

# APPENDIX A

## TESTING THE CRITICAL PARAMETERS OF RMS CONVERTERS

### Introduction

RMS converters share many basic characteristics with precision rectifier circuits; therefore, most of their testing is similar in nature. However, there are two basic parameters of rms converters that must be evaluated differently; one is additional error versus crest factor which is usually not tested at all in precision rectifier circuits. The other parameter is ac accuracy vs. bandwidth, which may be specified for 1% additional error or for a  $\pm 3\text{dB}$  change.

Adequate performance in both of these parameters is important to insure that the rms converter can properly compute the rms value of an incoming pulse or other waveform containing significant harmonic content. This also insures that both the rise time and slew rate of the converter are sufficiently fast to avoid rolling off the edges of incoming pulse trains.

The following sections in this appendix give detailed examples of the practical test setups and procedures necessary to properly evaluate the performance of an rms converter.

### Testing Accuracy vs. Crest Factor

One of the critical parameters that defines an rms converter's performance is its accuracy as a function of the crest factor of its input waveform (see Section 1). Since average-responding devices such as precision rectifiers have considerable errors when measuring nonsinewave input signals, this parameter applies only to *true* rms converters.

Figure 63 shows a test setup for measuring accuracy versus crest factor. A function generator or pulse generator is followed by an rms-AGC amplifier (see Figure 39) whose output is a constant rms voltage. This circuit greatly simplifies the task of maintaining a constant rms output while varying the function generator duty cycle to obtain the various crest factors needed to test the rms converter. Because of the different measuring methods of the two pieces of test equipment, the true rms meter monitors the *rms* level of the input waveform supplied to the rms converter while the oscilloscope connected to the same point gives a visual display of the *peak* amplitude of the

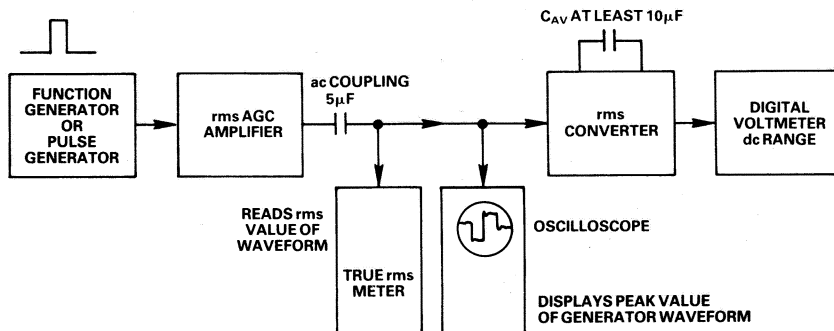


Figure 63. A Crest Factor Test Setup

waveform. The crest factor of the input waveform can then be found by dividing its peak value by its rms value.

$$\text{Crest Factor} = \frac{\text{Peak voltage (from oscilloscope)}}{\text{RMS voltage (from true rms meter)}}$$

The digital voltmeter monitors the output of the rms converter. The difference between the readings of the rms meter and the digital voltmeter will equal the error of the rms converter. The error in percent of reading is equal to this voltage divided by the true rms voltage times 100%.

$$\text{Error \% of Reading} = \frac{\text{Error voltage}}{\text{True rms voltage}} \times 100\%$$

### Testing ac Accuracy (or Bandwidth vs. Input Level)

Two basic methods for testing the ac accuracy of rms converters are commonly used. The first method maintains accuracy by using a true rms meter to monitor the level of a sinewave oscillator which feeds the input of the rms converter under test (Figure 64). The true rms meter **MUST** have an accuracy greater than that of the rms converter being tested. A digital voltmeter measures the dc output of the rms converter. The voltage reading of the true rms meter is then compared to that of the digital voltmeter. Accuracy is specified as a percent of reading error. AC coupling of the sinewave oscillator output is used to prevent any dc offset that may be present at the output from being measured by the rms converter.

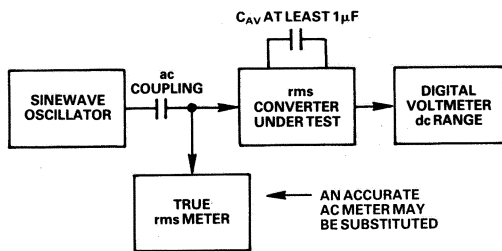


Figure 64. Testing ac Accuracy

A second and more accurate method for measuring ac accuracy involves the use of a precision ac voltage standard to replace the sinewave oscillator and true rms meter of the previous method (see Figure 65). This is easier to use, since the desired test voltage may simply be dialed in (the first method required a careful adjustment of the oscillator output level for each change in test voltage). However, an unfortunate disadvantage of this method is the relatively high cost of a precision ac voltage standard.

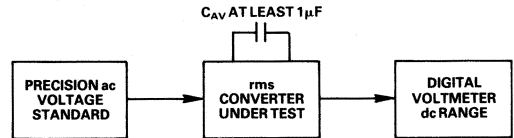


Figure 65. Testing ac Accuracy – Alternate Method

### Testing dc Conversion Accuracy

The method shown in Figure 66 can be used for testing the various dc parameters of rms converters. This scheme utilizes a stable dc voltage source (which could be a bipolar 12-bit DAC), a temperature-stable precision inverter and a digital voltmeter set to its dc range. This configuration, by virtue of its excellent common-mode rejection, allows error measurements to be taken directly, without computation. Note that this setup may be easily automated for operation via a computer, thus allowing the quick and accurate in-house testing of rms converters.

The dc conversion accuracy is specified as a maximum percent of input voltage plus or minus a fixed offset in millivolts. The dc reversal error of an rms converter is defined as the difference in output voltage that occurs when first a positive and then a negative input voltage, of the same level, is applied to the input of the converter. This error occurs because the absolute value section has a slightly different scale factor for plus and minus inputs. DC reversal error is specified as a percent of input level.

### Testing dc and ac Linearity

The test setup of Figure 66 can be used for testing ac or dc linearity of an rms converter over its full range of input amplitudes.

To test dc linearity, several dc voltages should be applied to the input of the device under test; these voltages should span the nominal input voltage range of the converter. Several readings should be taken over this range; the error for each input voltage can be read directly and then converted into a percent of full-scale value. Typical input voltages range from  $\pm 1\text{mV}$  to  $\pm 10$  volts for the AD536A and AD637 and  $\pm 1\text{mV}$  to  $\pm 300\text{mV}$  for the AD636. For low level dc testing, an accurate 1/100th voltage attenuator is required, unless a very high resolution bipolar dc source is available.

When measuring ac linearity, a precision ac sinewave voltage source, many times more accurate than the rms converter itself, must be used; this replaces the dc source shown in the figure. Measurements are

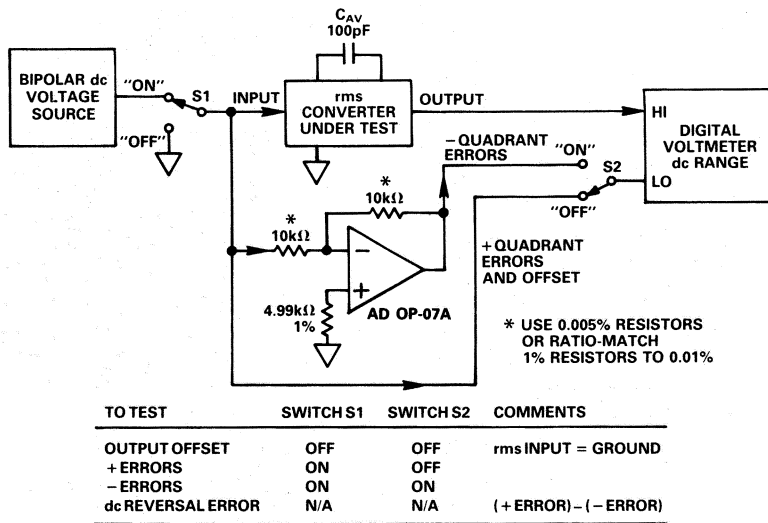


Figure 66. Testing dc Conversion Accuracy

taken by varying ac input levels while keeping the input frequency constant. Normally, an input frequency of 1kHz is used. This frequency is deliberately chosen to be fairly low in order to eliminate any high frequency rolloff which might be introduced by the rms converter at very low input levels.

## USE OF CROSSPLOTS TO SPEED TESTING OF RMS CONVERTERS

### Introduction

The use of an X-Y or crossplot display method (showing  $V_{IN}$  vs.  $V_{OUT}$ ) using an oscilloscope is a very useful tool for evaluating the performance of precision rectifiers and the offset and linearity of rms converters. The X-Y pattern gives, at a glance, a visual display of input offset, output offset, scale fac-

tor, and linearity of a rectifier circuit. Parasitic oscillations and other elusive problems frequently undetected by automatic test equipment are very noticeable using this method.

### Setting Up the Crossplot Test System

A crossplot test system can be easily set up using ordinary laboratory test equipment. This equipment should consist of a sine-wave oscillator or function generator, an accurate input attenuator (or an oscillator incorporating a precision attenuator), and an oscilloscope with a differential input preamplifier. If possible, the oscilloscope should use a Tektronix 7A22 or similar type variable bandwidth preamplifier to filter any stray noise pickup at low input voltages.

Figure 67 illustrates the correct method for intercon-

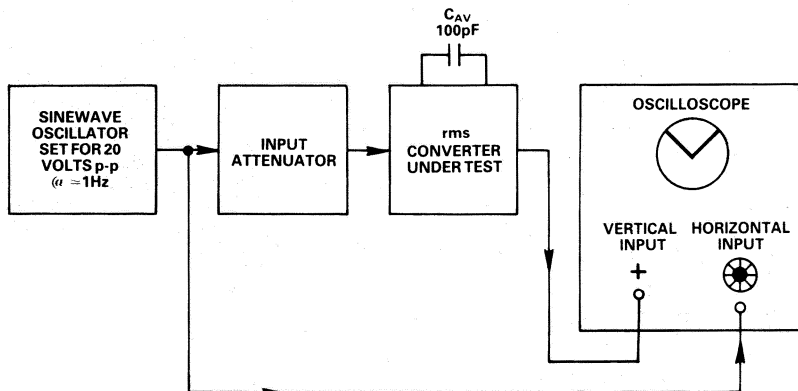


Figure 67. A Crossplot Test System

necting the test equipment for a crossplot test setup. The sine-wave oscillator output connects to the rms converter's input as well as the oscilloscope's vertical and horizontal input jacks. The output from the rms converter connects to the oscilloscope's positive vertical input jack. This setup will measure the slope of the rms converter as well as its input and output offset voltages.

### Evaluation of Crossplot Patterns

The crossplot pattern of Figure 68 displays an "ideal" slope pattern with no offsets. The sine-wave input voltage is displayed on the oscilloscope's horizontal axis. For a 20 volt peak-to-peak input signal, the horizontal amplifier of the oscilloscope should normally be set for 2 volts per horizontal division with the zero input level occurring at the zero axis crossing. The rms converter's output is displayed on the oscilloscope's vertical axis, and since it is of one polarity (in this case positive), it will lie entirely on one side of the zero axis. The vertical axis amplitude will rise and fall with the amplitude of the sine-wave input voltage. For these tests, the rms converter's averaging capacitor should be disconnected and replaced with a minimum sized unit, (typically 100pF), otherwise, its output would simply be a

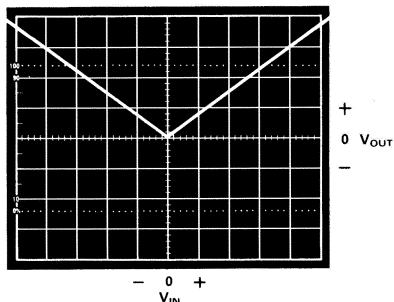
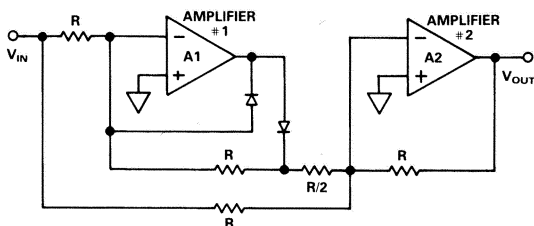


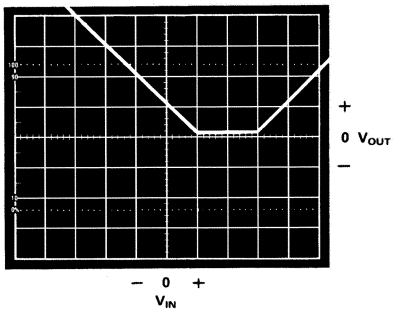
Figure 68. An Ideal Crossplot Pattern



OFFSETS IN EITHER AMPLIFIER WILL CAUSE A SHIFT TO THE RIGHT (OR LEFT) IN THE CROSSPLOT PATTERN.

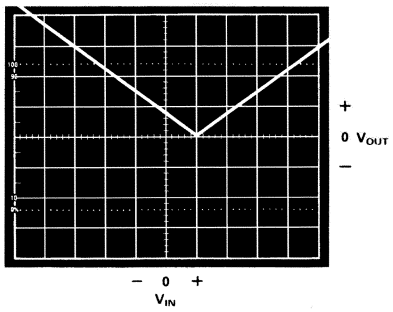
Figure 69. Two Amplifiers are Used in This Absolute Value Circuit Which is Typical of rms Converter Input Sections

straight horizontal line whose vertical amplitude would equal the rms equivalent voltage of the input signal.



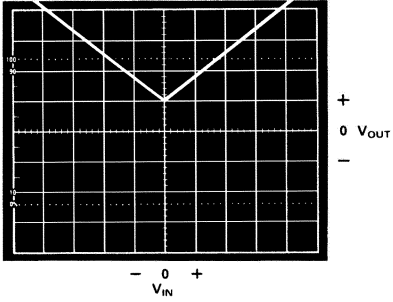
THIS OFFSET CREATES A FLAT SPOT OR "DEAD ZONE" IN THE INPUT TO OUTPUT TRANSFER CHARACTERISTICS. THE FLAT SPOT IS PRODUCED BECAUSE THE ABSOLUTE VALUE CIRCUIT WILL NOT ALLOW THE CONVERTER OUTPUT TO GO NEGATIVE. THE CENTER OF THE SHIFT MAY BE ON EITHER SIDE OF  $0V_{IN}$  DEPENDING ON WHICH INPUT AMPLIFIER HAS THE OFFSET.

Figure 70. Input Offset in Absolute Value Circuit



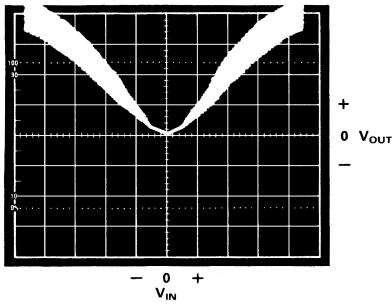
THE INTERSECTION POINT, OR BOTTOM TIP OF THE "V", MAY OCCUR ON EITHER SIDE OF  $0V_{IN}$  DEPENDING ON WHICH AMPLIFIER IN THE ABSOLUTE VALUE CIRCUIT HAS THE OFFSET.

Figure 71. Input Offset in Absolute Value Circuit



THE INTERSECTION POINT, THE BOTTOM TIP OF THE "V", MAY OCCUR TO EITHER SIDE OF  $0V_{OUT}$  DEPENDING UPON THE POLARITY OF THE OFFSET.

Figure 72. Offset at Amplifier Output



THIS WAVEFORM INDICATES DYNAMIC INSTABILITY PROBLEMS IN AN RMS CONVERTER.

Figure 73. Oscillation/Instability

## AN RMS CROSSPLOT TESTER

This precision tester will measure the offsets and errors of rms converters and precision rectifiers. The unit requires  $\pm 15$  volt power supplies and an audio generator.

### Circuit Description (Figure 74)

From the input jack a 20 volt peak-to-peak signal generator voltage is divided down by an input attenuator which is used to select the desired input voltage range for the device under test. Amplifier  $A_1$ , an input buffer, drives the center of the symmetry potentiometer ( $R_5$ ) and the precision rectifier circuit; these would load down the input attenuator without buffering. Amplifier  $A_2$ , a precision half-wave rectifier, in conjunction with summing amplifier  $A_3$ , form a precision full-wave rectifier circuit.

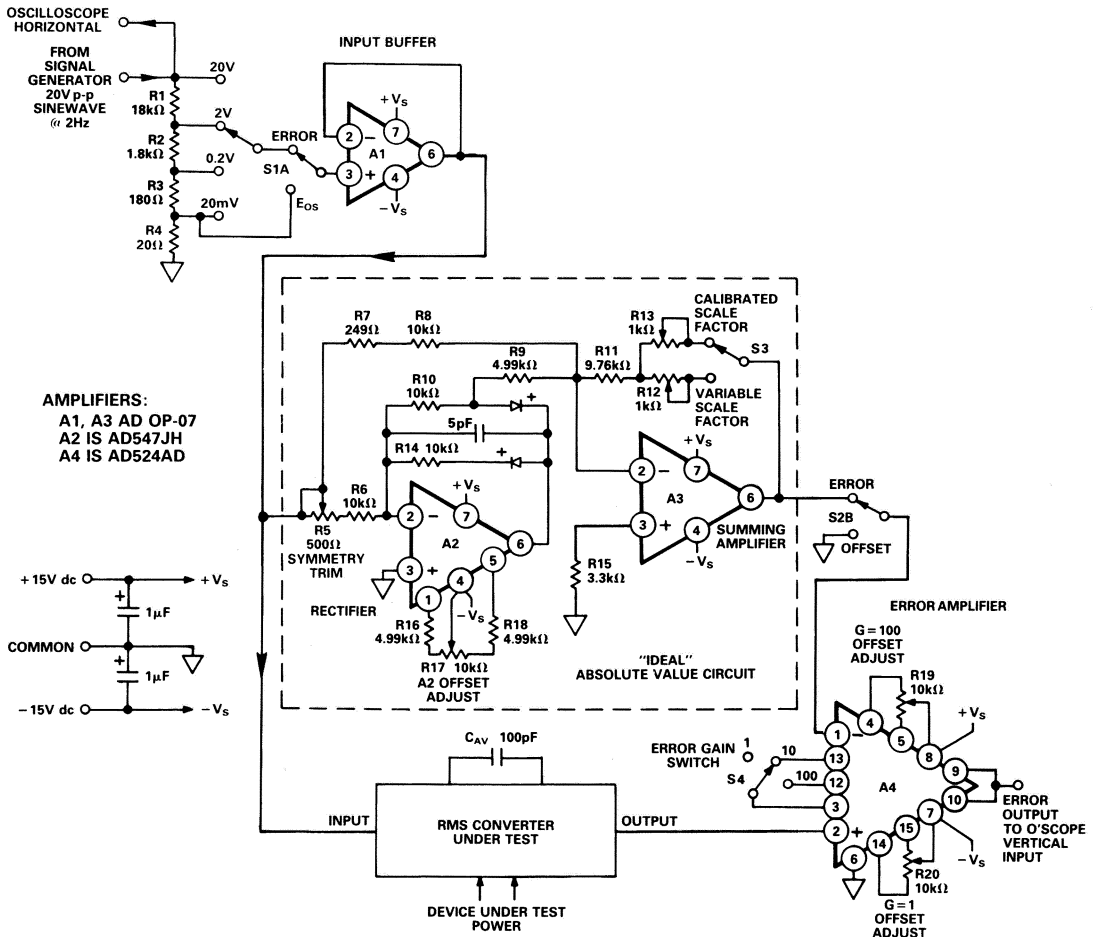
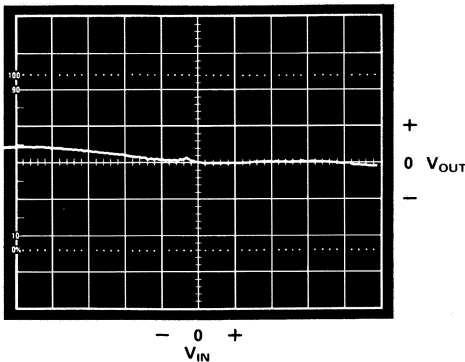


Figure 74. An rms Crossplot Tester

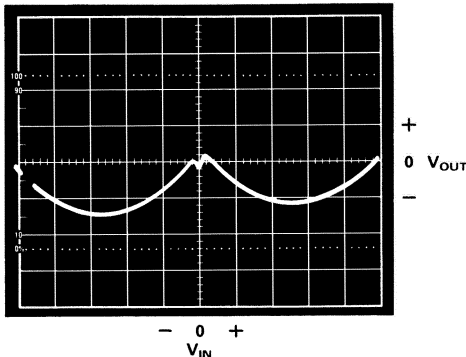
Amplifier  $A_3$  has provision for either variable gain or fixed, preset gain.

With switch  $S_2$  in the error mode, the output of the precision rectifier is compared to the output of the device under test by error/amplifier  $A_4$ ; this *difference* output is the error of the device under test. When displayed as a crossplot pattern on an oscilloscope, the difference output will be a direct measure of an rms converter's nonlinearity, Figures 75 and 76 show typical crossplot patterns for linearity measurement. The precision rectifier circuit is carefully calibrated and is assumed to be "perfect". Amplifier  $A_4$  operates at several selectable voltage gains, and,



THIS PATTERN INDICATES AN rms CONVERTER HAS A LINEARITY CLOSE TO THAT OF AN "IDEAL UNIT. APPROXIMATELY 0.01% @ 5mV PER VERTICAL DIVISION

Figure 75. Good Linearity



THIS CROSSPLOT PATTERN IS BOWED AND UNSYMMETRICAL. APPROXIMATELY 0.4% @ 50mV PER VERTICAL DIVISION.

Figure 76. Poor Linearity

therefore, the error output of the test box will be the actual error of the device under test times the amplifier gain. When  $S_2$  is in the  $E_{OS}$  position *no* subtraction takes place; therefore, this position is used for checking the slope and offset of the rms converter under test (refer to the previous section).

The 100pF averaging capacitor  $C_{AV}$  is used for stability of the rms converter under test and does not average out the input waveform, thus the converters operate as precision rectifiers for testing purposes. Separate power supply jacks should be provided for testing the AD636 rms converter which operates at lower power supply voltages, typically +3V and -5 volts dc.

### Calibration

- Step 1. Using an oscilloscope with vertical and horizontal preamplifiers connected to their respective jacks on the rms crossplotter, ground pin 2 of the AD524 ( $A_4$ ) and adjust trim potentiometer  $R_{17}$  for a symmetrical "V" pattern with the input selector on the 20mV position and the input jack connected to an audio sine-wave generator adjusted for 20 volts peak to peak at  $\approx$  1Hz. The "V" should be centered and equal on both sides.
- Step 2. With gain switch  $S_4$  set for a gain of 1, adjust trim potentiometer  $R_{20}$  for zero output offset as shown in Figure 68.
- Step 3. Repeat step 2, setting  $S_4$  for a gain of 100. Adjust trim potentiometer  $R_{19}$ .
- Step 4. With a dual polarity 10 volt dc reference connected to the generator input jack, alternate the polarity of the reference back and forth from plus to minus to adjust the symmetry trim potentiometer  $R_5$  for equal readings of +10.000 volts dc from pin 6 of  $A_3$  to ground as measured by a high input impedance digital voltmeter. The voltmeter must have enough sensitivity to resolve voltages as low as 1mV for this adjustment.
- Step 5. Finally, with a +10 volt dc reference connected to the generator input jack, adjust trim potentiometer  $R_{13}$  for an output of +10.000 volts dc at pin 6 of  $A_3$ ; recheck symmetry (step 4).