



4341

## Low Cost TRUE RMS-TO-DC CONVERTER

### FEATURES

- **LOW COST**
- **HIGH ACCURACY:**  $\pm 0.2\%$   $\pm 2\text{mV}$
- **VERSATILE:** AC and DC Inputs

### DESCRIPTION

The 4341 RMS-to-DC converter features low cost without sacrificing performance. The 4341 computes a DC voltage proportional to the true rms value of signals which may be complex waveforms, DC levels, or a combination of both.

The input and output are fully protected against over-voltages and short circuits. Provisions for the external adjustment of gain, offset voltage, DC-reversal error, and frequency response make the 4341 versatile enough to fill the majority of your applications.

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## SPECIFICATIONS

### ELECTRICAL

$T_a = +25^\circ\text{C}$ ,  $V_s = \pm 15\text{VDC}$ , unless otherwise noted.

PARAMETER	CONDITIONS
TRANSFER FUNCTION	$E_{\text{rms}}(t) = \sqrt{\frac{1}{T} \int_0^T [E_{\text{IN}}(t)]^2 dt}$
INPUT Peak Operating Voltage Absolute Maximum Voltage Impedance	$\pm 10\text{V}$ $\pm \text{Supply}$ $5\text{k}\Omega$
OUTPUT Voltage Current Resistance	$0$ to $+10\text{V}$ $+5\text{mA}$ , min $1\Omega$ , max
BANDWIDTH $\pm 1\%$ of Theoretical Output $-3\text{dB}$	$80\text{kHz}$ $450\text{kHz}$
CONVERSION ACCURACY <sup>(2)</sup> Input: $500\text{mVrms}$ to $5.0\text{Vrms}$ Input: DC to $10\text{kHz}$ Sine Wave Input: $10\text{mVrms}$ to $7\text{Vrms}$ Input: DC to $20\text{kHz}$	$\pm 0.5\%$ of Reading, max <sup>(1)</sup> $\pm 2\text{mV} \pm 0.2\%$ of Reading
STABILITY Accuracy vs Temperature Accuracy vs Supply Voltage	$\pm 0.1\text{mV} \pm 0.01\%$ of Reading/ $^\circ\text{C}$ $\pm 0.1\text{mV} \pm 0.01\%$ of Reading/ $\%$ of Supply Voltage Change
TEMPERATURE RANGE Operating Storage	$-25^\circ\text{C}$ to $+85^\circ\text{C}$ $-40^\circ\text{C}$ to $+85^\circ\text{C}$
POWER REQUIREMENTS Rated Voltage Voltage Range Quiescent Current	$\pm 15\text{VDC}$ $\pm 14\text{VDC}$ to $\pm 16\text{VDC}$ $\pm 12\text{mA}$ , typ, $\pm 24\text{mA}$ , max

NOTES: (1) After standard trim procedure (see below). (2) Model 4341 will convert DC inputs. Lower frequency AC inputs require a large value of averaging capacitor to minimize ripple at output. (see Figure 2).

## STANDARD TRIM PROCEDURE

If the 4341 is used to measure sine waves or distorted sine waves, only two trims are needed to achieve an accuracy of  $\pm 0.5\%$  of reading from  $500\text{mVrms}$  to  $5\text{Vrms}$  up to  $10\text{kHz}$ . Refer to Figure 1.

1. Set  $E_{\text{IN}} = 5.000\text{Vrms} \pm 0.02\%$  and adjust  $R_1$  such that  $E_0 = 5.000\text{VDC} \pm 2\text{mV}$ .
2. Set  $E_{\text{IN}} = 500\text{mVrms} \pm 0.02\%$  and adjust  $R_2$  such that  $E_0 = 500\text{mVDC} \pm 0.2\text{mV}$ .
3. Repeat Step 1.

## THEORY OF OPERATION

The true rms value of a time-varying signal  $E(t)$  over a time period  $T$  is

$$E_{\text{rms}}(t) = \sqrt{\frac{1}{T} \int_0^T [E_{\text{IN}}(t)]^2 dt}$$

The required operations are squaring, averaging and square rooting. A simplified schematic diagram of the 4341 is shown in Figure 1. The  $A_1$  circuit produces a current,  $i_1$ , which is proportional to the rectified input voltage. The  $A_2$  circuit is a logarithmic amplifier which produces a voltage proportional to  $2 \log E_{\text{IN}}$  or  $\log E_{\text{IN}}^2$ . The logarithmic gain of the  $A_2$  circuit is derived from the inherent exponential characteristics of transistor junctions. By using proprietary

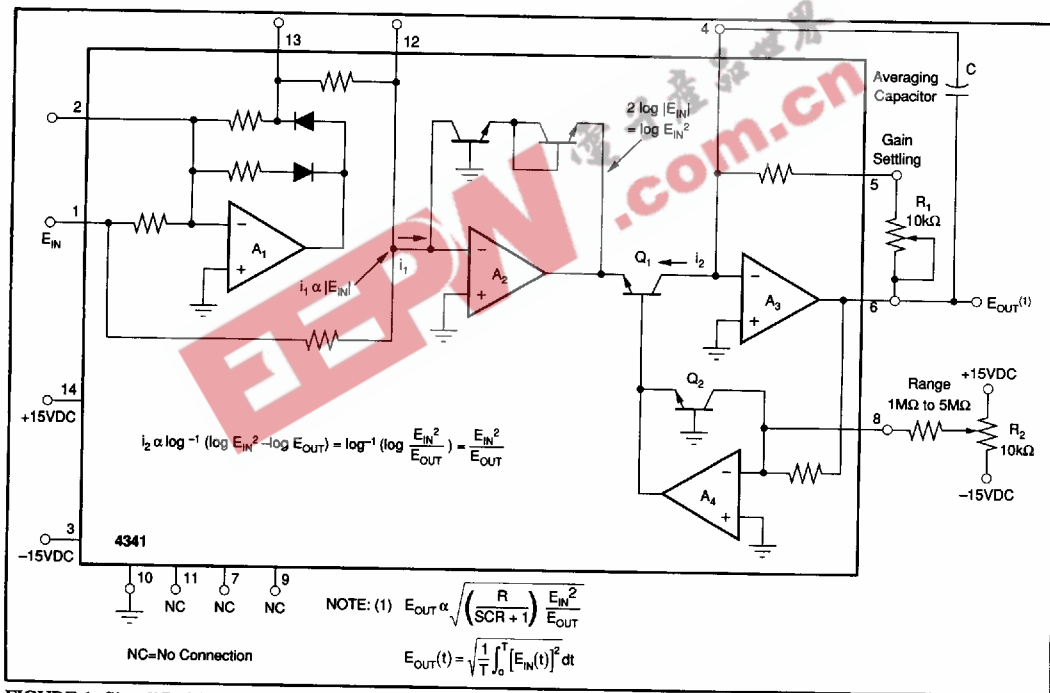


FIGURE 1. Simplified Schematic

monolithic components, the circuit provides an accurate log function over many decades which is relatively insensitive to temperature variations. Amplifier  $A_4$  uses the same techniques as  $A_2$  to generate  $\log E_{OUT}$ .

Transistor  $Q_1$  produces a collector current,  $i_2$ , proportional to the antilog of its base-emitter voltage such that

$$i_2 \propto \log^{-1}(\log E_{IN}^2 - \log E_{OUT})$$

$$= \log^{-1}(\log E_{IN}^2 / E_{OUT}) = E_{IN}^2 / E_{OUT}$$

The  $A_3$  circuit, which contains the external capacitor, takes the time average of the  $i_2$  signal and produces  $E_{OUT}$ , which is directly proportional to the rms value of  $E_{IN}$ .

Figures 2 and 3 show the effects of the external filter capacitor on ripple magnitude and response time. As the frequency of the input approaches DC, the 4341 begins to act like a full wave rectifier such that the output is the absolute value of the input. While the 4341 will accurately convert DC input voltages, the averaging capacitor must be made very large to minimize ripple at low frequencies.

### CHOOSING THE AVERAGING CAPACITOR

A single-pole low-pass RC filter provides the averaging function. The time constant is  $1/2 RC$  where  $R$  is  $10k\Omega$  when the 4341 is adjusted for unity gain. To select the best value of  $C$ , make a tradeoff between output ripple and response time. Figure 2 shows the ripple magnitude vs frequency for several typical values of capacitor. Response time vs capacitor value is shown in Figure 3. (Note that rise times and fall times are different for the same value of capacitor).

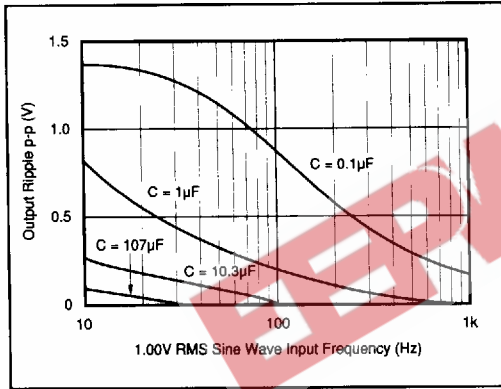


FIGURE 2. Output Ripple Magnitude vs Input Signal Frequency.

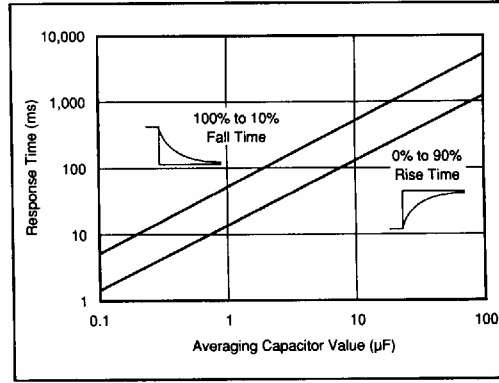


FIGURE 3. Response Time vs Value of Averaging Capacitor.

While the ripple magnitude for signals other than sine waves can be analytically determined, it is tedious. The fastest method of choosing  $C$  is to apply a representative input signal and observe the output for various values of  $C$ .  $C$  can be 100s of microfarads, but should have a leakage current less than  $0.1\mu A$  to minimize gain errors. With very large values of  $C$ , the input signals with frequencies approaching DC level could be averaged. Since the output is always a positive voltage,  $C$  can be a polar capacitor.

### EXPANDED TRIM PROCEDURE FOR GREATER ACCURACY

If the 4341 is used in applications to measure complex waveforms, the following expanded trim procedure is recommended. (Refer to Figure 4).

First, set all potentiometers at mid turn position.

1. DC Reversal Error — Apply  $+10.000V \pm 1mV$  and  $-10.000V \pm 1mV$  to  $E_{IN}$  alternatively, adjust  $R_5$  such that  $E_O$  readings are the same  $\pm 2mV$ .
2. Gain Adjustment — Apply  $E_{IN} = +10.000VDC \pm 1mV$ , adjust  $R_1$  such that  $E_O = +10.000VDC \pm 1mV$ .
3. Input Offset — Apply  $+10.0mV \pm 0.1mV$  and  $-10.0mV \pm 0.1mV$  to  $E_{IN}$ , adjust  $R_4$  such that  $E_O$  readings are the same  $\pm 0.1mV$ .
4. Offset — Ground  $E_{IN}$ , adjust  $R_3$  such that  $E_O = 0 \pm 0.1mV$ . Repeat Step (3).
5. Low Level Accuracy — Apply  $E_{IN} = +10.0mV \pm 0.1mV$ , adjust  $R_2$  such that  $E_O = +10.0mV \pm 0.1mV$ .

### NONUNITY GAINS

Gain values greater than unity can be achieved by inserting resistor  $R_X$  between pin 5 and pin 6.  $R_X \approx (A^2 - 1) \times 10k + 2k$  where  $A$  is the desired value of gain ( $1 < A \leq 10$ ). ( $R_X$  is in  $\Omega$ ).

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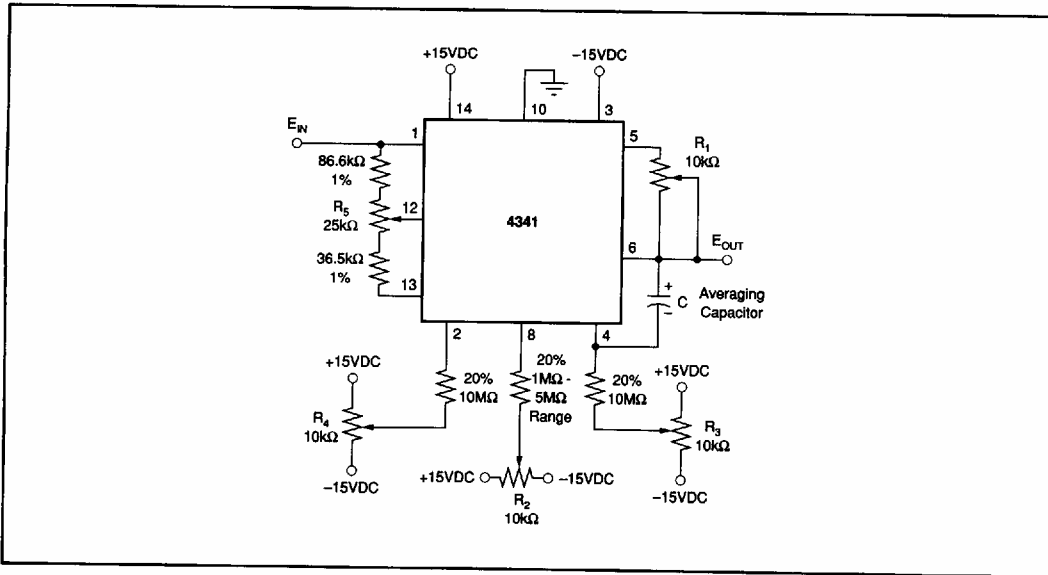


FIGURE 4. Expanded Trim Procedure (High Accuracy Applications).

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