External Sweep and Adaptive Measurement of DUTs with extreme Transients using the Settling Function of the Audio Analyzers UPL and UPD

Application Note 1GA12_1L

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New edition 9/96

Subject to change

Products:

Audio Analyzer UPL

Audio Analyzer UPD

ROHDE&SCHWARZ

1. Conclusion

When measuring audio components with unknown transients, the experienced engineer watches the settling of the DUT before accepting a measured result to be valid. The settling function in the UPL/UPD simulates this process and automates it by continuously comparing the measured value with a number of measured values stored before. A measured value is only accepted as being valid if it is within the tolerance limits entered by the user. This application note explains the settling process and gives hints for practical use.

2. Why is settling required?

When the generator setting of the UPL/UPD is changed, the known settling time a device under test can be taken into account together with the delay displayed on the analyzer panel. Settling processes within the UPL/UPD are automatically taken into account so that there is no need for the user to consider these times. The analyzer supplies settled and valid results.

If a DUT with unknown transients is connected between the generator and the analyzer, or if a DUT is fed from an external generator, the measurement result exhibits usually a transient response following a signal change or manipulation on the DUT (with high measurement rate relative to settling time) until a steady display is obtained. The steady-state value is then accepted as the valid result.

The aim of the settling function in the UPL/UPD is to simulate and replace the manual control steps performed by an experienced engineer. A measured value is only output if it satisfies a certain user-defined accuracy (max. deviation from steady-state value, later the term "tolerance" will be used). The settling function should preferably be used where measurements have to be made on DUTs with unknown or changing settling time. Settling can be combined with a delay so that from the time the measurement is started (changed generator setting or signal change with external sweep) an unwanted signal characteristic is ignored before the settling process starts. The settling function can also be used for steadying the display by rejecting values which do not satisfy the selected accuracy.

3. How is settling implemented?

The value measured by the UPL/UPD is continuously compared with n number (user-selected number of SAMPLES) of measured values stored before.

A measured value is only accepted as being valid if - compared with the previous values measured - it is within the tolerance limits entered by the user. Otherwise it will not be displayed but added to the number of reference values for the next measured value.

4. Where can settling be used?

Settling can be selected for:

- External sweep (START COND _ FREQ CH1 | FREQ CH2 | VOLT CH1 | VOLT CH2)
- Frequency measurements (FREQ/PHASE _ FREQ)
- Phase measurements (FREQ/PHASE _ FREQ&PHASE)
- Function measurements for all functions except FFT, POLARITY and WAVEFORM

Settling for the external sweep mode and settling for the frequency, phase or function measurements can be combined.

Exception:
Settling in conjunction with external sweep triggering on a frequency change (setting START COND _ FREQ CH1 | FREQ CH2) cannot be combined with settling of the frequency results.
Reason: the frequency results are already settled values which do not have to be subjected to settling again.

All settling settings can be activated in the relevant sections of the ANALYZER panel under the SETTLING menu.

5. Settling parameters:

The appropriate settling parameters are stored for each measurement function and will be restored whenever this function is selected.

EXPONENTIAL Settling

displays a result comparison mask with exponential characteristic (tolerance funnel) whose range is determined by the user-defined tolerance setting. This setting is recommended for measurements on DUTs with normal exponential transient response and usually covers the majority of applications (see Fig. 1).

FLAT Settling

displays a result comparison mask with a completely flat characteristic (tolerance band) whose range is determined by the user-defined tolerance setting. With very small tolerances, this setting supplies a measurement result if the DUT is in full steady-state condition and there is no significant noise superimposed on the signal. Due to these stringent settling conditions, the time required for obtaining a valid measured value is usually longer than with the EXPONENTIAL setting (see Fig. 1).

AVERAGE Settling

causes an arithmetic averaging of the number of measured values set under SAMPLES. After restarting a measurement by pressing the SINGLE or START key on the UPL/UPD or by entering a parameter which will cause a new measurement, as for instance a change of the generator signal or of the settling parameters themselves, the average value will be output on completing the number of measurements set under SAMPLES.
If the result memory is full, the oldest value will be overwritten by the new result and the average value is output. In this phase, an abrupt change of the signal will cause a floating change of the average value (lowpass behaviour).

Tolerance:

The tolerance value is the max. permissible deviation of a settled value from the steady-state final value. The maximum permissible deviation of the current measured value from the 2nd/ 3rd/ 4th/ and 5th last measured value is determined by the EXPONENTIAL **|** FLAT setting.

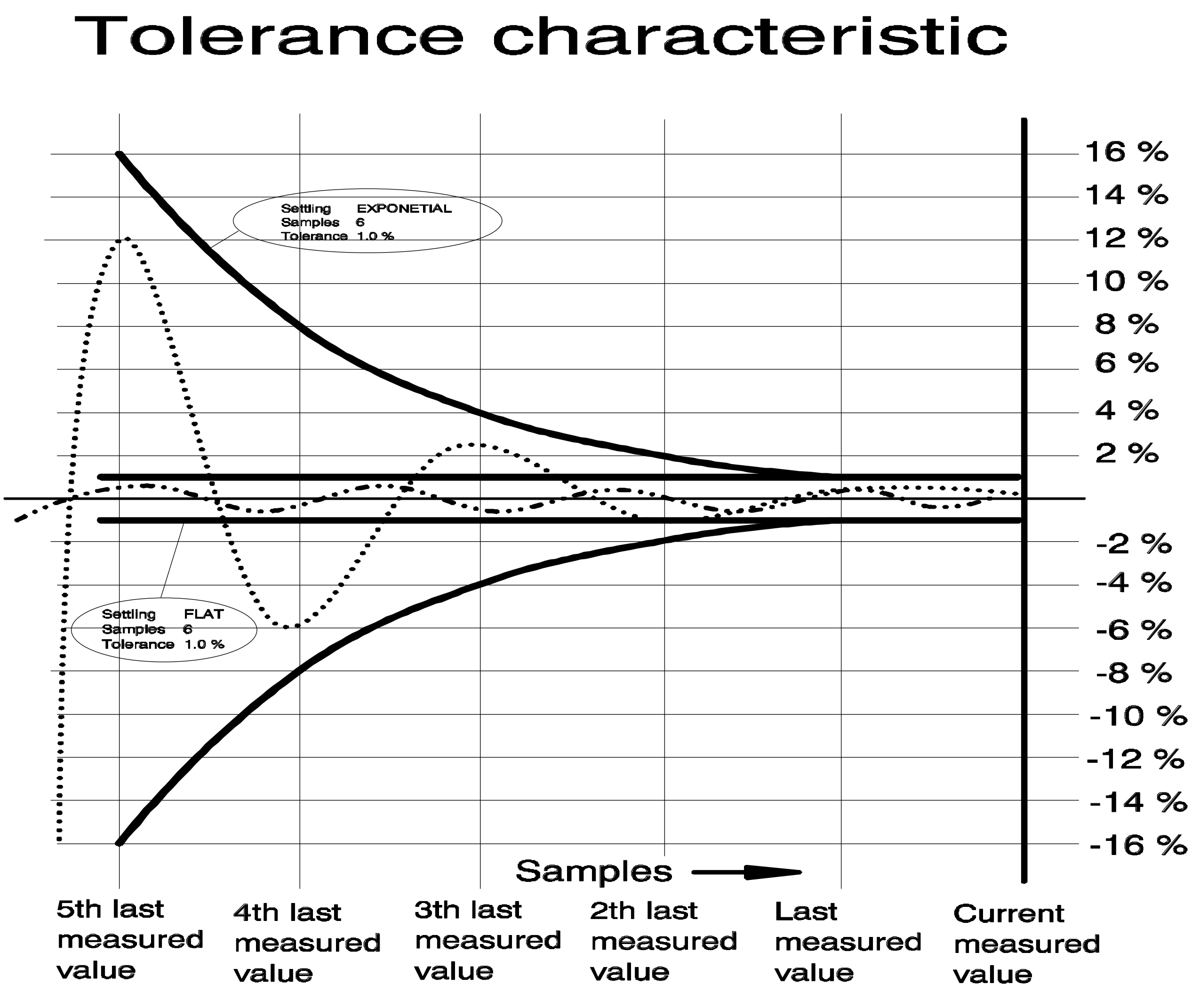

Fig.1 Tolerance characteristic

If for instance the number of samples selected is 6, the latest measured value will be compared with the five previous values. If a tolerance = 1% (or 0.086 dB) has been entered, this means that the current value should agree with the

- last measured value to within ±1% (or ±0.086 dB)
- 2nd last measured value to within ±2% (or ±0.172 dB)
- 3rd last measured value to within ±4% (or ±0.340 dB)
- 4th last measured value to within ±8% (or ±0.668 dB)
- 5th last measured value to within ±16% (or ±1.289 dB)

(with EXPONENTIAL settling).

If for instance in a level measurement the current measured value is 1 V, the previous values must be in the following ranges to be accepted as valid:

- last measured value 0.99 to 1.01 V
- 2nd last measured value 0.98 to 1.02 V
- 3rd last measured value 0.96 to 1.04 V
- 4th last measured value 0.92 to 1.08 V
- 5th last measured value 0.84 to 1.16

If a tolerance = 0.1 dB has been entered, this means the current measured value should agree with the

- last measured value to within ±0.1 dB
- 2nd last measured value to within ±0.2 dB
- 3rd last measured value to within ±0.4 dB
- 4th last measured value to within ±0.8 dB
- 5th last measured value to within ±1.6 dB

Resolution:

For very small measured values, in particular at the lower measurement limit of the UPL/UPD, or in case of signals with superimposed noise, there is a relatively large measurement uncertainty or fluctuation of the readout so that the measured values are often out of the tolerance limits.
In this case a minimum value will be considered for the resolution of the measured values, the so-called resolution value which is used as a starting value for a resolution characteristic and has exactly the same shape (EXPONENTIAL or FLAT) as the tolerance characteristic.

A value well away from the exponential tolerance characteristic due to superimposed noise is irrelevant for the transient response of the DUT. If the measured value lies within the user-defined resolution, it will be accepted as being valid.

If for instance the current measured value does not comply with the required tolerance as compared with the 4th last value, the amount of the difference between the current value and the 4th last value is determined and compared with the resolution value No. 4. If this difference value is better than the resolution value, the measured value is considered as a valid result (see Fig. 2).

The EXPONENTIAL curves are calculated to the base of 2. The points of the exponential tolerance curve, eg based on a tolerance of 1%, are calculated as 1%, 2%, 4% and 8%. The points of the resolution curve, eg based on a resolution of 0.5 mV, are calculated as 0.5 mV, 1 mV, 2 mV and 4 mV. The offset from the current measured value from the 3rd last value is -7.91 % and therefore does not lie within the desired tolerance limits. If the difference between the current measured value (24 mV) and the 3rd last measured value (22.1 mV) is smaller than or equal to the resolution value [S2] (2 mV), the current measured value will nevertheless be accepted as being valid.

$|24 \text{ mV} - 22.1 \text{ mV}| = 1.9 \text{ mV}$
Since 1.9 mV < 2 mV, the current measured value is valid.

Relationship between tolerance and resolution

Example by means of the following panel setting:

Settling	EXPONENTIAL
Samples	5
Tolerance	1.0 %
Resolution	0.5 mV

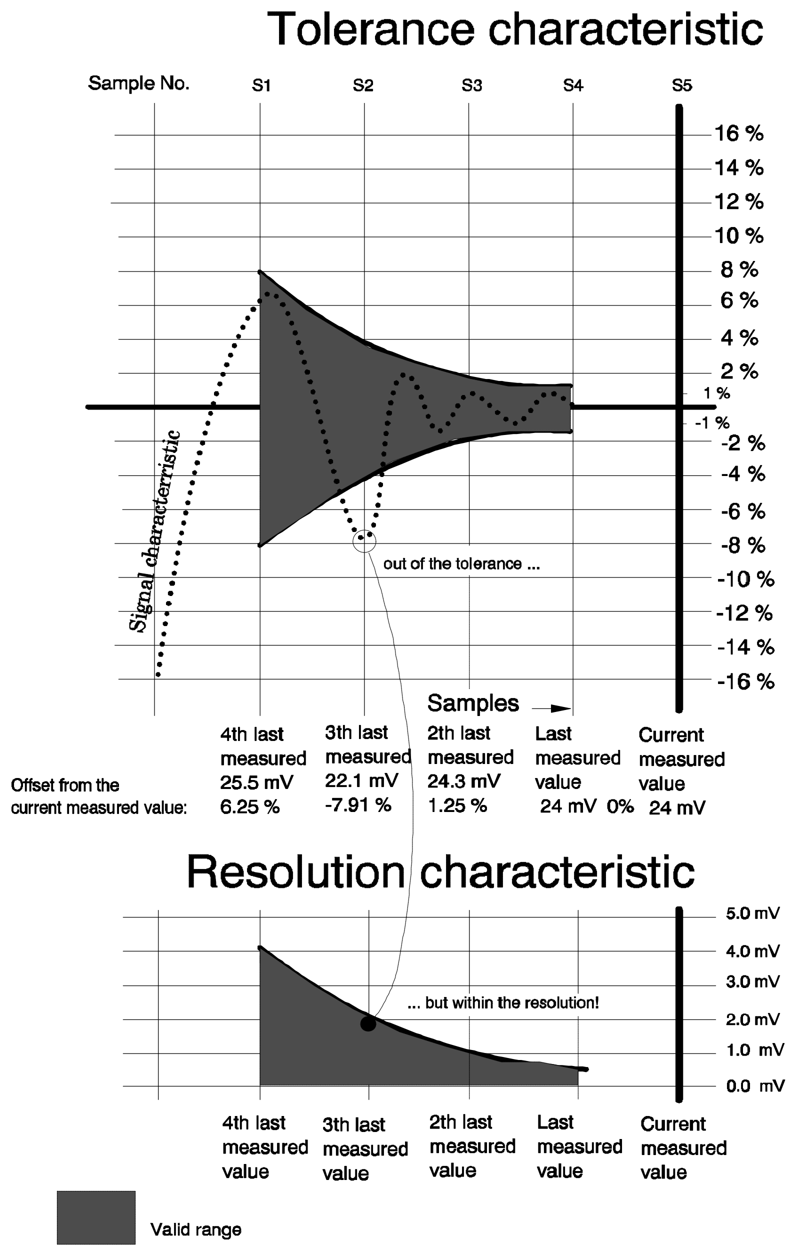

Fig. 2 Relationship between tolerance and resolution

Timeout (only in function settling mode)**:**

Timeout states the time which may elapse from the start of a measurement until a settled measurement result is recognized. If no stabilization of the measured value detected, the measurement is discontinued and the remark "Input - Press SHOW I/O" output instead of a measured value. During a sweep, a gap shown in the displayed curve indicates that a value is missing. In the settling mode with external sweep (see next paragraph) no timeout is considered.
If the high-speed option UPD-B3 is fitted in the UPD, the timeout period starts for both channels simultaneously after "delay" has elapsed. With the high-speed option not fitted, the channels CH1 and CH2 are measured sequentially and the timeout period is reset upon every channel change after "delay" has elapsed.
With UPL, the timeout period starts for both channels simultaneously at any case.

6. Settling with external sweep:

For better understanding of the following explanations, please read in the UPL/UPD Manual chapter "Ways of Starting the Analyzer, External Sweep", the description of the menu items

- "Min VOLT"
- "Start"
- "Stop"
- "Variation".

If external sweep (START COND _ FREQ CH1 | FREQ CH2 | VOLT CH1 | VOLT CH2) is used together with the settling function, the measurement procedure will be as follows (see Fig. 3):

1. Check whether at the test input a level of at least the value specified under Min VOLT is present. (Only applies to external sweep with triggering upon frequency changes) (STARTCOND _ FREQ CH1 | FREQ CH2)
   No: execute step 1.

2. Wait for frequency stabilization with setting START COND _ FREQ CH1 | FREQ CH2, level stabilization with setting START COND _ VOLT CH1 | VOLT CH2 by means of the settling function.

3. Check whether the level or frequency are within the range defined by "Start" and "Stop".
   No: execute step 1.
   Yes: wait the time indicated under "Delay" to allow the DUT to settle.
   Perform function measurement (including function settling, if required)
   Display result of function measurement

4. Check whether the level or frequency have varied by at least the value stated under "Variation".
   No: execute step 4
   Yes: execute step 1

Remarks concerning the delay:

A delay in the external sweep mode with settling function is only useful if measurements are made on DUTs exhibiting slow level transients (eg hearing aids with volume limitation or compander/expander circuits with fast level rise times and slow decay times. A frequency change has to be set as a trigger condition (START COND _ FREQ CH1 | FREQ CH2). If the settling function provides very quickly stabilized values for the frequency measurement but the level is still far from stabilization, the delay can be used to wait for level settling.

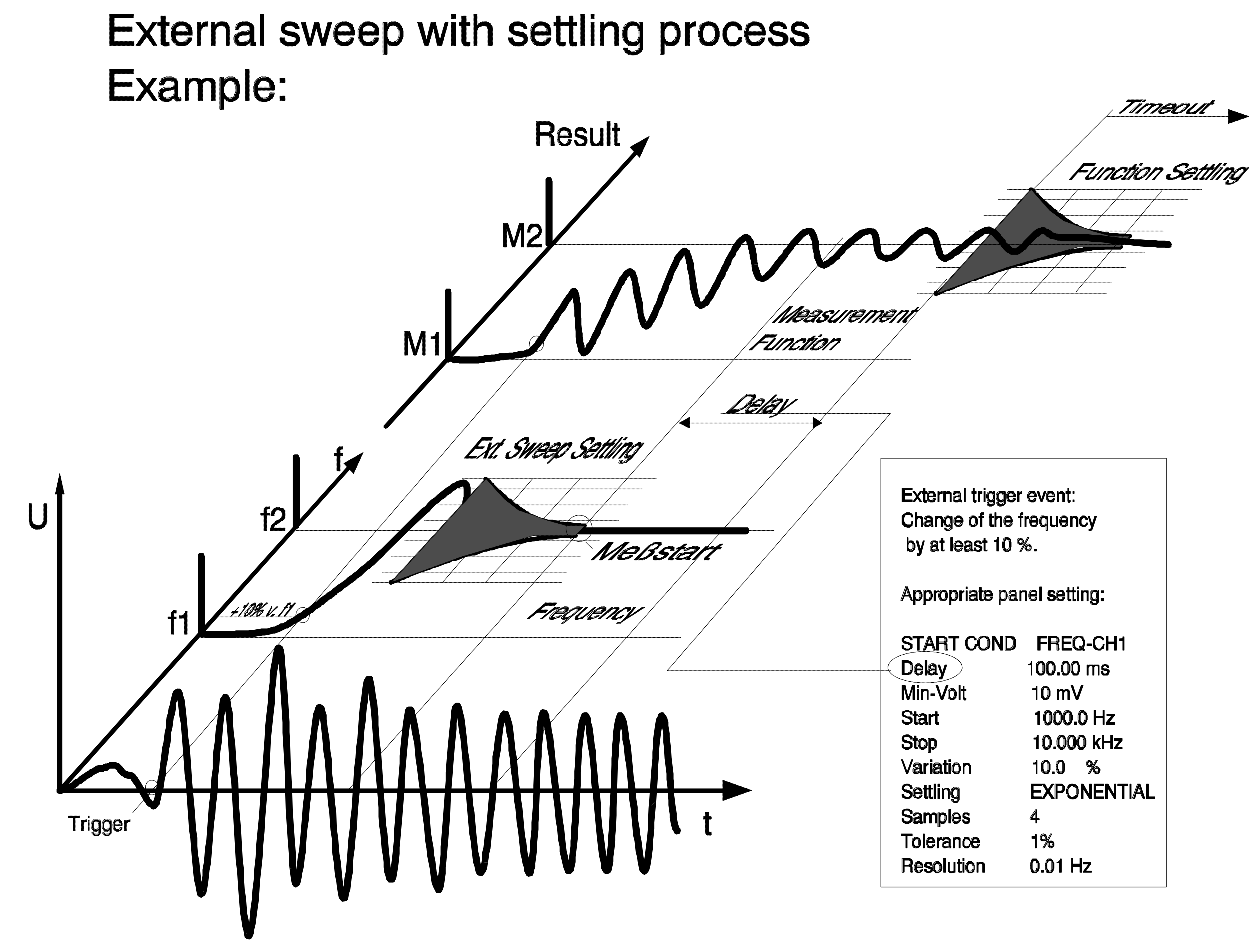

Fig. 3 External sweep mode with settling

Optimization of settling parameters:

To ensure maximum measurement rates in conjunction with the settling function, the DELAY time under START COND _ AUTO (see also UPL/UPD Manual) must be observed. This is the time elapsing from the setting of the generator until the restart of a measurement (and hence start of the settling process) to allow for any dead times of the DUT. The settling time of the generator and of the analyzer is automatically taken into account by the UPL/UPD. If a value of 0.0 s is entered for the DELAY, no additional delay will be effective and the maximum measurement rate be achieved.

Since the settling function of the UPL/UPD can be applied to individual measurements, the appropriate settling parameters can easily be determined by the observing the measurement results and by trial and error.

Determination of suitable settling parameters

Delay value with the use of the UPL/UPD generator, measurement with timetick (START COND _ TIME) and graphical display. Change the level in the generator and measure the time needed for the test signals to respond.

Delay = (number of measured values - 1) * timetick spacing.

Delay value in external sweep mode

With unknown signals, short dead times of the DUT up to approx. 100 ms can be determined with the aid of the WAVEFORM function, for longer dead time use of a storage oscilloscope is recommended. If test tapes, test CDs etc are used, the manufacturer's specs may be helpful. Trying out different delays for the external sweep is usually not very expedient although settled values may be obtained, but due to the dead time these values may represent the old settled value prior to the change.

Number of samples

A high number of samples places high demands on the transient response of the DUT. A value that is suitable for all applications cannot be given.

Tolerance value

Select bargraph display such that the min/max values are within the desired tolerance limits. A tolerance specification of 1% is suitable for most AF applications. For test tapes with heavy noise and strong level fluctuations, for instance, the tolerance value should not be selected too small, since otherwise settled measured values would not be obtained. Tolerance value around 5% for 3 samples may be useful.

Resolution value

Observe the reading. The resolution value should always be close to the UPL/UPD resolution. If for instance the level measurement result is fluctuating by 2 mV, an approx. five-times higher value, ie 10 mV, would be a suitable resolution value.

Note:

Too high a resolution value would permanently signal settled values although the tolerance conditions would constantly be violated.

The longest time required by the UPL/UPD for measurement of the DUT can be determined by trial and error. This time can be slightly increased and used as timeout to obtain maximum measurement rate with timeout being exceeded.

If noisy signals are weighted via the settling function, a settled display can be obtained by selecting suitable tolerance limits. The measurement rate will however be reduced since many measured values will have to be rejected until the settling condition is satisfied (see AVERAGE).

7. Measurements on Tape Recorders

A practical application (measurements on a tape recorder) is described in the following, where the DUT controls the analyzer via external sweep:

In many audio measurements or test routines, the audio analyzer is not only used for measurement, logging and storage of the results but also for controlling the whole process. If however measurements are made on reproduction units using standard sound carriers (tape recorders / cassette recorders with standard tapes, disk players / CD players with standard disks or CDs), the recorded medium determines the sequence of the measurements and the measurement rate.

There are various possibilities of performing such measurements:

- Audio analyzer and measurements are controlled by a process controller with the aid of a test program.
- Audio analyzer controls the measurements taking into account the sequences and timing on the sound carriers.
- The DUT itself controls the entire measurement process and the audio analyzer.

The main disadvantage of the first two methods is evident:
Since the sound carrier cannot execute the control, appropriate delays must be inserted into the test program to ensure that a measurement is neither started too early nor too late. This means that the delays within the test program have to be thoroughly matched to the specific measurement task. If a different sound carrier is then used however, the times have to be adapted again so that a whole variety of test programs has to be written for the various test tapes and disks.

The Audio Analyzer is not only able to operate as a process controller and to control in this way both the measurement process and itself, but it can also be controlled by A DUT via the external sweep. The disadvantage described above can thus be evaded and no program modifications have to be made for the various tapes or disks. This means an enormous saving in time when changing to another standard sound carrier.

The **external control** of the UPL/UPD is made by entries in the **analyzer section "START COND"**.
The user can choose here the input parameter which is to trigger the measurement. Variation of the input frequency or of the input level are the criteria for parameter selection (both in channel 1 and 2).

The following example describes the **measurement of the frequency response of a tape recorder**. A sound/speech tape with fixed frequencies of 8 s duration and a standard tape to MTT-650 C were used, with frequency variation being the trigger parameter so that every time a frequency change of more than a certain amount is detected, a new measurement will be started. To obtain correctly settled results, a few settings have to be made under "START COND":

START COND	Input value	Explanation
Delay	0.0000 s	**Delay time between trigger and measurement.** A delay is not very useful for the external sweep mode if the transient response of the DUT is not known and would only reduce the measurement speed.
Min Volt	0.1000 V	**Requires minimum input level.** If there are level gaps on a tape, these may cause hum pickup of constant amplitude for tapes or recorders of poorer quality. To avoid unwanted triggering of the external sweep by the hum (the hum is constant and therefore supplies a settled measured value), it is recommended to enter a minimum level which is above the hum level to enable triggering.
Start	20.000 Hz	**Start frequency of measurement sequence.** The selected start frequency should be somewhat beyond the actual frequency, since this frequency may vary due to departures of the tape from the nominal speed. In the worst case, too tight tolerance limits may have the effect that the first measured value does not trigger a measurement since the conditions set under START COND have not been met. This is shown by a missing curve section at the beginning of the measurement curve.
Stop	20.000 kHz	**Stop frequency of measurement sequence.** The above applies analogously to the stop frequency of the external sweep. The entered value must cover a greater frequency range than the measurement frequencies expected. The entered frequency direction must correspond to that of the test tape to enable recording of a sweep (see differences between continuous and single sweep described further below).
Variation	5.000 %	**Required minimum variation of input frequency to cause triggering.** Due to the wow & flutter of the tape, this value should not be selected too small. If the variation is too small, the measurement may cause multiple triggering within the period, in which the measurement frequency has a relatively constant level. This multiple triggering of an almost constant frequency may however cause erasure of the previously recorded measurement curve (see differences between continuous and single sweep described further below).
Settling	EXPONENTIAL	**Type of settling condition.** FLAT could also be selected. Since this is however a much more severe settling condition, it is likely to cause problems with tape recorders due to the level and frequency fluctuations which can only be overcome by increasing the tolerance limits to an unacceptable degree. Therefore, use of the exponential tolerance characteristic is recommended.
Samples	5	**Number of measured values used for comparison in the settling algorithm.** The number of samples influences the requirements placed on the settled measured value and has to be optimized for these requirements and for the DUT.
Tolerance	1.000 %	**Permissible tolerance of measured value.** Due to the *wow & flutter of the tape* this value should not be selected too small. If this value is too small or the departure of the DUT from the nominal speed too great, it may be possible that no settled value is obtained and despite triggering no curve will be recorded and "**press show I/O"** is permanently signalled since the permissible measurement time is exceeded (see under timeout).
Resolution	1.0000 Hz	**Entry of a resolution limit.** The entry of the resolution limit only determines whether the settled measured value is within the tolerance or the resolution limits. It is only useful to define a value if the measured values are close to the resolution limit of the UPL/UPD so that the entered tolerance will be exceeded by an uncertainty of ±1 count in the last digit of the display and therefore would not furnish a settled value. With a measured value far above the UPL/UPD resolution limit, care should be taken that the value entered is not too high with the effect that settled values would permanently be signalled and the tolerance entry would be meaningless.

The following settings can be made for measuring the frequency response with the selected **function RMS & S/N** in the analyzer window:

menu line	Input value	Explanation
Meas Time	AUTO	Automatic matching of the measurement rate to the DUT ensures that at varying frequencies the correct clock rate is always used for measurement. This eliminates the risk of errors caused by too fast measurement at too low frequencies and simulating strongly fluctuating levels.
Fnct Settl	OFF **EXPONENTIAL** FLAT AVERAGE	To improve the reproducibility of the results, a settling algorithm can be switched on, which may differ from the one defined under START COND. To speed up measurements, settling can be switched off for the measurement function.
Samples	3	A greater number of samples for the settling process enhances stabilization of the measured values but also extends the measurement time. For a trade-off, the number entered should suit the specific measurement task.
Tolerance	5.0000 %	Due to the large *level fluctuations* on the tape, this value should not be too low, since otherwise no settled values are obtained despite triggering.
Resolution	0.0010 V	Same conditions as under START COND apply.
Timeout	8.0000 s	The entered value limits the time within which the measurement has to be completed. If this time is exceeded before a triggered value is detected as being settled, the measurements is aborted and "**press show I/O**" displayed on the UPL/UPD. An error message as for instance "measuring time too long" will be output. The UPL/UPD is waiting for the next trigger event and there is gap in the curve displayed. Since the sound signals on the sound/speech tape have a duration of 8 s as per definition, it is useless to enter a longer time.

For measurements on replay devices **some special points** have to be considered:

- The level on the tapes is often relatively low so that the low signal-to-noise ratio causes considerable interference to the measurement.
- Due to the variable pressure of the test tape on the playback head the sound signals to be measured are provided with an amplitude modulation causing fluctuations of the measured values which additionally results in a low low signal-to-noise ratio.
- Due to wrong speed, the measured frequency does not exactly agree with the recorded test frequency (tape or disk is running too slow or too fast) and moreover wow & flutter is superimposed due to the inconstant speed.
- Some tapes carry in addition to the standard audio frequencies speech signals between the individual sound signals which should not be recorded by the audio analyzer.

All these special points have to be considered when performing measurements on replay devices to avoid misinterpretation of the results or wrong conclusions about the DUT.

For reproducible measurement results it is essential that there is no erroneous triggering in the external sweep mode. Only correctly settled and stabilized values should be evaluated and logged. The settling algorithms, which a measured value can be subjected to, can be switched on for various measurements:

- for external sweep under START COND
- for frequency and phase measurement
- for the selected measurement function (RMS & N, THD etc)

The significance of selecting settling for the measurement function becomes evident when performing measurements eg on hearing aids. These instruments feature completely different settling time constants for frequency and level variations. As a result, the input level to be measured (for internal gain control) would be far from being stable if indication were limited to the settled frequency only.

In contrast to other audio analyzers, the settling function selected in the UPL/UPD is not only effective in the sweep mode, but also in the manual and remote-control mode. This philosophy has two advantages:

1. The settling function can be switched on also in the normal measurement mode to stabilize the display. The 2σ method serves the same purpose eg in wow & flutter measurements on tape recorders.

2. Before starting the sweep mode, which may be time-consuming, the user can test in the manual mode the settling parameters required for the DUT to obtain reproducible results and then start the sweep mode.

As already mentioned above, the user can enter limit values for the **tolerance** and for the **resolution**. The functioning of the settling mechanism can easily be explained on the basis of these two functions (see also Fig. 2).

The output signal of the DUT can follow an abrupt change of the input signal only with a delay and with transients due to internal timing elements. If the output signal is measured too early, it will not have reached a steady state and the measured value will be wrong. With the settling function switched on, a number of measured values selected under SAMPLES is compared with the specified tolerance range. As long as a value is out of the tolerance range, it is not accepted as a settled value and the settling criterion will be repeated for the next measured value and the selected number of previous values.

To avoid that due to measured value fluctuations close to the resolution limit of the UPL/UPD a stable value is never recognized, measured values violating the tolerance limits will be compared with the resolution limits. If the measured value or one of the previous samples is out of the tolerance limits but complies with the resolution limits, it will be considered as constant and evaluated. Great care has to be taken in this case to avoid that a measured value complying with the possibly wider resolution limits will be taken for a stable value although the DUT itself has not yet reached steady state.

This procedure shows that even measurements on tapes with inserted speech do not cause any problems, since due to the permanent change of frequency and level of a spoken word a stable measured value will not be recognized and the result therefore not be falsified.

Another input parameter is the **delay**. While the entry of a delay is not expedient for measurements with external triggering, it is absolutely necessary for measurements on DUTs with delay. Two special cases are for instance measurements on hearing aids (where the level has a considerably longer time constant than the response to frequency changes) or the measurements on a **tape recorder with tape monitoring:**

If the signal is to be detected at the monitoring head and the measurement results be subjected to the settling algorithm, the settled signal coming from the test tape would permanently cause triggering and logging of unwanted measured values. It is the purpose of a built-in delay to provide sufficient time for a signal change to be transferred from the recording head to the playback head and to cause a restart of the measurement only after this defined delay. After the time entered under DELAY has elapsed, the settling function can capture the settled new level or frequency value without unwanted triggering in between.

With this type of measurements, the generator signal is used so that the time of the signal change is exactly known. The delay starts immediately after this change.

The integration of the delay into the external sweep is shown in Fig. 3.

The illustration shows that the delay becomes effective after completion of the settling algorithm under START COND (ie after a change of the input parameter has been recognized) and function settling will be performed after the delay has elapsed. This is to prevent that for instance a stochastically occurring spike will be misinterpreted as an input signal change and cause a delay of the measurement by the entered delay time.

Differences between continuous and single sweep:

Erroneous triggering due to wrongly set settling parameters has different effects in the various external sweeps.

Example: unwanted trigger upon AC supply hum of 100 Hz, sweep from high to low frequency

a) continuous sweep:

If the actual test frequency is higher than the interference frequency, the unwanted trigger and the subsequent actual trigger at the test frequency will be interpreted as a frequency inversion with respect to the sweep direction and the curve section recorded until this time will be erased. This inversion of the direction causes a restart of the sweep.

b) single sweep:

If the actual test frequency is higher than the interference frequency, the unwanted trigger and the subsequent actual trigger at the test frequency will be interpreted as a frequency inversion with respect to the sweep direction and all further test frequencies above this interference frequency of 100 Hz will be ignored, ie they do not cause triggering (in contrast to the continuous sweep, the recorded curve is retained).
When a test frequency lower than the interference frequency less the entered variation occurs, the external sweep triggers again and the curve is recorded. Erroneous triggering at the interference frequency results of course in a straight line between the last valid measured value and the interference frequency; after this line the curve would be properly recorded again.

Special features of two-channel measurements in external sweep mode

Example: Frequency-response measurement with **Start Cond = FREQ CH 1**

While in channel 1 the frequency measurement result is continuously updated in the upper right window, the measured value valid at the time of triggering is displayed in the window of channel 2. This display will not be changed until the next valid trigger event occurs and the value is overwritten by the new value. To check whether the UPL/UPD triggers at all frequencies recorded on the tape, this value can always be read even if the time of the actual trigger has not been observed. In channel 2, it is always the last triggered frequency and associated level value that is displayed in the corresponding windows.

Note:
In magnetic tape measurements and taking the worst case, a level dropout may occur exactly at this point in channel 2 and cause a wrong frequency indication if the S/N ratio becomes too poor for the frequency counter! This shortcoming can however be eliminated by exchanging the channels, since then no triggering will be made at this point (Min Volt condition not complied with). The actual time of triggering is then at another point of the tape. It is highly unlikely that the channel originally used for triggering will have a dropout now at this point. The first case is rather unlikely, but it can occur with poor-quality and older tapes.

Further experience gained in tape measurements:

Measurements using AUTO FAST for function settling:

Despite an entered minimum threshold of 0.1 V, measured values may sporadically show outliers. These can be seen from the part of the curve where the minimum threshold is joined to a meaured value which does not represent the actual frequency response. This may occur both at high and at low test frequencies.

Moreover, the reproducibility of measurements when using poor-quality tapes or recorders is not as good as with the AUTO measurement rate (in some cases about 0.5 dB). For measurements on tapes of poor quality or with low S/N ratio the AUTO rate should preferably be used.

Measurements using AVERAGE:

- By selecting a high number of average samples (30 to 50) many measured values will get lost since averaging takes too long. The loss of measured values leads to a reduction in reproducibility.
- Despite a great number of samples, outliers cannot be completely prevented (eg especially not at 1 kHz with the MTT-650C). Whether a measurement series will be disturbed by an outlier depends on the entered variation and the resulting test frequencies as well as on the number of samples selected and the required measurement time relative to the sweep speed on the tape.
- With greater level changes on the tape, a wider band of measured values can be obtained with multiple measurements despite averaging over 30 to 50 samples. Such level changes occur especially at low frequencies up to about 200 Hz.
- Due to the level fluctuations on the tape, a greater number of samples (30 to 50) hardly has any advantages over eg S = 10. Only in the flat part of the frequency response the reproducibility is better (at the expense of the frequency sampled, see above). With S = 10, the band of measured values has practically the same width over the entire curve , ie.→ **S = 10 to 15 is recommendable**, but depends nevertheless on the DUT!
- With AVERAGE (S=10), the measurement using AUTO FAST also causes a poorer reproducibility especially at low frequencies since the measurement is too fast.