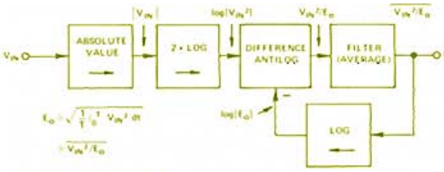
LOW-COST RMS-MEASURING CIRCUIT

MODEL 440 HAS LESS THAN 2mV ±0.05% ERROR, COSTS $42. IN 100'S

The Analog Devices Model 440* is a "true-rms" to dc converter designed for applications in instrumentation, measurement, and data acquisition, wherever stationary waveforms of unknown or arbitrary shape are encountered. The process of computing the root mean-square (rms) involves squaring the positive or negative input signal, averaging it to obtain the mean-square, and square-rooting to obtain the *root mean-square*. The Model 440 performs these operations in a feedback configuration, using logarithmic circuitry for squaring and rooting.



WHY RMS?

There are a number of solid reasons for measuring rms, rather than some other property of a waveform, based on its physical and mathematical properties.

The rms is a fundamental physical measurement: it is a measure of the heating value of a voltage or current applied to a resistor. Over the averaging interval, all waveforms having the same rms voltage or current will dissipate exactly the same amount of energy in the resistor, irrespective of the variation with time. This is true whether the waveform is constant (dc), sinusoidal, biased-ac, random, or a train of pulses.

The rms is a fundamental statistical parameter: for any stationary (unchanging general shape) zero-mean (e.g., ac-coupled) process, the rms is equal to the standard deviation of that process. Whether the distribution measured by the electrical waveform involves electrical random noise or the size of apples on a conveyor belt, the rms is a valid measure of the standard deviation, for large sample size.

The rms permits combination of uncorrelated quantities: If orthogonal or uncorrelated quantities are summed, the rms of their sum is equal to the square-root of the sum of the squares of their individual rms values.

RMS vs. MAD (MEAN-ABSOLUTE DEVIATION)

Low-cost rms meters (and, sadly, some expensive meters) have, in the past, been likely to read a calibrated version of the average of the absolute deviation (i.e., the full-wave rectified signal), rather than rms. Since the most popular ac waveform has been the sine-wave, the mad has been multiplied by 1.111 to read true rms. Unfortunately, this calibration constant can differ widely from waveform to waveform (see table); while it can be preset for known waveforms, this is out of the question for unknown or variable-duty-cycle waveforms, such as SCR's (silicon controlled-rectifier) and variable-width pulse trains.

TECHNIQUES

While many techniques are available to the computer-minded experimenter, the two in widest use are thermal converters and computing types using feedback, such as the 440. While the former have very wide bandwidth (at the high end) and are capable of excellent accuracy, they involve significant dissipations and temperature rise, cannot average slowly-varying waveforms very well, and may require op-amp buffers that will degrade performance. Computing types, on the other hand, are quite flexible; by the use of additional capacitance, for example, the 440 can accurately (1%) convert rms to dc over bands from 100kHz (-3dB @ 500kHz) down to 1Hz (10μF connected externally).

With offset drift of ±0.2mV/°C maximum and "accuracy" drift of ±0.02%/°C maximum, reasonable accuracy is maintained over the whole 0° to 70°C temperature range. Besides low cost, wide bandwidth, good accuracy, and flexibility, the 440 also boasts small size (1.5" x 1.5" x 0.41", 38x38x10.4mm) and light weight (40g). Available from stock, it's priced at $62 (1-9), 440J, and $75, 440K.

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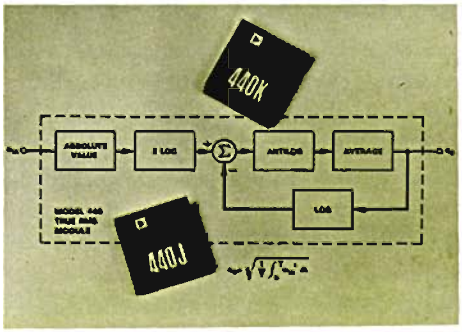
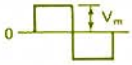
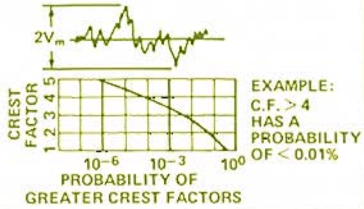
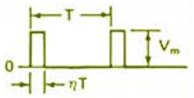
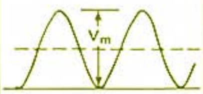


RELATIONSHIPS BETWEEN RMS AND OTHER PARAMETERS OF SEVERAL COMMON WAVEFORMS

WAVEFORM	CREST FACTOR V_M/RMS	$\frac{\text{RMS}}{\text{MAD}}$
SINE WAVE 	$\sqrt{2}$ 1.414	$\frac{\pi}{2\sqrt{2}}$ 1.111
SYMMETRICAL SQUARE WAVE 	1	1.00
TRIANGULAR WAVE OR SAWTOOTH 	$\sqrt{3}$ 1.732	$\frac{2}{\sqrt{3}}$ 1.155
GAUSSIAN NOISE 		$\sqrt{\frac{\pi}{2}}$ 1.253
PULSE TRAIN 	$\frac{1}{\sqrt{\eta}}$ η : C.F. 1 : 1 1/4 : 2 1/16 : 4 1/64 : 8 1/100 : 10	$\frac{1}{\sqrt{\eta}}$ 1 2 4 8 10
SINE-SQUARED 	$\sqrt{8/3}$ 1.633	1.225

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*For information on the Model 440, request L8.