RMS-to-DC Converters

The root mean square (rms) is a fundamental measurement of the magnitude of an ac signal. Defined practically, the rms value assigned to the ac signal is the amount of dc required to produce an equivalent amount of heat in the same load. Defined mathematically, the rms value of a voltage is defined as the value obtained by squaring the signal, taking the average, and then taking the square root. The averaging time must be sufficiently long to allow filtering at the lowest frequencies of operation desired. We will show a few examples of how efficiently analog circuits can perform this function. More details of rms-to-dc converters can be found in Reference 1.

The first method, called the *explicit* method, is shown in Figure 1. The input signal is first squared by an analog multiplier. The average value is then taken by using an appropriate filter, and the square root is taken using an op amp with a second squarer in the feedback loop. This circuit has limited dynamic range because the stages following the squarer must try to deal with a signal that varies enormously in amplitude. This restricts this method to inputs which have a maximum dynamic range of approximately 10:1 (20 dB). However, excellent bandwidth (greater than 100 MHz) can be achieved with high accuracy if a multiplier such as the AD834 is used as a building block (see Figure 2).

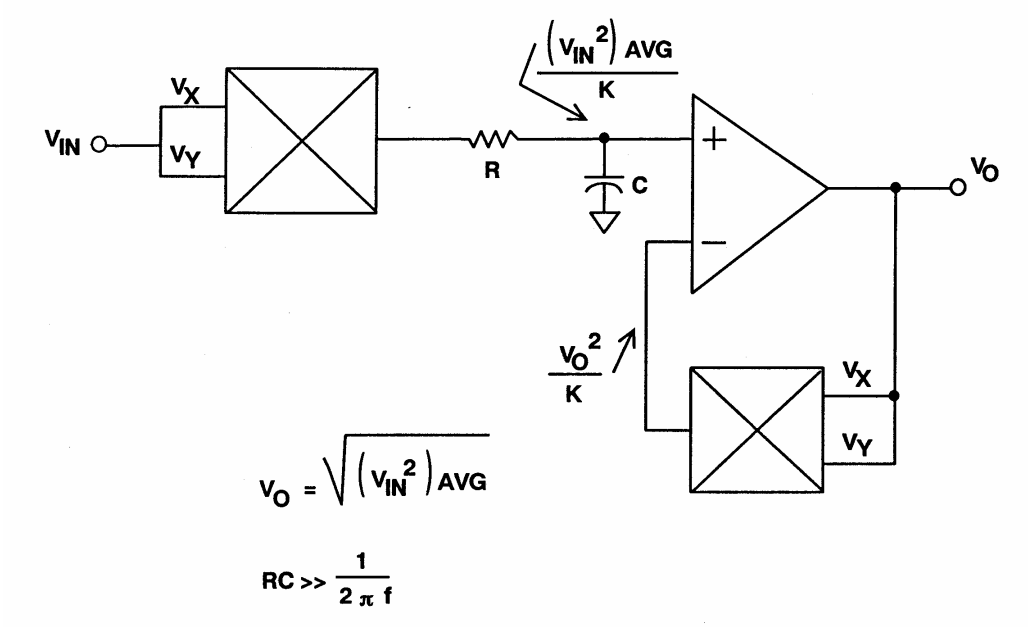

Figure 1: Explicit RMS Computation

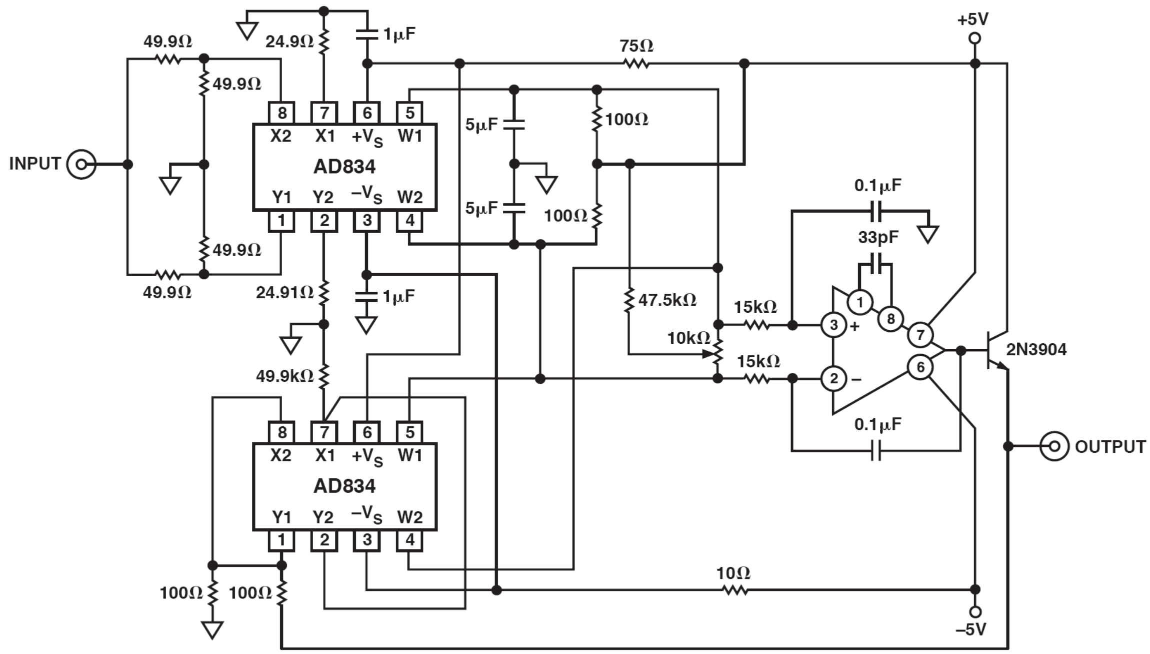

Figure 2: Wideband RMS Measurement with the AD834 Analog Multiplier

Figure 3 shows the circuit for computing the rms value of a signal using the *implicit* method. Here, the output is fed back to the direct-divide input of a multiplier such as the AD734. In this circuit, the output of the multiplier varies linearly (instead of as the square) with the rms value of the input. This considerably increases the dynamic range of the implicit circuit as compared to the explicit circuit. The V_{IN}^2/V_Z circuit may be current driven and need only be one quadrant if the input first passes through an absolute value circuit. The disadvantage of the implicit rms-to-dc approach is that it generally has less bandwidth than the explicit computation.

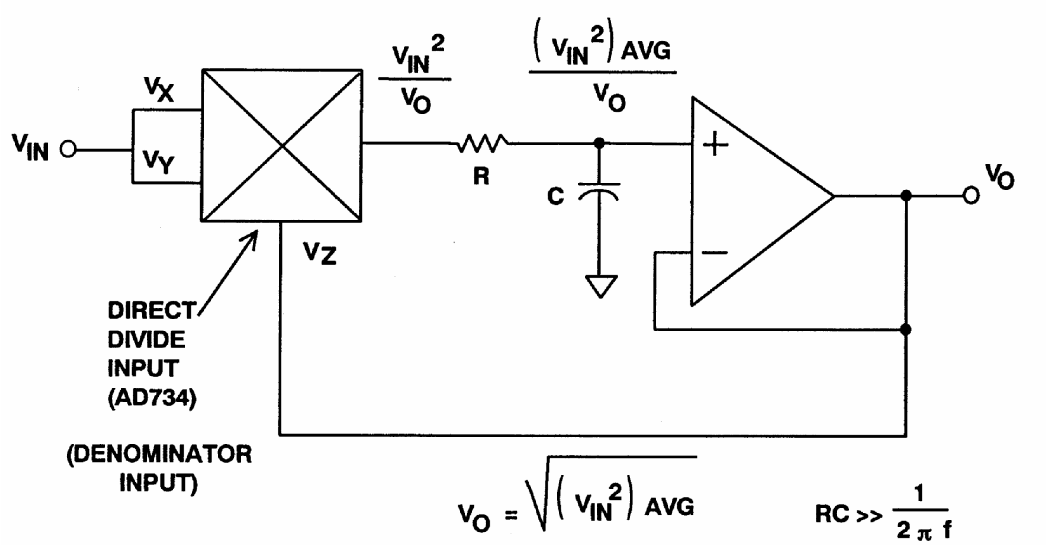

Figure 3: Implicit RMS Computation

While it is possible to construct such an rms circuit from an AD734 analog multiplier, it is far simpler to use a dedicated rms-to-dc circuit. Figure 4 shows a simplified diagram of a typical monolithic rms-to-dc converter, the AD536A.

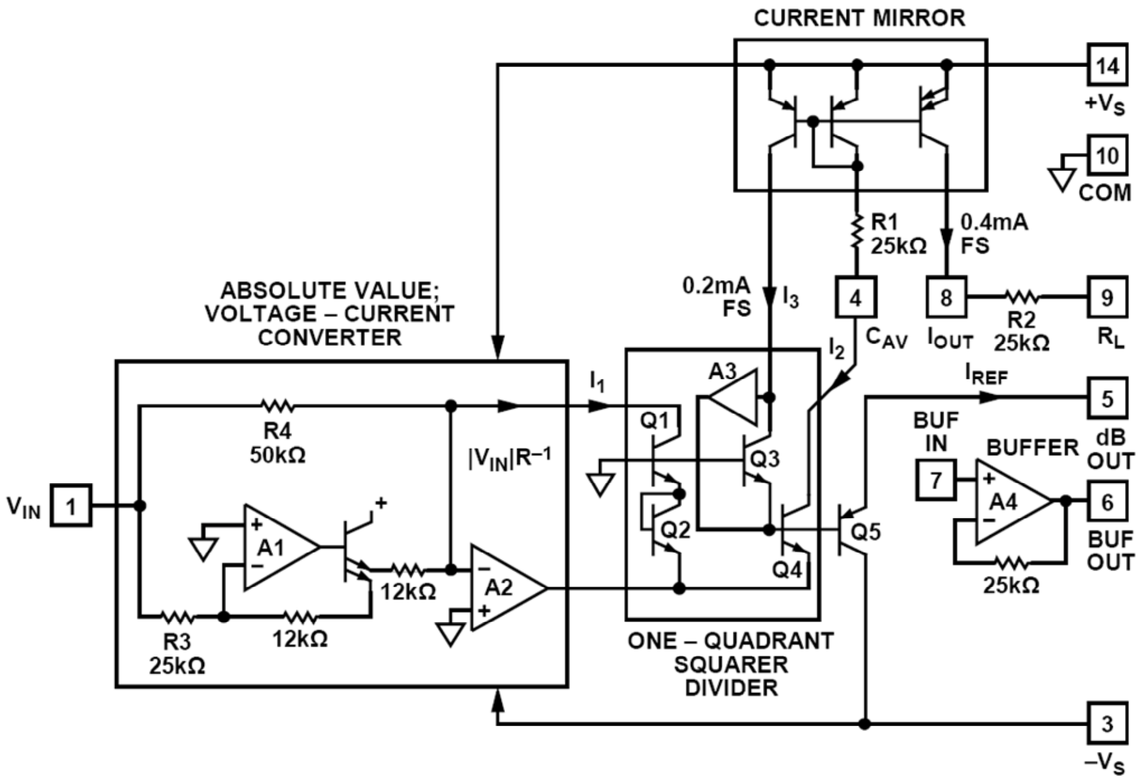

Figure 4: The AD536A Monolithic RMS-to-DC Converter

It is subdivided into four major sections: absolute value circuit (active rectifier), squarer/divider, current mirror, and buffer amplifier. The input voltage V_{IN}, which can be ac or dc, is converted to a unipolar current, I_1, by the absolute value circuit A_1, A_2. I_1 drives one input of the one-quadrant squarer/divider which has the transfer function: $I_4 = I_1^2/I_3$. The output current, I_4, of the squarer/divider drives the current mirror through a lowpass filter formed by R1 and externally connected capacitor, C_{AV}. If the $R1C_{AV}$ time constant is much greater than the longest period of the input signal, then I_4 is effectively averaged. The current mirror returns a current, I_3, which equals AVG[I_4], back to the squarer/divider to complete the implicit rms computation. Thus:

$$I_4 = AVG\,[I_1^2/I_4] = I_1\ rms \qquad \text{Eq. 1}$$

The current mirror also produces the output current, I_{out} , which equals $2I_4$. I_{out} can be used directly or converted to a voltage with R2 and buffered by A4 to provide a low impedance voltage output. The transfer function becomes:

$$V_{out} = 2R2 \bullet I_{rms} = V_{IN}\ rms \qquad \text{Eq. 2}$$

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 externally supplied emitter current (I_{REF}) to Q5 approximates I_3. However, the gain of the dB circuit has a TC of approximately 3300 ppm/°C and must be temperature compensated.

There are a number of commercially available rms-to-dc converters in monolithic form which make use of these principles. The AD536A is a true rms-to-dc converter with a bandwidth of approximately 450 kHz for V_{rms} > 100 mV rms, and 2 MHz bandwidth for V_{rms} > 1 V rms. The AD636 is designed to provide 1 MHz bandwidth for low-level signals up to 200 mV rms. The AD637 has a 600 kHz bandwidth for 100 mV rms signals, and an 800 MHz bandwidth for 1 V rms signals. Low cost, general purpose rms-to-dc converters such as the AD736 and AD737 (power-down option) are also available.

REFERENCE:

1. Charles Kitchen and Lew Counts, *RMS-to-DC Conversion Application Guide, Second Edition,* Analog Devices, Inc., 1986.

2. Hank Zumbahlen, *Basic Linear Design*, Analog Devices, 2006, ISBN: 0-915550-28-1. Also available as *Linear Circuit Design Handbook*, Elsevier-Newnes, 2008, ISBN-10: 0750687037, ISBN-13: 978-0750687034. Chapter 2.