ANALOG DEVICES

Wideband, High Accuracy True RMS-to-DC Converter

MODEL 442

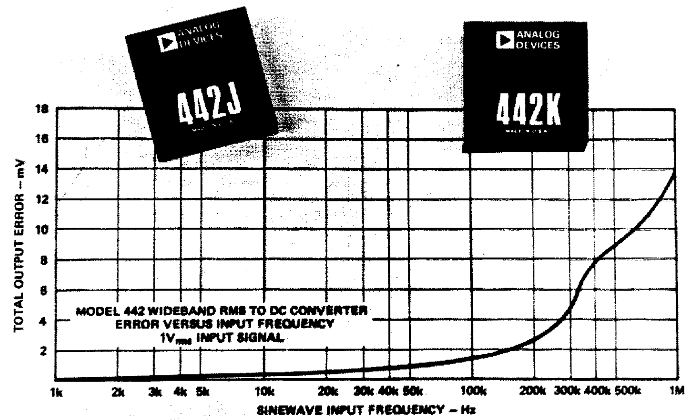
FEATURES

Dc to 8MHz Response (-3dB)
High Accuracy:
- With No Ext. Trim: ±2mV ±0.15% of Rdg., max
- With Ext. Trim: ±1mV ±0.05% of Rdg., max

Low Drift: ±(35μV ±0.01% of Reading)/°C max, 442L
Fast Settling Time: 5ms to 1%
Small Size: 1.5" x 1.5" x 0.4"
All Hermetically Sealed Semiconductors

APPLICATIONS

Wideband rms Instrumentation
Telephone, Telegraph & Modem Test Equipment
Vibration Analysis
Sound & Noise Level Instrumentation
Mean Square Measurements



GENERAL DESCRIPTION

Model 442 is a high performance true rms-to-dc converter featuring 8MHz bandwidth, low drift to ±35μV/°C ±0.01% of reading/°C maximum, and ±1% reading error to 800kHz. Unlike competing designs, model 442 achieves its high accuracy over a very wide input signal range. With no external adjustment, accuracy is held to within ±2mV ±0.15% of reading for input signals of 0 to 2V_{rms}. If optional adjustments are performed, this accuracy can be improved to ±1mV ±0.05% of reading. Model 442 is designed to be used in high performance instrumentation where response to low level, high speed signals, is of greatest importance.

The compact, log-antilog circuit design of model 442 results in high accuracy measurements on sinewave signals and complex waveforms such as pulse trains. Reading error increases 0.2% for signals with crest factors up to 7. In addition, true rms measurement can be performed directly on signals containing both ac and dc components.

Model 442 is available in three low drift selections offering maximum drift performance over 0 to +70°C range; model 442L: ±(35μV ±0.01% of rdg.)/°C max; model 442K: ±(50μV ±0.01% of rdg.)/°C max; model 442J: ±(100μV ±0.01% of rdg.)/°C max.

WHERE TO USE MODEL 442

Excellent untrimmed performance along with simple, optional trims make model 442 the ideal component for all types of laboratory and OEM rms instrumentation where wideband measurements must be made with high accuracy. Model 442 is ideally suited for measuring thermal noise, transistor noise and switch contact noise. True rms measurement is the only technique to accurately measure system noise and thereby assist the designer in reducing this noise. Model 442 is also useful for measuring mechanical phenomena such as strain, stress, vibration, shock, expansion and contraction. The electrical signals produced by these mechanical actions are often noisy, nonperiodic, nonsinusoidal and superimposed on dc levels, therefore requiring true rms devices for accurate measurements.

Model 442 is also required for accurate measurements on low repetition rate pulse trains. For pulse trains with crest factors of 10, a 3dB bandwidth of 400 times the pulse rate is required to achieve 1% accuracy and 4000 times the pulse rate is needed for 0.1% accuracy.

Model 442 may also be connected (see Figure 3, page 2) to measure the MEAN SQUARE of a signal ($e_o = e_{in}^2/V_R$). The Mean Square of a random signal is equal to the variance (σ^2).

TOTAL ACCURACY

Total output error is specified as the sum of two components; a fixed term plus a percentage of output signal. Model 442 has a rated sinewave accuracy of ±1mV ±0.05% max (externally trimmed), which for a one volt rms sinewave, results in a ±1.5mV maximum error (±1mV fixed error plus ±0.5mV reading error). The fixed error component is comprised of output offsets and linearity errors. Both of these error terms have been minimized in the model 442 as a result of special output circuit design and sophisticated factory offset trim procedures. Output offset can be adjusted for minimum error by means of an external adjustment (see Figure 2). The % of reading error is attributed to nonlinearity and scale factor errors. Scale factor error may also be reduced by external adjustment of an optional 5kΩ potentiometer (see Figure 2, page 2).

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West Coast 213/595-1783
Mid-West 312/894-3300
Texas 214/231-5094

SPECIFICATIONS (typical @ +25°C and V_S = ±15V dc, unless otherwise noted)

MODEL	442J	442K	442L
TRANSFER EQUATION	$e_o = \sqrt{avg\ (e_{in})^2}$	*	*
ACCURACY[1]			
Total Error, Sinewave Input, f ≤ 20kHz			
No External Adjustment			
Input Range: 0 to $2V_{rms}$	±2mV ±0.15% of Rdg., max	*	*
External Adjustment			
Input Range: 0 to $2V_{rms}$[2]	±1mV ±0.05% of Rdg., max	*	*
$10mV_{rms}$ to $2V_{rms}$[3]	±0.5mV ±0.05% of Rdg., max	*	*
Additional Error, Sinewave Input, 20kHz ≤ f ≤ 500kHz			
With or Without External Adjustment			
For Any Input Range	(±25µV ±0.0025% of Rdg) x $\left(\frac{f(kHz) - 20kHz}{1kHz}\right)$, max	*	*
vs. Temperature (0 to +70°C), max	±100µV/°C plus ±0.01% of Rdg./°C	±50µV/°C plus ±0.01% of Rdg./°C	±35µV/°C plus ±0.01% of Rdg./°C
vs. Supply Voltage	±0.1mV/%	*	*
Warm-Up Time	5 minutes	*	*
FREQUENCY RESPONSE, SINEWAVE INPUT			
±1% Reading Error[3]			
Input: $7V_{rms}$	500kHz	*	*
$2V_{rms}$	700kHz	*	*
$1V_{rms}$	800kHz	*	*
$0.2V_{rms}$	120kHz	*	*
$0.1V_{rms}$	80kHz	*	*
$0.01V_{rms}$	25kHz	*	*
-3dB Reading Error			
Input: $7V_{rms}$	5MHz	*	*
$2V_{rms}$	8MHz	*	*
$1V_{rms}$	7MHz	*	*
$0.2V_{rms}$	3MHz	*	*
$0.1V_{rms}$	2MHz	*	*
$0.01V_{rms}$	300kHz	*	*
Internal Filter Time Constant	1.5ms	*	*
External Filter Time Constant[4]	15ms/µF	*	*
Total Averaging Time Constant[4]	1.5ms + 15ms/µF	*	*
CREST FACTOR			
±0.2% Additional Reading Error	7	*	*
±0.5% Additional Reading Error	10	*	*
INPUT SPECIFICATIONS			
Voltage			
Signal Range	$\pm 10V_{peak}$ min	*	*
Safe Input	$\pm V_S$	*	*
Impedance	2.5kΩ ±10%	*	*
OUTPUT SPECIFICATIONS[5]			
Rated Output			
Voltage	+10.0V min	*	*
Current	+5mA min	*	*
Impedance	0.1Ω	*	*
Offset Voltage, @ +25°C	±2mV max	*	*
With External 20kΩ Trim Pot	Adjustable to Zero	*	*
POWER SUPPLY[6]			
Voltage, Rated Specifications	±15V dc	*	*
Voltage, Operating	±(6 to 18)V dc	*	*
Current, Quiescent	±12mA	*	*
TEMPERATURE RANGE			
Rated Performance	0 to +70°C	*	*
Operating	-25°C to +85°C	*	*
Storage	-55°C to +125°C	*	*
CASE SIZE	1.5" x 1.5" x 0.4"	*	*
PRICE			
(1–9)	$98	$124	$149
(10–24)	$91	$115	$139

*Specifications same as model 442J.

[1] Error is specified as the sum of two components: a fixed term plus a percentage of output signal (reading). Refer to TOTAL ACCURACY, page 1.

[2] Refer to OPTIONAL AC CALIBRATION PROCEDURE, page 3.

[3] Refer to AC CALIBRATION PROCEDURE, page 3.

[4] Connect optional filter capacitor between pin 1 and pin 2 (see Figure 2). Pin 1 is protected for shorts to ground and the positive supply voltage. Pin 1 is not protected for negative voltage greater than 1 volt.

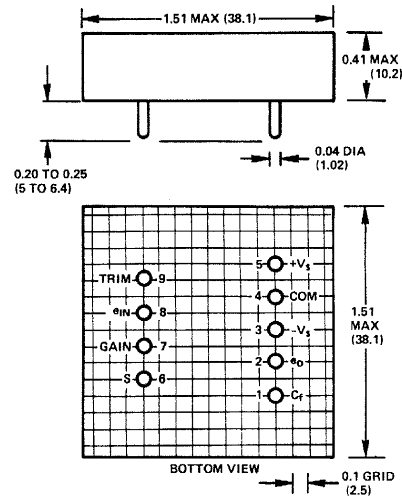
[5] Protected for short circuit to ground and/or either supply voltage.

[6] Recommended power supply: Analog Devices' model 904, $41 (1–9).

Specifications subject to change without notice.

OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).



Weight: 40 grams

MATING SOCKET AC1016
PRICE (1-9) $5.00

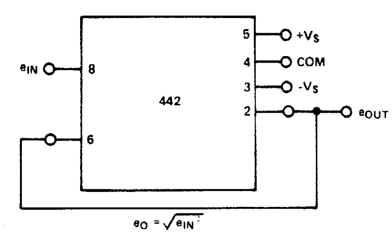
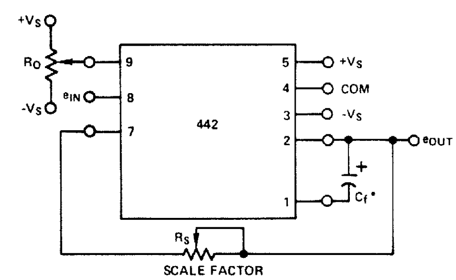


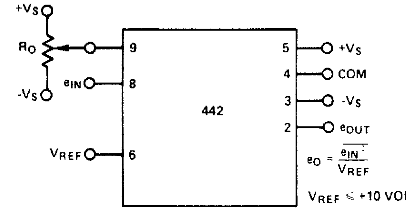
Figure 1. Wiring Connections for RMS Measurements (No External Trim)



R_S = 5kΩ ANALOG DEVICES 79PR5k $5.50 ea. (1-9)
R_O = 20kΩ, ANALOG DEVICES 79PR20k $5.50 ea. (1-9)

*SELECT C_f FOR INCREASED AVERAGING TIME CONSTANT. $\tau(ms) = 1.5 + 15C_f\ (\mu F)$

Figure 2. Optional External Adjustment for RMS Measurements



R_O = 20kΩ, ANALOG DEVICES 79PR20k $5.50 ea. (1-9)

Figure 3. Wiring Connections for Mean Square Measurements with Adjustable Scale Factor (V_{REF})

OPTIONAL EXTERNAL ADJUSTMENT PROCEDURES

In rms designs, high accuracy is achieved by minimizing input and output offsets. Model 442 is internally trimmed for low input offsets and can accurately measure signals as low as 5mV. The optional adjustment trims outlined below (see Figure 2) minimize output error.

DC Calibration Procedure (Allow a 5 min. warm-up)

1. Ground pin 8 and adjust R_O for $e_O = 0$ volts.
2. Apply $1.000V_{dc}$ to pin 8; adjust R_S for $e_O = 1.000V_{dc}$.

AC Calibration Procedure (Allow a 5 min. warm-up)

The ac calibration procedure results in higher accuracy when compared to the DC CALIBRATION PROCEDURE. The AC PROCEDURE yields sinewave error of ±0.5mV ±0.05% of reading maximum, for $10mV_{rms}$ to $2V_{rms}$ inputs. When using the AC CALIBRATION PROCEDURE, use $C_f = 1\mu F$ or larger in order to minimize low frequency errors.

1. Apply a precision $10mV_{rms}$, 1kHz sinewave to pin 8. Adjust R_O for $e_O = 10mV_{dc}$.
2. Apply a precision $1.000V_{rms}$, 1kHz sinewave input to pin 8 and adjust R_S for $e_O = 1.000V_{dc}$.

Optional AC Calibration Procedure

To minimize error at 0 volts and $1V_{rms}$, step 1 above should be modified to read:

1. Ground pin 8 and adjust R_O for $e_O = 0$ volts.

Figure 4 illustrates the results of using the AC CALIBRATION PROCEDURE for zero error at $10mV_{rms}$ and $1V_{rms}$.

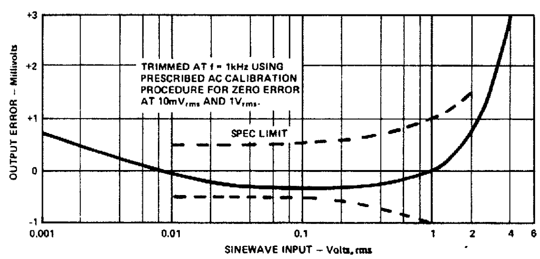


Figure 4. Trimmed Output Error Versus Sinewave Input Level (f = 1kHz)

HIGH FREQUENCY ACCURACY VERSUS SIGNAL LEVEL

Model 442's excellent wideband performance shown in Figure 5 results from its high speed input stage and from the use of reduced values of critical circuit resistance to minimize frequency response degradation due to stray capacitance. A special compensation circuit is also incorporated to extend the bandwidth for low level signals. Model 442 is optimized for operation from $10mV_{rms}$ to $2V_{rms}$ input levels, making it ideal for DVM applications.

The cross-over of the $100mV_{rms}$, and $200mV_{rms}$ curves with the $10mV_{rms}$ curve in Figure 5 results from the nonlinearities that remain after performing the AC CALIBRATION PROCEDURE – refer to Figure 4.

LOW FREQUENCY ACCURACY VS. FILTER CAPACITOR

Figure 6 shows output error versus frequency with external filter capacitor (C_f) as a parameter. This capacitor reduces low frequency error without affecting high frequency accuracy. To select C_f, the lowest frequency component of the input signal (f_L) is determined. Model 442's averaging time constant, $\tau(ms) = 1.5 + 15C_f\ (\mu F)$, is selected to be approximately 10 times the period of f_L. Low leakage capacitors, such as tantalum electrolytic, are recommended.

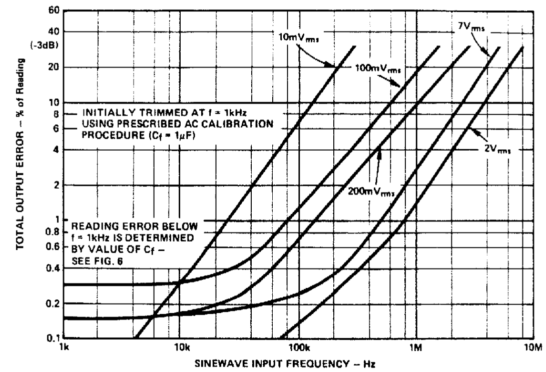


Figure 5. Trimmed Output Error at High Frequency Versus Input Signal Level

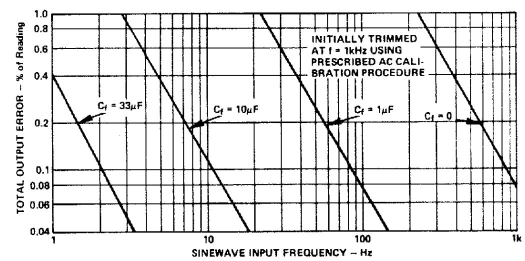


Figure 6. Trimmed Output Error at Low Frequency Versus C_f

SETTLING TIME AND OUTPUT RIPPLE VS. FILTER CAPACITOR

The external filter capacitor affects low frequency accuracy, ripple and settling time. Output ripple is reduced as C_f is increased (see Figure 7). There is no upper limit on the size of C_f, however settling time is increased as C_f increases. Figure 8 shows settling time to 1% accuracy for $1V_{rms}$ step changes. Increasing changes settle in about 3τ; decreasing step changes settle in about 5τ where τ is defined by: $\tau(ms) = 1.5 + 15C_f$.

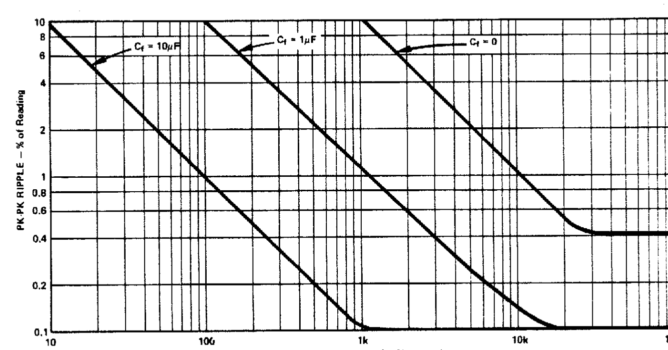


Figure 7. Output Ripple Versus External Filter Capacitor (C_f)

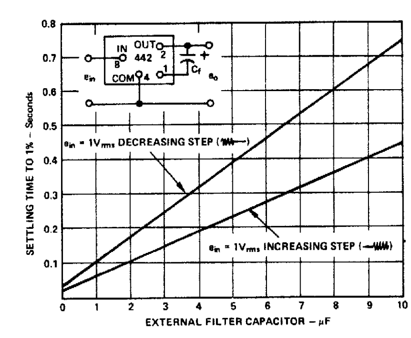


Figure 8. Settling Time Versus Filter Capacitor (C_f)

USING A TWO POLE FILTER FOR LOW RIPPLE AND FAST RESPONSE

The output of model 442 contains an ac ripple signal that introduces a small dc error. Adding external capacitance in parallel with the internal filter capacitor will reduce the ripple, but will result in a corresponding increase in settling time (see Figure 9).

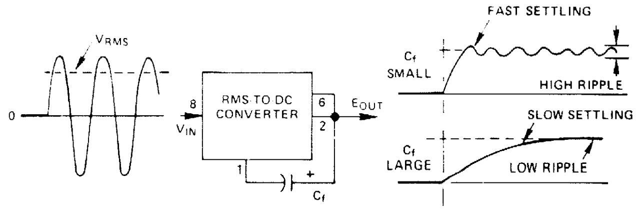


Figure 9. Settling Time and Low Frequency Ripple

A circuit which results in dramatic improvement in ripple while achieving fast settling time is shown in Figure 10. A comparison of ripple for the circuits of Figures 9 and 10 is shown in Figure 11. Percent ripple is plotted as a function of frequency. Note the dramatic reduction of ripple for Figure 10. The frequencies at which 0.1% and 1% ripple occur are reduced by factors of about 80 and 20 respectively.

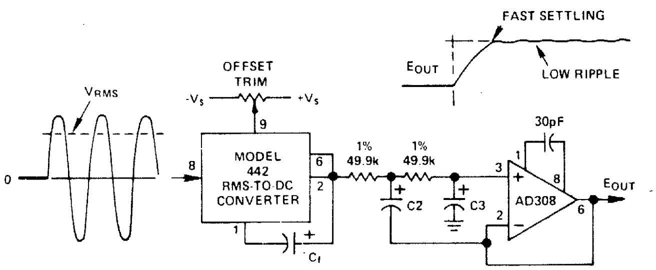


Figure 10. External 2-Pole Filter

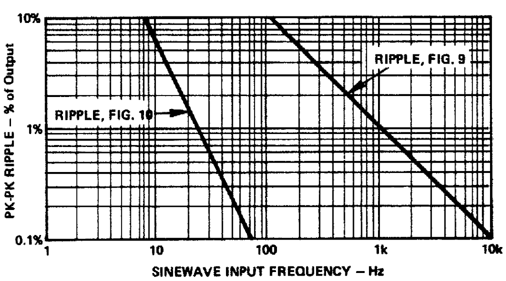


Figure 11. Ripple for Figures 9 & 10; $C_f = 1\mu F$

Figures 12 and 13 make it easy to determine capacitance and settling time to <1%, for a desired percentage ripple and a given lower input frequency, f_L.

1. Determine the lowest frequency, f_L, for which an output ripple of either 1% or 0.1% is desired.
2. Referring to Figure 12, find the value of capacitance, C_1, as the ordinate corresponding to the intersection of f_L and the 1% or 0.1% ripple lines.
3. Calculate values of C_f, C_2 and C_3: $C_f = C_1 - 0.1\mu F$; $C_2 = ½C_1$; $C_3 = 0.7C_2$. Refer to Figure 6 to estimate the low frequency errors corresponding to the selected value of C_f.
4. To find the settling time to <1%, use f_L corresponding to 1% ripple for the chosen C_1, and consult Figure 13. Find the value for settling time at the intersection of f_L and each direction of input rms change (increasing and decreasing).
5. The capacitance values calculated are for signals with C.F. ⩽ 2. For C.F. = 2 to 10, multiply the capacitance values by 10.

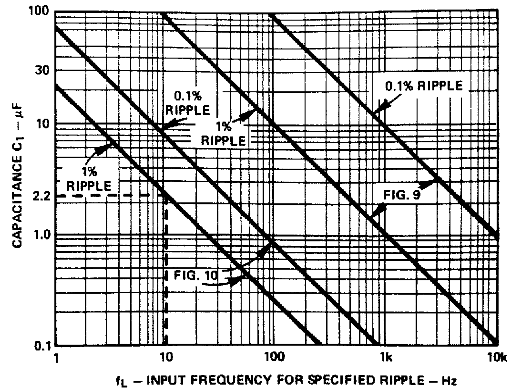


Figure 12. Total capacitance (C_1) as a function of f_L, for 0.1% and 1% pk-pk ripple. For the circuit shown in Figure 10 the resulting capacitor values for 1% ripple at f_L = 10Hz are: C_1 = 2.2µF; C_f = 2.1µF; C_2 = 1.1µF and C_3 = 0.7µF. The settling times are 0.2s (increasing) and 0.4s (decreasing). For corresponding conditions in the circuit of Figure 9, C_1 = 100µF and settling times are 2.8s (increasing) and 4.2s (decreasing).

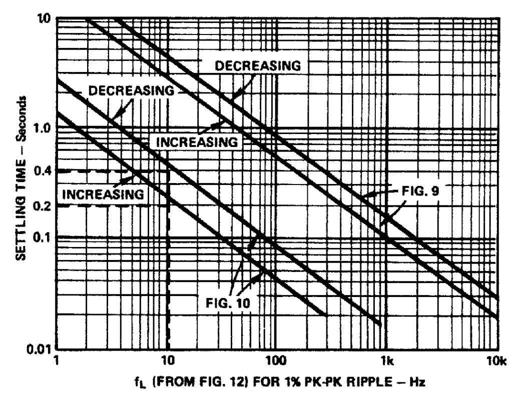


Figure 13. Settling Time to 1% of Step Change of RMS for the Circuits of Figures 9 and 10 as a Function of f_L.

ACCURACY AND SIGNAL CREST FACTOR

Accuracy of true rms measurements on waveforms other than sinewaves is determined from the signal crest factor. Figure 14 is a curve of reading error for crest factors from 1 to 10. In this figure, a $1V_{rms}$ pulse train with variable duty cycle and peak amplitude was selected because of its ability to generate a wide range of crest factors by simply varying the duty cycle (C.F. = $1/\sqrt{\eta}$.) Pulse width is held constant at 200µs to eliminate effects of high frequency error caused by narrow pulse width. RMS level is held constant at 1 volt by varying pulse amplitude. C_f was chosen to be 10µF to minimize the effects of low frequency error.

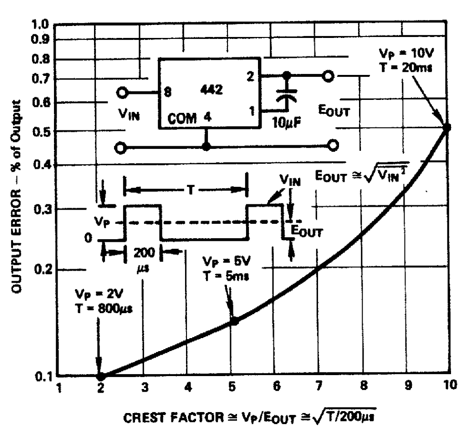


Figure 14. Trimmed Output Error Versus Crest Factor

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