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Institute of
Oceanographic Sciences
Deacon Laboratory

INTERNAL DOCUMENT No. 350

Interface for calibration tank

P K Smith

1995

Natural Environment Research Council

INSTITUTE OF OCEANOGRAPHIC SCIENCES
DEACON LABORATORY

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DOCUMENT DATA SHEET

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Interface for calibration tank.

REFERENCE

Institute of Oceanographic Sciences Deacon Laboratory, Internal Document, No. 350, various pagination. (Unpublished manuscript)

ABSTRACT

This instrument is designed to interface between the output from temperature sensors and a PC386 computer when calibrating the temperature sensors.

The output from the sensors is a frequency which varies with temperature and this is converted to digital signals for the computer. For the convenience of the operator the frequency and amplitude are displayed on the front panel

KEYWORDS

TEMPERATURE CALIBRATION
TEMPERATURE SENSORS

ISSUING ORGANISATION

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INTRODUCTION

The Calibration Interface is designed to interface between the output from a temperature sensor and a PC 386 Computer when calibrating the temperature sensors. The output from the sensors is a frequency which varies with temperature and this is converted to digital signals for the computer. For the convenience of the operator the frequency and the amplitude is displayed on the front panel.

DESCRIPTION OF CALIBRATION FACILITY

The calibration facility consists of a Grant temperature controlled tank with cooler unit, the IOS designed Calibration Interface board 90-1, tank interface circuit , oscilloscope and a Tandon 386 PC.

The calibration Interface contains the 4 interface boards 90-1, the tank interface circuit, an rms. to dc converter and power supplies. Also on the front panel is a voltmeter and a frequency meter

INPUTS

The inputs are shown on a separate diagram. In summery they are;

6 Psychrometers

4 SST's

2 Air Temperature sensors

2 Spare channels

OPERATION OF THE CALIBRATION INTERFACE.

For a complete description of the calibration procedure refer to "MultiMet Temperature Sensor maintenance and calibration" by K G Birch & P K Smith, Internal Document No. 310. Here follows a simplified set of instructions for the operation of the Calibration Interface.

Set up the temperature sensors in the tank. Start the software and this will indicate which channels to use. Connect the sensor outputs to the channel inputs on the Calibration interface as indicated by the software with the LEMO to XLR leads. Use the 4 way for Psychrometers and air temperature sensors and 3 way for the SST's. Connect the BNC output to an oscilloscope.

Check the sensors are working by switching through all the channel which are in use with the rotary switch and also switch from wet to dry in the psychrometers channels. Ensure the amplitude is between 2.5 and 3.5 volts. The frequency reading will depend on the tank temperature and the type of sensor. Observe the wave form on the oscilloscope which should be a sine wave.

If all sensors are working correctly switch from manual to auto and continue with the calibration.

When the calibration has finished the amplitude, and wave form is entered in the history file for Vector psychrometers. As the amplitude varies slightly with tank temperature this measurement is done at about 18 C. Switch to manual and set the temperature on the tank Controller. The frequency is also noted when using the sensor interface tubes where the sensors are replaced with a standard resistor.

Finally connect the Cannon lead to the Calibration Interface and to the Canon on the Psychrometer and check the motor. Make a note in the history file if noisy or not running.

CIRCUIT DESCRIPTION

RMS. to DC converter

This is a true rms. to dc converter. The usual method is ac averaging and is performed by taking the absolute value of a signal (full or half wave rectification), filtering it, and scaling by the ratio of rms. to ac average which for sine waves will be a ratio of 1.111 This will only read correctly for undistorted sine waves. As some of the interfaces have distorted outputs the method used here is for any wave shape. First is to take the absolute value, square it, and divide by the fed-back output (using the logarithmic characteristics of transistor junctions), and filter the result. The resulting approximation

$$E_O = \text{Avg.}\{ V_{in}{}^2 / E_O \} = \sqrt{\text{Avg.}(V_{in}{}^2)}$$

is valid if the averaging time constant is sufficiently long compared with the periods of the lowest frequency components of the signal. The circuit is based around the integrated circuit Maxim MX536 AJD.

The input impedance of this circuit is not large. The data sheet quotes 16.7 kΩ. This reduces the measured value about 25%. A unity gain operational amplifier buffers the signal to provide more accurate measurements. The rms. to dc converter and the operational amplifier is supplied from the +12V supply. The negative 12 volt rail is provide by a 7661 integrated circuit.

Calibration Board IOSDL 90-1

Introduction

This is a brief introduction to the calibration board. The board is one of four circuit boards to provide optically isolated inputs to a Tandon PC.. These optically isolated inputs to isolate the electronic interfaces of the various temperature sensing devices from the counter board. This counter board has internal timing to measure the frequency output from the temperature interface circuits.

On the first board only channels 5 and 6 are used, the first four are cascaded to provide a 1ns gate for the opto-isolators. On the last board there are two spare channels that have not been allocated. These have no input wiring, or opto-isolators, but are otherwise fully populated.

Power for the boards is provided by the PC. However power for the electronic interfaces is provided by a 24 volt power supply limited to 500mA.

The inputs of the boards are connected to the XLR connectors on the front panel, and then connected to the electronic interfaces of the temperature sensors with four core METVIN cable The outputs are connected with 60 way ribbon cable to the rear panel connectors and to the PC with 60-way ribbon cable.

Construction Notes

Unfortunately whilst designing the printed circuit board, the 60 way connector was placed upside down on the board. Rather than go through the laborious task of redesigning the board, it was decided to put a half twist in the 60-way cable from the PC. Also since it the board that is odd, the twist is on the board 60-way socket.

Several mistakes are also present on the board these have been ringed on the enclosed photocopy of the PCB layout.

1) The lower pad of diode D2 should be connected to pin 2 of IC 2

2) On IC 3 there should be no connection to pin 3 instead it should be connected to pin 2.

3) On the 60-way connector pins 55 and 56 should not be connected together.

TABLES OF CONNECTIONS

The wiring for the METVIN cables is shown in table 1.

The connectors used on the cables are as follows

Psychrometer and Air Temps.	4 way LEMO series 3	4 way XLR
SST's	3 way LEMO series 3	3 way XLR

Cable Wiring

Psychrometer and Air Temperature Cables			
LEMO Pin No.	Colour	XLR Pin No.	Signal
1	Red	1	+24V
2	Blue	2	Dry channel
3	Green	3	0V
4	Yellow	4	Wet channel
Case	Screen	Case	
SST Cables			
1	Red	1	+24V
2	Blue	2	Dry output
3	Green	3	0V
n.c.	Yellow	n.c.	
Case	Screen	Case	

Front panel XLR connectors to Interface PCB

Board 1	Signal	XLR	Pin No.
1	Channel 6	FP1	4
2	0V		
3	n.c.		
4	n.c.		
5	n.c.		
6	n.c.		
7	Channel 5	FP1	2
8	0V		
9	n.c.		
10	n.c.		
11	n.c.		
12	n.c.		

Board 2	Signal	XLR	Pin No.
1	Channel 12	FP 4	4
2	0V		
3	Channel 10	FP 3	4
4	0V		
5	Channel 9	FP 3	2
6	0V		
7	Channel 11	FP 4	2
8	0V		
9	Channel 8	FP 2	4
10	0V		
11	Channel 7	FP 2	2
12	0V		

Board 3	Signal	XLR	Pin No.
1	Channel 18	FP 8	2
2	0V		
3	Channel 15	FP 6	2
4	0V		
5	Channel 16	FP 6	4
6	0V		
7	Channel 17	FP 7	2
8	0V		
9	Channel 14	FP 5	4
10	0V		
11	Channel 13	FP 5	2
12	0V		

Board 4	Signal	XLR	Pin No.
1	n.c.		
2	n.c.		
3	Channel 22	FP 12	2
4	0V		
5	Channel 21	FP 11	2
6	0V		
7	n.c.		
8	n.c.		
9	Channel 20	FP 10	2
10	0V		
11	Channel 19	FP 9	2
12	0V		

Rear panel 60 way connectors from interface PCB

Pin No.	Designation	Board 1	Board 2	Board 3	Board 4
1	+5V				
2	+5V				
7	0V				
8	0V				
13	0V				
14	0V				
16	Input		Channel 7	Channel 13	Channel 19
18	Gate		Channel 7	Channel 13	Channel 19
19	0V				
20	0V				
22	Input		Channel 8	Channel 14	Channel 20
24	Gate		Channel 8	Channel 14	Channel 20
25	+12V				
26	0V				
28	Input	Channel 5	Channel 11	Channel 17	Channel 23
30	Gate	Channel 5	Channel 11	Channel 17	Channel 23
31	+5V				
32	+5V				
37	0V				
38	0V				
43	0V				
44	0V				
45	Link *				
46	Input	Channel 3	Channel 9	Channel 15	Channel 21
48	Gate	Channel 3	Channel 9	Channel 15	Channel 21
49	0V				
50	0V				
51	Link *				
52	Input	Channel 4	Channel 10	Channel 16	Channel 22

54	Gate	Channel 4	Channel 10	Channel 16	Channel 22
55	+12V				
56	0V				
58	Input	Channel 6	Channel 12	Channel 18	Channel 24
60	Gate	Channel 6	Channel 12	Channel 18	Channel 24

CIRCUIT DIAGRAMS

General Arrangement

Interface

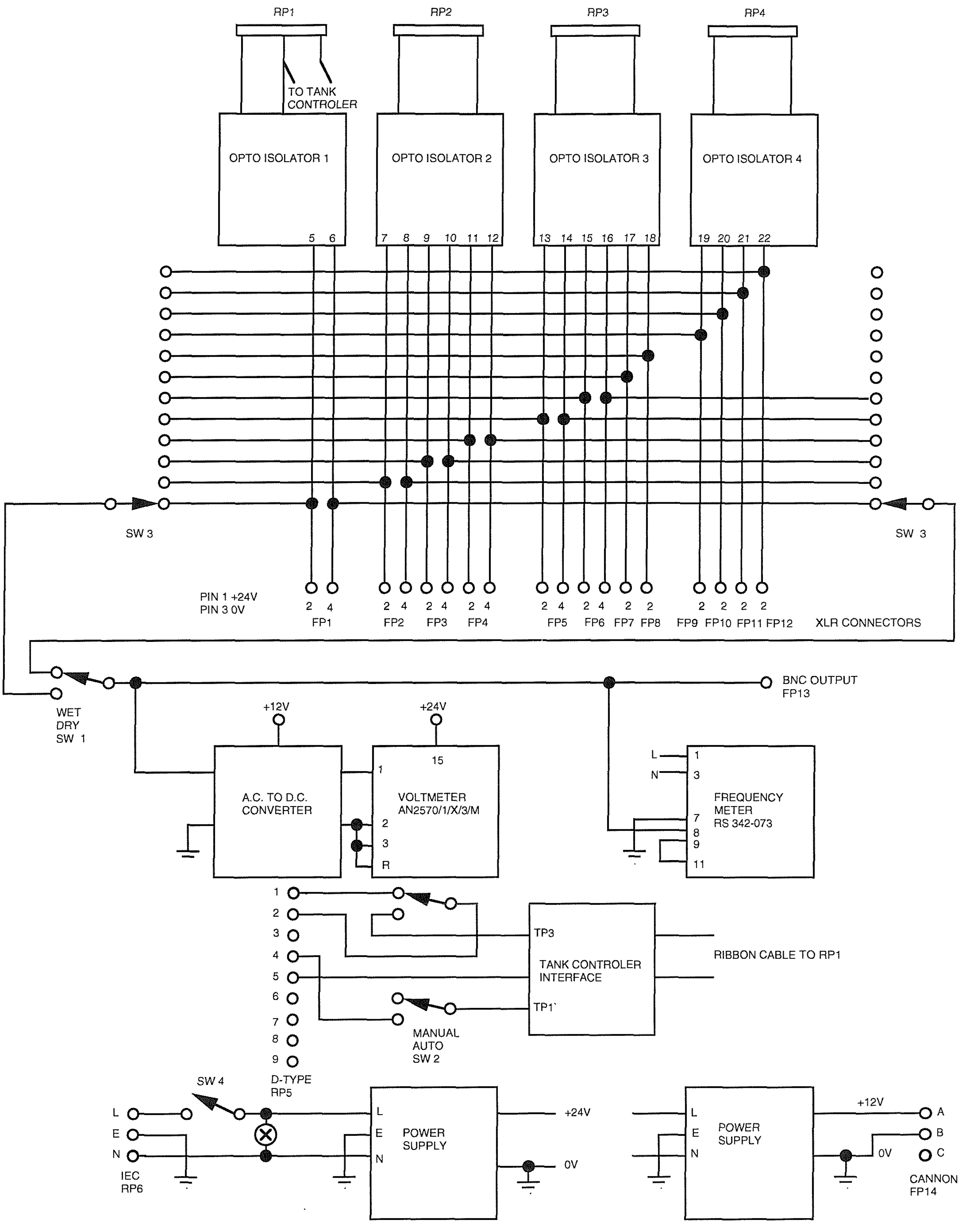
ac to dc converter

Parts Lists

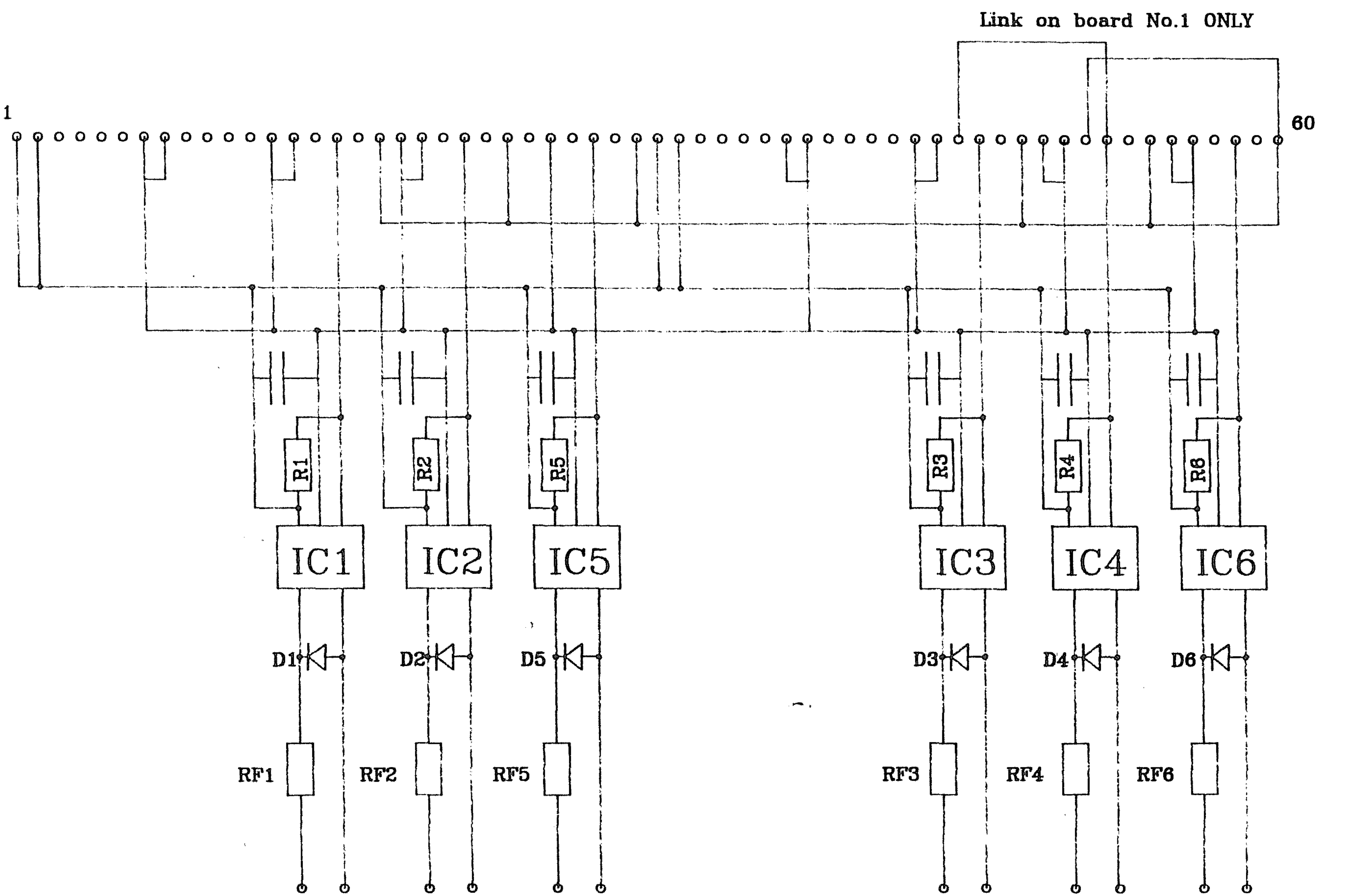
PCB Layout

Component location layout

Channel location on PCB



TITLE:- GENERAL ARANGEMENT
DRN:- PKS
DATE:- 31/03/1995



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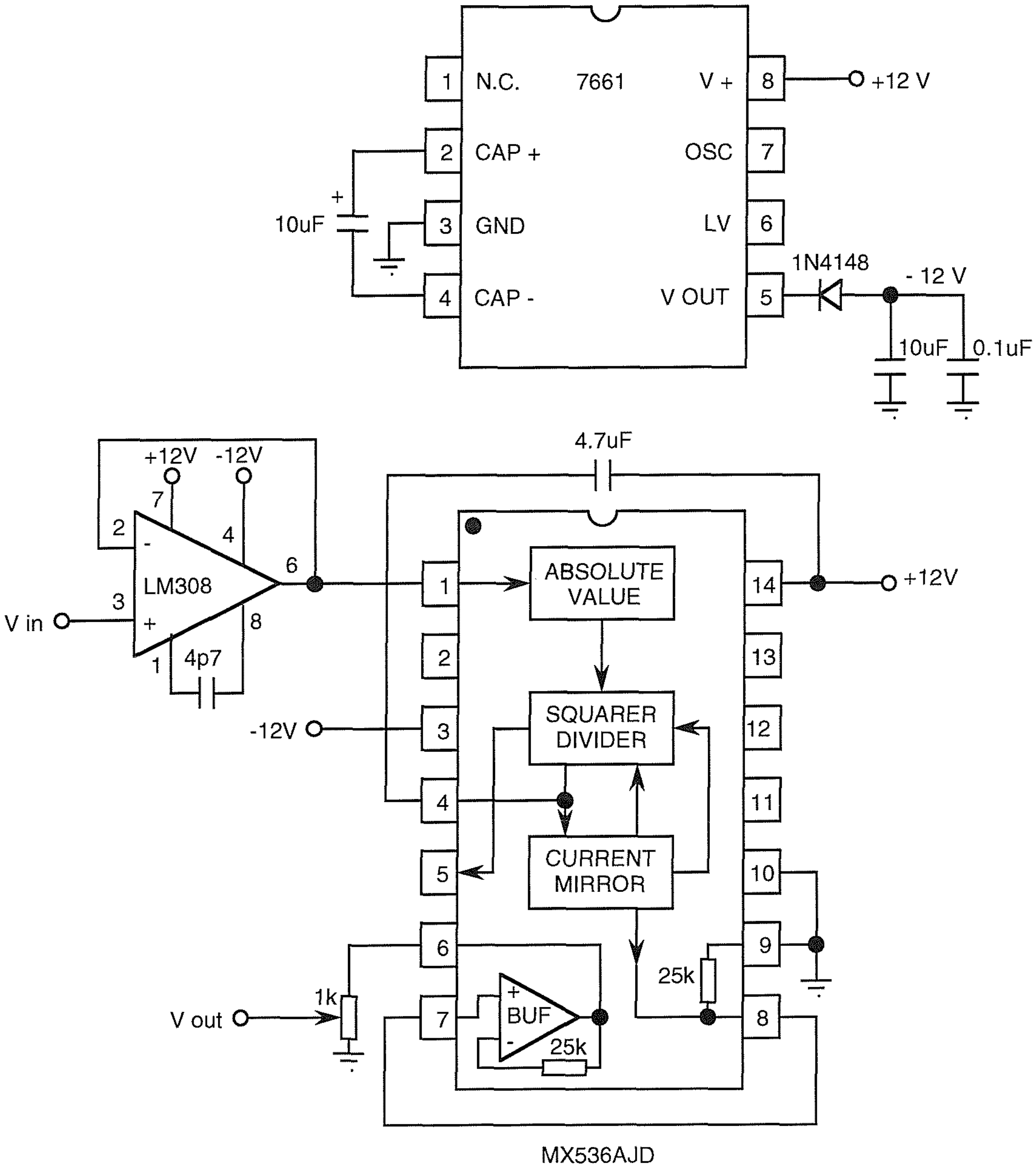


TITLE:- A.C. TO D.C. CONVERTER
DRN:- PKS
DATE:- 31/03/1995

Electronic Component Description					Identification		
Circuit Diagram Symbol	Name	Rating	Grade	Type	Trade or Suppliers Name	Reference Number	Alternatives or Remarks
	Interface x 4						
R1 - R6	Resistor	1/8 W		560R	Stores		
RF1 - RF6	Resistor	1/8 W		1k	Stores		
C1 - C6	Capacitor			0.1μF	Stores		
D1 - D6	Diode			1N4148	Stores		
IC1 - IC6	Integrated Circuit			H11L1			
PL 1	Connector			60 way			
Pl2	Connector			12 way	FEC 105-369		
	A.C. to D.C.						
R1	Potentiometer			1 k	Stores		
C1	Capacitor			4.7uF	Stores		
C2	Capacitor			4p7	Stores		
C3	Capacitor			10uF	Stores		
C4	Capacitor			10uF	Stores		
C5	Capacitor			100nF	Stores		
D1	Diode			1N4148	Stores		
IC1	Integrated Circuit			MX536AJD	FEC		
IC2	Integrated Circuit			LM308	Stores		
IC3	Integrated Circuit			7661	RS 633-773		

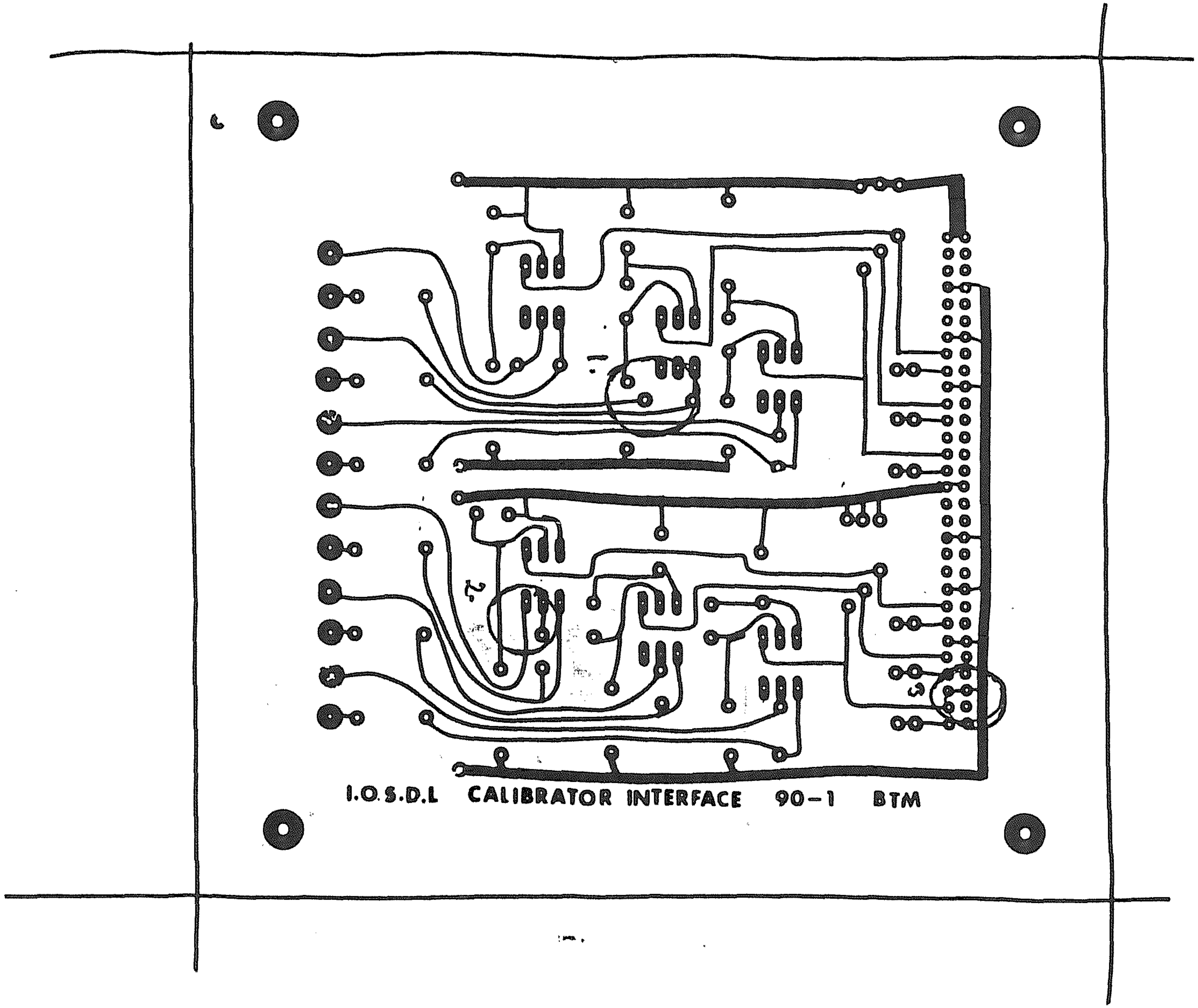
ReIC4marks	Issue	Date	Remarks	Issue	Date	Remarks	Issue	Date

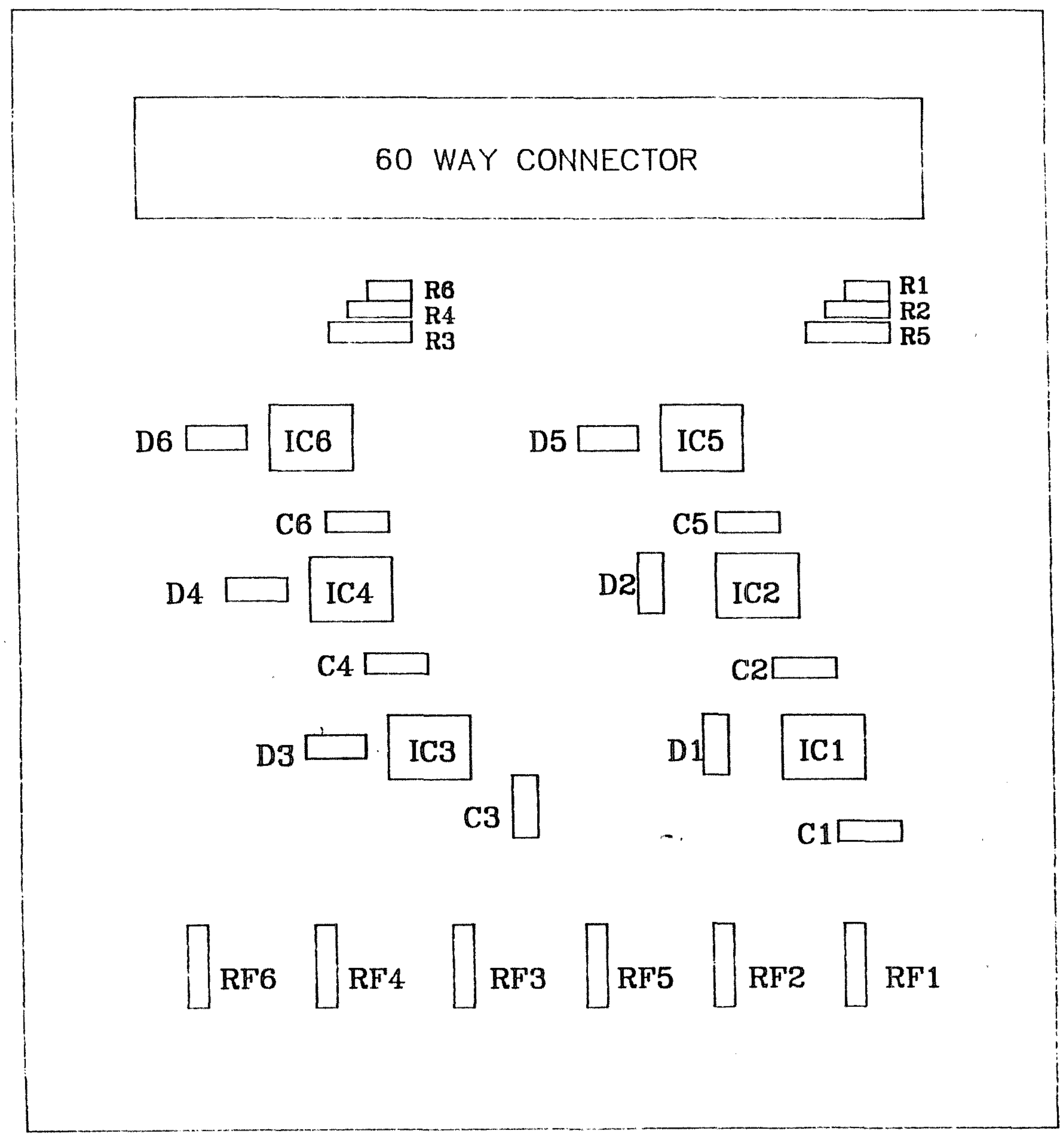
	Electronics Comps Drg No. I.O.S./
	Compiled By PKS
	Sheet Number 1
Institute Of Oceanographic Sciences	**Date 31/03/1995**

Electronic Component Description					Identification		
Circuit Diagram Symbol	Name	Rating	Grade	Type	Trade or Suppliers Name	Reference Number	Alternatives or Remarks
IB1	Interface Board				G & B REF. 1463		
PS1	Power Supply			+12V	RS 591-310		
PS2	Power Supply			+24V	RS 591-326		
VM	Voltmeter			AN2570/1/X/3/M			
FM	Frequency Meter				RS 342-073		
SW1	Switch			DPDT	RS 330-985		
SW2	Switch			DPDT	RS 330-985		
SW3	Switch			12 way 2 Wafers	RS 327-894	RS 327-136	
SW4	Switch			SPST Illumated	RS 199-166		
FP1-6	Connector			XLR 4 Way	RS 405-657		
FP7-10	Connector			XLR 3 Way	RS 405-613		
FP11-12	Connector			XLR 4Way	RS 405-657		
FP13	Connector			BNC	RS 455-674		
FP14	Connector			Cannon 3 way			
RP1-4	Connector			60 Way IDC	FEC 622 6016ES		
RP5	Connector			9 Way D Type	Stores		
RP6	Connector			Mains IEC	RS 489-122		
	Control knob				RS 500-077		
	Case			Style 5	RS 222-086		

Remarks	Issue	Date	Remarks	Issue	Date	Remarks	Issue	Date

Institute Of Oceanographic Sciences	**Electronics Comps Drg No. I.O.S./**
	Compiled By PKS
	Sheet Number 2
	Date 31/03/1995


I.O.S.D.L CALIBRATOR INTERFACE 90-1 BTM



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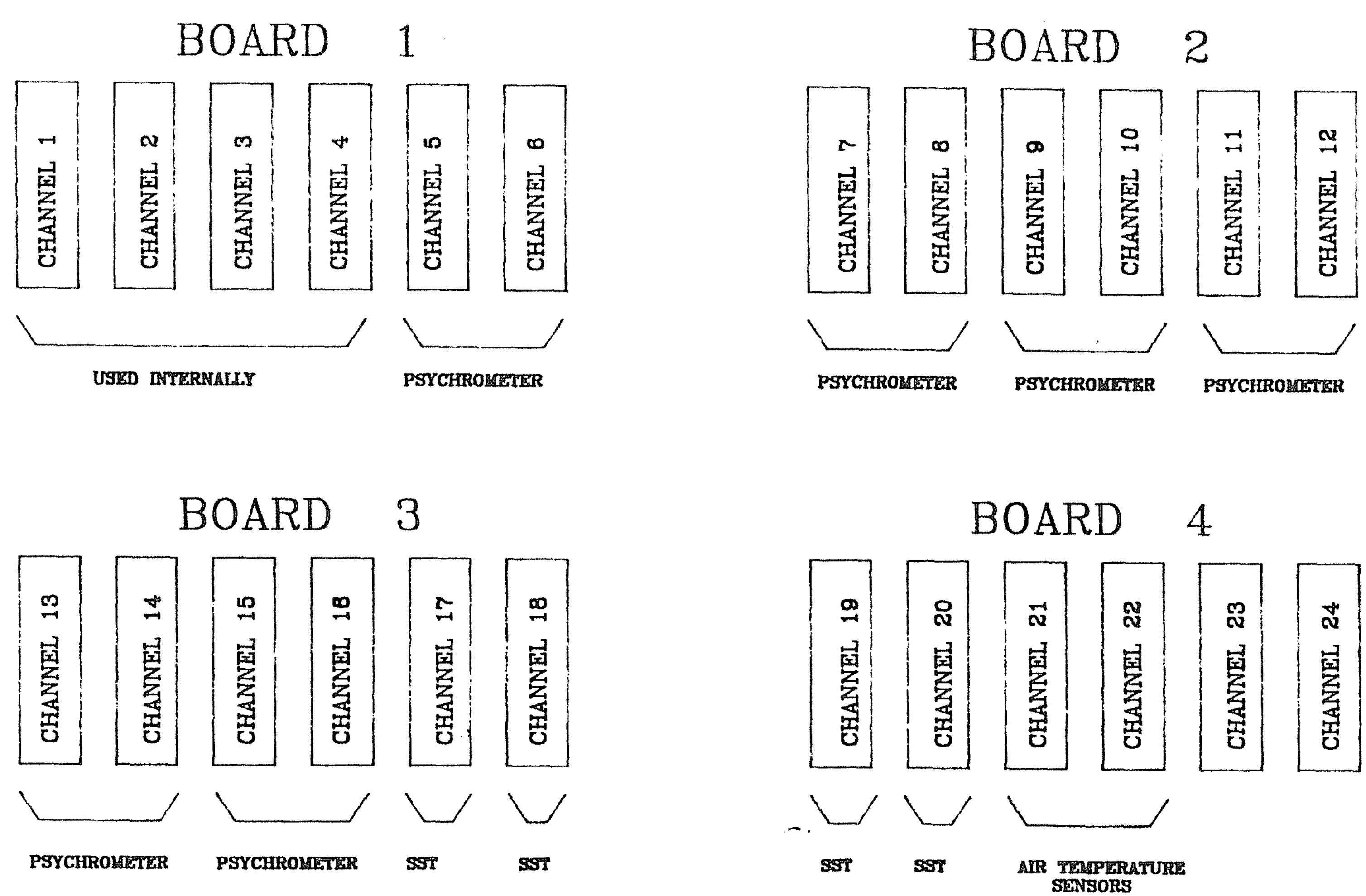

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MECHANICAL DRAWINGS AND DATA SHEETS

Mechanical Drawings

ac to dc data sheet

Volt meter data sheet

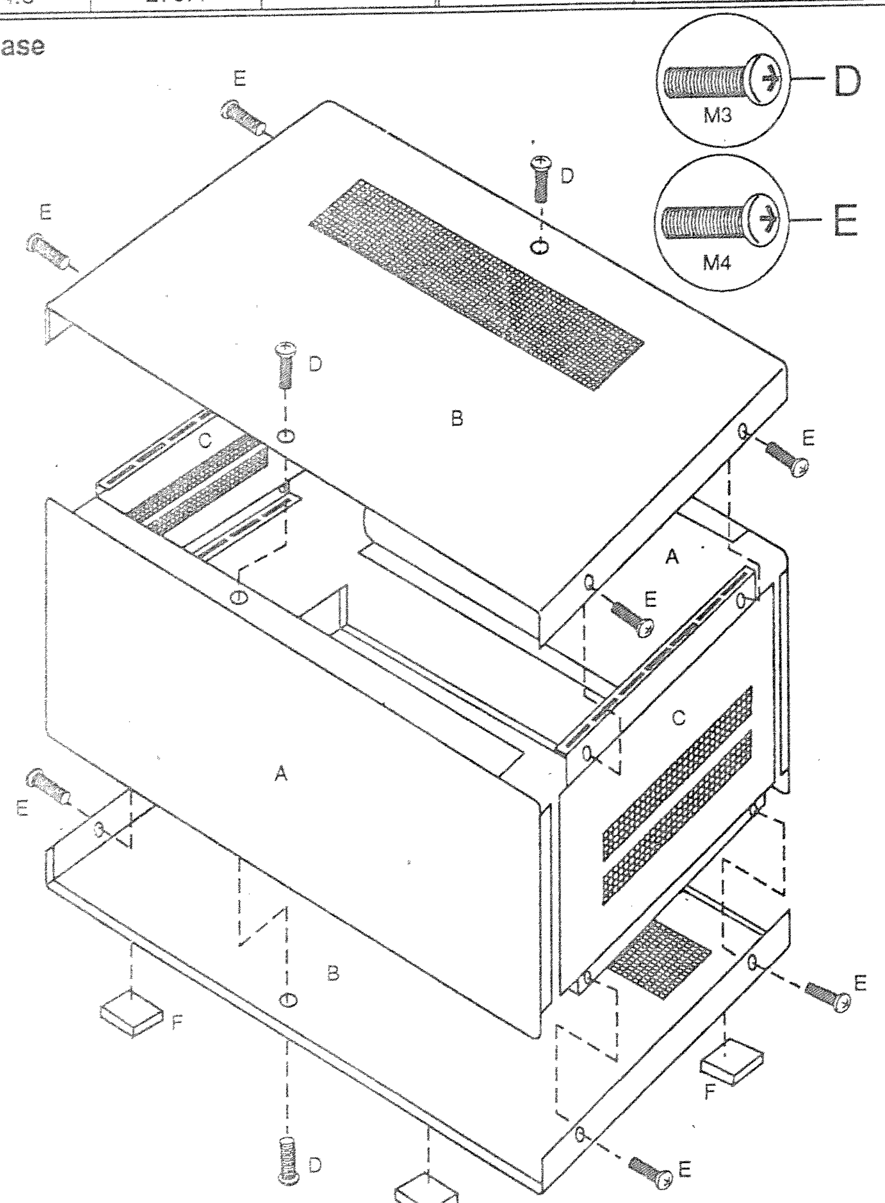
Frequency meter data sheet

Metal Cases

This instruction leaflet covers the following products:-

RS Stock No.	W	D	H	RS Stock No.	W	D	H
222-020	203.2	177.8	65	222-064	304.8	279.4	132.6
223-992	203.2	177.8	88.1	222-086	304.8	279.4	177
222-042	203.2	279.4	65	224-010	304.8	279.4	211.5
223-988	203.2	279.4	132.6	224-026	431.8	177.8	65
222-036	304.8	177.8	65	222-070	431.8	279.4	132.6
223-994	304.8	177.8	177	222-092	431.8	279.4	177
224-004	304.8	279.4	65	224-032	431.8	279.4	211.5
222-058	304.8	279.4	88.1				

Exploded View of Case



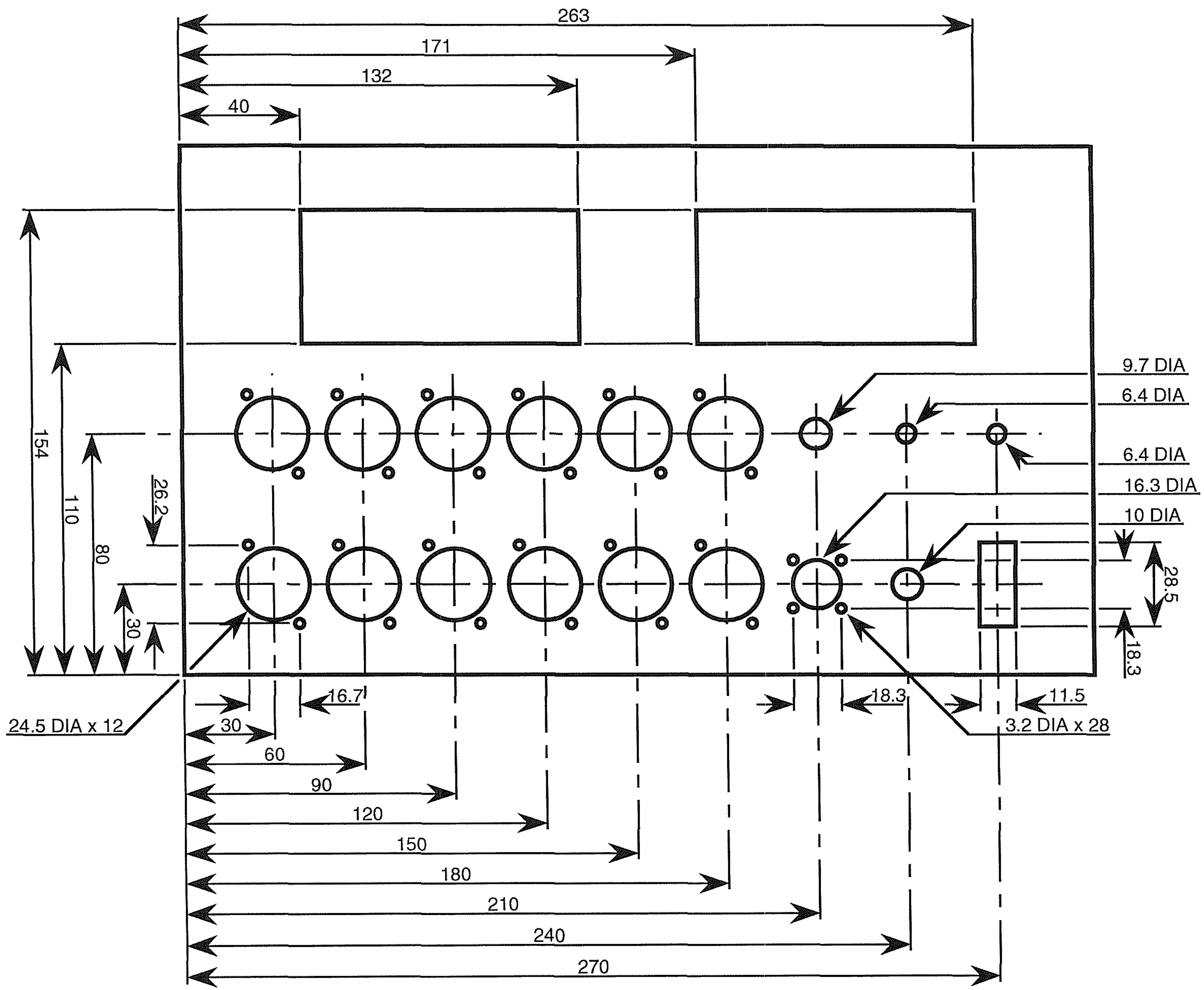
Case Contents

A. 2-off front and rear painted panels.
B. 2-off top and bottom painted covers.
C. 2-off painted side panels.
D. 4-off round head M3 screws.
E. 8-off round head M4 screws.
F. 4-off self-adhesive rubber feet.

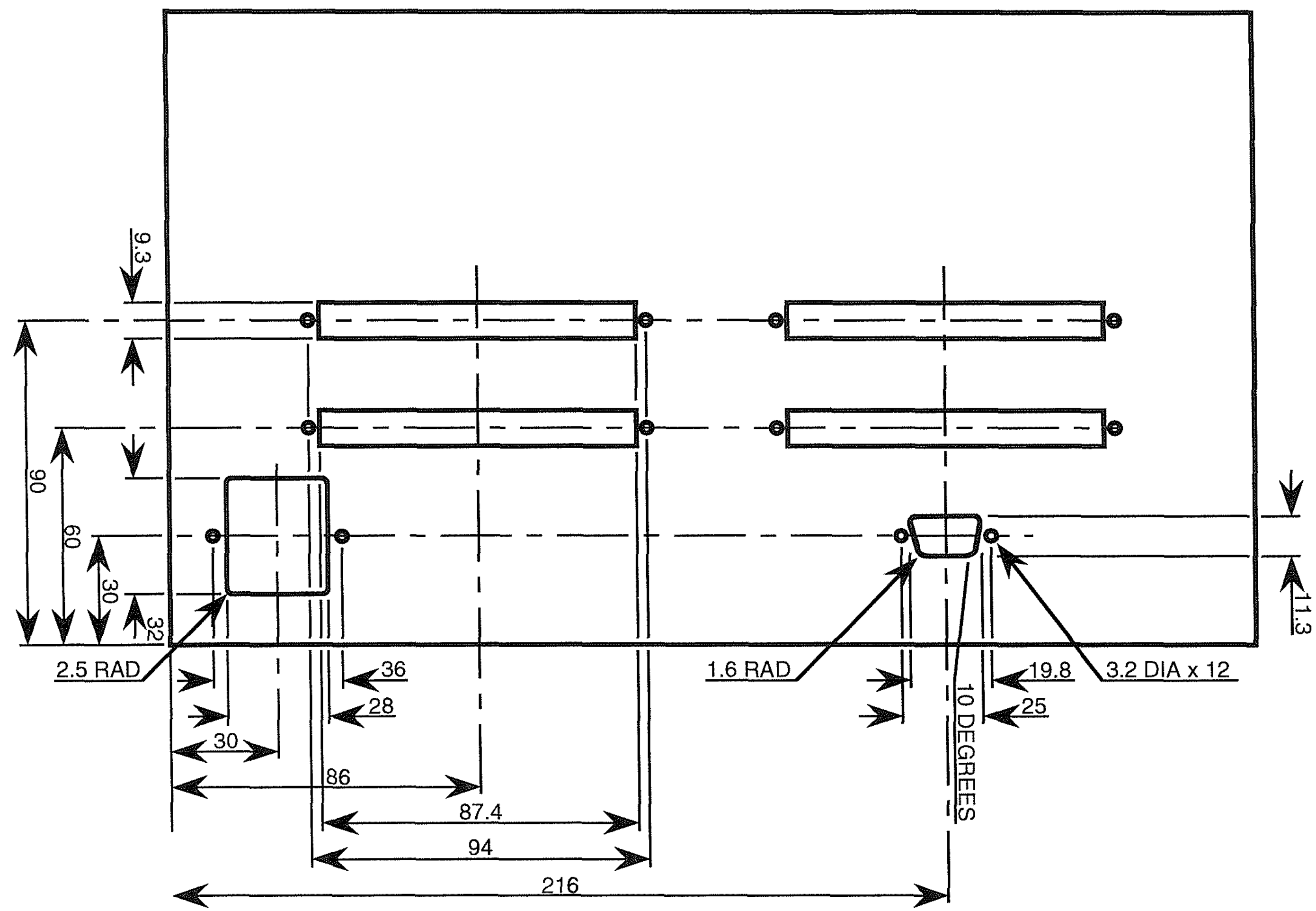
Case Assembly

1. Attach the side panels to the base using 4 of the M4 screws provided.
2. Attach the front and rear panels using 2 of the M3 screws provided.
3. Secure the top panel to the base assembly using 4 of the M4 screws and 2 of the M3 screws as per steps 1. and 2.
4. Attach the 4 self-adhesive rubber feet to the base, case assembly is now complete.

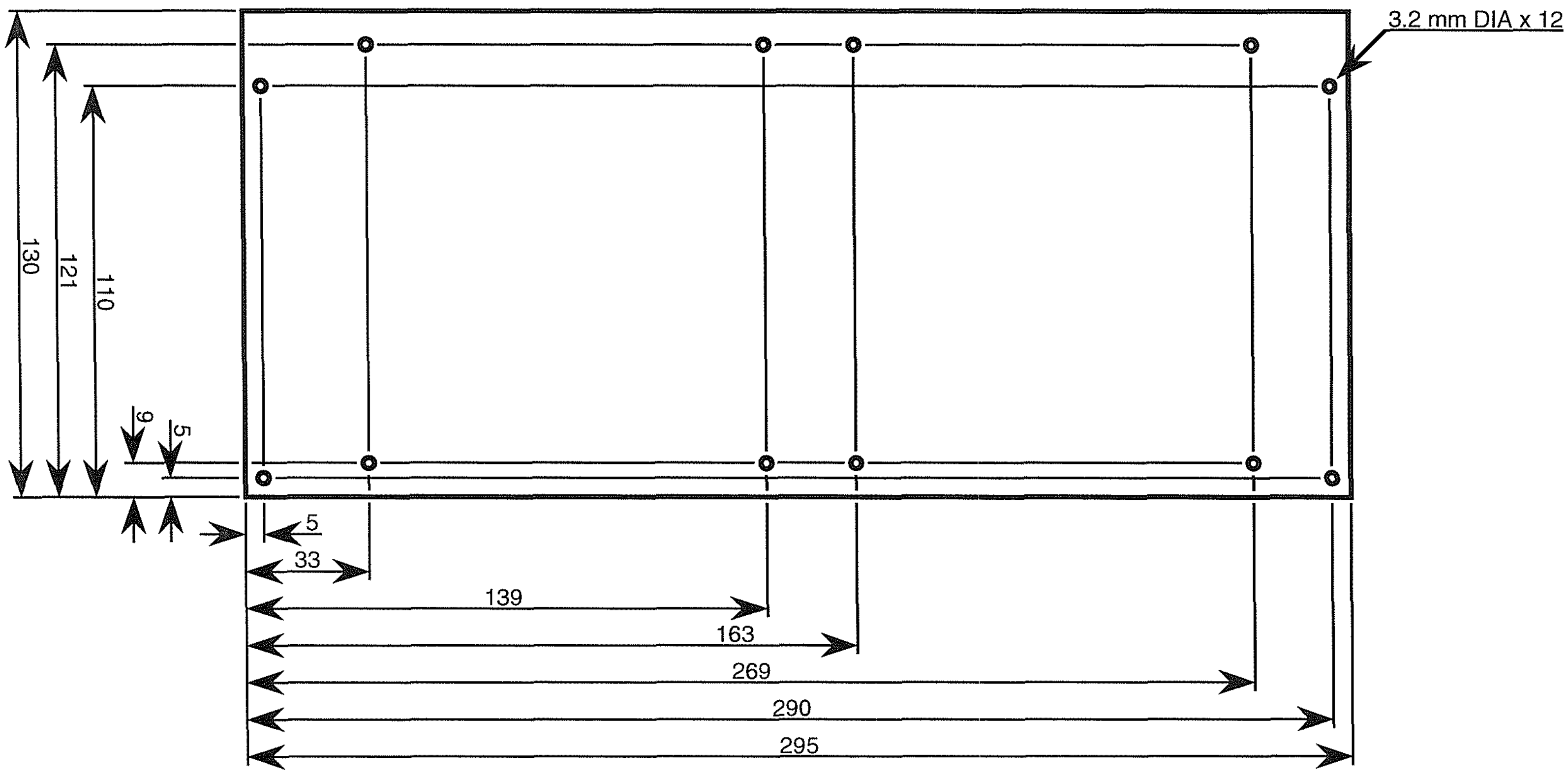
Note: The side panels incorporate slotted brackets which are ideal for supporting PCBs or chassis plates inside the case.



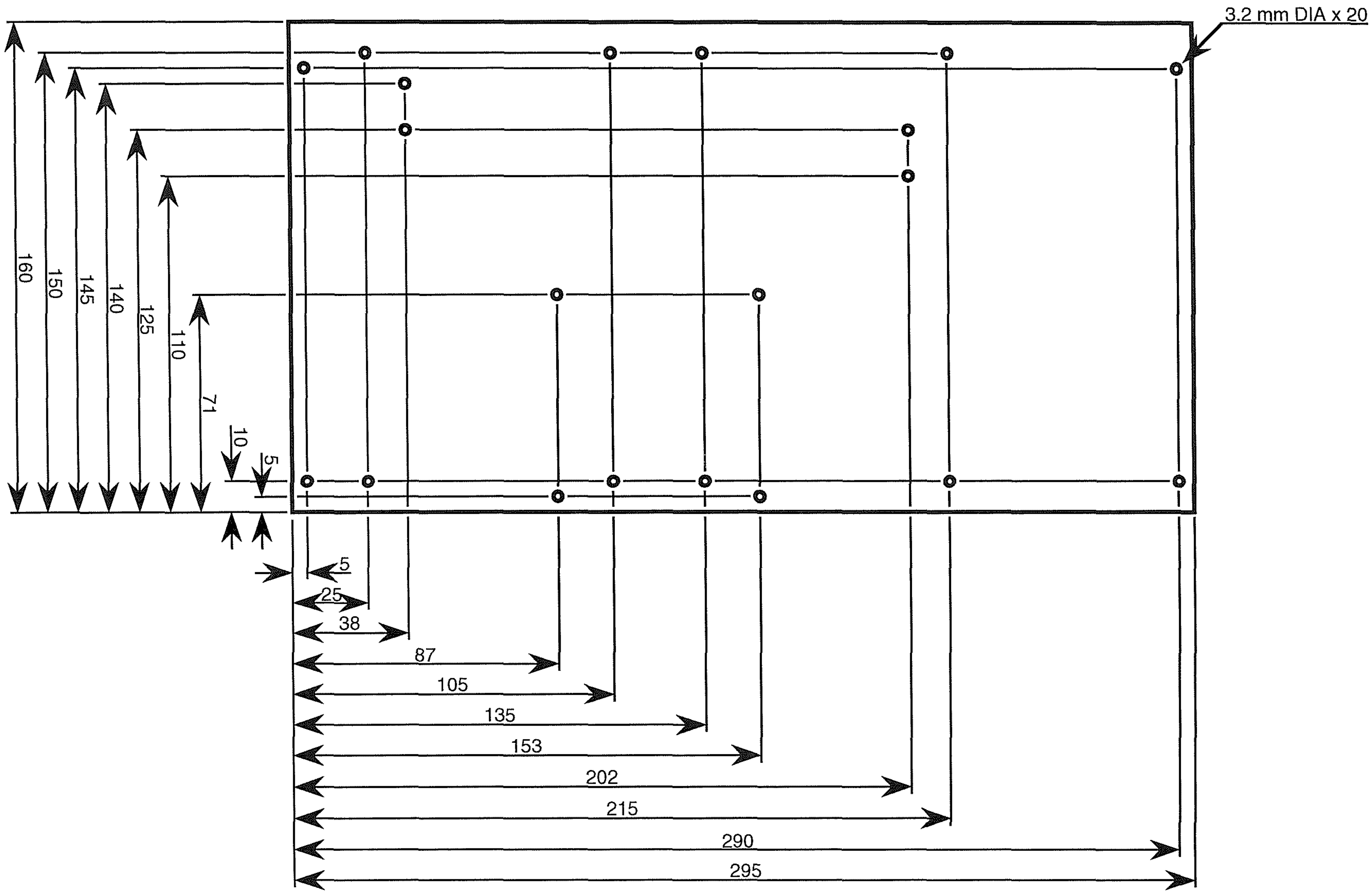
MAT:- AS SUPPLIED	TITLE:- CAL FRONT PANEL
SCALE:- 2:1	DRN:- PKS
TOL:- 0.1mm	DATE:- 01/12/1994



MAT:- AS SUPPLIED	TITLE:- CAL REAR PANEL
SCALE:- 2:1	DRN:- PKS
TOL:- 0.1mm	DATE:- 01/12/1994



MAT:- 14 GUAGE NS4	TITLE:- CAL TOP PANEL
SCALE:- 2:1	DRN:- PKS
TOL:- 0.1mm	DATE:- 19/12/1994



MAT:- 14 GUAGE NS4	TITLE:- CAL BOTTOM PANEL
SCALE:- 2:1	DRN:- PKS
TOL:- 0.1mm	DATE:- 19/12/1994

Orientation
RMS-to-DC Converters

The devices catalogued here are high-accuracy true-rms-to-dc-conversion ICs. Devices of this class compute the instantaneous square of the input signal, average it, and take the square root of the result, to provide a dc voltage that is proportional to the rms of the input (and, in the case of the AD536A, an auxiliary dc voltage that is proportional to the *log* of the rms, for dB measurements).

Excellent pre-trimmed performance, improvable by simple optional trims, makes these devices ideal for all types of laboratory and OEM rms instrumentation where amplitude measurements must be made with high accuracy, independently of waveshape.

An alternative to rms that has been widely used in the past, principally for measurements on sine waves, is mean absolute-deviation, or "ac average." It is performed by taking the absolute value of (i.e., full-wave or half-wave rectifying) a signal, filtering it, and scaling it by the ratio of rms to m.a.d. for sine waves, 1.111, so that it reads correctly (for undistorted sine waves). Unfortunately, this ratio varies widely as a function of the waveform and will give grossly incorrect results in many cases. The table shows a few representative examples comparing rms with m.a.d.

Examples of applications include noise measurement – for example, thermal noise, transistor noise, and switch-contact noise. True-rms measurement is a technique that provides consistent theoretically valid measurements of noise amplitude (standard deviation) from different sources having different properties.

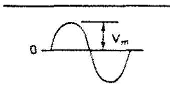
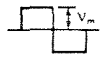
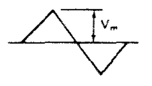
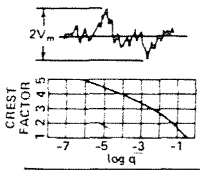
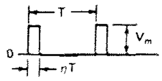
True-rms devices are also useful for measuring electrical signals derived from mechanical phenomena, such as strain, stress, vibration, shock, expansion, bearing noise, and acoustical noise. The electrical signals produced by these mechanical actions are often noisy, non-periodic, nonsinusoidal, and superimposed on dc levels, and require true-rms for consistent valid, accurate measurements. RMS converters are also useful for accurate measurements on low-repetition-rate pulse-trains having high *crest factors* (ratio of peak to rms), and for measurements of the energy content of SCR waveforms at differing firing angles.

The basic approach used in these converters for computing the rms is to take the absolute value, square it, and divide by the fed-back output (using the logarithmic characteristics of transistor junctions), and filter the result. The resulting approximation

$$E_o = \text{Avg.}\left[\frac{V_{in}^2}{E_o}\right] \cong \sqrt{\text{Avg.}\ (V_{in}^2)}$$

is valid if the averaging time-constant is sufficiently long compared with the periods of the lowest-frequency ac components of the signal.

The simplest form of averaging involves a single-pole filter, using an external filtering capacitance. Increased values of capacitance for filtering will improve the accuracy for low frequency rms measurements and provide reduced ripple at the output, but at the cost of increased settling time. For fastest settling and minimum ripple, the data sheets show how an additional stage of 2-pole filtering is useful (the internal buffer amplifier of the AD536A permits this to be accomplished without external active elements). The additional filtering permits improvement of settling time or reduction of ripple (or both) because of substantial reduction of C_{ext}.

WAVEFORM		RMS	MAD	$\frac{RMS}{MAD}$	CREST FACTOR
	SINE WAVE	$\frac{V_m}{\sqrt{2}}$ $0.707\ V_m$	$\frac{2}{\pi}V_m$ $0.637\ V_m$	$\frac{\pi}{2\sqrt{2}} = 1.111$	$\sqrt{2} = 1.414$
	SYMMETRICAL SQUARE WAVE OR DC	V_m	V_m	1	1
	TRIANGULAR WAVE OR SAWTOOTH	$\frac{V_m}{\sqrt{3}}$	$\frac{V_m}{2}$	$\frac{2}{\sqrt{3}} = 1.155$	$\sqrt{3} = 1.732$
	GAUSSIAN NOISE CREST FACTOR IS THEORETICALLY UNLIMITED. q IS THE FRACTION OF TIME DURING WHICH GREATER PEAKS CAN BE EXPECTED TO OCCUR	RMS	$\sqrt{\frac{2}{\pi}}$ RMS = 0.798 RMS	$\sqrt{\frac{\pi}{2}}$ 1.253	C.F. / q: 1 / 32% 2 / 4.6% 3 / 0.37% 3.3 / 0.1% 3.9 / 0.01% 4 / 63ppm 4.4 / 10ppm 4.9 / 1ppm 6 / 2×10^{-9}
 η: "DUTY CYCLE"	PULSE TRAIN η / MARK/SPACE: 1 / ∞ 0.25 / 0.3333 0.0625 / 0.0667 0.0156 / 0.0159 0.01 / 0.0101	$V_m\sqrt{\eta}$ V_m $0.5V_m$ $0.25V_m$ $0.125V_m$ $0.1V_m$	$V_m\eta$ V_m $0.25V_m$ $0.0625V_m$ $0.0156V_m$ $0.01V_m$	$\frac{1}{\sqrt{\eta}}$ 1 2 4 8 10	$\frac{1}{\sqrt{\eta}}$ 1 2 4 8 10

RFORMANCE SPECIFICATIONS

nsiderable information regarding rms-to-dc converter cir- design, performance, selection, and applications is to be nd in the NONLINEAR CIRCUITS HANDBOOK.[1] In ad- on, useful applications information on auxiliary filtering be found in the article "Measure RMS with Less Ripple ess Time,"[2] and a discussion of the design of the AD536A be found in the 1976 IEEE International Solid-State Cir- s Conference *Digest of Technical Papers,* page 10.

e most-salient feature of a true rms-to-dc converter is that deally has no error due to an indirect approximation to rms. Static errors are due only to scale-factor, linearity, d offset errors; dynamic errors are due to insufficient av- ing time at the low end and finite bandwidth and slewing e at the upper end. Linearity errors affect crest factor in band. Dynamic errors are also a function of signal ampli- de, due in part to the variation of bandwidth of the "log" nsistors with signal level.

al Error A specification for quick reference, this is the ximum deviation of the dc component of the output volt- e from the theoretical output value over a specified range signal amplitude and frequency. It is shown as the sum of xed error and a component proportional to the theoreti- l output ("% of reading"). It is specified for a sinusoidal put in a given frequency and amplitude range. The fixed ror-component includes all offset errors and irreducible nlinearities; the %-of-reading component includes the linear le-factor error.

al Error, external trim (adjustment) is the amount by ich the output may differ from the theoretical value when e output offset and scale factor have been trimmed. Note t the fixed error-component cannot be reduced to zero, en though the output offset can be nulled at zero input. is is because of residual input offsets and inherent non- earities in the converter.

al Error vs. Temperature is the average change of %-of-full-scale error component plus the average change of percent of reading error component per degree Celsius, over the rated temperature range.

Frequency for 1%-of-Reading Error is the minimum value of frequency (at the high end) at which the error increases from the midband value by 1% of reading. It is a function of peak-to-peak input amplitude.

Frequency for ±3dB Reading Error is the minimum value of frequency (at the high end) at which the error may equal 30% of reading. It is a function of amplitude.

Crest Factor (a property of the signal) is the ratio of peak signal voltage to the ideal value of rms; the specified value of crest factor is that for which the error is maintained within specified limits at a given rms level for a worst-case – rectangular pulse – input signal.

Filter Time Constant and External Capacitor: The time constant of the internal averaging filter, and the increase of time constant per μF of added external capacitance.

Input: The voltage range over which specified operation is obtained, the maximum voltage for which the unit operates, the maximum safe input voltage, and the effective input resistance.

Output: The maximum output range for rated performance, the minimum current guaranteed available at full-scale output voltage, and the source resistance of the output circuit.

Power Supply: Power-supply range for specified performance, power-supply range for operation, and quiescent current drain. Note that the AD536 can be operated from single or dual supplies.

Temperature Range: The range of temperature variation for operation within specifications. Temperature coefficients are determined by three-point measurements ($T_H - 25°C$), ($25°C - T_L$), when measured.

nlinear Circuits Handbook, Analog Devices, Inc., 1974, 1976, pp, edited by D. H. Sheingold, $5.95; send check or complete ster-Charge data to P.O. Box 796, Norwood MA 02062

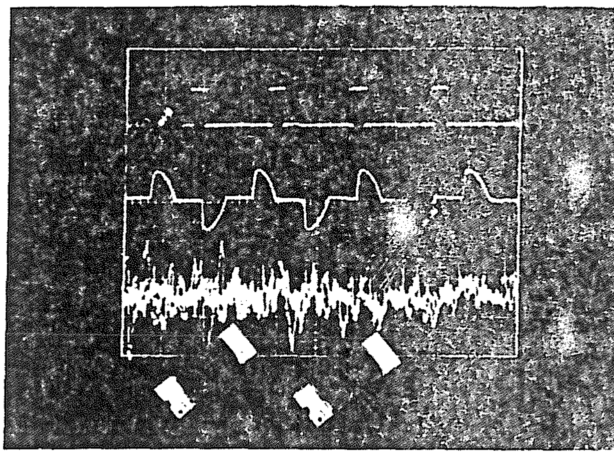
NALOG DIALOGUE 9-3, 1975, pp 21-22

ANALOG DEVICES

Integrated Circuit True rms-to-dc Converter

AD536A

FEATURES
True rms-to-dc Conversion
Laser-Trimmed to High Accuracy
  0.2% max Error (AD536AK)
  0.5% max Error (AD536AJ)
Wide Response Capability:
  Computes rms of ac and dc Signals
  300kHz Bandwidth: $V_{rms} > 100mV$
  2MHz Bandwidth: $V_{rms} > 1V$
  Signal Crest Factor of 7 for 1% Error
dB Output with 60dB Range
Low Power: 1mA Quiescent Current
Single or Dual Supply Operation
Monolithic Integrated Circuit
-55°C to +125°C Operation (AD536AS)
Low Cost



PRODUCT DESCRIPTION
The AD536A is a complete monolithic integrated circuit which performs true rms-to-dc conversion. It offers performance which is comparable or superior to that of hybrid or modular units costing much more. The AD536A directly computes the true rms value of any complex input waveform containing ac and dc components. It has a crest factor compensation scheme which allows measurements with 1% error at crest factors up to 7. The wide bandwidth of the device extends the measurement capability to 300kHz with 3dB error for signal levels above 100mV.

An important feature of the AD536A not previously available in rms converters is an auxiliary dB output. The logarithm of the rms output signal is brought out to a separate pin to allow the dB conversion, with a useful dynamic range of 60dB. Using an externally supplied reference current, the 0dB level can be conveniently set by the user to correspond to any input level from 0.1 to 2 volts rms.

The AD536A is laser trimmed at the wafer level for input and output offset, positive and negative waveform symmetry (dc reversal), and full scale accuracy. As a result, no external trims are required to achieve the rated accuracy of the unit.

There is full protection for both inputs and outputs. The input circuitry can take overload voltages well beyond the supply levels. Loss of supply voltage with inputs connected will not cause unit failure. The output is short-circuit protected.

The AD536A is available in two accuracy grades (J, K) for commercial temperature range (0 to +70°C) applications, and one grade (S) rated for the full -55°C to +125°C military range. The AD536AK offers a maximum total error of ±2mV ±0.2% of reading and the AD536AJ and AD536AS have maximum errors of ±5mV ±0.5% of reading. All three versions are available in either a hermetically sealed 14-pin DIP or a 10-pin TO-100 metal can.

PRODUCT HIGHLIGHTS
1. The AD536A computes the true root-mean-square level of a complex ac (or ac plus dc) input signal and gives an equivalent dc output level. The true rms value of a waveform is a more useful quantity than the average rectified value since it relates directly to the power of the signal. The rms value of a statistical signal also relates to its standard deviation.
2. The crest factor of a waveform is the ratio of the peak signal swing to the rms value. The crest factor compensation scheme of the AD536A allows measurement of highly complex signals with wide dynamic range.
3. The only external component required to perform measurements to the fully specified accuracy is the capacitor which sets the averaging period. The value of this capacitor determines the low frequency ac accuracy, ripple level and settling time.
4. The AD536A will operate equally well from split supplies or a single supply with total supply levels from 5 to 36 volts. The one milliampere quiescent supply current makes the device well-suited for a wide variety of remote controllers and battery powered instruments.
5. The AD536A directly replaces the AD536, and provides improved bandwidth and temperature drift specifications.

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

MODEL	AD536AJ	AD536AK	AD536AS
TRANSFER EQUATION	$V_{OUT} = \sqrt{\text{avg.}\ (V_{IN})^2}$	*	*
CONVERSION ACCURACY			
Total Error, Internal Trim[1] (Fig. 1)	±5mV ±0.5% of Reading, max	±2mV ±0.2% of Reading, max	*
vs. Temperature, T_{min} to +70°C	±(0.1mV ±0.01% Reading)/°C max	±(0.05mV ±0.005% of Reading)/°C max	±(0.1mV ±0.005% of Reading)/°C max
+70°C to +125°C	–	–	±(0.3mV ±0.005% of Reading)/°C max
vs. Supply Voltage	±(0.1mV ±0.01% Reading)/V	*	*
dc Reversal Error	±0.05% of Reading	*	*
Total Error, External Trim[1] (Fig. 2)	±3mV ±0.3% of Reading	±2mV ±0.1% of Reading	*
ERROR vs CREST FACTOR[2]			
Crest Factor 1 to 2	Specified Accuracy	*	*
Crest Factor = 3	–0.1% of Reading	*	*
Crest Factor = 7	–1% of Reading	*	*
FREQUENCY RESPONSE[3]			
Bandwidth for 1% additional error (0.1dB)			
$10mV < V_{IN} \leq 100mV$	6kHz	*	*
$100mV < V_{IN} \leq 1V$	40kHz	*	*
$1V < V_{IN} \leq 7V$	100kHz	*	*
±3dB Bandwidth			
$10mV < V_{IN} \leq 100mV$	50kHz	*	*
$100mV < V_{IN} \leq 1V$	300kHz	*	*
$1V < V_{IN} \leq 7V$	2MHz	*	*
AVERAGING TIME CONSTANT (Fig. 5)	25ms/μF C_{AV}	*	*
INPUT CHARACTERISTICS			
Signal Range, ±15V Supply	±20V Peak	*	*
Signal Range, +5V Supply	±5V Peak	*	*
Safe Input, All Supply Voltages	±25V max	*	*
Input Resistance	16.7kΩ ±25%	*	*
Input Offset Voltage	±2mV max	±1mV max	*
OUTPUT CHARACTERISTICS			
Offset Voltage	±2mV max	±1mV max	*
vs. Temperature	±0.1mV/°C	*	±0.2mV/°C max
vs. Supply Voltage	±0.1mV/V	*	±0.2mV/V max
Voltage Swing, ±15V Supplies	0 to +10V min	*	*
±5V Supply	0 to +2V min	*	*
Output Current	(+5mA, –130μA) min	*	*
Short Circuit Current	+20mA	*	*
Resistance	0.5Ω max	*	*
dB OUTPUT (Fig. 13)			
Error, V_{IN} 7mV to 7V rms, 0dB = 1V rms	±0.5dB	±0.2dB	*
Scale Factor	–3mV/dB	*	*
Scale Factor TC (Uncompensated, see Fig. 13 for Temperature Compensation)	–0.3% Reading/°C (–0.03dB/°C)	*	*
I_{REF} for 0dB = 1V rms	20μA (5μA min, 80μA max)	*	*
I_{REF} Range	1μA to 100μA	*	*
I_{OUT} TERMINAL			
I_{OUT} Scale Factor	40μA/Volt rms	*	*
I_{OUT} Scale Factor Tolerance	±25%	*	*
Output Resistance	10^8 Ω	*	*
Voltage Compliance	$-V_S$ to $(+V_S - 2.5V)$	*	*
BUFFER AMPLIFIER			
Input and Output Voltage Range	$-V_S$ to $(+V_S - 2.5V)$ min	*	*
Input Offset Voltage, R_S = 25k	±4mV max	*	*
Input Current	100nA typ, 300nA max	*	*
Input Resistance	10^8 Ω	*	*
Output Current	(5mA, –130μA) min	*	*
Short Circuit Current	+20mA	*	*
Small Signal Bandwidth	1MHz	*	*
Slew Rate[4]	5V/μs	*	*
POWER SUPPLY			
Voltage, Rated Performance			
Dual Supply	±3.0V to ±18V	*	*
Single Supply	+5V to +36V	*	*
Quiescent Current			
Total V_S 5V to 36V, T_{min} to T_{max}	2mA max (1mA typ)	*	*
TEMPERATURE RANGE			
Rated Performance	0 to +70°C	*	–55°C to +125°C
Storage	–55°C to +150°C	*	*

[1] Accuracy is specified for 0 to 7V rms, dc or 1kHz sinewave input with the AD536A connected as in the figure referenced.
[2] Error vs crest factor is specified as an additional error for 1V rms rectangular pulse input, pulse width = 200μs.
[3] Input voltages are expressed in volts rms, and error is percent of reading.
[4] With 2k external pulldown resistor.

*Specifications same as AD536AJ.

Specifications subject to change without notice.

STANDARD CONNECTION

The AD536A is simple to connect for the majority of high accuracy rms measurements, requiring only an external capacitor to set the averaging time constant. The standard connection is shown in Figure 1. In this configuration, the AD536A will measure the rms of the ac and dc level present at the input, but will show an error for low frequency inputs as a function of the filter capacitor, C_{AV}, as shown in Figure 5. Thus, if a $4\mu F$ capacitor is used, the additional average error at 10Hz will be 0.1%, at 3Hz it will be 1%. The accuracy at higher frequencies will be according to specification. If it is desired to reject the dc input, a capacitor is added in series with the input, as shown in Figure 3; the capacitor must be non-polar. If the AD536A is driven with power supplies with a considerable amount of high frequency ripple, it is advisable to bypass both supplies to ground with $0.1\mu F$ ceramic discs as near the device as possible.

The input and output signal ranges are a function of the supply voltages; these ranges are shown in Figure 17. The AD536A can also be used in an unbuffered voltage output mode by disconnecting the input to the buffer. The output then appears unbuffered across the 25k resistor. The buffer amplifier can then be used for other purposes. Further the AD536A can be used in a current output mode by disconnecting the 25k resistor from ground. The output current is available at pin 8 (pin 10 on the "H" package) with a nominal scale of $40\mu A$ per volt rms input, positive out.

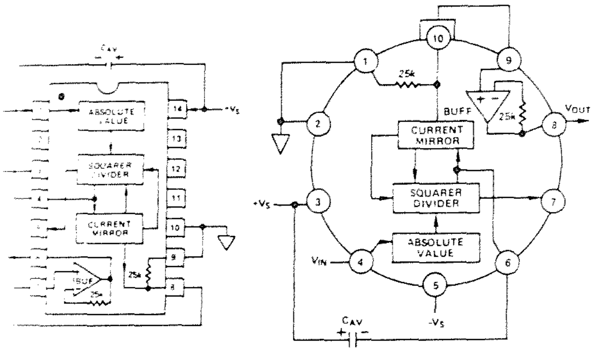


Figure 1. Standard rms Connection

OPTIONAL EXTERNAL TRIMS FOR HIGH ACCURACY

If it is desired to improve the accuracy of the AD536A, the external trims shown in Figure 2 can be added. R_4 is used to trim the offset. Note that the offset trim circuit adds 249Ω in series with the internal 25kΩ resistor. This will cause a 1% increase in scale factor, which is trimmed out by using R_1 as shown.

The trimming procedure is as follows:

1. Ground the input signal, V_{IN}, and adjust R_4 to give zero volts output from pin 6. Alternatively, R_4 can be adjusted to give the correct output with the lowest expected value of V_{IN}.
2. Connect the desired full scale input level to V_{IN}, either dc or a calibrated ac signal (1kHz is the optimum frequency); then trim R_1 to give the correct output from pin 6, i.e., 1.000V dc input should give 1.000V dc output. Of course, a 1.000V peak-to-peak sinewave should give a 0.707V dc output. The remaining errors, as given in the specifications, are due to the nonlinearity.

The major advantage of external trimming is to optimize device performance for a reduced signal range; the AD536A is internally trimmed for a 7V rms full scale range.

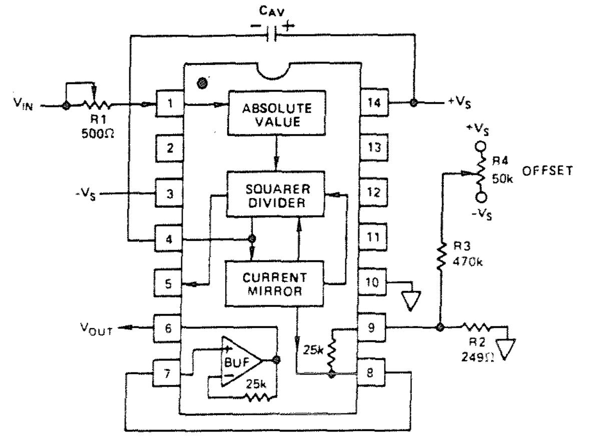


Figure 2. Optional External Gain and Output Offset Trims

SINGLE SUPPLY CONNECTION

The applications in Figures 1 and 2 require the use of approximately symmetrical dual supplies. The AD536A can also be used with only a single positive supply down to +5 volts, as shown in Figure 3. The major limitation of this connection is that only ac signals can be measured since the differential input stage must be biased off ground for proper operation. This biasing is done at pin 10; thus it is critical that no extraneous signals be coupled into this point. Biasing can be accomplished by using a resistive divider between $+V_S$ and ground. The values of the resistors can be increased in the interest of lowered power consumption, since only 5 microamps of current flows into pin 10 (pin 2 on the "H" package). AC input coupling requires only capacitor C_2 as shown; a dc return is not necessary as it is provided internally. C_2 is selected for the proper low frequency break point with the input resistance of 16.7kΩ; for a cut-off at 10Hz, C_2 should be $1\mu F$. The signal ranges in this connection are slightly more restricted than in the dual supply connection. The input and output signal ranges are shown in Figure 17. The load resistor, R_L, is necessary to provide output sink current.

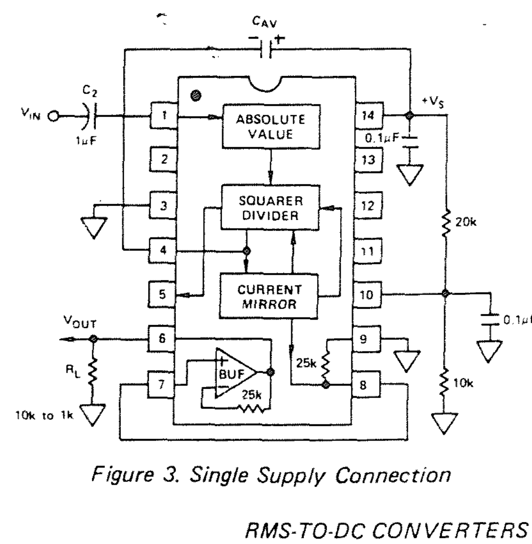


Figure 3. Single Supply Connection

CHOOSING THE AVERAGING TIME CONSTANT

The AD536A will compute the rms of both ac and dc signals. If the input is a slowly-varying dc, the output of the AD536A will track the input exactly. At higher frequencies, the average output of the AD536A will approach the rms value of the input signal. The actual output of the AD536A will differ from the ideal output by an average (or dc) error and some amount of ripple, as demonstrated in Figure 4.

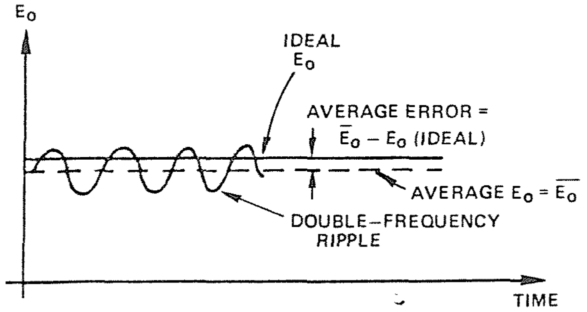


Figure 4. Typical Output Waveform for Sinusoidal Input

The dc error is dependent on the input signal frequency and the value of C_{AV}. Figure 5 can be used to determine the minimum value of C_{AV} which will yield 1% or 0.1% dc error above a given frequency. For example, if a 60Hz waveform is to be measured with a dc error of less than 0.1%, C_{AV} must be greater than 0.65μF. If a 1% error can be tolerated, the minimum value of C_{AV} is 0.22μF.

The ac component of the output signal is the ripple. There are two ways to reduce the ripple. The first method involves using a large value of C_{AV}. Since the ripple is inversely proportional to C_{AV}, a tenfold increase in this capacitance will effect a tenfold reduction in ripple. When measuring waveforms with high crest factors, (such as low duty cycle pulse trains), the averaging time constant should be at least ten times the signal period. For example, a 100Hz pulse rate requires a 100ms time constant, which corresponds to a 4μF capacitor (time constant = 25ms per μF).

The primary disadvantage in using a large C_{AV} to remove ripple is that the settling time for a step change in input level is increased proportionately. Figure 5 shows that the relationship between C_{AV} and settling time is 100 milliseconds for each microfarad of C_{AV}. The settling time is twice as great for decreasing signals as for increasing signals (the values in Figure 5 are for decreasing signals). Settling time also increases for low signal levels, as shown in Figure 6.

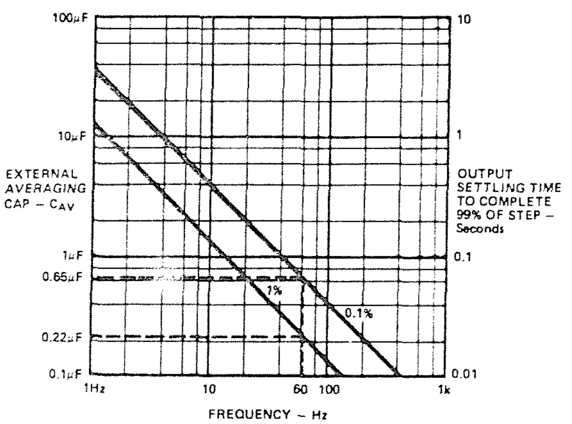


Figure 5. Lower Frequency for Stated % of Reading Error and Settling Time for Circuit Shown in Figure 1

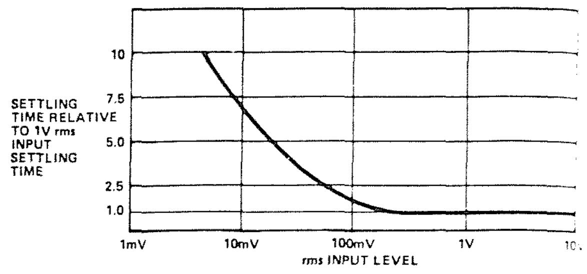


Figure 6. Settling Time vs Input Level

A better method for reducing output ripple is the use of a "post-filter". Figure 7 shows a suggested circuit. If a single-pole filter is used (C_3 removed, R_X shorted), and C_2 is approximately twice the value of C_{AV}, the ripple is reduced as shown in Figure 8, and settling time is increased. For example, with C_{AV} = 1μF and C_2 = 2.2μF, the ripple for a 60Hz input is reduced from 10% of reading to approximately 0.3% of reading. The settling time, however, is increased by approximately a factor of 3. The values of C_{AV} and C_2 can therefore be reduced to permit faster settling times while still providing substantial ripple reduction.

The two-pole post-filter uses an active filter stage to provide even greater ripple reduction without substantially increasing the settling times over a circuit with a one-pole filter. The values of C_{AV}, C_2, and C_3 can then be reduced to allow extremely fast settling times for a constant amount of ripple. Caution should be exercised in choosing the value of C_{AV}, since the dc error is dependent upon this value and is independent of the post filter.

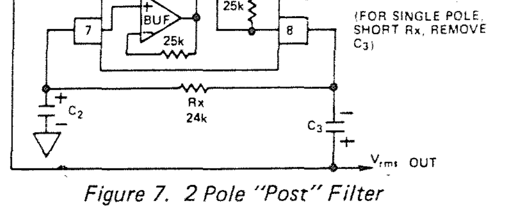


Figure 7. 2 Pole "Post" Filter

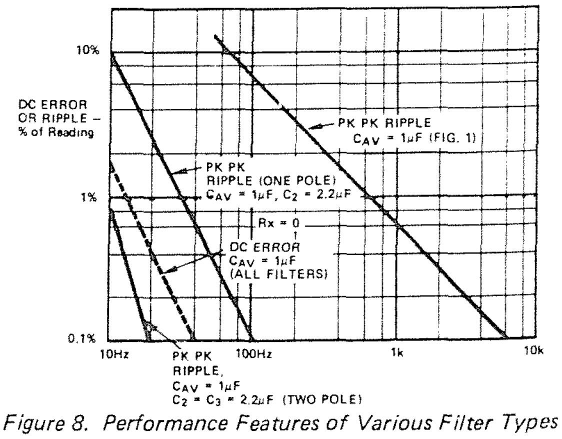


Figure 8. Performance Features of Various Filter Types

AD536A PRINCIPLE OF OPERATION

The AD536A embodies an implicit solution of the rms equation that overcomes the dynamic range as well as other limitations inherent in a straight-forward computation of rms. The actual computation performed by the AD536A follows the equation:

$$V_{rms} = \text{Avg.} \left[\frac{V_{IN}^2}{V_{rms}} \right]$$

Figure 9 is a simplified schematic of the AD536A; it is subdivided into four major sections: absolute value circuit (active rectifier), squarer/divider, current mirror, and buffer amplifier. The input voltage, V_{IN}, which can be ac or dc, is converted to a unipolar current I_1, by the active rectifier A_1, A_2. I_1 drives one input of the squarer/divider, which has the transfer function:

$$I_4 = I_1^2 / I_3$$

The output current, I_4, of the squarer/divider drives the current mirror through a low pass filter formed by R_1 and the externally connected capacitor, C_{AV}. If the R_1, C_{AV} time constant is much greater than the longest period of the input signal, then I_4 is effectively averaged. The current mirror returns a current I_3, which equals Avg. $[I_4]$, back to the squarer/divider to complete the implicit rms computation. Thus:

$$I_4 = \text{Avg.}\ [I_1^2/I_4] = I_1\ rms$$

The current mirror also produces the output current, I_{OUT}, which equals $2I_4$. I_{OUT} can be used directly or converted to a voltage with R_2 and buffered by A_4 to provide a low impedance voltage output. The transfer function of the AD536A thus results:

$$V_{OUT} = 2R_2\ I_{rms} = V_{IN}\ rms$$

The dB output is derived from the emitter of Q_3, since the voltage at this point is proportional to $-\log V_{IN}$. Emitter follower, Q_5, buffers and level shifts this voltage, so that the dB output voltage is zero when the externally supplied emitter current (I_{REF}) to Q_5 approximates I_3.

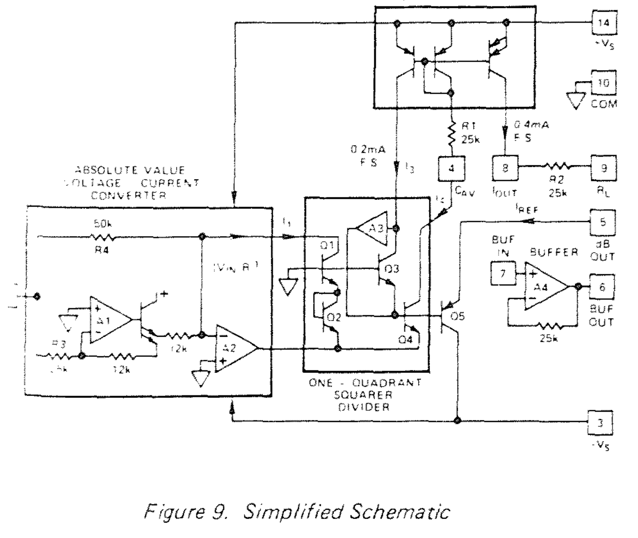
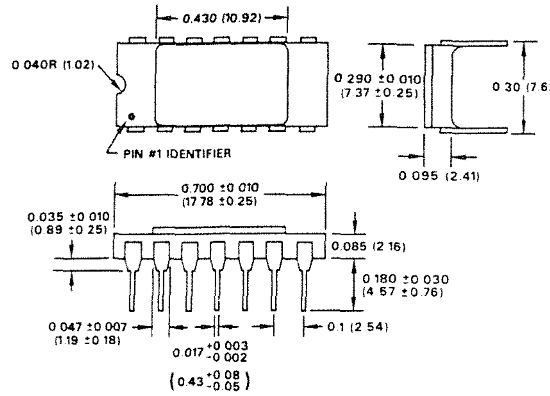


Figure 9. Simplified Schematic

"D" PACKAGE (TO-116)



"H" PACKAGE (TO-100)

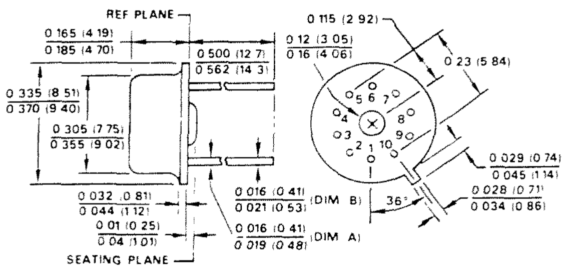


Figure 10. Physical Dimensions
Dimensions shown in inches and (mm).

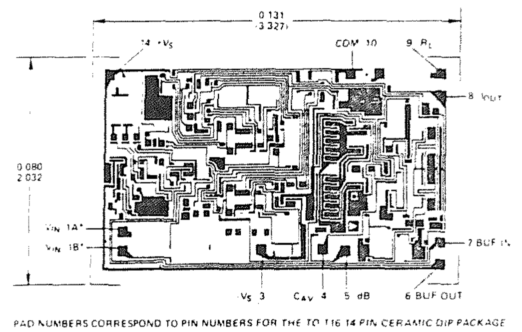


Figure 11. Chip Dimensions and Pad Layout.
Dimensions shown in inches and (mm).

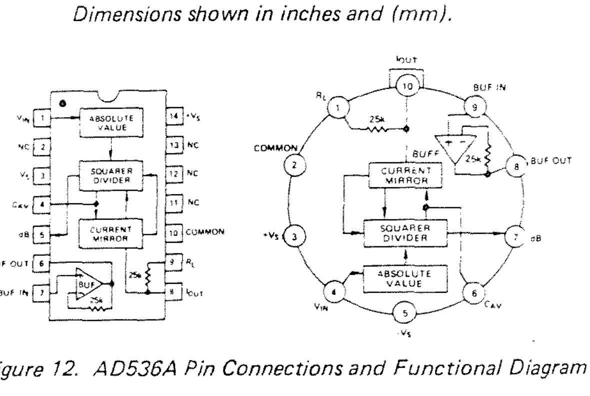


Figure 12. AD536A Pin Connections and Functional Diagram

CONNECTIONS FOR dB OPERATION

A powerful feature added to the AD536A, which is not available in any other computing rms circuit, is the logarithmic or decibel output. The internal circuit which computes dB is very accurate and works well over a 60dB range. The connection for dB measurements is shown in Figure 13. The user selects the 0dB level by setting R_1 for the proper 0dB reference current (which is set to exactly cancel the log output current from the squarer-divider at the desired 0dB point). The external op amp is used to provide a more convenient scale and to allow compensation of the 0.3%/°C temperature drift of the dB circuit. The special T.C. resistor, R_3, is available from Tel Labs, Londonderry, NH, type number Q-81. The linear rms output is available at pin 8 with an output impedance of 25kΩ; thus some applications may require an additional buffer amplifier if this output is desired.

dB Calibration:

1. Set V_{IN} = 1.00V dc
2. Adjust R_1 for dB out = 0.00V
3. Set V_{IN} = +0.1V dc
4. Adjust R_2 for dB out = -2.00V

Any other desired 0dB reference level can be used by setting V_{IN} and adjusting R_1 accordingly. Note that adjusting R_2 for the proper gain automatically gives the correct temperature compensation.

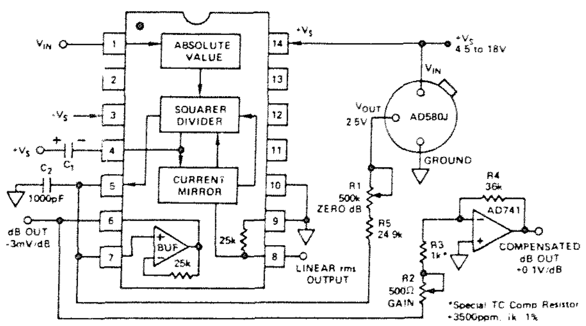


Figure 13. dB Connection

FREQUENCY RESPONSE

The AD536A utilizes a logarithmic circuit in performing the implicit rms computation. As with any log circuit, bandwidth is proportional to signal level. The solid lines in the graph below represent the frequency response of the AD536A at input levels from 10 millivolts to 1 volt rms. The dashed lines indicate the upper frequency limits for 1%, 10%, and 3dB of reading additional error. For example, note that a 1 volt rms signal will produce less than 1% of reading additional error up to 100kHz. A 10 millivolt signal can be measured with 1% of reading additional error (100μV) up to only 6kHz.

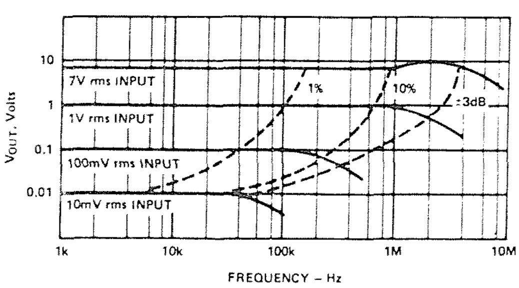


Figure 14. High Frequency Response

AC MEASUREMENT ACCURACY AND CREST FACTOR

Crest factor is often overlooked in determining the accuracy of an ac measurement. Crest factor is defined as the ratio of the peak signal amplitude to the rms value of the signal (C.F. = V_p/V_{rms}). Most common waveforms, such as sine and triangle waves, have relatively low crest factors (<2). Waveforms which resemble low duty cycle pulse trains, such as those occurring in switching power supplies and SCR circuits, have high crest factors. For example, a rectangular pulse train with a 1% duty cycle has a crest factor of 10 (C.F. = $1/\sqrt{\eta}$).

Figure 15 is a curve of reading error for the AD536A for a 1 volt rms input signal with crest factors from 1 to 10. A rectangular pulse train (pulse width 100μs) was used for this test since it is the worst-case waveform for rms measurement (all the energy is contained in the peaks). The duty cycle and peak amplitude were varied to produce crest factors from 1 to 10 while maintaining a constant 1 volt rms input amplitude.

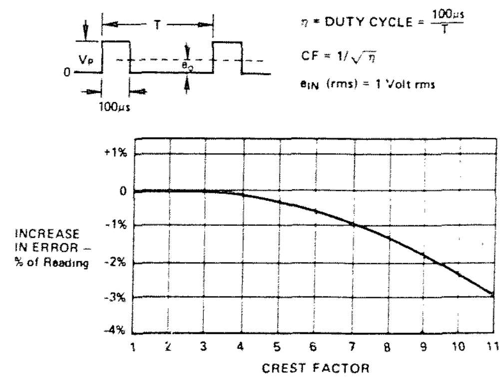


Figure 15. Error vs. Crest Factor

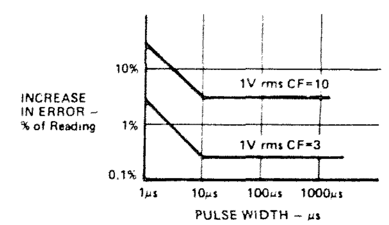


Figure 16. AD536A Error vs. Pulse Width Rectangular Pulse

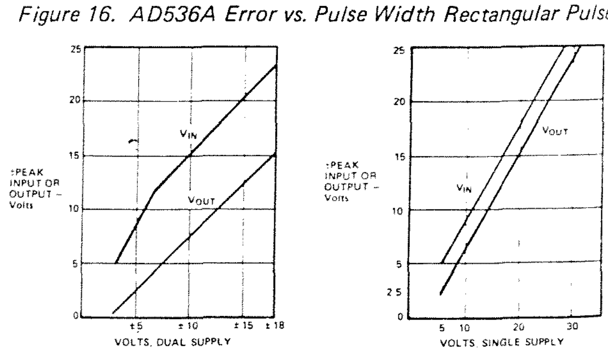
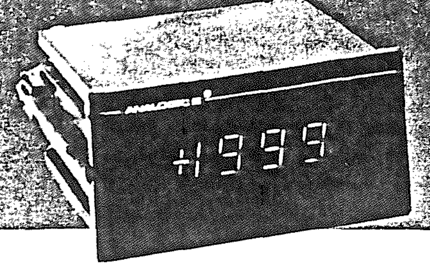


Figure 17. AD536A Input and Output Voltage Ranges vs. Supply



AN2570

±1999 count

Full Performance, Low Cost

DIGITAL PANEL INSTRUMENT

DESCRIPTION

The Analogic AN2570 is a bipolar 3½-digit (±1999 counts) full performance digital panel instrument. Low cost, without loss of desirable instrumentation features, is made possible through state-of-the-art LSI technology and Analogic's years of leadership in digital panel instrumentation design.

A full scale input range of ±1.999 volts or ±199.9mV, coupled with four available power configurations, (two DC and two AC) make the AN2570 universally applicable. Instrumentation features such as a bipolar differential input, 50 picoAmps of bias current, automatic zero correction and a virtually "blow-up-proof" signal input front end make it easy to use. A host of interface and control signals, including parallel BCD data output, provides maximum versatility for today's instrumentation design.

The displays [illegible]gned for maximum readability. Up close, several feet away, or off at an angle, the four large, red LED digits are bright, clear, crisp and free from glare and interpretation problems even under high ambient light conditions. If an input overload condition occurs, all four digits are automatically blanked to prevent an erroneous reading; however, the polarity sign and decimal point remain on to show that the instrument is working properly.

Among the outstanding features that assure high reliability and accuracy are: Comprehensive Quality Control and reliability procedures (e.g., minimum 100 hour temperature-cycled burn-in with power on/off cycle), instantaneous warmup and display (no waiting for readings to settle), isolation that "floats" the measuring circuits up to 1400 volts from the power-line ground (maintains electrical separation between signal and power lines), maximum rejection of ripple and noise due to input signal filtering, and true dual-slope integration.

Packaged in a standard DIN/NEMA high impact plastic case, with front panel accessible span control, every AN2570 is conformance tested before shipment. Rated performance is guaranteed by a Quality control certificate and calibration report enclosed with every instrument.

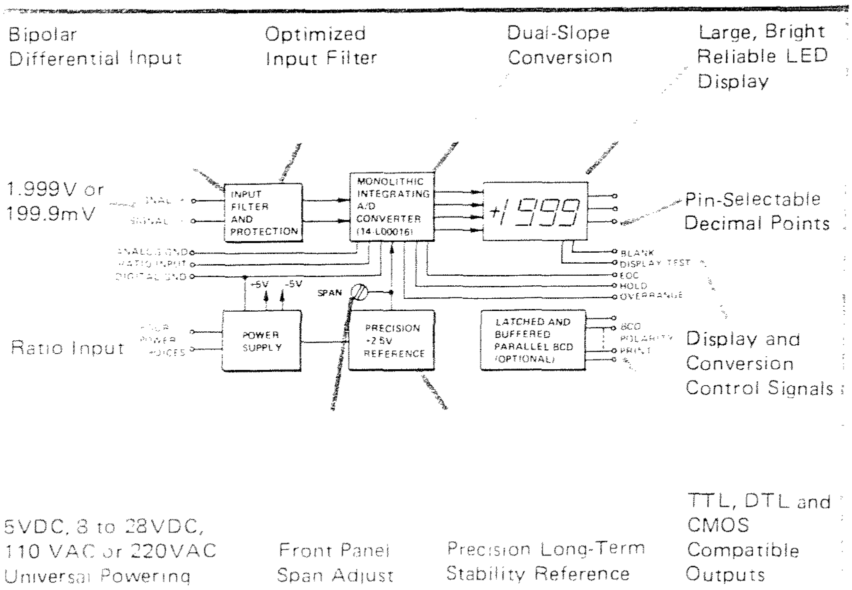


Figure 1. AN2570 Functional Block Diagram

FEATURES

- Full Performance at Low Cost.
- Accuracy: ±0.05% of Reading ±1 Count.
- Bipolar Differential Input.
- Optimized Signal Input Filter.
- 50 Picoamps Bias Current.
- Input Protected to 300 Volts.
- Automatic Zero.
- Automatic Overrange Indication.
- Automatic Polarity.
- Fourth Generation LSI Design.
- Large 0.43" LED Display.
- Supercool Design for more than 100,000 hours MTBF.
- Wide Operating Temp. Range: −10°C to +65°C.
- 1400 Volts Power Transformer Isolation.
- Universal Powering:
  +5VDC ±5% @ 170mA
  +8VDC to +28VDC @ 90mA
  110VAC ±20% @ 1.6 Watts
  220VAC ±20% @ 1.6 Watts.
- Ratiometric Operation.
- DISPLAY TEST, HOLD, BLANK, EOC, and OVERRANGE Control Signals.
- Externally Programmable Decimal Points.
- 100msec Integration for Highest NMRR and CMRR.
- Standard DIN/NEMA High Impact Plastic Case (UL 94V-0 Rated).
- Metal Case Available.
- Latched and Buffered Parallel BCD Output Available.
- Rear Screw Terminal Connector Available.

APPLICATIONS

- Portable Battery Powered Instruments.
- Process Control Equipment.
- Automotive, Marine, Railroad, and Aircraft Instrumentation.
- Ratiometric Indicators.
- Computer Controlled Systems.
- Biomedical Instrumentation.

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AN2570 SPECIFICATIONS

ANALOG INPUT

Configuration	Bipolar, differential input
Full Scale Range	±1.999VDC or ±199.9mVDC (See Ordering Code)
Input Resistance	>1000 megohms
Bias Current	50pA typical, 100pA maximum
Input Protection	±300 volts DC or AC RMS continuous without damage
Input Filter	Single pole, optimized signal enhancement filter
Normal Mode Rejection Ratio	65dB typical, @ 50 or 60Hz.
Ratiometric Operation	Ratio input for use with external reference. (Consult factory)

COMMON MODE

Signal Return to Analog Ground	
Voltage (CMV)	±0.25VDC or AC peak
DC Rejection Ratio (CMRR) DC	110dB typical, 90dB minimum
AC Rejection Ratio (CMRR) AC	90dB typical, 70dB minimum @ 50 to 60Hz
Analog Ground to AC Power Line	
Voltage (CMV)	1400 Volts DC or AC peak
AC Rejection Ratio (CMRR) AC	140dB typical, 120dB minimum at 50 to 60Hz

PERFORMANCE

Accuracy	±0.05% of reading ±1 count
Resolution	±0.05% for ±1999 counts
Range Tempco	±35ppm of reading/°C typical, ±50ppm of reading/°C maximum
Zero Stability	Auto zero, ±1μV/°C maximum zero drift
Code Centers	Less than 20μV RMS uncertainty, resulting in very stable readings.
Step Response	Less than 400msec for ±0.05% of reading accuracy for a "+" or "–" full scale step input

DISPLAY

Type	Seven segment planar LED, red, 0.43" (11mm) high
Polarity Indication	Automatic. plus "+" or minus "–" sign displayed
OVERRANGE Indication	All digits blanked to prevent erroneous readout, "+" or "–" sign and decimal point remain on.
Decimal Points	3 positions, externally programmable with jumper, TTL/DTL, open collector or relay logic. (See Figure 9.)
HOLD	Logic "0" (open collector or equivalent) holds last reading in display.
BLANK	Logic "0" (open collector or Equivalent) blanks display.
DISPLAY TEST	Logic "0" (sink 0.2mA to digital ground) tests all 23 segments of display by displaying "1888".

ANALOG TO DIGITAL CONVERSION

Technique	Dual slope, six phase conversion with automatic zero correction, complete conversion each cycle.
Rate	2.5 conversions per second nominal, internally triggered. See "HOLD" command for display control.
Input Integration Period	100 milliseconds nominal for optimum 50 and 60Hz noise rejection.

DIGITAL OUTPUTS

Parallel BCD (Optional)	15 parallel lines provide latched and buffered BCD output, POLARITY, and PRINT command. All are TTL/DTL and CMOS compatible, 2TTL loads each. (See Figure 3.)
OVERRANGE	Logic "0" indicates that input exceeds ±1999 counts, CMOS compatible, 0 to +5VDC.
EOC	Falling edge of "End of Conversion" signal indicates conversion complete, CMOS compatible, 0 to +5VDC.

POWER

Choice of 4 power inputs	+5VDC ±5% @ 170mA nominal +8 to +28VDC @ 90mA nominal (Specifically designed for Automotive, Marine, Railroad, and Aircraft applications; protected against supply reversals.) 110VAC RMS ±20%, 47 to 500Hz @ 1.6 Watts nominal (88 to 132VAC input range) 220VAC RMS ±20%, 47 to 500Hz @ 1.6 Watts nominal (176 to 264VAC input range)

ENVIRONMENTAL & PHYSICAL

Operating Temperature Range	–10°C to +65°C
Storage Temperature Range	–40°C to +85°C
Relative Humidity	0 to 90%, noncondensing
Case	DIN/NEMA standard, high impact molded plastic case UL94V-0 Rated. Metal case available. (See Ordering Code)
Dimensions	DIN/NEMA (See Figure 6.)
Weight	5oz (150 grams) nominal, DC Powered; 8oz (230 grams) nominal, AC powered.
EMI/RFI	Shielding on 5 sides with metal case option.
Special Line Noise Suppression	Provision made for surge suppressors, varistors and line input passive Pi filtering for industrial applications. Consult factory.

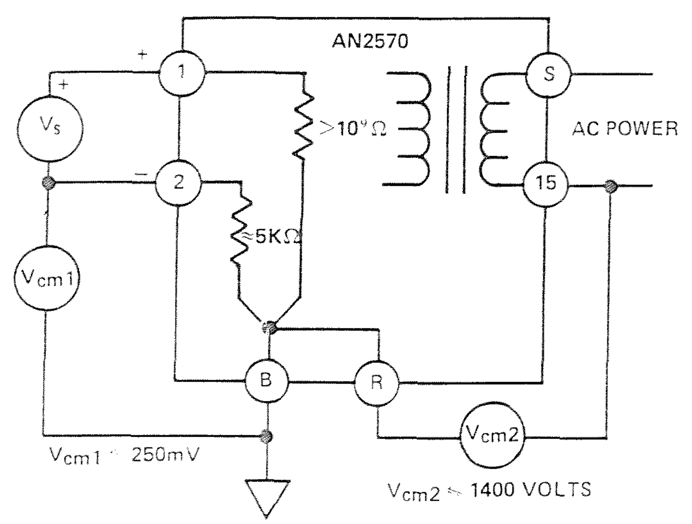
RELIABILITY

MTBF	>100,000 hours, calculated
Burn-In	≥100 hours with 0°C to +55°C temperature cycles and power on/off cycles.
Vibration	Each unit vibrated at 5gs for 30 seconds
Calibration	NBS traceable. Detailed certificate of calibration shipped with each unit.
Recalibration	Recommended 15-month intervals
Warranty	24 months

PRINCIPLES OF OPERATION

The AN2570 utilizes a true dual-slope form of analog-to-digital conversion, instrumented in a fourth-generation monolithic integrated circuit. In each conversion cycle, the internal offset voltages are sensed and compensated for automatically. The displayed data is the digitized ratio of the input signal to the precision reference within the instrument. Optionally, the user may introduce his own reference (scaled for +2 volts DC), where the output maximum count of 1999 would then represent an input equal to the full value of the external reference. A front panel-accessible span control permits the user to calibrate the precision internal reference to system standards; Analogic's precision reference is calibrated traceable to NBS standards.

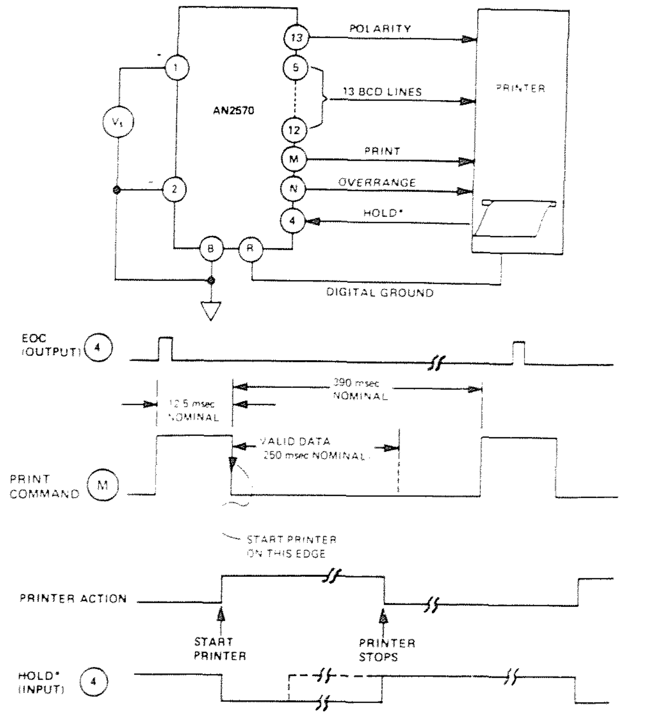
The AN2570 provides a number of status and control signals: an OVERRANGE output line goes to a low level when the conversion exceeds 1999 counts; an EOC output pulse is negative going when the conversion cycle is completed; grounding the input of the DISPLAY TEST line checks the operation of the segments of each display digit; maintaining the HOLD input line at a low level retains and displays the results of the last conversion and also keeps that value latched in the buffered output registers of the BCD option, if installed; and grounding the BLANK line blanks the display. Relationships among these signals are shown in the Timing Diagram of Figure 3. Note that the status/control functions are shared on common lines: HOLD/EOC, and BLANK/OVERRANGE.



Definitions:

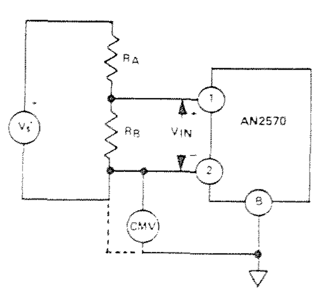
V_s	Voltage source to be measured.
V_{cm1}	Common mode voltage between pins (2) and (B). Typically this would be due to ground loops or other system noise. Note that only a differential input such as on the AN2570 can reject this type of noise and interference.
V_{cm2}	Common mode voltage (isolation potential) between power line and digital ground.
Pin (1)	Positive input for voltage to be measured.
Pin (2)	Negative input (return) for voltage to be measured.
Pin (B)	Analog ground. For single-ended inputs, jumper pins (2) and (B) together; for differential inputs, connect as shown.
Pin (R)	Digital ground. Internally connected to analog ground via Kelvin connection. All *digital signals, such as Decimal Points,* HOLD, BLANK, EOC, DISPLAY TEST, OVERRANGE, BCD etc. should be returned to this point.

Figure 2. Input Configurations and Common Mode Voltages



*If Printer is unable to operate at a rate of 2.5 readings/second, HOLD control signal from Printer may be used to synchronize AN2570 measurements to speed of printer.

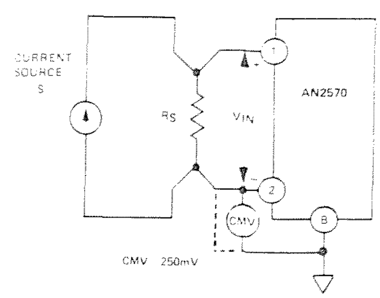
Figure 3. Using AN2570 with a printer.



For signal voltages V_s greater than 2 Volts, select R_A and R_B for proper scaling such that V_{in} is ≤2 Volts for a "1.999" Display*. Program Decimal Point accordingly (See Fig. 9).

*according to $V_{IN} = \left(\frac{R_B}{R_A + R_B}\right) \times V_S$.

Figure 4. Input Voltage Scaling.



Select shunt resistance R_s according to following:

$$R_S = \frac{\text{Desired Full Scale Count}}{\text{Full Scale Range of Input Current}} \times K$$

when K = 0.001 for 1.999 V_{IN}
K = 0.0001 for 199.9m V_{IN}

Figure 5. Current Measurement with AN2570.

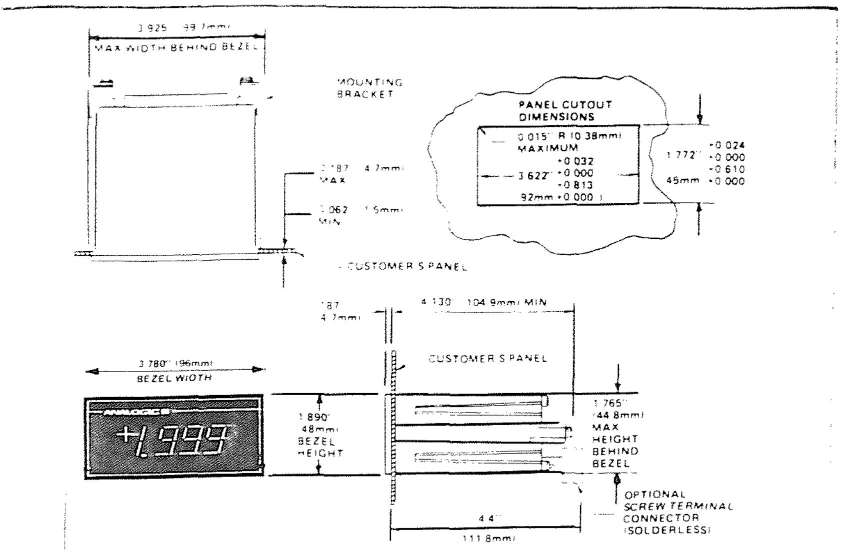


Figure 6. Panel Mounting and Outline Dimensions

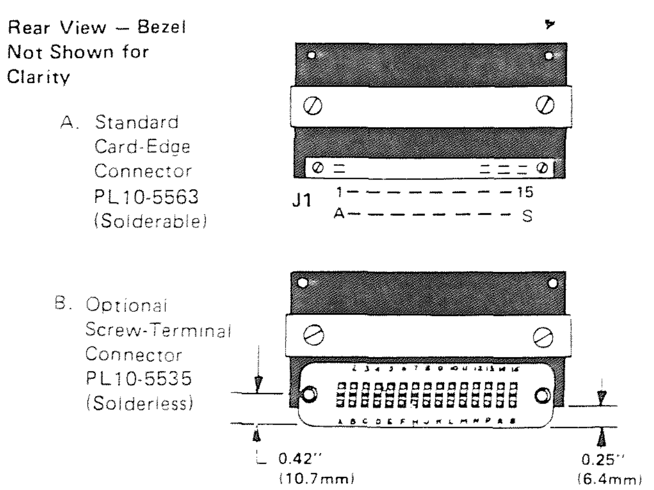


Figure 7. Rear Panel Connectors (Metal Case Option Shown)

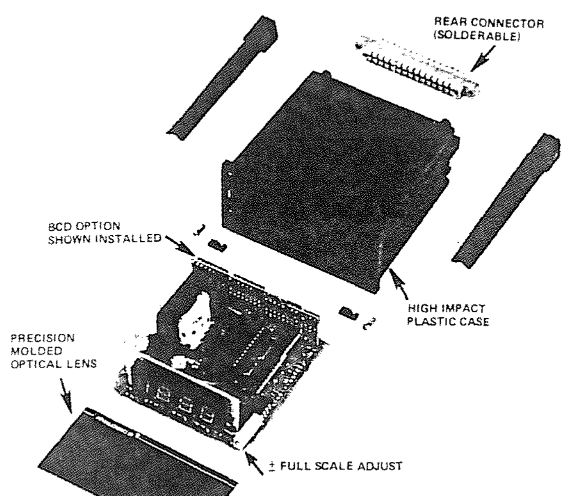


Figure 8. Disassembled View of the AC Powered AN2570.

ORDERING CODE

AN2570 □ / □ / □ / □

For	Enter
±1.999 Volts Input Range	1
±199.9 mVolts Input Range	01

For	Enter
No BCD Output	X
Parallel Buffered BCD Output	1

For	Enter
+5VDC Power Input	X
110VAC ±20%	1
220VAC ±20%	2
+8 to +28VDC	3

For	Enter
Plastic Case (UL 94V-0 Rated)	P
Metal Case	M

(Connectors optional)

J1 PIN DESIGNATIONS

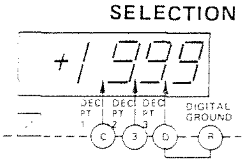
Ratio Input	**A**	**1**	Signal IN (+)≠
Analog Ground≠	**B**	**2**	Signal Return (—)≠
Decimal Point 1	**C**	**3**	Decimal Point 2
Decimal Point 3	**D**	**4**	EOC/HOLD
BCD (2)*	**E**	**5**	BCD (1)*
BCD (8)*	**F**	**6**	BCD (4)*
BCD (20)*	**H**	**7**	BCD (10)*
BCD (80)*	**J**	**8**	BCD (40)*
BCD (200)*	**K**	**9**	BCD (100)*
BCD (800)*	**L**	**10**	BCD (400)*
PRINT*	**M**	**11**	DISPLAY TEST
BLANK/OVERRANGE	**N**	**12**	BCD (1000)*
–5.1VDC Output	**P**	**13**	POLARITY*
Digital Ground≠	**R**	**14**	+5V†
AC Power IN†	**S**	**15**	AC Power or +8 to +28VDC IN†

≠See Figure 2.
*These signals are active with BCD option only.

†POWER CONNECTIONS

+5VDC	Pin 14 for +5VDC, Pin R for Power Return
+8 to +28VDC	Pin 15 for +8 to +28VDC, Pin R for Power Return
110VAC	Pins S and 15
220VAC	Pins S and 15

DECIMAL POINT SELECTION



To display the desired decimal point, simply connect the appropriate pin as shown to Digital Ground (Pin R, J1) using a jumper lead.

Figure 9. Decimal Point Position Terminals

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AVAILABLE FROM:

RS

Universal Digital Tachometer/Ratemeter
Stock No. 342-073
Operating information and technical specification

SECTION 1

General description and Ex Factory setting
This microprocessor based instrument is designed primarily as a wide ranging speed/rate measuring instrument with several additional versatile features as follows:

Standard user selectable functions

1	Rate Measurement:	Direct reading from 0.001-99999 units or scaled via the pulse DIVIDING facility
2	Totaliser counter:	Count input pulses either direct or via input pulse divider
3	Accumulative timer:	Total time between series of pulses first to last
4	Interval timer:	Time between each successive input pulse

Ex Factory settings
The instrument is set to the TACHOMETER mode for direct reading of RPM or Pulses/minute as follows:

Mains input	Set to 240V AC via rear panel selector
Measuring mode	Set to RPM
Measuring range	3 RPM to 99,999 RPM
Resolution	Set to ±1 RPM (decimal point on far right)
Pulses/revolution	One per revolution
Pulse Divider	Set to 001 (divide by 1) Pulses/Rev
Sensor selector	Set for NPN 3-wire sensor input

THESE SETTINGS CAN BE CHANGED BY REFERRING TO CONFIGURATION SECTION

SECTION 2

Mechanical details

HOUSING	
Bezel	48 × 96mm DIN Standard
Depth behind Bezel	108mm including Terminals
Panel Cut-out	42.5 × 91.5mm
Maximum panel thickness	10mm
Material	Noryl - Glass Filled Nylon (Black)
Fixing arrangement	Two side clamps (supplied)

Fixing Clamp details
Two clamps are provided which are retained to the housing by a simple spring action on the two brass studs protruding from each side of the housing and only require a small screwdriver to attach or remove the instrument from a panel.
PLEASE observe the way the clamps are fitted when unpacking the instrument, by reversing the action it will be easy to refit.

DO NOT OVER TIGHTEN THE LEADSCREWS

Bezel Removal - access to function switches
The 'Snap Fit' Bezel can be prised off with thumb and finger to gain access to the 10 × FUNCTION SWITCHES, the Red display filter should be placed on a clean non-scratch surface with the MATT side uppermost.
MATT SIDE OF FILTER FACES OUTWARDS WHEN RE-FITTING THE BEZEL.
Switches should be set BEFORE fitting the instrument Panel.

SEE CONFIGURATION SECTION FOR DETAILS

SECTION 3

Electrical Connections
Via a 12-way screw terminal connector details are given below:

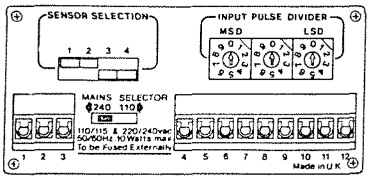
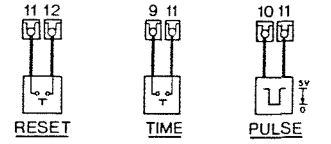


Diagram 1

a Termination numbers

1 = AC Live input (110/115 or 220/240V AC 50/60 Hz - see note below)
2 = NOT USED
3 = AC Neutral input, switch right = 110/115V AC, switch Left = 220/240V AC
4 = N/C Not connected (spare)
5 = 5V dc @ 120mA supply for Sensor and Encoder power
6 = 10V dc (Nom.) @ 50mA supply for 10-30V dc proximity sensors and encoders
7 = OV common for sensors, dc supply output and magnetic PU
8 = Signal input - all sensors
9 = Mode select for Time Accumulative function, when connected to OV line terminal 11 and Count function selected
10 = Pulse output (parallel output from input signal - not predivided)
11 = OV common line for Terminals 9, 10 and 12
12 = Reset (when connected to OV Line)

b External Reset connections -all modes
Reset as per the diagram using a suitable Normally Open Switch.



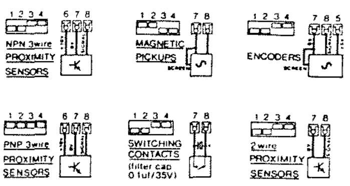
c External ACCUMULATIVE TIME/TOTALIZER function selection.
First select TOTALIZER MODE on DIL switch no. 2 behind front filter then link connections as shown.

d Pulse output
A pulse output is available equal to the INPUT pulse rate which is derived BEFORE any pulse division, primarily for parallel indicator connections, there is no limit to the number of instruments which can be cascade connected.

SECTION 4

Sensor inputs and selection (refer to diagram 1).
The Instrument is capable of being operated via a wide variety of industrial sensing devices which generate pulses of various types, the Diagrams show the popular types, including typical examples from the RS range where appropriate.

Auxilliary power supplies - NOTE. ONLY ONE LOAD SUPPORTED
10V dc available for 10-30V 3-wire sensors Terminal 6 = 10V dc
5V dc available for optical encoders and sensors Terminal 5 = 5V dc

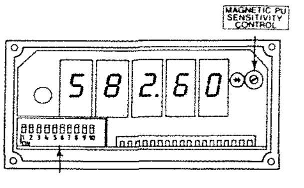


3-Wire Types
The instrument operates with virtually any NPN or PNP Sensor, including Inductive, Optical and Capacitive versions.
All types are connected to the same terminals, the selector switches should be set to the specific version chosen.
Inductive types are generally recommended for most applications.
Suggested types RS Stock No. 633-458 or 308-578 for example.

2-Wire NAMUR type Proximity Sensors
Not recommended for general use, WITH APPROVED BARRIER DEVICES it may be possible to use on intrinsically safe applications under controlled conditions.
ONLY CERTIFIED SENSOR/BARRIER DEVICES CAN BE USED IN HAZARDOUS AREAS. The Tachometer itself MUST BE SITED OUTSIDE HAZARDOUS ZONES.

5V dc Shaft Encoders and Sensors
An Encoder is usually only necessary where a faster update is needed where pulse rates are below 0.8 seconds. For example on linear speeds, an Encoder may be fitted with a Surface Wheel which has a defined circumference, for example 500mm and have 500ppr. This would produce 1 pulse/mm and the Tachometer will display in mm/min. The divider can be used to change this to cm/min or metres/min.

Magnetic Pickup input
Most types of magnetic pickup sensors not incorporating an integral preamplifier can be used. A sensitivity control is fitted as standard, accessed from the front via removal of the front bezel. IT IS FACTORY SET TO SUIT MOST APPLICATIONS.
Not recommended for slow pulse rate applications as the output signal is directly and inversely proportional to velocity. Normally used either with multi-toothed gearwheels or single pulse/rev high speed applications. Suggested RS Stock No. 304-166 or 304-172.



Contact closures switching
This method not recommended except for slow pulse rate applications. IT IS ESSENTIALTO FIT BOUNCE SUPPRESSION CAPACITOR.

SECTION 5

Application notes - method of sensing
The first consideration is access to a moving part of the machinery related to the measurement required. It is always best to opt for 1 pulse/event especially as you will most likely have to fabricate a target to suit your machine unless an optical sensor is chosen.

Sensor selection guide
The UDT can be oprerated from a variety of pulse generating devices, the right sensor for your application is important, the notes below are to assist your choice.

Non-contact sensing
Generally there are three main types:
1 Inductive Proximity Sensors
2 Optical Proximity Sensors
3 Magnetic Pick up Sensors

Inductive Proximity Sensors
Proximity sensors are ideal for most applications including slow mechanical motion, there is no lower limit to their switch rate (3-wire types), they can be used at rates up to 2kHz depending on the sensor specification.

Advantages
a Generally of totally sealed construction and maintenance free
b Impervious to coolants and many liquids in industrial processes and are usually dust and grime proof.
c Relatively easy to install
d Operate over a very wide speed range, especially good at low speed
e Airgap not dependent on velocity
f Can have long distance between sensor and instrument

Disadvantages
a Not suitable for use with fine pitch gears
b Not suitable for very high speeds or high velocity

Selection of physical size
Sensor size has a direct bearing on target size, so the target size is important, especially where an existing potential target is being considered.
Mechanical strength is a consideration, a larger sensor may be preferred, these have the advantage of a wider airgap but the final choice depends on overall factors and space available.
Sensor targets must be large enough in area to cover the sensing face, space between targets must be greater than the target size, ideally up to 3 times the diameter of the sensor, this does depend to some extent on the *maximum speed/velocity at the sensing diameter.*
CHECK THE PULSE DURATION REQUIREMENTS OF THE SPECIFIC SENSOR CHOSEN WITH THE PERIPHERAL SPEED/TARGET SIZE AVAILABLE TO ENSURE THAT THE SENSOR HAS SUFFICIENT TIME TO SWITCH ON/OFF.

Optical Proximity Sensors
This type of sensor can be used where the addition of a metallic target is difficult or where counting from an object being produced is essential:

Advantages
a Installation of 'Target' easy
b Sensing distance much greater with reflective target
c Individual objects can be sensed
d Can access more difficult applications

Disadvantages
a Normally suitable for single applications, e.g. rpm or counting
b Maintenance of optics, cleaning etc may be required
c Can have limitations on high speeds
Typical Optical proximity Sensor Stock No. 302-508

Magnetic Pick up Sensors - speed measuring applications only
'Velocity conscious' devices, they are normally used with gearwheels.

Advantages
a Can be used on very small projections/gears etc
b Can be used at very high speeds
c Wide temperature of operation

Disadvantages
a *Require very small air gap*
b Can be susceptible to 'noise' requiring screened cable
c Not ideal for long cables
d Not suitable for slow rates/velocities

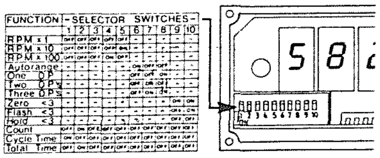
Shaft Encoders
These devices are ideal for applications where multiple pulses are needed on very low speeds where a Shaft Encoder with a surface speed contact wheel is required to indicate linear units such as metres/min. They are only necessary in this case from either a mechanical aspect or to shorten the update time of the display.

Contact Closure Devices
Can be used in very slow pulse rate applications, contact bounce suppression circuitry must be used. They are not recommended for medium to fast switching applications.

SECTION 6

CONFIGURATION OF FUNCTIONS
TACHOMETER/RATEMETER FUNCTION
Displayed Resolution
User selectable from 0 to 0.000
fixed or fully autoranging
Fixed ranges

a	1	99999 Units
b	0.1	9999.9
c	0.01	999.99
d	0.001	99.999
e	0.001	99999 autorange mode



UNDERRANGE FEATURE
With Underrange set to 3RPM Pulses/min, to measure direct inputs below this rate one of the alternative underrange modes must be selected.
SEE FUNCTION CHART

INPUT PULSE DIVIDER (refer to diagram 1).
This feature allows direct input pulse division in the range 1 - 999, simply set the number of pulses on the three digital switches on the rear panel to the value of pulses/revolution.
This can also be combined with the fixed multiplier to create a change in displayed value in relation to the input rate.

INTERNAL FIXED MULTIPLIER
The multiplier can be set to ×1 or ×10 or ×100 of the input pulse rate AFTER first going through the divider unit.
Therefore a divider scaling range can be effectively achieved as follows using a combination of input pulse division and internal multiplication:

DIVIDER Scaling range		Fixed Multiplier setting
1	999	× 1
0.1	99.9	× 10
0.01	9.99	× 100

Note: If the pulse rate AFTER DIVISION is less than 3 pulses/min the Underrange feature must be changed to FLASH or HOLD mode.

CALCULATION EXAMPLE - TACHOMETER WITH DIVIDER SCALING
1 Assume shaft speed max. = 215 rpm
2 Client requires to display 128.20 metres/min for 215rpm
3 Available shaft has 17 pulses via large toothed gear and prox. sensor

Therefore: Pulse rate at 215rpm = 3655 per min (17 × 215)
Displayed value required = 128.20
Ratio = pulse rate ÷ required display value
= 3655 ÷ 128.20
= 28.51

a Set input Divider to 285 (Actual ratio 28.51)
b Set fixed Multiplier to ×10
c Divider effective value = 28.5
therefore displayed value = 3655 ÷ 28.5
= 128.24 (error 0.035%)

Other uses of the Divider module - low frequency measurement
With Divider set to 60, the instrument in effect displays Hz or units/second.

Average reading feature
The divider scaling feature can be used to provide averaging of readings within certain limits.
Example:
Input pulse rate say 1000 pulses/min. update time will be 0.8s. This can be changed by setting the input divider to 100 and the multiplier to × 100. The processor will see pulses at the rate of 10 per min. which is 6 secs between pulses, therefore the update will be 6 secs at this specific speed rate.

COUNT TOTALISER MODE - FUNCTION SWITCH 2
The instrument can be used as a Totaliser Counter with or without the input pulse divider.
THE MULTIPLIER DOES NOT OPERATE IN THIS MODE.
Maximum count 99999 units direct reading, the overflow feature allows counting up to 8 digits, least significant values being lost as the ranges are successively exceeded.
When count exceeds 99999 a decimal point will appear as follows:

Display	Actual count
99999	99999 Direct Count value
999,99	99999(9) ( ) = overflow Counts lost
9999.9	99999(99)
99999.	99999(999) Maximum value

TOTAL ACCUMULATIVE TIME MODE - FUNCTION SWITCH 2
Operates simultaneously with the Count mode, Time is equal to Total Seconds between first and last input pulse, i.e. after the Divider is used. The display of Total Time is via links on Terminal connector.
A contact between 9-11 displays Time continously, releasing the Hold will Display the Total Count achieved up to that moment.

CYCLE TIME - TIME INTERVAL MODE - FUNCTION SWITCH 1
Cycle time is the time interval between successive pulses, automatically updates after each pulse, can be used to measure cycle time of repetitive events, particularly useful to measure seconds per event or revolution, such as reciprocating machinery.
Time range = 0.01 - 99999 seconds. Autoranging only.

SECTION 7

General Technical specification

Display	5-digit red LED 11.5mm (0.4″) High brightness type
Target Indicator	Red LED flashes/glows in display
Resolution	Tachometer mode - user selectable max 0.001 digits
Autorange/manual	Tachometer mode only, user selectable Auto only in time ranges Count absolute
Timebase	Crystal controlled
Sample time	Tachometer only = 0.8 secs or time between pulses whichever is slower
Accuracy	Tachometer direct reading mode = 0.01% ±1 digit
Time modes	= 0.01 seconds or least significant digit whichever is larger
Overrange	Tachometer only = display flashes
Underrange	Tachometer mode only Three options: 1 reset to zero below 3rpm 2 flashes displayed value below 3rpm 3 holds last reading till next pulse

Measuring ranges

Tachometer mode only	0.001 - 99999 units/min direct reading Maximum input frequency = 10kHz Maximum displayed value = 99999 units Minimum value = 0.001 units
Time modes only	Minimum = 0.01 secs Maximum = 99999 secs Autoranging only
Count mode only	5 Digit display 8 Digit capability with automatic overflow of least significant digits
Input Signal level	Maximum = 10V p/p in Prox. mode Minimum = 1V peak in mag. pickup mode
Pulse output	A parallel 5V CMOS pulse output is available 1:1 with input pulse rate
Operating temperature	0 to +45°C
Storage temperature	−30°C to +70°C

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