AD2011 -

ANALOG DEVICES

True RMS AC Reading, Multi-Range Digital Panel Meter

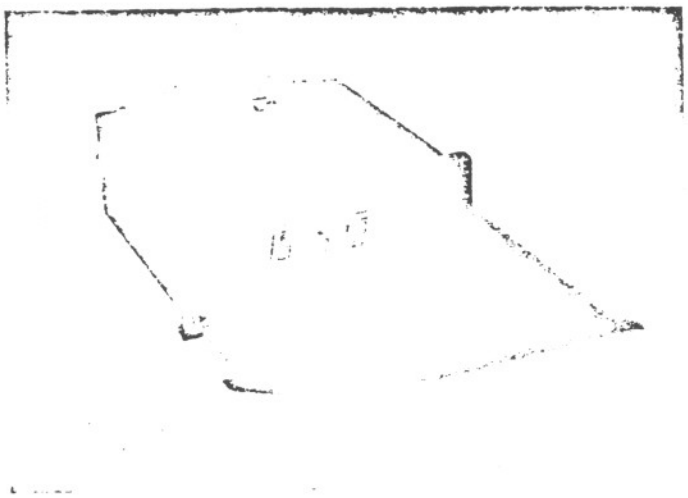
AD2011

FEATURES

- True RMS Measurements
- High Accuracy/Wide Frequency Response
- AC Line Powered
- Bright Seven Segment Gas Discharge Display
- Four Input Ranges: 1V, 10V, 100V, 1000V RMS Full Scale
- Floating Opto-Isolated Input
- BCD Data Outputs
- Programmable Overload

APPLICATIONS

- Accurate True RMS Measurements of Complex AC, or AC + DC Waveforms
- Digital RMS Readout for Test Equipment, Power Controllers, Process Control Equipment and Analytical and Scientific Instruments



Analog Devices' AD2011 is a 3 digit, AC line powered Digital Panel Meter which computes and displays the true RMS value of any AC input. To facilitate application, the AD2011 features four calibrated input ranges of 1V, 10V, 100V and 1000V RMS full scale and has a fully floating, opto-isolated input section that allows making accurate measurements with common mode voltages up to 300V RMS. BCD data outputs and full control signals are provided for interfacing the AD2011 to data logging or digital feedback control systems.

TRUE RMS MEASUREMENTS

Unlike most AC meters which display RMS but measure the rectified average of AC input signals, the AD2011 uses implicit computing techniques to derive the actual RMS value of AC signals. Thus, the accuracy of the AD2011 does not depend on input waveforms. Pulse trains, triangular pulses, and SCR-chopped sinewaves even with high crest factors (ratio of peak to RMS) and pure sinewaves are all measured with high accuracy and no recalibration over a wide frequency range. By using a computing rather than a thermal RMS converter, the AD2011 has a faster response and offers the possibility of extending the low frequency sensitivity by adding an external capacitor. DC or AC+DC inputs are acceptable also; the input of the AD2011 is DC coupled. Or, one can easily AC-couple the input if it is desirable to measure an AC signal riding on a constant DC voltage, as in measuring the ripple of a DC power supply.

Table 1 shows how well the AD2011 DPM performs for typical waveforms encountered in general applications, including worst case pulse trains, compared to the performance of the most commonly used "averaging" type meters, calibrated for RMS of a sinewave.

WAVEFORM		TYPICAL AD2011 ERROR	TYPICAL "AVERAGE" RESPONDING METER ERROR
	Sinewave	±0.2%	±x%
	Symmetrical Square Wave	±0.5%	±x% +11% (High)
	Triangular or Sawtooth	±0.4%	±x% -4% (Low)
	Gaussian Noise	±0.4%	±x% -11.3% (Low)
	Pulse Train (10% Duty Cycle)	±0.9%	±x% -30% to -65% (Low)
	SCR'D (90° Firing)	±0.9%	±x% -14% to -28% (Low)
	Sinewave (110° Firing)	±0.9%	±x% -20% to +3% (Low)

Table I. AD2011 Performance

FOUR CALIBRATED INPUTS

Realizing the difficulty of designing and calibrating accurate AC attenuators, Analog Devices breaks from DPM tradition and provides four separate inputs on the AD2011 — 1V, 10V, 100V and 1000V RMS full scale. Factory calibration provides excellent accuracies on all four ranges, but if only one range is needed, proper calibration will yield an error of ±0.1% reading ±0.1% full scale ±1 digit on that range. By using transformer

(continued on page 3)

Route 1 Industrial Park; P.O. Box 280; Norwood, Mass. 02062
Tel: 617/329-4700 TWX: 710/394-6577
West Coast 213/595-1783 Mid-West 312/894-3300 Texas 214/231-5094

SPECIFICATIONS (typical @ +25°C unless otherwise noted)

DISPLAY
- Beckman Gas Discharge, Seven Segment, 0.55" High (1.4cm) Displays
- Overload, Center Segment Dashes
- Decimal Points Selectable at Input Connector
- Display Blank
- Display Test

INPUT (Full details on input ranges given in Table 2)
- Type: Single-Ended, Floating, DC Coupled
- Overrange Capacity: (not displayed)
  40% on 1, 10, 100V RMS ranges
  10% on 1kV RMS range

TEMPERATURE RANGE
- Operating: 0 to +50°C
- Storage: –40°C to +85°C

CONVERSION RATE
- Internal Trigger: 5 conv/sec
- External Trigger: 90 conv/sec maximum
- Hold and Read on Command

CONVERSION TIME
- 11msec max

RESPONSE TIME
- Internal Time Constant: 170msec
- Settling Time to 0.1% RDG at Full Scale: 1.30 sec
- Provisions for external capacitor to extend low frequency response (see application section)

INTERFACE SIGNALS
- DTL/TTL Compatible

	IN	OUT
Logic "0"	<0.8V	<0.4V
Logic "1"	>2.0V	>2.4V

- Inputs
  Hold – Logic "0" or grounding on this input disables the internal trigger and the results of the last conversion are held and displayed. Applying a hold input during conversion will allow that conversion to be completed and that reading will then be held (1TTL load).
  External Trigger – Operation in external trigger mode requires the hold input to be a logic "0" or grounded. Logic "0" pulse applied to this input will initiate a conversion (1TTL load).
  External Blank – A logic "0" at this input will blank all segments of the display. Conversions are not affected (1TTL load).
  Display Test – Logic "1" on this input will turn on all segments of the display. During this test, conversions are disabled. If a conversion is in progress when a display test is made, invalid data is produced (10TTL loads).
  Overload Input – A logic "1" to "0" transition at this input sets the overload latch causing the status output to reset, and the display to dash. In normal use, the 800BCD output is connected to this input to give a full scale count of 999. However, other BCD outputs (or logic combinations) can be used to provide any full scale count (see application section) (1TTL load).
  Decimal Points – Grounding the appropriate pin will illuminate the desired decimal point. If external control is desired, any external drive circuitry must be capable of withstanding 90V when the decimal points are turned off (not TTL/DTL compatible).
- Data Outputs
  Status – A logic "1" at this output shows that a conversion is in progress. BCD data is valid when status is at logic "0" (drives 6TTL loads).
  BCD Outputs – Twelve lines bring out positive true data for three digits. Data is not latched and is valid only when the status output is a logic "0" (drives 6TTL loads).
  Overload – A logic "1" on this output shows that the input has exceeded the DPM's pre-programmed overload state. (The AD2011 requires the overload input be connected for the overload output to appear.) (drives 6TTL loads.)

POWER
- AC line, 5 watts (see options)

WARMUP
- 20 minutes to specified accuracy

ADJUSTMENTS
- Input Offset
- Zero Width
- Gain
- Recommended Calibration Interval – 6 months

SIZE
- 4.18" Width x 1.93" Height x 4.48" Depth (106 x 49 x 114mm)
- 5.10" (130mm) max to Rear Connector

WEIGHT
- 20 ounces (567 grams)

OPTIONAL FEATURES AND ORDERING GUIDE
- Power Supply Inputs:
  AD2011 115VAC ±10% 50–60Hz
  AD2011/E 220VAC ±10% 50–60Hz
  AD2011/H 240VAC ±10% 50–60Hz
  AD2011/F 100VAC ±10% 50–60Hz

PRICE
- 1–9, $295
  (Consult factory for OEM quantity pricing)
- Display Lens Options
  Lens 7* – Red with ADI logo
  Lens 8 – Red without ADI logo
  Lens 13 – Amber with ADI logo
  Lens 14 – Amber without ADI logo
  *Lens 7 is supplied if no lens option is specified.
- Connectors
  P1 – 36 pin, 0.0156" Spacing Card Edge Connector, Viking #2Vk 18D/1–2 or Equivalent
  P1 – Optional Order AC2610 at $5.00 each
  P2 – 30 pin, 0.0156" Spacing Card Edge Connector, Viking #2Vk, 15D/1–2 or Equivalent
  P2 – Optional Order AC1501 at $3.50 each

(continued from page 1)

and opto-isolation techniques, common mode voltages up to 300V RMS can be accommodated, even with digital outputs and control lines connected. This not only facilitates making measurements in various electrical environments, but is essential in making current measurements, which are rarely referenced directly to ground.

LARGE, BRIGHT, EASILY READ DISPLAYS

The AD2011 displays the digital output on large (0.55″) high Beckman seven segment gas discharge displays. These displays are easily read at distances up to 50 feet (15 meters) and over viewing angles of 130° in all ambient lighting conditions. Controls are provided for three decimal points, display testing by illuminating all segments, and blanking the entire display. The AD2011 is provided with a special, non-glare lens available in red or amber.

NEW POSSIBILITIES FOR APPLICATIONS

With the availability of the AD2011, the cost of making true RMS measurements has decreased significantly. Now, many measurements can be made more accurately by replacing iron-vane analog meters or average reading meters with the AD2011. Some of these applications include:

- Measurements of SCR chopped waveforms from lighting, motor and furnace controllers.
- Noise and vibration measurements.
- Accurate measurement of transformer parameters.
- Fluid flow measurement.

DESIGNED AND BUILT FOR RELIABILITY

High reliability has been designed into the AD2011. In the AD2011, IC technology is utilized to minimize parts count and lower heat dissipation for cooler operation. Manufacturing processes are controlled by continuous quality assurance inspections to insure proper workmanship and testing. Like every other Analog Devices' DPM, the AD2011 is fully tested for electronic specifications and is given one full week of failure-free burn-in before shipment. The design, manufacturing and testing procedures at Analog Devices are designed to insure reliable DPMs.

DESCRIPTION OF OPERATION

The block and timing diagram for the AD2011 is shown in Figures 1 and 2. The front end consists of frequency compensated input attenuators for the 10V, 100V and 1kV range a protected input for the 1V range, and an RMS converter. The RMS converter combines logarithmic and implicit computing techniques, as opposed to explicit schemes, to achieve low overall error and wide dynamic range (i.e., $VRMS = \sqrt{\frac{1}{T}\int_0^T Vin^2\,dt}$, implicitly $VRMS = \overline{V_{in}^2}/VRMS$ – see Figure 3).

The signal from the converter is fed into a single slope A/D converter. Once triggered, a capacitor in the ADC charges linearity up to the DC level present at the RMS converter output. While this is taking place, the logic processor is counting clock pulses. Once the ADC comparator sees that the capacitor has reached the same level as the RMS converter output, the counter is stopped and the count proportional to the RMS input is displayed. Each conversion can take as much as 11msec to be completed for full scale reading. Conversion is terminated (counter is stopped) by the comparator switching state, or in the case of an input overload, the counter going into a pre-programmed overload state. This overload count can be programmed by gating the appropriate BCD outputs into the overload input line. To use the counter up to a 999 full scale count, it is only necessary to connect the 800s BCD line to the overload input line (see text on programming overload in Application section). Using the internal trigger command, 5 conversions per

RANGE	999mV	9.99V	99.9V	999V
SPECIFICATION[1]				
Resolution	1mV	10mV	100mV	1V
Input Impedance	100MΩ/10pF	100kΩ/300pF	1MΩ/30pF	10MΩ/3pF
Bias Current	10nA	0	0	0
Maximum Safe Sustained Overvoltage	240V RMS (340VP)	125V RMS (180VP)	300V RMS (425VP)	1100V RMS (1555VP)
Accuracy[2] DC or 45-1kHz Sinewave	±0.1%RDG/±0.1% FS/±1 Digit	±0.3%RDG/±0.1% FS/±1 Digit	±0.3%RDG/±0.1% FS/±1 Digit	±1%RDG/±0.1%FS/ ±1 Digit
Temperature Coefficient Gain -	±.03%RDG/°C	±.03%RDG/°C	±.03%RDG/°C	±.03%RDG/°C
Zero -	<±80μV/°C	<±800μV/°C	<±8mV/°C	<±80mV/°C
Crest Factor 100% FS -	7 Max	7 Max	3 Max	1.4 Max
25% FS -	10 Max	10 Max	10 Max	5 Max
Common Mode Rejection	100dB @ 60Hz	80dB @ 60Hz	60dB @ 60Hz	40dB @ 60Hz
Common Mode Voltage	300V RMS @ 60Hz	300V RMS @ 60Hz	300V RMS @ 60Hz	300V RMS @ 60Hz
Frequency Response -3dB-	30Hz – 300kHz	30Hz – 300kHz	30Hz – 300kHz	30Hz – 10kHz
1%	45Hz – 50kHz	45Hz – 50kHz	45Hz – 50kHz	45Hz – 1kHz
Volt X Frequency Limit	10^6 V-Hz	10^7 V-Hz	10^7 V-Hz	10^7 V-Hz

[1] Specifications typical at 25°C unless otherwise noted.
[2] AD2011 units are calibrated at the factory to these specifications. Individual ranges can be calibrated for ±0.1%RDG ±0.1%FS ±1 digit accuracy at the expense of higher errors on the other ranges.

Table 2. AD2011 Specification Table

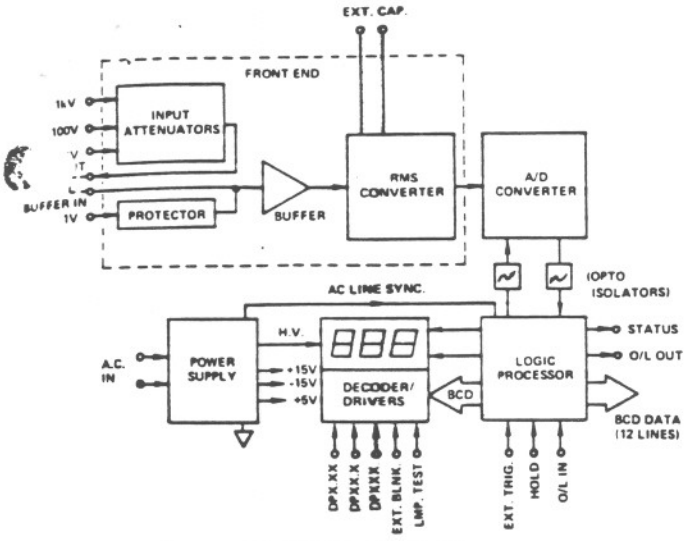


Figure 1. AD2011 Block Diagram

second are made. External triggering will allow up to 90 conversions per second. The conversions are synchronized so as to be performed during the negative half cycle of the power line when the display is blanked, thereby eliminating display flicker.

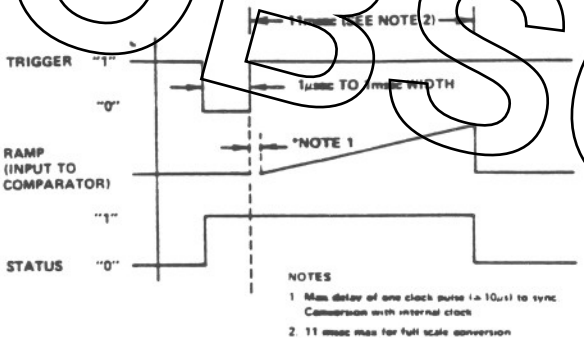


Figure 2. AD2011 Timing Diagram

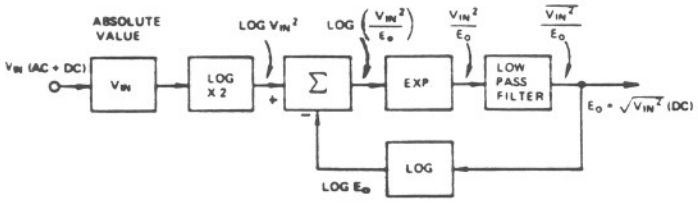


Figure 3. AD2011 Log-Antilog RMS to DC Converter (using Implicit Computing)

MEASURING VARIOUS INPUT RANGES

The AD2011 is designed to measure the RMS value of inputs over ranges of 1, 10, 100 and 1000V RMS full scale without the need of scaling the inputs externally. When using the 10V, 100V and 1000V input ranges, it is only necessary to connect the attenuator output to the buffer input with a short jumper (Pins P and S of the P2 connector). Disconnect the attenuator [illegible] sing the 1V range. Only one input range should be con- . and shielded or coaxial cable is recommended. If a manual switch is used for changing input ranges, the switch must be of the break-before-make type to prevent damage to the AD2011 input, and care should be taken to insure that the unused input ranges are completely disconnected.

ELIMINATING AC LINE NOISE EFFECTS

The AD2011 DPM is an AC line powered, AC measuring device. It can be used in laboratories as well as noisy environments, such as factories and machine shops. Noise occurring in the AC line due to other sources – motors, heaters, machines – connected to it can affect the reading of the DPM. To eliminate this source of error, a 470μH R.F. choke can be connected in series with each of the three wires of the AC line at the P1 connector of the DPM. For safety, always use 3 wire AC only.

MEASUREMENTS OF VERY LOW FREQUENCIES

If the input signal to be measured has a frequency of DC to about 45Hz, the AD2011 will "track" the input signal and the constantly changing readout may be difficult to read. To extend the low frequency response of the AD2011, two pins are provided at the connector P2 to allow an external capacitor to be attached. Table 3 will aid in choosing the proper value of external capacitance.

FREQUENCY	CAPACITOR VALUE	SETTLING TIME TO 1% ACCURACY	SETTLING TIME TO 0.1% ACCURACY
30Hz	4.7μF	0.5 sec	2.0 sec
20Hz	15.0μF	1.0 sec	3.0 sec
10Hz	80.0μF	7.0 sec	10.0 sec
5Hz & below	Consult Factory		

Table 3. Capacitor Selection For Extended Low Frequency Response

CAUTION: Polarity is important. A high quality, low leakage electrolytic capacitor (10V minimum rating) should be used with plus (+) on Pin B (external capacitor) and minus (-) on Pin A (external capacitor) at connector P2.

PROGRAMMABLE OVERLOAD INPUT

The AD2011 DPM features overload indication by showing dashes on the center segments of the Beckman displays. A logic "1" also appears at overload output, Pin J, of the connector P1. Normally, the AD2011 is shipped with this feature disconnected. To program the DPM to indicate an overload condition at the next count after 999, connect the 800's BCD output, Pin S, to the overload input, Pin L, of the connector P1. When the count exceeds 999, the 800's BCD output transitions from logic "1" to logic "0". This "trailing edge" transition triggers the DPM to indicate an overload condition.

The AD2011 can be programmed to indicate "overload" at any count between 000 to 999 by connecting appropriate BCD outputs through external logic. Figure 4 shows a schematic of one suggested method of programming the AD2011. In this example, 495mV RMS was chosen as a full scale value.

OVERRANGE

The AD2011 DPM is capable of accurately measuring input voltages 40% over the full scale count of 999 on the 1V, 10V and 100V input ranges, without overrange indication (the 1kV range is limited to 10%). By leaving the overload input Pin L, connector P1, open, the DPM counter will continue to count while the display will have returned to all zeros and progressed from there. External logic and indicators can be used to indicate that the range of the displays has been exceeded.

AC OR DC COUPLING

The AD2011 provides accurate measurements of AC, DC or AC+DC waveforms. The input ranges are internally DC coupled and the AD2011 measures the RMS value of AC+DC input

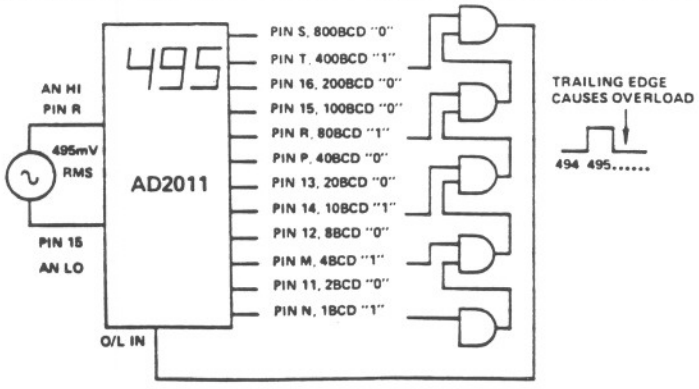


Figure 4: This schematic shows the state of each BCD output line with an input of 495mV RMS. Those lines deemed to be at logic "0" are left open, and those at logic "1" are connected to the AND gates. When the input comes up to 495mV RMS, a logic "1" appears at the O/L input. Should the input go beyond, the O/L input will have a logic "1" to logic "0" transition which will cause the DPM to indicate an "overload" condition.

voltages. If measurements of AC voltages riding on a DC offset are desired, the AD2011 must be AC coupled to remove the DC component. For AC coupling, a blocking capacitor connected in series with DPM input is needed (Figure 3). Table 4 provides the proper choice of blocking capacitor and resistor. To cover the complete response of the AD2011, the capacitor under the 45Hz column is needed. For very low frequencies, use the capacitor indicated under the 10Hz column.

INPUT RANGE	RESISTOR	BLOCKING CAPACITOR FOR 1% ERROR AT FREQUENCY 45Hz	10Hz	MINIMUM CAPACITOR VOLTAGE RATING[1]
1V	100kΩ	0.33μF	2.0μF	100V
10V	n/a[2]	0.33μF	2.0μF	100V
100V	n/a	0.033μF	0.2μF	300V
1000V	n/a	3300pF	0.02μF	1kV

[1] NOTE: Capacitor voltage rating should accept the maximum peak AC voltage plus the DC component.
[2] Not Applicable

Table 4. Blocking Capacitor and Resistor Selection for AC Coupling AD2011

DIGITAL DATA OUTPUTS

The digital data outputs are unlatched, positive true, parallel BCD, at DTL/TTL logic levels. All data outputs are valid when the STATUS line is low (logic "0"). Erroneous data will be present when the conversion is in process and the STATUS line is high.

EXTERNAL CONTROL SIGNALS

External Hold

Logic "0" or grounding the HOLD input disables the internal trigger, and the last conversion is held and displayed. If a HOLD input is applied during conversion, the conversion will be completed and displayed. No further conversions will be made unless the HOLD input is removed or an EXTERNAL TRIGGER pulse is applied.

External Trigger

Operating in the EXTERNAL TRIGGER mode requires that the HOLD line be held at logic "0" or grounded. A negative going trigger pulse (logic "1" to logic "0" and return) of 1μs minimum and 1ms maximum width applied to the trigger input

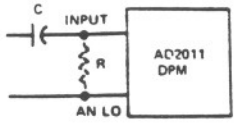


Figure 5. AC Coupling AD2011 Input

will initiate a conversion. The external trigger input will initiate a conversion. The external trigger input must be a pulse since the STATUS is set on the negative-going edge of the pulse and the conversion is initiated on the positive-going edge of the pulse. Triggering at high rates asynchronously with line frequency may cause modulation of the display brightness, since the display is blanked both during conversion and during the negative half of the line cycle. Care should be taken to insure that triggering does not occur during conversion, as this will cause an erroneous conversion.

Decimal Points

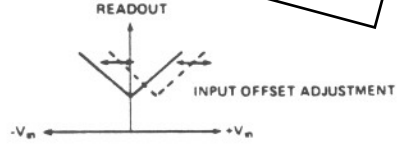
Grounding the appropriate pin will illuminate the desired decimal point. If external control is desired, any external drive circuitry must be capable of withstanding 90V when the decimal points are turned off.

AD2011 CALIBRATION PROCEDURE

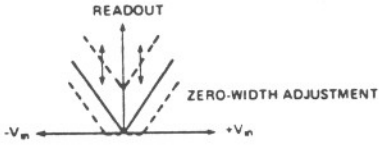
"WARNING: For the safety of personnel and interconnected equipment, all calibration adjustments should be made using a plastic calibration tool."

Remove panel meter lens and observe location of adjustments (see Figure 7).

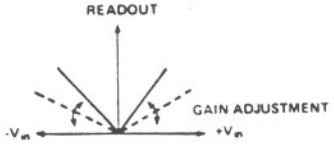
1) Turn zero width adjustment fully clockwise.
2) *Ground 1V input range by shorting Pin R to analog low, Pin 15 at input connector (P2). Adjust input offset for a minimum reading on display.



3) Return zero width adjustment until display *just* transitions to zero. (Further return on this adjustment will cause an error in near zero readings.)



4) Remove short and apply a calibrated DC voltage of some value near full scale (example; +900mVDC for the 1V full scale range). Adjust gain for a display reading of the input voltage. Reverse polarity of input voltage and check display. Reading should be within ± one digit.



*Note: If only one range is used for a particular application, use the input pin for that range for optimum calibration (see Note 2, Table 2).

P1

PIN REF	PIN FUNCTION	PIN REF	PIN FUNCTION
1	AC RTN	A	AC RTN
2	–	B	–
3	AC HI	C	AC HI
4	–	D	–
5	DIG GND/AC COMMON	E	–
6	DPX.XX	F	DPXXX.
7	LAMP TEST	H	DPXX.X
8	HOLD	J	O/L OUT
9	STATUS	K	EXT TRIGGER
10	EXT BLANK	L	O/L IN[2]
11	2	M	4
12	8	N	1
13	20	P	40
14	10	R	80
15	100	S	800
16	200	T	400
17	–	U	–
18	ANALOG LO	V	–

KEY=

P2

PIN REF	PIN FUNCTION	PIN REF	PIN FUNCTION
1	–	A	EXT CAP (-)
2	–	B	EXTERNAL CAP (+)
3	–	C	–
4	–	D	–
5	–	E	1000V[1]
6	–	F	–
7	–	H	–
8	–	J	–
9	–	K	–
10	–	L	–
11	ANALOG LO	M	100V[1]
12	ANALOG LO	N	10V[1]
13	ANALOG LO	P	ATTEN. OUT
14	ANALOG LO	R	1V
15	ANALOG LO	S	BUFFER IN

KEY=

1) When using the 10V, 100V or 1000V input ranges, a connection must be made between the attenuator out (Pin P) and Buffer In (Pin S) on P2. Disconnect this jumper when using the 1V input.

2) To provide overload indication for readings greater than 999, connect 800 BCD output (Pin S) to overload input (Pin L) on P1. Always connect the overload input.

Figure 6. AD2011 Signal & Pin Designation

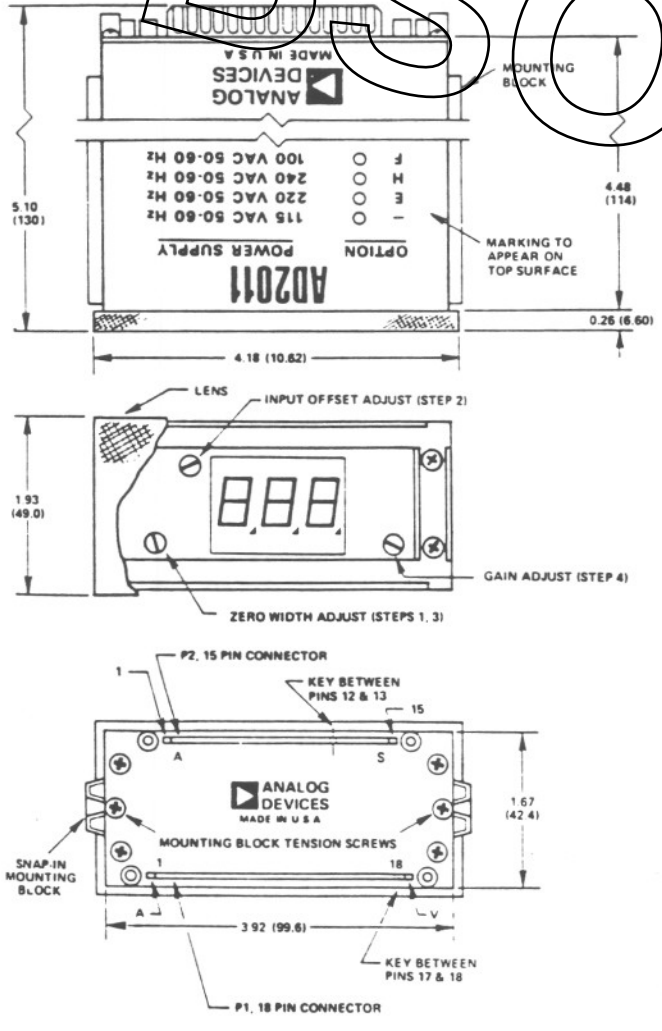


Figure 7. AD2011 Mechanical Outline (Dimensions shown in inches and (mm))

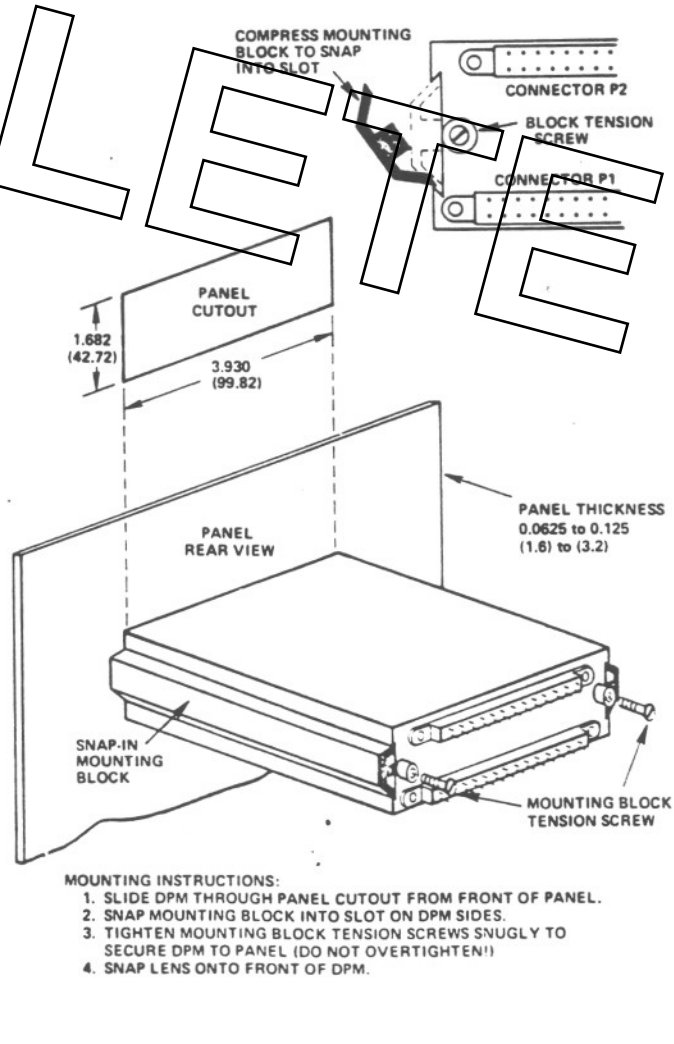


Figure 8. AD2011 Mounting Instructions (Dimensions shown in inches and (mm)).