Application Report

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AN-1451 LM4935 Automatic Gain Control (AGC) Guide

ABSTRACT

This report provides information on the operation and settings of the automatic gain control circuit.

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1 Automatic Gain Control (AGC) Overview

A microphone is typically used in an environment where the level of the audio source is unknown. The LM4935 features an Automatic Gain Control (AGC) circuit that addresses this situation by compensation for significant variations in level from a microphone's input. It maintains a fixed level during recording or playback. The following scenarios showcase the real world benefits of the AGC circuit:

Scenario 1:

A user talks too loudly or too close to the microphone. This causes a clipped voice signal at the output of the microphone preamplifier.

Without AGC

The user at the receiving end hears a clipped signal. This clipped signal sounds distorted. Further, it may damage the receiving-end transducer or may cause hearing loss.

With AGC

The AGC automatically lowers the microphone preamplifier gain. This prevents voice signal clipping. The resulting undistorted, unclipped voice signal is then presented to the user on the receiving end.

Scenario 2:

A user talks too softly or too far away from the microphone.

Without AGC

The resultant low-level voice signal may not be heard clearly or at all by the user at the receiving end.

With AGC

The AGC will automatically increase the gain of the microphone preamplifier to a level that is heard clearly by the user at the receiving end.

As shown in the scenarios above, the AGC operates by automatically adjusting the gain of the microphone preamplifier to maintain a pre-defined target level at the amplifier's output. The AGC loop is shown in Figure 1.

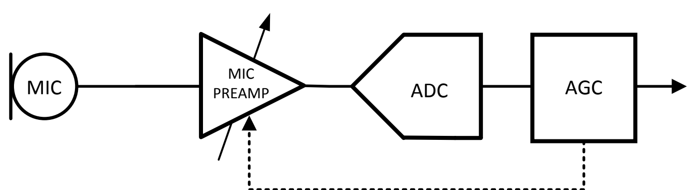

Figure 1. AGC Loop

2 AGC Operation

The AGC circuit adjusts the level of the input applied to the ADC. This optimizes the dynamic range of the voice data when the level of the source is unknown. A target level for the output is set so that any transients on the microphone input will not clip during normal operation. The AGC circuit compares the output of the ADC to this target level and increases or decreases the gain of the microphone preamplifier to compensate. The ADC's full dynamic range is realized when the AGC optimizes microphone preamplifier output signal magnitude.

To ensure that the AGC circuit does not reduce the quality of the speech by constantly modulating the microphone preamplifier gain, the ADC output is passed through an envelope detector. The envelope detector frames the output of the ADC into time segments roughly equal to the phonemes found in speech (AGC_FRAMETIME). To calculate this, the AGC circuit must also know the ADC's sample rate (ADC_SAMPLERATE). If, after a programmable number of these segments (AGC_HOLDTIME), the level is consistently below target, the microphone amplifier's gain is increased at a programmable rate (AGC_DECAY). If the signal ever exceeds the target level (AGC_TARGET), the gain of the microphone is reduced immediately at a programmable rate (AGC_ATTACK). The AGC's operation is demonstrated in Figure 2.

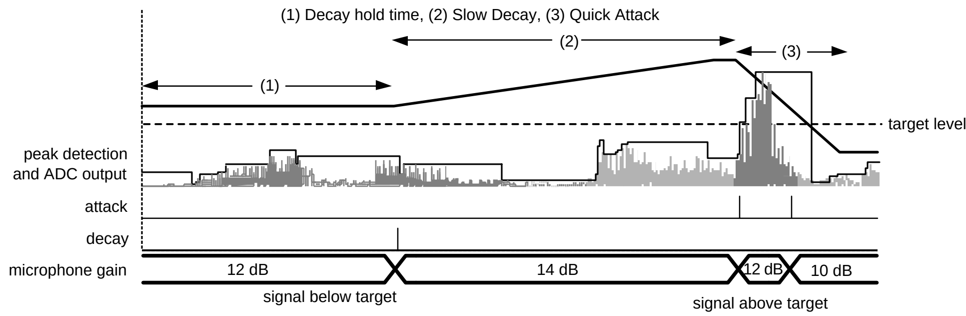

Figure 2. AGC Operation Example

The ADC input signal shown in Figure 2 is initially at a low level. After the hold time has finished, the gain rises ((1)→(2)). Later, the microphone output signal's amplitude increases and reaches the threshold for a gain reduction. This reduction is programmed to decrease the gain at a faster rate ((2)→(3)), to allow the elimination of typical popping noises.

Only ADC outputs that are considered signal (rather than noise) are used to adjust the microphone preamplifier gain. The signal-to-noise ratio (SNR) of the expected input signal is set by NOISE_GATE_THRESHOLD. In some situations, it is preferable to remove audio considered to be solely background noise from the audio output; for example the background noise during a conference calls. This can be done by setting NOISE_GATE_ON. This does not affect the performance of the AGC algorithm.

The AGC algorithm should not be used where high amplitude background noise is present. If the type of input data, application, and microphone is known, the AGC will typically not be required for good performance. The AGC is intended for use with inputs with a large dynamic range or unknown nominal level. When setting NOISE_GATE_THRESHOLD, be aware that in some mobile phone scenarios the ADC SNR will be dictated by the microphone performance rather than the ADC or the signal. Microphone preamplifier gain changes are performed on zero crossings ensuring no zipper noise. Enable the ADC's high pass filter to eliminate DC offsets, wind noise, and pop sounds from the output of the ADC.

3 AGC Settings Explained

3.1 AGC_TARGET (bits 3:1(0x08h))

This is the predefined audio signal magnitude target level at the input of the ADC that is maintained by the AGC algorithm. This target level can be programmed from –6dBFS to –20dBFS in 2dBFS steps. There is a delay between when the AGC attenuates the ADC input and when it reads the ADC output. During this delay, the ADC input signal may clip if there is not enough headroom available. The headroom should be approximately the difference between the average signal level and the level of the expected transients. In order to maximize the dynamic range of the ADC, the reference level of the expected transients should be set at the maximum input level of the ADC (Full scale = 1Vrms). Therefore, it is recommended to set AGC_TARGET at the difference between the average signal level and 0dBFS. For typical speech patterns, an AGC_TARGET setting of -12dBFS or -14dBFS is a good starting point.

3.2 AGC_FRAME_TIME (bits 5:3(0x07h))

This sets the frame time to be used by the AGC algorithm. In a given frame, the AGC's peak detector determines the peak value of the incoming microphone audio signal level and compares this value to the target value of the AGC (AGC_TARGET) in order to adjust the microphone preamplifier's gain. The length of a frame determines the sample rate of the AGC. The frame time can be set from 96ms to 1000ms, an adjustment range for a wide variety of speech patterns.

3.3 AGC_HOLDTIME (bits 4:0(0x0Ah))

This bit sets the amount of delay (by controlling the number of frames passed to the ADC) before the AGC algorithm begins to adjust the gain of the microphone preamplifier. The hold time can be set from 0 to 31 frames. The length of each frame is set by AGC_FRAME_TIME. For example, an AGC_HOLDTIME set for 2 frames and an AGC_FRAMETIME set for 96ms gives a total delay time of 192ms.

Delay Time = (AGC_HOLDTIME) x (AGC_FRAME_TIME)

Delay Time = (2) x (96ms) = 192ms

For this particular example, the AGC algorithm will not adjust the microphone preamplifier gain until a delay of 192ms after a signal is present on the ADC.

3.4 AGC_ATTACK (bits 7:5(0x0Ah))

Setting this bit sets the rate at which the AGC will reduce the microphone preamplifier's gain when the input signal level is larger than the target level set by AGC_TARGET. Whenever the input level is greater than the target level, the AGC immediately decreases the microphone preamplifier gain on the next zero crossing. The attack time is the amount of time between each step to decrease the gain. It has a range from 32ms to 4096ms.

3.5 AGC_DECAY (bits 6:4(0x09h))

This bit sets the rate at which the AGC will increase the microphone preamplifier gain when the input signal level is smaller than the target level set by AGC_TARGET. Whenever the input signal level is lesser than the target level, the AGC waits for the hold time and then increases the microphone preamplifier gain on the next zero crossing. To ensure maximum SNR, the AGC does not increase the microphone preamplifier gain when the input signal level is below the noise floor as set by the NOISE_GATE_THRES. The decay time is the amount of time between each step to increase the gain. It has a range from 32ms to 4096ms.

3.6 AGC_MAX_GAIN (bits 3:0(0x09h))

This bit sets the maximum gain that the AGC can apply to the microphone preamplifier. The maximum gain can be set from 6dB to 36dB in 2dB steps.

3.7 AGC_TIGHT (bit 7(0x09h))

Setting this bit allows the AGC gain algorithm to control the microphone preamplifier gain so that the output signal level closely matches the AGC target level.

The AGC is used to optimize the microphone preamplifier output signal level, whether intended for the LM4935's analog output stages or as an input signal for the ADC. When the analog path is used, this bit should be cleared. This allows greater dynamic range for the audio signal at the output stages. When the microphone input is routed to the ADC for recording or playback, the AGC_TIGHT bit should be set to ensure that the audio signal tightly adheres to the target level.

3.8 ADC_SAMPLERATE (bits 5:4(0x06h))

This variable is used by the AGC algorithm. It informs the AGC circuit about the closest expected ADC sample rate. This bit does not set the actual ADC sample rate. ADC_SAMPLERATE can be set to 8kHz, 12kHz, 16kHz, or 24kHz. It is recommended that the selected ADC_SAMPLERATE setting closely matches the actual ADC sample rate so that the AGC works properly.

3.9 NOISE_GATE_THRES (bits 7:5(0x08h))

This setting tells the AGC magnitude of the expected background noise level relative to the peak signal level. The presence of signals below this level will be removed from the ADC output and will not produce an AGC gain change. This prevents background noise from being unnecessarily amplified during periods of silence in a conversation. The noise gate threshold level can be set from –72dB to –30dB. This level must be defined even if the noise gate is not in use, because this level is required by the AGC algorithm.

3.10 NOISE_GATE_ON (bit 4(0x08h))

Setting this bit will mute cause the amplifier to mute signals that are below the noise gate threshold level defined by NOISE_GATE_THRES. When the noise gate is enabled and no signal is detected, the noise gate waits for a delay time equal to (AGC_FRAMETIME) x (AGC_HOLDTIME) to pass and then mutes any signal below the noise gate threshold level. When a signal larger than the noise gate threshold level is detected, the noise gate unmutes the signal on the next zero crossing. Figure 3 and Figure 4 show the effect of the noise gate on the same audio signal.

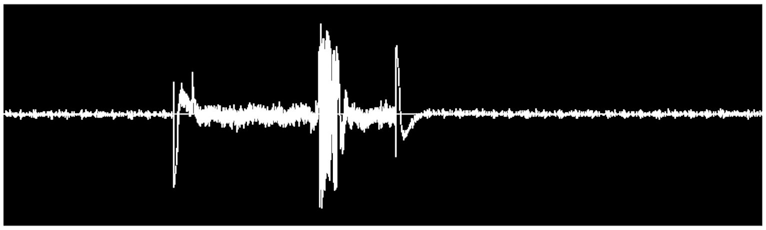

Figure 3. A Noisy Audio Signal with NOISE_GATE_ON Disabled

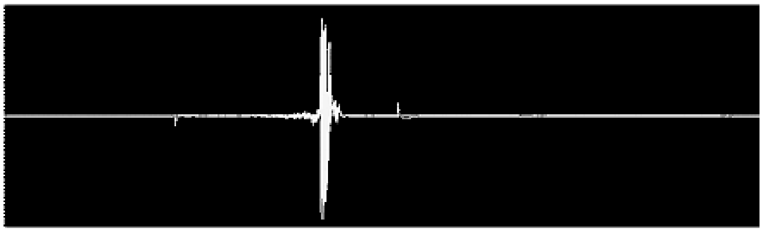

Figure 4. The Same Audio Signal (Figure 3) with NOISE_GATE_ON Enabled

When using the noise gate, there is a tradeoff between eliminating background noise during moments of silence and maintaining the original relevant audio information. Figure 4 shows the elimination of background noise found from the noisy waveform shown in Figure 3. However, some of the audio transients were also reduced. This is a result of the noise gate's action: once it detects a signal larger than the noise gate threshold, the gate unmutes the signal on the next zero crossing. Setting NOISE_GATE_THRES to its minimum of –72dB reduces the possibility of relevant audio information being muted, but may increase the chance of unwanted background noise leaking through.

4 Recommended AGC Settings

Here are the recommended starting points for tuning the AGC for voice conversations.

AGC_TARGET = -12dB

AGC_FRAMETIME = 96ms

AGC_HOLDTIME = 1 frame

AGC_ATTACK = 64ms

AGC_DECAY = 64ms

AGC_MAX_GAIN = 36dB

AGC_TIGHT = Enabled

ADC_SAMPLERATE = closest sample rate to the actual sample rate of the ADC

NOISE_GATE_THRES = -72dBFS

NOISE_GATE_ON = Enabled

The effect of the AGC is highly subjective and system dependent, therefore further tuning may be required.

5 Revision History

Rev	Date	Description
0.1	04/24/06	Initial release.

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