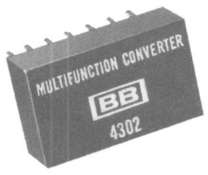
BURR-BROWN®



4302

Low Cost
MULTIFUNCTION CONVERTER

FEATURES

- VERSATILE
- SMALL PACKAGE: Dual-in-Line
- EASY TO USE

DESCRIPTION

Burr-Brown's multifunction converter model 4302 is a low cost solution to many analog conversion needs. Much more than just a multiplier/divider, the 4302 performs many analog circuit functions with a high degree of accuracy at a low total cost.

FUNCTIONS	ACCURACY
Multiply	±0.25%
Divide	±0.25%
Square	±0.03%
Square Root	±0.07%
Exponentiate	±0.15% (m = 5)
Roots	±0.2% (m = 0.2)
Sine θ	±0.5%
Cosine θ	±0.8%
Tan $^{-1}$ (Y/X)	±0.6%
$\sqrt{X^2 + Y^2}$	±0.07%

Typical accuracies expressed as a % of output full scale (+10VDC) at 25°C.

International Airport Industrial Park • Mailing Address: PO Box 11400 • Tucson, AZ 85734 • Street Address: 6730 S. Tucson Blvd. • Tucson, AZ 85706
Tel: (602) 746-1111 • Twx: 910-952-1111 • Cable: BBRCORP • Telex: 066-6491 • FAX: (602) 889-1510 • Immediate Product Info: (800) 548-6132

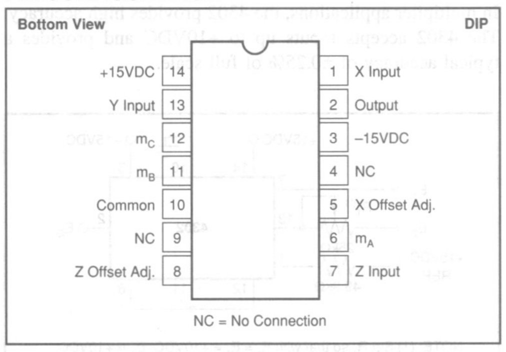
SPECIFICATIONS

ELECTRICAL

$T_A = +25°C$, $V_S = \pm15VDC$, unless otherwise noted.

MODEL	4302
TRANSFER FUNCTION	$E_O = V_Y \left[\frac{V_Z}{V_X}\right]^m$
RATED OUTPUT	
Voltage	+10.0V
Current	5mA
INPUT	
Signal Range	$0 \le (V_X, V_Y, V_Z) \le +10V$
Absolute Maximum	$(V_X, V_Y, V_Z) \le \pm18V$
Impedance (X/Y/Z)	100kΩ/90kΩ/100kΩ
EXPONENT RANGE	
Roots ($0.2 \le m < 1$)	$m = \frac{R_2}{R_1 + R_2}$ Refer to Functional Diagram Below.
Powers ($1 < m \le 5$)	$m = \frac{R_1 + R_2}{R_2}$
($m = 1$)	$R_1 = 0\Omega$, R_2 not used
POWER REQUIREMENTS	
Rated Supply	±15VDC
Range	±12 to ±18VDC
Quiescent Current	±10mA
TEMPERATURE RANGE	
Operating	–25°C to +85°C
Storage	–25°C to +85°C

PIN CONFIGURATION



PACKAGE INFORMATION[1]

MODEL	PACKAGE	PACKAGE DRAWING NUMBER
4302	14-Pin Plastic DIP	003

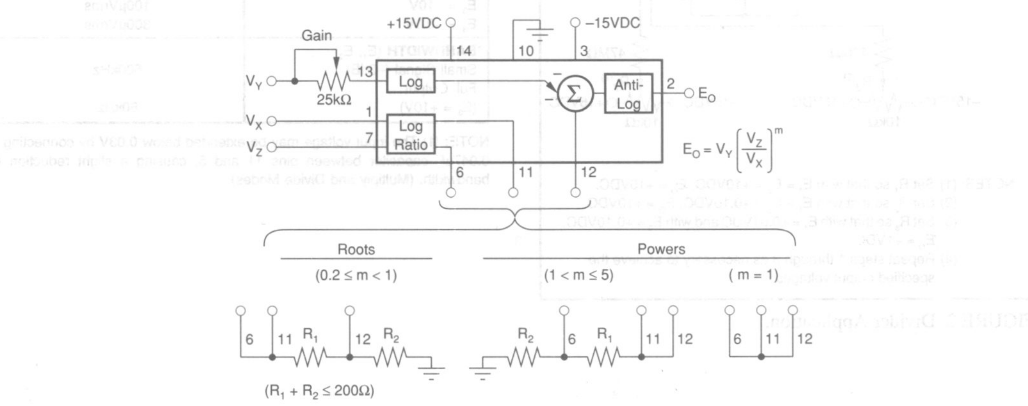
NOTE: (1) For detailed drawing and dimension table, please see end of data sheet, or Appendix D of Burr-Brown IC Data Book.

APPLICATION INFORMATION

General specifications for the 4302 multifunction converter are presented on this page. These specifications characterize the 4302 as a versatile three input multifunction converter.

The following pages are applications intended to help you apply the 4302 to your particular circuit function need. These pages contain dedicated circuit configurations in order to produce the functions of: multiplication, division, exponentiation, square rooting, squaring, sine, cosine, arctangent, and vector algebra.

It is the purpose of this product data sheet to enable you to apply the 4302 to your analog conversion needs quickly and efficiently.



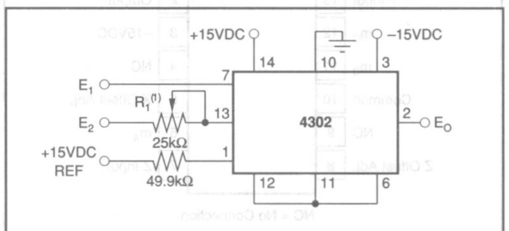
Many of the following circuit configurations using the 4302 require a reference voltage for scaling purposes. The reference voltage is shown to be +15VDC (+15VDC REF), since in most cases the +15VDC power source for the 4302 has sufficient time and temperature related stability to achieve the specified typical accuracies. If the particular supplies which are available for powering the 4302 do not have the necessary stability for the required conversion accuracy, an additional +15VDC precision supply may be required.

4302 Functional Diagram.

MULTIPLIER/ DIVIDER FUNCTIONS

MULTIPLIER

In multiplier applications, the 4302 provides high accuracy. The 4302 accepts inputs up to +10VDC and provides a typical accuracy of ±0.25% of full scale.



NOTE: (1) Set R_1 so that with $E_1 = E_2 = +10VDC$, $E_O = +10VDC$.

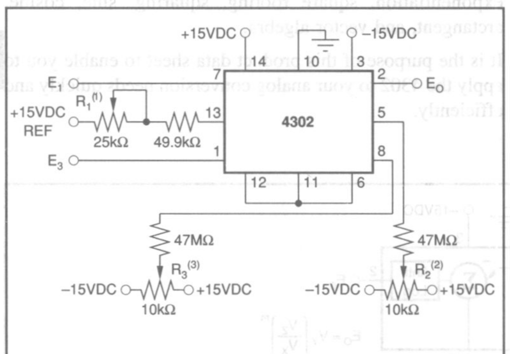
FIGURE 1. Multiplier Application.

TRANSFER FUNCTION	$E_O = +\frac{E_1E_2}{10}$
ACCURACY	
Total Errors	
Typical at +25°C	±25mV
Maximum at +25°C	±50mV
(for input range)	$0.03V \le E_1^{(1)} \le 10V$
	$0.01V \le E_2 \le 10V$
vs Temperature	±1mV/°C
Offset Errors ($E_1 = E_2 = 0$)	
Output Offset (at 25°C)	±10mV
vs Temperature	±0.2mV/°C
NOISE (10Hz to 1kHz)	100µVrms
BANDWIDTH (E_1, E_2)	
Small Signal (–3dB)	500kHz
Full Output	60kHz

NOTE: (1) The input voltage may be extended below 0.03V by connecting a 0.047µF capacitor between pins 11 and 5, causing a slight reduction in bandwidth. (Multiply and Divide Modes).

DIVIDER

As a divider, the 4302 provides a typical conversion accuracy of ±0.25% of full scale.



NOTES: (1) Set R_1 so that with $E_1 = E_3 = +10VDC$, $E_O = +10VDC$.
(2) Set R_2 so that with $E_1 = E_3 = +0.10VDC$, $E_O = +10VDC$.
(3) Set R_3 so that with $E_1 = +0.01VDC$ and with $E_3 = +0.10VDC$, $E_O = +1VDC$.
(4) Repeat steps 1 through 3 as necessary to achieve the specified output voltages.

FIGURE 2. Divider Application.

TRANSFER FUNCTION	$E_O = +10\ (E_1/E_3)$
ACCURACY	
Total Errors	
Typical at +25°C	±25mV
Maximum at +25°C	±50mV
(for $E_1 \le E_3$ ad input range)	$0.03V \le E_1^{(1)} \le 10V$
	$0.01V \le E_3 \le 10V$
vs Temperature	±1mV/°C
Offset Errors ($E_1 = 0$, $E_3 = +10V$)	
Output Offset (at 25°C)	±10mV
vs Temperature	±1mV/°C
NOISE (10Hz to 1kHz)	
$E_3 = +10V$	100µVrms
$E_3 = +0.1V$	300µVrms
BANDWIDTH (E_1, E_3)	
Small Signal (–3dB)	500kHz
Full Output	
($E_3 = +10V$)	60kHz

NOTE: (1) The input voltage may be extended below 0.03V by connecting a 0.047µF capacitor between pins 11 and 5, causing a slight reduction in bandwidth. (Multiply and Divide Modes).

EXPONENTIAL FUNCTIONS

Model 4302 may be used as exponentiator over a range of exponents from 0.2 to 5. The exponents 0.5 and 2, square rooting and squaring, respectively, are often used functions and are treated below. Other values of exponents (m) may be useful in terms of linearization of nonlinear functions or simply for producing the mathematical conversions. Characteristics of m = 0.2 and m = 5 are presented on the right. For other values of m, the curves presented in Figure 3 may be used to interpolate the error for a nonspecified value of m.

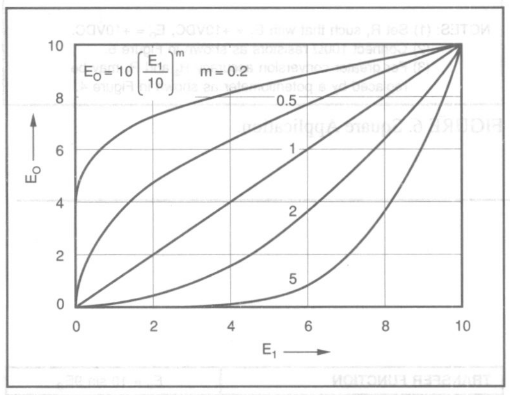
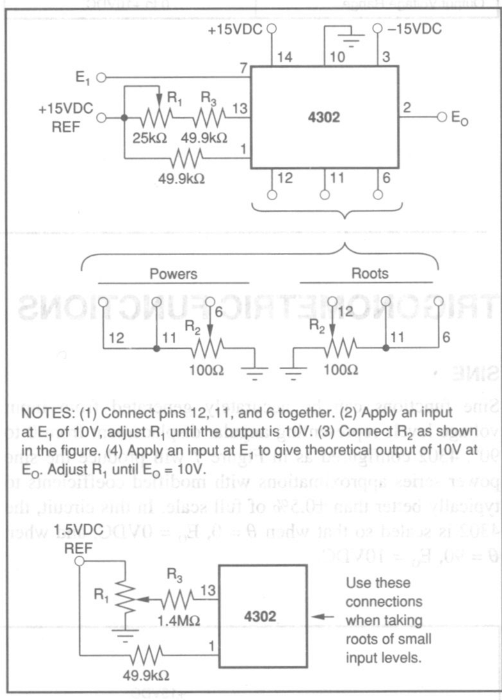


FIGURE 3. Exponentiator Transfer Characteristics.

TRANSFER FUNCTION	$E_O = 10\left(\frac{E_I}{10}\right)^m$
Total Conversion Error (typical)	
m = 0.2	
$0.5VDC < E_I \leq 10VDC$	±2mVDC
$0.1VDC < E_I \leq 0.5VDC$	±25mVDC
m = 5	
$1VDC < E_I \leq 10VDC$	±15mVDC
Exponent Range (continuous)	$0.2 \leq m \leq 5$
Input Voltage Range	0 to +10VDC
Output Voltage Range	0 to +10VDC



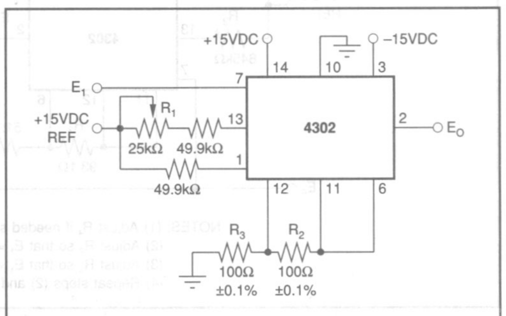
NOTES: (1) Connect pins 12, 11, and 6 together. (2) Apply an input at E_I of 10V, adjust R_1 until the output is 10V. (3) Connect R_2 as shown in the figure. (4) Apply an input at E_I to give theoretical output of 10V at E_O. Adjust R_1 until E_O = 10V.

FIGURE 4. Exponential Functions.

SQUARE ROOT

As a Square Rooter (m = 0.5), the 4302 provides a typical total conversion accuracy of ±0.07%. Refer to Figure 5 and notes for connections and adjustments, respectively.

TRANSFER FUNCTION	$E_O = 10\sqrt{\frac{E_I}{10}}$
Total Conversion Error (typical)	
$0.5VDC < E_I \leq 10VDC$	±7mV
$0.02VDC < E_I \leq 0.5VDC$	±55mV
Input Voltage Range	0 to +10VDC
Output Voltage Range	0 to +10VDC



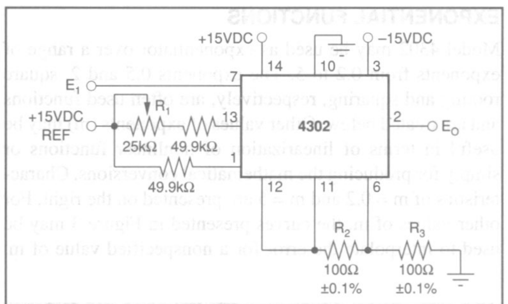
NOTES: (1) Connect pins 12, 11, and 6 together. Set R_1 such that with E_I = +10VDC; E_O = +10VDC.
(2) Connect 100Ω resistors as shown in Figure 5.
(3) For greater conversion accuracy, R_2 and R_3 may be replaced by a potentiometer as shown in Figure 4.

FIGURE 5. Square Root Application.

SQUARE

Configured as a Square Function Converter (m = 2), the 4302 produces high conversion accuracies of typically 0.03%. Refer to Figure 6 and accompanying notes.

TRANSFER FUNCTION	$E_O = 10 \left(\frac{E_1}{10}\right)^2$
Total Conversion Error (typical) $0.1VDC \le E_1 \le 10VDC$	±3mV
Input Voltage Range	0 to +10VDC
Output Voltage Range	0 to +10VDC



NOTES: (1) Set R_1 such that with E_1 = +10VDC, E_O = +10VDC.
(2) Connect 100Ω resistors as shown in Figure 6.
(3) For greater conversion accuracy R_2 and R_3 may be replaced by a potentiometer as shown in Figure 4.

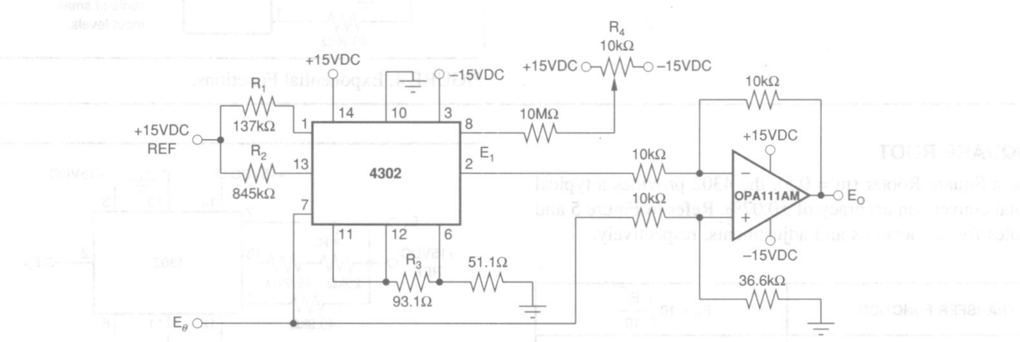
FIGURE 6. Square Application.

TRIGONOMETRIC FUNCTIONS

SINE

Sine functions can be accurately generated from input voltage levels representing angular displacement from 0 to 90°. 4302 configured as in Figure 7 will produce the sine power series approximations with modified coefficients to typically better than ±0.5% of full scale. In this circuit, the 4302 is scaled so that when $\theta = 0$, E_O = 0VDC, and when $\theta = 90$, E_O = 10VDC.

TRANSFER FUNCTION	$E_O = 10 \sin 9E_\theta$
Power Series Approximation $E_O = 1.5708E_\theta - 1.5924 \left(\frac{E_\theta}{6.366}\right)^{2.827}$	
Total Conversion Error (typical)	±50mV
Input Voltage Range ($0 \le \theta \le 90°$)	0 to +10VDC
Output Voltage Range ($0 \le \sin\theta \le 1$)	0 to +10VDC



NOTES: (1) Adjust R_4 if needed so that E_1 < 1mVDC when E_θ = 0.
(2) Adjust R_2 so that E_1 = +0.8045VDC when E_θ = +5VDC.
(3) Adjust R_3 so that E_1 = +5.709VDC when E_θ = +10VDC.
(4) Repeat steps (2) and (3) as necessary.

FIGURE 7. Sine Application.

COSINE

Connected as in Figure 2, 4302 will generate a cosine function of the input voltage. Typical accuracies of ±0.8% can be expected from this configuration.

TRANSFER FUNCTION	$E_O = 10 \cos 9E_\theta$
Power Series Approximation $E_O = 10 + 0.3652\, E_\theta - 0.4276E^{1.504}$	
Total Conversion Error (typical) Input Voltage Range ($0 \le \theta \le 90°$) Output Voltage Range ($1 \le \cos\theta \le 0$)	±80mV 0VDC to +10VDC +10VDC to 0VDC

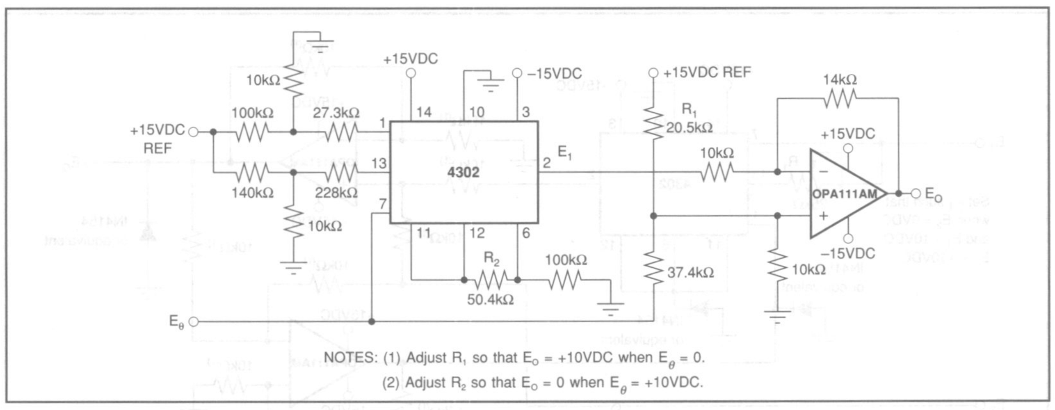


FIGURE 8. Cosine Application.

ARCTANGENT

4302 and the associated circuitry shown below will produce the inverse tangent of a ratio. This application is particularly well suited to conversion from rectangular coordinates to polar coordinates where

$$E_\theta = \tan^{-1}\frac{E_Y}{E_X}$$

The accuracy of conversion depends upon the levels of the input signals. Refer to table at right.

TRANSFER FUNCTION	$E_O = \tan^{-1}\left(\frac{[E_1]}{[E_2]}\right)$
Power Series Approximation	$E_O = \dfrac{\left(\frac{[E_1]}{[E_2]}\right)^{1.2125}}{1 + \left(\frac{[E_1]}{[E_2]}\right)^{1.2125}}(90°)$
Total Conversion Error $2 < E_1, E_2 \le 10$VDC $0.1 < E_1, E_2 \le 2$VDC $0.03 < E_1, E_2 \le 0.1$VDC Input Voltage Range (E_1, E_2) Output Voltage Range $0 \le E_\theta \le 90°$	 ±55mVDC ±65mVDC ±340mVDC +0.01VDC to +10VDC 0VDC to +9VDC

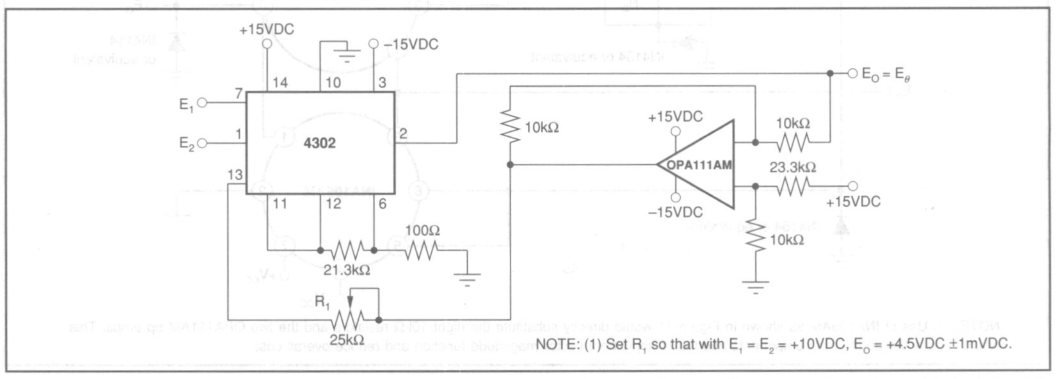
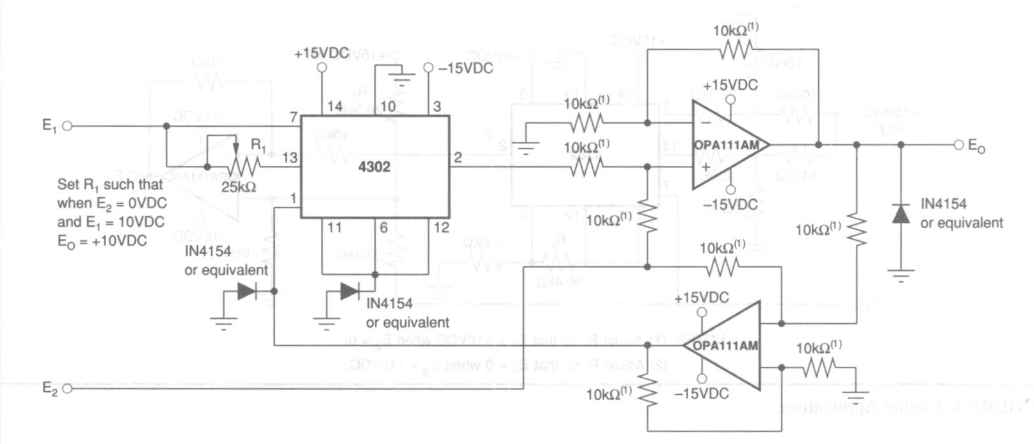


FIGURE 9. Arctangent Application.

VECTOR MAGNITUDE FUNCTION

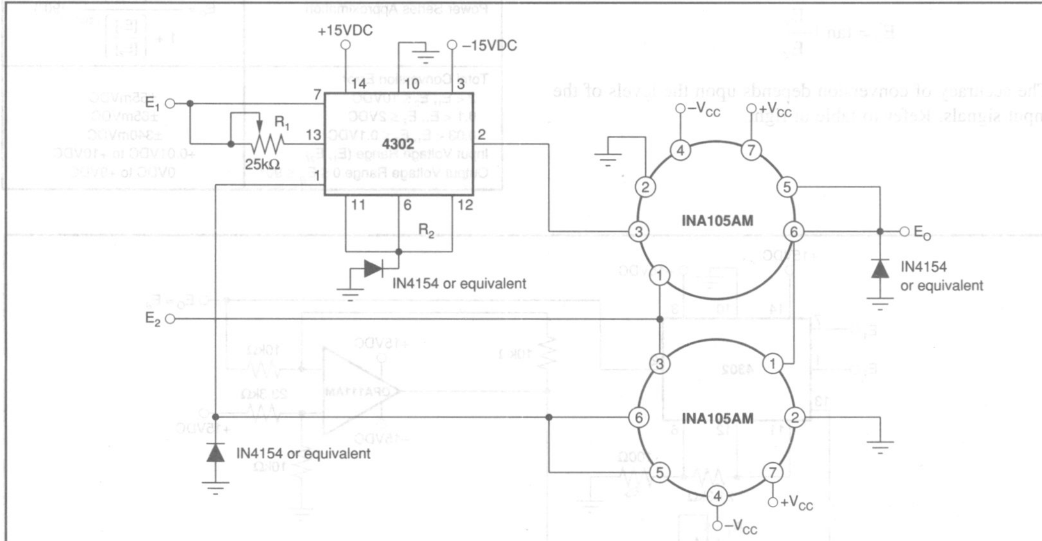
The 4302 will produce the square root of the sum of the squares of two inputs. This function is companion to the arctangent of a ratio for the conversion of rectangular to polar coordinates.

TRANSFER FUNCTION	$E_O = \sqrt{E_1^2 + E_2^2}$
Input Voltage Range E_1 E_2 (refer to notes 1 and 2)	0 to +10VDC –10VDC to +10VDC
Output Voltage Range	0 to +10VDC
Conversion Error	±7mVDC



NOTE: (1) Rs = 10kΩ ±0.02%. (2) Figure 10 shows one practical way to implement the transfer function $E_O = \sqrt{E_1^2 + E_2^2}$ using 4302. It shows use of OPA111AM op amp. OPA111AM rated output is ±10V. This limits the range of E_1 and E_2, such that the conditions $E_1 \leq \sqrt{100 - E_2}$ and $|E_2| \leq (5 - E_1^2/20)$ and $\sqrt{E_1^2 + E_2^2} \leq 10$ are always satisfied. (a) The above conditions imply, $0V \leq E_1 \leq 10V$ and $-5V \leq E_2 \leq 5V$. (b) The above conditions also imply that for applications where $E_1 = |E_2|$ the range would be limited to 4.142V max.

FIGURE 10. Implementation of Transfer Function.



NOTE: (1) Use of INA105AM as shown in Figure 11 would directly substitute the eight 10kΩ resistors and the two OPA111AM op amps. This would reduce the number of components needed to implement vector magnitude function and reduce overall cost.

FIGURE 11. Vector Magnitude Function Application.

BURR-BROWN®

4341

Low Cost
TRUE RMS-TO-DC CONVERTER

FEATURES

- LOW COST
- HIGH ACCURACY: ±0.2% ±2mV
- 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 overvoltages 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.

International Airport Industrial Park • Mailing Address: PO Box 11400 • Tucson, AZ 85734 • Street Address: 6730 S. Tucson Blvd. • Tucson, AZ 85706
Tel: (602) 746-1111 • Twx: 910-952-1111 • Cable: BBRCORP • Telex: 066-6491 • FAX: (602) 889-1510 • Immediate Product Info: (800) 548-6132

SPECIFICATIONS

ELECTRICAL

$T_A = +25°C$, $V_S = ±15VDC$, unless otherwise noted.

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

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

THEORY OF OPERATION

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

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

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_{IN} or log E_{IN}^2. The logarithmic gain of the A_2 circuit is derived from the inherent exponential characteristics of transistor junctions. By using proprietary

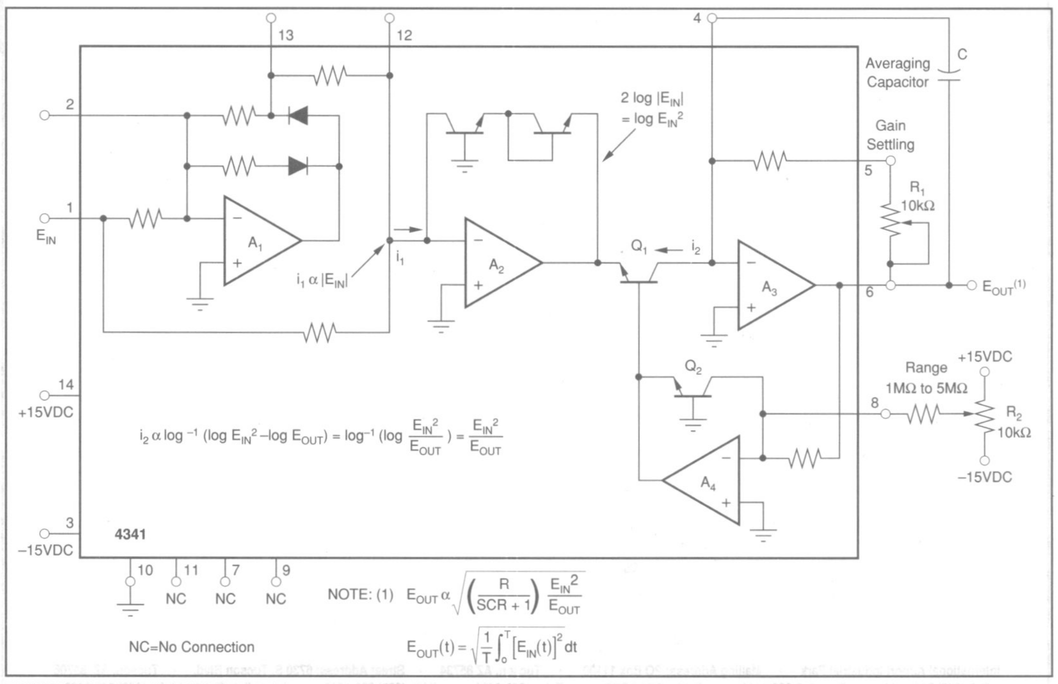


FIGURE 1. Simplified Schematic.

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

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

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

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 10kΩ 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).

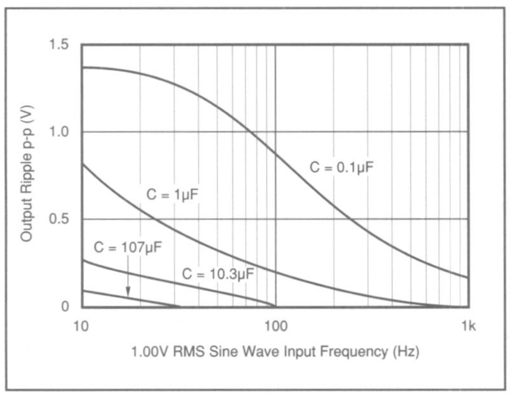


FIGURE 2. Output Ripple Magnitude vs Input Signal Frequency.

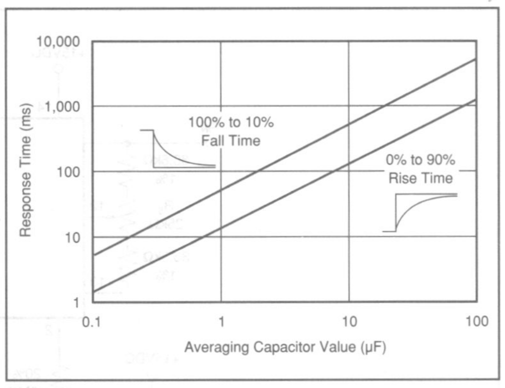


FIGURE 3. Response Time vs Value of Averaging Capacitor.

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

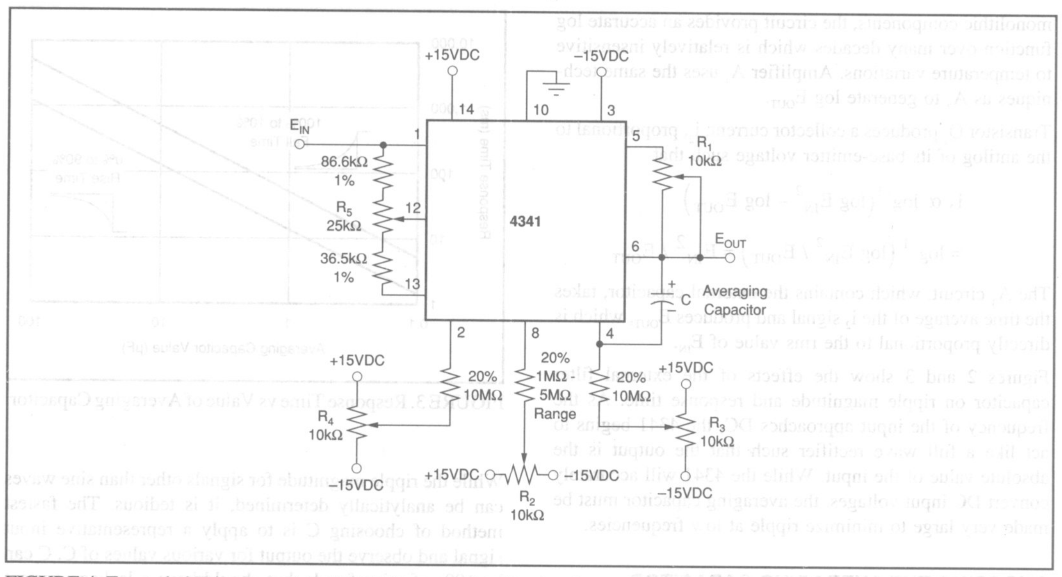


FIGURE 4. Expanded Trim Procedure (High Accuracy Applications).