Wideband AGC has 60-dB dynamic input range

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Automatic-gain-control (AGC) circuits serve in many applications to maintain signals at fixed levels. However, in applications such as digital-receiver circuits and back-channel modems, the function of the AGC often aims more at increasing dynamic input range through the controlled application of both gain and attenuation. In this type of application, the AGC is usually upstream of a high-speed ADC. The main function of the AGC is to keep the signal within the ADC's analog-input range, which is usually on the order of 1V p-p. The circuit in Figure 1 provides more than 60 dB of dynamic input range at 150 MHz. A novel feature of this design is that it uses no high-frequency rectifying diodes, which eliminates the nonideal characteristics associated with these diodes.

To understand how the circuit works, first look at the 50-kV potentiometer attached to the CLC501 clamping amplifier. The potentiometer places a reference signal on the noninverting input of the clamping amplifier. The CLC501 clamps at 1V and –3V via the voltage dividers attached to pins 4 and 8. The reference voltage, multiplied by the noninverting gain, routes to the integration capacitor, C_i, through the 10-kV resistor, R_I. The voltage developed on C_i goes to the gain-control input of a CLC522 high-bandwidth, variable-gain amplifier (VGA). You configure the VGA with a maximum voltage gain of about 20 dB by properly selecting the R_F and R_G resistors. This VGA has a gain-control input range of ±1V and a typical gain-control bandwidth of 165 MHz. Therefore, the selection of C_i is a compromise between providing sufficient filtering to suppress ripple on the gain-control input and keeping the R_I C_i time constant small. Unfiltered ripple modulates the signal passing through the VGA, so you must minimize the R_I C_i time constant to reduce attack and settling times.

As an IF carrier signal on the output of the VGA begins to exceed the reference level on the noninverting input, current begins to flow into the summing junction of the clamping amplifier. The clamping amplifier begins to produce an inverted signal to keep the summing junction at the reference level. Viewed on an oscilloscope, this signal appears as a negative-going half-wave signal riding on the dc output. As the VGA's input level increases, the amplitude of the half-wave restoring signal increases until it reaches the –3V clamp. The restoring signal then begins to square and pulse-width-modulate with further increases in input level until it attains 50% duty cycle.
A key requirement for the clamping amplifier is very fast overload recovery. The clamping amplifier used in this design has a typical recovery time of 1 nsec. The circuit maximizes the inverting gain of the clamping amplifier within the constraints set by the 150-MHz operating point and the control of third-order harmonic distortion that results from output-stage loading in the VGA. These constraints set practical limits on the values of the clamping amplifier's $R_F$ and $R_G$ resistors. To minimize the parts count, the design couples the AGC output into the 50V spectrum-analyzer input with a 453V coupling resistor. Although the VGA is capable of driving 50V loads, the combined load of the spectrum analyzer and the clamping amplifier's $R_G$ would result in increased third-order harmonic distortion. A better, although more costly, approach would be to isolate the VGA with a unity-gain follower, such as the CLC111.

The setup and operation of this circuit is straightforward. The setting of the potentiometer has two distinct effects on the circuit's performance: First, the potentiometer setting affects the AGC's output level. Second, the potentiometer setting affects the amount of compression applied to the input signal as it passes through the VGA. Increasing the voltage-reference level reduces signal compression, and output level and third-harmonic distortion increase as the VGA output stage becomes more heavily loaded. Reducing the reference voltage increases compression, and it reduces third-harmonic distortion at the expense of output level.

For the lowest distortion with high-level output capability, you should consider an additional drive amplifier. It is possible to add this drive amplifier between the VGA and the clamping amplifier. This configuration allows you to lower the compression threshold of the circuit and allow operation at increased output levels. Good choices for this amplifier would be the CLC449 or the CLC425. If you also used a unity-gain follower, distortion would decrease even further.

In a production design, you would normally replace the potentiometer with a precision voltage reference to increase temperature stability, improve reliability, and reduce manufacturing effort and cost.

The circuit provides 60 dB of dynamic input range, ranging from a 80-mV reference (13 dB above the noise floor) to 80 mV. Harmonic distortion is –45 dBc with 5 dB of compression set at the maximum 80-mV input level. Noise at the output is approximately 45 nV/√Hz. The AGC fully settles in 1 to 2 msec from a zero to full-scale input transition. Because second-harmonic distortion increases with VGA input-stage drive, greater dynamic input range is available with a corresponding increase in distortion as the input level increases from 80 to 320 mV. At maximum compression, as the input level is increased, the rise of harmonic distortion ultimately limits the dynamic input range. Conversely, when the AGC is at maximum gain, as the input level decreases, the noise floor ultimately limits the dynamic input range.

Within the noise and distortion limits of the VGA, the AGC loop is set up to provide both signal amplification and compression to maintain the output signal within the specified limits. If you need lower second-harmonic distortion, consider lowering the maximum AGC input level at the expense of dynamic input range.

You can configure this design to operate from audio to 150 MHz. At lower frequencies, you must increase $C_I$ to lower the filter section's corner frequency. When operating at lower bandwidth, you can reconfigure the circuit for reduced distortion. In general, a reduction in the current flowing through the VGA's $R_G$ resistor reduces second-harmonic distortion. You can reduce the current by increasing $R_F$ or $R_G$, or both. An increase in $R_F$ results in a reduction in bandwidth and an increase in gain. With higher gain, the circuit needs less input drive to reach the reference-output level. Additionally, an increase in $R_G$ directly reduces the current flowing through the resistor but at the cost of gain. If you increase only $R_G$, the circuit will need a higher input-drive level to reach the
reference-output level, which will increase the distortion back to the original levels. Increasing both 
$R_f$ and $R_c$ results in the lowest distortion. (DI #1933)