [ANALog|ISDN|E1|T1|PCM]** and **INPut:SOURce [ANALog|ISDN|E1|T1|PCM]**).
- Activate one of the user-defined multitone signals stored in the internal memories #5 – 8 (command **OUTPut:MTONE:ACTivE [5|6|7|8]**) or one of the predefined test signals for Loudness (p. 213), Echo Return Loss or Singing Return Loss (p. 206) measurements (**OUTPut:MTONE:ACTivE [LOUDNESS|ERL|SRLHI|SRLLO]**).
- Select the appropriate trigger mode (p. 270).
- Adjust the output level (p. 234f) and – only for D-A operation – the input range (p. 189).
- Transmit the multitone signal (**OUTPut:MTONE:START**).
- Query the required multitone measurement results by sending the corresponding query commands to the *RT-2X* unit.

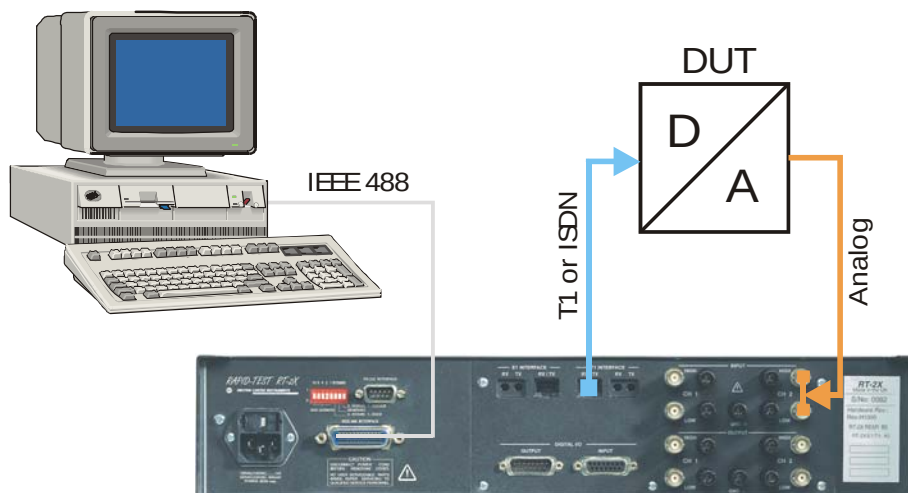


Fig 55 D-A Setup

NOTE In the half channel operation, not all measurement functions of *RT-2X* are available. Please refer to the corresponding command descriptions.

D-D Operation

If the ISDN or E1/T1 or PCM option is installed, it is possible to operate *RT-2X* as a purely digital test system.

- Adjust the sampling rate to 8 kHz (**SYSTem:MODE 8Ksamplingrate**).
- Switch the generator & analyzer to digital operation (**OUTPut:SOURce [ISDN|E1|T1|PCM]** and **INPut:SOURce [ISDN|E1|T1|PCM]**).
- Activate one of the user-defined multitone signals stored in the internal memories #5 – 8 (command **OUTPut:MTONE:ACTive [5|6|7|8]**).
- Adjust the *RT-2X* output level (p. 234f).
- Select the appropriate trigger mode (p. 270).
- Transmit the multitone signal (**OUTPut:MTONE:START**).
- Query the required multitone measurement results by sending the corresponding query commands to the *RT-2X* unit.

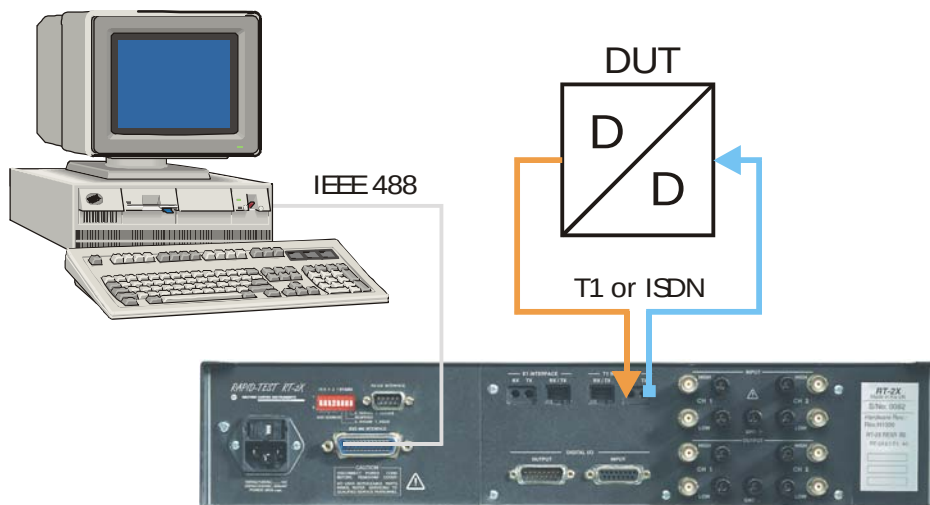


Fig 56 D-D Setup

NOTE In the D-D operation, not all measurement functions of *RT-2X* are available. Please refer to the corresponding command descriptions.

Output Level

The user must define the output level – i.e. the amplitude – of the test signal (e.g. multitone burst, stepped sweep or chirp) before the unit generates the signal. *RT-2X* offers three alternatives to set this value:

- The *MT Level* defines the amplitude of the active multitone signal.
- The *BinLevel* defines the reference amplitude for the signal bins of the active multitone signal.
- The *SineLevel* defines the reference amplitude for the stepped or gliding sweep ('chirp').

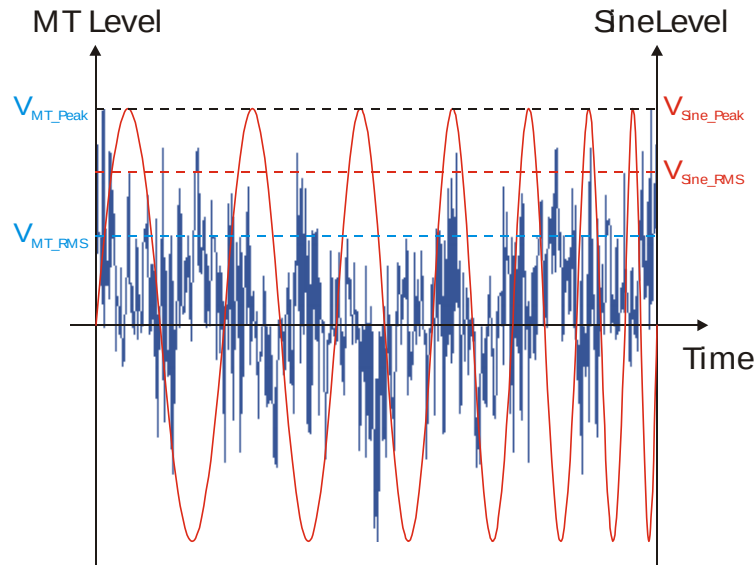


Fig 57 MT Level vs. SineLevel

Fig 57 shows the time plot of a multitone & sweep signal and visualizes their Peak & RMS levels. The mathematical correlation between V_{MT_Peak} and V_{MT_RMS} as well as V_{Sine_Peak} and V_{Sine_RMS} is given by following formulas:

$$V_{MT\_RMS} = \frac{V_{MT\_Peak}}{C_f}$$

$$V_{Sine\_RMS} = \frac{V_{Sine\_Peak}}{\sqrt{2}}$$

Equation 24 MT Level and SineLevel

In the case of $V_{MT\_Peak} = V_{Sine\_Peak}$, a direct correlation between V_{MT_RMS} and V_{Sine_RMS} can be established:

$$V_{MT\_RMS} = V_{Sine\_RMS} \frac{\sqrt{2}}{C_f}$$

Equation 25 MT Level vs. SineLevel

NOTE It is possible to apply a custom-defined *weighting* or *amplitude shape* to multitone signal or stepped sweep respectively.

MT Level

Define the *MT Level* with command **OUTPut[1|2]:LEVel <Level> [V|VP|DBV|DBVP|DBM|DBFSP|%FSP|DBFS|%FS|DBM0]**. Note that it can be expressed as *peak* or as *RMS* level in *linear* or *logarithmic* units.

In practice, the use of a peak unit is advantageous for those setups where the dynamic range of the DUT & transmission line is known.

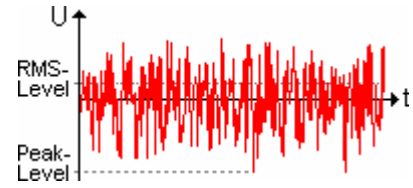


Fig 58 Overall Output Level

Binlevel

The *BinLevel* reflects the amplitude of the signal bins in a multitone signal. By default, all signal bins of a multitone signal have identical BinLevels that can be defined by **OUTPut[1|2]:BINlevel <BinLevel> ...**

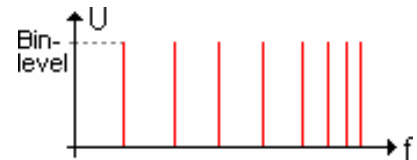


Fig 59 Binlevel

NOTE When adjusting the BinLevel of a multitone burst, keep in mind that its overall output level will be higher by $\sqrt{n}$. Therefore, never set the BinLevel to a value that corresponds to the full dynamic range of your DUT.

SineLevel

OUTPut[1|2]:SINElevel <SineLevel> [DBVP|VP|DBV|V|DBM|DBFSP|%FSP|DBFS|%FS|DBM0] defines the *SineLevel*, i.e. the RMS level of a generated sine signal. This command is normally used to adjust the output level of a stepped sweep, chirp, arbitrary sine signal or a multitone signal with only one signal bin.

If the command is applied on a multitone burst with several signal bins, **<SineLevel>** defines the multitone level that is equivalent to the level of a sine signal.

Please refer to **Fig 57** (p. 234) to understand how the MT Level and the SineLevel relate to each other, depending on the selected level unit (Peak or RMS).

Correlation Formulas

Following formulas summarize the correlation between the MT Level (U_{MT_Level}), Binlevel ($U_{BinLevel}$) and SineLevel ($U_{SineLevel}$).

$$U_{MT\_Level} [Vp] = U_{SineLevel} [Vp] = U_{MT\_Level} [V] * Cf = U_{SineLevel} [V] * \sqrt{2}$$

$$U_{BinLevel} [V] = (U_{MT\_Level} [V]) \sqrt{n}$$

Equation 26 Output Level Correlations

whereby Cf = Crest factor
 n = number of signal bins

Multitone Binlevel Weighting (Individual Binlevel)

RT-2X allows weighting the BinLevels of the signal bins. In other words, the operator can individually attenuate the signal bin levels of a multitone signal.

This feature is used to compensate for the frequency response of a test setup, e.g. of a reference speaker. Thus, it becomes possible to stimulate the DUT with a constant level at every signal bin.

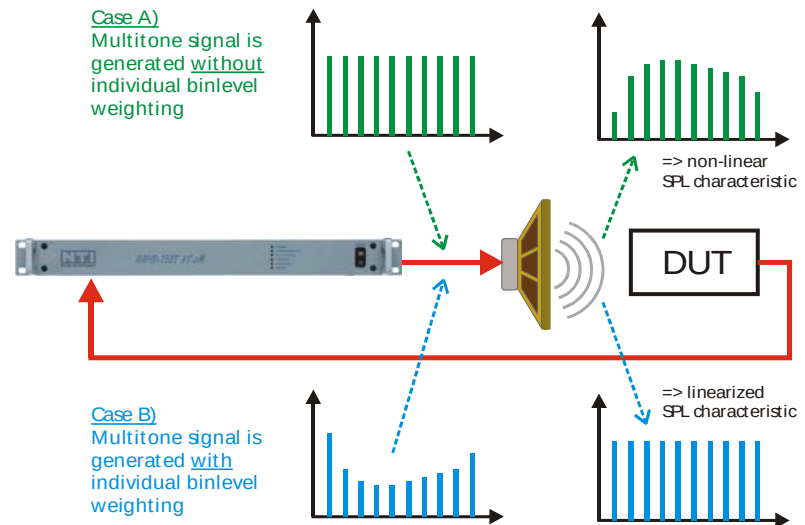


Fig 60 Multitone Binlevel Weighting Example

- Insert "WTD" to **OUTPut:MTONE:PARAmeter** <SigNo>,<SigName>,<Blocklength>,WTD,... and append the individual attenuation factors to apply an individual BinLevel weighting on the active multitone signal (p. 69).
- Alternatively, use command **OUTPut[1'2]:MTONE:EQUAlize** to let RT-2X automatically apply a BinLevel weighting that compensates for the frequency response of the DUT.
- Clear the individual BinLevel weighting with command **OUTPut:MTONE:CLEArweightings**.

NOTE At least one signal bin must be left unweighted, i.e. with an attenuation of 0 dB. The BinLevel of this signal bin is the reference for the output level (defined by command **OUTPut[1'2]:SINElevel ...** or **OUTPut[1'2]:BINlevel ...**), whereby the attenuation of the weighted signal bins are referred to the unweighted signal bin(s).

Example

Given A multitone signal with three signal bins (#3, #11, #32 @ $f_s = 48$ kHz, blocklength = 512, i.e. frequencies 281.25 Hz, 1031.25 Hz and 3 kHz) has to be transmitted through a reference speaker. A level measurement shows that the speaker attenuates the signal with -3 dB @ 281 Hz and with -6 dB @ 3 kHz (level result e.g.: 3/0.7000E+01 dBV, 11/1.0000E+01 dBV, 32/0.4000E+01 dBV)

Required The signal bin levels of the multitone signal shall be equalized in a way that the speaker has a constant sound pressure vs. frequency.

⇒ The BinLevels of the multitone signal have to be weighted on channel 1 with -3dB @ #3 and with -6 dB @ #11. The BinLevel of #32 (i.e. 3 kHz) of channel 1 as well as all BinLevels of channel 2 are not weighted. The string below shows the RT-2X command that defines such a multitone signal with an individual BinLevel weighting on channel 1:

Result `OUTPUT:MTONE:PAR 4,"3tone",512,WTD,3,3,3,11,32,3,11,32,-0.35254506,2.43579567,2.64434581,-0.35254506,2.43579567,2.64434581,-3.00000,-6.00000,0.00000,0.00000,0.00000,0.00000`

Stepped Sweep Amplitude Shaping

RT-2X allows shaping the output level vs. frequency of a stepped sweep. In other words, the operator can individually attenuate every level of a stepped sweep.

This feature is used to compensate for the frequency response of a test setup, e.g. of a reference speaker. Thus, it becomes possible to stimulate the DUT with a constant level at every frequency.

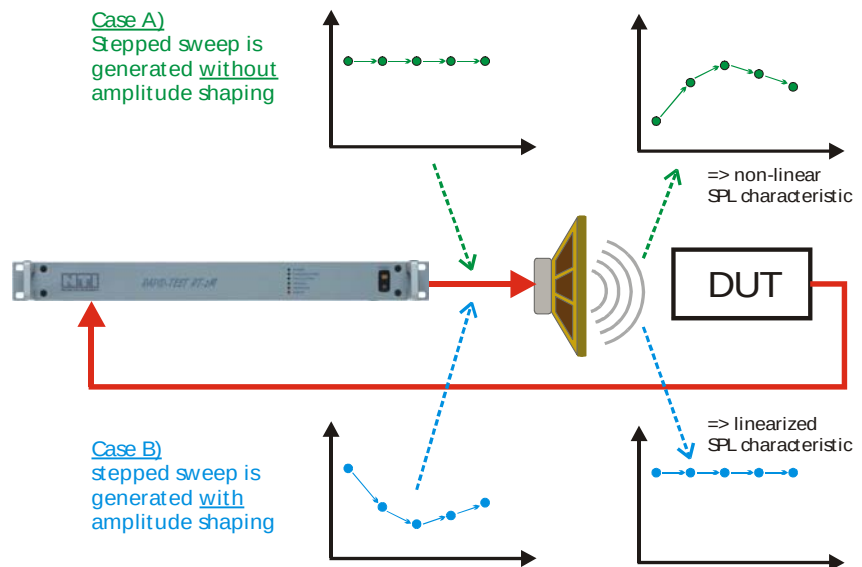


Fig 61 Stepped Sweep Amplitude Shaping Example

OUTPut:STEPpedSweep:A
MPLitudeShape:SET

<Shape1>,<Shape2>,...,<Shape#Steps+1> defines the individual shapes of the stepped sweep levels as attenuation factors, expressed in [dB].

NOTE At least one frequency must not be attenuated (i.e. <Shape_x> =0). This frequency is the reference for the output level definition.

Example

Given A stepped sweep with four frequencies ($f_{start} = 20$ Hz, $f_{stop} = 20$ kHz $\Rightarrow f_1 = 20$ Hz, $f_2 = 200$ Hz, $f_3 = 2$ kHz, $f_4 = 20$ kHz) has to be transmitted through a reference speaker. A level measurement shows following results: -1.5 dBV @ 20 Hz, -1.0 dBV @ 200 Hz, 0 dBV @ 2 kHz and -0.5 dBV @ 20 kHz (returned result vector: 2.00000E+01/-1.51249E+00 dBV, 2.00000E+02/-0.97894E+00 dBV, 2.00000E+03/+0.13587E-01 dBV, 2.00000E+04/-0.49761E+00 dBV).

Required The stepped sweep shall be equalized in a way that the speaker has a constant sound pressure level vs. frequency.

$\Rightarrow$ The levels of the stepped sweep have to be attenuated with 0 dB @ 20 Hz (reference level), -0.5 dB @ 200 Hz, -1.5 dB @ 2 kHz and -1.0 dB @ 20 kHz. The string below shows the RT-2X command that defines the attenuation on chn. 1 of the stepped sweep:

Result OUTPUT:STEPPEDSWEEP:AMPLITUDESHAPE:SET 0, -0.5, -1.5, -1

NOTE The <Shape_n> values refer to the reference (i.e. not attenuated) level. The output level of this reference frequency is defined by the command OUTPut[1'2]:SINelevel <SineLevel>

Output Level Query

Use the following commands to query the current output level:

- **OUTPut[1,2]:LEVel?** [V|VP|DBV|DBVP|DBM|DBFSP|%FSP|DBFS|%FS|DBM0] for the *MT Level*.
- **OUTPut[1,2]:BINlevel?** [V|VP|DBV|DBVP|DBM|DBFSP|%FSP|DBFS|%FS|DBM0] for the *BinLevel*.
- **OUTPut[1,2]:SINlevel?** [V|VP|DBV|DBVP|DBM|DBFSP|%FSP|DBFS|%FS|DBM0] for the *SineLevel*.
- **OUTPut:MTONE:PARAmeter?** returns the attenuation factors of the weighted multitone signal bins, referred to the unweighted reference signal bin.
- **OUTPut:STEPpedswEEP:AMPLitudeSHAPE:SET?** returns the attenuation factors of the shaped stepped sweep levels, referred to the reference frequency.

The commands can be used regardless whether the output level has been defined as *MT Level*, as *BinLevel* or as a *SineLevel*.

Obviously, the commands allow expressing the current output level in another unit. For instance, if the MT Level of a multitone signal has been defined in dBV, the amplitude of the signal bins can be queried in dBm etc.

PCM Interface

The optional PCM interface for *RT-2X* is a very flexible module for the generation and analysis of PCM-encoded (Pulse Code Modulated) audio signals:

- 2-channel multitone test signal transmission in A-D, D-A or D-D operation (p. 232ff).
- Various clock frequencies between 64 and 2048 kHz.
- User-defined bit clock, frame synchronization and audio data format.

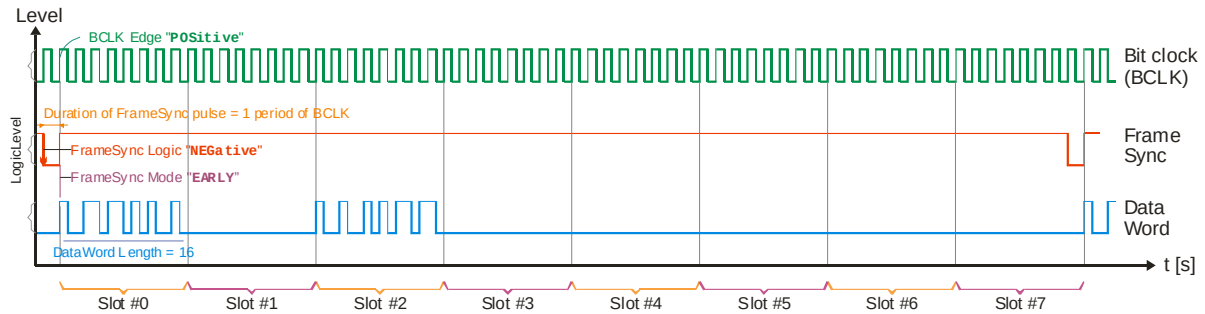


Fig 62 PCM data format example

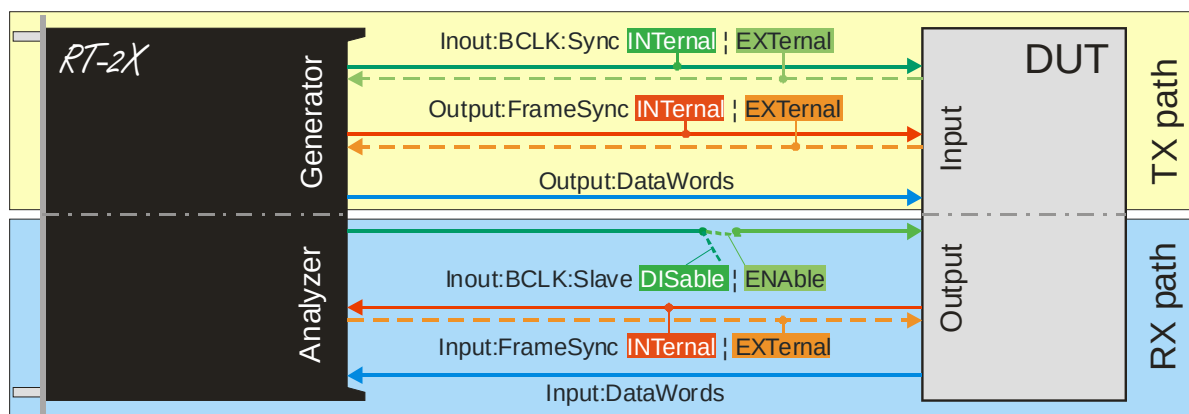


Fig 63 BCLK and FrameSync modes

PCM Bit Clock

The BCLK settings always apply on the TX and RX paths.

- **INOUT:PCM:LOGiclevel** <LogicLevel> defines the physical signal level (i.e. voltage) of the generated & incoming PCM data stream.

NOTE The LogicLevel applies for the BCLK, FrameSync and DataWord signals.

- **INOUT:PCM:BCLK:FREquency** <Frequency> defines the frequency (i.e. sampling rate) of the *RT-2X* houseclock (64, 104, 128, 256, 512, 1024, 1544, 2048 kHz).
- **INOUT:PCM:BCLK:EDGE** [POSitive|NEGAtive] sets the logic of the bit clock (sync to rising or falling edge).
- **INOUT:PCM:BCLK:SYNC** [EXTErnal|INTernAl] defines, whether the master bit clock is created internally (i.e. *RT-2X* houseclock = master bit clock) or by an external device (e.g. DUT clock = master bit clock).
- **INOUT:PCM:BCLK:SLAVE** [DISAbLe|ENABLe] allows synchronizing the DUT's output section to the the bit clock of *RT-2X*.

PCM FrameSync

The FrameSync pulse is used for synchronizing *RT-2X* and the DUT to the DataWords. The pulse has a fixed duration of one (1) bit clock period.

- **INOUT:PCM:FRAMESync:LOGic [POSitive|NEGative]** defines, whether the first (active) edge of the FrameSync pulse is rising or falling.
- **INOUT:PCM:FRAMESync:MODE [EARLy|LATe]** defines, whether the DataWords are synchronized to the first (i.e. active) or second edge of the FrameSync pulse.
- **OUTPut:PCM:FRAMESync:SYNC [EXtErnal|INTernal]** defines, whether the *RT-2X* generator or the DUT creates the FrameSync pulses for the TX data.
- **INPut:PCM:FRAMESync:SYNC [EXtErnal|INTernal]** defines, whether the *RT-2X* analyzer or the DUT creates the FrameSync pulse for the RX data.

Example I

FRAMESync:LOGic NEGative

BCLK:FREQUENCY 128 kHz, BCLK:EDGE POSitive, DATA:WLEnGth 8

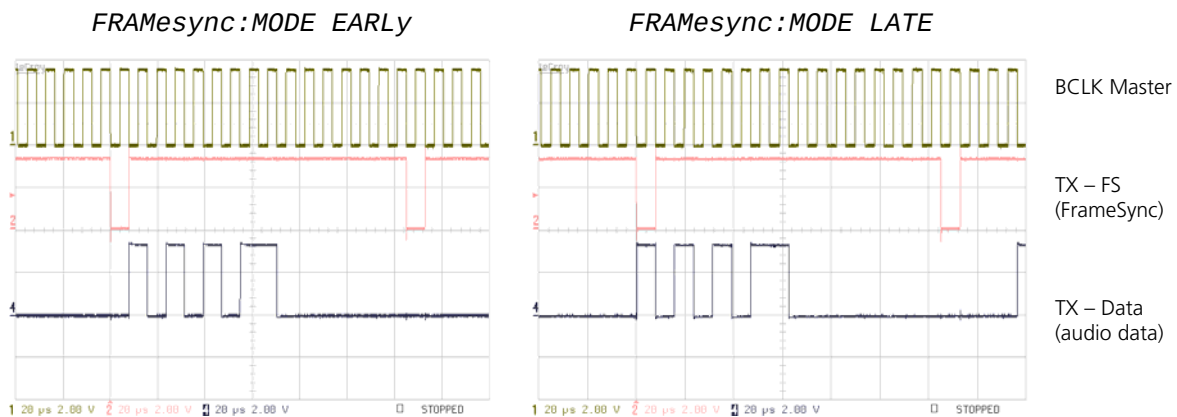


Fig 64 FrameSync Examples I

Example II

FRAMESync:MODE EARLy

BCLK:FREQUENCY 128 kHz, BCLK:EDGE POSitive, DATA:WLEnGth 8

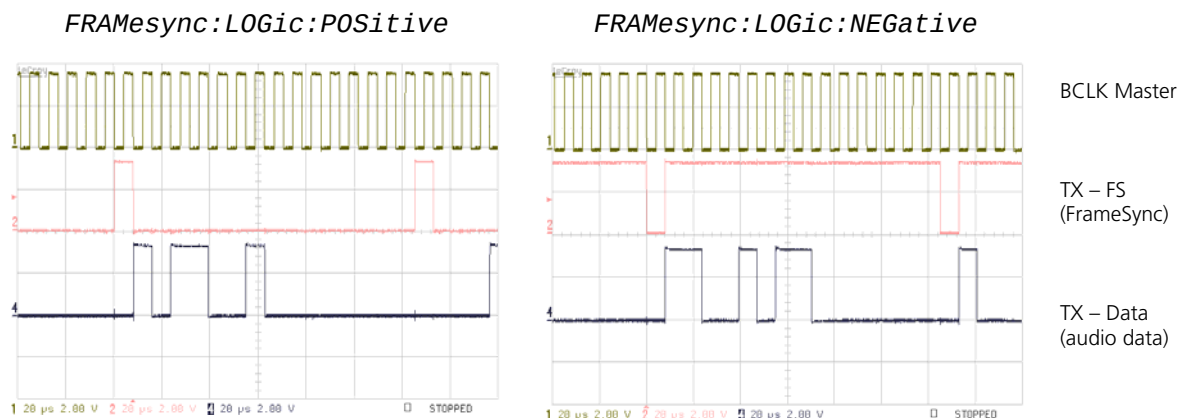


Fig 65 FrameSync Examples II

PCM Audio Data Transmission

RT-2X allows independently generating and analyzing 2-channel DataWords (i.e. test signals) via the serial PCM data transmission.

- **INOUT:PCM:DATA:WLENgth [8|13|14|16]** defines the DataWord length (i.e. resolution) of the transmitted audio test signal.
- **OUTPut:PCM:SLOTnumber <Channel1> <Channel2>** assigns the generated 2-channel test signal to the required PCM slots.
- **OUTPut:PCM:DATA:DIRection [MSBFIRST|LSBFIRST]** defines, whether the generated DataWords start with the MSB or the LSB (i.e. Most or Least Significant Bit).
- **OUTPut:PCM:LAW [ALAW|ULAW|OFF]** activates a Law-encoding for the generated audio test signals.
- **INPut:PCM:SLOTnumber <Channel1> <Channel2>** defines the two slots in the incoming PCM data stream, that comprise the 2-channel test signal.
- **INPut:PCM:DATA:DIRection [MSBFIRST|LSBFIRST]** defines, whether the incoming DataWords start with the MSB or the LSB (i.e. Most or Least Significant Bit).
- **INPut:PCM:LAW [ALAW|ULAW|OFF]** activates a Law-decoding for the incoming audio test signals.

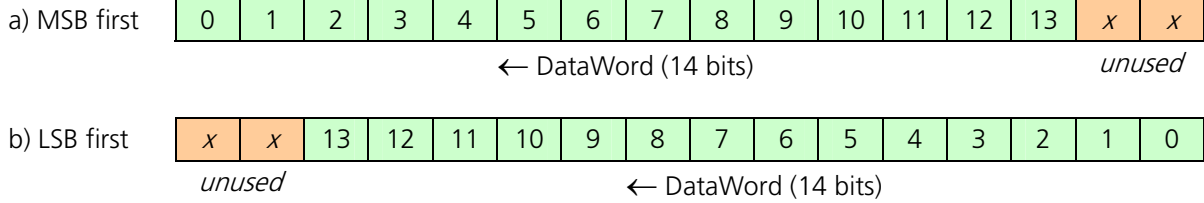
<i>BLCK [kHz]</i>	<i>DataWord length [bits]</i>	<i>No. of Channels</i>	<i>Possible Chn. Numbers</i>	<i>Example for Slotnumber Assignment</i>
64	8	1	0	OUTPUT:PCM:SLOTNUMBER 0 X *
104	13	1	0	OUTPUT:PCM:SLOTNUMBER 0 X *
128	8	2	0..1	OUTPUT:PCM:SLOTNUMBER 0 1
	13	1	0	OUTPUT:PCM:SLOTNUMBER 0 X *
	14	1	0	OUTPUT:PCM:SLOTNUMBER 0 X *
	16	1	0	OUTPUT:PCM:SLOTNUMBER 0 X *
256	8	4	0..3	OUTPUT:PCM:SLOTNUMBER 0 3
	13	2	0..1	OUTPUT:PCM:SLOTNUMBER 0 1
	14	2	0..1	OUTPUT:PCM:SLOTNUMBER 0 1
	16	2	0..1	OUTPUT:PCM:SLOTNUMBER 0 1
512	8	8	0..7	OUTPUT:PCM:SLOTNUMBER 0 7
	13	4	0..3	OUTPUT:PCM:SLOTNUMBER 0 3
	14	4	0..3	OUTPUT:PCM:SLOTNUMBER 0 3
	16	4	0..3	OUTPUT:PCM:SLOTNUMBER 0 3
1024	8	16	0..15	OUTPUT:PCM:SLOTNUMBER 0 15
	13	8	0..7	OUTPUT:PCM:SLOTNUMBER 0 7
	14	8	0..7	OUTPUT:PCM:SLOTNUMBER 0 7
	16	8	0..7	OUTPUT:PCM:SLOTNUMBER 0 7
1544	8	24	0..23	OUTPUT:PCM:SLOTNUMBER 0 23
	13	12	0..11	OUTPUT:PCM:SLOTNUMBER 0 11
	14	12	0..11	OUTPUT:PCM:SLOTNUMBER 0 11
	16	12	0..11	OUTPUT:PCM:SLOTNUMBER 0 11
2048	8	32	0..31	OUTPUT:PCM:SLOTNUMBER 0 31
	13	16	0..15	OUTPUT:PCM:SLOTNUMBER 0 15
	14	16	0..15	OUTPUT:PCM:SLOTNUMBER 0 15
	16	16	0..15	OUTPUT:PCM:SLOTNUMBER 0 15

Table 17 PCM Parameters

* Only one slot possible; active slot on chn.1 – X defines inactive channel

Example

DataWord length = 14 bit



PCM Alarm Table

Alarm	LED Indicator	Description	Explanation
<i>FS OUT LOSS</i>	FRAME ERROR	TX - FS Loss of Sync	There is either no external FrameSync signal present at TX-FS or the external FrameSync signal does not meet the specifications. The FS OUT LOSS alarm can only occur if the Output FrameSync (TX-FS) is set to EXternal.
<i>FS IN LOSS</i>	FRAME ERROR	RX - FS Loss of Sync	There is either no external FrameSync signal present at RX-FS or the external FrameSync signal does not meet the specifications. The FS IN LOSS alarm can only occur if the Input FrameSync (RX-FS) is set to EXternal.
<i>PLL UNLOCKED</i>	CARRIER SYNC	RT-2X can not lock to external Master BCLK	The internal PLL circuit of <i>RT-2X</i> can not lock to the external BCLK signal. The PLL UNLOCKED alarm can only occur if the BCLK:SYNC mode is set to EXternal.
<i>BCLK FREQ OUT OF RANGE</i>	LOSS OF SYNC	BCLK Master clock frequency out of range	The external BCLK signal does not meet the specifications. The BCLK FREQ OUT OF RANGE alarm can only occur if the BCLK:SYNC mode is set to EXternal.

Table 18 PCM Alarms

PCM Connector Pinning

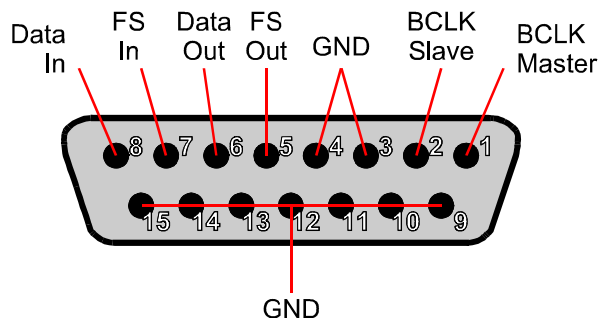


Fig 66 PCM Interface Connector Pinning

PureSound™ Chirp (Gliding Sweep) Parameters

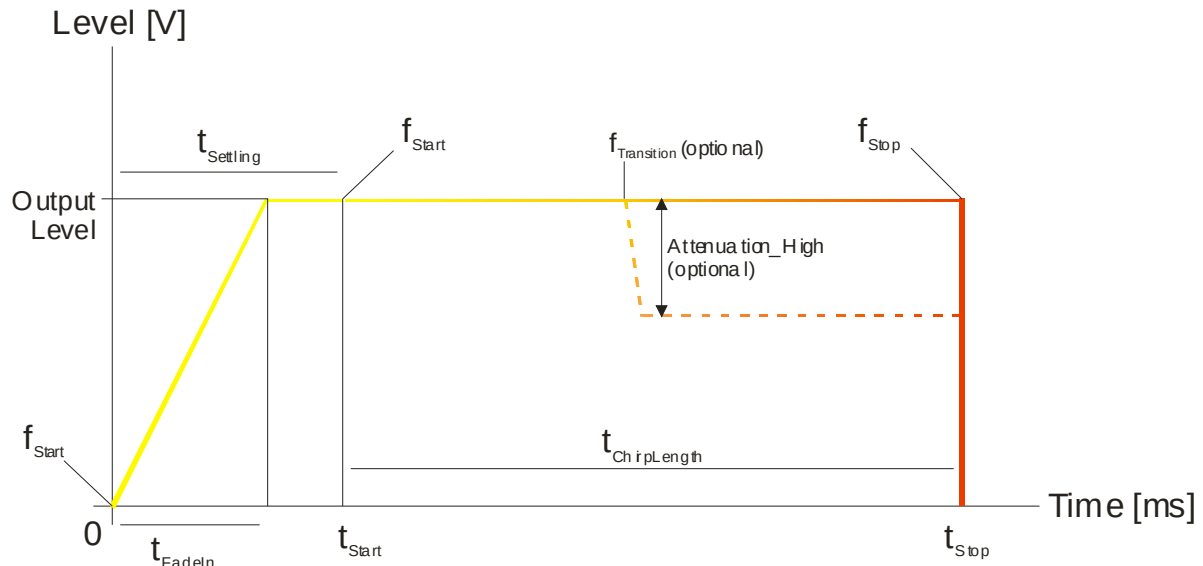


Fig 67 Chirp Parameters

Fig 67 visualizes the parameters that define the chirp for a Rub & Buzz test.

- **INOUT:PUResound:MODE RNB** switches the unit to the PureSound™ Rub & Buzz mode.
- **OUTPut:PUResound:CHIRp:FSTArT <Frequency>** and **OUTPut:PUResound:CHIRp:FSTOp <Frequency>** define the start and stop frequencies f_{Start} , f_{Stop} of the chirp. The start frequency can be lower or higher than the stop frequency (e.g. 20 Hz → 800 Hz or 800 Hz → 20 Hz).

NOTE The generated chirp level is attenuated in the range 5 – 20 Hz as follows:
0 dB @ 20 Hz → -0.6 dB @ 10 Hz → -1.3 dB @ 5 Hz.

- **OUTPut:PUResound:CHIRp:SETTling <Duration>** defines the *settling* time, i.e. the time during which RT-2X generates a sine signal with constant frequency f_{Start} before it starts transmitting the chirp. This allows the DUT settling to the test signal.
- **OUTPut:PUResound:CHIRp:FADEin <Duration>** defines the *fade in* time, i.e. the time during which the RT-2X output voltage is raised continuously from 0 V to the user-defined output level (refer to the commands **OUTPut[1'2]:LEVel ...**, **OUTPut[1'2]:BINlevel ...** and **OUTPut[1'2]:SINelevel ...**). A fade-in may be required to reduce initial transients. Normally, t_{FadeIn} is below or equal to t_{Settling} .
- **OUTPut:PUResound:CHIRp:LENGth <Duration>** defines the *chirp length*. This represents the duration of the core sweep, i.e. the time from t_{Start} to t_{Stop} . Consequently, the overall chirp duration $t_{\text{Total}} = t_{\text{Settling}} + t_{\text{ChirpLength}}$.
- **OUTPut:PUResound:CHIRp:AMPLitudeshape <Frequency>, <Attenuate_HI>, <Attenuate_LO>** allows attenuating the chirp level above or below an user-defined frequency. This optional feature is intended for woofer or compression driver testing, where the DUT or the operator must be protected from very loud sound levels (e.g. > 100 Hz with a woofer or < 2 kHz with compression tweeter). Keep in mind that certain Rub & Buzz effects might disappear if the chirp level is not high enough.

Please refer to chapter **PureSound™ Steepness Measurement** (p.250) for further details.

PureSound™ Correlation Analysis

The detailed analysis and verification of sound samples is one of the most demanding QC requirements in the industry. So far, there was no reliable test available for the

- Ringer melodies of mobile phones
- Music signals of MP3 players or other audio devices
- Speech signals of voice synthesizers etc.

The sound correlation analysis of *RT-2X* provides a 100% reliable solution for this task. It compares a reference signal ("golden sample") against the test signal and determines the similarity between these two signals.

Fig 68 gives an example of a good and a corrupted sample of the same signal. First, the signal of the good sample is recorded by *RT-2X* and stored in the internal memory as reference signal. Next, the signal is replayed by the device that has to be tested, whereby *RT-2X* compares the signal against the stored reference and provides three results:

- The *sound correlation*, representing the similarity of the test signal against the stored reference signal. The result is expressed in percent, ranging from 0 % (no correlation) to 100 % (signals are identical).
- The *level correction* indicates how much the test signal and the reference signal differ in RMS level. The result is expressed in %.
- The *RMS level* of the recorded sound sequence, expressed in dBV, V, dBSPL, dBPA or dBm.

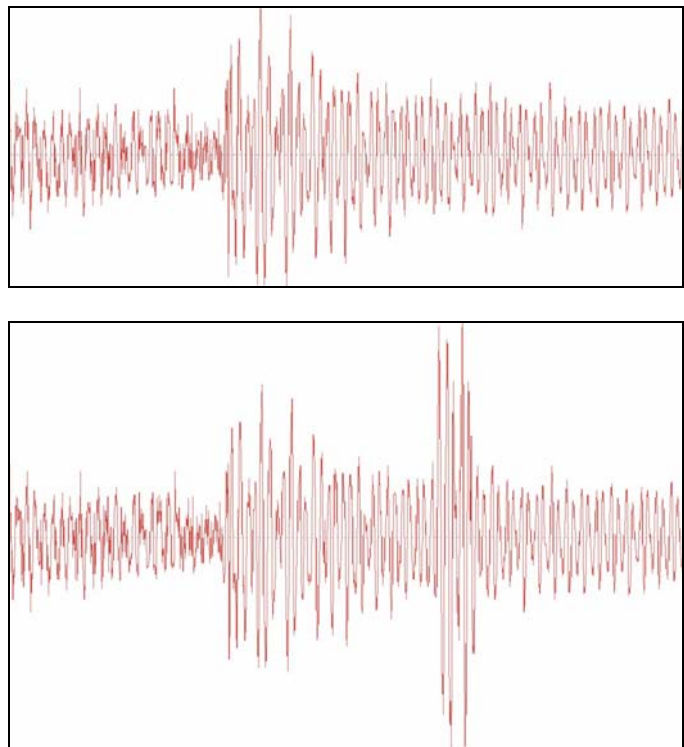


Fig 68 Sound Sequence, Correct and Corrupted

Fig 69 shows a sound correlation test setup. The sound sequence can be fed electrically or by an acoustical coupling to *RT-2X*.

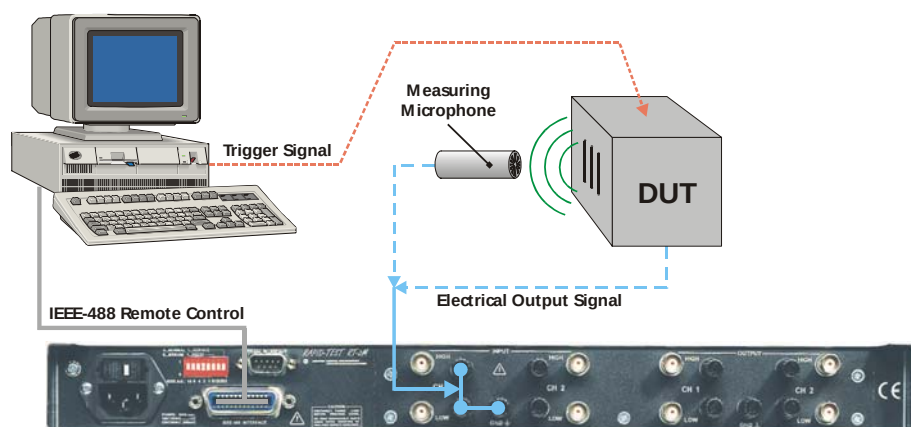


Fig 69 Sound Correlation Test Setup

Reference Signal Acquisition

1. Define the active memory location (A or B) for the reference signal with the command **MEASurement:PUResound:STEEpness:REFerence:ACTive [A|B]**.
2. Assign a user-defined name to the active reference signal (memory A or B) with the command **MEASurement:PUResound:STEEpness:REFerence:NAME <RefName>**.
3. Define the period length, during which the analyzer has to sample the incoming signal after triggering with the command **MEASurement:PUResound:LENGth <Duration>**.
4. Transmit the signal from a golden sample and save it in the active **RT-2X** memory as the reference signal **MEASurement:PUResound:STEEpness:REFerence:USELastmeas**.
5. Optionally, you can transfer the recorded data of the active reference signal to the PC with command **MEASurement:PUResound:STEEpness:REFerence:GET?** and back to **RT-2X** with command **MEASurement:PUResound:STEEpness:REFerence:SET ,...**

Test Signal Analysis

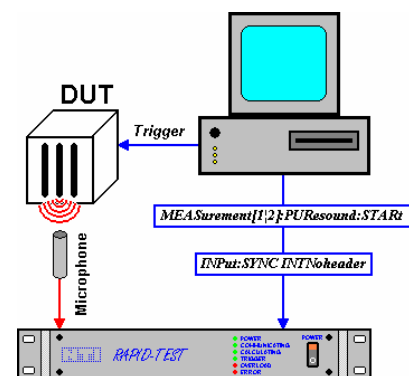
1. Select the reference signal with **MEASurement:PUResound:STEEpness:REFerence:ACTive [A|B]** (possibly, you first have to record the reference signal or transfer a previously stored reference signal from the PC to **RT-2X** as described above).
2. Transmit the test signal and make sure that the analyzer triggers & samples it correctly.
3. Query the *sound correlation* with **MEASurement:PUResound:STEEpness:CORRelation?**. The returned result indicates the trigger delay between the reference sequence and the sample, followed by the sound correlation result (0 to 100 %).
4. Query the *level correction* with **MEASurement:PUResound:STEEpness:LEVelcorrection?**. The returned data reflect the signal duration and the level correction result.
5. Query the RMS level of the test signal (**MEASurement:PUResound:STEEpness:RMSLevel?**).

Triggering & Signal Acquisition

Case a) The PC triggers the DUT

The PC triggers the DUT to generate the sound sequence and simultaneously forces **RT-2X** to start the data acquisition.

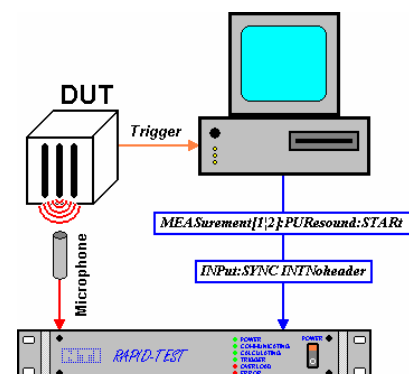
- Use the trigger mode **INPut:SYNC INTNoheader**.
- Let the PC trigger the DUT to generate the sound sequence
- Simultaneously, start the signal acquisition with the command **MEASurement[1|2]:PUResound:STARt**.



Case b) The DUT triggers the PC

The DUT triggers the PC exactly at the time when it generates the sound sequence $\Rightarrow$ the PC in return triggers **RT-2X** to start the data acquisition

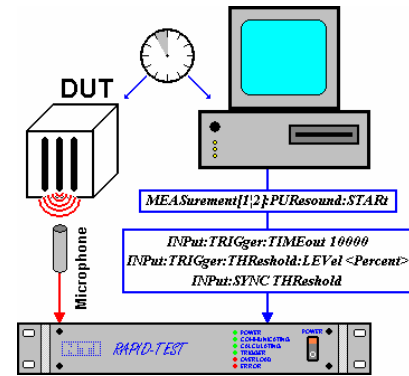
- Use the trigger mode **INPut:SYNC INTNoheader**.
- As soon as the PC receives the trigger signal from the DUT, it has to start the signal acquisition with the command **MEASurement[1|2]:PUResound:STARt**.



Case c) The DUT generates the sound at a predictable time

The DUT generates the sequence at a known time but with an uncertainty of few seconds $\Rightarrow$ the PC triggers the *RT-2X* slightly in advance for the incoming sound sequence.

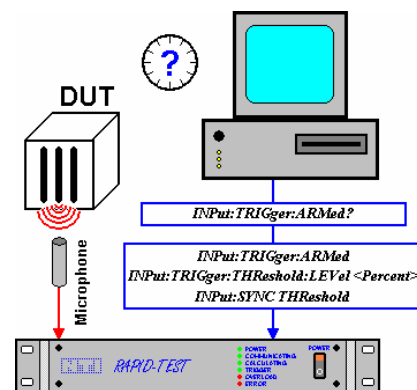
- Use the trigger mode **INPut:SYNC THReshold** (p. 276).
- Define an appropriate threshold level with command **INPut:TRIGger:THReshold:LEVel <ThreshLevel>**.
- Set the trigger timeout to 10 seconds with command **INPut:TRIGger:TIMEout 10000**.
- Prepare the *RT-2X* analyzer for the incoming signal with **MEASurement[1|2]:PUResound:STARt** few seconds before the signal comes in.



Case d) The DUT generates the sound at an unpredictable time

The time of the incoming signal is not known $\Rightarrow$ *RT-2X* has to be armed in advance to wait for the incoming sound sequence.

- Use the trigger mode **INPut:SYNC THReshold** (p. 276).
- Define an appropriate threshold level with command **INPut:TRIGger:THReshold:LEVel <ThreshLevel>**.
- Arm the analyzer (**INPut[1|2]:TRIGger:ARMed**, p. 269).
- Repeatedly query the *RT-2X* analyzer status with **INPut:TRIGger:ARMed?**. As soon as the unit has triggered, it returns the string "STOPPED", thus indicating that the sound correlation results can be queried by the PC.
- Re-arm the analyzer and repeat the status query for the next incoming sequence.



Sound Correlation Example

Fig 70 (p. 247) visualizes the different parameters and measurement results of a sound correlation analysis. Thus, it helps understanding the backgrounds and applying this feature properly.

HINT The two sequences in the example are identical, except of their RMS level. Apart from that, the *RT-2X* analyzer has triggered to different peaks of the sequence.

To simplify the understanding of the returned results, the two sequences have been placed in a way that the trigger event is located at the same point on the time-axis.

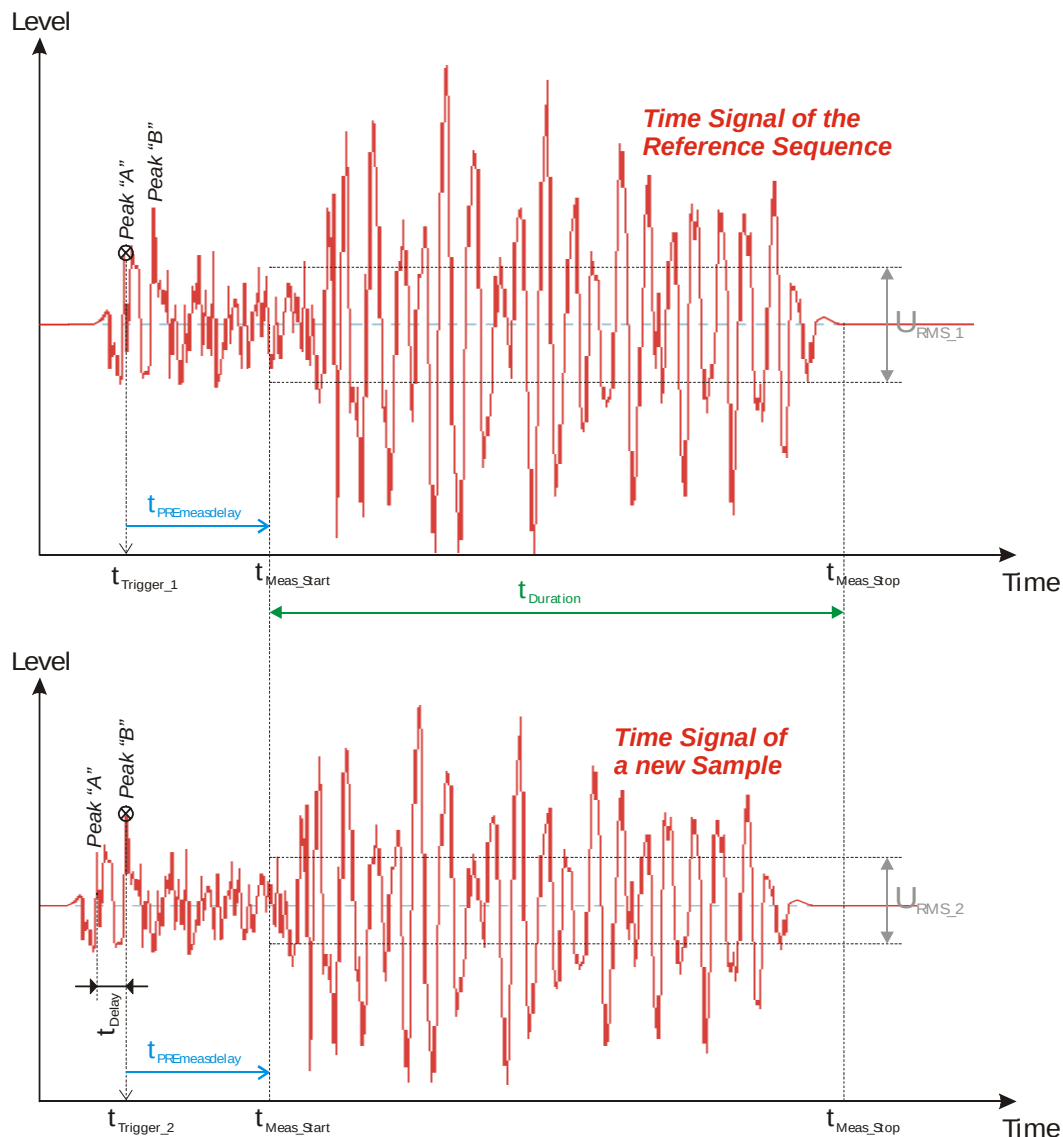


Fig 70 Sound Correlation Parameters

- $t_{Trigger\_1}$ and $t_{Trigger\_2}$ indicate the times when the analyzer has triggered to the incoming signal. In the example, this has happened at peak "A" of the reference sequence, but at a later point (peak "B") of the sample.
- t_{Delay} is the time difference between the trigger points of the reference sequence and the sample (peak "A" – "B"). *RT-2X* automatically recognizes & compensates this delay.
- $t_{PREmeasdelay}$ is the user-defined delay from the trigger point to the start of the data acquisition. This delay is only applied in the trigger mode **THReshold** (p. 276).
- $t_{Duration}$ is the user-defined duration of the signal acquisition. It is applied for the reference sequence and the sample.
- U_{RMS_1} and U_{RMS_2} represent the RMS level of the reference sequence and of the sample. Consequently, the level correction result in % = $(U_{RMS\_1} / U_{RMS\_2}) * 100$.

HINT *RT-2X automatically compensates for the trigger delay and the level correction. Therefore, in the example, the sound correlation result would be close to 100 %.*

PureSound™ Mode

The PureSound™ option for *RT-2X* is a revolutionary approach for signal analysis in the *time domain*. It is based on the patented algorithm (No. EP 073751 and US 5,884,260) by Frank Leonhard and is best described as the *detection of changes in the instantaneous energy by means of transient analysis*.

NOTE **The PureSound™ option must be enabled with a license code. Please contact your NTI agent for further details.**

The applications of the PureSound™ option can be divided in two groups:

1. *Steepness measurement* of a transmitted chirp (i.e. gliding sweep) or an externally generated signal. The analysis provides an extremely accurate indication of audible defects such as *Rub & Buzz* of electroacoustic transducers.
2. *Sound correlation* analysis, whereby *RT-2X* compares the reference signal of a "golden sample" against the test signal, thus detecting discrepancies. This mode can be used to check for the quality of ringer melodies, music or speech signals etc.

NOTE **The PureSound™ mode allows analyzing internally as well as externally generated test signals.**

Enter the PureSound™ mode as follows:

- Switch the *RT-2X* generator & analyzer to A-A operation (**SYSTem:MODE 48Ksamplingrate, OUTPut:SOURce ANALog, INPut:SOURce ANALog**).
- Reset the analyzer and disable the LCL & RL mode if required (i.e. if they are active) with **INPut:TRIGger:BREak, INOUT:LCLBridge:MODE OFF & INOUT:RLBridge:MODE OFF**.
- Activate the PureSound™ mode with **INOUT:PUREsound:MODE [RNB|CORRELATION]**.

As soon as the PureSound™ mode is active, *RT-2X* allows executing all Rub & Buzz or sound correlation analysis commands as described in chapters **PureSound™ Steepness Measurement** (p. 250) and **PureSound™ Correlation** (p. 244).

HINT If a test shall comprise of a PureSound™ analysis and of a multitone or stepped sweep measurement these tests have to be executed one after the other (i.e. not in parallel).

NOTE **In the PureSound™ mode only a restricted number of *RT-2X* measurement functions are available. Please refer to the detailed command descriptions.**

Input Filter Characterstics

The PureSound™ analysis applies six bandpass filters on an incoming signal. These filters represent the psychoacoustic perception of the human hearing system and provide the six result blocks of a Rub & Buzz measurement.

Refer to **Fig 71** for the characteristics of the six PureSound™ bandpass filters.

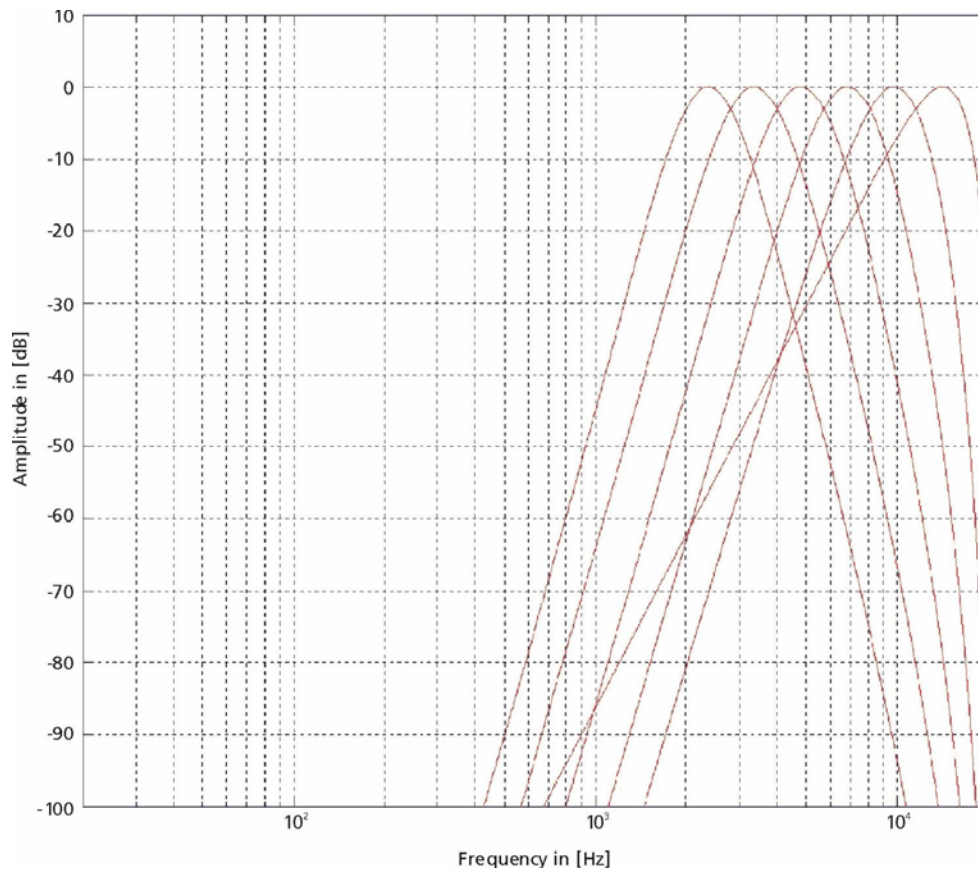


Fig 71 PureSound™ Input Filters

PureSound™ Steepness Measurement

The PureSound™ steepness measurement allows detecting virtually all kinds of audible defects on the incoming signal. For instance, Rub & Buzz defects that are caused by faulty transducers or other mechanical devices can be detected with 100% reliability (refer to **NTI's** application notes *Transients & Steepness Analysis* and *PureSound™ for Rub & Buzz Detection*).

Steepness Measurement

- Activate the steepness analysis mode with **INOUT:PUResound:MODE RNB**.
- Enter the signal duration with **MEASurement:PUResound:LENGth <Duration>**. It is recommended to select the same **<Duration>** as of the test signal.
- **MEASurement:PUResound:STEEpness:UNIT [PA|S|V|S]** defines the unit, in which the acquired steepness results shall be expressed:
 - Pa/S (i.e. Pascal per second) for setups with a microphone with defined sensitivity.
 - V/S (i.e. Volt per second) is used for other electrical input signals.
- **MEASurement:PUResound:NREsults <#Results>** defines the number of returned steepness results (i.e. the resolution of the returned result vector).
- If required, define individual PASS/FAIL limits for the six bands (see next chapter) and activate these limits (**MEASurement:PUResound:STEEpness:VARLimit:ACTive[1|2|3|4|5|6]**).
- Activate the noise cancellation if the test is executed in a noisy environment (p. 252).
- Use command **INPut:SYNC ...** to select the trigger mode **INTNoheader** for the **RT-2X** chirp analysis or **THReshold** for the acquisition of an externally generated signal.
- Start the signal acquisition with **OUTPut[1|2]:PUResound:CHIRp:START** (analysis of **RT-2X** chirp) or **MEASurement[1|2]:PUResound:START** (analysis of externally generated signal).
- Query the steepness values of a band (**MEASurement:PUResound:STEEpness[1|2|3|4|5|6]?**) or the PASSED / FAILED result (**MEASurement:PUResound:STEEpness:OK?**, see below).

NOTE **RT-2X** is also able to execute a Rub & Buzz test with an externally generated chirp, supposed that the latter is a linear, gliding frequency sweep with constant amplitude.

Steepness Limits for PASS/FAIL Test (Rub & Buzz Detection)

The PureSound™ option allows checking steepness results against user-defined PASS/FAIL limits. The individual limits for each of the six bands are stored in the non-volatile **RT-2X** memory. As soon as a steepness measurement is recorded, the unit checks it against the corresponding limits and returns the PASSED / FAILED result upon request.

Define the individual band limits with **MEASurement:PUResound:STEEpness:VARLimit SET [1|2|3|4|5|6] <NoOfPoints> [PA|S|V|S] <X_Interval₁>, <X_Interval₂>, ..., <X_Interval_{NoOfPoints}>, <Y_Limit₁>, <Y_Limit₂>, ..., <Y_Limit_{NoOfPoints}>**.

- **[1|2|3|4|5|6]** selects the active band, i.e. the steepness band where the limits are applied.
- **<NoOfPoints>** defines the number of points that build the limit.
- **[PA|S|V|S]** selects the unit, in which the steepness band limits are expressed (Pascal per second or Volt per second).
- **<X_Interval_n>** defines the position of a point on the X-axis (i.e. time axis), relative to the total duration of the signal acquisition (= 100%).
- **<Y_Limit_n>** defines the absolute steepness limit for every point, expressed in the active unit. The limits between two neighbored points are interpolated linearly.

NOTE The positions of the points are defined relative to the total signal duration. Therefore, if the user enters another duration, the absolute positions of the points change as well.

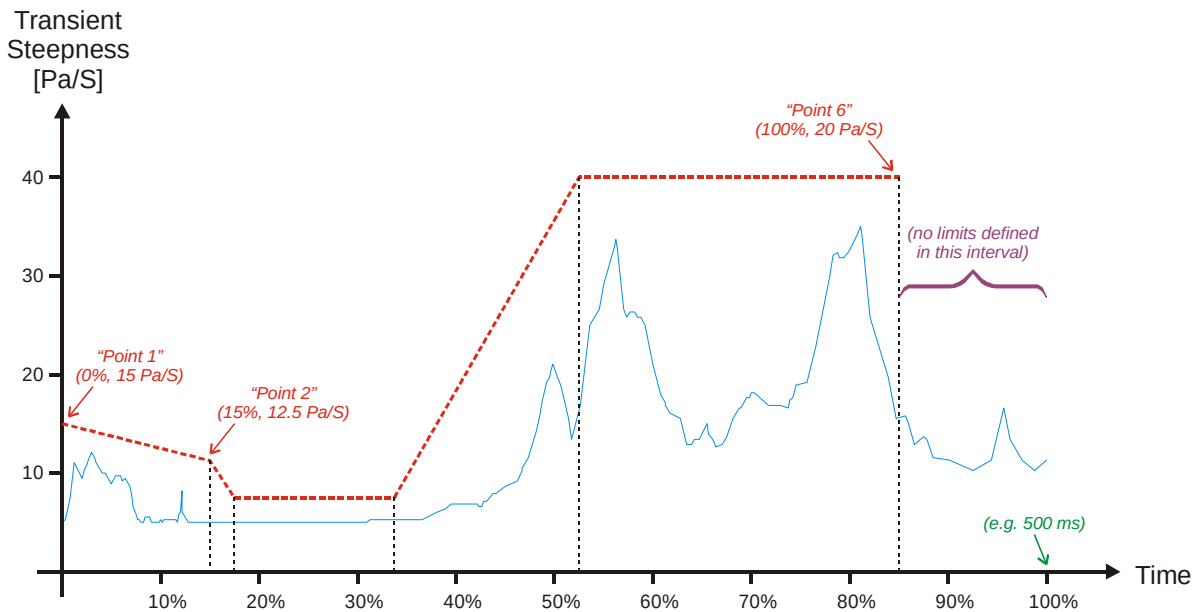


Fig 72 Variable Limits Definition

Fig 72 shows an example of a recorded steepness graph (only one band displayed) with its individual limits.

- **<NoOfPoints>** = 6; therefore, the limits band consists of five intervals.
- The steepness results are expressed in the unit Pa/S.
- The positions of the six points are 0%, 15%, 17.5%, 20%, 33%, 52.5% and 85% of the total signal duration. Under the assumption that the signal duration is 500 ms, these values equal 0 ms, 75 ms, 87.5 ms, 100 ms, 166.7 ms, 262.5 ms and 425 ms.
- The corresponding limits are 15 Pa/S, 12.5 Pa/S, 10 Pa/S, 10 Pa/S, 40 Pa/s and 40 Pa/S.
- The interval between 85% and 100% of the test signal has no limit and is therefore not checked.

The limit definition command for the shown example would be the following (refer to p. **138**):

```
MEASurement:PUResound:STEEpness:VARLimit SET 3 6 PA|S 0.00E+00,1.50E+01,
1.75E+01,2.00E+01,3.33E+01,5.25E+01,0.85E+02,1.50E+01,1.25E+01,1.00E+01,
1.00E+01,0.40E+02,0.40E+02
```

The application of individual steepness limits is an extremely powerful tool to execute a concise, yet fast and reliable signal analysis as e.g. Rub & Buzz detection.

- Activate the individual transient steepness limit test (Rub & Buzz detection) with the command **MEASurement:PUResound:STEEpness:VARLimit:ACTive[1|2|3|4|5|6]**.
- Adjust the **INPut:SYNC** mode to **INTNoheader** or **THReshold** (refer to p. **270**).
- Start the signal acquisition with **OUTPut[1|2]:PUResound:CHIRp:STARt** (analysis of **RT-2X** chirp) or **MEASurement[1|2]:PUResound:STARt** (analysis of externally generated signal).
- Query the PASSED / FAILED result with **MEASurement:PUResound:STEEpness:OK?**.

Noise Cancellation

RT-2X provides a sophisticated, patented feature to cancel out the effects of ambient noise. In practice, the test system repeats every measurement that has exceeded the currently active steepness limits. Next, it verifies whether the results of the repeated measurement show the same kind of "noise" than the previous run (systematic error) or not (random noise). If a systematic error (same kind of defect at all runs) has occurred, *RT-2X* returns a "FAILED". Otherwise, i.e. in case of random noise (limits have been exceeded at different points), the unit cancels out the recorded transients and returns a "PASSED". This way, *RT-2X* can be operated even in noise environments without compromising on the accuracy or reliability of the test results.

Enter the maximum number of runs that can be executed in case of a recorded defect with the command **MEASurement:PUResound:NREsults <#Results>**. Consequently, *RT-2X* repeats the test for the defined number of cycles (= <#Results>) if the user-defined limits are exceeded (i.e. if the test = FAILED).

Rub & Buzz Test

RT-2X stimulates the DUT with a chirp, i.e. a *gliding* sweep from 20 – 6'000 Hz. This test signal excites all possible Rub & Buzz defects of subwoofers, speakers or even tweeters (in case of the latter, the stimulus might need to be introduced after the crossover). Simultaneously, the analyzer measures the transient steepness of the input signal in 6 bands between 2 – 20 kHz, representing the human hearing perception. Thus, the PureSound™ analysis detects all audible Rub & Buzz defects and provides a clear indication of this.

In addition to the chirp, a stepped sweep is transmitted to measure the frequency and impedance response, resonance frequency f_0 , sound pressure level (SPL) and polarity of the transducer (refer to chapter **Stepped Sweep Generation**, p. 255) and **Stepped Sweep Setup Parameters**, p. 257).

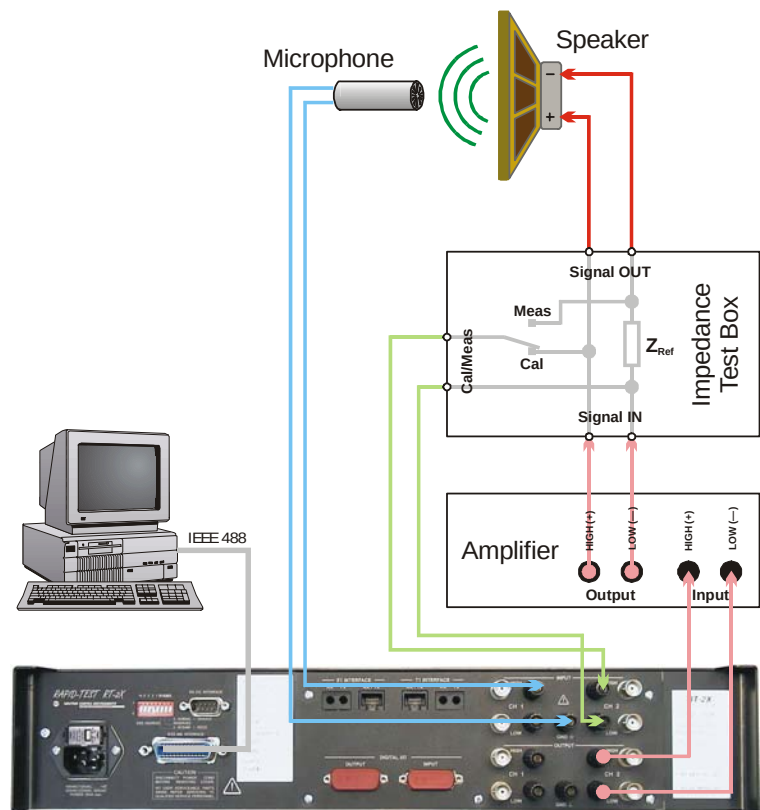


Fig 73 Transducer Test Setup

NOTE A shunt resistor is required to measure the impedance vs. frequency. Please ask your agent for the NTI impedance test box *RT-1B*.

RL Mode

In the *RL mode*, *RT-2X* can execute RL, ERL or SRL measurements.

NOTE For RL, ERL and SRL measurements, the LCL/RL option must be installed.

Enter the RL mode as follows:

- Switch the *RT-2X* generator & analyzer to A-A operation.
- Disable the LCL and the PureSound™ mode if required (i.e. if they are active) with **INPut:TRIGger:BRake**, **INOUT:LCLBridge:MODE OFF**, **INOUT:PUREsound:MODE OFF**.
- Activate the RL Bridge (**INOUT:RLBridge:MODE ON**).

As soon as *RT-2X* is in the RL mode, it allows executing all RL, ERL or SRL related commands. The detailed operation instructions are described in chapters **Return Loss (RL)** (p. 222) and **Echo Return Loss (ERL) and Singing Return Loss (SRL)** (p. 206).

NOTE In the RL mode, not all measurement functions of *RT-2X* are available. Please refer to the command descriptions.

RS232 Serial Interface

By connecting a Nullmodem-cable between the PC and the *RT-2X* standard RS232 interface (D-Sub 9pin connector) a serial communication can be established, supporting virtually all *RT-2X* instructions and queries, described in chapter **Commands** (p. 27).

<i>Baudrate</i>	38400	<i>Termination of transmitted commands PC → RT-2X</i>	CR LF (Carriage Return Line Feed)
<i>Databits</i>	8	<i>Answers from RT-2X → PC</i>	LF (Line Feed)
<i>Stopbits</i>	1		
<i>Parity</i>	None		
<i>Protocol</i>	Hardware		

Table 19 RS232 Setup Parameters

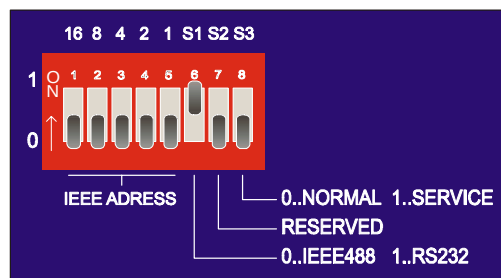


Fig 74 DIP-switch Settings for RS232 Operation

NOTE Activate the RS232 interface by setting the DIP-switch on the *RT-2X* rear panel labeled 'S1' (6th switch from left) to '1' (upper position). The T1 signaling commands & queries are not available under RS232 control.

Sine Signal Generation (Arbitrary)

OUTPut:ARBSIN <Frequency>, <Time> lets **RT-2X** generate a sinusoidal tone with an user-defined frequency [Hz] and duration [ms]. The parameters <Frequency> and <Time> are fully independent from the current multitone signal parameters (i.e. blocklength, sampling rate etc.).

- The available frequency band for the arbitrary sine generation is 1 Hz – 22 kHz @ $f_s = 48$ kHz and 1 Hz – 4 kHz @ $f_s = 8$ kHz respectively, whereby the frequency can be defined with a resolution of 0.01 Hz.
- The available signal duration ranges from 0 ms to 30'000 ms and can be defined with a resolution of 1 ms.

OUTPut:ARBSIN BREAK immediately stops the arbitrary sine wave generation.

Adjust the level of the generated sine wave with command **OUTPut[1,2]:LEVel** <Level> [V_iVP_iDBV_iDBVP_iDBM_iDBFSP_i%FSP_iDBFS_i%FS_iDBM0] or command **OUTPut[1,2]:SINelevel** <SineLevel> [DBVP_iVP_iDBV_iV_iDBM_iDBFSP_i%FSP_iDBFS_i%FS_iDBM0].

NOTE The actual output level of the arbitrary sine generator differs from the selected value below 20 Hz and above 20 kHz as follows (refer to Fig 75):

- –4 dB @ 1 Hz to 0 dB @ 20 Hz
- 0 dB @ 20 Hz to –0.5 dB @ 22 kHz.

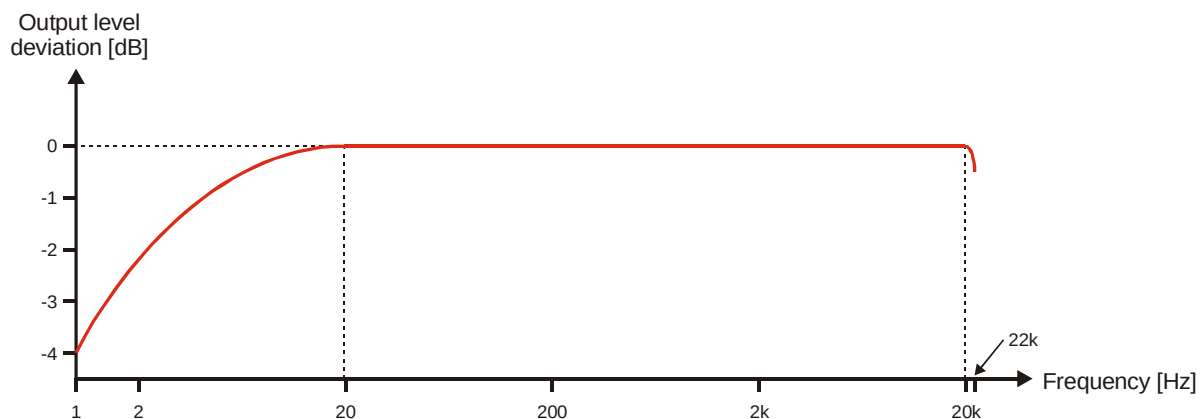


Fig 75 Arbitrary Sine Output Level Deviation

Stepped Sweep Generation

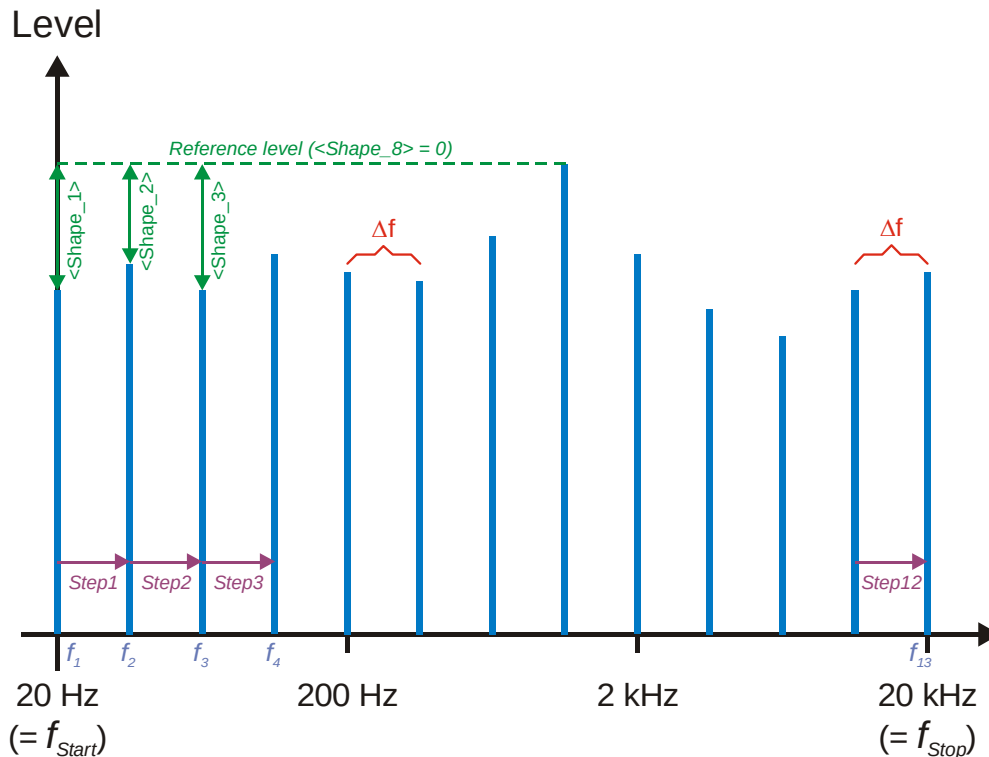


Fig 76 Sweep Generator Parameters

- **OUTPut:STEPpedswEEP:FSTART** *<StartFrequency>* defines the sweep's *start frequency* f_{start} that can be lower or higher than f_{stop} .
- **OUTPut:STEPpedswEEP:FSTOP** *<StopFrequency>* defines the sweep's *stop frequency* f_{stop} that can be higher or lower than f_{start} .
- **OUTPut:STEPpedswEEP:NSteps** *<#Steps>* defines the number of *steps* between f_{start} and f_{stop} (i.e. the frequency resolution of the stepped sweep) Please note that the *number of frequencies* = *<#Steps>* + 1.
- **OUTPut[1|2]:SINelevel** *<SineLevel ...* defines the reference *output level* of the stepped sweep.
- **OUTPut:STEPpedswEEP:AMPLitudeshape:SET** *<Shape1>,<Shape2>,...,<Shape#Steps+1>* allows attenuating the individual output levels of the sweep frequencies, whereby the number of *<Shape_n>* values must be = *<#Steps>* + 1. Furthermore, at least one level must not be attenuated (i.e. *<Shape_x>* = 0) to act as reference for the output level definition.
- **OUTPut:STEPpedswEEP:AMPLitudeshape:ACTIVE** [*ENABLE|DISABLE*] activates or disables the last defined amplitude shaping for the active sweep (supposed that the listed conditions are met).
- **OUTPut:STEPpedswEEP:STATUS?** queries the values of the parameters *<StartFrequency>*, *<StopFrequency>* and *<#Steps>* of the active sweep.
- **OUTPut:STEPpedswEEP:AMPLitudeshape:SET?** queries the *<Shape_n>* values that were defined with the last **OUTPut:STEPpedswEEP:AMPLitudeshape:SET ...** command.

NOTE The stepped sweep generation is only possible in the 48 kHz mode.

Stepped Sweep Setup Parameters

Delays

There are two ways to delay the start of the analyzer's data acquisition. If both delays are active, they will be applied one after the other (refer to **Fig 78**).

- **MEASurement:STEPpedSweep:SETTling:CYCLes** <Cycles> defines a frequency-dependent delay for the start of the signal acquisition. This may be necessary to allow the DUT settling at the beginning of a new generator frequency.
- **MEASurement:STEPpedSweep:SETTling:DElay** <Delay> defines a fixed delay between the start of the frequency generation and the start of the signal acquisition. This delay can be used to compensate for the propagation time of the signal, e.g. caused by an acoustical transmission.

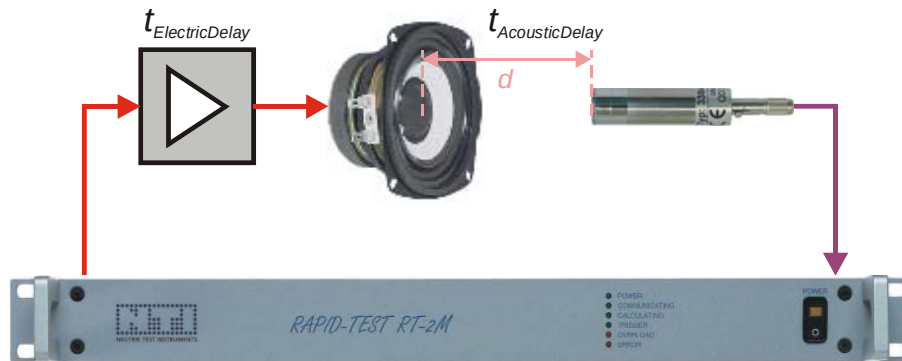


Fig 77 Signal Propagation Delay

Fig 77 visualizes the signal propagation delay that can be caused by electrical devices (e.g. a codec) or the acoustical signal path. The overall propagation delay can be calculated with following formulas (d = distance membrane – microphone; v_{Sound} = speed of sound):

$$\begin{aligned} t_{PropagationDelay} &= t_{ElectricDelay} + t_{AcousticDelay} \\ &= t_{ElectricDelay} + \frac{d}{v_{Sound}} \end{aligned}$$

Equation 27 Signal Propagation Delay

Example

Given $d = 0.5$ m; $v_{Sound} = 340$ m/s; $t_{ElectricDelay} = 1$ ms = 0.001 s

$$\Rightarrow t_{PropagationDelay} = 0.001 + \frac{0.5}{340} = 0.0025 \text{ [s]} = 2.5 \text{ [ms]}$$

In this case it would be recommended to apply a <Delay> of 3 or 4 ms

Noise Immunity

A noisy environment can affect the accuracy of acoustical measurements. Therefore, **RT-2X** allows enabling an internal filter that rejects signal components that have a different frequency from the actually present sweep frequency.

Activate the internal noise filter with **MEASurement:STEPpedSweep:NOIS immunity** [OFF|ON].

High Precision Mode

In most applications, *RT-2X* requires only half a signal period for an accurate level measurement. However, certain drivers (e.g. speakers, transducers, capsules) create highly asymmetric non-linear distortions, thus downgrading the level measurement accuracy (typ. ~0.5 dB).

Therefore, *RT-2X* supports a special mode, wherein the full signal period is acquired and analyzed to ensure maximum measuring accuracy (deviation < 0.5 dB). Activate this mode with the command **MEASurement:STEPpedSweep:HIPrecision ON** in following cases:

- The stepped sweep output level is close to the maximum allowed input level of the driver.
- A high measuring resolution (< 0.5 dB) is required at low frequencies.
- The driver's resonance impedance R_0 is close to its DC resistance R_{DC} :
- High-end wideband drivers (e.g. headphones, car speakers).

$$\frac{R_0}{R_{DC}} \leq 1.5$$

NOTE The high precision mode makes the stepped sweep measurement slower.

Settling

When measuring an audio device with unknown transient behaviour it is sometimes required to monitor the acquired measurement result at the current frequency for a while until it has settled. For this purpose *RT-2X* supports an automated settling algorithm.

If the settling is active, *RT-2X* checks every incoming sample before it is accepted as a valid measurement result. Furthermore, the unit does not start generating the next sweep frequency before this condition is met, unless that a timeout expires.

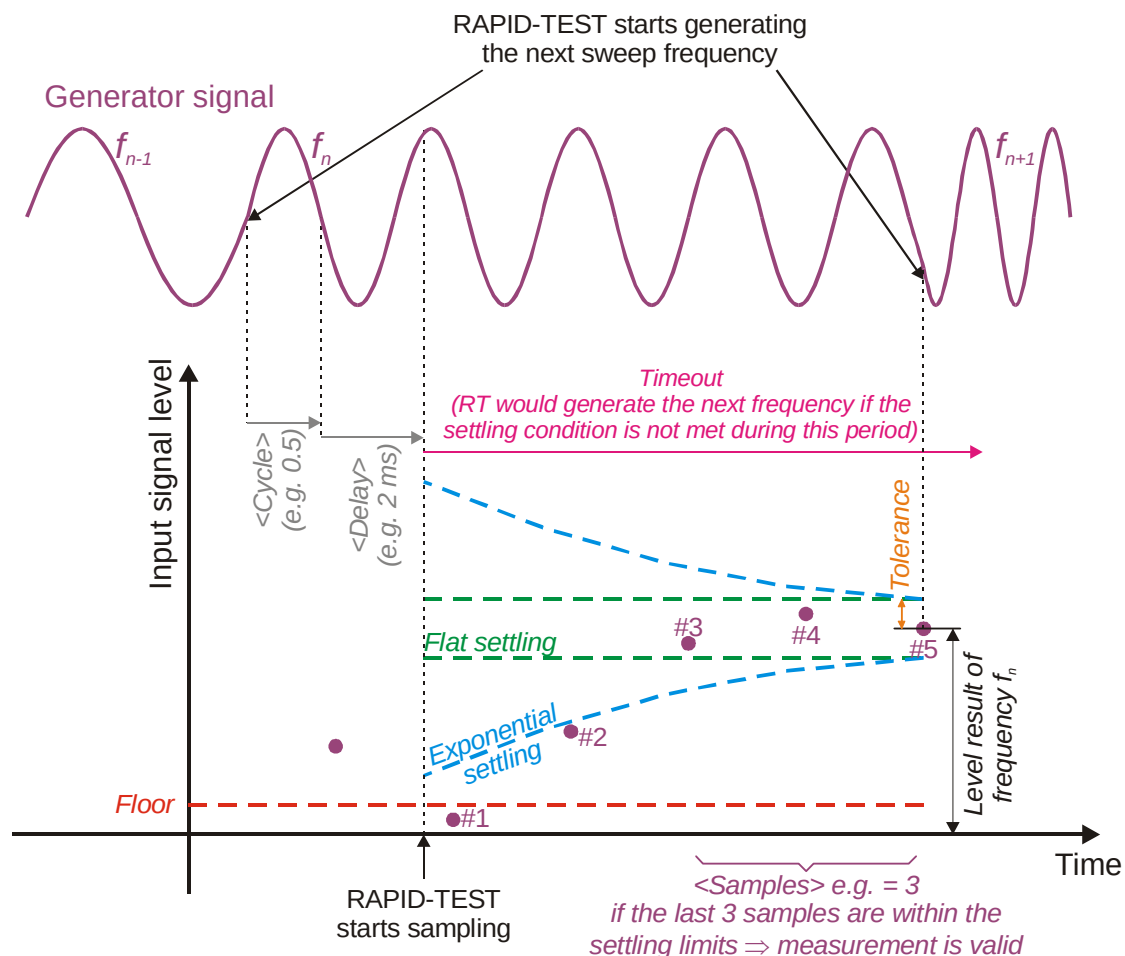


Fig 78 Sweep Settling Parameters

NOTE *RT-2X* applies pre-defined settling parameters depending on the acquisition mode (*RMSLEVEL* or *DISTORTION*, p. 262). Amending the default setting is only recommended if truly required and if you feel safe with the settling parameter definition.
Improper settling noticeably slows down the stepped sweep transmission.

- Select the settling type with the command **MEASurement:STEPpedswEEP:SETTling:TYPE** [*RMSLEVEL*|*HARMONIC2*| *HARMONIC3*|*HARMONIC4*|*HARMONIC5*|*THD*|*THDN*], with regard to the measurement to be executed (Level / Phase or 2nd, 3rd, 4th, 5th Harmonic or THD or THD+N).
- **MEASurement:STEPpedswEEP:SETTling:MODE** [*OFF*|*NORMAL*|*SELECTIVE*] applies the settling on the full frequency band (*NORMAL*) or an user-defined band (*SELECTIVE*).
- In the selective settling mode, command **MEASurement:STEPpedswEEP:SETTling:FBEGin** <Frequency1> and **MEASurement:STEPpedswEEP:SETTling:FENd** <Frequency2> define the frequency band, wherein the settling is active. Typically, <Frequency1> and <Frequency2> are defined around the resonance frequency *f*₀ of the DUT. The benefit of this mode is that it provides fast and accurate measurement results around the resonance frequency of samples with a high *Q*_{ms} (mechanical quality factor).
- **MEASurement:STEPpedswEEP:SETTling:ACTive** [*CHANNEL1*|*CHANNEL2*|*BOTHCHANNELS*] defines the input channel(s) where the settling is applied.
- **MEASurement:STEPpedswEEP:SETTling:ALGorithm** [*EXPonential*|*FLAT*] selects the settling algorithm. *FLAT* represents a band of constant width, i.e. the last samples must be within the user-defined limits to be accepted. *EXPONENTIAL* represents a tolerance mask that is exponentially less restrictive for older samples.
- **MEASurement:STEPpedswEEP:SETTling:FLOor** <Floor> [*V*|*DBV*] defines the absolute minimum sample level for the settling. If only noise below this limit is coming in, it will not be considered for the settling.
- **MEASurement:STEPpedswEEP:SETTling:NOISe** <Level> [*V*|*dBV*|*dB SPL*|*dB Pa*] defines a relative acceptance band for the settling. If e.g. the input signal is stable, but a little noisy, it might not meet the *EXPONENTIAL* settling condition. In this case, the command allows to widen the acceptance condition a little.

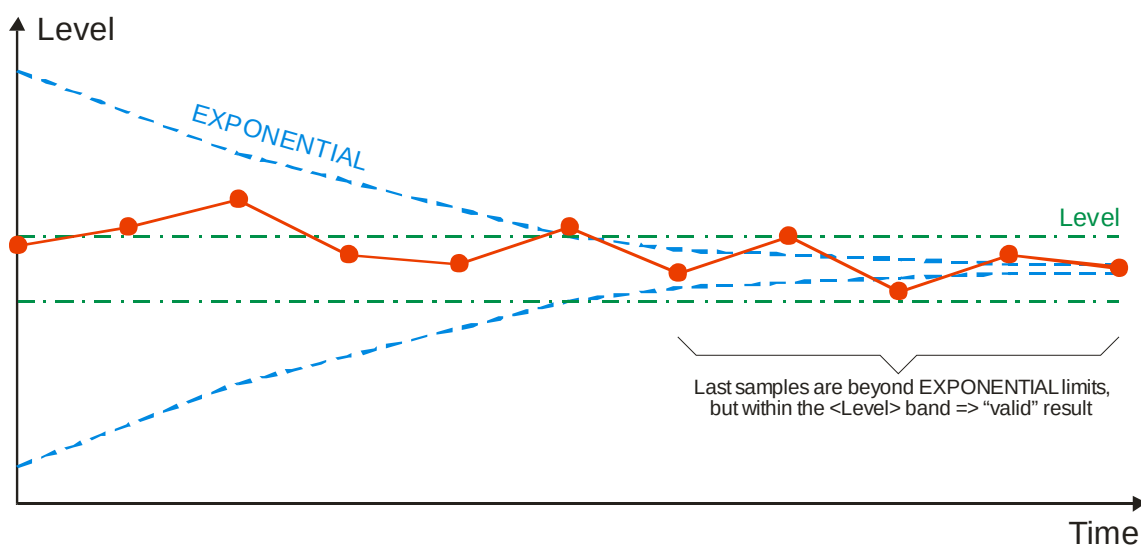


Fig 79 Example of Settling with User-defined "Noise Level"

- **MEASurement:STEPpedswEEP:SETTling:TOLerance** <Tolerance> [%'DB] defines the width of the active settling tolerance. Every sample that meets the continuously calculated tolerance limits is accepted as "valid".
- **MEASurement:STEPpedswEEP:SETTling:SAMple** <Samples> defines, how many samples in a row must be valid (i.e. within the tolerance limits) to become a measurement result.
- **MEASurement:STEPpedswEEP:SETTling:TIMEout** <Timeout> gives the time, after which the measurement is aborted for the current frequency in case that the unit was not able to acquire a valid sample.
- **MEASurement:STEPpedswEEP:SETTling:STATus?** queries the settling parameters.

NOTE The following rules allow optimizing the sweep settling for distortion measurements:

- Apply an anechoic test box (i.e. acoustical shielding).
- Adjust the driving level for the DUT to a rather high voltage.
- Select the settling mode OFF and carefully optimize the RT-2X input range.
- Enter the stepped sweep start & stop frequencies, whereby the latter should be below the start frequency (e.g. 20 kHz → 20 Hz).
- Activate the settling (mode NORMAL) only on the active input channel.
- Apply the settling type "RMS Level" or "k2", "k3" rather than "THD+N".
- Increase the "Tolerance" or enter a longer "Timeout" if the DUT does not settle properly.

Smoothing

The command **MEASurement:STEPpedswEEP:SMOothing:MODE [OFF|AVERAGE]** activates the data smoothing, whereby the measured level results are averaged over a certain number of neighbored samples.

- **MEASurement:STEPpedswEEP:SMOothing:ACTIVE ...** defines the active channel(s).
- **MEASurement:STEPpedswEEP:SMOothing:RESolution <Percent>** defines the lower and the upper limit of the frequency window.

$$\text{LowerLimit} = \frac{f_{\text{current}}}{2^{\frac{\langle \text{Percent} \rangle}{100}}}$$

$$\text{UpperLimit} = f_{\text{current}} * 2^{\frac{\langle \text{Percent} \rangle}{100}}$$

Equation 28 Calculation of Frequency Window Limits

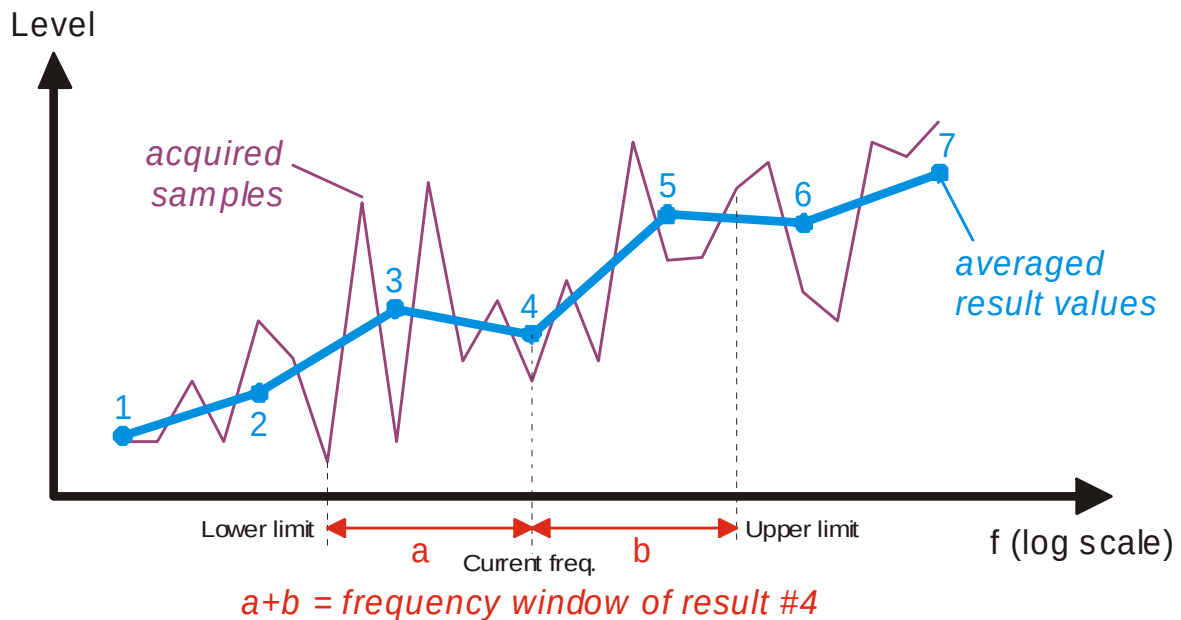


Fig 80 Data Smoothing Principle

Fig 80 explains the data smoothing frequency window that is defined in percent of the octave of the current frequency.

Example

Given: Current frequency = 1'500 Hz; width of the frequency window = 33.33%

⇒ lower limit of frequency window: $1500 / 2^{0.33} = 1'193 \text{ Hz}$

⇒ upper limit of frequency window: $1500 * 2^{0.33} = 1'886 \text{ Hz}$

Result: The measurement result at 1'500 Hz is calculated by averaging all samples that are acquired in the band from 1'193 Hz to 1'886 Hz

Stepped Sweep Transmission

Acquisiton Mode

Prior to the signal transmission, the stepped sweep acquisition mode must be adjusted properly (commands **MEASurement:STEPpedswEEP:ACQUisition** [**RMSLEVEL**,**DISTORTION**] and **MEASurement:STEPpedswEEP:DISToRTion:ACQUisitionlength** <Length>, p. 144), depending on the measurement function:

- **RMSLEVEL** for Level or Phase measurements.
- **DISTORTION** for 2nd, 3rd, 4th or 5th harmonic, THD or THD+N analysis.

Test Execution & Triggering

RT-2X always applies the **INTNoheader** trigger mode for a stepped sweep analysis, regardless of the last **INPut:SYNC ...** command. During the test, the **RT-2X** generator & analyzer are synchronized so that the sweep speed is automatically adjusted to the actual setup. The analysis of an externally generated sweep is not possible.

- Optimize the **RT-2X** input range as described in chapter **Input Range** (p. 189).
- initiate the sweep transmission & acquisition with **OUTPut:STEPpedswEEP:STARt**.

NOTE	Stepped sweep measurements are only supported in the 48 kHz mode.

Stepped Sweep Measurements

NOTE Make sure that following modes are adjusted properly before executing a stepped sweep measurement:

- Acquisition mode (p. 262).
- Settling (p. 258f).

Distortion

RT-2X supports three different stepped sweep distortion measurements:

- 2nd, 3rd, 4th, 5th harmonic (**MEASurement[1|2]:STEPpedswEEP:DISTortion:HARMONIC:UNIT [DB|%|DBV|V|DBM]**, **MEASurement[1|2]:STEPpedswEEP:DISTortion:HARMonic? [2|3|4|5]**).
- THD (commands **MEASurement[1|2]:STEPpedswEEP:DISTortion:THD:UNIT [DB|%]** and **MEASurement[1|2]:STEPpedswEEP:DISTortion:THD?**)
- THD+N (commands **MEASurement[1|2]:STEPpedswEEP:DISTortion:THD:UNIT [DB|%]** and **MEASurement[1|2]:STEPpedswEEP:DISTortion:THD?**).

NOTE The speed and accuracy of a distortion measurement depends directly from the thorough adjustment of the settling parameters. Please refer to the corresponding chapter (p. 258f).

Level

- **MEASurement[1|2]:STEPpedswEEP:RMSLevel:UNIT [DBV|V|DBSPL|DBPA]** defines the unit for the level result.
- **MEASurement[1|2]:STEPpedswEEP:RMSLevel?** queries the level results of the last successful sweep acquisition.

Phase

- Define the phase unit with **MEASurement:STEPpedswEEP:PHASe:UNIT [RAD|DEG]**.
- Query the phase result at a single frequency or the phase results of all sweep frequencies with the command **MEASurement[1|2]:STEPpedswEEP:PHASe? <MeasFrequency>**, whereby the optional parameter **<MeasFrequency>** defines the single frequency.

Test Setups

Start Commands

OUTPut:MTONe:STARt

- The generator immediately starts transmitting the multitone burst.
- The analyzer starts sampling immediately after the start command **OUTPut:MTONe:STARt** (trigger mode **INTNoheader**) or as soon as the trigger condition is met (trigger modes **INTernal**, **EXTernal** or **THReshold**).
- In the trigger modes **INTernal**, **EXTernal** and **THReshold**, the maximum allowed time delay between the test signal generation (initiated by the start command) and the triggering of the analyzer is 10 seconds (default = 500 ms) This timeout can be adjusted with the command **INPut:TRIGger:TIMEout <Timeout>**.

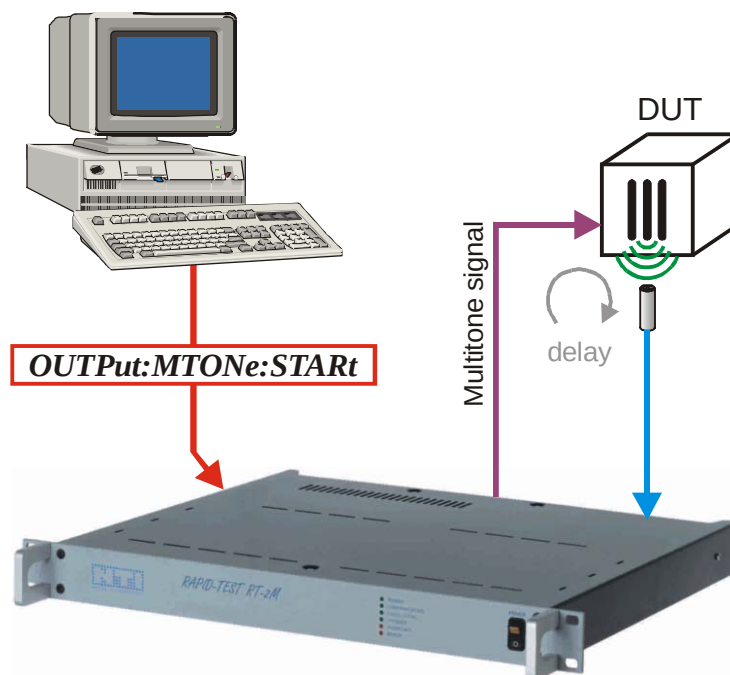


Fig 81 Command OUTPut:MTONe:STARt

Typical applications:

- *Internal* multitone analysis, i.e. the test signal is transmitted from the **RT-2X** generator through the DUT to the analyzer of the same **RT-2X** unit. Thereby, the maximum allowed delay is 10 seconds.
- *External* signal analysis, whereby the 'arrival' time of the incoming signal is predictable within few seconds (please refer also to p. 229).

OUTPut:STEPpedswEEP:STARt

- The generator immediately starts transmitting the stepped sweep.
- The analyzer starts sampling immediately after command **OUTPut:STEPpedswEEP:STARt**.
- Optionally, a delay between the start command and the beginning of the settling procedure can be applied (refer to chapter **Stepped Sweep Delays**, p. 257).

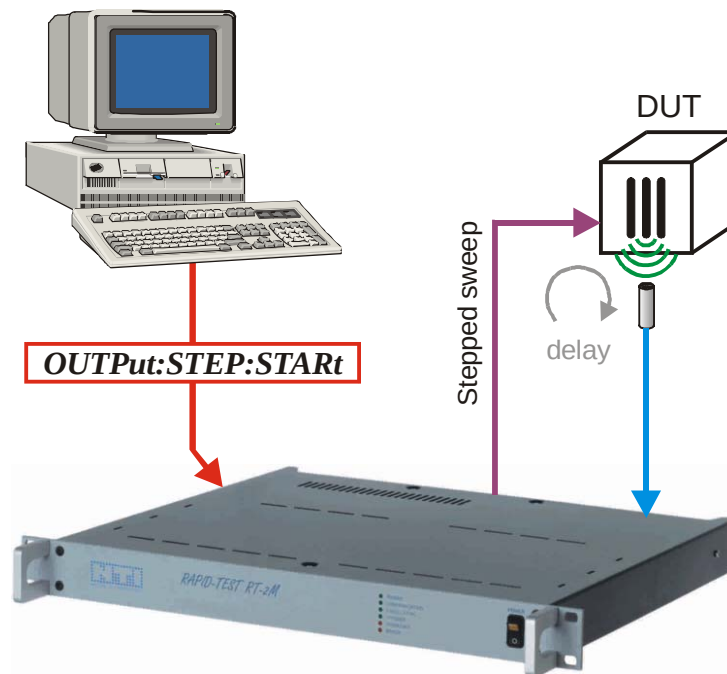


Fig 82 Command OUTPut:STEPpedswEEP:STARt

NOTE The RT-2X unit that generates the stepped sweep must analyze it as well.

Typical applications of the stepped sweep analysis are frequency response measurements of electroacoustic transducers (tweeters, drivers, woofers etc.)

OUTPut[1|2]:PUResound:CHIRp:STARt

NOTE This command is only available if the PureSound™ option is enabled.

- The generator immediately starts transmitting the chirp (i.e. gliding sweep).
- In the trigger mode **INTNoheader**, the analyzer starts sampling immediately after command **OUTPut[1|2]:PUResound:CHIRp:STARt**.
- Alternatively, in the trigger mode **THReshold**, the analyzer starts sampling as soon as the trigger condition is met. In this case a maximum timeout of 10 seconds can be applied with command **INPut:TRIGger:TIMEout <Timeout>**.

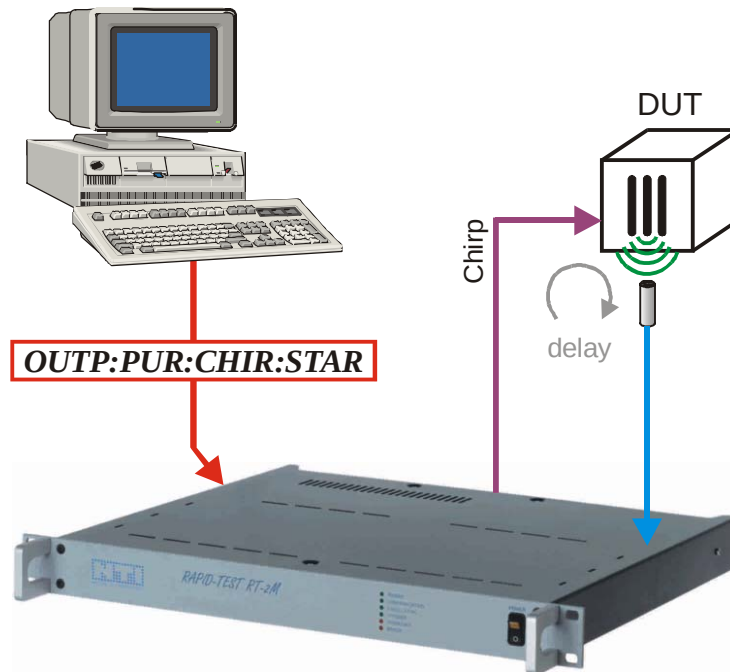


Fig 83 Command OUTPut[1|2]:PUResound:CHIRp:STARt

This command is used for Rub & Buzz transducer tests, whereby the chirp can be generated by the same **RT-2X** unit that analyzes the transmitted test signal *or* by an external device, supposed that the latter is able to provide a linear + gliding sweep and that the 'arrival' time of the chirp is predictable within few seconds.

MEASurement[1|2]:PUResound:STARt

NOTE This command is only available if the PureSound™ option is enabled.

- The analyzer starts sampling immediately (trigger mode *INTNoheader*) or as soon as the *THReshold* trigger condition is met, whereby this must happen within a maximum timeout of 10 seconds after the command *MEASurement[1|2]:PUResound:STARt*.
- The generator does not send out any test signal.

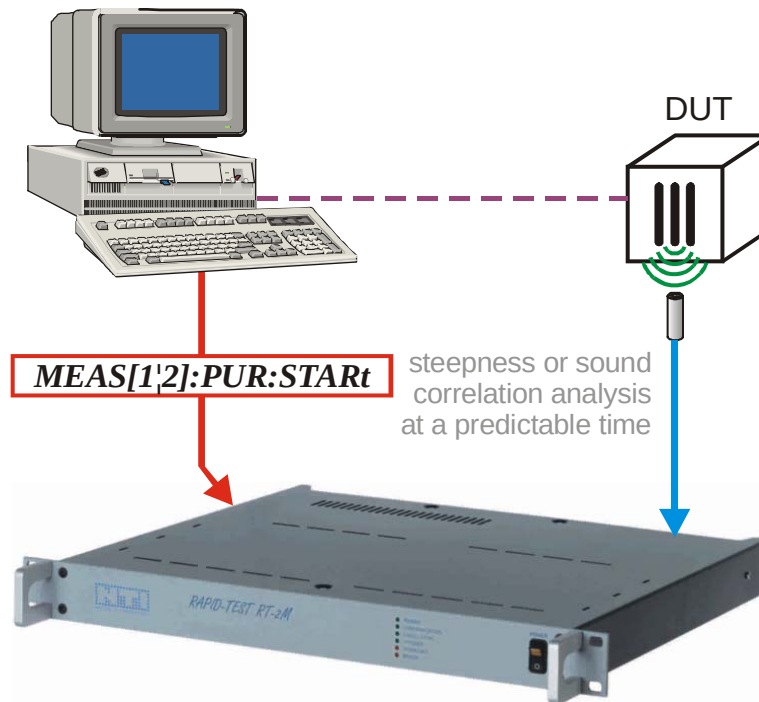


Fig 84 Command *MEASurement[1|2]:PUResound:STARt*

This command is typically used for *steepness* measurements or the *sound correlation* analysis of an *externally generated sound sequence*, whereby the 'arrival' time of the signal is *predictable* within few seconds.

INPut:TRIGger:ARMed

- The analyzer is armed, i.e. it waits until the trigger condition (**INTernal**, **EXTernal** or **THReshold**) is met before it starts sampling.
- The generator does not send out any test signal.
- Please note that the command is only available in the **Normal Mode** (p. 231).

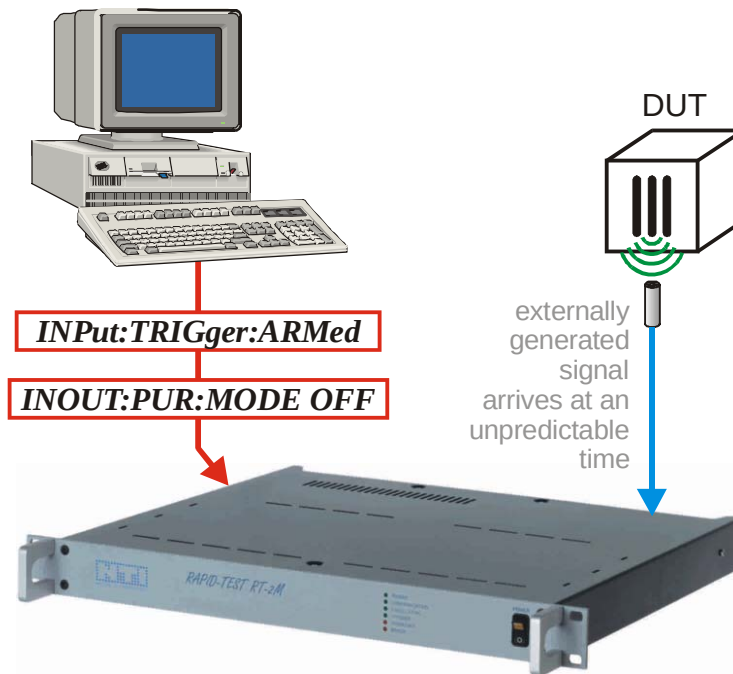


Fig 85 Command INPut:TRIGger:ARMed

Typical applications of an armed analyzer in the Normal mode:

- *Analysis* (e.g. RSS Selective Level, Frequency etc.) of an *externally generated audio signal*, whereby the 'arrival' time of the signal is not predictable (please refer also to p. 229).
- *Transmission line testing* (e.g. a broadcast network, a satellite link etc.), whereby the sending unit (e.g. a remote **RT-2X**) is *physically separated* from the analyzer.

NOTE After the **INPut:TRIGger:ARMed** command, not all measurement functions of **RT-2X** are available. Please refer to the command descriptions.
Reset the analyzer – if required – with command **INPut:TRIGger:BRake**

INPut[1|2]:TRIGger:ARMed

NOTE This command is only available if the PureSound™ option is enabled.

- The analyzer is armed, i.e. it waits until the **THReshold** trigger condition is met before it starts sampling.
- The generator does not send out any test signal.
- Please note that the command is only available in the **PureSound™ Mode**, (p 248).

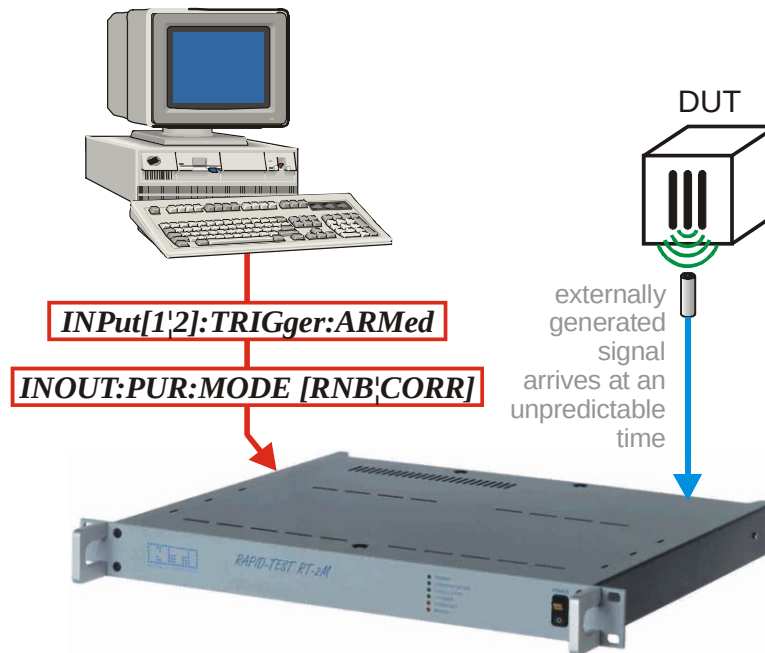


Fig 86 Command INPut[1|2]:TRIGger:ARMed

Typically it is used to arm the analyzer in the PureSound™ mode to analyze the steepness or sound correlation of an *externally generated signal*, whereby the 'arrival' time of the signal is not predictable.

NOTE After the `INPut:TRIGger:ARMed` command, not all measurement functions of **RT-2X** are available. Please refer to the command descriptions.
Reset the analyzer – if required – with command `INPut:TRIGger:BRake`

Triggering & Signal Acquisition

A core requirement for the correct signal analysis is to properly trigger the *RT-2X* analyzer to the incoming signal. *RT-2X* supports three alternatives:

1. Transmission of a proprietary *header* (i.e. trigger signal) that 'announces' the incoming multitone burst (chapter **Multitone Burst Structure**, p. 198). The analyzer starts sampling the incoming signal as soon as this header is recognized.
2. Transmission of the multitone burst *without* the proprietary header. In this case the analyzer must be triggered to start the data acquisition with the command **OUTPut:MTONe:STARt**.
3. Definition of a *threshold level* in the analyzer. As soon as the level of the incoming signal exceeds this threshold, the analyzer triggers and starts sampling the signal (similar to a scope trigger).

The 1st method is applied in most cases, supposed that:

- The multitone signal is generated & analyzed by a *RT-2X* unit.
- No major ambient noise is present.
- The time delay on the signal path is < 10 seconds.
- The DUT does not change the frequencies of the transmitted signal.
- A transmission line shall be tested with two or more remote *RT-2X* units (p. 278).

The 2nd approach is mainly used if:

- The test is located in a noisy environment.
- The frequencies of the multitone signal are changed on the transmission path.

The 3rd alternative is used:

- For the analysis of externally generated signals.
- For transmission line testing with two or more remote *RT-2X* units (p. 278).

NOTE Refer to pages 264 – 269 for further information about test setups, trigger modes and start commands.

Trigger Modes

The command **INPut:SYNC** [*INTernal*|*INTNoheader*|*EXTernal*|*EXTNoheader*|*THReshold*] defines, whether:

- The multitone burst must comprise of the proprietary header (*INT*, *EXT*) or not (*INTN*, *EXTN*, *THR*).
- The *RT-2X* analyzer synchronizes its sampling clock to the generator of the same instrument (*INT*, *INTN*, *THR*) or to the incoming multitone burst (*EXT*, *EXTN*).
- The *RT-2X* analyzer triggers (i.e. starts sampling) to the command **OUTPut:MTONe:STARt** (*INTN*, *EXTN*) or to the proprietary header of an incoming multitone burst (*INT*, *EXT*) or to a threshold level (*THR*).

Table 20 provides an overview on the trigger modes and their applications in respect to the two test initialization commands of *RT-2X*.

<i>Trigger Mode</i>	<i>Test Initialization Command</i>	
	<i>OUTPut:MTONe:StARt</i>	<i>INPut:TRIGger:ARMed</i>
<i>INTernal</i>	Generator transmits multitone burst with proprietary header. Analyzer triggers only to a proprietary header. Timeout = 50 – 10'000 ms (selectable). Analyzer sampling clock is synchronized to the internal generator.	Generator is deactivated. Analyzer triggers only to a proprietary header. No timeout. Analyzer waits, until the trigger condition is met. Analyzer sampling clock is synchronized to the internal generator.
<i>INTNoheader</i>	Generator transmits multitone burst without proprietary header. Analyzer starts sampling directly after the initialization command. Analyzer sampling clock is synchronized to the internal generator.	Generator is deactivated. Analyzer starts sampling directly after the initialization command. Analyzer sampling clock is synchronized to the internal generator.
<i>EXTernal</i> ⁷	Generator transmits multitone burst with proprietary header. Analyzer triggers only to a proprietary header. Timeout = 50 – 10'000 ms (selectable). Analyzer sampling clock is synchronized to 'clock sync' block of incoming burst.	Generator is deactivated. Analyzer triggers only to a proprietary header. No timeout. Analyzer waits, until the trigger condition is met. Analyzer sampling clock is synchronized to 'clock sync' block of incoming burst.
<i>EXTNoheader</i> ⁷	Generator transmits multitone burst without proprietary header. Analyzer starts sampling directly after the initialization command. Analyzer sampling clock is taken from the previous burst transmission in the EXT mode.	Generator is deactivated. Analyzer starts sampling directly after the initialization command. Analyzer sampling clock is taken from the previous burst transmission in the EXT mode.
<i>THReshold</i>	Generator transmits multitone burst without proprietary header. Analyzer triggers as soon as the input signal exceeds the threshold level, whereby the corresponding delay of Table 21 applies. Timeout = 50 – 10'000 ms (selectable). Analyzer sampling clock is synchronized to the internal generator.	Generator is deactivated. Analyzer triggers as soon as the input signal exceeds the threshold level. No timeout. Analyzer waits, until the trigger condition is met. Analyzer sampling clock is synchronized to the internal generator.

Table 20 Test Initialization vs. Trigger Modes

NOTE

In the case of a dual-channel burst transmission, the *RT-2X* analyzer will start sampling on *both channels simultaneously*, as soon as the trigger condition has been met on either channel.

After command *INPut:TRIGger:ARMed* the analyzer is reset by a successful triggering or with command *INPut:TRIGger:BRear*.

⁷ Only available in the normal mode for A-A devices!

INTernal

Command: **INPut:SYNC INT** (default status).

- The generated multitone burst comprises of a proprietary header (trigger + 'Sync Block') and the user-defined multitone signal.
- The analyzer only triggers (i.e. starts sampling) to an incoming multitone burst with proprietary header.
- The analyzer is synchronized to the internal clock.

Applications of the trigger mode "INTernal":

- The **RT-2X** unit generates & analyzes the user-defined multitone burst after the initialization command, whereby the ambient noise level must be low and no frequency shifts occur in the DUT.
- An external unit (e.g. a remote **RT-2X** or a replay-device) generates a multitone burst with proprietary header that shall be analyzed by **RT-2X**, whereby the burst must arrive at a known time (± 4 seconds) and no frequency shifts occur in the DUT.

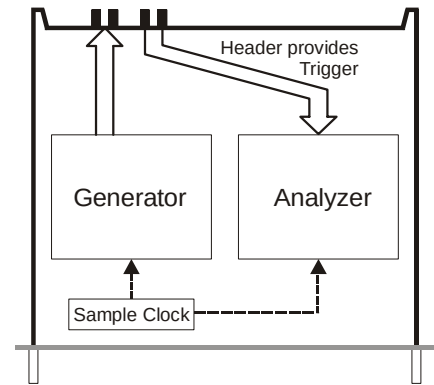


Fig 87 INT Mode

Initialization commands:

a) **OUTPut:MTONE:STArT**

- The **RT-2X** generator immediately transmits the burst.
- The **RT-2X** analyzer immediately starts waiting for an incoming multitone burst with proprietary header during a user-defined timeout period (**INPut:TRIGger:TIMEout <Timeout>**).

b) **INPut:TRIGger:ARMed**

- No multitone burst is generated.
- The analyzer immediately starts waiting for an incoming multitone burst with proprietary header (no timeout) *or* until it is reset with command **INPut:TRIGger:BRear**.

INTNoheader

Command: **INPut:SYNC INTN**.

- The generated multitone burst comprises only of the user-defined multitone signal (no proprietary header).
- The analyzer only triggers (i.e. starts sampling) to the initialization command.
- The analyzer is synchronized to the internal clock.

Applications of the trigger mode "INTNoheader":

- The **RT-2X** unit generates the user-defined multitone burst and starts sampling the incoming signal after the initialization command, independent of ambient noise or muted generator output connectors.
- The **RT-2X** unit shall start sampling at a user-defined time, regardless whether the incoming signal is a multitone burst or another signal.

Initialization command: **OUTPut:MTONe:STARt**

- The **RT-2X** generator immediately transmits the burst.
- The **RT-2X** analyzer immediately starts sampling the incoming signal.

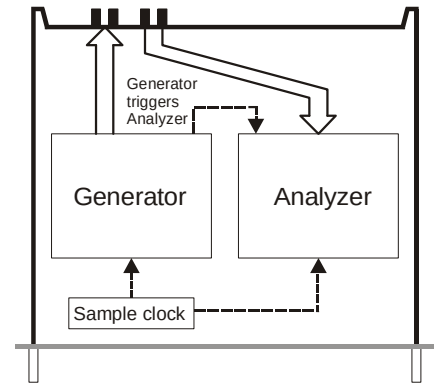


Fig 88 INTN Mode

EXternal

Command: **INPut:SYNC EXT**.

- The generated multitone burst comprises of a proprietary header (trigger + 'Sync Block') and the user-defined multitone signal.
- The analyzer only triggers (i.e. starts sampling) to an incoming multitone burst with proprietary header.
- The analyzer is synchronized to the 'clock sync' block of the proprietary header of an incoming multitone burst to compensate for frequency shifts.

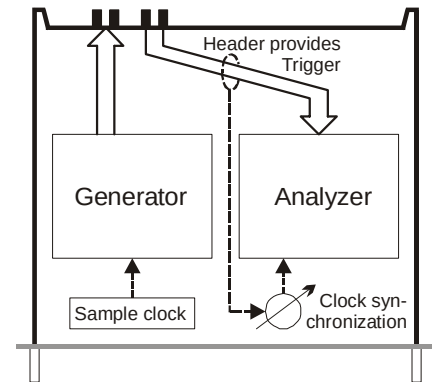


Fig 89 EXT Mode

Applications of the trigger mode "EXternal":

- The **RT-2X** unit generates & analyzes the user-defined multitone burst after the initialization command, whereby the ambient noise level must be low and frequency shifts are allowed.
- An external unit (e.g. a remote **RT-2X** or a replay-device) generates a multitone burst with proprietary header that shall be analyzed by **RT-2X**, whereby the burst must arrive at a known time (± 4 seconds).

Initialization commands:

a) **OUTPut:MTONE:START**

- The **RT-2X** generator immediately transmits the burst.
- The **RT-2X** analyzer immediately starts waiting for an incoming multitone burst with proprietary header during a user-defined timeout period (**INPut:TRIGger:TIMEout <Timeout>**).

b) **INPut:TRIGger:ARMed**

- No multitone burst is generated.
- The analyzer immediately starts waiting for an incoming multitone burst with proprietary header (no timeout) *or* until it is reset with command **INPut:TRIGger:BREak**.

EXTNoheader

Command: **INPut:SYNC EXTN**.

- The generated multitone burst comprises only of the user-defined multitone signal (no proprietary header).
- The analyzer only triggers (i.e. starts sampling) to the initialization command.
- The analyzer is synchronized to the sampling clock of several previously received multitone bursts that had been transmitted in the EXT mode.

Initialization command: **OUTPut:MTONe:START**

- The *RT-2X* generator immediately transmits the burst.
- The *RT-2X* analyzer immediately starts sampling the incoming signal.

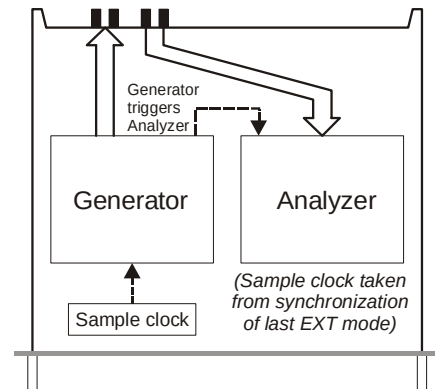


Fig 90 EXTN Mode

NOTE The EXT mode is only required for very specific applications and needs a very profound understanding of the setup.

THReshold

Command: **INPut:SYNC THR**.

- The generated multitone burst comprises only of the user-defined multitone signal (no proprietary header).
- The analyzer triggers (i.e. starts sampling) if the input level exceeds a user-defined threshold level (like a scope trigger).
- The analyzer is synchronized to the internal clock.

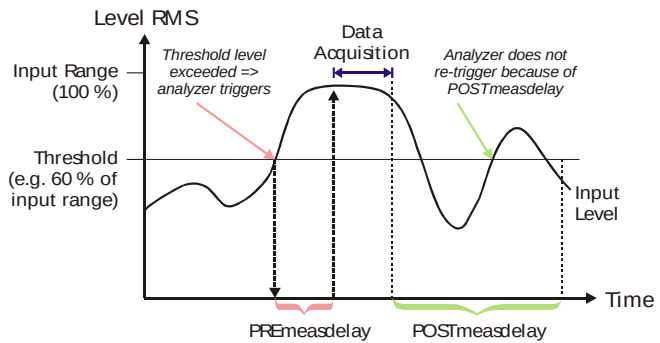


Fig 91 Example of Threshold Triggering with Delay

Adjust the threshold level for the active input channel by using the command **INPut:TRIGger:THReshold:LEVel <ThreshLevel>**. It defines the threshold in % of the current input range. In A-D or D-D operation, the reference level is 0 dBFS_p = 100 %.

If required, let the analyzer wait with the data acquisition for a time delay $t_{PreMeasDelay}$ after the trigger condition has been met (**Fig 91**).

Define this delay with the command **INPut:TRIGger:THReshold:PREmeasdelay <PreMeasDelay>** after having completed the signal definition.

If no delay has been defined or after the commands **OUTPut:MTONe:PARAmeter ...** or **OUTPut:MTONe:ACTive ...**, the default delays of **Table 21** apply.

f_s	Blocklength	Default Delay
8 kHz	128	128 ms
	256	256 ms
	512	256 ms
	1024	640 ms
	2048	512 ms
48 kHz	512	74 ms
	1024	170 ms
	2048	170 ms
	4096	426 ms
	8192	341 ms

Table 21 Default Delays of Threshold Trigger

Furthermore, it is possible to prevent the analyzer from re-triggering for a user-defined time delay $t_{PostMeasDelay}$ with the command **INPut:TRIGger:THReshold:POSTmeasdelay <PostMeasDelay>** after the data acquisition is completed (refer to **Fig 91**).

ATTENTION Define and activate the multitone signal before setting the time delays $t_{PreMeasDelay}$ and $t_{PostMeasDelay}$.

The trigger mode "THReshold" is typically used for the analysis of externally generated signals.

Initialization commands:

a) **OUTPut:MTONe:STARt**

- The **RT-2X** generator immediately transmits the burst.
- The **RT-2X** analyzer immediately starts waiting for an incoming signal that exceeds the threshold during a user-defined timeout period (**INPut:TRIGger:TIMEout <Timeout>**).

b) **INPut:TRIGger:ARMed**

- No multitone burst is generated.
- The analyzer immediately starts waiting for an incoming signal that exceeds the threshold level (no timeout) *or* until it is reset with command **INPut:TRIGger:BRake**.

Time Delay Measurement

Based on the measurement of the phase shift of a device, the *Signal Bin Delay* $T_{SignalBin}$ can be calculated according to the following equation.

$$T_{SignalBin} [\text{sec}] = \frac{\varphi_{SignalBin} [\text{deg}]}{f_{SignalBin} [\text{Hz}] * 360^\circ [\text{deg}]}$$

Equation 29 *Signal Bin Delay*

The signal bin delay $T_{SignalBin}$ calculation refers to the phase $\varphi_{SignalBin}$ and the frequency $f_{SignalBin}$ of a certain signal bin in a transmitted multitone signal.

The maximum signal bin delay that can be measured with ~~RT-2X~~ depends on the frequency of the signal bin. In practice, the signal bin should be defined at the lowest possible frequency, i.e. Bin_{Min} (p. 226). In such a case, $T_{SignalBin}$ can equal up to 49.8 ms (if $\varphi = 359^\circ$ and $f_{SignalBin} = 20$ Hz).

Transmission Line Testing

RT-2X allows measuring the characteristics of transmission lines (e.g. broadcast network, satellite link etc.), whereby the sending unit (e.g. a remote *RT-2X*) is *physically separated* from the analyzer.

Set up the sending & receiving *RT-2X* units as follows:

1. Define the multitone test signal according to the specific demands of the test (available bandwidth, number of bins, signal duration etc.). Save exactly this multitone signal on all involved units. Set the trigger mode of the generator to **INPut:SYNC INternal**.
2. Adjust the output level of the sending *RT-2X* to a value that leaves enough headroom to the dynamic range of the transmission line (no clipping must occur!).
3. Adjust the input range of the analyzing *RT-2X* unit(s) (p. 189).
4. On the analyzing *RT-2X* unit(s), set the trigger mode to **INPut:SYNC EXternal**.
5. Initialize the analyzing *RT-2X* unit(s) with command **INPut:TRIGger:ARMed** (p. 268)
6. Transmit the test signal with **OUTPut:MTONe:START** (if a transmission line shall be measured, it is necessary to first interrupt the broadcast signal on this line).
7. Query the required measurement results from the analyzing unit(s).

HINT The NTI software package *RT-Eval* allows saving a *RAPID-TEST* multitone signal as *.WAV (wavefile) or as PCM file. Thus, it is possible to feed such a file to a DUT that is able to replay or to convert it to the analog domain, where the signal is analyzed by a *RT-2X* unit.

Trigger Configuration

The most important topic of transmission line measurements with *RT-2X* is the definition and application of an appropriate trigger. For this purpose, three trigger configurations are available:

- **LOOSE** - standard configuration for industrial applications (noisy signals with a poor dynamic range, or internal link between generator & analyzer). The trigger condition is met rather easily, i.e. a false triggering has to be expected if the multitone signal is introduced into an ordinary broadcast program etc.
- **TIGHT** - special configuration for broadcast applications. The trigger condition has been tightened by far vs. **LOOSE** to avoid false triggering. This requires an accurate setting of the generator output level and the analyzer input range.
- **USER** - this parameter allows defining the trigger condition. However, since this application requires a very thorough and detailed understanding of the whole triggering complex, this approach is only for very advanced users, who have a profound understanding of all possibilities and their consequences.

ATTENTION Improper configuration of the **USER** trigger can result in an 'always' or 'never' condition, where the analyzer triggers on almost every incoming signal, or never recognizes any trigger, even if it is a correct one.

The trigger signal of a *RT-2X* multitone burst comprises three signal bins at different frequencies and with individual levels. To avoid false triggering, the receiving *RT-2X* permanently monitors the input signal for this pattern. Furthermore, the analyzer checks whether two more, predefined signal bins are 'empty', i.e. whether no level can be detected at these two frequencies. If this is the case, the analyzer recognizes the incoming signal as a *RT-2X* multitone burst and triggers to it.

Fig 92 visualizes the characteristic of a *RT-2X* trigger signal. The bottom bars (**T**) at the frequencies 1, 3 and 5 represent the set signal bins and their amplitudes, defined against the ground level of the generator, whereby signal bin 1 and 5 have identical amplitudes. The frequencies 2 & 4 represent the empty bins. Obviously, the levels of the five signal bins, together with their frequencies, make the uniqueness of the *RT-2X* trigger signal.

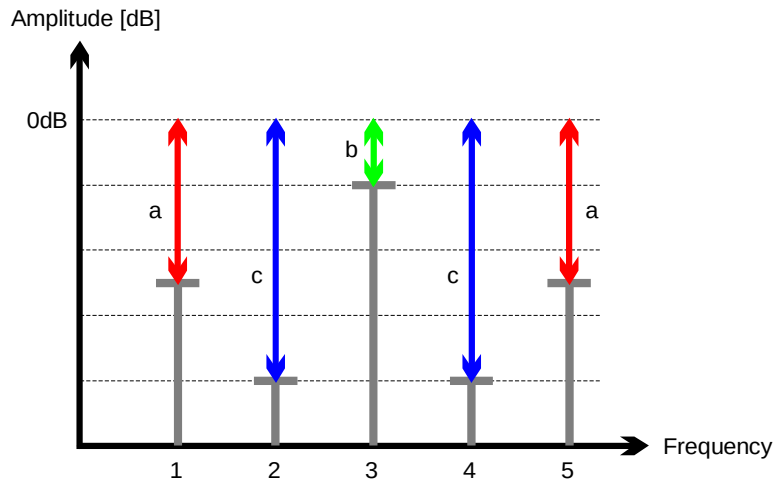


Fig 92 Trigger Definition

The application of the User trigger allows individually defining the 'headroom' between the 0dB line and the bottom bars (**T**). This is a very delicate operation and therefore not recommended for new users of *RT-2X*. In case that this feature truly has to be used, please refer to the explanations of **INPut:TRIGger:CONFIguration ...** and **INPut:TRIGger:USRConfiguration ...** as well as to the helpfile of the RT-EVAL software package.

The reference level of the analyzer especially for long-distance transmission lines cannot be of the same reference voltage potential as the generator. It is therefore configured by setting the current input range of the analyzing *RT-2X* unit as the reference level. This level equals the maximum detectable amplitude of all incoming signals (all higher levels would be clipped), and is represented by the 0 dB line on top of **Fig 92**.

Consequently, all received signals will be analyzed against 0 dB. On applying the trigger detection criteria, this would mean that the level pattern of an incoming multitone trigger must be within a certain range, defined by the trigger configuration of the analyzer.

Application Hints

Executing transmission line measurements with *RT-2X* is very demanding, especially if the generator & analyzer (i.e. the sending & receiving unit) are located remotely. Nevertheless, by considering the instructions listed above and the following hints, it should not become a major problem to establish a properly working set-up.

- The most effective approach to successfully execute a first test run is to place the sender & receiver not too far apart (e.g. in the same room), with both units already being controlled by individual PCs. Such a setup will probably not include a long transmission line, but is ideally suited to adjust the required settings of the majority of the involved systems to allow a proper measurement.
- For the first signal measurements, reduce the number of stages involved to a minimum to simplify the search for possible errors. As soon as the first successful tests are completed, the number of systems in the signal path can be increased stepwise, and the respective settings can be optimized to the actual demands.
- A very helpful tool to find out possible problems is to use a monitor speaker to make the transmitted multitone burst audible at the different stages of the line. Consequently, by listening to the sound of the burst, the operator can simply localize critical components and optimize their transmission behavior.

The most frequent obstacle of transmission line test setups is the 'refusal' of the analyzer to trigger to the incoming multitone burst. This effect is usually caused by improper adjustments of



the involved *RT-2X* generator / analyzer, or by sound enhancing instruments (e.g. equalizer, compressor, limiter, compander etc.) on the transmission line, which modify the trigger signal in a way that cannot be recognized anymore.

Consequently, the efforts to overcome non-successful triggering have to focus on the proper adjustment of the sending and the receiving *RT-2X*, as well as on the mutual optimization between the trigger signal and the sound enhancing systems.

Units

Correspondences Digital – Analog Units

<i>Digital Units</i>		<i>Corresponding Analog Units</i>		<i>Scale</i>
Decibel Full Scale Peak	[dBFSp]	Volt Peak	[dBVp]	log
Decibel Full Scale RMS	[dBFS]	Decibel Volt RMS	[dBV]	log
Percent Full Scale peak	[%FSp]	Volt peak	[Vp]	linear
Percent Full Scale RMS	[%FS]	Volt RMS	[V]	linear
-	[dBm0]	-	[dBm]	log

Table 22 Correspondences between Digital and Analog Units

In the digital operation, the relationship between the two units dBFSp and %FSp is defined by **0 dBFSp = 100 %FSp**, whereby both values represent the maximum possible digital output level.

dBm

This is basically an *analog RMS level* unit. It refers to the level of a 1 mW signal that is dissipated across 600 Ω. In practice, the reference impedance does not need to be 600 Ω. However, the I/O impedance of the test instrument & the DUT have to match, i.e. must be identical.

The definition for true dBm is

$$U[\text{dBm}] = 20 * \log_{10} \left(\frac{U_{Z1020}[V_{RMS}]}{\sqrt{0.001[\text{W}] * |Z1020|}} \right)$$

Equation 30 dBm Definition

whereby U_{Z1020} [V] is the voltage across $|Z1020|$ [Ω], i.e. the absolute value of the load impedance at 1020 Hz.

NOTE Some test instruments do not refer their dBm measurements to the actual load impedance, but to an assumed value of 600 Ω. In practice, this corresponds to the *dBu* unit, which refers to a reference level of 0.7746 V. Nevertheless, RT-2X always measures dBm according to Equation 30.

Make sure that RT-2X generates or measures a dBm level correctly by activating the corresponding output- & input-impedance as described in chapter **IEEE Standard Status Data Structure** (p. 183). Keep in mind that the dBm level depends on the actual impedance.

- If the RT-2X output level is expressed in dBm (**OUTPut[1'2]:LEVel <Level> DBM**), the actual output *Voltage* (expressed in *V*, *dBV*, *Vp* or *dBVp*) depends on the output impedance (commands **OUTPut[1'2]:IMPedance ...**, **OUTPut[1'2]:STATus?**).
- If the measurement results Level, Distortion, RSS or Noise are expressed in dBm, the returned values depend on the actual input impedance (refer to the commands **INPut[1'2]:IMPedance ...**, **INPut[1'2]:STATus?**).

NOTE To generate or measure a dBm level correctly, the selected I/O impedance of RT-2X must match to the corresponding impedance of the DUT.

NOTE A generated dBm level or measurement result changes if the I/O impedance is changed. Therefore, always select the RT-2X I/O impedance before the multitone burst is transmitted.

On the other hand, keep in mind that the output level, expressed in a RMS or peak unit, will not change its value if the output impedance is changed.

dBm0

dBm0 is a *relative RMS level* unit and the 'digital equivalent' to dBm. For instance, a level of 0 dBm0, fed into a (correctly installed) D-A converter, results in an output level of 0 dBm.

NOTE RT-2X supports dBm0 only in digital operation.

The relation between the peak level units %FSp, dBFSp and the RMS level unit dBFS is

$$100\%FSp = 0dBFSp = -20 * \log_{10}(\sqrt{C_f})dBFS$$

Equation 31 FSp to FS Conversion

Next, from the ITU G7.11 standard the relation between dBFS and dBm0 can be derived.

$$\begin{aligned} -3.01 dBFS &= 3.17 dBm0 \quad \{u - Law Coding\} \\ &= 3.14 dBm0 \quad \{A - Law Coding\} \end{aligned}$$

Equation 32 dBFS to dBm0 Conversion

The difference between a level expressed in dBFS or dBm0 is +6.18 (μ-Law) or +6.15 (A-Law). In other words:

$$x dBFS = (x + 6.18) dBm0_{\mu-Law} = (x + 6.15) dBm0_{A-Law}$$

NOTE Digital signals, expressed in dBm0, must be either μ-Law or A-Law coded.

Example #1

Given A sinusoidal signal (Crest factor $C_f = \sqrt{2}$) with full scale amplitude.

$$\Rightarrow 100 \%dBFSp = -20 * \log_{10}(\sqrt{2}) dBFS = -3.01 dBFS$$

Example #2

Given Multitone signal with $C_f = 2.42$, Output level $U_{Out} = -23.5$ dBFSp, μ-Law coding

$$\begin{aligned} \Rightarrow -23.5 dBFSp &= \{-23.5 - 20 * \log_{10}(2.42)\} = -31.18 dBFS \\ &= -25.0 dBm0 \end{aligned}$$



Overview

Unit	Explanation	Conversion Formula
V	Volt RMS	
V_{Peak}	Volt Peak	
dB	Decibel: relative voltage level (U_1 measured against the reference voltage U_2)	$dB = 20 * \log_{10} \left(\frac{U_1 [V]}{U_2 [V]} \right)$
dBPA	dB Pascal: air pressure in logarithmic scale	$dBPA = 20 * \log_{10} \left(\frac{U [V]}{MicSensitivity [V / Pa]} \right)$
dBV	dB Volt: RMS voltage referred to 1 V _{RMS}	$dBV = 20 * \log_{10} \left(\frac{U [V]}{1 [V]} \right)$
dBVp	dB Volt Peak: peak voltage referred to 1 V _{Peak}	$dBVp = 20 * \log_{10} \left(\frac{U [V_{Peak}]}{1 [V_{Peak}]} \right)$
dBm	Power relative to 1mW. Please note that every dBm result refers to the actual input impedance Z, as e.g. Z = 600 Ω.	$dBm = 20 * \log_{10} \left(\frac{U [V]}{\sqrt{0.001 [W] * Z [Ohm]}} \right) = 10 * \log_{10} \left(\frac{P [W]}{P_0 [W]} \right)$
dBm0	dBm referred to or measured at a point of zero transmission level.	$\begin{aligned} x \text{ dBFS}p &= x + 3.17 \text{ dBm0 (@ } \mu\text{-Law coding)} \\ &= x + 3.14 \text{ dBm0 (@ A-Law coding)} \end{aligned}$
dBn	dB above reference noise. Weighted circuit noise power in dB referred to 1 pW @ 600 Ω, which is defined as 0 dBn (−90 dBm). The last letter indicates the applied weighting (e.g. dBnc).	$dBn = 20 * \log_{10} \left(\frac{U [V]}{\sqrt{1.0 * 10^{-12} [W] * Z [Ohm]}} \right)$
dBnc	Weighted circuit noise power in dBn, acquired on a line by measuring set with 'C' message weighting.	
dBnc0	Noise, measured in dBnc, referred to zero transmission level point (OTLP).	$dBnc0 = dBnc - 10 * \log_{10} \left(\frac{Z [Ohm]}{600 [Ohm]} \right)$

Voltage Divider

RT-2X supports measurements of voltages higher than the specified max. input range, supposed that a voltage divider is inserted between the DUT and the RT-2X input connectors. For instance, testing a 100 V PA-system would exceed the maximum allowed RT-2X input voltage, but becomes possible with the setup shown below.

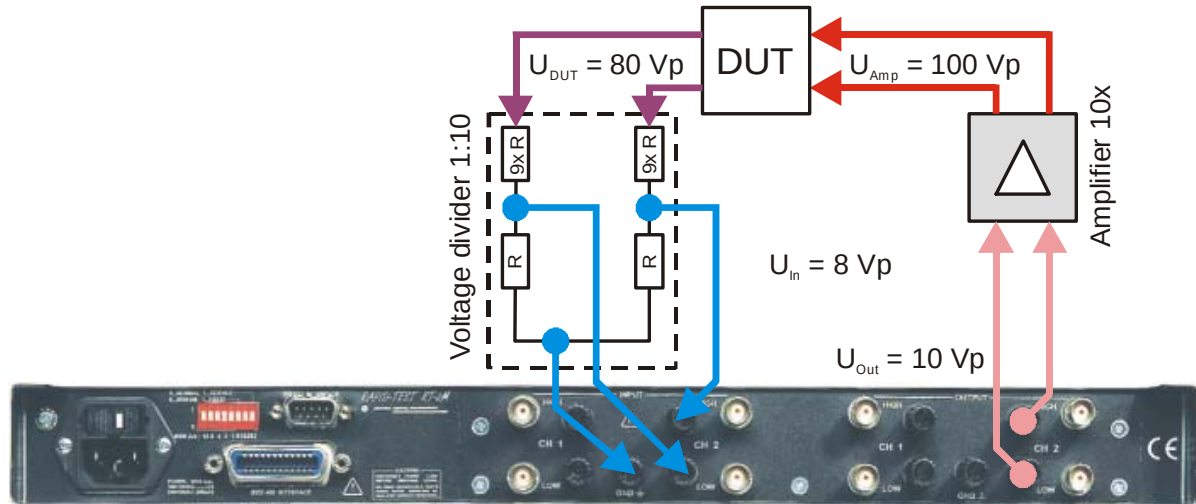


Fig 93 High-Voltage Measurement with Voltage Divider

To get correct measurement results, enter the ratio of the connected voltage divider (in the given example: <Ratio> = 10) with command **INPut[1|2]:VOLTagedividerratio <Ratio>**.

NOTE RT-2X automatically adjusts the input range according to the entered ratio. In other words, adjust the input range by entering the voltage U_{DUT} .

NOTE Make sure that the voltage divider is dimensioned properly according to the transmitted signal power.

Wiring of Analog Circuits

Analog DUTs can be connected directly to the 4 mm 'banana' or the BNC connectors on the rear panel of *RT-2X* (Note: Some older *RT-2X* units do not provide of BNC connectors).

These connectors can be used for balanced or unbalanced setups (see below), whereby *balanced* connections between the *RT-2X* inputs & outputs and the DUT are preferred in practice.

Use shielded cables for the wiring between the DUT and *RT-2X* to minimize noise and hum. Connect the shield of the cables to ground only on one side to avoid ground loops.

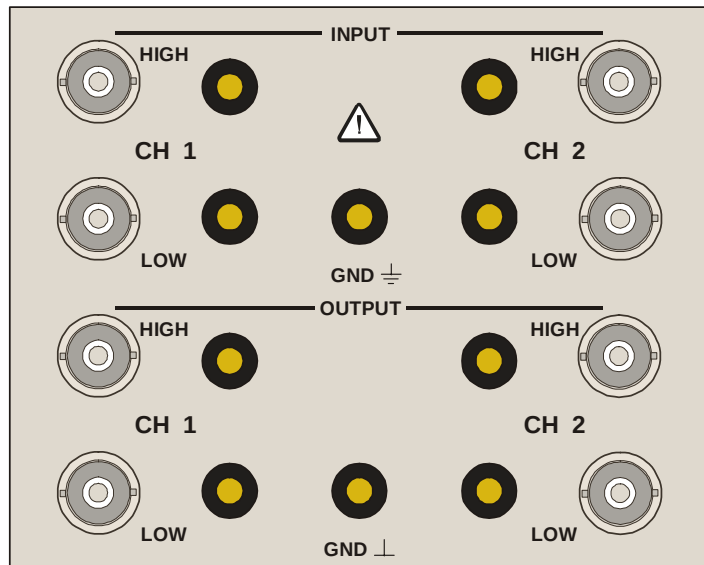


Fig 94 AnalogOutput & Input Connectors

Analog Input Connections

DUT Output ↔ Balanced RT-2X Input

Apply the *balanced* input connection to get a high noise and hum immunity. This applies for almost all measurements.

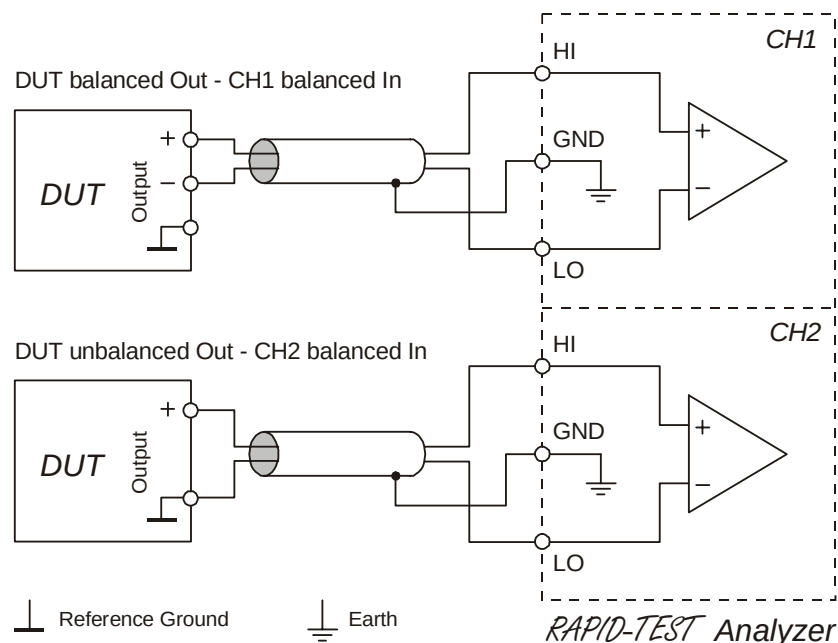


Fig 95 Balanced Input Connection through Banana Cables

Fig 95 shows the possible wiring between a DUT and the balanced input section of *RT-2X* by using shielded cables with *banana* connectors. In both cases, the 'hot' signal ("+") is connected to the HI input, whereby the shield of the cable is tied to earth on the side of *RT-2X*.

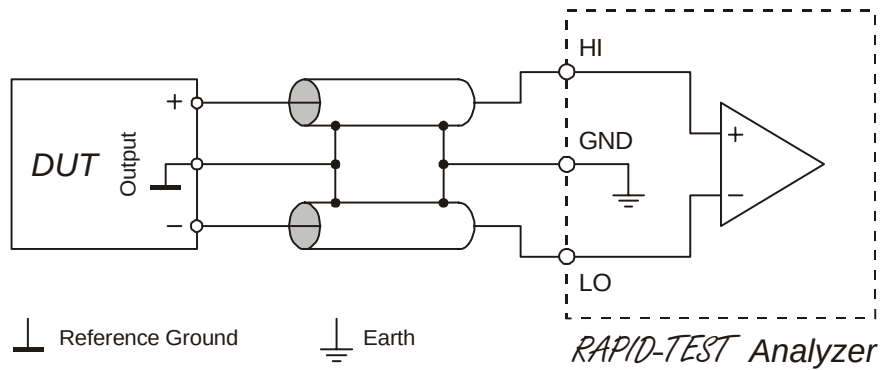


Fig 96 Balanced Input Connection through BNC Cables

Fig 96 shows the only possible wiring between a DUT and the balanced input section of *RT-2X* by using shielded cables with *BNC* connectors. Please note that ground loops could occur if the 'Reference Ground' is connected to earth within the DUT.

DUT ↔ Unbalanced RT-2X Input

The *RT-2X* input section can handle *unbalanced* signals as well. Unbalanced connections have one hot signal against chassis ground and are only recommended for short lines (below 3 ft / 1 m) and in noise-free environments.

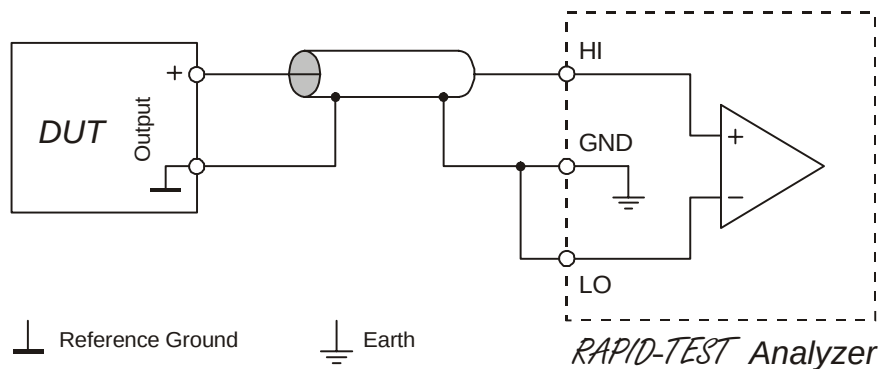


Fig 97 Unbalanced Input Connection

Fig 97 shows an example of how to connect an unbalanced DUT to the *RT-2X* input section. This wiring can be established either through banana or BNC connectors.

In this setup, the 'hot' output signal from the DUT is connected to the HIGH input of *RT-2X*, whereby the cable's shield is used as the return signal, i.e. as common ground. Please note that the LO input of *RT-2X* must be connected to the cable shield / GND.

Analog Output Connections

Balanced RT-2X Output ↔ DUT

NTI recommends connecting the *RT-2X* output section with the DUT through a *balanced* wiring. For most applications this setup is preferable to an unbalanced wiring.

Fig 98 and **Fig 99** show such a wiring between the *RT-2X* generator and the balanced inputs of a DUT, established through banana and BNC cables. In both cases, the output Voltage $U_{Out} = 1\text{ V}_p$ is achieved by superposing the two voltages of the HIGH and the LO output, U_{Out_HI} and U_{Out_LO} .

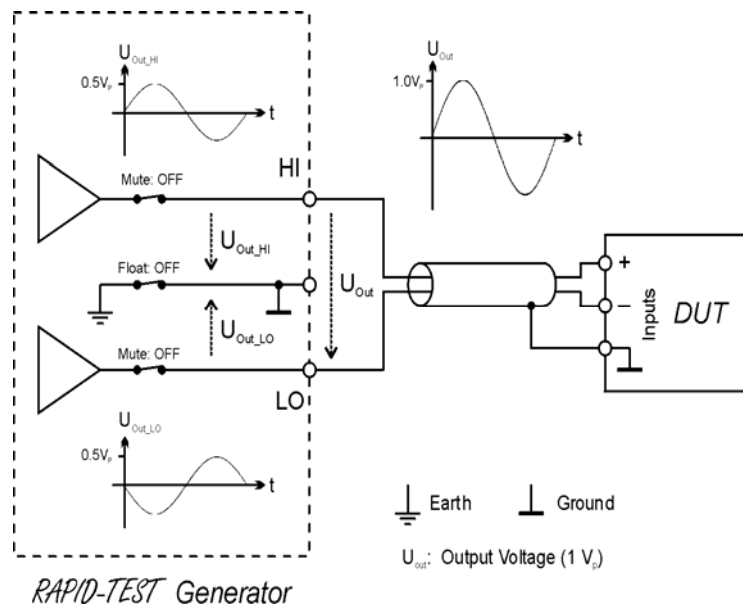


Fig 98 Balanced Output Connection through Banana Cables

In case of a balanced connection through *banana* cables, link the reference ground of the *RT-2X* generator to earth by closing the FLOAT relay with command **OUTPut:FLOAT OFF**.

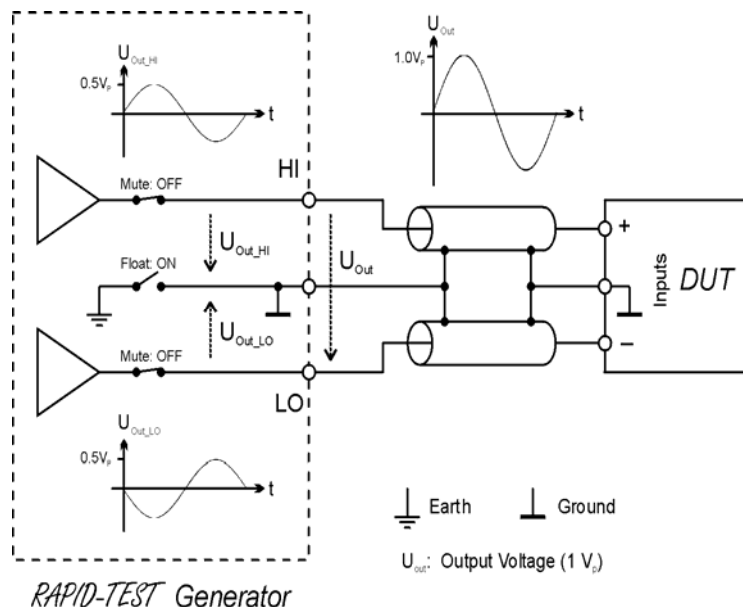


Fig 99 Balanced Output Connection through BNC Cables

In case of a balanced output connection through *BNC* cables, open the FLOAT relay to avoid a ground loop (unless the DUT has no ground connection). Use the command **OUTPut:FLOAT ON** for this setting.

NOTE NTI strongly recommends to establish balanced connections, where both the RT-2X HI and LO output are connected to the DUT.

If the DUT has only an *unbalanced input*, it is still possible to connect it to the *balanced output* of RT-2X by using Banana cables.

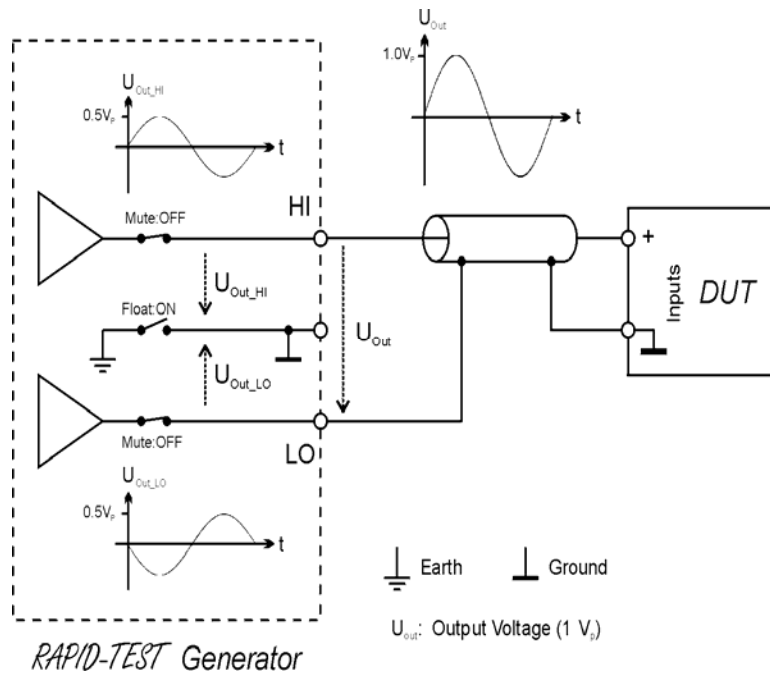


Fig 100 Balanced Output to Unbalanced DUT Connection through Banana Cables

In this case the RT-2X output level U_{Out} defined through the command **OUTPut[1'2]:LEVel <Level> [V|VP|DBV|DBVP|DBM|DBFSP|%FSP|DBFS|%FS|DBM0]** is equal to the DUT's input level.

Unbalanced RT-2X Output ↔ DUT

Another application is the *unbalanced output* connection of *RT-2X* to a DUT. In this case, the actual output level of *RT-2X* will always be 50 % (–6 dB) below the value of **OUTPut[1'2]:LEVel** <Level> [V|VP|DBV|DBVP|DBM|DBFSP|%FSP|DBFS|%FS|DBM0]. The reason for this effect is explained in the following picture.

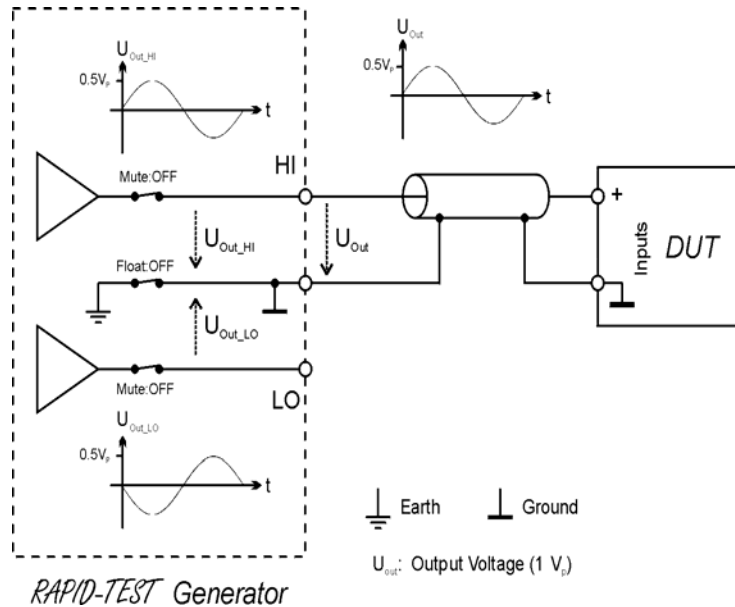


Fig 101 Unbalanced Output Connection through BNC Cables

Obviously, the "LO"-component of the differential output signal is not connected to the DUT, thus resulting in an output voltage $U_{Out} = U_{Out\_HI}$, equaling the "HIGH"-signal. In other words, the actual output signal – i.e. the signal that is fed into the DUT – corresponds to *half* the amplitude of the selected output level.

NOTE In case of an unbalanced output connection, the actual output voltage only equals half the selected output level ($U_{Out} = U_{Selected} - 6 \text{ dB}$).

APPENDIX

Technical Specifications

Analog Generator & Analyzer

Level flatness of the combined generator & analyzer

- 100 Hz – 10 kHz < ±0.1 dB
- 20 Hz – 20 kHz < ±0.2 dB

Temperature coefficient

0.025 dB / 5 °C in the operation range +5 to +45 °C with minimum 12 mm (½") free rack space above & below the RT-2X and free air circulation

Analog Multitone Generator

Number of frequencies (signal bins) per multitone signal 1 – 31

Sampling rate (fs) 48 kHz or 8 kHz

Frequency range

- 48 kHz sampling rate 20 Hz – 20 kHz
- 8 kHz sampling rate 20 Hz – 4 kHz

Number of channels 2 independent channels with individual levels

Level range (balanced) –60 to +29 dBVp in 0.1 dB steps (0.1 mVp to 28 Vp)
–60.8 to +28.1 dBm @ 600 Ω, sine signal (1–tone)

Level setting resolution 0.1 dB

Maximum load 150 Ω HIGH to LOW (level ≤ 23 dBVp [14.14 Vp])
2.0 kΩ HIGH to LOW (whole level range)

Variable BinLevel dynamic range 60 dB

Level accuracy @ 1 kHz < ±0.1 dB

Level flatness

- 100 Hz – 10 kHz < ±0.1 dB
- 20 Hz – 20 kHz < ±0.2 dB

Frequency resolution

- 48 kHz sampling rate 5.85 – 93.6 Hz (depending on blocklength)
- 8 kHz sampling rate 3.91 – 62.5 Hz (depending on blocklength)

Frequency accuracy < ±50 ppm

Blocklength

- 48 kHz sampling rate 512, 1024, 2048, 4096, 8192
- 8 kHz sampling rate 128, 256, 512, 1024, 2048

Residual distortion < –86 dB (16 bit DAC)

Number of stereo multitone signal memories 8 programmable (4 per sampling rate)
3 predefined (ERL, SRLLO, SRLHI)

Selectable output impedance per channel 150, 200, 600, 850, 900 Ω; complex (220 + 820 Ω || 115 nF)
optional: 4 custom-defined impedance (real or complex)

Output impedance accuracy

- real impedance Return Loss ≥ 46 dB or 1% of resistor value
- complex impedance Return Loss ≥ 35 dB or 1% of resistor value, 5% of capacitor value

Analog Stepped Sweep Generator

<i>Number of channels</i>	2 channels with individual levels
<i>Sampling rate (fs)</i>	48 kHz
<i>Frequency range</i>	20 Hz – 20 kHz
<i>Level range (balanced)</i>	–60 to +29 dBVp in 0.1 dB steps (0.1 mVp to 28 Vp) –60.8 to +28.1 dBm @ 600 Ω
<i>Level setting resolution</i>	0.1 dB
<i>Maximum load</i>	150 Ω HIGH to LOW (level $\leq$ 23 dBVp [14.14 Vp]) 2.0 k Ω HIGH to LOW (whole level range)
<i>Amplitude shape dynamic range</i>	60 dB
<i>Level accuracy @ 1 kHz</i>	$< \pm 0.1$ dB
<i>Level flatness</i>	
• 100 Hz – 10 kHz	$< \pm 0.1$ dB
• 20 Hz – 20 kHz	$< \pm 0.2$ dB
<i>Frequency resolution</i>	1 – 500 steps
<i>Frequency accuracy</i>	$< \pm 50$ ppm
<i>Residual distortion</i>	< -86 dB (16 bit DAC)

Analog Chirp Generator

<i>Number of channels</i>	2 channels with individual levels
<i>Sampling rate (fs)</i>	48 kHz
<i>Frequency range</i>	20 Hz – 6 kHz
<i>Level range (balanced)</i>	–60 to +29 dBVp in 0.1 dB steps (1 mVp to 28 Vp) –60.8 to +28.1 dBm @ 600 Ω
<i>Level setting resolution</i>	0.1 dB
<i>Level accuracy @ 1 kHz</i>	$< \pm 0.1$ dB
<i>Level flatness</i>	
• 100 Hz – 6 kHz	$< \pm 0.1$ dB
• 20 Hz – 6 kHz	$< \pm 0.2$ dB
<i>Maximum load</i>	150 Ω HIGH to LOW (level $\leq$ 23 dBVp [14.14 Vp]) 2.0 k Ω HIGH to LOW (whole level range)
<i>Frequency accuracy</i>	$< \pm 50$ ppm

External Output Load

	<i>Without LCL/RL option</i>	<i>With LCL/RL option</i>
<i>Absolute maximum DC load</i>		
• High/Low to GND	± 10 V _{DC}	± 77 V _{DC} ⁸ (AC-coupling ON)
• High to Low	± 20 V _{DC}	± 77 V _{DC} ⁸ (AC-coupling ON)
<i>Absolute maximum AC load</i>	.I. (not permitted)	150 V _{AC} ⁸ (refers to standard ringing voltage: 2 sec. ON – 4 sec. OFF, f = 15 – 68 Hz, R _{Source} $\geq$ 400 Ω)

⁸ Refer to paragraph **LCL/RL Option → Protection circuit** for further details

Analog Analyzer

<i>Number of channels</i>	2 independent channels with individual input range	
<i>Sampling rate (fs)</i>	48 kHz or 8 kHz	
<i>Bandwidth</i>		
• 48 kHz sampling rate	20 Hz – 20 kHz	
• 8 kHz sampling rate	20 Hz – 3.4 kHz	
<i>Input range</i>	–60 to +40 dBVp in 0.1 dB steps (1 mVp to 100 Vp)	
<i>Measurement range</i>	< 1 μVp to 100 Vp (–120 dBVp to 40 dBVp)	
<i>Level accuracy @ 1 kHz</i>	< ±0.1 dB	
<i>Level flatness @ fs = 48 kHz</i>		
• 100 Hz – 10 kHz	< ±0.1 dB	
• 20 Hz – 20 kHz	< ±0.2 dB	
<i>Level flatness @ fs = 8 kHz</i>		
• 20 Hz – 3.4 kHz	< ±0.2 dB	
• 3.4 kHz – 4 kHz	–3 dB @ 3.55 kHz to –26.5 dB @ 4 kHz	
<i>Level resolution at full scale</i>	20 bit	
<i>Residual distortion @ fs = 48 kHz</i>		
level +25 to –20 dBVp		
• THD+N (1-tone)	< –86 dB	
• Multiton-SINAD (3-tone)	> 86 dB	
<i>Residual noise @ fs = 48 kHz</i>	< –100 dBV (10 μV)	
<i>Residual input idle channel noise</i>	< –18 dB _{rnc} (–108 dBm @ 600 Ω)	
@ fs = 8 kHz, C-message filter active, inputs shorted, input range @ –60 dBVp		
<i>Phase accuracy (interchannel)</i>	±1 deg @ 20 Hz – 20 kHz	
<i>Residual interchannel crosstalk @</i>		
level +25 to –20 dBVp		
• 20 Hz – 10 kHz	< –80dB	
• 10 kHz – 20 kHz	< –75dB	
<i>Internal frequency resolution</i>	<i>Blocklength</i>	<i>Frequency resolution</i>
@ fs = 48 kHz	512	46.9 Hz
	1024	23.4 Hz
	2048	11.7 Hz
	4096	5.86 Hz
	8192	2.93 Hz
<i>Internal frequency resolution</i>	<i>Blocklength</i>	<i>Frequency resolution</i>
@ fs = 8 kHz	128	31.3 Hz
	256	15.6 Hz
	512	7.81 Hz
	1024	3.90 Hz
	2048	1.95 Hz
<i>Internal frequency accuracy</i>	±50 ppm	



Frequency measurement range and accuracy of an external signal, $f_s = 48$ kHz	Blocklength	Measurement range	Measurement accuracy ⁹
	512	187.5 – 19968.8 Hz	$\pm (0.4 \text{ Hz} + 25 \text{ ppm of } f_m)$
	1024	93.8 – 19968.8 Hz	$\pm (0.2 \text{ Hz} + 25 \text{ ppm of } f_m)$
	2048	46.8 – 19992.2 Hz	$\pm (0.1 \text{ Hz} + 25 \text{ ppm of } f_m)$
	4096	23.45 – 19992.2 Hz	$\pm (0.05 \text{ Hz} + 25 \text{ ppm of } f_m)$
	8192	23.43 – 19998.05 Hz	$\pm (0.025 \text{ Hz} + 25 \text{ ppm of } f_m)$
Frequency measurement range and accuracy of an external signal, $f_s = 8$ kHz	Blocklength	Measurement range	Measurement accuracy ⁹
	128	115 Hz – 3.55 kHz	$\pm (0.28 \text{ Hz} + 25 \text{ ppm of } f_m)$
	256	62.5 Hz – 3.55 kHz	$\pm (0.14 \text{ Hz} + 25 \text{ ppm of } f_m)$
	512	31.25 Hz – 3.55 kHz	$\pm (0.07 \text{ Hz} + 25 \text{ ppm of } f_m)$
	1024	23.43 Hz – 3.55 kHz	$\pm (0.035 \text{ Hz} + 25 \text{ ppm of } f_m)$
	2048	23.43 Hz – 3.55 kHz	$\pm (0.018 \text{ Hz} + 25 \text{ ppm of } f_m)$
Selectable input impedance per channel	100 k, 900, 850, 600, 200, 150 Ω ; complex (220 + 820 $\Omega \parallel 115$ nF) optional: 4 custom-defined impedance (real or complex)		
Input impedance accuracy			
▪ real impedance	Return Loss ≥ 46 dB or 1% of resistor value		
▪ complex impedance	Return Loss ≥ 35 dB or 1% of resistor value, 5% of capacitor value		
Input impedance coupling			
▪ real impedance	DC coupled		
▪ complex impedance	AC coupled		
Phantom power voltage	48 V _{DC} or 15 V _{DC}		
Phantom voltage accuracy	± 1 V _{DC}		
Phantom power inward resistance	6.8 k Ω @ 48 V 1.0 k Ω @ 15 V		
ICP power supply option			
▪ Open circuit voltage	25.7 V $\pm 5\%$		
▪ Current Source	3.6 mA $\pm 20\%$		
Signal transmission time	260 – 1500 ms (depending on sampling rate and blocklength)		
Synchronization & trigger modes	▪ Internal with header (analyzer triggers to proprietary header of the same RT-2X) ▪ Internal without header (analyzer triggers to generator of the same RT-2X; no proprietary header involved) ▪ External with header (analyzer triggers to proprietary header that was generated by an external signal source) ▪ Threshold (analyzer triggers as soon as the input signal exceeds the custom-defined threshold level)		
Filters	▪ C-message weighting filter according to north american standard ▪ CCITT psophometric weighting filter according to ITU O.41 ▪ A-weighting filter according to IEC 651 ▪ 750 μs De-emphasis		
Standard measurements	Level vs. frequency, Selective Level, Gain vs. frequency, Distortion vs. frequency, Noise vs. frequency, Phase vs. frequency, Crosstalk vs. frequency, MT-SINAD, Frequency (full band or selective)		
Optional measurements	Longitudinal Conversion Loss (LCL), Longitudinal Conversion Transfer Loss (LCTL), Return Loss (RL), Echo Return Loss (ERL), Singing Return Loss (SRL high, SRL low) Transient Steepness (Rub & Buzz, sound correlation)		

⁹ f_m = measured frequency (e.g.: $f_s = 48$ kHz, blocklength = 2048, $f_m = 2'100$ Hz $\Rightarrow$ accuracy = ± 0.1525 Hz)

Test cycle time @ $f_s = 48 \text{ kHz}$, 500 ms typical
 blocklength 512, 3 signal
 bins

Test cycle time @ $f_s = 8 \text{ kHz}$, 620 ms typical
 blocklength 128, 3 signal
 bins

External Input Load

	Without LCL/RL option	With LCL/RL option
Absolute maximum DC load		
▪ input impedance = 100 k Ω , HIGH/LOW to GND	$\pm 120 \text{ V}_{\text{DC}}$	$\pm 77 \text{ V}_{\text{DC}}$ ¹⁰ (AC-coupling ON)
▪ input impedance $\neq 100 \text{ k}\Omega$, HIGH/LOW to GND	$\pm 30 \text{ V}_{\text{DC}}$ (overvoltage protection switches to 100 k Ω if $U_{\text{In}} > \pm 30 \text{ V}_{\text{DC}}$)	
Absolute maximum AC load		
▪ input impedance = 100 k Ω , HIGH/LOW to GND	$\pm 120 \text{ V}_{\text{AC}}$ (sine signal)	150 V _{AC} (refers to standard ringing voltage: 2 sec. ON – 4 sec. OFF, $f = 15 - 68 \text{ Hz}$, $R_{\text{Source}} \geq 400 \Omega$)
▪ input impedance $\neq 100 \text{ k}\Omega$, HIGH/LOW to GND or HIGH to LOW	$\pm 30 \text{ V}_{\text{pAC}}$ ¹¹ (overvoltage protection switches to 100 k Ω if $U_{\text{In}} > \pm 30 \text{ V}_{\text{DC}}$)	

¹⁰ Refer to paragraph **LCL/RL Option** → **Protection circuit** for further details

¹¹ Example: 30 V_{pAC} $\cong$ 28.8 dBm @ 600 Ω , sine signal

LCL / RL Option

Measuring standard	IEEE 455-1985			
Reference impedance	736 Ω			
Protection circuit	- Threshold output AC load 28.28 Vp (20 V_{RMS})¹² - Threshold input AC load 125 Vp (88.4 V_{RMS})¹² - Maximum DC load ± 77 VDC (AC-coupling ON) or 0 VDC (AC-coupling OFF) - Maximum AC load 150 V_{RMS} (refers to standard ringing voltage: 2 sec. ON – 4 sec. OFF, f = 15 – 68 Hz, R_{Source} $\geq$ 400 Ω)			
Maximum output level	- LCL, LCTL A-A, A-D mode 7.0 Vp (16.9 dBVp, 15.2 dBm) @ 736 Ω - LCTL D-A mode 200.0 %FSp (6.0 dBFSp, 9.2 dBm0)			
Maximum input level	- LCL mode 15.2 dBm @ 736 Ω - LCTL A-A mode 12.0 Vp (21.6 dBVp, 20.0 dBm) @ 736 Ω - LCTL A-D mode 15.2 dBm0 @ 736 Ω - LCTL D-A mode 7.0 Vp (16.9 dBVp, 15.2 dBm) @ 736 Ω			
LCL, LCTL measuring accuracy	LCL range	20 – 200 Hz	200 Hz – 4 kHz	4 – 20 kHz
	0 – 60 dB	< 0.5 dB	< 0.3 dB	< 0.5 dB
	60 – 70 dB	< 1.5 dB	< 0.8 dB	< 1.5 dB
	70 – 80 dB	< 5.5 dB	< 3.0 dB	< 5.5 dB
	80 – 85 dB	< 8.5 dB	< 6.0 dB	< 8.5 dB
RL output level	–20 to +14 dBVp			
RL measuring accuracy with a real DUT	RL range	<i>fs</i> = 8 kHz, i.e. bandwidth 200 Hz – 4 kHz	<i>fs</i> = 48 kHz, i.e. bandwidth 200 Hz – 20 kHz	
	0 – 30	± 0.5	± 0.6	
	30 – 35	± 0.9	± 1.0	
	35 – 40	± 1.5	± 1.6	
RL measuring accuracy with a complex DUT	RL range	<i>fs</i> = 8 kHz, i.e. bandwidth 200 Hz – 4 kHz	<i>fs</i> = 48 kHz, i.e. bandwidth 200 Hz – 20 kHz	
	0 – 20	± 1.0	± 1.1	
	20 – 25	± 1.6	± 1.7	
	25 – 30	± 2.8	± 3.0	
Measuring error due to active AC-coupling	frequency	maximum level measuring error	maximum phase measuring error	maximum RL measuring error
	20 Hz	–0.62 dB	4.93 deg	4.70 dB
	50 Hz	–0.18 dB	2.01 deg	1.20 dB
	100 Hz	–0.09 dB	1.01 deg	0.30 dB
	200 Hz	–0.06 dB	0.34 deg	0.10 dB
	1000 Hz	–0.05 dB	0.10 deg	0.05 dB

¹² RAPID-TEST activates an internal protection circuit if an external voltage exceeds the threshold level. In this case, the output / input connectors of RAPID-TEST are shorted, i.e. the resulting current is only limited by the source resistance of the DUT



Digital Physical Interface

	<i>ISDN BRI Interface</i>	<i>E1 Interface</i>	<i>T1 Interface</i>
<i>Interface characteristics</i>	S ₀ Bus (2B+D) according to ITU I.430	according to ITU rec. G.703	according to ITU G.703, ANSI T1.403
<i>RT-2X subscriber type</i>	Terminal Equipment (TE)	./.	./.
<i>Signaling</i>	./.	CAS (channel associated signaling) ABCD bit signaling in channel 16 according to ITU G704 und G732	CAS (channel associated signaling) "robbed bit" signaling
<i>Framing format</i>	./.	CAS multiframe / CAS&CRC-4 multiframe	D4 / ESF
<i>Line coding</i>	AMI	HDB3 / AMI	B8ZS / AMI
<i>Impedance (terminated)</i>	100 Ω or open	120 Ω balanced	100 Ω
<i>Connectors</i>	2* RJ45	TX & RX Bantam jacks (TF-jacks) or RJ45	TX & RX Bantam jacks or RJ45
<i>Voice channels</i>	2* B-channel	30	24
<i>Clock source</i>		Recovered or internal (± 25 ppm)	Recovered or internal (± 25 ppm)
<i>Voice channel coding (companding)</i>		μ -Law, A-law according to ITU rec. G.711	μ -Law, A-law according to ITU rec. G.711

Digital Generator

	<i>ISDN BRI Interface</i>	<i>E1/T1 Interface</i>
<i>Generator type</i>	Multitone arbitrary	
<i>Sampling rate</i>	8 kHz	
<i>Frequency range</i>	20 Hz – 4 kHz	
<i>No. of frequencies per signal</i>	1 – 31	
<i>Frequency resolution</i>	3.91 – 62.5 Hz (depending on blocklength)	
<i>Blocklength</i>	128, 256, 512, 1024, 2048	
<i>Level range</i>		
• <i>in dBFSp</i>	–72.3 to +6 dBFSp ¹³	
• <i>in dBm0, μ-law, sine signal</i>	–69.1 to +9.17 dBm0 ¹³	
<i>Level setting resolution</i>	0.1 dB	
<i>Number of channels</i>	2 independent channels with individual levels are assigned to B1 and B2 of the BRI	2 independent channels with individual levels can be assigned to any of the 24 channels
<i>Output clock source</i>	Recovered	Recovered or internal ± 25 ppm
<i>Companding</i>	μ -Law / A-law according to ITU G.711 or none (8 bit linear)	
<i>Number of signal memories</i>	4 dual-channel	
<i>Signaling</i>	Activation/deactivation control, no D-channel signaling supported	Robbed bit signaling • full access to ABCD bits • user-defined slot-independent sequences

¹³ 0 – 6 dBFSp (3.17 – 9.17 dBm0) for the determination of the DUT's coder overload capacity

Digital Analyzer

	ISDN BRI Interface	E1/T1 Interface																		
<i>Bandwidth</i>		20 Hz – 4 kHz																		
<i>Frequency resolution</i>		1.95 – 31.25 Hz (depending on blocklength)																		
<i>Filters</i>		Refer to analog analyzer specs																		
<i>Synchronization & trigger modes</i>	- Internal with header (analyzer triggers to proprietary header of the same RT-2X) - Internal without header (analyzer triggers to generator of the same RT-2X; no proprietary header involved) - Threshold (analyzer triggers as soon as the input signal exceeds the custom-defined threshold level)																			
<i>Sampling rate</i>		8 kHz																		
<i>Measurement functions</i>	Level vs. frequency, Selective Level, Gain vs. frequency, Distortion vs. frequency, Noise vs. frequency, Phase vs. frequency, Crosstalk vs. frequency, MT-SINAD, Frequency (full band or selective)																			
<i>Frequency measurement range and accuracy of an external signal, $f_s = 8$ kHz, internal clock source</i>	<table> <tr> <th><i>Blocklength</i></th><th><i>Measurement range</i></th><th><i>Measurement accuracy</i>¹⁴</th></tr> <tr> <td>128</td><td>115 Hz – 3.55 kHz</td><td>$\pm (0.28 \text{ Hz} + 25 \text{ ppm of } f_m)$</td></tr> <tr> <td>256</td><td>62.5 Hz – 3.55 kHz</td><td>$\pm (0.14 \text{ Hz} + 25 \text{ ppm of } f_m)$</td></tr> <tr> <td>512</td><td>31.25 Hz – 3.55 kHz</td><td>$\pm (0.07 \text{ Hz} + 25 \text{ ppm of } f_m)$</td></tr> <tr> <td>1024</td><td>23.43 Hz – 3.55 kHz</td><td>$\pm (0.035 \text{ Hz} + 25 \text{ ppm of } f_m)$</td></tr> <tr> <td>2048</td><td>23.43 Hz – 3.55 kHz</td><td>$\pm (0.018 \text{ Hz} + 25 \text{ ppm of } f_m)$</td></tr> </table>	<i>Blocklength</i>	<i>Measurement range</i>	<i>Measurement accuracy</i> ¹⁴	128	115 Hz – 3.55 kHz	$\pm (0.28 \text{ Hz} + 25 \text{ ppm of } f_m)$	256	62.5 Hz – 3.55 kHz	$\pm (0.14 \text{ Hz} + 25 \text{ ppm of } f_m)$	512	31.25 Hz – 3.55 kHz	$\pm (0.07 \text{ Hz} + 25 \text{ ppm of } f_m)$	1024	23.43 Hz – 3.55 kHz	$\pm (0.035 \text{ Hz} + 25 \text{ ppm of } f_m)$	2048	23.43 Hz – 3.55 kHz	$\pm (0.018 \text{ Hz} + 25 \text{ ppm of } f_m)$	
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2048	23.43 Hz – 3.55 kHz	$\pm (0.018 \text{ Hz} + 25 \text{ ppm of } f_m)$																		
<i>Measurement accuracy</i>	Depending on current coding (μ - or A-law ITU G.711)																			
<i>Number of channels</i>	2 independent channels with individual levels are assigned to B1 and B2 of the BRI	2 independent channels with individual levels can be assigned to any of the 24 channels																		
<i>Companding</i>	μ -Law / A-law according to ITU G.711 or none (8 bit linear)																			
<i>Signal transmission time</i>	400 – 1500 ms (depending on blocklength)																			
<i>Test cycle time @ blocklength 128, 3 signal bins</i>	620 ms typical																			
<i>Signaling</i>	No D-channel signaling supported	Robbed Bit signaling - full access to ABCD bits - sequence recorder records all signaling transitions in each slot																		
<i>Alarm detection</i>	none	- Red alarm: 192 consecutive zeros - Blue alarm: < 5 zeros within 3 ms - Yellow alarm: S-Bit, bit 2 for 256 consecutive channels set to zero or 16 consecutive patterns 00FF in the FDL (depending on mode) - Loss of synchronization (LOS) - Frame error - Changed frame alignment - Pulse violation																		

¹⁴ f_m = measured frequency (e.g. blocklength = 2048, $f_m = 2'100$ Hz $\Rightarrow$ accuracy = ± 0.1525 Hz)

PCM Interface - Timing

The PCM timing specifications are divided into four applications, depending whether the BCLK-Master or FrameSync is generated externally or internally.

The setup & hold periods are expressed in [% of T] or [ns], whereby the value of T is given by the current BCLK-mode according to following table:

PCM mode [kHz]	T [ns]
2048	488.28
1544	647.67
1024	976.56
512	1953.1
256	3906.3
128	7812.5
104	9615.3
64	15625

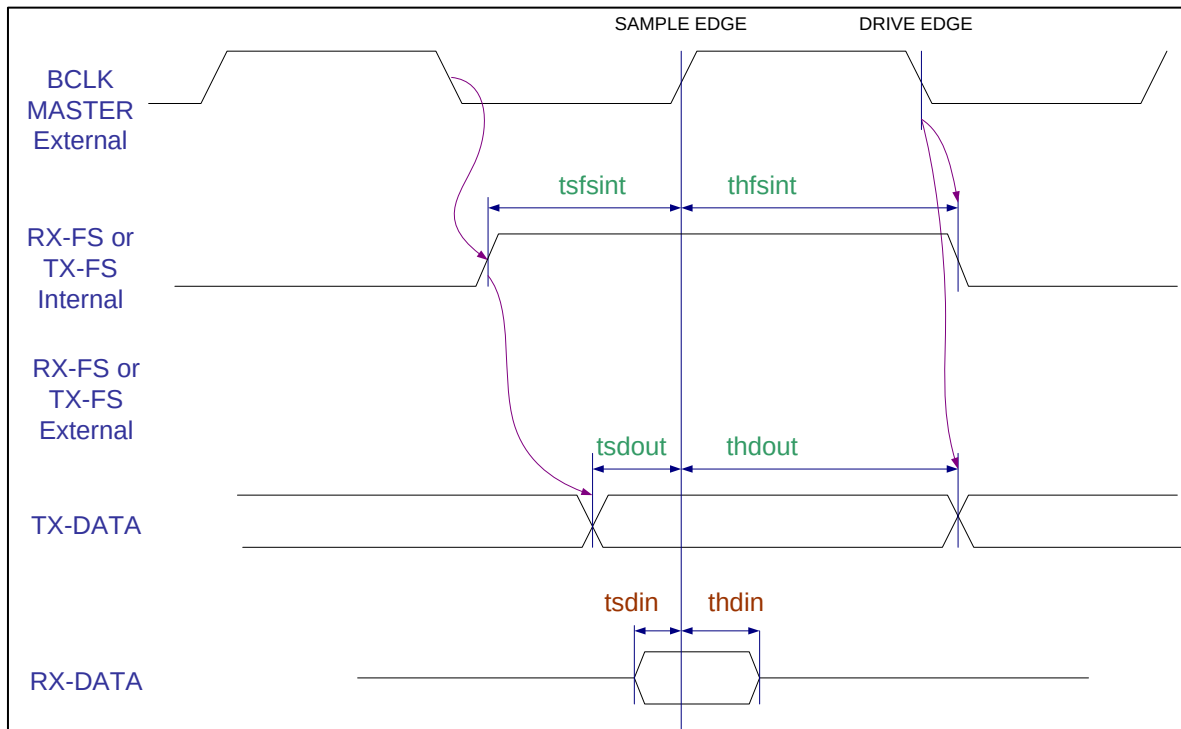
BCLK Master internal – FrameSync internal

minimum timing provided by RT-2X PCM interface	tsdout	36 [% of T]
	thdout	50 [% of T]
	tsfsint	43 [% of T]
	thfsint	49 [% of T]
minimum timing required by customer	tsdin	57 [ns]
	thdin	42 [ns]

BCLK Master external – FrameSync internal

minimum timing provided by RT-2X PCM interface	tsdout	22 [% of T]
	thdout	51 [% of T]
	tsfsint	29 [% of T]
	thfsint	50 [% of T]
minimum timing required by customer	tsdin	0 [ns]
	thdin	46 [ns]

Maximum allowed setup/hold times = 1 BCLK period



<i>Tsdout</i>	TX-data setup time before BCLK Master	(guaranteed by PCM Interface)
<i>Thdout</i>	TX-data hold time after BCLK Master	(guaranteed by PCM Interface)
<i>Tsfsint</i>	RX-FS, TX-FS setup time before BCLK Master	(guaranteed by PCM Interface)
<i>Thfsint</i>	RX-FS, TX-FS hold time after BCLK Master	(guaranteed by PCM Interface)
<i>Tsdin</i>	RX-data setup time before BCLK Master	(required at DUT)
<i>Thdin</i>	RX-data hold time after BCLK Master	(required at DUT)

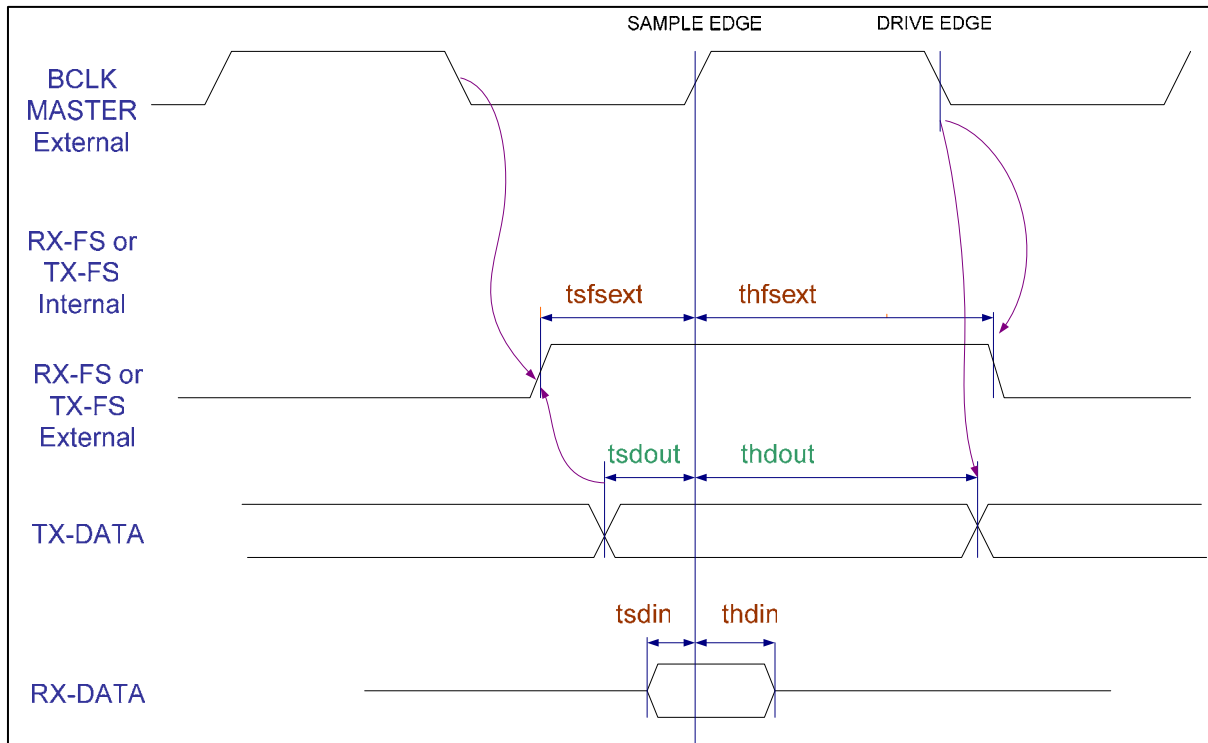
**BCLK Master internal –
FrameSync external**

minimum timing provided by RT-2X	tsdout	137 [ns]
	thdout	50 [% of T]
minimum timing required by customer	tsfsext	186 [ns]
	thfsext	42 [% of T]
	tsdin	57 [ns]
	thdin	67 [ns]

**BCLK Master external –
FrameSync external**

minimum timing provided by RT-2X	tsdin	76 [ns]
	thdin	51 [% of T]
minimum timing required by customer	tsfsext	125 [ns]
	thfsext	50 [% of T]
	tsdin	0 [ns]
	thdin	46 [ns]

Maximum allowed setup/hold times = 1 BCLK period



PCM Interface – Jitter

Maximum allowed jitter (no THD+N degradation)

<i>Jitter frequency [kHz]</i>	<i>maximum BCLK jitter pp [ns] *</i>	<i>maximum BCLK jitter [mUI]</i>
0.50	41	
1.00	35	
2.00	21	
5.00		8
10.00		16
20.00		35
50.00		70
100.00		140
200.00		280
500.00		500
1000.00		500

PCM Interface – Logic Level

		<i>5.0 V</i>	<i>3.3 V</i>	<i>2.5 V</i>
VIHmin		2.0	2.0	2.0
VILmax		0.8	0.8	0.8
VOHmin	IOH = -50 μ A	4.6	3.0	2.4
	IOH = -12 mA	3.9	2.3	1.7
VOLmax	IOH = +50 μ A	0.2	0.2	0.2
	IOH = +12 mA	0.4	0.4	0.4

DTMF Generator

<i>DTMF availability</i>	Analog and digital mode
<i>DTMF tones (4 x 4 keys)</i>	1 – 9, *, 0, #, A – D
<i>Frequency deviation</i>	±5 % selectable in 0.01% steps
<i>Frequency accuracy</i>	±25 ppm
<i>Amplitude ratio</i>	0.1 – 10 selectable
<i>DTMF tone length</i>	1 – 5000 ms selectable

DTMF Analyzer

<i>DTMF key recognition</i>	Analog
<i>Valid input signal levels</i>	maximum –20 dB below input range
<i>Freq. deviation acceptance</i>	±1.5 %
<i>Tone duration acceptance</i>	minimum 50 ms
<i>Interdigit pause acceptance</i>	minimum 50 ms

Options & Accessories

<i>PureSound™ license</i>	Key code to enable the transient steepness analysis functions. Required for Rub & Buzz and sound correlation measurements. Also includes RT-Speaker software for production applications.
<i>RCIO impedance module</i>	Additional, 2-chn. user-defined input & output impedance (real or complex). Maximum 4 pcs. RCIO impedances. • CA: 300 Ω + (1000 Ω // 220 nF) • CB: 200 Ω + (1000 Ω // 220 nF) • CC: 240 Ω + (164 Ω // 55 nF) • CD: 270 Ω + (750 Ω // 147 nF) • CE: 370 Ω + (620 Ω // 320 nF) • CF: 200 Ω + (680 Ω // 100 nF) • CG: 287 Ω + (847Ω // 96nF) • DA: 900 Ω + 2.16 μF • DB: 600 Ω + 2.16 μF • RA: 1200 Ω Other configurations available upon request.
<i>XLR adapter</i>	Hook-up box for RT-2X input connectors. Provides 2 pcs. XLR inputs, e.g. for the operation of the 3382 and 3384 measuring microphones.
<i>M2010 measuring microphone</i>	Balanced ½" omni-directional microphone, 20 Hz – 20 kHz, flatness ±0.5 dB (class 1.5), 10 – 48 V Phantom power

**General**

<i>Dimensions</i>	483 x 318 x 88 mm (19" x 12.5" x 3.5", i.e. 2 rack units high)
<i>Weight</i>	11 kg (24 lbs.)
<i>Remote control interfaces</i>	GPIB (IEEE-488.2) RS232 (38400 bps, 8 databits, 1 stopbit, no parity; protocol RTS/CTS; requires NTI RS232 cable)
<i>Standard software</i>	RT-EVAL evaluation software package National Instruments LabView and LabWindows CVI drivers
<i>Mains power requirements</i>	• 100, 120, 230 V_{AC} • 50, 60 Hz • 60 VA
<i>Calibration</i>	1 year recommend calibration interval
<i>Operating temperature</i>	+5 to +45 °C (+40 to +110 F), R.H. < 90 % non condensing