AND8227/D

Compandor Application Automatic Gain Control

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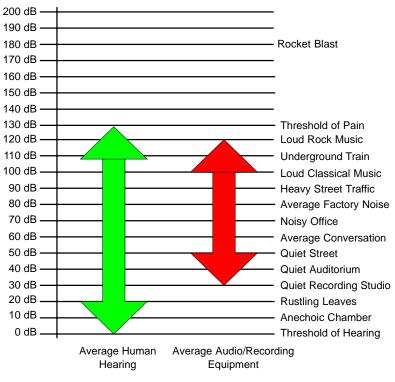ON Semiconductor

APPLICATION NOTE

INTRODUCTION

A human ear has the ability to detect a wide dynamic range, from the softest whisper to the loudest blast of a rocket launch. The electronic and acoustic sound equipment used to record or reproduce this wide spectrum of sound will be restricted by its physical limitations (Figure 1). Lower physical limitations of the equipment are the electrical and/or noise floor where the audio signal (i.e. whisper, quiet passages) is buried in the noise floor of the equipment and all that can be heard is the white noise of the equipment.

200 dB	
190 dB	
180 dB	Rocket Blast
170 dB	
160 dB	
150 dB	
140 dB	
130 dB	Threshold of Pain
120 dB	Loud Rock Music
110 dB	Underground Train
100 dB	Loud Classical Music
90 dB	Heavy Street Traffic
80 dB	Average Factory Noise
70 dB	Noisy Office
60 dB	Average Conversation
50 dB	Quiet Street
40 dB	Quiet Auditorium
30 dB	Quiet Recording Studio
20 dB	Rustling Leaves
10 dB	Anechoic Chamber
0 dB	Threshold of Hearing

Average Human Hearing   Average Audio/Recording Equipment

Figure 1. Typical Dynamic Range

When the audio signal exceeds the dynamic range capability or upper limitation of sound equipment (i.e. sound system, recording system, or playback system), the peaks may be distorted by clipping and/or damage the loudspeakers. Therefore, it is necessary to simultaneously keep the operating level of the audio signal as high as possible to minimize distortion from the noise floor, yet limit the peaks of the signal from causing the system to overload.

The audio signal levels can be manually adjusted (i.e. fader or knob of the equipment) by constantly monitoring the audio signal level. The gain is increased during low signal amplitudes and the gain is reduced during high signal amplitudes. However, manual control of the audio signal level is a difficult task, because to simultaneously detect the audio signal level, and adjust the gain in time without running into the physical limitation of the equipment, is impossible. Therefore, a fast acting Automatic Gain Control

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(AGC) system is needed that will constantly monitor the input signals to always adjust the gain to maximize the signal to noise ratio without creating peak signal distortion. This paper will discuss the AGC and its typical applications.

AGC

The Automatic Gain Control (AGC) is an automatic time−varying gain of a signal according to the input signal level. AGC is typically made up of a signal detector (Rectifier) and a gain computer (Gain Cell/Op Amp), where the signal detector detects the signal level of the input signal and the gain computer controls the gain or output signal level depending on the output of the signal detector. These components can be configured in many ways to suit the user's application. If the AGC is used to reduce the dynamic range of a signal, it is called compression, while if it used to increase the dynamic range, it is called expansion. ON Semiconductor offers a family of products called the Compandor that is specifically designed for this application. For more information please refer to our website *www.onsemi.com*.

Signal Detector

The two most common methods of input signal detection are peak signal, and average or RMS signal detection. With peak signal detection, the AGC will base its gain control on the peak levels of the input signal. The detected levels will always be greater than, or equal to, input signal levels (Figure 2). The peak level detection is useful to insure that the peaks do not exceed certain threshold to avoid clipping or damaging the loudspeakers. An example of an ideal signal for use of peak detector is a percussive signal.
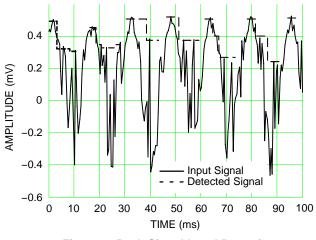
Figure 2. Peak Signal Level Detection

The average or RMS signal detection will use the average or RMS (Root Mean Square) of the input signal. The averaging/RMS time (time constant) over, which the input signal is averaged/RMS'd, will depend on the user. The time constant is usually referred to as attack and release times. The

average/RMS detected levels can be above or below the signal at any given instant (Figure 3). The averaging/RMS level detection is useful when it is necessary to compress or limit, but still retain a fair amount of the dynamic sensation, and is more likely to be used with more complex musical signals.
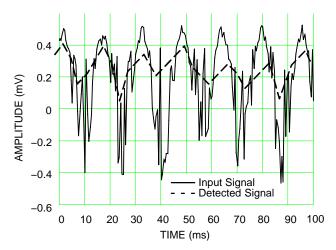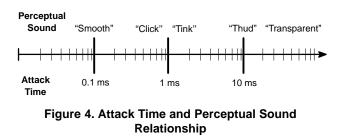
Figure 3. Average/RMS Signal Level Detection

The time constants (Attack and Release Time) of the average/RMS detector can be manually controlled to produce a sound to user's preference.

The attack time is the latency of a compression circuit from detection of a signal to the engagement of its steady state level. With faster attack time, the output audio will produce a smoother sound. But with slower attack time, the compression will be averaged/RMS'd over longer periods of time, which will produce a sound that is more like a "thud." A disadvantage of a long attack time is, it cannot react to sudden shifts in the signal level quickly. Figure 4 shows the attack time and its associated perceptual sound.

Figure 4. Attack Time and Perceptual Sound Relationship

The release time determines how long it takes for the AGC to return to unity gain after going into compression/ expansion. With slow release time, the smoother the output audio signal sounds. With faster release times, the AGC tracks every little change in the signal level, producing a potentially uneven effect that decreases the dynamics, but increases the average output level which produces a buzzing sound (see Figure 5 for release time and perceptual sound relationship).
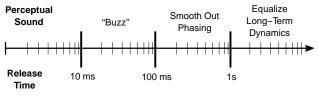
Figure 5. Release Time and Perceptual Sound Relationship

Gain Computer

The gain computer takes the control signal from the signal detector and adjusts the gain of the signal. ON Semiconductor's implementation of the gain computer is a gain cell, which is current in and current out with a current control signal from the signal detector (Figure 6).
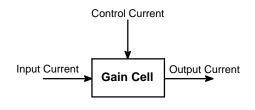

Figure 6. Gain Cell

APPLICATION

Typical applications of an AGC are compressors and limiters. Compressors and limiters perform similar tasks, but one essential point makes them different. Limiters abruptly limit the signal above a certain level, while compressors control the signal more gently over a wide range.

Limiter

A limiter continuously monitors the signal and intervenes as soon as the level exceeds a user adjusted threshold (usually from −40 dB to +20 dB). Any signal exceeding this threshold will be immediately returned to the adjusted level (Figure 7).

Figure 7. Limiter I/O Relationship

Figure 8. "Hard" Compression Knee

Figure 9. "Soft" Compression Knee

Additionally, the AGC has two ways to implement the compression over the threshold, "hard" (Figure 8) and "soft" (Figure 9) knee response. The hard knee response is considered more severe, because of the sharp transition to compression, as can be seen in Figure 10. With hard knee response, the signal is distorted and the harmonic distortion is increased.
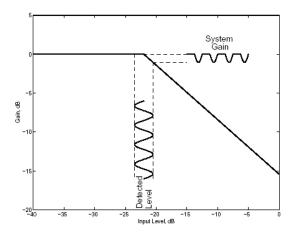

Figure 10. Hard Knee Gain Response

A soft knee response is considered more musical, because of the smooth transition to compression. The soft knee response also reduces the amount of harmonic and inharmonic distortions introduced during the gain control.
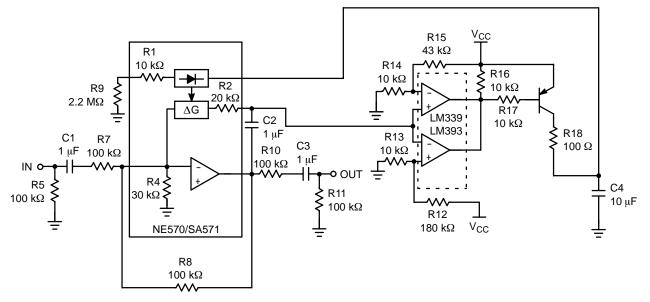
Figure 11. Limiter Circuit Diagram

ON Semiconductor's NE570/SA571 compandor can be easily used to make an excellent limiter. Figure 11 shows a typical circuit for a hard knee limiter which requires an NE570/SA571 compandor, LM393 dual comparator, and a PNP transistor. The signal detector (rectifier) is set at constant level by R9. For small signals, the ΔG cell will not compress or expand the input signal, and the circuit will run at unity gain as set by R8 and R7. When the output signal tries to exceed a + or −1.0 V peak, a comparator (LM393) threshold is exceeded as set by R12, R13, R14, and R15. When the comparator threshold is exceeded, the PNP is turned on and it rapidly charges C4 which activates the ΔG cell. Negative feedback through the ΔG cell reduces the gain and the output signal level. The attack time is set by the RC product of R18 and C4, and the release time is determined by C4 and the internal rectifier resistor, which is 10 kΩ. The circuit shown attacks in less than 1.0 ms and has a release time constant of 100 ms. R9 trickles about 0.7 μA through the rectifier to prevent C4 from becoming completely discharged. The gain cell is activated when the voltage on Pin 1 or 16 of the compandor exceeds two diode drops. If C4 were allowed to become completely discharged, there would be a slight delay before it recharged to >1.2 V and activate the limiting action.

A stereo limiter can be built out of one NE570/SA571, one LM339 and two PNP transistors. The resistor networks R12, R13 and R14, R15, which set the limiting thresholds, could be common between channels. To gang the stereo channels together (limiting in one channel will produce a corresponding gain change in the second channel to maintain the balance of the stereo image), then Pins 1 and 16 should be jumpered together. The outputs of all four comparators may then be tied together, and only one PNP

transistor and one capacitor C4 need be used. The release time will then be the product 5.0 kΩ X C4 since two channels are being supplied current from C4.

Compressor

A compressor also monitors the input signal continuously and has a certain threshold level like the limiter. With compression, the signals are not reduced in level abruptly once the threshold has been exceeded, but rather by a ratio of the input range (1:1 to 20:1) set by the user (Figure 12).
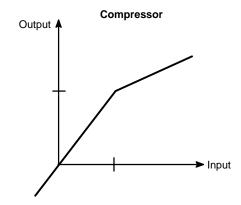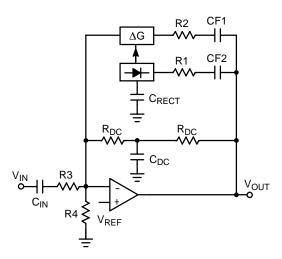

Figure 12. Compressor I/O Relationship

The compressor like the limiter has two ways to implement the compression above the threshold, hard and soft knee response.

ON Semiconductor's current line of compandor's can easily be configured as a soft knee compressor with a fixed compression ratio of 1:2. Figure 13 shows the typical circuit of compressor with ON Semiconductor's compandors.

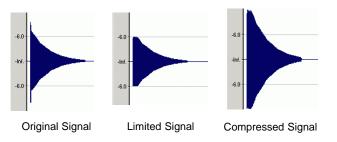**Figure 13. Typical Compressor Circuit**

Figure 14. Examples of Limiter and Compressor for a Percussive Instrument

An example of the difference between the limiter and compressor is shown in Figure 14. The figure on the left shows an original signal that represents a percussive instrument. The center figure shows the response of the limiter. The right figure shows the compressed signal.

SUMMARY

To overcome the physical dynamic range limitations of the audio equipment, a need arises for an AGC. This paper describes examples of implementation of AGC. ON Semiconductor offers a full line of compandors and low noise op amps for many different implementations of an AGC.

PUBLICATION ORDERING INFORMATION