Radio Spectrum Processor

Automatic Gain Control (AGC) Reference Note

Overview

The SDRplay Radio combines together the Mirics flexible tuner front-end and USB bridge to produce a SDR platform capable of being used for a wide range of worldwide radio and TV standards. The API allows the end user to program their own demodulators or applications around the platform. The SDRplay module uses the Mirics Msi001 polyband tuner. This tuner does not utilize a traditional analogue AGC scheme but instead uses a digitally controlled AGC scheme. This means that all AGC functionality needs to be implemented within software to prevent overload of the RF front end circuits and to correctly setup the tuner gain parameters. This document outlines a so-called “dead-reckoning” AGC scheme suitable for use with the digitally gain-controlled tuner.

Traditional analogue AGC approach

Traditional analogue gain control systems typically operate two AGC loops, one controlling the gain at IF whilst the other controls gain at RF. The IF AGC loop regulates the signal level into the demodulator to ensure optimum use of the ADC dynamic range. The RF AGC loop uses a wideband detector, typically at the LNA or mixer output, to sense any large interfering signals and modulate the LNA gain appropriately to avoid distortion in the RF front-end. Depending on the particular implementation these two loops may or may not operate autonomously (i.e. without baseband or demodulator intervention).

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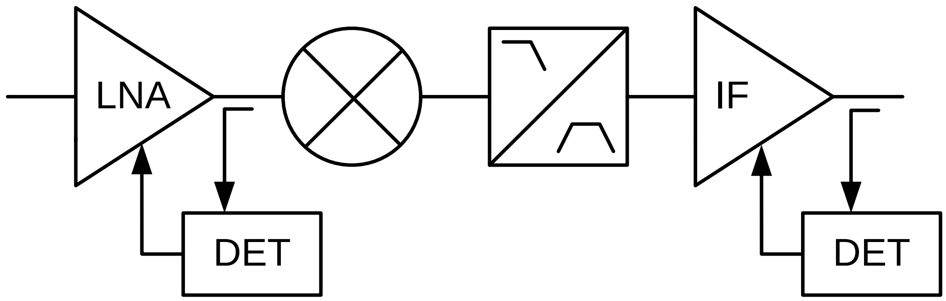


Figure 1: Analogue AGC Architecture

Continuously variable LNA gain control is difficult to implement, typically the LNA noise characteristics are degraded faster than the improvements are made to the linearity. The loop bandwidth of the detector tends to be narrow to avoid noise pick up which make them slow to respond to rapidly changing events.

Dead-reckoning method for use with digital gain control

Digital gain control allows for the precise switching between gain states with the effect of each gain control state producing a known and repeatable effect on receiver performance. The only task is to understand the order in which to switch between these states to meet the needs of the application. Since the tuner gain and its associated noise figure is very well understood by the controller it can use the level seen at the ADC input to know precisely the wanted signal level at the input to the receiver. The term 'dead-reckoning' is used to describe this concept.

As with many digitally controlled receivers the gain control at both the RF and IF frequencies is used to optimize the tradeoff between the receiver noise figure, the linearity of the receiver and the wanted signal level at the ADC.

The SDRplay gain lineup

In the SDRPlay module there are two RF AGC gain steps, the low noise amplifier and the RF mixer. These are used to optimize the receiver noise figure and linearity performance. The actual gain steps associated with the LNA and RF mixer will be dependent upon the frequency of use. The table below shows the different LNA and RF mixer gain reduction steps for different frequencies. The IF gain is controlled in 1dB increments and has 59dB of dynamic range, this allows a constant level to be maintained at the ADC input.

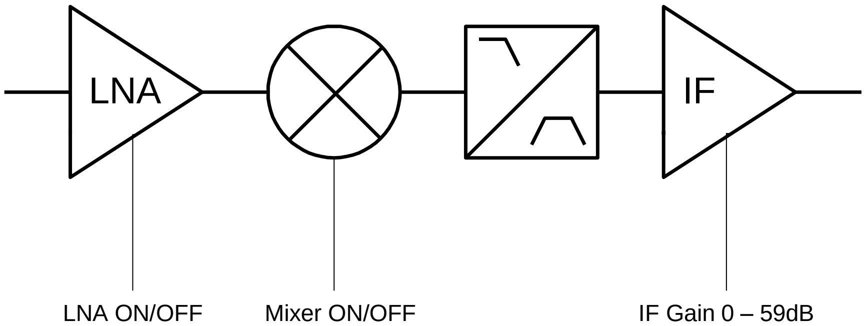


Figure 2: Digital AGC Architecture

Frequency of Use	LNA Gain Reduction	Mixer Gain Reduction	IF Gain Reduction
0.1kHz - 60MHz	19dB	24dB	0dB to 59dB In 1dB increments
60MHz - 120MHz	24dB	19dB	
120MHz - 240MHz	24dB	19dB	
240MHz - 380MHz	19dB	24dB	
430MHz - 1000MHz	7dB	19dB	
1000MHz - 2000MHz	5dB	19dB	

All gain steps are specified as gain reduction values and represent the amount of gain that will be removed from the maximum gain state, for example;

- 7dB of LNA gain reduction will result in: Receiver gain = Max Gain – 7dB
- 19dB of mixer gain reduction will result in: Receiver gain = Max Gain – 19dB
- 59dB of IF gain reduction will result in: Receiver gain = Max Gain – 59dB.

The SDRplay digital gain control system.

For very small input signals then maximum sensitivity is required so the LNA and mixer are both switch on to achieve maximum gain and sensitivity. As the signal strength increases the level at the ADC is maintained by adjusting the IF or baseband (BB) gain in 1dB increments. This can be set freely as it has no effect on the system noise figure or linearity.

As the signal level increases further then the noise of the receiver become less important and the possibilities of large signals compressing the receiver becomes more of a concern. At this point the LNA gain reduction is used which improves the linearity at the expense of receiver noise figure.

At very large signals then both the mixer and the LNA gain reductions can be used. The mixer gain reduction will not improve linearity but will prevent compression of the baseband or IF stage.

This concept is pictured more graphically in Figure 3 illustrating the early use of the LNA gain step. Receiver SNR can be seen to increase one-for-one with increasing wanted signal level, until the LNA gain reduction is engaged. At this point the system noise figure is reduced but the linearity is improved. The input power at which the LNA gain step is used is governed by the need to maintain the minimum SNR.

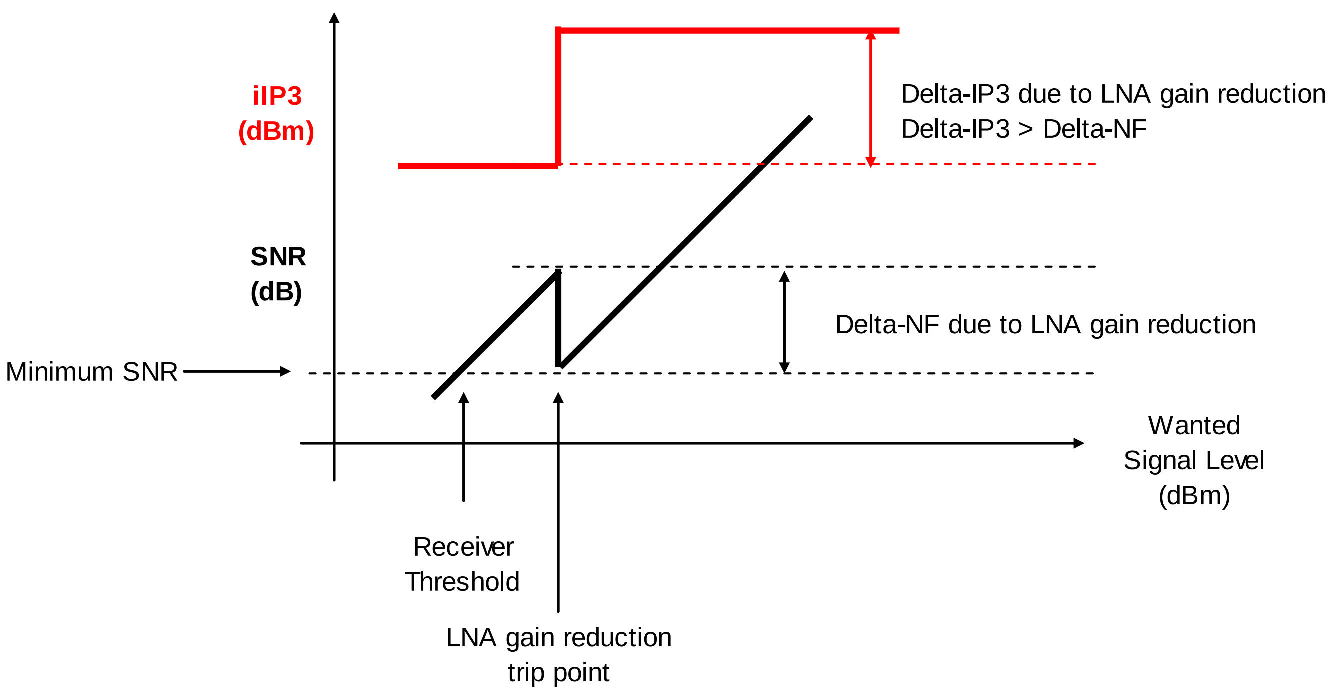


Figure 3: Receiver Dynamic Range Vs Wanted Signal Level

If the LNA gain threshold is set to low then there will be insufficient signal to noise when the LNA gain step is applied and so the receiver will experience noise or even signal loss. The LNA threshold should be set such that the increased noise figure of the LNA in it's off state should still allow the minimum signal SNR to be maintained. A level of margin should also be factored into this equation to allow for overall gain variation of the receiver and tolerance for the systems noise. The following equation can be used to help set the overall LNA threshold.

$$\text{LNA\_Threshold} = \text{Thermal Noise} + 10 \times \text{LOG(IFBW)} + \text{NF with LNA Off} + SNR_{MIN} + \text{Margin}$$

Setting the receiver gain and LNA thresholds in SDRPlay

In SDRplay the gain reduction numbers used within the API represent the total of the LNA, Mixer and BB gain reduction values. By summing all three together the gRdB value can be calculated for use with the API commands. For example in the 60MHz to 120MHz band the maximum gRdB value can be calculated as;

LNA GR	+	Mixer GR	+	BBGR	=	Total Gain Reduction
24	+	19	+	59	=	102dB of total gain reduction

The tables in Appendix A of the API specification show the default gain reduction tables used in each band. An extract from the 60MHz to 120MHz band table is shown below. It can be seen that the total gRdB value is the sum of the LNA, Mixer and BB gain reduction values. At the point in which the LNA gain reduction becomes engaged the input to the ADC would drop by 24dB and so to maintain a constant ADC set point the BB gain reduction must be adjusted by 24dB.

gRdB	Baseband Gain Reduction	LNA Gain Reduction	Mixer Gain Reduction
25	25	0	0
26	26	0	0
27	27	0	0
28	28	0	0
29	5	24	0
30	6	24	0
31	7	24	0
32	8	24	0
33	9	24	0

The threshold at which the LNA turns on can be altered using the API command *mir_sdr_SetGrParams*. Within this command is the *lnaGrThreshold* attribute. This attribute will define the total gRdB value at which the LNA should turn on. The IF gain reduction values will automatically be adjusted to account for the new threshold. In the example above if the *mir_sdr_SetGrParams* was used to adjust the LNA threshold to 32 the new AGC table would be amended to;

gRdB	Baseband Gain Reduction	LNA Gain Reduction	Mixer Gain Reduction
25	25	0	0
26	26	0	0
27	27	0	0
28	28	0	0
29	29	0	0
30	30	0	0
31	31	0	0
32	8	24	0
33	9	24	0

The mixer gain reduction point is not adjustable and is always used when the full range of IF and LNA gain reductions values have been used.

A Basic AGC Algorithm for SDRPlay

It is normal to start by defining a set point for the ADC input. The ADC set point is specified in dBfs (decibels relative to full scale) and will normally lie in the range 0dBfs (full scale) to -50dBfs (50dB below full scale). Additionally an operating window is also specified within which no further AGC updates will occur

The basic AGC algorithm works by measuring the average ADC input power and comparing this against the desired set point of the ADC. If the ADC power measurement shows the power to be 10dB higher than the set point then 10dB of total gain reduction would be applied to the receiver. The power would then be measured again and the process would continue until the ADC power sits within a defined operating window around the ADC Set point.

It is normal to program the gain reduction values in offset mode in this way it will not be necessary to maintain a record of the current gain reduction value as this will be done within the driver. By programming in this manner we are able to tell the receiver to reduce the current value by 10dB without knowledge of what the current gain value actually is.

Once we are sure the current gain reduction value has been applied then the power in further USB packets can be measured to check that the gain lies within a specified window.

Handling USB Latency for gain changes.

Due to the latency involved in USB transfers it is important to ensure that the gain updates have been applied to the receiver before making any additional changes to the gRdB value. Without doing this it is possible to make a series of gain changes before they have been transferred over the USB and applied to the receiver thus causing the AGC loop to become unstable. To help with this the *grChanged* integer is included within the *mir_sdr_ReadPacket*. This is an integer value which is used to indicate that the last gain transfer has been received and applied by the tuner. It is an indicator used to isolate the applied gain change to within a particular packet. This can then be used as an identifier for making ADC power measurements so that the AGC loop knows that all subsequent measurements should be made after that packet has been received. Similar indicator bits are also present for changes in RF frequency (rfChanged) and ADC sample frequency (fsChanged) and would be applied in a similar manner.

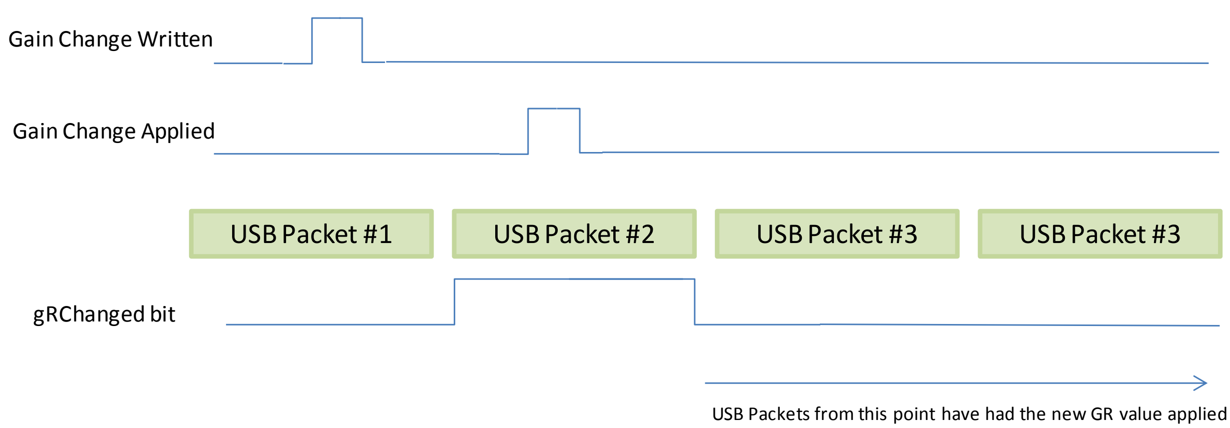
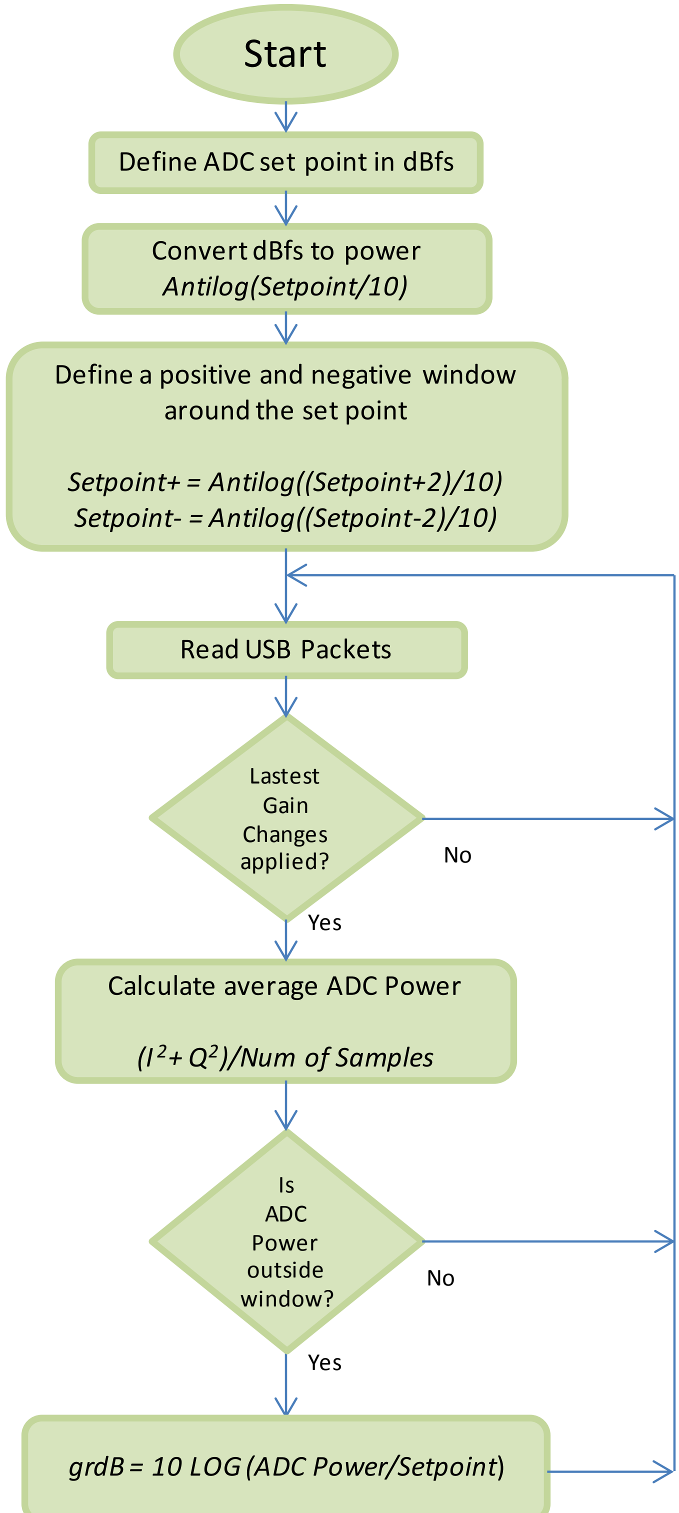


Figure 4: gRChanged bit showing applied gain changes taking effect.

Flowchart of the AGC Algorithm

The diagram below shows the flowchart for the basic AGC algorithm.



For more information contact support@sdrplay.com

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