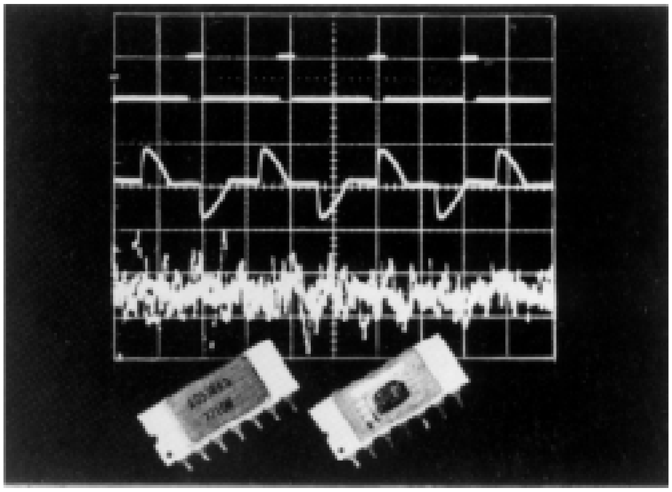
MONOLITHIC IC RMS-TO-DC CONVERTER

AD536K Laser-Trimmed to 0.2% Max Error; Needs No User Adjustment Operates on Single or Dual Supply; dB and Linear Outputs Provided

by Lew Counts, Barrie Gilbert, and Dave Kress



The AD536 is the industry's first monolithic rms-to-dc converter. It permits the true-rms value of complex wideband ac and dc signals to be measured with errors less than 0.2% of reading ±2mV without external trim circuits. Its bandwidth, for signals greater than 0.1V rms, is 20kHz, for the above accuracy, and 100kHz for -3dB.

Computing the true rms value of a waveform gives an exact measure of the power in the signal, regardless of the wave shape. (Rectified average, which has been used extensively in multimeter instruments, is an accurate measure only for sine waves, but shows errors of 10% or greater for most other waveforms.) The photograph shows three types of waveform for which accurate results are obtainable with the AD536. It can readily handle signals with crest factors as great as 10; at crest factor of 6 (pulse duty-cycle of 1:36), error is increased by only 1% of reading.

In addition to the linear output, a dB output, having a 60dB dynamic range, is available; it is especially useful in audio applications, and in acoustic noise measurements. Using an externally supplied reference current, the user can set the 0dB level at any convenient value from 0.1V to 2.0V.

The 536 is a low-power device, drawing only 1mA at any supply voltage in its rated span of 5V to 36V (±3V to ±18V, with bipolar supplies); this is a useful feature for battery powered applications, and – with the small size – for portable instruments.

The AD536 is packaged in a 14-pin hermetically sealed dual in-line ceramic DIP. It is available in two 0° to 70° versions, the AD536J, with maximum pretrimmed error of 0.5% ±5mV, and the AD536K, with maximum error of 0.2% ±2mV. Prices are $15 and $26.50 (1-24), and $9.95 and $18.50 in 100's.

The accuracy and low price of the AD536 result directly from a unique, automatic laser-trimming process in which all AD536 chips are trimmed, *at the wafer level,*[1] for input-and-output offsets, positive-and-negative waveform symmetry, and full-scale accuracy. As a result, no external trimming is required (unless even-better performance – by up to a factor of two – is desired).

As Figure 1 shows, the only external component needed for rms measurement is an averaging capacitor, to set the averaging period, and thus to establish the low-frequency accuracy and ripple level, as well as the response speed and settling time. Use of the internal buffer amplifier and external passive elements to add one or two poles of active filtering can improve settling times at least tenfold without increased ripple. Information for filter design can be found on the data sheet and in *Dialogue* 9-3 (page 21).

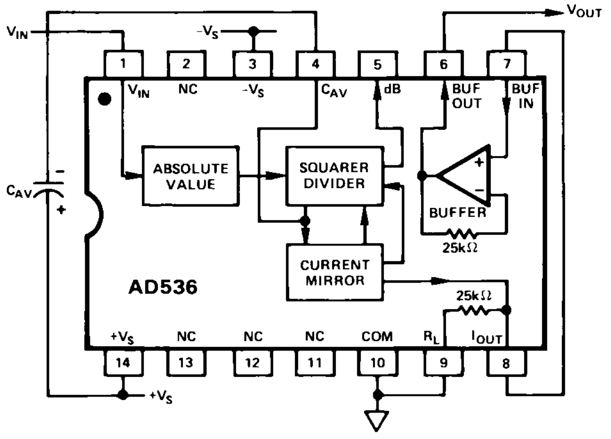


Figure 1. Standard connection for rms-to-dc conversion.

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[1] See "Laser-Trimming IC's on the Wafer", DIALOGUE 9-3, 1975.

HOW IT WORKS[2]

The AD536 computes the root-mean-square relationship:

$$V_{rms} = \sqrt{\overline{V_{IN}^2}} \qquad (1)$$

where V_{rms} is a voltage, and $\overline{V_{IN}^2}$ is the average of the squared instantaneous values of the input voltage over a nominal period.

It does so by performing the implicit computation,

$$V_{rms} = \frac{\overline{V_{IN}^2}}{V_{rms}} \cong \overline{\left[\frac{V_{IN}^2}{V_{rms}}\right]} \qquad (2)$$

The approximation indicated in (2) can be considered exact if the averaging time is sufficiently long for V_{rms} to be essentially constant for the range of periods that is of interest.

Figure 2 is a simplified schematic of the AD536. In the AD536, the computations indicated in (2) are performed with currents. The four basic sections of the device are an input absolute-value voltage-to-current converter, a one-quadrant squarer-divider core, a current-mirror, and buffer-follower.

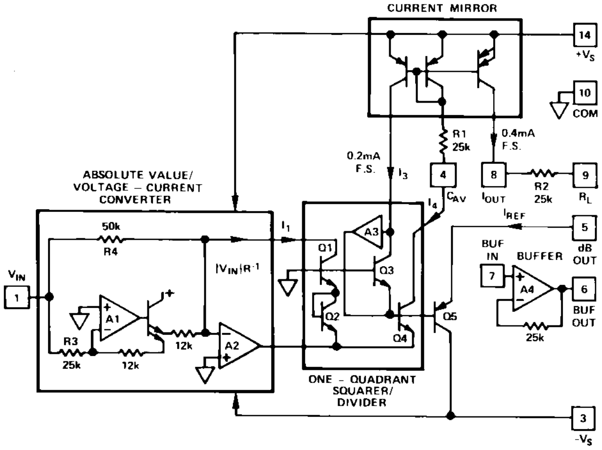

Figure 2. Simplified schematic.

The input stage takes the absolute value of the input signal (i.e., *rectifies* it) and converts it to a current, I_1, which is applied to the squaring input of the squarer-divider. The output current, I_4, drives the current mirror through a low-pass filter, formed by R1 and C_{AV}. If R_1C_{AV} is a long time, compared to the longest period of the input signal, the current entering the current-mirror is $\overline{I_4}$. An identical current, I_3, is returned to the division input, to compute the quantity, $I_4 = I_1{}^2/I_3$. Since I_3 is equal to the average value of I_4, it is also equal to the desired value of output current.

The current mirror produces another identical current, I_{OUT}, which is thus a current corresponding to the rms value of input voltage. It can be either used as a current or converted to a voltage by R2, which can then be unloaded by the buffer follower.

The dB output is derived from the emitter of Q3, since the voltage at this point is proportional to -log V_{IN}. Emitter follower, Q5, buffers and level-shifts this voltage, so that the dB output voltage is zero when the external current, I_{REF}, applied to the emitter of Q5, is approximately equal to I_3.

APPLICATIONS

Besides its obvious applicability to a wide variety of physical measurement, such as noise and vibration, the low cost and small space required by the AD536 (due to both its small size and the fact that it's so complete that it needs very little auxiliary circuitry) permit OEM designers of instruments, apparatus, and systems to add measurement options at lower cost than ever before.

Since many audio signal-handling circuits utilize single supplies and ac coupling, the single-supply connection is one which will prove popular. Figure 3 shows a way of accomplishing operation with a single 5V supply – with the AD2026* low-cost digital panel meter – to build what must needs be the world's lowest-cost high-accuracy rms digital meter.

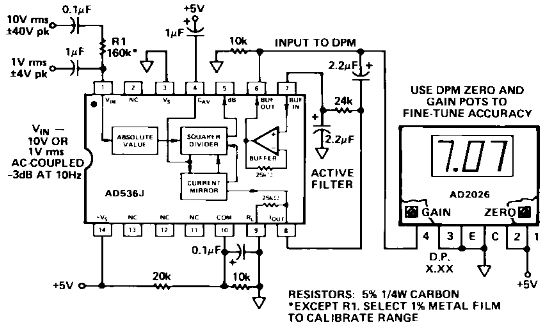

Figure 3. Low-cost true-rms DPM, using AD536 and AD2026 Panel Meter, and single 5V supply, for true rms ±1 digit ±0.5% of reading.

The input common, at pin 10, is biased off ground; it is critical that no extraneous signals be coupled into this point. The input is coupled via a capacitor; and the dc return is via the internal amplifier circuits. The input high-pass time constant is determined by the coupling capacitance and the 16.7kΩ input resistance; the values shown in the diagram are for 10Hz cutoff. Signal range is 0 to ±4V peak, 0.999V rms. The external 10kΩ load provides a path for sink current.

Decibel measurements will also be popular. Figure 4 shows a scheme for building an analog dB-meter with linear dB readout, using a single supply, such as a 9V battery. The AD580* precision 2.5V reference provides a regulated voltage to the zero-dB set potentiometer, R1, and also a current for biasing pin 10 off ground via the 2.2kΩ resistor.

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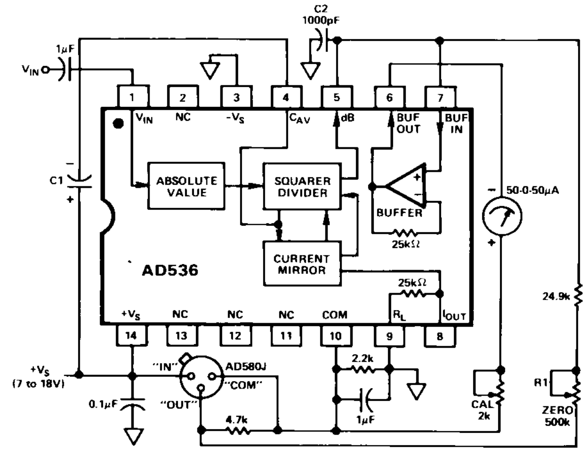

Figure 4. Single-supply rms-dB meter using the AD536.

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[2] The reader who is unfamiliar with rms circuits will find much useful information about rms measurements (and other nonlinear devices, such as multipliers, dividers, logs, etc.) in the 536-page *Nonlinear Circuits Handbook*, available from Analog Devices, Inc., P.O. Box 796, Norwood MA 02062, for only $5.95 (Check or Master Charge).