Linear-in-dB Variable Gain Amplifier Provides True RMS Power Measurements

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A generally increasing demand for bandwidth, whether in cellular, broadband access, CATV, MMDS or LMDS applications, is drastically pushing the need for highly linear signal blocks. The tight channel spacing allocated by the FCC drives the need for strict power control and spectral grooming of all radiated emissions. Added frequency selectivity requirements are placed on the receiver stages, requiring adaptive transmitter and receiver designs to ensure that a minimum SNR is satisfied over all operating conditions. Automatic Gain Control (AGC) circuitry is used in receiver applications to scale the input signal to an optimum level prior to baseband detection or IF sampling.

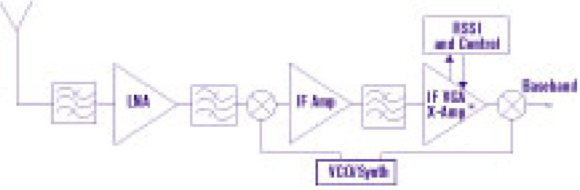

Figure 1. Variable Gain Amplifiers are used in receivers to present a constant signal amplitude to the baseband stage. A precise level from the VGA allows full use of the input range of the baseband ADC.

Figure 1 illustrates a typical heterodyne receiver using a variable gain amplifier to provide AGC to the baseband detection circuitry. The intermediate frequency (IF) to baseband frequency translation is most efficient when the input signal is scaled to an optimum level. In the case of an IF sampling receiver design, it is desirable to present an input signal level to the ADC that utilizes the full available resolution. Therefore, signal leveling is essential in high data rate receiver designs.

A Linear-in-dB Variable Gain Amplifier

Linear-in-dB scaled variable gain amplifiers, such as the AD8367, are designed for IF gain control applications. These devices use the advanced X-AMP(tm) architecture to deliver high-speed linear performance over a wide control range. They offer two gain control modes, providing positive and negative gain control slopes to facilitate both VGA and AGC circuit designs. The added functionality of an on-chip RMS detector allows for the implementation of a complete AGC subsystem in an integrated format.

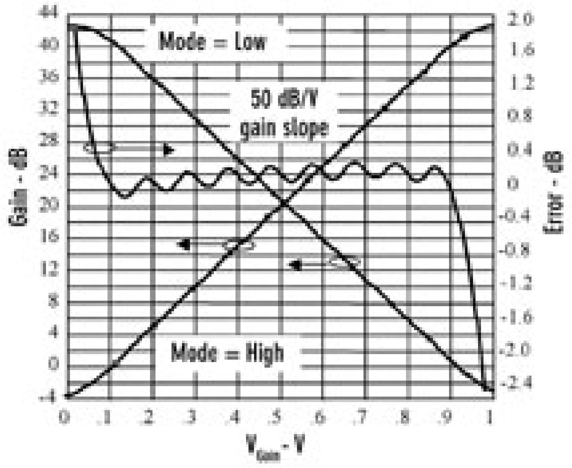

Figure 2. The relationship between gain and gain control voltage of an X-AMP VGA is linear-in-dB and stable over temperature, frequency and supply.

Figure 2 shows the gain control transfer function and gain law conformance of an X-AMP VGA in both gain-up and gain-down modes of operation. The linear-in-dB gain control is implemented using the patented X-AMP architecture. The X-AMP utilizes a resistive ladder network with variable transconductance cells to provide continuously adjustable variable gain. The interpolating nature of the X-AMP results in a minimum gain law conformance error over a broad frequency range. In this example the device provides a 45-dB gain control range with a gain slope of 50 dB/V. Using proprietary temperature compensation techniques, X-AMP VGAs exhibit a gain law that is essentially independent of supply and temperature.

A Logarithmic True RMS Detector

In addition to its use as a VGA, some variable gain amplifiers such as the AD8367 can also be used to measure IF signal strength. Figure 3 shows how to connect the AD8367 in AGC mode. The on-chip RMS detector measures the output signal strength, and compares this value to an internally set reference voltage using an error integrator. The integrator output appears as a current on the DETO pin. This current generates a voltage across the CAGC capacitor, which drives the GAIN pin. The applied VAGC voltage continuously adjusts the variable gain to ensure a constant 354 mVrms output at the VOUT pin regardless of input signal type.

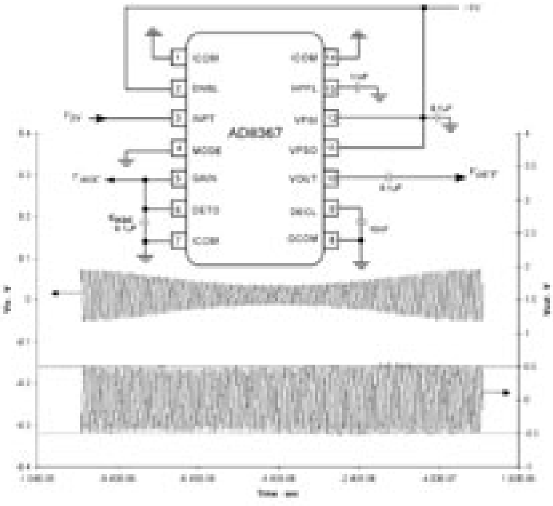

Figure 3. AGC application circuit with time domain waveforms embedded.

Because of the precise linear-in-dB gain-control relationship of the VGA, however, the resultant VAGC signal will be proportional to the log of the input RMS level and will, by definition, be independent of signal type. So while this circuit can be seen as an AGC circuit with built-in RSSI, it can also be utilized as a stand-alone RMS detecting log-amp.

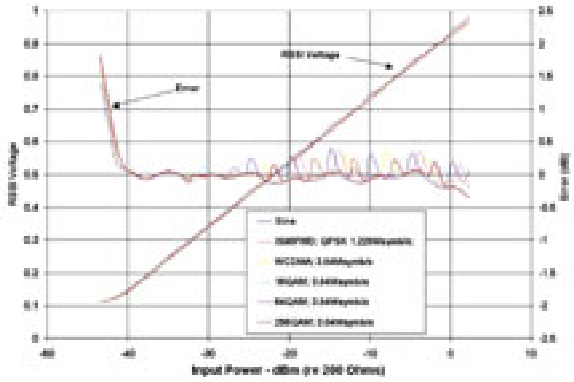

Figure 4. When connected in AGC mode, the AD8367's VAGC output provides a linear-in-dB RSSI output which is independent of input signal type.

Figure 4 shows the relationship between VAGC and a variety of complex waveforms at an IF of 70 MHz. Using the 70 MHz sine-wave as a reference, the measurement error can be compared for various modulation schemes. While the circuit provides -0.2/+0.4 dB of measurement uncertainty due to the interpolation error of the VGA, there is no perceptible change in the detected output voltage, as the input waveform switches between various complex modulation schemes. Over temperature the measurement accuracy is only slightly degraded, remaining within &#177 1 dB for a 45-dB measurement range from -40 to +85&#176C.
AGC circuits designed using X-AMP VGAs in conjunction with accurate power detectors can provide stable signal leveling as well as surprisingly accurate signal strength indication. The AD8367 is an example of an effective, plug and play, complete AGC circuit. Its linear-in-dB gain-control and accurate power-detector enable it to consistently scale signals to the optimal level. It correctly determines signal strength, even those with high peak to average ratios, over a wide band. Most importantly, its performance and ease of use reduces design time and effort. For more information visit http://www.analog.com.

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