Application Report
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The Built-In AGC Function in TSC2100/01 and TLV320AIC26/28/32/33 Devices

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ABSTRACT

Applying the built-in AGC function requires initializing or setting up a group of corresponding control registers inside the TSC2100/01 and TLV320AIC26/28/32/33 devices. This application report describes how to set up the AGC properly and provides examples.

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1 Introduction

One or more automatic gain control (AGC) modules are built into the analog input circuitry of a touch screen controller (TSC) with audio codec devices, such as the TSC2100 and TSC2101, or an audio codec device, such as TLV320AIC26 (AIC26 for short) and TLV320AIC33 (or AIC33), to help users to improve audio recording performance under certain applications and environments.

An AGC is a smart programmable gain amplifier (PGA) in which the input signal, corresponding to its amplitude or volume, is automatically adjusted in a specified manner. The AGC is useful where the audio input volume changes dynamically and frequently so that any manual or linear PGA cannot provide proper gain. As an example, during a teleconference, because some people sit near the microphone and some farther away, the voice signal to the microphone may be too weak or too strong; thus, any non-automatic PGA can delivery only poor recording results. An AGC, on the other hand, can automatically adjust the gain, as shown in Figure 1 (see the Reference section of this application report), so that the signal is maintained at a certain nominal constant level (called target gain) over a changing range of real-world conditions.

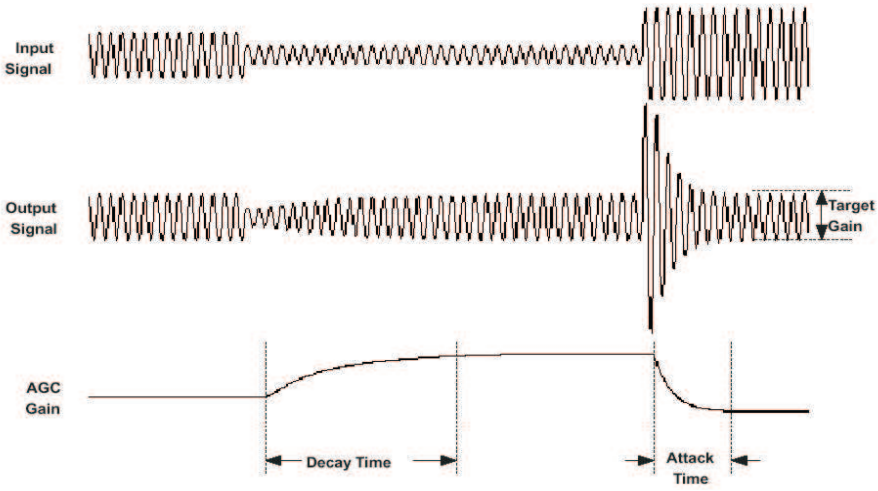

Figure 1. AGC Function

Using the AGC function on a TI device involves the initialization or configuration of a group of control registers, through the device's SPI or I2C interface and by software. This application report provides a detailed explanation and setup examples for using the built-in AGC on TI devices TSC2100, TSC2101, AIC26, AIC28, AIC32, or AIC33.

2 AGC Variables

Usually, an AGC module or algorithm includes a set of variables or parameters, such as that shown in Table 1. These variables make it possible for the AGC to be used in many different applications and situations.

Table 1. AGC Variables Description

AGC VARIABLE		FUNCTION/DESCRIPTION
AGC Gain	Target Gain	The desired nominal output level or gain, at which the AGC attempts to maintain the output signal level. See Figure 1. Target gain is defined relative to the full scale (0 dB) of the ADC range and thus it can be, for example, –8 dB or –20 dB. Or: Time taken by the output signal average to decay down to the Target Gain level when the input signal increased.
Transient/ Dynamic Variables	Attack Time	When the input signal becomes larger, attack time defines the length of the transient time (a delay time in milliseconds or ms) for the output signal to reach the target gain. See Figure 1. Or: Time taken by the output signal average to decay down to the Target Gain level when the input signal increased.
	Decay Time	When the input signal becomes weaker, decay time defines the length of the transient time (a delay time in milliseconds or ms) for the output to reach the target gain. See Figure 1. Or: Time taken by the output signal average to increase to the Target Gain level when the input signal decreased.

Table 1. AGC Variables Description (continued)

AGC VARIABLE		FUNCTION/DESCRIPTION
Noise-Related Variables	Noise Threshold	A level or threshold for AGC to distinguish noise from a small signal, so that noise lower than the threshold cannot be amplified. For the AGC, a signal lower than the noise threshold is considered as *noise*, and a signal higher than the noise threshold it considered to be the *signal* or *normal*.
	Maximum Gain Applicable	The level or limitation of the AGC gain, applicable to the input signal, in those cases in which, if noise is louder than the noise threshold, that noise can be restricted to the maximum gain.
	Hysteresis	The hysteresis around the noise threshold to avoid the AGC gain from cycling between high gain and no gain (0 dB) when the input signal is around the noise threshold.
	Normal-to-Silence Debounce Time	The debounce/delay time for AGC gain to change from normal (high gain) to silence (0 dB) after the audio input signal became lower than the noise threshold minus hysteresis.
	Silence-to-Normal Debounce Time	The debounce/delay time for AGC gain to change from 0 dB (silence) to high gain (normal) after the audio input signal became higher than the noise threshold plus hysteresis.

Note the following characteristics of the AGC in device TSC2100, TSC2101, AIC26, AIC28, AIC32 or AIC33:

- The AGC uses an absolute average of the signals for calculating the algorithm.
- When the absolute average of the input signal becomes lower than the noise threshold, the AGC reduces the gain to 0 dB in the soft stepping of 0.5 dB every FS.
- The AGC hysteresis is illustrated in Figure 2.

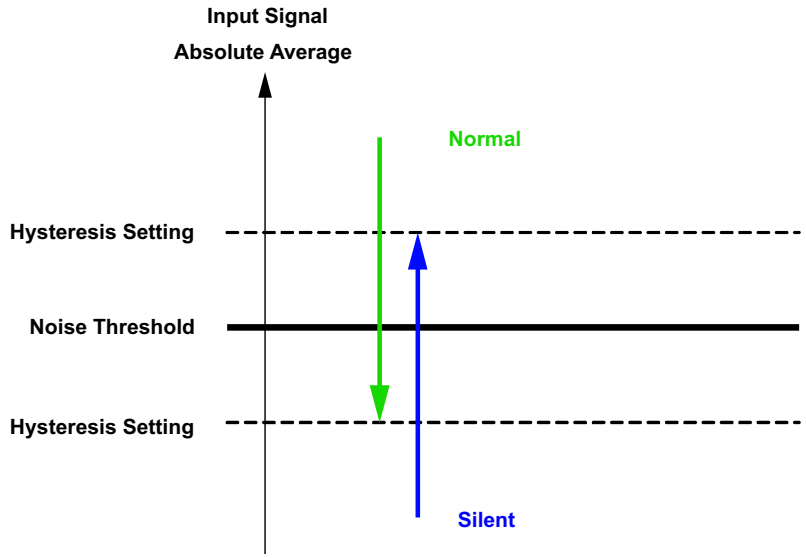

Figure 2. AGC Hysteresis

Experience and trade-offs may be needed when selecting the values of the variables in Table 1. For example, if the noise threshold selected is too low, the larger noise may be picked up and amplified with a large gain; on the other hand, if the noise threshold selected is set too high, the weaker signal may be considered by the AGC as noise and fail to be amplified. Similarly, if the maximum gain applicable variable is kept too high, then any noise which is above the noise threshold may become gained by a large amount and create a noisy output; but if it is kept too low, normal speech signals may not be gained up enough to reach the target gain level at the output.

The selection of the AGC variables depend greatly on practical application and environment. Some variables become more important under certain conditions. For example, if the input signal is often hovering around the noise threshold, hysteresis and debounce time become critical.

3 AGC Settings and Status

In the TSC2100, TSC2101, AIC26, AIC28, AIC32, or AIC33 device, control registers are located in the internal memory-mapped pages. The built-in AGC variables or parameters, as given in Table 1, should be initialized and configured by writing to the corresponding control registers. Table 2, Table 3, and Table 4 list the applicable values of AGC variables in these TI devices, including the bit locations inside the devices' control registers.

Table 2. TSC2100 or AIC26 AGC Variable Values and Locations

AGC VARIABLE	APPLICABLE VALUES	LOCATIONS
Target Gain (dB)	– 5.5 , –8, –10, –12, –14, –17, –20, –24	Page2/Reg01H/D7 ~ D5
Attack Time (ms)	8, 11, 16, 20	Page2/Reg01H/D4 ~ D1
Decay Time (ms)	100, 200, 400, 500	
Noise Threshold (dB)	– 60, –70, –80, –90	Page2/Reg06H/D5 ~ D4
Maximum Gain Applicable[1]	From 0 dB to +59.5 dB with resolution of 0.5 dB	Page2/Reg1EH/D15 ~ D9
Hysteresis (dB)	0, 1, 2, 4	Page2/Reg1DH/D10 ~ D9
Normal-to-Silence Debounce Time (ms)	0, 0.5, 1, 2, 4, 8, 16, 32	Page2/Reg1EH/D8 ~ D6
Silence-to-Normal Debounce Time (ms)	0, 0.5, 1, 2, 4, 8, 16, 32	Page2/Reg1EH/D5 ~ D3

(1) When the AGC Noise Threshold variable is set to be less than or equal to –70 dB, the Maximum Gain Applicable variable must be set as greater than or equal to –Noise Threshold –58.5 dB.

Table 3. TSC2101 or AIC28 AGC Variable Values and Locations

AGC VARIABLE	APPLICABLE VALUES	LOCATIONS		
		HEADSET INPUT	HANDSET INPUT	CELL-PHONE INPUT
Target Gain (dB)	–5.5, –8, –10, –12, –14 , –17, –20, –24	Page2/Reg01H/ D7 ~ D5	Page2/Reg1EH/ D7 ~ D5	Page2/Reg24H/ D7 ~ D5
Attack Time (ms)	8, 11, 16, 20	Page2/Reg01H/ D4 ~ D1	Page2/Reg1EH/ D4 ~ D1	Page2/Reg24H/ D4 ~ D1
Decay Time (ms)	100, 200, 400, 500			
Noise Threshold	30 dB to –90 dB with resolution of 10 dB[1]	Page2/Reg24H/D13 ~ D11		
Maximum Gain Applicable [2]	From 0 dB to +59.5 dB with resolution of 0.5 dB	Page2/Reg26H/D15 ~ D9		Page2/Reg27H/ D15 ~ D9
Hysteresis (dB)	No Hysteresis (= 0), 1, 2, 4	Page2/Reg1DH/D10 ~ D9		Page2/Reg24H/ D10 ~ D9
Normal-to-Silence Debounce Time (ms)	0, 0.5, 1, 2, 4, 8, 16, 32	Page2/Reg26H/D8 ~ D6		Page2/Reg27H/ D8 ~ D6
Silence-to-Normal Debounce Time (ms)	0, 0.5, 1, 2, 4, 8, 16, 32	Page2/Reg26H/D5 ~ D3		Page2/Reg27H/ D5 ~ D3

(1) Noise Threshold applicable values do not include –70, –80 and –90 for cell-phone input.
(2) When the AGC Noise Threshold variable is set to be less than or equal to –70 dB, the Maximum Gain Applicable variable must be set as greater than or equal to –Noise Threshold –58.5 dB.

Table 4. AIC32 or AIC33 AGC Variable Values and Locations

AGC VARIABLE	APPLICABLE VALUES	LOCATIONS	
		LEFT AGC	RIGHT AGC
Target Gain (dB)	– 5.5, –8, –10, –12, –14, –17, –20, –24	Page0/ Reg26/D6 ~ D4	Page0/Reg29/D6 ~ D4
Attack Time (ms)	8, 11, 16, 20	Page0/Reg26/D3 ~ D2	Page0/Reg29/D3 ~ D2
Decay Time (ms)	100, 200, 400, 500	Page0/Reg26/D1 ~ D0	Page0/Reg29/D1 ~ D0

Table 4. AIC32 or AIC33 AGC Variable Values and Locations (continued)

AGC VARIABLE	APPLICABLE VALUES	LOCATIONS	
		LEFT AGC	RIGHT AGC
Noise Threshold	– 30 dB to –90 dB with resolution of 2 dB	Page0/Reg28/D5 ~ D1	Page0/Reg31/D5 ~ D1
Maximum Gain Applicable(1)	From 0 dB to +59.5 dB with resolution of 0.5 dB	Page0/Reg27/D7 ~ D1	Page0/Reg30/D7 ~ D1
Hysteresis (dB)	No Hysteresis (= 0), 1, 2, 3	Page0/Reg28/D7 ~ D6	Page0/Reg31/D7 ~ D6
Normal-to-Silence Debounce Time (ms)	0, 0.5, 1, 2, 4, 8, 16, 32, 64, 64*2 , 64*3 , …, … 64*23, 64*24	Page0/Reg34/D7 ~ D3	Page0/Reg35/D7 ~ D3
Silence-to-Normal Debounce Time	0, 0.5, 1, 2, 4, 8, 16, 32	Page0/Reg34/D2 ~ D0	Page0/Reg35/D2 ~ D0

(1) When the AGC Noise Threshold variable is set to be less than or equal to –70 dBm, the Maximum Gain Applicable variable must be set as greater than or equal to –Noise Threshold –58.5 dB.

In addition to the AGC variables listed in Table 1 through Table 4, Table 5 also lists several control and status bits designed for AGC use.

Table 5. AGC Control and Status

AGC CONTROL/STATUS		DEFINITION	LOCATION
Control	AGC Enable	Enable (= 1) or disable (= 0) the AGC function	**– TSC2100/AIC26:** Page2/Reg01H/D0
			– TSC2101/AIC28: headset: Page2/Reg01H/D0 handset: Page2/Reg1EH/D0 cell-In: Page2/Reg24H/D0
			– AIC32/AIC33: left: Page0/Reg26/D7 right: Page0/Reg29/D7
	Clip-Stepping Enable	Enable (= 1) or disable (= 0) Clip stepping. Clip stepping is, when ADC is saturated, the AGC reduces the gain 0.5 dB per frame until the ADC is not saturated. (Not recommended for normal usage because it tries to break the AGC loop.)	**– TSC2100/AIC26:** Page2/Reg06H/D3
			– TSC2101/AIC28: head/handset: Page2/Reg06H/D3 cell-In: Page2/Reg24H/D8
			– AIC32/AIC33: left: Page0/Reg28/D0 right: Page0/Reg31/D0

Table 5. AGC Control and Status (continued)

AGC CONTROL/STATUS		DEFINITION	LOCATION
Status	Actual Gain Applied by AGC	The actual gain AGC applied on the input signal, which is from -12 dB to +59.5 dB (from -34.5 dB to +12 dB for cell-in on TSC2101/AIC28 device) with the resolution of 0.5 dB.	**– TSC2100/AIC26:** Page2/Reg01H/D15~D8
			– TSC2101/AIC28: headset: Page2/Reg01H/D15~D8 handset: Page2/Reg1EH/D15~D8 cell-In: Page2/Reg1FH/D14~D8
			– AIC32/AIC33: left: Page0/Reg32 right: Page0/Reg33
	Noise Threshold Flag	Indicating input signal lower (= 1) or higher (= 0) than Noise Threshold. Note that this flag is generated when the input signal is lower than Noise Threshold minus Hysteresis for a period of time given by Noise-to-Silence debounce time. The flag is reset when the input signal is higher than Noise Threshold plus Hysteresis for a period of time given by Silence-to-Normal Debounce time.	**– TSC2100/AIC26:** Page2/Reg04H/D11
			– TSC2101/AIC28: head/handset: Page2/Reg04H/D11 cell-In: Page2/Reg24H/D14
			– AIC32/AIC33: left: Page0/Reg36/D5 right: Page0/Reg36/D1
	Saturation Flag	Indicating that the AGC output is saturated (= 1) or not saturated (= 0) on the ADC full scale. Note that when this flag = 1, this indicates that the AGC cannot further gain up the input signal even if the output signal has not reached the target gain.	**– TSC2100/AIC26:** Page2/Reg04H/D0
			– TSC2101/AIC28: head/handset: Page2/Reg04H/D0 cell-In: Page2/Reg1FH/D7
			– AIC32/AIC33: left: Page0/Reg36/D4 right: Page0/Reg36/D0

4 Application Examples

Three examples for the AGC setup follow. Example 1 can be used as a starting point for an application where the noise is small compared to the input signal amplitude. Example 2 may be more suitable as the starting point for a condition where noise is relatively large. Example 3 can be used as the starting point in general.

4.1 Example 1

1. Target gain = –5.5 dB
2. Attack time = 20 ms and decay time = 500 ms
3. Noise threshold = –90 dB
4. Maximum gain applicable = 50 dB
5. Hysteresis disabled.
6. Debounce time from normal to silence = 0 ms
7. Debounce time from silence to normal = 0 ms

Note that with Example 1 settings, the background noise may become considerable when noise is beyond the noise threshold because the maximum gain applicable is higher (+50 dB) and thus *big* noise may get gained up with high gain.

4.2 Example 2

1. Target gain = –10 dB
2. Attack time = 20 ms and decay time = 500 ms
3. Noise threshold = –90 dB
4. Maximum gain applicable= 40 dB
5. Hysteresis = 2 dB
6. Debounce time from normal to silence = 2 ms
7. Debounce time from silence to normal = 0 ms.

Note that the Example 2 settings, even though the noise is above the noise threshold, will not be as much gain as in Example 1; the AGC output gain has also been reduced due to the smaller maximum gain applicable.

4.3 Example 3

1. Target gain = –5.5 dB
2. Attack time = 8 ms and decay time = 500 ms
3. Noise threshold = –90 dB
4. Maximum gain applicable= 59.5 dB
5. Hysteresis = 2 dB
6. Debounce time from normal to silence = 0 ms
7. Debounce time from silence to normal = 0 ms

   Without speech or signal, decrease the Maximum Gain Applicable variable to have an acceptable level of amplified noise. Next, with the lowest speech or signal source, increase the Noise Threshold variable to a level so that the weak signal can be detected and gained. Then, increase the attack time if the speech initially sounds bad; decrease the decay time if the speech sounds too noisy for too long at the end.

5 References

1. *TSC2100, Programmable Touch Screen Controller With Integrated Stereo Audio Codec and Headphone/Speaker Amplifier* data sheet (SLAS378)
2. *TSC2101, Audio Codec With Integrated Headphone, Speaker Amplifier and Touch Screen Controller* data sheet (SLAS392)
3. *TLV320AIC26, Low Power Stereo Audio Codec With Headphone/Speaker Amplifier and 12-Bit Battery/Temperature/Auxiliary ADC* data sheet (SLAS412)
4. *TLV320AIC28, Stereo Audio Codec With Integrated Headphone and Speaker Amplifiers* data sheet (SLAS418)
5. *TLV320AIC32, Low Power Stereo Audio Codec for Portable Audio/Telephony* data sheet (SLAS479)
6. *TLV320AIC33, Low Power Stereo Audio Codec for Portable Audio/Telephony* data sheet (SLAS480)

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