TRUE RMS MEASUREMENT USING THE AD531

by Lew Counts

To determine the RMS value of a stationary waveform, most low-cost (and a few expensive) "RMS" meters simply measure the average of the absolute value of the input, using a full-wave rectifier, then multiply it by 1.111, the ratio of RMS: Average for sine waves. Though valid for undistorted sine waves, this approach leads to substantial errors with random noise, triangular waves, or square waves (but they may be calibrated), and to even worse errors with arbitrary waveforms, for which no calibration is possible. For a train of zero-based square pulses, the error is proportional to $\sqrt{(\text{duty cycle})}$ – (duty cycle). Figure 1 shows the error as a function of firing angle for an SCR circuit.

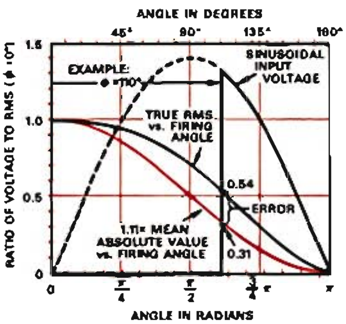

Figure 1. RMS and Mean Value of Ideal Full-Wave SCR Output as a Function of Firing Angle ϕ

A *better way* is to use a true-RMS circuit. A simple low-cost implementation, involving the AD531K* (a monolithic IC multiplier/divider: XY/I), two AD741 op amps, and a few miscellaneous components, is shown in Figure 2. It is a feedback loop, embodying the implicit relationship, $\overline{V_{in}^2/E_{out}} = E_{out}$, whence $E_{out} = \sqrt{\overline{V_{in}^2}}$, if RC is a sufficiently-long time constant.

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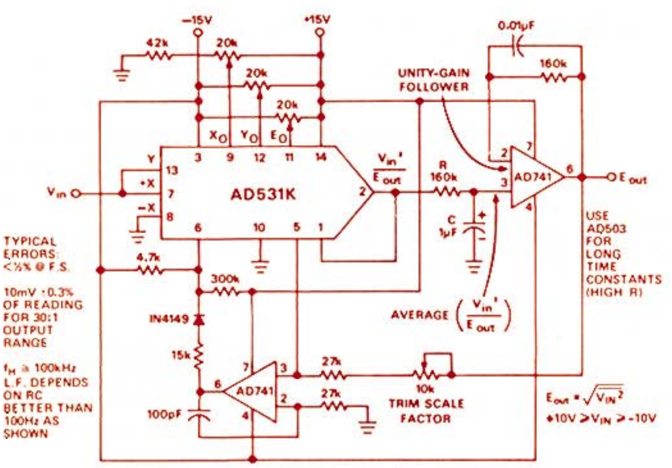

Figure 2. True-RMS-to-DC Converter Using AD531

*For complete information on the AD531, use the reply card. Request J12.

30dB AUTOMATIC GAIN CONTROL WITH THE AD531

The circuit of Figure 1 will maintain 3V peak-to-peak output for inputs ranging from 0.1Vp-p to more than 12Vp-p, with better than 2% regulation from 0.4Vp-p to 6Vp-p, and distortion well below 1%. Input frequency can range from 30Hz to 400kHz (-3dB). The level is adjustable either manually or by an external dc reference voltage. The input signal can be either single-ended or differential.

The feedback circuit works in a straightforward manner: if the input signal increases, the output will tend to increase. Its negative peaks, as recognized by the diode and stored on the 1µF capacitor, tend to increase, causing the output of the inverting integrator to increase. This, in turn, causes the denominator to increase, reducing the gain of the AD531 multiplier/divider (XY/I), and tending to keep the output level constant.

In the steady state, the average voltage at point A must be ideally equal to one-half the voltage at point B, but of opposite polarity, making the net input to the integrator equal to zero, and holding the output of the integrator at whatever constant level is necessary to keep the loop in balance. In that state, the negative peak value of E_{out} is approximately one diode drop below V_A, so

$$|E_{out}\ (\text{peak})| \cong \tfrac{1}{2}V_B + \text{diode drop}$$

In practice, the *set level* potentiometer would be adjusted empirically to calibrate the output at the desired level.

In the simple practical example given here, to illustrate the principle, an unembellished half-wave diode-and-capacitor circuit reads the peak level of the waveform. Naturally, other properties of the waveform, such as mean absolute value or RMS might be used as a measure; also, somewhat more sophisticated temperature-compensated rectification circuitry might be used.

The control voltage (V_C) at the output of the amplifier ranges from about -2V (lowest AD531 gain) to the amplifier's lower limit, -13.5V (to handle the smallest input signals). Linearity of V_C is not important, since it is a manipulated variable inside the loop.

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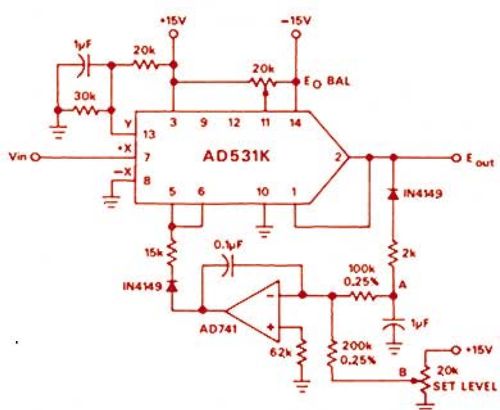

Figure 1. Automatic Gain Control Using the AD531 Has ~30dB Dynamic Range of Input