
Measurement of Transient Responses in AGC Circuits using the Audio Analyzers UPL and UPD

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Subject to change

Products:

Audio Analyzer UPL

Audio Analyzer UPD



ROHDE & SCHWARZ

1. Conclusion

In many applications, circuitries with automatic gain control are used, for example in the fields of tape recording or hearing aids. This application note describes the typical characteristic of these control circuitries and the difficulties in measurements using oscilloscops. With the audio analyzers UPL and UPD these measurements can be done much easier, the analysis can be done manually or automatically by using a special software tool.

2. Transient Responses in AGC

In the field of audio, AGC is used for a variety of applications. A few examples are given below:

- Volume range control for tape recording
The application covers equipment from simple cassette recorders for playing over recorded music through to portable professional reporting facilities mainly used for voice recording, eg in interviews, etc. In the case of high-tech equipment, different transient responses, eg for voice and music, can be selected.
- Compression circuits for reducing the dynamic range
Circuits of this kind are frequently used by transmission media when the enormous dynamic range of a symphony orchestra is to be recorded on a sound carrier or for adapting such a musical event to the transmission conditions of broadcasting. Very often, listening to music in vehicles makes it necessary to use compression circuits to avoid soft tones being drowned by the vehicle noise.
- New techniques in sound broadcasting
Digital sound broadcasting of the future offers completely new ways for adapting the music signal to the requirements of the human ear. For instance, with Digital Audio Broadcast (DAB) the use of compander circuits is being considered. They would allow the listener to chose a setting which is adapted to his personal requirements.
- Use in hearing aids
Up to now it was not always easy for persons with a hearing defect to optimally adjust their hearing aid. On the one hand the volume had to be turned up sufficiently to be able to follow a conversation without any difficulty, but at the same time shock reactions caused by sudden environmental noise, for instance traffic noise, had to be avoided. Things could be put right by an improved technique. With the aid of filter circuits and automatic gain control, modern hearing aids can be adapted to the patient's individual hearing defect so that a clear relief is obtained.

The characteristic of the various AGC (automatic gain control) circuits has to be determined in development, quality assurance and production, a measurement task which is anything but simple.

3. Definitions

Fig. 1 shows a typical characteristic of an AGC circuit. A low-amplitude signal is boosted with the gain g to obtain the output signal V_1 . At first, a sudden level increase at the input does not change the gain, ie the output level varies accordingly, but due to the reduced gain g , the rated output level V_2 is obtained in a minimum of time. The time required for the reduction is the attack time t_a and defined as the period elapsed between applying a higher signal level to the input and obtaining the rated level with a specific tolerance Δ_a at the output.

After switching off the level burst at the input, the circuit responds with a sudden level change before an increased gain reduces the output signal to its original level V_1 . Normally, the time required for this gain

increase, the release time, is much longer than the attack time. Speech intervals or short breaks in music should not immediately reset the AGC circuit to "maximum sensitivity". The release time, t_r is defined as the time required for attaining the output level with the respective tolerance Δ_r . The compression ratio is also defined. It specifies the gain reduction caused by the sudden level change. The ratio of the dynamic range of the input signal to the dynamic range of the output signal is given in dB.

$$\text{Compression ratio} = \frac{\text{Input dynamic range in dB}}{\text{Output dynamic range in dB}}$$

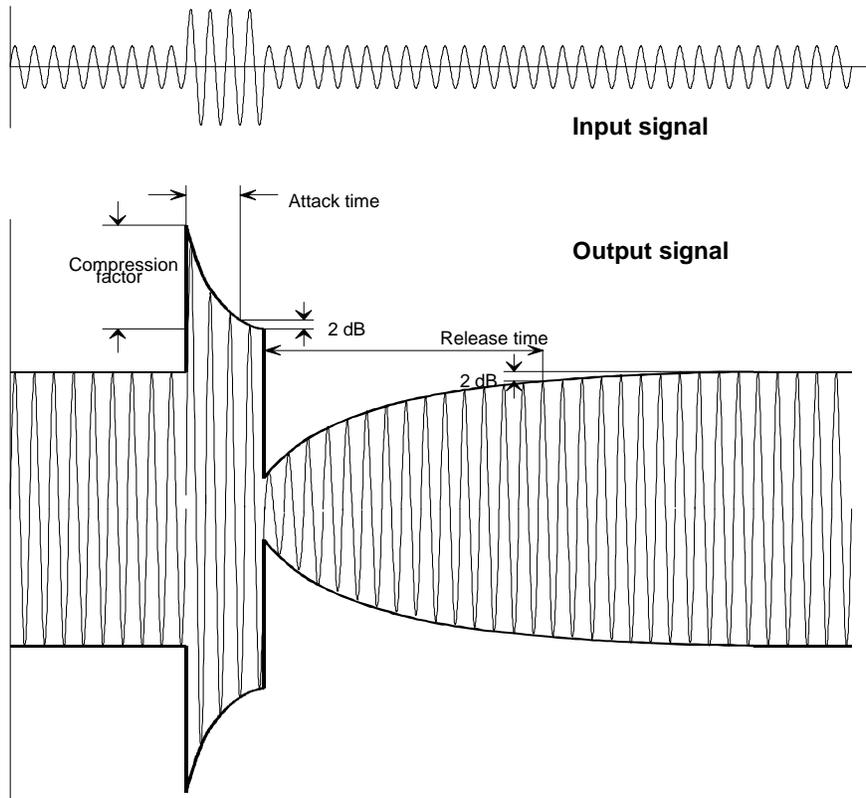


Fig. 1: Response of an AGC circuit

4. Measurements with Audio Analyzer UPD and UPL

Transient responses of AGC circuits are normally measured and displayed on an oscilloscope. The output signal is displayed versus time. Since a complete control cycle may take up some time, 20 seconds and more are quite common, the measuring instrument must be able to store the measurement results over a relatively long period of time. At the same time it should be possible to determine the attack time which is normally in the milliseconds range so that a fairly good time resolution of the oscilloscope is required. Consequently, the measuring instrument requires a big memory and this is normally not available in standard oscilloscopes. A solution is to determine the attack and release time in two separate measurements with a different time resolution.

For evaluation the gain variation is read from the signal envelope.

With Audio Analyzers UPD and UPL the measurement is carried out using the WAVEFORM function. Same as with an oscilloscope, the signal is displayed versus time with a maximum of 7k samples being stored (up to 64 k samples with enhanced Waveform function in UPD in the single-channel mode).

For measurements requiring a longer period of time, a special function is available which avoids the above disadvantages and allows both parameters, attack and release time, to be determined in one single measurement. The COMPRESSED mode developed for this purpose is a variant of the WAVEFORM function. After the input signal has passed a rectifier where the magnitude of the measured level is determined, several samples are combined and the maximum value of these samples is displayed in a graph. The compression factor is adjustable and gives the number of samples combined. With this measurement the time axis is compressed. With a compression factor selected permitting at least one period to fit into the time window giving a single value, a positive signal envelope is displayed. This simplifies evaluation compared to the oscilloscope where the envelope has to be derived from the signal characteristic.

With the aid of this special measurement function up to 1024 samples may be combined to one value. A maximum of 7488 values can be recorded versus time which yields measurement cycles of up to 160 seconds. This corresponds to a "normal" oscilloscope with a memory capacity of 7.6 Mega-samples!

5. Instrument Settings for Practical Applications

GENERATOR	ANALYZER	DISPLAY
<ul style="list-style-type: none"> - Channel(s) 2 \equiv 1 - Output UNBAL BNC - Impedance 5 Ω - Common FLOAT - Max Volt 12.000 V - Ref Freq 1000.0 Hz - Ref Volt 1.0000 V ■ FUNCTION - SINE BURST - DC Offset OFF - SWEEP CTRL OFF - FREQUENCY 1.0000 kHz - VOLTAGE 1.0000 V - Low Level 100.00 mV - ON TIME 1000.0 cyc - INTERVAL 30.000 s - BurstOnDel 0.0000 s 	<ul style="list-style-type: none"> - Reference VALUE: 1.0000 V ■ FREQ/PHASE OFF ■ MONITOR - OFF ■ FUNCTION - WAVEFORM - Meas Mode COMPRESSED - Comp Fact 192 - Unit V - Ref Volt 1000.0 V - Trig Level 1.0000 V - Trig Slope RISING - Trace Len 29.948 s ■ SPEAKER - OFF 	<ul style="list-style-type: none"> ■ OPERATION CURVE PLOT - User Label OFF ■ TRACE A - FILE - Filename AGC_COMP.TR - Unit V - Reference VALUE: 1000.0 V - Scale MANUAL - Spacing LIN - Top 1.0000 V - Bottom 0.0000 V ■ TRACE B - OFF ■ X AXIS - TIME - Unit s

Fig. 2: Possible instrument settings for measurements on a DAT recorder with AGC

For measuring the transient response a test signal is produced in the generator section of the audio analyzer in the SINE BURST function. The amplitude after the level change is set, ie the amplitude with the burst signal on (entry under VOLTAGE) and the "off-state amplitude" when the burst signal is off (entry under "Low Level") are set. The time ratio of the signal is determined by entering the burst duration (ON TIME) and the interval (INTERVAL). Care should be taken that the selected burst times are long enough to allow the DUT to settle completely. Under "BurstOnDel" a delay time for the burst can be entered during which the low level is output.

The standard measurement frequency is 1 kHz.

Settings for the analyzer section can be obtained from the above description. COMPRESSED mode is selected under the WAVEFORM function. A compression factor is set permitting the complete burst interval to be displayed. This can be verified under "Trace Length" where the displayed period is indicated. When setting the compression factor make sure that at least one period of the test signal is covered. Since the analyzer uses a sampling rate of 48 kHz, at least 48 samples have to be compressed for a

correct capture of a 1-kHz signal. Fig. 2 shows the panel with possible settings; the selected compression factor of 192 is sufficient for signal frequencies down to 250 Hz. The trigger level is set so that the measurement is triggered by the level change.

In the display panel the scale can be selected and limit values, labels, etc be entered.

6. Manual Evaluation

Manual evaluation is performed in the display with the aid of the cursor functions. Provided adequate time and level ratios of the burst signal have been selected for the DUT, a curve like that shown in Fig. 3 is obtained. Care should be taken that the DUT is in settled state after the level change and switch-off of the burst signal. If this is not the case a longer burst or interval time will be required.

The actual evaluation is performed by setting one of the two cursors to the starting point of the burst and the other to the point in the curve at which the DUT has settled within a defined tolerance. The time difference between the two cursors is the attack time. Proceed analogously for determining the release time.

If the cursor function "* - O" is used, which can be activated via softkey, the attack time or release time can be directly read from the graphics display (see Fig. 3).

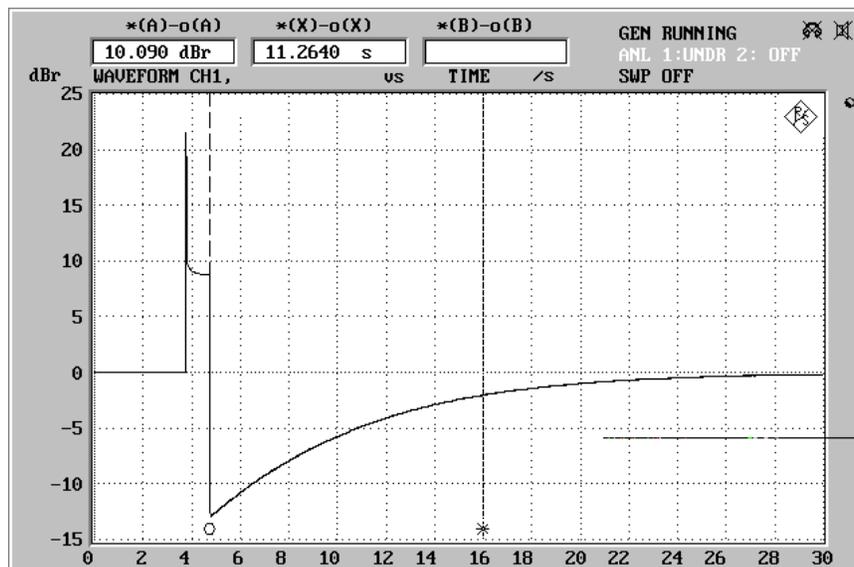


Fig. 3: Example for manual determination of the release time

7. Automatic Measurement with Program AGC.BAS

7.1. Software Requirements

With the aid of the autocontrol function, measurement sequences can be program-controlled. In this case the Audio Analyzer has to be equipped with option UPD-K1. The corresponding option for UPL is UPL-B10.

The measurement of the transient response can also be performed automatically. A respective application program, the BASIC program AGC.BAS, can be obtained from your local Rohde & Schwarz representative. The supplied floppy also comprises the instrument setups required for the measurement. In addition to this universal sequence controller option, firmware version 2.12 or higher is required in the UPD, firmware version 1.0 or higher in the UPL. For installation a directory C:\AGC has to be created and all files of the floppy disc should be copied into this directory.

7.2. Operation of Measurement Program

For starting the program switch the audio analyzer from manual to automatic control using function key F3 on the external keyboard, and load the AGC.BAS program in the respective path C:\AGC. After entering RUN or confirmation with the respective softkey the start menu is entered. Pressing the softkey CONFIG (=F6) the user is asked to enter the following parameters required for setting the test conditions:

Test Frequency:	Entry of test signal frequency
Generator Level:	Entry of amplitude prior to the voltage change in dBr
Level Step:	Entry of level change in dB
Burst On Time:	Entry of burst duration in ms
Interval Time:	Total time required for determining the attack and release time; entry in seconds
Test Tolerance:	Entry of tolerance level in dB to which the DUT should be settled after the level burst has been switched on and off
Generator Reference Value:	Entry of voltage in mV, corresponds to 0 dBr of the generator level
Analyzer Reference Value:	Entry of voltage in mV, corresponds to 0 dBr of the analyzer level
Y Scaling Max Value:	Entry of upper value of Y-axis
Y Scaling Min Value:	Entry of lower value of Y-axis

The user has to confirm the correct entry of all parameters, otherwise the entry can be repeated. All settings required for the analyzer section are carried out automatically by the test program, the user need not worry about selecting the correct compression factor or the scales for the graphics display. An error message is output if the entered generator parameter do not allow a measurement to be carried out.

Settings are stored automatically and are thus available for further measurements even after the program has been terminated and the analyzer switched off.

Pressing the softkey MEASURE (=F8) starts measurement. After measurement, softkeys are displayed at the lower edge of the screen. With the aid of these softkeys - the functions of which are also assigned to

the respective keys of the external keyboard - the user may manipulate the program functions. The following functions are available:

GOTO UPD (=F5)	stops the current program and switches to manual control of UPD/UPL without terminating BASIC; thus for instance the scale can be changed or a comment entered in the graphics display;
REPEAT (=F6)	triggers the next measurement sequence; a new measurement can be started even before the current measurement is terminated;
CONT (=F8)	branches to the start menu for entering test parameters
HARDCOPY (=F12)	outputs the screen content to the interface selected in the options panel (printer, plotter or file)

7.3. Measurement and Evaluation

After starting the measurement sequence, the instrument waits for the delay time to elapse before the level burst is applied to the DUT. The program determines a delay time of 10% of the selected interval time. Level values are continuously entered into the display, the "Measurement running" message displayed at the top left of the display indicates that a measurement is going on.

Upon termination of the measurements the data set is evaluated in the following steps:

1. From the set generator level at the beginning and the measured output level, the gain is calculated.
2. A test is made whether the DUT had settled to a value within 1 dB during the delay time before the level burst was applied (ie during the first 10% of the measurement time). If this is not the case the message "Interval too short" is output and further evaluation is stopped.
3. A test is made whether the DUT had settled to a value within 1 dB during the last 10% of the interval time after the input level was reduced (release time). If this is not the case the message "Interval too short" is output and further evaluation is stopped.
4. The time of the level change is evaluated.
5. A test is made whether the DUT had settled for at least 10% of the burst time to a value within 1 dB before the level burst was reset. If this is not the case the message "Burst too short" is output and further evaluation is stopped.
6. Determination of time at which the DUT has settled to the set level tolerance. The attack time is determined and output.
7. The time of the level reduction is evaluated.
8. The time is determined at which the DUT was settled to the set level tolerance after the input level reduction. The release time is calculated and output.
9. The compression ratio is calculated as ratio of the programmed level step and the measured output level change after settling.

Fig. 4 shows the display of the Audio Analyzers UPD/UPL after the measurement. The results are numerically displayed, the times used for the evaluation are marked in the display by dotted lines.

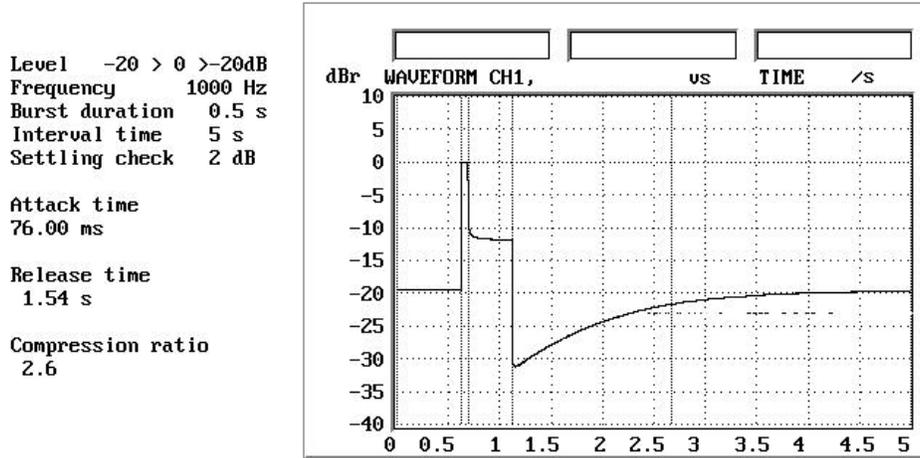


Fig. 4: Example of a display obtained with the measurement program

7.4. Terminating the Application Program

The program is terminated by pressing the ESCAPE key on the external keyboard or the CANCEL key on the UPD/UPL.

The software can be aborted any time with the key combination "CTRL BREAK". The program is restarted with RUN.