

## Mobile Phone Testing with RAPID-TEST

**RAPID-TEST is a very flexible audio test instrument especially designed for high-volume production lines of subassembled or completed mobile phones. The system supports the standard audio measurement functions as well as a highly sophisticated rub & buzz detection, based on a patented algorithm.**

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### 1. Introduction

RAPID-TEST is a state-of-the-art audio test system that meets all requirements of today's high-volume mobile phone production:

- **Easy integration:** Setting up the system, operating it and adjusting it to the specs of a new product is simple and straightforward.
- **Flexibility:** The system provides a wide range of measurement functions, HW interfaces and accessories.
- **Speed:** The system executes complete device tests within a minimum of time (typically 0.5 - 1.5 seconds).
- **Cost efficiency:** the overall test cost including investments, set-up time, operation and service is clearly below the reject costs of a production without quality control.

The following chapters describe a RAPID-TEST integration at different stages of a mobile phone production. Various hints and tips support the user in optimizing the audio quality verification in terms of saving time & money.

### 2. Test Strategy

Mobile phone productions typically comprise several tests and measurements of the audio quality:

1. Preassembled housing (transducer & microphone audio quality).
2. Populated PCB (electrical components)
3. Auxiliary features (vibration alert, DTMF)
4. Final test of the completed phone.

#### 2.1 Preassembly Test

The failure rate of preassembled housings can be up to 5%, due to faulty transducers or microphones as well as defects that occur during assembly. It is obvious that sorting out defective housings after this process is much more efficient than rejecting the costly phones at the end of the production line.

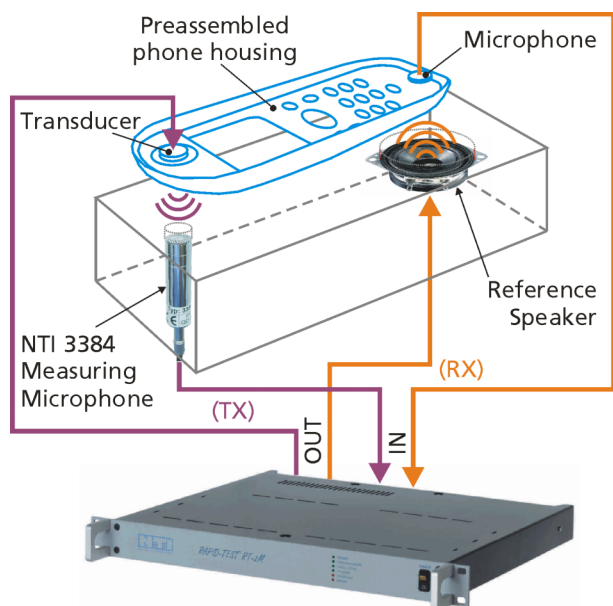


Fig. 1 Preassembled housing test

The audio quality test of preassembled housings typically comprises following measurements (please refer to *chapter 3*):

- Frequency response
- Sound pressure level (SPL)
- Microphone sensitivity
- Distortion or Rub & Buzz

If the preassembled housings are sourced from external suppliers (e.g. die-casting companies), it is recommended to test the subassemblies at their location.

### 2.2 Electrical PCB Test

Another subassembly that should be tested is the populated PCB (printed circuit board). This way, following defects can be detected before the board is assembled into the phone:

- Missing or defective components.
- Passive components with wrong value.
- PCB errors.

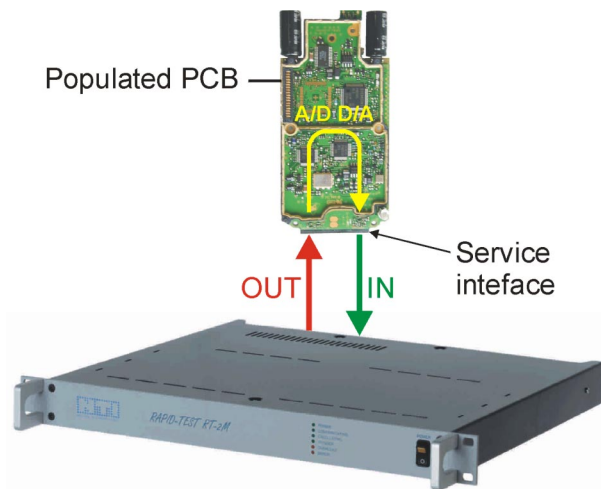


Fig. 2 PCB test

Depending on the production process the electrical PCB test is executed after population or before inserting the board into the mobile phone housing. The test typically measures the following parameters (refer to *chapter 3*):

- Level → false assemblies
- Distortion → faulty components
- Noise → Codec problems

Please note that the PCB test requires looping the signal through the audio circuit on the board.

### 2.3 Final Audio Test

At the end of the assembly line the mobile phone undergoes a final audio test. Normally, the following parameters are measured (refer to *chapter 3*):

- Frequency response
- Distortion or Rub & Buzz
- Noise
- SPL, microphone sensitivity
- Loudness rating (SLR, RLR)

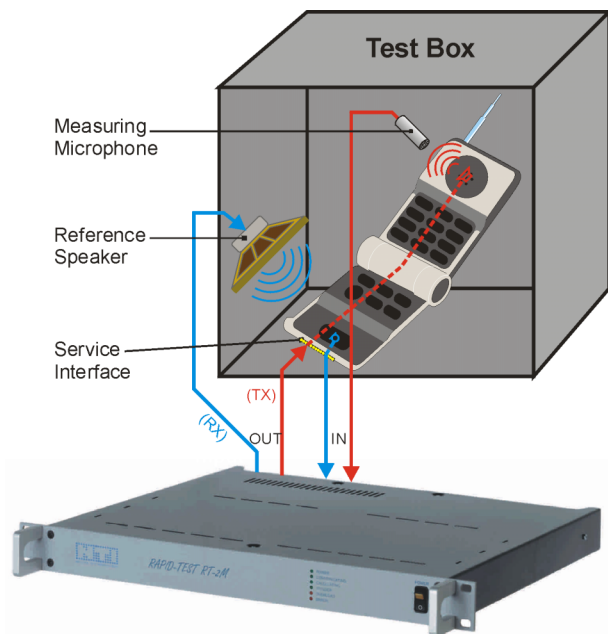


Fig. 3 Final audio test

The test investigates the audio quality of the transmit (TX) path, i.e. the user's speech and the receive (RX) path, i.e. replay quality. For this purpose the service interface, the microphone and the transducer of the mobile phone must be linked as shown in *Fig. 3*.

RAPID-TEST features minimum test cycle times to meet a core requirement of high volume production. The key is measuring the transmit (TX) and receive (RX) path simultaneously with a stereo multitone signal.

This way, a costly test box with complicated acoustical decoupling is obsolete. RAPID-TEST just transmits a multitone signal with separated signal bins (i.e. frequencies) on the two channels to avoid interference. Thus, the two paths can be analyzed accurately within a single cycle.

## 2.4 Vibration Alert Test

RAPID-TEST and NTI's vibration sensor are the ideal solution to test the vibration alert of a mobile phone. The test comprises two measurements:

- Frequency of the vibration alert
- Vibration level

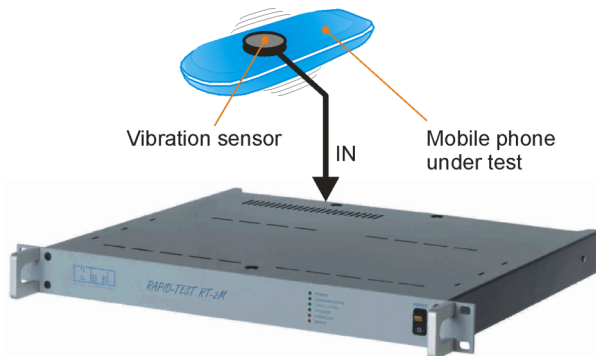


Fig. 4 Vibration alert test

Please refer to NTI's application note „Vibration Alert Testing with RAPID-TEST“ for further details.

## 2.5 DTMF Test

Verifying the DTMF coder of a mobile phone requires a robot that presses the keys in a defined order.

At the other end, the built-in DTMF decoder of RAPID-TEST permanently monitors & analyzes the incoming key tones:

- DTMF code
- Frequency
- Amplitude ratio

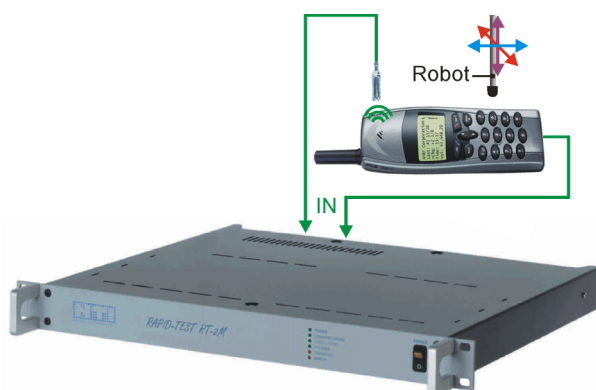


Fig. 5 DTMF test

The DTMF tones can be picked up electrically through the service interface or acoustically. Please refer to NTI's application note „DTMF Analysis“ for further details.

## 2.6 Ringer Melody Test

RAPID-TEST offers a unique feature to verify conventional and polyphonic ringer melodies as well as music sequences. This „correlation analysis“ is part of the PureSound™ option. It compares the current sound sample (e.g. ringer melody) against a „golden sample“ that has been acquired & stored previously. Thus, the correlation analysis supports the automated detection of audible signal defects as e.g.:

- Wrong melody
- Level discrepancies
- Time delays
- Clicks etc.

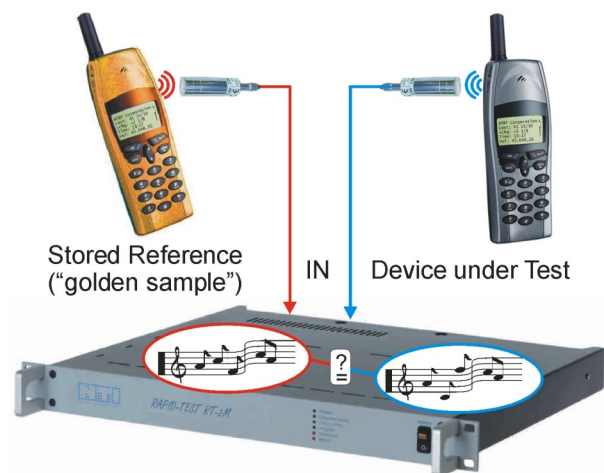


Fig. 6 Ringer melody verification

## 2.7 Audio test with RF modulator

It is also possible to test the audio transmission quality over a RF link. The basic setup is shown in Fig. 7.

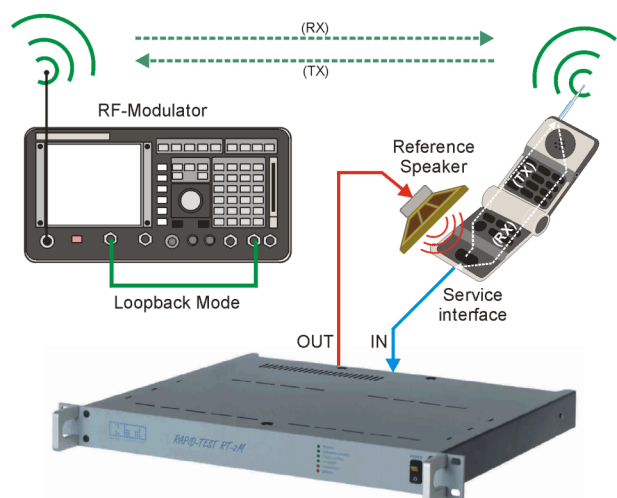


Fig. 7 Audio test with RF modulator

### 3. Audio Signal Analysis

RAPID-TEST offers a wide range of test signals and analysis modes for optimum audio testing at every production stage:

- Multitone signals for comprehensive, yet simultaneous & fast measurements.
- Stepped sweep for maximum resolution and high test signal levels.
- Chirp (gliding sweep) for Rub & Buzz detection.
- Generation of arbitrary sine signals to stimulate an external device.
- Analysis of externally generated signals, e.g. with a selective frequency or level measurement, correlation analysis etc.

The following table lists the standard test signals and measurement functions that are supported by RAPID-TEST.

	Multitone	Stepped sweep	Chirp
Level (frequency response)	+	+	
SPL, microphone sensitivity	+	+	
Distortion	+		
Noise	+		
Phase, polarity	+	+	
Loudness rating (SLR, RLR)	+		
Frequency of the dominant signal	+		
Signal energy per frequency band	+		
Rub & Buzz			+

Table 1 Availability of measurement functions

In most cases the multitone approach is the best solution for audio testing in high-volume mobile phone production lines. Due to the combination of flexibility, accuracy and speed, this test method became the worldwide standard applied by leading manufacturers.

On the other hand, stepped or gliding sweeps allow analyzing specific characteristics of the tested devices. Please refer to the next paragraphs for further details.

#### 3.1 Multitone

A multitone signal is composed of several sine tones with individual, user-defined frequencies.

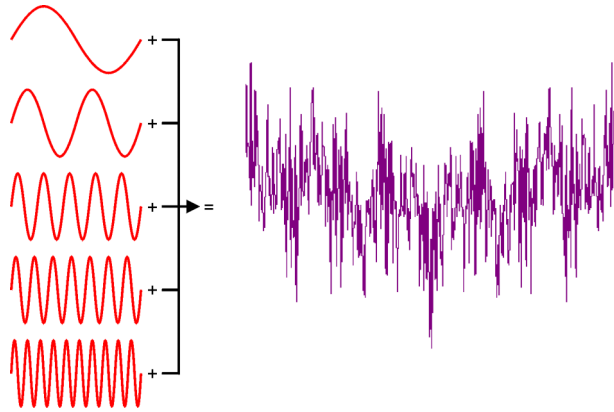


Fig. 8 Multitone signal composition

The analyzer calculates the spectrum of the transmitted signal with a FFT (Fast Fourier Transformation). Subsequently, the required measurement results can be queried by the controlling PC.

Multitones are the most frequently used test signals in large volume production lines due to the following advantages:

- Minimum cycle time: The short duration of a multitone test (typ. 500 ms - 1.5 s) perfectly meets the speed requirement of a high volume production.
- Flexibility: A single multitone test allows simultaneously calculating up to seven audio measurement results.
- 2 channels: The two multitone signal channels can be defined completely independently. Thus, simultaneous testing of the transmit (TX) and the receive (RX) path is possible.
- High immunity against ambient noise: The frequency selectivity of a multitone analysis automatically filters out ambient noise.
- High correlation to real-world signals: Multitone signals are much more similar to human speech than a single sine test tone. Thus, the acquired results are more realistic, especially for complex devices such as codecs.

### 3.2 Stepped Sweep

Stepped sweeps are generated by increasing the frequency of a sinusoidal signal in several steps.

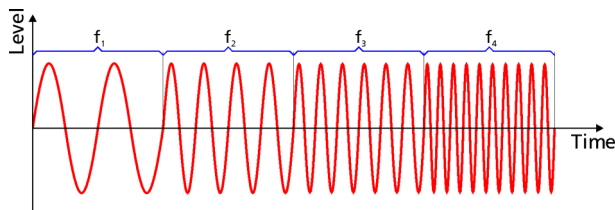


Fig. 9 Stepped sweep

Talking device analysis, stepped sweeps have three major advantages:

- **High resolution:** The frequency response can be acquired with higher resolution (e.g. 500 points @ 20 Hz - 20 kHz).
- **Signal level:** A stepped sweep allows driving the tested device (DUT) with a higher level at individual frequencies than a multitone signal.
- **Noise filtering:** Applying a tracking filter on the incoming signal results in high immunity against ambient noise.

On the other side, stepped sweep transmission normally last much longer than multitone measurements, especially if the number of test frequencies is high (> 100) or if the tracking filter is active.

RAPID-TEST supports stepped sweep testing including level and phase measurements.

### 3.3 Chirp (gliding sweep)

A chirp is generated by increasing the frequency of a sinusoidal signal continuously (i.e. not stepwise).

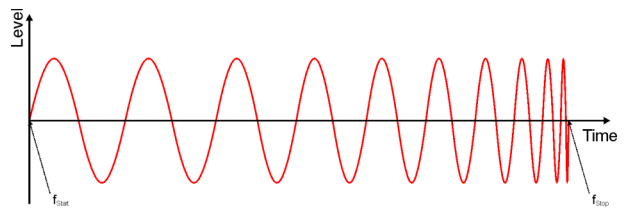


Fig. 10 Gliding sweep

A chirp is the optimum test signal for acoustical Rub & Buzz detection due to following reasons:

- **Virtually infinite frequency resolution:** A test signal for Rub & Buzz detection must comprise all possible resonance frequencies of defective devices.
- **Maximum signal level:** A chirp can be generated at the maximum allowed transducer input level, which is required to excite all Rub & Buzz defects.

RAPID-TEST supports chirp generation solely for Rub & Buzz detection with the patented transient analysis method of the PureSound™ option.

In a mobile phone production, this test should be applied on preassembled housings or for the final audio test (*chapter 2*).

Further information is filed in the NTI application note „RAPID-TEST and PureSound™“.

## 4. Test Optimization

Apart from the selection of a proper test signal & measurement function, the number of test signal frequencies, cycle time and ambient noise rejection need to be optimized according to the specific requirements of the corresponding test.

### 4.1 Test Signal Frequencies

Standard mobile phone audio tests typically cover 3 - 5 frequencies in the voice band.

The optimum test signal is a multitone, since it requires only one signal transmission for the acquisition of several measurement results (e.g. frequency response + distortion + SPL etc.).

Another advantage of multitone is the fact that they comprise several frequencies. Thus, data compressing devices as e.g. codecs are tested under „real-world“ conditions.

Furthermore, the 2-channel architecture of RAPID-TEST allows testing the transmit (TX) and receive (R) path simultaneously. In this case, the frequencies of the two channels must be defined individually to prevent crosstalk, e.g.

- Chn. 1 (TX): 280 Hz, 1 kHz, 3 kHz
- Chn. 2 (RX): 375 Hz, 1.1 kHz, 2.9 kHz

### 4.2 Cycle time

The production cycle time is a strongly limiting factor for every audio test. Typically, the available audio test duration is limited to 0.5 - 5 sec. (without handling time):

1. Preassembled housing: 0.5 - 1 sec.
2. Populated PCB: 5 - 10 sec.
3. Final audio test: 1.0 - 5 sec.
4. DTMF generator: 2 - 5 sec.
5. Vibration alert: 1 sec.
6. Buzzer, ringer melody: 1 - 10 sec.

Tests 1. - 3. require transmitting the test signal through the device. Due to the speed advantage multitone is the best solution for this task.

Alternatively, a stepped sweep can be used, supposed that only the frequency response has to be acquired.

Testing the last three parameters is not as time-critical, since the external signal generation lasts longer than the analysis.

### 4.3 Ambient Noise

Audio testing in production environments is compromised by ambient noise. Unfortunately, preventing or damping this noise is frequently very costly or not possible at all.

Therefore, immunizing the audio test system is the only solution. There are actually several solutions available:

- a) Test principles that are less sensitive to ambient noise.
- b) Filtering.
- c) Active noise cancellation.

#### a) Robust test method

Multitone testing has the advantage of being very immune to ambient noise by nature. This is due to the highly frequency-selective analysis that automatically filters out externally generated signal components.

Moreover, a longer blocklength (i.e. number of samples) of the multitone signal further improves its noise immunity.

#### b) Filtering

Stepped sweep analysis can only be immunized by applying a tracking filter. However, this suffers under the drawback of a slowing down the measurement.

On the other hand, applications that require more than 31 test signal frequencies shall be executed with a stepped sweep, due to the better signal-to-noise ratio.

#### c) Active noise cancellation

RAPID-TEST offers this feature only for Rub & Buzz analysis. In case of a failed device, the test is repeated and extracts the random signal components (i.e. ambient noise) by comparing the results of the two cycles. Thus, only systematic effects (i.e. the characteristics of the DUT) remain.

Obviously, the cycle time rises proportionally to the (restrictable) number of executed repetitions.

Last but not least it has to be stated clearly that e.g. a simple box around the test stand, lined with acoustically damping material is one of the most efficient solutions to reduce the negative impact of ambient noise on the audio test.



## APPENDIX: Programming

NTI offers a powerful tool for straightforward and quick test system integration into an automated environment: RT-Eval, the free evaluation SW with its code generator directly translates the system setup into program code. The user has just to copy & paste the generated code into the production control software.

**NOTE** Replace instruction „SendToRT“, „ReadFromRT“ with the proper commands for your IEEE communication interface. Define the multitone signal as well as the output level and input range according to the requirements of your test.

### A1 Initialization

The following commands define the basic setup parameters of the RAPID-TEST unit:

```
! REM ----- INITIALIZATION PART -----

! REM ***** SYSTEM MODE INITIALIZATION *****
SendToRT "SYSTEM:MODE 48KSAMPLINGRATE"

! REM ***** MTONE INITIALIZATION (ACTIVE SIGNAL) *****
! REM --- PLEASE NOTE: The Multitone signal is calculated by the RapidTest.
! REM --- Perform this initialization only once, since the signal is stored
! REM --- in the internal nonvolatile memory of the RAPIDTEST.
SendToRT "OUTPUT:MTONE:PAR 1, '3TONES', 512, 3, 3, 3, 11, 32, 4, 12, 31, 1.41362E-01,
        -2.09299E+00, 2.76446E+00, 2.08811E+00, 3.13357E+00, 2.67119E+00"

! REM ***** MTONE SETTINGS *****
SendToRT "OUTPUT:MTONE:ACTIVE 1"

! REM ***** OUTPUT SETTINGS *****
SendToRT "OUTPUT:SOURCE ANALOG"
SendToRT "OUTPUT1:MUTE OFF"
SendToRT "OUTPUT2:MUTE OFF"
SendToRT "OUTPUT:MTONE:MTONELENGTH 0"
SendToRT "OUTPUT:MTONE:PRETRIGGERLENGTH 0"
SendToRT "OUTPUT:FLOAT OFF"
SendToRT "OUTPUT1:IMPEDANCE 150"
SendToRT "OUTPUT2:IMPEDANCE 150"

! REM ***** INPUT SETTINGS *****
SendToRT "INPUT:SOURCE ANALOG"
SendToRT "INPUT1:RANGE -20.10 dBVp"
SendToRT "INPUT2:RANGE -18.00 dBVp"
SendToRT "INPUT1:LINK OFF"
SendToRT "INPUT2:LINK OFF"
SendToRT "INPUT:SYNC INTERNAL"
SendToRT "INPUT:TRIGGER:TIMEOUT 500"
SendToRT "INPUT:SWFILTER OFF"
SendToRT "INPUT:DEEMPHASIS OFF"
SendToRT "INPUT1:IMPEDANCE PHANTOM"
SendToRT "INPUT2:IMPEDANCE 100k"

! REM ***** OUTPUT LEVEL SETTINGS *****
SendToRT "OUTPUT1:LEVEL 1.00000 dBVp"
SendToRT "OUTPUT2:LEVEL 1.00000 dBVp"

! REM ----- END INITIALIZATION PART -----
```



### A2 Transmit / Receive Path Test

The TX / RX test can be applied on the preassembled housing, the populated PCB as well as the completed mobile phone. RAPID-TEST channel 1 analyzes the TX path (transducer), channel 2 the RX path (microphone) e.g. with following measurements:

- Frequency response (TX and RX).
- Distortion (TX and RX)
- SPL (TX), microphone sensitivity (RX).

**NOTE Measuring the microphone sensitivity correctly requires that RAPID-TEST drives the reference speaker in a way that the latter creates a defined sound pressure level with flat frequency response. Please refer to the „Equalize“ function (RT-Eval) or the „Individual Binlevel“ (Reference Manual).**

```

! REM ----- MULTITONE MEASUREMENT PART -----
! REM Execute the measurement
SendToRT "OUTPUT:MTONE:START"

! REM ***** MEASUREMENT Level [dBVp] *****
SendToRT "MEAS1:LEVEL:UNIT dBVp"
SendToRT "MEAS2:LEVEL:UNIT dBVp"
! REM --- Query and interpret the channel 1 measurement result string.
SendToRT "MEAS1:LEVEL?"
ReadFromRT
! REM --- Query and interpret the channel 2 measurement result string.
SendToRT "MEAS2:LEVEL?"
ReadFromRT
! REM --- Check for errors.
SendToRT "SYSTEM:ERR?"
ReadFromRT

! REM ***** MEASUREMENT Distortion [dBV] *****
SendToRT "MEAS1:DISTORTION:UNIT dBV"
SendToRT "MEAS2:DISTORTION:UNIT dBV"
! REM --- Query and interpret the channel 1 measurement result string.
SendToRT "MEAS1:DISTORTION?"
ReadFromRT
! REM --- Query and interpret the channel 2 measurement result string.
SendToRT "MEAS2:DISTORTION?"
ReadFromRT
! REM --- Check for errors.
SendToRT "SYSTEM:ERR?"
ReadFromRT

! REM ***** MEASUREMENT Selective RSS Level *****
SendToRT "MEAS1:SEL:UNIT dBSPL"
SendToRT "MEAS2:SEL:UNIT V"
! REM --- Query and interpret the channel 1 measurement result string.
SendToRT "MEAS1:SEL? 3 33"
ReadFromRT
! REM --- Query and interpret the channel 2 measurement result string.
SendToRT "MEAS2:SEL? 3 33"
ReadFromRT
! REM --- Check for errors.
SendToRT "SYSTEM:ERR?"
ReadFromRT

```

Calculation formula for microphone sensitivity: 
$$S [mV / Pa] = \frac{U_{Mic} [mV]}{SPL_{1in} * p_0} = \frac{U_{Mic} [mV]}{10^{\frac{SPL [dB]}{20}} * 20 * 10^{-6}}$$



### A3 Vibration Alert Test

This test measures the vibration level and frequency. Take care to properly synchronize the vibration alert of the device under test (DUT) with the RAPID-TEST signal acquisition.

Please refer to NTI's application note „Vibration Alert Testing with RAPID-TEST“ für further details.

```
! REM ***** MTONE INITIALIZATION (ACTIVE SIGNAL) *****
SendToRT "OUTPUT:MTONE:PAR 1, 'SINE', 4096, 1, 1, 44, 44, 0.000E00, 0.000E00"

! REM ***** INPUT SETTINGS *****
SendToRT "INPUT1:RANGE -14.00 dBVp"
SendToRT "INPUT1:LINK OFF"
SendToRT "INPUT:SYNC INTNOHEADER"
SendToRT "INPUT:SWFILTER OFF"
SendToRT "INPUT:DEEMPHASIS OFF"
SendToRT "INPUT1:IMPEDANCE 100k"

! REM ***** MTONE SETTINGS *****
SendToRT "OUTPUT:MTONE:ACTIVE 1"

! REM ----- MEASUREMENT PART -----
! REM Activate the vibration alert of the device under test
SendToRT "OUTPUT:MTONE:START"
! REM Stop the vibration alert of the device under test

! REM ***** MEASUREMENT SELECTIVE RSS *****
SendToRT "MEASUREMENT1:SELECTIVERSS:UNIT DBV"
SendToRT "MEASUREMENT1:SELECTIVERSS? 2 43"
ReadFromRT
! REM Parse the result string & check the results

! REM ***** MEASUREMENT SELECTIVE FREQUENCY *****
SendToRT "MEASUREMENT1:FREQUENCY:SELECTIVE? 2 43"
ReadFromRT
! REM Parse the result string & check the results

! REM ***** ERROR QUERY *****
SendToRT "SYSTEM:ERRORS?"
ReadFromRT
! REM Interpret the returned error messages
```



### A4 Ringer Melody Test

The RAPID-TEST correlation analysis compares a sound sequence that comes from the device under test (DUT) with a previously recorded „golden sample“. The calculated results are:

- **Correlation:** similarity of the samples, expressed in [%].
- **RMS Level:** signal amplitude, expressed in [V], [dBV], [dBm] or [dBSPL].
- **Level Correction:** difference in the RMS levels of the samples, expressed in [%].

```
! REM ----- INITIALIZATION PART -----
! REM ***** SYSTEM MODE INITIALIZATION *****
SendToRT "SYSTEM:MODE 48KSAMPLINGRATE"
! REM ***** INPUT SETTINGS *****
SendToRT "INPUT:SOURCE ANALOG"
SendToRT "INPUT1:RANGE -10.00 dBVp"
SendToRT "INPUT1:LINK OFF"
SendToRT "INPUT:SYNC THRESHOLD"
SendToRT "INPUT:TRIGGER:TIMEOUT 1000"
SendToRT "INPUT:TRIGGER:THRESHOLD:LEVEL 25.100"
SendToRT "INPUT:TRIGGER:THRESHOLD:PREMEASDELAY 20"
SendToRT "INPUT:TRIGGER:THRESHOLD:POSTMEASDELAY 0"
SendToRT "INPUT:SWFILTER OFF"
SendToRT "INPUT:DEEMPHASIS OFF"
SendToRT "INPUT1:IMPEDANCE PHANTOM"

! REM ***** SOUND CORRELATION SETTINGS *****
SendToRT "INOUT:PURESOUND:MODE CORRELATION"
SendToRT "MEAS:PURESOUND:STEEPNESS:REFERENCE:ACTIVE A"
! REM ***** SOUND CORRELATION REFERENCE *****
! REM The RAPIDTEST stores the sound correlation reference data nonvolatile.
! REM Therefore the reference data initialization has do be performed only
! REM once. Use the Query "MEASurement:PUResound:STEEpness:REFerence:GET?"
! REM to get the actual active sound correlation reference. Consider that
! REM the returned data string is in a binary compressed data format. The
! REM queried sound correlation reference can be reinitialized on the
! REM RAPIDTEST by sending the binary data string together with the command
! REM "MEASurement:PUResound:STEEpness:REFerence:SET <ReferenceData>"
! REM Refer to the command description in the RAPID-TEST Reference Manual
! REM ***** END INITIALIZE SOUND CORRELATION REFERENCE *****

SendToRT "MEAS:PURESOUND:LENGTH 3000"
SendToRT "MEAS:PURESOUND:STEEPNESS:UNIT Pa|s"
SendToRT "INOUT:PURESOUND:MODE OFF"

! REM ----- END INITIALIZATION PART -----

! REM ----- SOUND CORRELATION MEASUREMENT PART -----

! REM Execute the measurment
SendToRT "INOUT:PURESOUND:MODE CORRELATION"
SendToRT "MEASUREMENT1:PURESOUND:START"
```

(continued on next page)



```
! REM ***** MEASUREMENT Correlation Result *****
SendToRT "MEAS:TRAN:STEEPNESS:CORRELATION?"
ReadFromRT
! REM --- Check for errors.
SendToRT "SYSTEM:ERR?"
ReadFromRT

! REM ***** MEASUREMENT Steepness RMS Level Result *****
SendToRT "MEAS:PURESOUND:STEEPNESS:RMSLEVEL:UNIT dBV"
! REM --- Query and interpret measurement result string.
SendToRT "MEAS:PURESOUND:STEEPNESS:RMSLEVEL?"
ReadFromRT
! REM --- Check for errors.
SendToRT "SYSTEM:ERR?"
ReadFromRT

! REM ***** MEASUREMENT Level Correction Result *****
SendToRT "MEAS:TRAN:STEEPNESS:LEVELCORRECTION?"
ReadFromRT
! REM --- Check for errors.
SendToRT "SYSTEM:ERR?"
ReadFromRT

SendToRT "INOUT:PURESOUND:MODE OFF"
! REM ----- END SOUND CORRELATION MEASUREMENT PART -----
```

Please refer to the RAPID-TEST Reference Manual für further details.