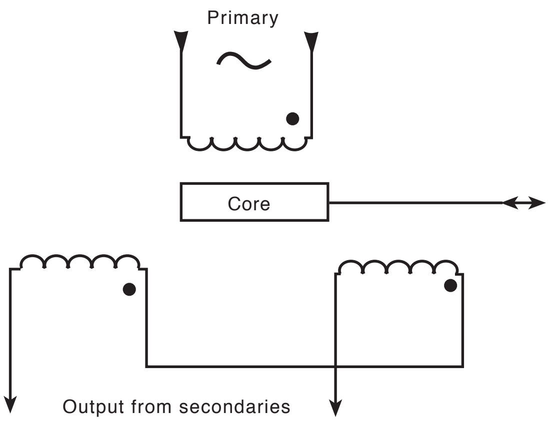
Data Sheet

Linear variable differential transformer displacement transducers (LVDTs) and instrumentation

Introduction

The LVDT is a transducer for converting positional information into an electrical signal. It is wound as a transformer with a single primary and two secondaries wound around a cylindrical bobbin. A moveable nickel-iron core is positioned inside the windings, and it is the movement of this core which is measured, (Figure 1).

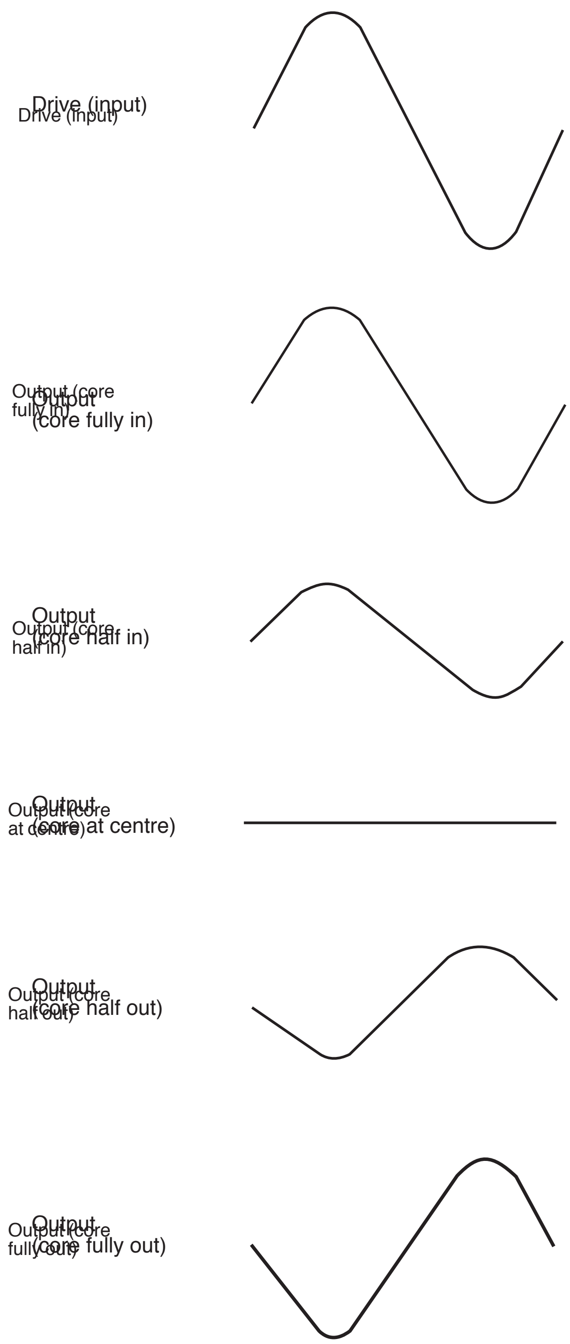
Figure 1 **Principle of operation**



To operate the transducer, it is necessary to drive the primary with a sine wave, the output from the secondaries is then monitored and consists of a sine wave with the positional information contained in the amplitude and phase. The output with the core at the centre of the stroke is zero, rising to maximum amplitude at either end of the stroke. The output is in phase with the primary drive at one end of the stroke and in anti-phase at the other end as shown in Figure 2.

In a good transducer, the relationship between position and phase/amplitude is linear. In addition to position measurement, LVDTs can be used in other types of transducers; for instance load cells, accelerometers or pressure sensors.

Figure 2 **LVDT input/output waveforms**



LVDTs

Miniature ac energised

Two miniature ac energised LVDT transducers which provide an economically priced solution for displacement sensors with outstanding rugged construction and high performance. Two sizes are offered ±1mm (RS stock no. 646-527) and ±3mm (RS stock no. 646-533). However these transducers can be used for displacement measurements up to 8mm in applications where the infinite resolution and repeatability are more important that linearity.

They are suitable for most applications of linear measurement and null sensing, having low residual voltage levels. The epoxy bonded construction makes the devices suitable for operation in wet or oily environments, but not suitable for total immersion. The temperature coefficient for zero is stated using a stainless steel armature carrier and measured relative to mild steel.

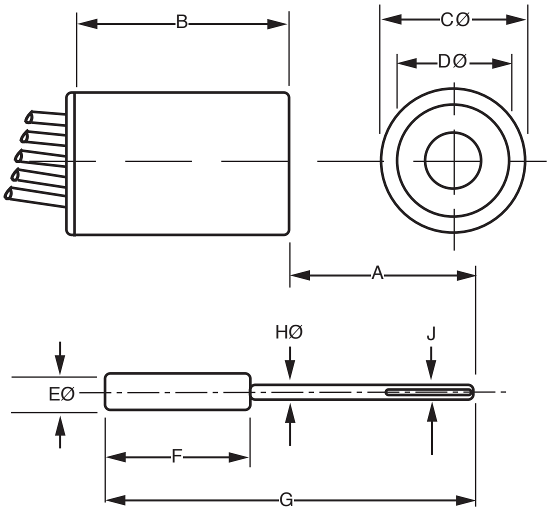
Electrical specification

Type	SM1	SM2
RS stock no.	646-527	646-533
Energising voltage	1 to 10V rms	
Energising frequency (kHz)	1 to 20	1 to 20
Calibration load (Ω)	100k	100k
Primary resistance (Ω)	102	69
Primary impedance (Ω) at 1kHz	120	135
2kHz	160	240
5kHz	310	560
10kHz	620	1000
20kHz	1300	1700
Secondary resistance (Ω)	204	200
Secondary impedance (Ω) at 1kHz	417	295
2kHz	756	450
5kHz	1830	930
10kHz	3646	1880
20kHz	7280	3900
Sensitivity (mV/v/mm typ.) at 1kHz	69	118
2kHz	110	134
5kHz	142	136
10kHz	147	130
20kHz	149	128
Zero phase shift frequency (kHz)	14	3.9
Residual voltage at zero (typ.) <% fsd	0.3	0.3

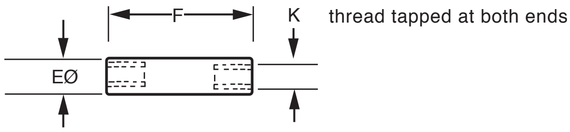
Features

- Low cost
- Rugged construction
- Short body length
- Large radial clearance in bore
- Good performance.

Figure 3 **SM1 and SM3 dimensions**



Threaded core (alternative)



	SM1	*SM3*
Stroke, ±mm		
Nominal calibrated	1	3
Increase in output	2	4
Dimensions, mm		
A, at electrical zero	12.5	15
B	15	35
C	9.52	9.52
D	3.5	3.5
E	2.5	2.5
F	9.9	20.6
G	25	42.5
H	1	1
J	M2 × 6-6g	M2 × 6-6g
K, unf thread	1-72 × 4	1-72 × 5
Weight, g		
Body, including leads	6	8
Armature assembly	0.5	1.5
Threaded core	0.2	0.7
Non-linearity, % of total stroke		
Silver grade	0.3	0.3
Standard grade	0.5	0.5
Materials	Case: 400 series stainless steel	
	Push rod: 300 series stainless steel	

Terminations

Red and blue ________ Energisation

White and green ________ Output

Yellow ________ Secondary centre tap

Note: Red and white are in phase for inward displacement.

Performance

Operating temperature ________ -40°C to +85°C

Temperature coefficient (typical)
Zero (with stainless steel carrier and relative to mild steel)

SM1 ________ 0.005% of 1mm/°C
SM3 ________ 0.005% of 3mm/°C

Sensitivity

SM1 ________ 0.010% of 1mm/°C at 5kHz
SM3 ________ 0.010% of 3mm/°C at 5kHz

Miniature dc energised

A range of four LVDTs with integral electronic oscillator and demodulators giving a dc output proportional to case position with very high accuracy and infinite resolution.

The DFg series has separate coil/electronic assemblies and a free case fitted with ply acetal homo polymer bearing which can be allowed to run on the inside of the coil assembly thus easing the guiding requirements.

The DG 2.5 has a non-rotating sprung loaded armature running in precision linear ball bearings providing a measuring repeatability of better than 0.1 microns.

All types incorporate a linear variable differential transformer (LVDT) as the measuring source together with oscillator, demodulator and filter providing a self-contained unit accepting a dc input and providing a dc output relative to armature position. High linearity and low mass of moving parts is ideally suited to a wide range of applications.

Electric specification

Sensitivity at 10V dc ________ 560mV/mm *(DFg5)*
energising (typical) ________ 780mV/mm *(others)*

Current at 10V dc
energising ________ 13mA 5.0mm 10mA 2.5mm

Input voltage range ________ 10 to 24V dc

Output ripple <1% fsd

Response time constant ________ 1.5 milliseconds

Frequency response ________ 100Hz for -3dB

Temperature range ________ -20°C to +80°C

Temperature coefficient ____ Zero:<0.010%/°C *(DFgl)*
% total stroke <0.005%/°C *(others)*
Sensitivity: <0.01%/°C

Non-linearity ________ 0.1% on 2.5 only
0.3% and 0.5% are available

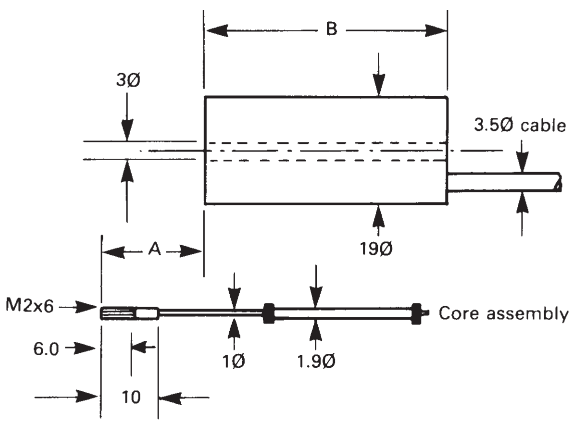
Termination _____ 3m pvc insulated 5 core 14/0.07mm screened cable

Calibration ________ Specification is provided with a transducer output impedance of 2.4kΩ into a calibration load of 20kΩ at 20°C. Variations of these parameters will result in changes of performance

Features

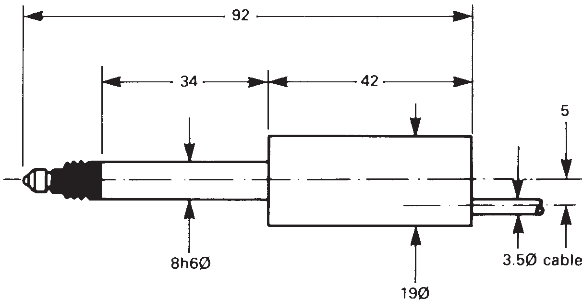
- High output
- 3 free armature types and one sprung armature type
- Ranges to 100mm
- Infinite resolution
- Excellent repeatability.

Figure 4 **DFg dimensions**



Type	*DFg1*	*DFg2.5*	*DFg5*
Linear stroke, ±mm	1	2.5	5
Dimensions, MM			
A, at electrical zero	21.5	21.5	18
B	37	37	43
Weight, g			
Body	26	26	30
Armature assembly	1.0	1.0	1.1
Armature (guided)	1.04	1.04	1.14

Figure 5 DG 2.5 dimensions



Dimensions, mm Variable dimensions stated in table

Weight,g	50
Spring rate, g/mm	13
Force at electrical zero,g	90

Terminations

Red	+ve supply
Blue	OV
White	+ve output
Green	OV output
Yellow	N/C

Long stroke ac and dc types

A range of long stroke LVDTs available as follows: ac energised types ±15mm (**RS** stock no. 646-549) and ±25mm (**RS** stock no. 646-555), dc energised types ±15mm (**RS** stock no. 646-498) ±25mm (**RS** stock no. 646-505) and ±50mm (**RS** stock no. 646-511). Universal joint rod ends for the ±15mm (**RS** stock no. 646-606) and ±25/50mm (**RS** stock no. 646-612) are also available.

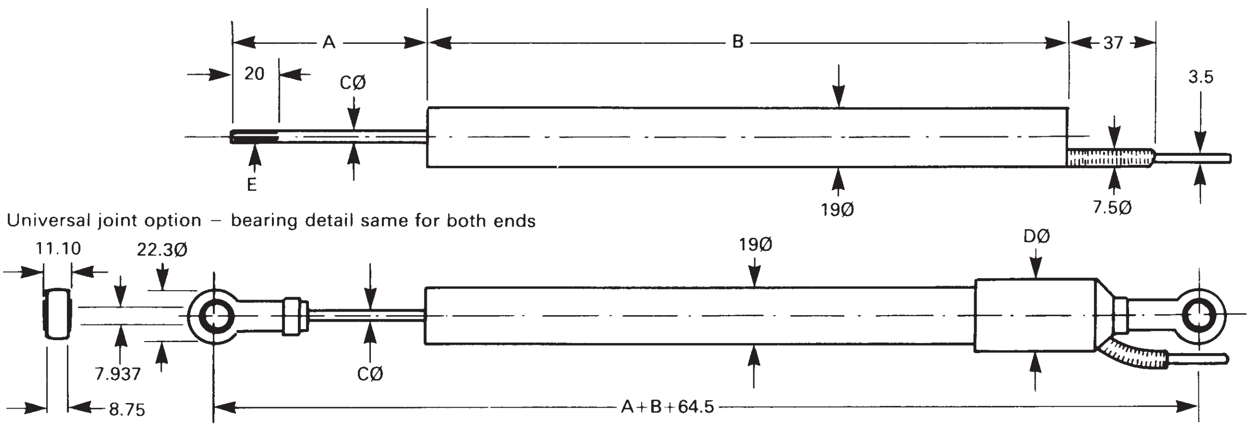
The inherent accuracy and long life of these transducers makes them ideally suited to more severe, or demanding, applications - particularly where vibration and dither make resistive transducers less reliable.

For optimum performance when using the ac types an energising frequency of 5kHz should be used.

Features

- Rugged construction
- Ranges to 100mm
- Infinite resolution
- Good linearity
- Excellent repeatability
- Universal joint (rod ends) available.

Figure 6 Long stroke LVDT dimensions



ac type	AC156	AC25	
dc type	DC15	DC25	DC50
Linear stroke, ±mm	15	25	50
Dimensions, MM A, at electrical zero	45	60	85
B	97	156	280
C	3.17	4.0	4.0
D	25	25	25
E	M3	M4	M4
Maximum stroke, ±mm	22	35	62

Weight, g			
Body, including leads	60	96	170
Armature assembly	10	18	25

Materials: Case: 400 series stainless steel. Armature carrier: 300 series stainless steel. Armature: NiFe. End caps: glass filled nylon.

Electrical specification - ac types

Type	AC15	AC25
Sensitivity mV/v/mm (typ.)	34	20
Energising current (mA)	6	4
Output impedance (Ω)	220	210
Input/Output phase shift	7	9
Zero phase shift at (kHz)	2.4	2
Energising voltage	1 to 10Vrms	
Energising frequency	5kHz	
Residual voltage at zero	<0.5%	
Temperature range	-40°C to +100°C	
Temperature coefficient in terms of % total stroke	Zero: <0.005%/°C Sensitivity: <0.008%/°C	
Non-linearity	0.5%	
Calibration	The specification provided is with a supply of 5V rms 5kHz and a calibration load of 100kΩ at 20°C. Variations of these parameters will result in changes of performance.	

Electrical specification - dc types

Type	DC15	DC25	DC50
Sensitivity mV/mm at 10V dc (typ.)	280	165	60
Energising current at 10V (mA)	10	18	40
Input voltage range (V)	9-24	9-24	9-24
Output ripple	<1% fsd		
Response time constant	0.4ms up to 50mm		
Frequency response	-3dB attenuation at 100Hz -20dB/decade above 100Hz		
Temperature range	-20°C to +80°C		
Temperature coefficient in terms of & total stroke	Zero: <0.005%/°C Sensitivity: <0.01%/°C		
Non-linearity	0.5%		
Calibration	Specification is provided with a transducer output impedance of 2kΩ into a calibration load of 20kΩ at 20°C. Variations of these parameters will result in change of performance.		

Hybrid oscillator and demodulator LVDT modules

The oscillator and demodulator have been designed to provide miniature and flexible signal conditioning. They are manufactured using thick film hybrid technology, which allows for a major reduction in size, and tighter control of performance. Their small size means that they can be assembled by the OEM user into equipment, or built into confined spaces.

Each hybrid has been designed to include the most commonly required options, which can be selected by linking pins on the device. However, if unusual frequencies, etc. are required, these can be accommodated by the addition of a few external components.

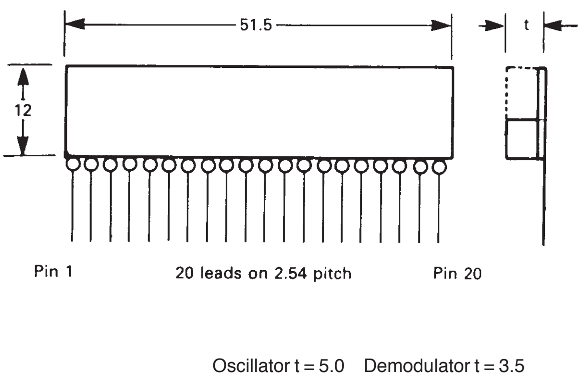
The oscillator is designed to provide a sine wave carrier for driving the transducer, and a square wave reference for the demodulator. The nominal output is 5V rms at 5 or 10kHz, but the device can operate over 1 to 20kHz, at 0.5 to 7V rms. It can also provide an output voltage proportional to supply voltage, or an external reference. If more than one oscillator is used, they can be synchronised to avoid interaction problems.

The demodulator is designed to amplify the output from the transducer, and convert it to a dc voltage. It provides a nominal 5V dc output (linear to 10V) for inputs from 2.5mV to 3.75V rms (corresponding to 0.5mV/v to 750mV/v for 5V energisation of transducer). 22 gains can be selected using links, and an external fine gain control can be added. Facilities also exist for adjusting zero anywhere in the range of the transducer, enabling end or centre zero. Again, a fine control can be added externally. The output filter characteristics can also be altered by addition of external components.

Features

- Simple LVDT conditioning
- Can be used with other transducers
- Small size
- Ease of use
- Low cost
- No additional components required
- Ideal for assembly to oem circuit boards.

Figure 7 **Oscillator and demodulator**



Oscillator electrical characteristics

Specifications quoted at 20°C, supply = ± 15V dc unless otherwise stated.

Parameter	Min.	Typ.	Max.	Units
Supply voltage (**Note** 1)		±7.5	±15	±18 V
Current consumption (off load) (full load)	±10 ±33	±13 ±36	±16 ±39	mA mA
Operating temperature	0		70	°C
Frequency (5kHz selected) (10kHz selected) (variable)	4.5 9.0 1.0	5.0 10.0	5.5 11.0 20.0	kHz kHz kHz
Amplitude (5V selected) (**Note** 1) (variable) (**Note** 1)	4.7 0.5	5.0	5.3 7.0	Vrms Vrms
Drive to transducer (**Note** 2)	0.0		50.0	mArms
Oscillator distortion (**Note** 3)		2	4	%
Temperature coefficient of amplitude (**Note** 6)		±0.004		%/°C
Temperature coefficient of frequency (**Note** 6)		±0.02		%/°C
Effect of supply voltage on amplitude (**Note** 6)		±0.01	±0.02	%/v
Effect of supply voltage on frequency (**Note** 6)		±0.05	±0.1	%/v
dc offset on output (**Note** 3)		±30	±100	mV
Output impedance		0.1	0.2	Ω
Internal reference output (**Note** 4)	-1.20	-1.22	-1.25	V
Internal ratiometric output	-1.21	-1.23	-1.24	V
Non-linearity in ratiometric mode		0.1	0.2	%
Warm up time		2	5	Mins
Settling time (**Note** 5)		20	40	ms

Notes:

1. Operation on low supply voltages will result in low amplitude signal output. The peak output voltage will be at least 5V below the supply rails. For example:

   Supply = 15V Peak = 10V RMS Output = 7V
   Supply = 12V Peak = 7V RMS Output = 5V
   Supply = 7.5V Peak = 2.5V RMS Output = 2V

   This will be relaxed slightly if the full output current is not required.
2. Oscillator output is protected against short circuits, open circuits and capacitive loads.
3. Distortion and dc offset are higher at lower frequencies. Application notes show how to reduce this if required. Distortion is mostly second harmonic which is removed by the demodulator.
4. Ratiometric output quoted for reference connected to input and with a supply of exactly 15V.
5. Time for oscillator output to settle within 1% of final amplitude and frequency.
6. Percentage figures are quoted as percentage of actual output - for instance 5V rms and 5kHz.

Demodulator electrical characteristics

Specifications quoted at 20°C, supply = ±15V unless otherwise stated

Parameter	Min.	Typ.	Max.	Units
Supply voltage (Note 1)		±7.5	±15	±18 V
Current consumption	±11	±13	±15	mA
Operating temperature	0		70	°C
Operating frequency	1		20	kHz
Gain of demodulator	1.33		2000	
ac input acceptable (Note 2)	2.5		3750	mV
Output voltage (Note 1)		5	10	V
Non-linearity		0.005	0.02	%
Input impedance	99	100	101	kΩ
Output impedance		0.2	1	Ω
Output load (Note 10)	2.5			kΩ
Output filter cut off frequency	450	500	550	Hz
Output ripple (Note 3)		25	50	mV
Response time (Note 4)	1.5	1.7	2.0	ms
Temperature coefficient of gain Temperature coefficient of zero (Note 5)		±0.004 ±0.003		%/°C %/°C
Effect of supply voltage on gain Effect of supply voltage on zero (Note 5)		±0.005 ±0.02	±0.01 ±0.04	%/v %/v
Effect of frequency on gain (Note 6) Effect of frequency on zero (Note 6)		1 0.5		% %
Amount of zero offset Z1 (Note 7) Z2 (Note 7) Z3(Note 7)	1.4 2.8 -5.2	1.5 3.0 -5.5	1.6 3.2 -5.8	V V V
Amount of potentiometer offset (Note 7)	0		2.0	V
Error in nominal gains (Note 8)		3	6	%
Zero offset on output (Note 8)		±30	±60	mV
Warm up time		2	5	Mins
Start up time (Note 9)		25	45	ms

Notes:

1. Operation on low supply voltages, will result in lower amplitude signal output. Output voltage will remain linear to within 5V of the supply rails and even further if output is not fully loaded.
2. With an oscillator output of 5V rms, this provides an acceptable transducer sensitivity of 0.5 to 750mV/v to give the nominal demodulator output of 5V dc.
3. Output ripple is quoted peak to peak. When the transducer is at the centre of its stroke (no output), the ripple is typically 15mV and rises to typically 40mV when at one extreme of its stroke. This is for an oscillator frequency of 5kHz. Ripple will fall with high oscillator frequencies. Main content is oscillator fundamental and 2nd harmonic.
4. Response time to settle within 1% of output step.
5. Percentage figures for zero drifts are quoted as percentage of 5V dc output.
6. This is total error over full frequency range.
7. This is amount of zero offset provided when demodulator fine gain is set to minimum. It will rise as gain is increased. This assumes use of oscillator reference to set zero.
8. These are errors when gain is set to middle of range (eg. 500mV/v).
9. Limited by oscillator start up. The figure quoted includes both.
10. Demodulator output is protected against open circuits and short circuits. like most integrated circuits, loading the output with a medium sized capacitive load (in the region of 10nF) can cause high frequency instability.

Connections

Oscillator	Demodulator	Pin
-15V	dc output voltage	1
Oscillator output	Fine gain adjust	2
Frequency select (CA)	Filter adjust (F2)	3
Frequency select (R10B)	Filter adjust (F1)	4
Frequency select (R5A)	Filter adjust (ZP)	5
Frequency select (R5B)	Coarse zero (Z1)	6
Frequency select (R10A)	Coarse zero (Z2)	7
Synchronising pin	Square wave input	8
Frequency select (R10B)	Coarse zero (Z3)	9
+15V supply	× 10 gain select	10
Not normally used	+15V supply	11
Reference in	0V supply	12
Remote oscillator sense	-15V supply	13
Square wave output	Gain tapping to pin 15 to 20	14
+15V supply	500mV/v	15
Oscillator output	200mV/v	16
0V supply	100mV/v	17
Ratio output	50mV/v	18
-15V supply	20mV/v	19
Reference output	10mV/v and input	20

Note: Oscillator pins 1 and 19, 2 and 16, 4 and 9, 10 and 15 are duplicated. Either pin may be used, but in the case of the oscillator output, pin 2 should be used for best performance.

Figure 8 **Oscillator block diagram**

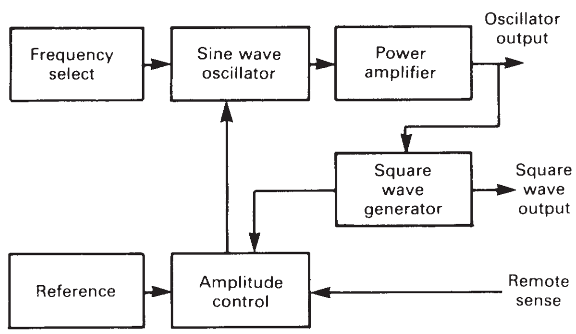
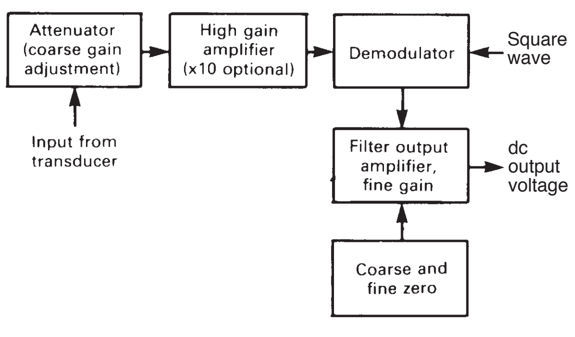


Figure 9 **Demodulator block diagram**



Introduction

The fact that the LVDT is an ac device means that there is a need for electronic signal processing to translate its output into a useful signal. This involves an oscillator to drive the primary of the transducer and a demodulator to convert the ac output from the transducer into a dc voltage. It is obvious that both these functions need to be carried out accurately if the full potential of the transducer is to be realised and so has good operating characteristics such as linearity, temperature drift, stability etc. These needs led to the development of the oscillator and demodulator hybrid's as described here. The two functions are contained in separate packages for the following reasons:

a) A single oscillator can be used with more than one demodulator.

b) Varying power dissipation in the oscillator due to varying primary loads will cause a temperature change. If both oscillator and demodulator were contained in the same package this could cause extra drift in the demodulator.

c) If both oscillator and demodulator were contained in one package the extra area and pins required would necessitate a DIL format. This would mean a larger area would be required on the PCB.

The main criteria in designing the hybrid pair were:

i) Cost.

ii) Small size (to enable mounting on a PCB).

iii) Ease of application.

iv) Flexibility of use.

v) Main use with LVDTs, but applicable to other transducers, such as full bridges and half bridges.

The best solution to these requirements is to use a thick film hybrid, based on surface mounted components, as this provides good compactness with reasonable cost. The circuit has been designed to meet the above criteria as closely as possible.

A thick film hybrid is made using a thin sheet of ceramic as a base (substrate). Conductive pastes of varying resistivities are then silk screened on to form connecting tracks and resistors. These resistors are then trimmed to the required value by cutting them with a laser beam. Discrete component (capacitors, transistors and ICs) are now added and soldered in place. These components are in surface mounted packages to avoid the needed to drill holes in the ceramic and to save space. The assembly is tested and then dip coated with conformal ceramic loaded coating for environmental protection. The unit is then retested and labelled. This assembly format was chosen in preference to more sophisticated techniques for reasons of cost and simplicity.

The following notes will first describe the application of the hybrid's to LVDTs, as these are the easiest to use due to their isolation between input and output. Application to half bridges and full bridges will then be explained.

Description of oscillator

The function of the oscillator is to provide an accurate sine wave voltage to drive the transducer, stable in both amplitude and frequency. It also provides a square wave phase reference to the demodulator and a voltage reference for use internally and for setting zeros in the demodulator. The mechanical format of the oscillator has already been given, together with a table of electrical specifications and a block diagram. Referring to the block diagram (Figure 8), the oscillator works as follows. The sine wave to drive the transducer is generated by an internal Wien bridge oscillator as this provides good performance. The frequency of the oscillator is set by linking pins or adding external re-sistors as described below. The sine wave is then passed through a power amplifier to provide sufficient current to drive most transducers (50mA) without the need for external buffers. The power amplifier contains protection circuitry as short circuits are likely in the environment where most transducers work.

The sine wave is output to the transducer and is used internally to generate a square wave for phase ref-erencing the demodulator. The oscillator output is monitored by the remote sense input, which enables allowance to be made for voltage drops in the transducer leads. This input is sampled by the square wave and compared to the reference input in the amplitude regulator to hold the oscillator voltage to a fixed level. The reference input is taken from the reference output or ratiometric output, enabling the oscillator voltage to be fixed or proportional to the supply voltage.

The oscillator contains a number of options that can be selected by linking pins, and will not require the addition of any external components.

The following functions are completely self contained:

- Frequencies of 5kHz, 10kHz, 15kHz.
- Amplitudes of 5V rms (fixed) in reference mode, or set to be 1/3 of supply voltage in ratiometric mode, that is 5V rms at ±15V dc supply.
- Remote sense of the oscillator output can be selected to allow for voltage drops in the transducer leads.
- Oscillators can be synchronised.
- Reference output voltage of -1.22V for use in the demodulator.
- Square wave output for use in the demodulator.

The following variations can be accommodated by adding a few external resistors:

- Frequencies of 1kHz to 20kHz.
- Amplitudes of 0.5 to 7V rms, either fixed or ratiometric.
- An external reference to set amplitude.
- Distortion reduction.

Description of demodulator

The function of the demodulator is to take the ac output of the transducer and convert it into a useful dc voltage proportional to displacement, load etc. It also contains circuitry to enable the adjustment of gain and zero to accommodate a wide range of transducers. The mechanical format of the demodulator has already been given, together with a table of electrical specifications and a block diagram.

Referring to the block diagram (Figure 9), the demodulator works as follows. The output from the transducer is fed into a coarse gain select circuit and is then amplified. This amplifier can have a gain of 25, or 250 if the ×10 option is used, the extra gain allowing oper-ation with low output transducers such as strain gauges.

The use of ac signal amplification reduces the effects of circuit drifting. Using larger amplitude, injection is made to a phase synchronous demodulator, which uses the square wave from the oscillator to convert it into a dc voltage with some superimposed ac. This is then fed through a low pass filter which removes the majority of the ac components leaving a steady dc voltage with slight ripple. The low pass filter includes circuitry for setting coarse zero, fine zero and fine gain, and also has connections so that the filter characteristics can be altered.

The demodulator contains a number of options that can be selected by linking pins which will not require the addition of any external components, it is also possible to add extra components to obtain other required functions.

A wide range of gains can be selected by linking pins, using the coarse gain select, the ×10 option and by linking the fine gain adjust pin to 0V or to the dc output. These gains are listed in the following table.

Range	Gain	mV input for 5V dc output	mV/V transducer sensitivity for 5V dc output and 5V rms oscillator	Coarse gain selected (mV/v)	Link fine gain adjust to	×10 linked to 0V?
1	1.33	3750	750	500	Output	No
2	2	2500	500	500	-	No
3	4	1250	250	500	0V	No
4	3.33	1500	300	200	Output	No
5	5	1000	200	200	-	No
6	10	500	100	200	0V	No
7	6.67	750	150	100	Output	No
8	10	500	100	100	-	No
9	20	250	50	100	0V	No
10	13.3	375	75	50	Output	No
11	20	250	50	50	-	No
12	40	125	25	50	0V	No
13	33.3	150	30	20	Output	No
14	50	100	20	20	-	No
15	100	50	10	20	0V	No
16	66.7	75	15	10	Output	No
17	100	50	10	10	-	No
18	200	25	5	10	0V	No
19	133	37.5	7.5	50	Output	Yes
20	200	25	5	50	-	Yes
21	400	12.5	2.5	50	0V	Yes
22	333	15	3	20	Output	Yes
23	500	10	2	20	-	Yes
24	1000	5	1	20	0V	Yes
25	667	7.5	1.5	10	Output	Yes
26	1000	5	1	10	-	Yes
27	2000	2.5	0.5	10	0V	Yes

As can be seen, there is some slight duplication, resulting in an effective total of 22 gains. There are also a further 9 ranges based on the 100 to 500mV/v ranges with the ×10 link, which overlap ranges 10 to 18.

If a fine zero control is not added adjustment can be made if required, by linking the appropriate pin or pins (Z1, Z2, Z3, ZP) to the reference voltage from the oscillator when they will provide the following nominal zero offsets:

	Fine gain adjust linked to		
	dc output	Nothing	0V
Z1	1.5V	2.3V	4.5V
Z2	3.0V	4.5V	9.0V
Z3	-5.5V	-8.3V	-16.5V
ZP	2.0V	3V	6.0V

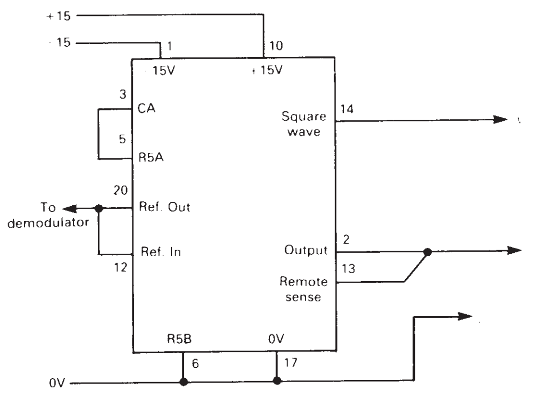
These offsets are additive, for instance if Z1 and Z2 are both linked it will give zero offsets of 4.5, 6.8 and 13.5V. With no external components, the filter will behave as shown in the electrical specification, that is with a cut off frequency of 500Hz.

If required, a fine gain control and fine zero control can be added, or other fixed gain and zero settings achieved by manipulating the gain select and zero select pins with external resistors. If other input impedances are required, an appropriate resistor can be wired in parallel with the input to reduce its nominal resistance of 100kΩ. It is also possible to adjust the characteristics of the low pass filter if required.

Applying the oscillator

Connecting the power supplies to the oscillator is simple, as either of the two ±15V pins can be used andsimplifies layout. Decoupling is included in the hybrid and addition is therefore not required except for any other circuitry on the pcb. The hybrid is tolerant of having one supply removed in the event of a fault and this should cause no damage, however reversal of the supplies can destroy the device. Hence, if supply reversal is likely, it would be wise to protect the whole pcb with diodes. It is not necessary for the two supplies to track each other exactly and a discrepancy of ±1V should have a negligible effect on performance.

Figure 10 **Basic oscillator configuration**



This arrangement provides the standard fixed 5V rms, 5kHz output. Frequency is set by linking R5A to CA and R5B to 0V. Amplitude is set by linking Ref. Out to Ref. In. The use of the reference means the 5V rms is fixed.

The remote sense is linked to output to allow control of amplitude.

The reference output is available for use by the demodulator or other circuitry that may require it. The maximum current that may be drawn from it is:

$$I(mA) = \frac{\text{Supply}}{12.1} - 0.35$$

For instance, if the supply is ±15V, maximum current is 0.89mA.

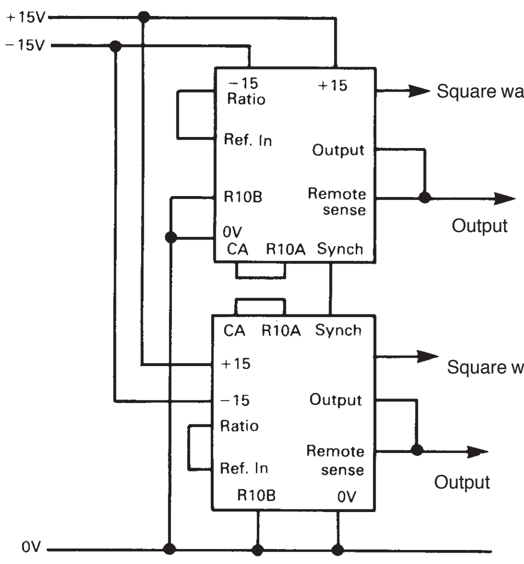
The square wave is output to the demodulator.

If it is required to use 10kHz instead of 5kHz, use R10A and R10B instead of R5A and R5B. If 15kHz is required use both.

If it is required to be operated in ratiometric mode, link Ref. In to Ratio Out instead of Ref. Out.

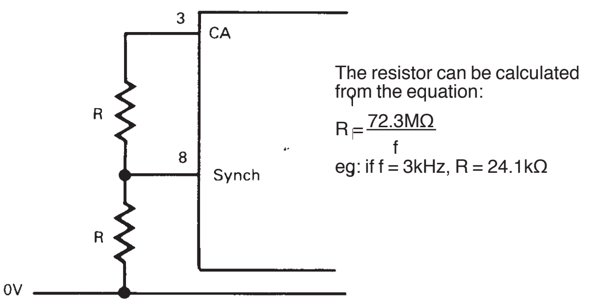
If oscillator synchronisation is required this can be achieved by linking Pin 8 on each oscillator. All the oscillators should be set to the same nominal frequency and amplitude.

Figure 11 **Two oscillators set to 10kHz in ratiometric mode and synchronised**



For other frequencies, it is necessary to add two external resistors. Ignore R5A, R5B, R10A, R10B and wire up as follows:

Figure 12 **Operation at different frequencies**



In practice, this equation will give good results at low frequencies, but a slightly lower resistor value will be needed at high frequencies, due to phase shifts in the internal amplifiers.

For other output amplitudes than 5V rms, there are two solutions. If the output is to be reduced, a resistor should be put between Ref. Out and Ref. In, instead of a wire link. If it is to be increased, the resistor should be put in series with the remote sense input.

Figure 13 **Lower output**

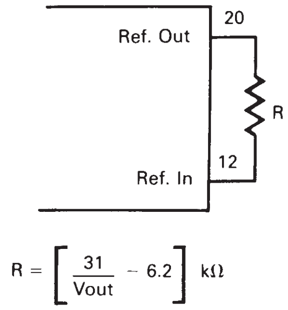
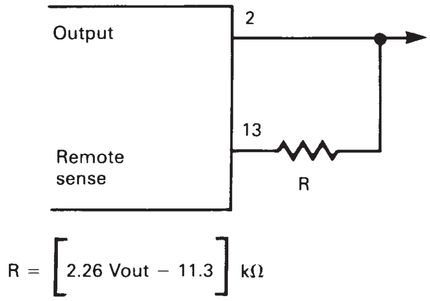


Figure 14 **Higher output**



For lower output amplitude when the ratio output is used instead of the reference output, the resistor will need to be increased slightly.

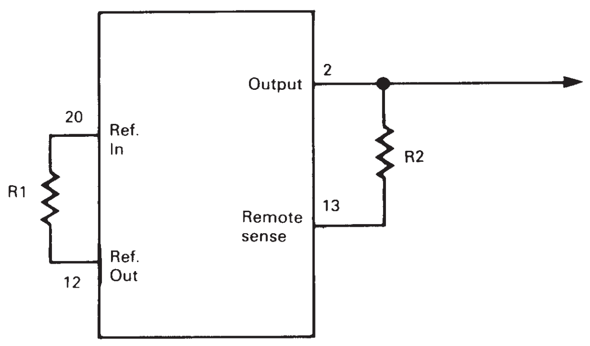
If required, the Sum input (Pin 11) can be used instead of Ref. In, in which case there is no internal resistance, and so:

$$R = \frac{31}{\text{Vout}}\ k\Omega$$

It is obvious that this method can also be used for increasing amplitude instead of the method mentioned above. However, the use of 'Sum' is not recommended, as it will introduce a slight degradation in temperature drift and distortion.

At low frequencies (especially below 2kHz) the distortion and dc offset in the oscillator output will start to increase markedly (to typically 8% at 1kHz). Where this is not acceptable, it can be improved by wiring resistors in series with both the reference inputs and the remote sense.

Figure 15 **Operation at low frequencies**



The output amplitude will be $V = \frac{R2 + 11.3K}{R1 + 6.2k} \times 2.74$

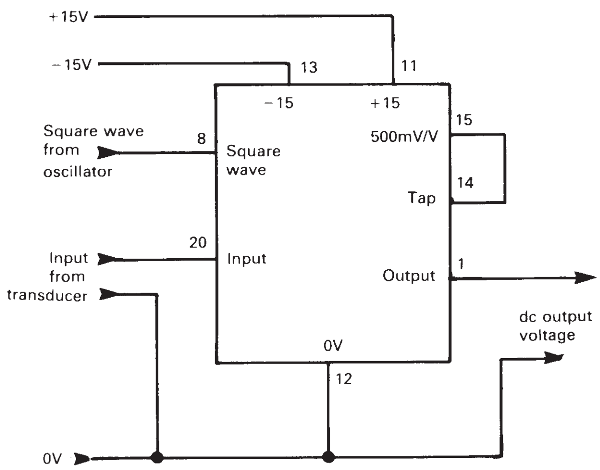
The resistors should be made as low as necessary to reduce the distortion to an acceptable level. If they are made too large, slightly higher temperature drift may result.

If required, an external reference can be used and resistors added, as described above, to obtain the correct oscillator amplitude. Note that the reference is negative and that output voltage is proportional to the reference voltage.

Applying the demodulator

The demodulator is similar to the oscillator with regard to power supplies. It is internally decoupled, and behaves the same under supply fault conditions.

Figure 16 **Basic demodulator configuration**



This is a very basic set up, to give 5V dc output with a 2.5V rms input (5-00mV/v transducer). Note that it is essential to have good layout of the square wave track, avoiding other connections to the demodulator, especially pins 2, 3, 4, 6, 7, 9 and 10. This is because the very fast switching of the square wave can induce pick up spikes in the output voltage. It is also important to keep the coarse gain select link to the tap input short and away from interference.

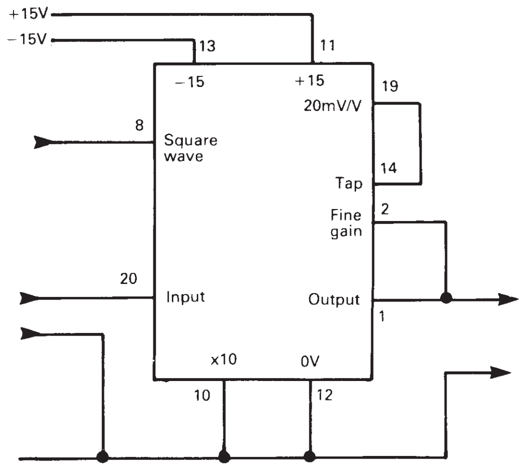
The above circuit does not include any zero offset, and has a single gain. Other gains (in accordance with the table given earlier) can be selected instead. Tap can be limited to any of the 6 coarse gain positions to give acceptable input sensitivities to 10, 20, 50, 100, 200 or 500mV/V.

If the ×10 pin is linked to 0V, this will increase the gain 10 times which means that the necessary transducer sensitivity is reduced 10 times, to give ranges of 1, 2, 5, 10, 20 or 50mV/V (3 overlap, the original 6). In addition to this the gain can be doubled or reduced by 1.5 times using the fine gain adjust pin. If the fine gain adjust is connected to 0V this doubles the gain, giving acceptable sensitivities of 0.5, 1, 2.5 … 100, 250mV/V. If the fine gain adjust is connected to the dc output, this reduces the gain, giving acceptable sensitivities of 1.5, 2, 7.5 … 300, 750mV/V. Refer to the table to see what to link for a particular gain. Note that the sensitivities quoted are for 5V dc output and 5V rms oscillator. Other outputs can be calculated using the gain figures given.

dc output = oscillator volts × transducer sensitivity × demodulator gain.

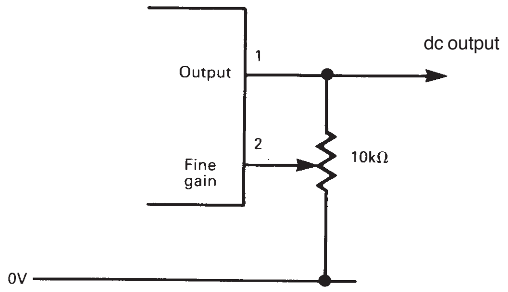
For example, if we have an oscillator output of 3V and a transducer sensitivity of 5mV/V (sensitivity = 0.005) with the demodulator set to a gain of 333 (range 22), this gives a dc output of 3 × 0.005 × 333 = 5V. Looking at the table, to get this gain we need to select the 20mV/V coarse gain, link fine gain adjust to the dc output, and include the ×10 link to 0V.

Figure 17 **Demodulator as described in electrical specifications which is a two pole, 500Hz cut off low pass filter**



The ripple figures quoted are with an oscillator frequency of 5kHz, but will be reduced at high oscillator frequencies. For instance, it will only be a quarter the figures quoted at 10kHz.

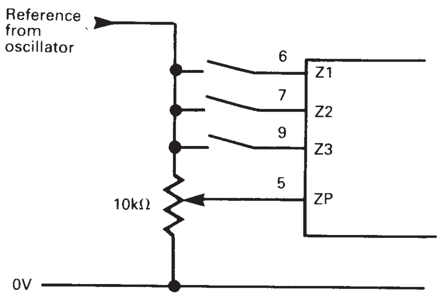
Figure 18 **Fine gain control**



From the examples above it can be seen that this will provide complete tracking between minimum and maximum gain on any coarse gain range. For example on the 500mV/V range, it will provide adjustment in the range 250 to 750mV/V.

To fine adjust the gain a select on test resistor can be inserted between fine gain adjust and either 0V or dc output. For instance a resistor between 0V and fine gain adjust will give adjust in the range 250 to 500mV/V as the resistor is varied from short circuit to open circuit.

Figure 19 **Coarse and fine zeros**



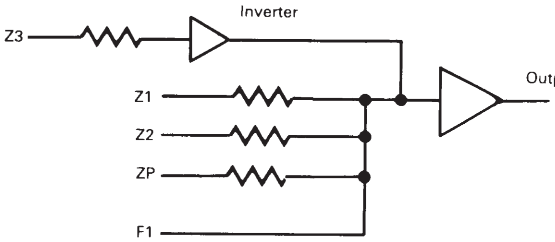
If the coarse zero pins are left open they introduce no zero offset. Linking the pins to the voltage reference will introduce the offsets given previously. Fine adjustment is provided by the potentiometer. If all zeros are linked in, this provides a small ± offset about zero, as will normally be required. Each demodulator draws 240µA from the voltage reference and care should be taken to ensure that the oscillator reference can supply the current (see equation given). If necessary a 20kΩ potentiometer can be used instead of the 10kΩ which reduces current to 160µA. Hence the minimum supply voltage needed for different numbers of demodulators is:

Number of demodulators	10kΩ	20kΩ
1	7.5V	7.5V
2	10.1V	8.1V
3	13.0V	10.1V
4	-	12.0V

Operation with more than four demodulators is not recommended.

If required, external resistors can be added to get other zero ranges. If resistors are wired in series with the Z1, Z2, Z3 pins, this will reduce the offset provided. The pin F1 gives zero adjust with no internal resistance and can be used with external resistors only. If it is required to use a select on test resistor to fine adjust zero, the Z3 should be wired to the reference via a resistor to give a small positive offset in the dc output. The select on test resistor is wired between the voltage reference and F1 to pull this back to exactly zero.

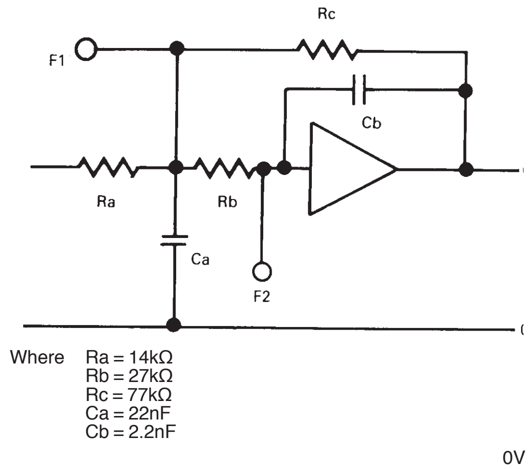
Figure 20 **Zero circuit**



Access to the F1 pin means that almost any zero offset can be accommodated, other zero coarse and fine settings are required these can be added. Selection of the external resistors is best done by experiments.

The characteristics of the low pass filter on the output can be changed if required. The general form of the filter is shown in Figure 21.

Figure 21 **Low pass filter**



Ra varies slightly as the coarse zeros are adjusted, but this only has a very slight effect.

$$\text{Cut off frequency} = \frac{1}{2\pi\sqrt{RbRcCaCb}}$$

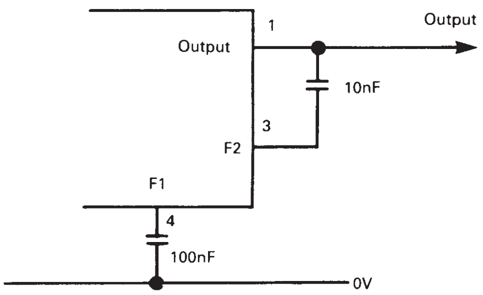
$$\text{Damping factor} = \sqrt{\frac{CbRb}{CaRc}} + \sqrt{\frac{CbRcn}{CaRb}} + \sqrt{\frac{CbRbRc}{CaR^2a}}$$

This is not the exact circuit equation and so there will normally be a slight error. Using the basic hybrid with no added components, this gives a frequency of 502Hz and a damping factor of 1.75.

Access to F1, F2 0V and output enables manipulation of Ca, Cb and Rb. Rc can also be affected, but this will modify the gain of the hybrid. One simple adjustment is to wire a 10kΩ resistor between F1 and F2. This gives a cut off frequency of approximately 1kHz while hardly affecting the damping.

If it is required to reduce the filter frequency, wiring capacitors in parallel with Ca and Cb in the ratio 10:1 will reduce the frequency, but not affect the damping factor. For instance, the circuit shown in Figure 22 will have a cut off frequency of 90Hz.

Figure 22



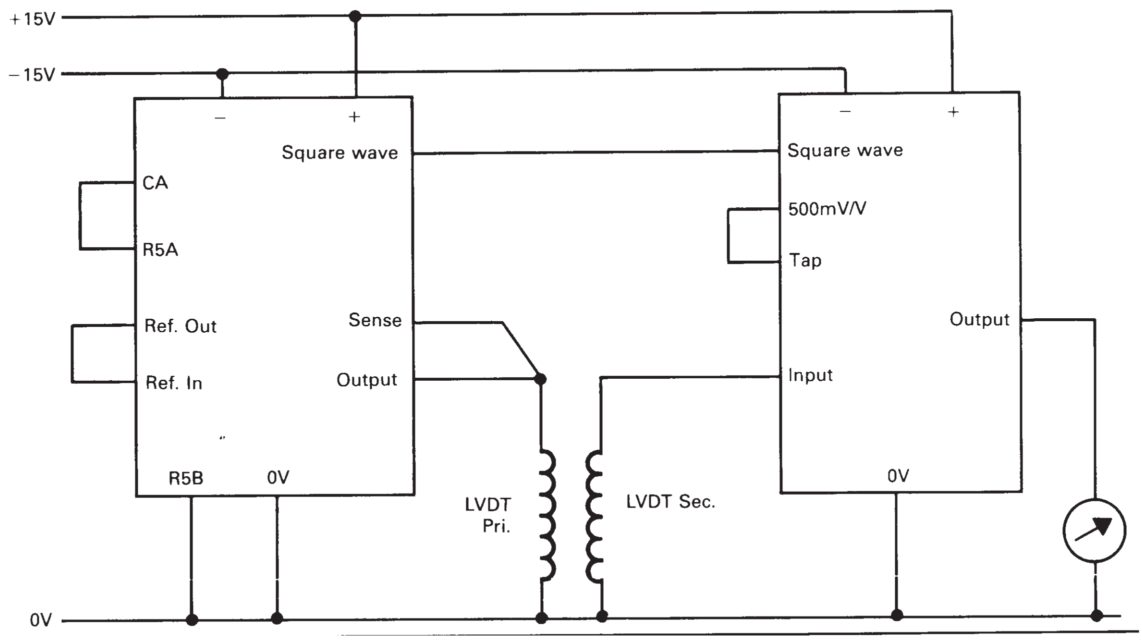
If it is required to examine the filter characteristics for a particular design, this can be achieved by feeding an excitation waveform into the Z3 pin and examining the dc output. Hence, using a sine wave, a gain/phase plot can be produced; and using a square wave, the step response can be checked. Output ripple can obviously be checked using the transducer input.

In most cases, the ripple on the output will be acceptable, or can be reduced by reducing the filter frequency or increasing the oscillator frequency. However, if neither is possible, it will be necessary to add a further filter stage after the demodulator. This should reduce ripple to a level acceptable to most fast A/D converters and will remove any slight spikes that may be on the output.

Applying the hybrid pair

This section gives some examples of using the hybrid pair.

Figure 23 **Basic circuit for LVDT, for a 5V dc output for a 500mV/V transducer, frequency 5kHz**



A two channel configuration can be achieved as Figure 23. This is by duplicating the demodulator circuit. The two LVDT primaries are wired in parallel and the secondaries each feed their own demodulators, the square wave being fed to both.

Figure 24 **Circuit for LVDT with fine gain and zero adjust, sensitivity range 2.5 to 7.5mV/V**

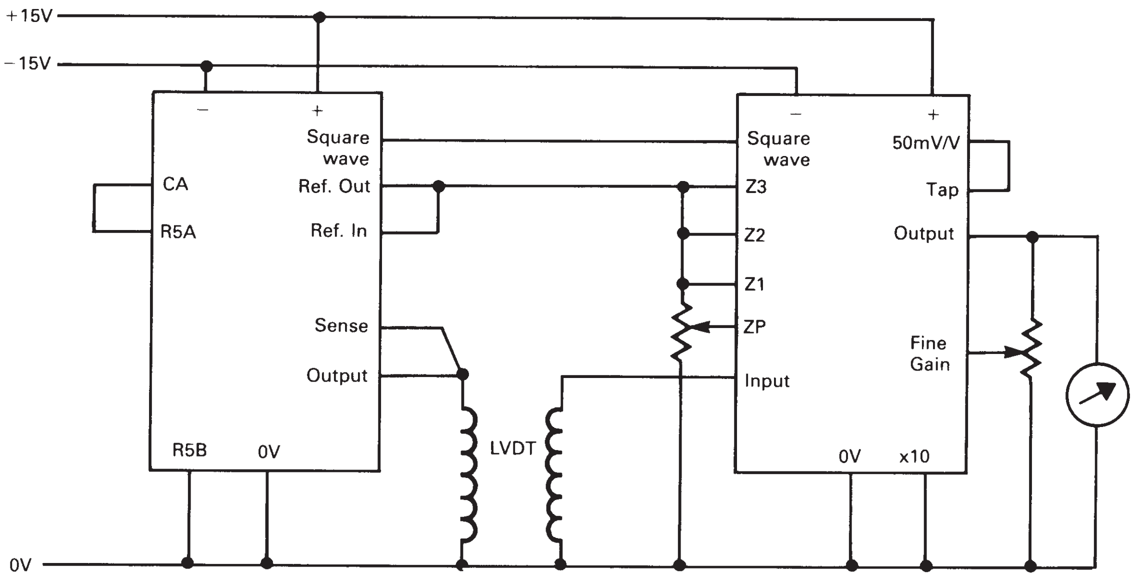
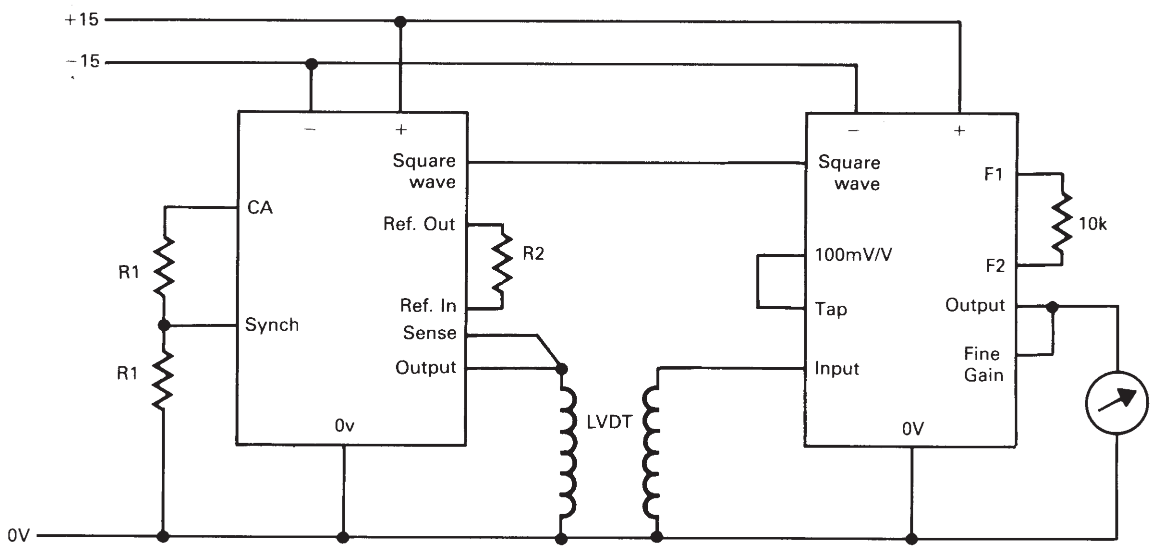


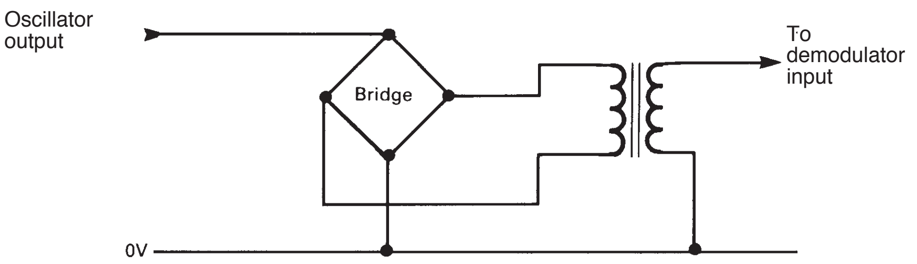
Figure 25 **Circuit for LVDT. Oscillator running at 20kHz 3V rms. Transducer sensitivity 20mV/V, demodulator gain set to 6.67 (see table). No zero offset. Output filter set to 1kHz.**



R1 = 3.6kΩ
R2 = 4.1kΩ
Output = 3 × 0.2 × 6.67 = 4V dc

If a full bridge is used, it is necessary to use an isolating transformer. It is recommended that this should be placed between the transducer output and the demodulator to avoid having high current passing through the transformer.

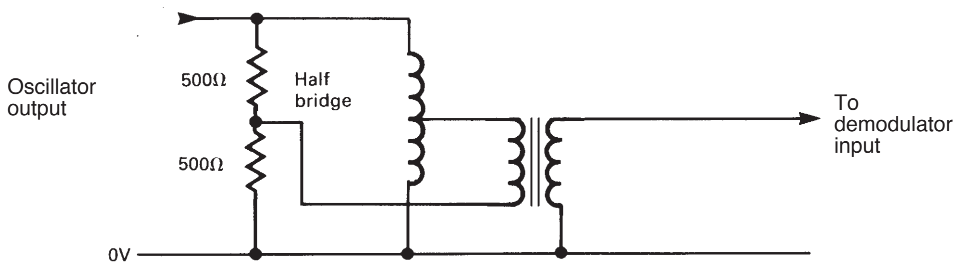
Figure 26 **Full bridge circuit**



If more than one transducer/demodulator is used, a transformer will be needed for each.

For use with half bridges, one of two methods can be used. The first is to use a transformer as above and complete the bridge using either two resistors (as below) or a centre tapped transformer winding.

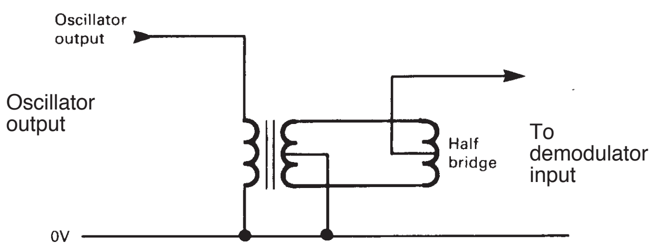
Figure 27 **Half bridge circuit**



Using resistors is the cheapest solution, but can introduce slight zero drift due to drift in the resistors.

A better method is to use a transformer on the oscillator output as this introduces less drift and a single transformer can be used for a number of transducers.

Figure 28 **Half bridge circuit with oscillator output transformer coupled**



If more half bridges are added, they are wired in parallel with the first one, with their centres being taken to separate demodulators. A recommended transformer is as follows:

Primary = 130 turns of 0.08mm wire
Secondary = Two windings of 65 turns, 0.25mm wire, bifilar wound.

Because of the extra load the transformer puts on the oscillator, the following limitations should be observed

a) Use 15V supply rails, or reduce oscillator voltage to 4V.

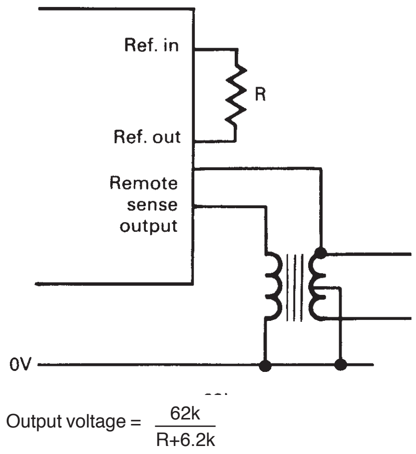
b) Reduce current capability of oscillator to 40mA.

c) Operate above 3kHz oscillator frequency. If required to go lower, reduce oscillator voltage linearly to 1V rms at 1kHz.

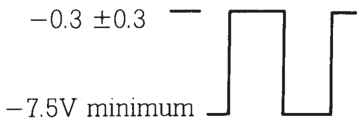
If these requirements cannot be fulfiled, it will be necessary to design an improved transformer. Due to the internal impedances in the transformer it is necessary to sense the output on the transducer side.

Note that the output is now bi-phase, with both outputs being 2.5V rms. This means that it is necessary to use a resistor on the reference in pin as shown in Figure 29.

Figure 29



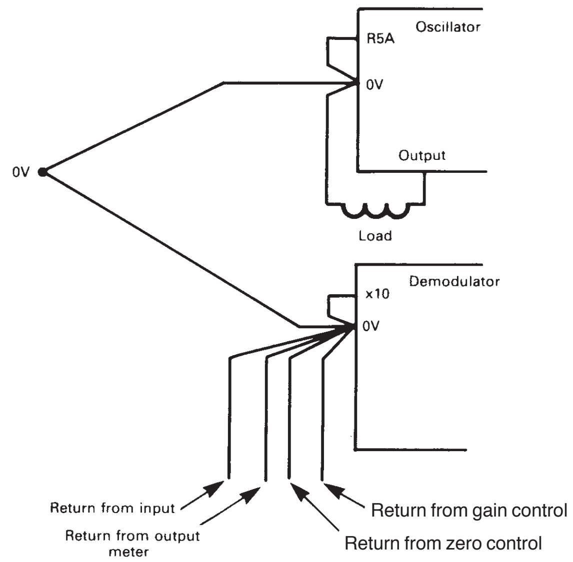
The hybrid oscillator is not recommended for driving more than four transducers (even if there is sufficient power drive) due to loading on the voltage reference and the square wave outputs. The two alternatives are to follow the oscillator with a buffer stage or design a separate oscillator. If a new oscillator is designed, it will need to provide a square wave in phase with the oscillator with the following amplitude:



If the hybrid oscillator is used, it will be necessary to buffer the square wave and voltage reference in addition to the main output. The output should be sensed on the output of the buffer.

Good earth layout is essential to avoid problems such as the demodulator output ripple being affected by oscillator loading. An ideal layout is shown in Figure 30.

Figure 30 **Earth layout**



This simplified layout may prove too idealised for most applications. The only point that is likely to cause problems is the return from the oscillator load, as this carries a high current and may need to be a short heavy gauge flexible conductor such as a braid.

2 channel LVDT signal conditioning, carrier amplifier (CAH) card (RS stock no. 646-583)

A standard sized single Eurocard containing oscillator and demodulation circuitry to drive the output of two ac LVDTs.

The operating principle is an ac carrier amplifier with a 5 volt rms 5kHz oscillator providing the output to the transducer. The transducer configuration can be lvdt inductive or resistive strain gauge incorporating half or full bridge. The maximum output of 5 volts can be obtained with a transducer sensitivity of between 0.5mV/v to 692mV/v, this being an effective amplifier gain of 2000:1.

Potentiometers for the adjustment of span and zero are board mounted. The zero control provides fine adjustment up to 20% depending upon the sensitivity setting. It is possible to offset the zero by 100% thus allowing a transducer which is inherently centre zero to operate with an end zero, ie. a plus/minus 5mm transducer can be set to operate as 0 to +10mm or 0 to -10mm. The board dimensions are based on the Eurosize frame and when used with a DIN 41612 64 pin edge connector it is compatible with a Euro racking system.

Electrical specification

Power supply ______ ±15V dc ±0.6V, 1% regulation or better. +20mA -40mA no load. +40mA -60mA max load

Supply protection ________ Reverse polarity protected

Transducer drive _______ 5V rms at 5kHz sinusoid max rated 50mA

Oscillator protection _ Open and short circuit protected

Transducer sensitivity range _______ 0.5 to 692mV/V in 9 coarse gain positions

Range of gain control _____________ 460 to 1 switched, 3 to 1 adjustable

Range of zero control _____ ±20% and ±100% switched

Output voltage __________________ ±5V into 10kΩ min Linear overrange to ±10V

Output impedance __________________________ <1Ω

Output protection ___ Open and short circuit protected

Output ripple _______________ <10mV p to p at 10kHz

Output filter _________ Cut off frequency -3dB at 500Hz second order

Non-linearity _______________________________ <0.1%

Temperature range __________________ 0°C to 70°C

Temperature coefficient Zero, better than 0.01% fro/°C
Gain, better than 0.01% fro/°C

Features

- 2000:1 amplifier
- 100% zero offset facility
- Eurocard frame sized board
- Span and zero potentiometers on front edge of board
- Ideal for OEM use.

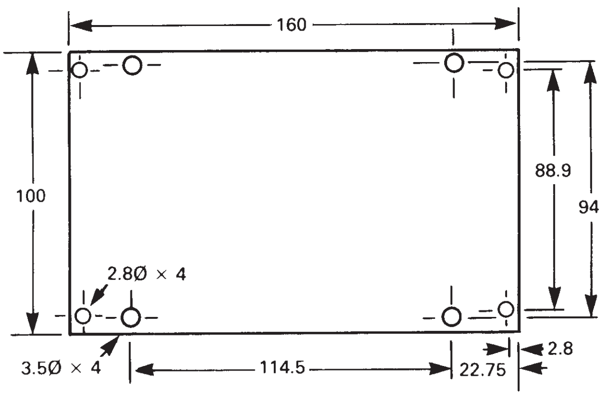


Figure 31 **CAH card dimensions**

Connections

Function			DIN 41612 Pins
Power supply			
+15V dc			32a & c
0V			30a & c
-15V dc			28a & c
Transducer drive			
Oscillator output	(LVDT Red)		22a & c
Oscillator 0V return	(LVDT Blue)		20a & c
Oscillator/2 for use with ½-bridges			18a & c
Synch (to synchronise cards)			21a
Transducer screens			24a & c
Channel A demodulator			
Input	(LVDT White)		16a & c
Input return	(LVDT Green)		14a & c
dc output			26a & c
Channel B demodulator			
Input	(LVDT White)		19a
Input return	(LVDT Green)		17a
dc output			23
Current drivers			
Driver A input			25a
Driver A output			27a
Driver B input			29a
Driver B output			31a
A±B/2 section			
A + B	output		7a
(A + B)/2	output		9a
A - B	output		11a
(A - B)/2	output		13a
Selected	output X		15a
Selected	output Y		15c
Potentiometers			
Span and zero potentiometers are connected to the edge connector, so that they can be replaced by off board components			
Channel A & B	zero	clockwise	8a & c
Channel A & B	zero	counterclockwise	10a & c
Channel A	zero	wiper	12a & c
Channel B	zero	wiper	5a
Channel A & B	span	clockwise	2a & c
Channel A	span	counterclockwise	4a & c
Channel A	span	wiper	6a & c
Channel B	span	counterclockwise	1a
Channel B	span	wiper	3a

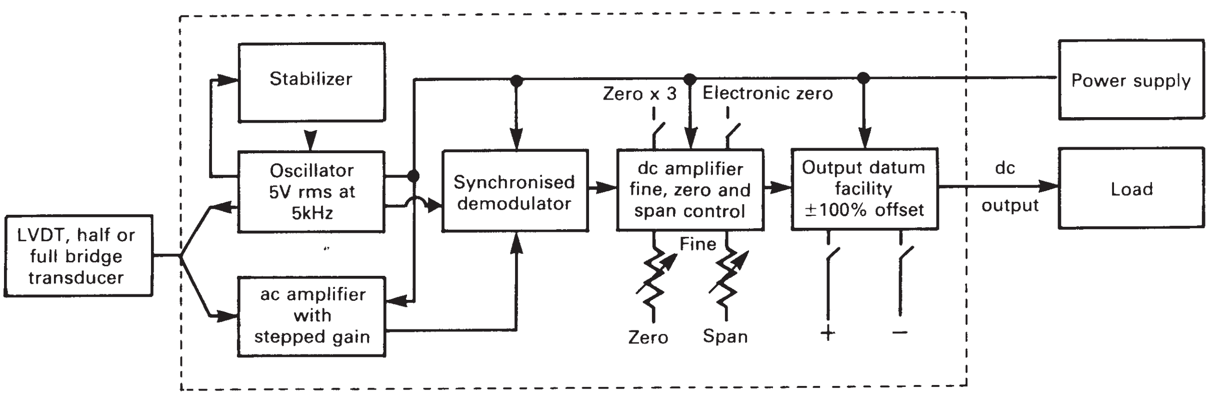


Figure 32 **CAH card block diagram**

Card function

The basic function of the card is to energise the transducer (LVDT, half bridge or full bridge) with an ac waveform, take the output of the transducer and convert it to a dc output voltage proportional to displacement, strain, load etc. It should be powered from a stable twin rail dc supply at ±15V or ±12V.

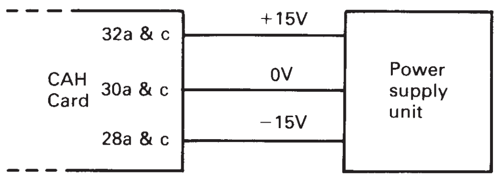
The A±B/2 facility offers four outputs based on the two transducer outputs (A and B). These are A+, A-B, (A+B)/2, (A-B)/2 and they can be used for measuring diameters etc, where two transducers are involved. The current drivers are wired up separately and so can be used with any of the dc outputs.

In order to exploit the transducer to the full, a number of facilities are provided. Span is adjustable in 9 coarse ranges and with a fine span control to allow the use of transducers with sensitivities in the range 0.5mV/V to 750mV/V for a full scale output of 5V dc. Coarse and fine zero controls are provided to enable the transducer to be zeroed anywhere in its stroke. Two operating frequencies are provided, 5kHz and 10kHz, and the output filter cut off frequency can be set to 500Hz or 1kHz to allow for the best response time/output ripple trade off. The standard card is provided with an input transformer and a pair of resistors to be used when half bridge transducers are in use. These two resistors are precision low drift types to reduce drift.

Wiring up

This section details how to connect the card to power supplies, transducers and readouts.

Figure 33 **Power supply**

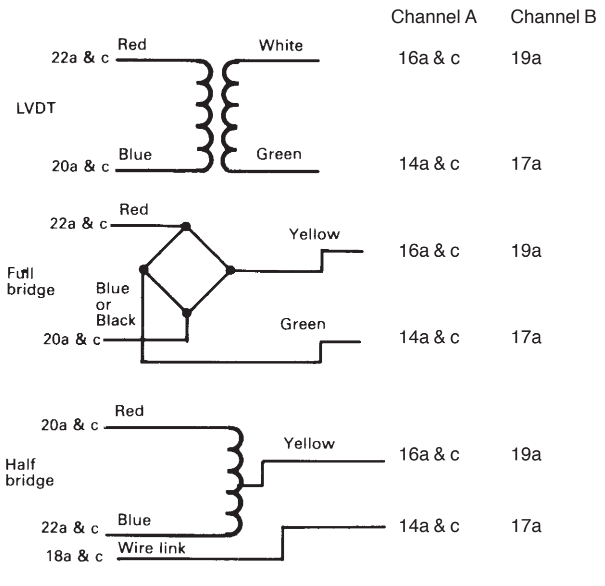


Transducers

The CAH card can be used with three different types of transducers; LVDT, full bridge or half bridge (either inductive or resistive).

Note: That on the dual channel card the two transducers are driven in parallel, but their outputs go to separate demodulators.

Figure 34 **Transducer wiring**

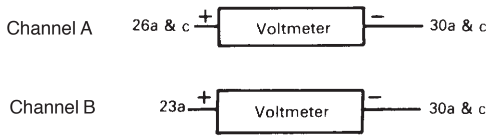


Note: That colours of wires may vary with different manufacturers. The colours quoted are standard for **RS** transducers. In all cases the transducer lead screen may be connected to Pins 24a & c.

Output voltages

The dc output voltage from the card can be read by putting a voltmeter (either digital or analogue) between the output and 0V (Pin 30a & c).

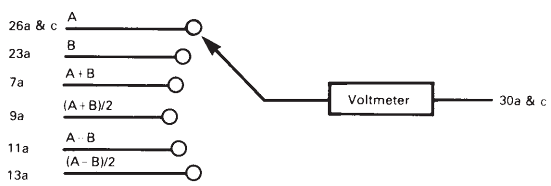
Figure 35 **Output voltage wiring**



Similarly, when the A±B/2 facility is used, the four outputs (A+B, A-B, (A+B)/2, (A-B)/2) can be read by connecting the voltmeter between the appropriate output pin and 0V. All outputs can be read at once.

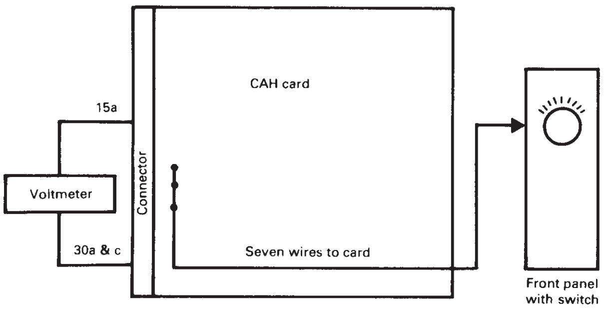
To enable the use of one meter, a six way selector switch can be used:

Figure 36 **A±B/2 wiring using single voltmeter**



In some cases it may be desired to mount this switch on a front panel attached to the card, with the selected output from the switch wiper being fed to a remote meter via the edge connector. For this purpose there are two output pins assigned to be "selected outputs", and the wiper of the switch should be wired to one of these. To enable this to be done, the appropriate pins (26, 23, 7, 9, 11 & 13) on the edge connector are wired to pads near the edge connector to enable wires to the switch to be attached (Figure 37).

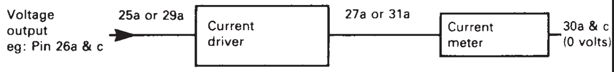
Figure 37



Current Outputs

These are provided by two current drivers, wired separately to the rest of the card electronics. They can be looked upon as voltage to current converters and can be operated with any of the six output voltages mentioned above.

Figure 38 **Current outputs**



The current drivers provide 2mA of output per volt input, so that ±5V on the voltage output causes ±10mA output.

Synch

Pin 21 is a synchronising pin to be used in systems using more than one card. Link pin 21 on all cards together with short wires to synchronise the oscillators.

If this is not done it is possible to create beat notes between oscillators causing fluctuations in the dc outputs.

Potentiometers

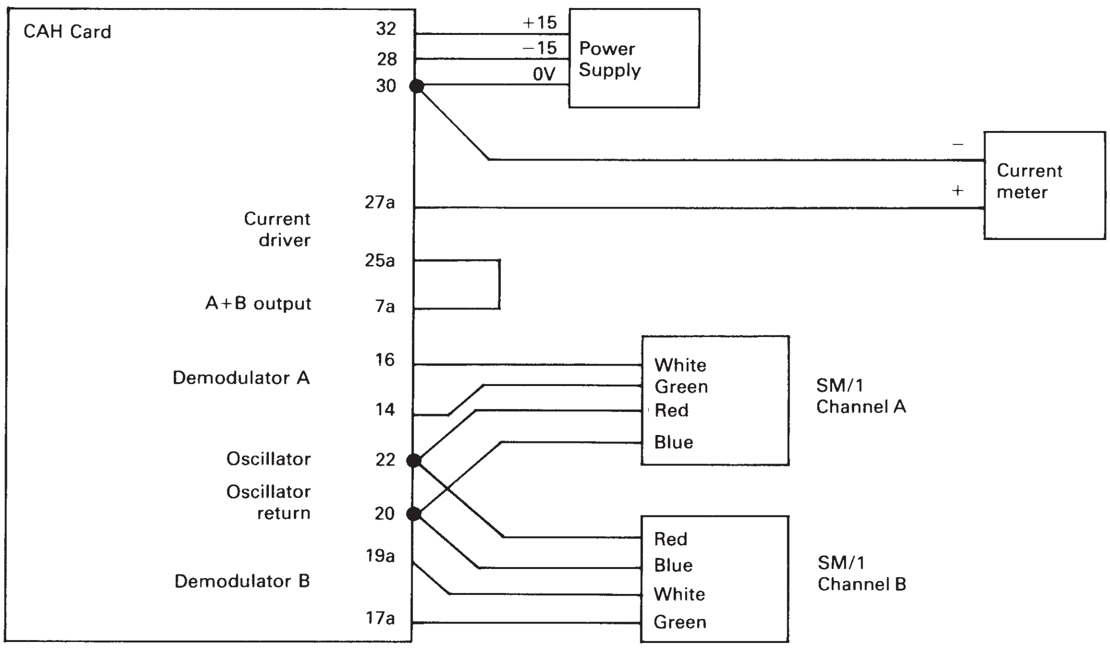
If it is required to mount the span or zero potentiometers remotely, the pins are available on the edge connect to do so. Wire lengths should be kept short to avoid pick up of electrical noise, and lengths greater than 0.5m may cause some degradation of performance.

The potentiometer leads should be wired to the pins specified in external connections, ensuring the clockwise and anticlockwise leads are not reversed.

Example

As an example, take a Dual Channel Card with A±B/2 facility, wired to a pair of 5m/1.0mm transducers. The A+B output should operate a current output driving a remote meter.

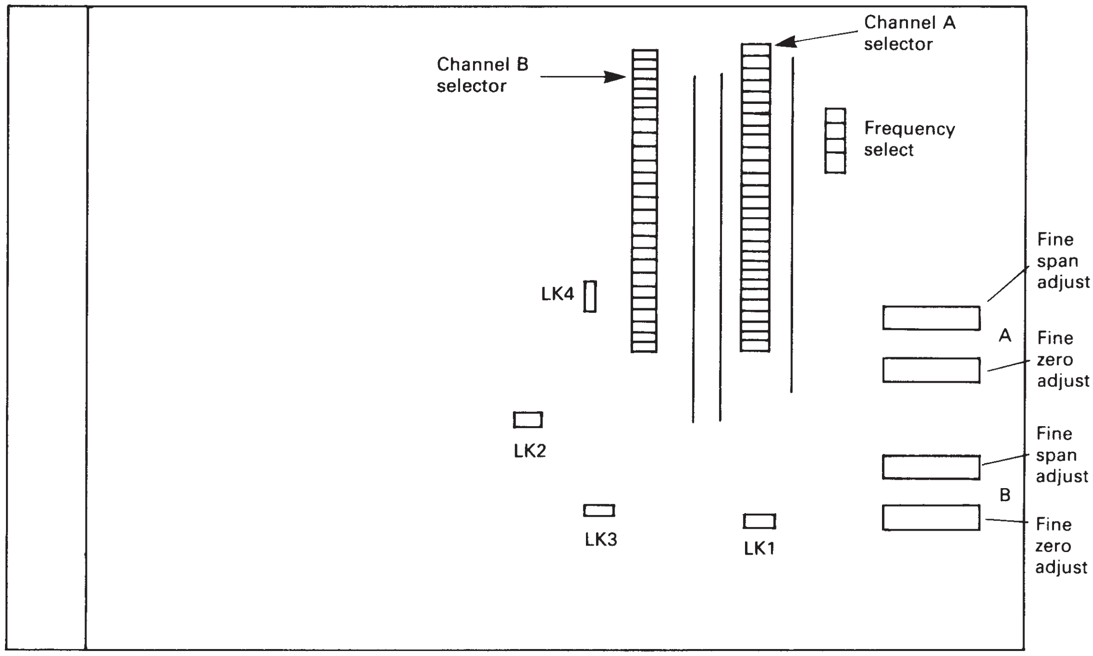
Figure 39 **A±B/2 wiring example**



Setting up

This section describes how to set up the card to work with the specific transducer. Facilities exist on the card for adjusting oscillator frequency, output filter frequency, demodulator input impedance, span and zero. This is carried out by moving links to short out selected pairs of vertical pins. These links simply lift off and push on to the pins. In the case of span and zero there are also potentiometers for fine adjustment.

Figure 40 **Card layout**



Oscillator frequency

Two oscillator frequencies are selectable using the four way set of pin pairs. If the links are placed over the two centre pairs the oscillator will run at 5kHz, and, if over the outer pairs, at 10kHz.

Figure 41 **Oscillator frequency links**

Frequency should be selected to be near the zero phase shift frequency of the transducer for minimum temperature drift. Most transducers are calibrated at 5kHz and so this frequency can be relied upon for good results. However, if a faster speed of response is required, then the 10kHz oscillator frequency can be used with most transducers (not ac long strokes).

Output filter frequency

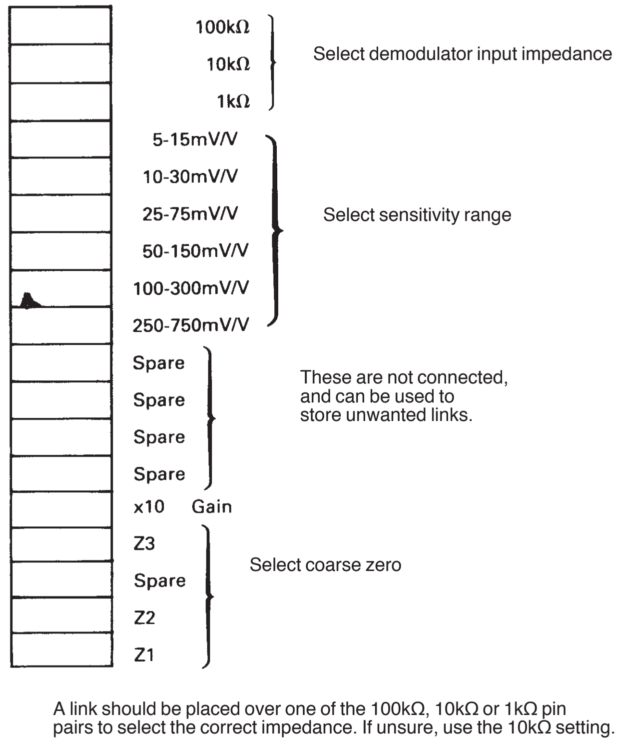
Each demodulator has a low pass filter on the output to remove the ac signal used to energise the transducer. The cut off frequency of this filter can be set to either 500Hz or 1kHz using pin pairs LK1-LK4. Under normal use the 500Hz setting would be used with the 5kHz oscillator frequency and 1kHz with the 10kHz oscillator. The benefit of using the higher frequency is that the output will follow the movement of the transducer armature more quickly, but use of the lower frequency results in less ripple on the dc output. The best compromise is with the settings above, but if, for example, a fast response with a long stroke is required, it will be necessary to use a 5kHz oscillator and a 1kHz filter. The disadvantage is an increase in ripple. LK1 and LK3 are used for Channel A. Put the link on LK1 for 1kHz filter frequency, or on LK3 for 500Hz.

LK2 and LK4 are used for Channel B. Put the link on LK2 for 1kHz filter frequency, or on LK4 for 500Hz.

Demodulator input impedance

Different transducers are calibrated into different loads. For instance most LVDTs are calibrated with 100kΩ loads, but half bridges use 1kΩ. For this reason the input impedance of the demodulator can be set to 100kΩ, 10kΩ or 1kΩ, using the three pin pairs at the top of the eighteen way selector. The channel A and B selectors are laid out as shown in Figure 42.

Figure 42 **Channel A and Channel B selectable links**



Span and zero

To set up the span and zero controls, examine the output that will finally be required, ie: the voltage or current output, to avoid errors in the current drivers. If the A±B/2 facility is being used, then it is possible to calibrate on (for instance) the A+B output, again for maximum accuracy.

Note that it is necessary in this case to zero the unwanted transducer, or remove the secondary and short the demodulator input so that one transducer is examined at a time.

With transducers such as load cells that have an obvious centre point (ie. no load) then it is merely necessary to set the card span and zero as described below. However, for LVDTs and half bridges it is necessary to find the mechanical zero (ie. centre of linear stroke) first. To accomplish this:

a) Remove transducer connections from card input to demodulator.

b) Short the demodulator input, to simulate a transducer at centre of stroke.

c) Read output from card.

d) Remove short and re-connect transducer.

e) Adjust transducer to give same output reading as at step (c). The transducer is now set to the middle of its linear stroke.

To set the card span and zero it is necessary to set some links and then use the fine span and zero controls for final adjustment. There are nine coarse span ranges, in two overlapping ranges of six each:

Range	Transducer Minimum	Sensitivity Maximum	Select Pin Pair	Select ×10 Link
1	250mV/v	750mV/v	250-750	No
2	100	300	100-300	No
3	50	150	50-150	No
4	25	75	25-75	No
5	10	30	10-30	No
6	5	15	5-15	No
4'	25	75	250-750	Yes
5'	10	30	100-300	Yes
6'	5	15	50-150	Yes
7	2.5	7.5	25-75	Yes
8	1	3	10-30	Yes
9	0.5	1.5	5-15	Yes

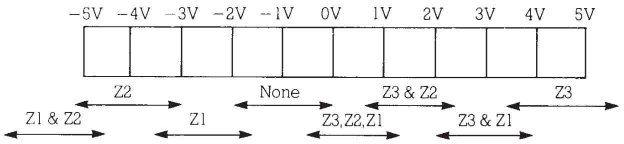
Selecting the ×10 link increase the gain of the amplifier and so reduces the necessary sensitivity of the transducer. The span control is used to set the span in the range between minimum and maximum. The above sensitivity ranges are for a standard ±5V or ±10mA output (10V or 20mA total range).

If a different output range is required (say V Volts) then the necessary transducer sensitivities shown should be multiplied by V/10. For example, if an output of ±3V is required (total range 6V) then range 1 becomes 250 × 0.6 to 750 × 0.6 which is 150 to 450mV/V.

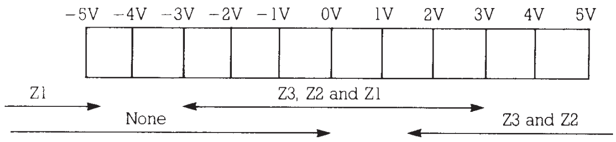
Eight coarse zero ranges are provided and selected by linking up to three off pin pairs Z1 to Z3. Again a fine control is used to set the zero anywhere required. One minimum gain, the amount of zero offset provided by the links is:

Z1	-1.5V	=	-30% of 5V
Z2	-3V	=	-60% of 5V
Z3	5.5V	=	110% of 5V
Potentiometer	-2V to 0V	=	-40% to 0% of 5V

This means that on minimum gain, the ranges provided are:



As the gain is increased this opens out, so that at maximum gain it becomes three times wider:



Note: That the normal mode of operation is with all three links on, to provide fine adjust about zero.

First select the appropriate coarse gain range by reference to the transducer data and the required output voltage. Set the transducer to the point at which zero output is required and set zero links and controls for 0V output. Set transducer to position at which full output is required and adjust span control for full scale output. Re-check zero.

If an offset zero is required (such as on a 4-20mA system) then set the transducer to the minimum position and adjust zero controls for 4mA. Set transducer to maximum position and adjust span for 20mA. Re-check 4 and 20mA positions until fully set up, as, because the zero position is offset, it is affected by the span controls.

Circuit operation

Most of the operating circuitry on the card is contained in the oscillator and demodulator hybrid's. A block diagram of the card is given below.

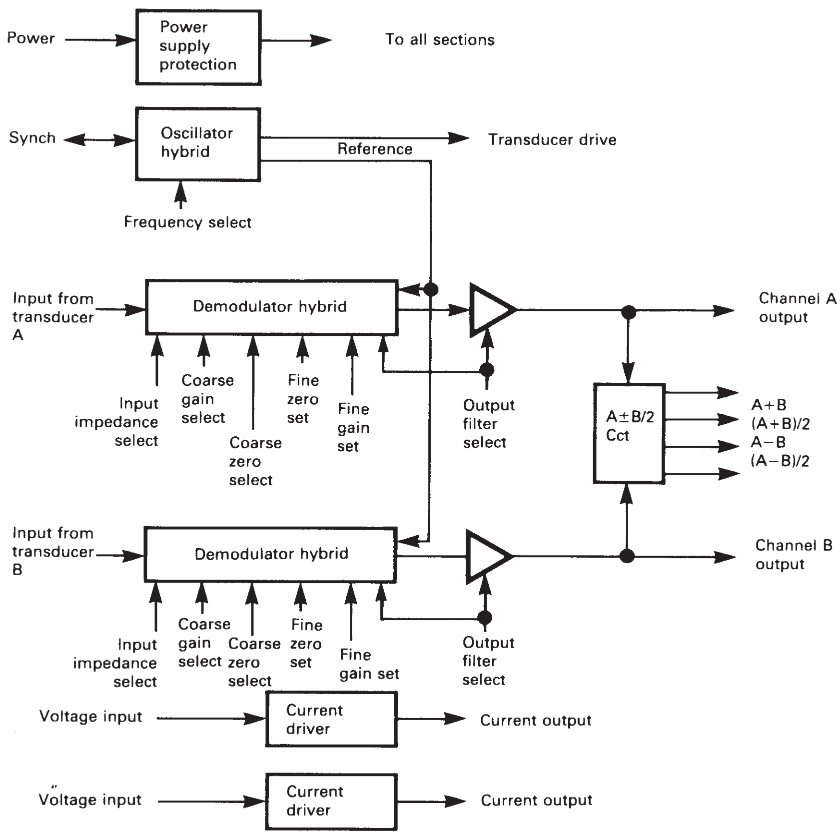
Power supply protection is provided to protect against reversed power rails, the circuit is also tolerant of the disconnection of one supply. A pair of zener diodes offers basic protection against voltage spikes on the supply rails.

The oscillator hybrid drives the transducer, at one of two frequencies, and the signal from the transducer is fed into the demodulator hybrid. This takes care of all the span and zero corrections.

The dc output from the demodulator is fed into another filter to reduce output ripple even further and hence to the output.

The A±B/2 circuit is a set of simple amplifiers based on precision resistors and provides all four outputs simultaneously. The current drivers are based on those in the C30 range and are wired separately so that they can be wired to any chosen output.

Figure 43 **CAH card block diagram**



Other assemblies

The CAH pcb has been designed for maximum flexibility so that most specials can be coped with without the necessity of a new pcb design. It should merely involve the addition or deletion of some components to either provide extra facilities or reduce cost. This section is intended to point out some of the more likely alternatives.

The circuit alternatives can be achieved by deleting the unnecessary options and replacing the headers and links to select only the gain and zero option required. All components involved in selecting input impedance and filter characteristics can be deleted.

This can be further extended by deleting the span and zero potentiometers. These can then be wired in via the edge connector or simply not used. Span ranges will then be set at their nominal centres as listed in the technical specification.

Deleting the zero links Z1, Z2 and Z3 means that there will be no zero offset.

Other oscillator frequencies can be easily provided.

Delete the four way frequency selecting header (as it is no longer needed) and put two resistors in positions R22 and R23. These resistors should be of the value:

$$R = \frac{1}{2\pi f c} = \frac{72.3M\Omega}{f}$$

Operation should be satisfactory in the range 2kHz to 20kHz, but should be checked. Operation below 2kHz must be carried out at lower output voltages or distortion becomes noticeable.

Lower oscillator amplitudes may be required, possibly to enable the card to work at lower supply voltages, or to reduce current consumption. Normal operation at 5V rms entails using a wire link for R21 which should be replaced by a resistor for lower output voltages. The value of this resistor should be:

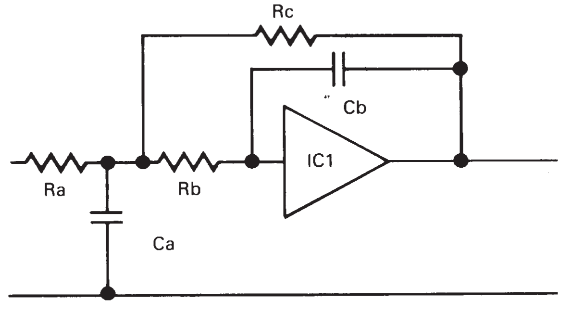
$$\frac{31k}{V} - 6.2k\Omega$$

If an output transformer is used (see below) this is different and becomes:

$$\frac{62k}{V} - 6.2k\Omega$$

If the oscillator frequency is changed, or, for a particular specification, it may be necessary to alter the characteristics of the low pass filter on the demodulator output. This will involve altering the two pole filter in the demodulator hybrid and also the single pole filter based around IC1. The demodulator filter is altered by adding C3 and C4 and changing R5 (C7, C8, R10 on channel B), and the circuit is approximately:

Figure 44 **Demodulator filter**



Ra	=	14k
Rb	=	27kΩ and has R5 in parallel, if LK1 installed
Rc	=	77kΩ
Ca	=	22nF and has C3 in parallel
Cb	=	2.2nF and has C4 in parallel

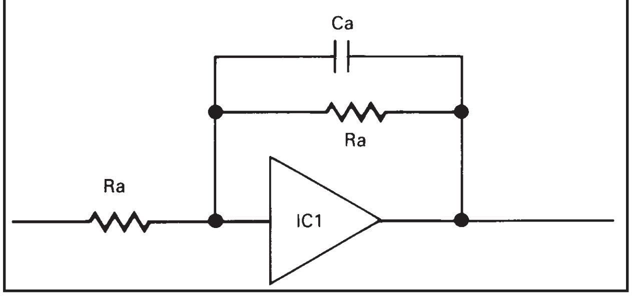
$$\text{Cut off frequency} \quad \frac{1}{2\pi \qquad RbRcCaCb}$$

$$\text{Damping factor} = \sqrt{\frac{CbRb}{CaRc}} + \sqrt{\frac{CbRc}{CaRb}} + \sqrt{\frac{CbRbRc}{CaR^2a}}$$

This is not the exact circuit, but will give good approximate answers. For example, adding C3 = 220nF and C4 = 22nF will give a cut off frequency of 46Hz, but not affect the damping factor. For a proper check of filter characteristics it is recommended that the zero links (Z1, Z2, Z3) be removed and an energistic waveform fed in on Pin 9 of the demodulator hybrid. In this way the gain/phase and step response of the filter can be checked.

Altering the single pole filter is more obvious from the circuit diagram and can be accomplished by changing C1, C2, R3, R4 (C5, C6, R8, R9 on channel B).

Figure 45 **Demodulator filter**



Ra	=	R3=R4
Ca	=	C2, + C1 if LK3 installed

$$\text{Cut off frequency} = \frac{1}{2\pi \; RaCa}$$

Some applications may require operation of the card with LVDTs only, in which case it is possible to delete the two demodulator input transformers TR1 and T2. If this is done it is necessary to link the pins where the transformer was, ie. link 2 to 3 and 5 to 6. If this transformer is deleted then R24 and R25 can also be removed as the card will no longer work with half bridges.

For applications that only include half bridges and LVDTs, it is possible to delete the input transformers as above and add an oscillator output transformer. This would also be wise for applications involving long transducer leads, where all three transformers should be installed. It can also be used to provide improved zero drift for low output half bridges as the two resistors R24 and R25 can introduce slight drift. If the output transformer is required then:

a) Remove links on Pins 2-3 and 5-6.
b) Install transformer (802221).
c) Delete resistors R24 and R25.
d) Add a wire link in position LK5.

e) Change R21 from a wire link to 6.2k or as required for other output voltages.

Because of the extra load the transformer puts on the oscillator, the following limitations should be observed:

a) Use 15V supply rails, or reduce oscillator voltage to 4V.

b) Reduce current capability of oscillator to 40mA.

c) Operate above 3kHz oscillator frequency. If required to go lower, reduce oscillator voltage linearly to 1V rms at 1kHz.

Single channel oscillator/demodulator OD5 (RS stock no. 285-908)

A compact oscillator demodulator unit with adjustable span and zero controls for use with any of the RS and most other manufacturers' ranges of LVDT ac transducers. The unit is of robust construction, housed in a die cast aluminium box providing a substantial degree of mechanical and environmental protection. The OD5 incorporates its own voltage regulation for operation from ac mains supply 240 or 120 volts. A three metre ac power cable is standard.

The unit gives output of 0 to ±5V into 10k ohms, or 0 to ±20mA into 100 ohms max. This together with a range of span controls 10:1 gives a very versatile single channel conditioner for wide range of transducers.

Figure 46 **OD5 dimensions**

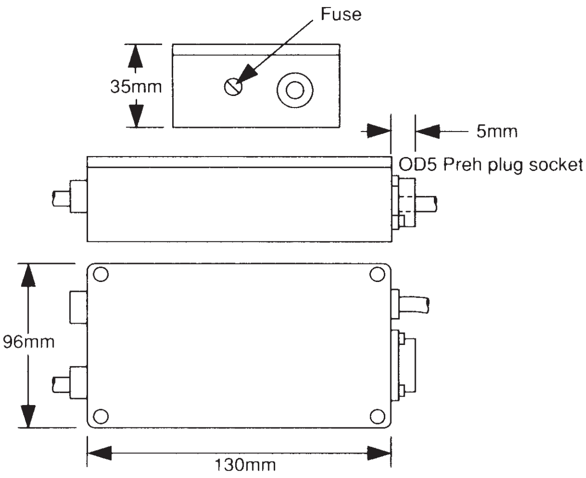


Figure 47 **OD3 internal layout**

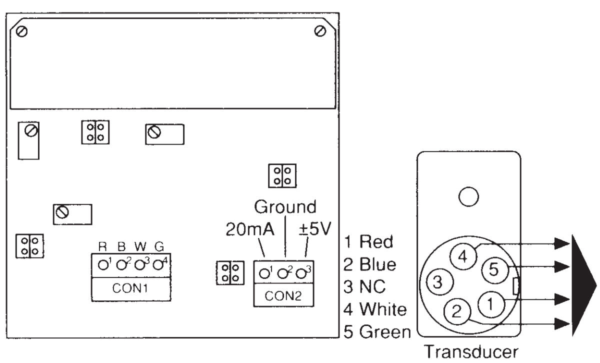
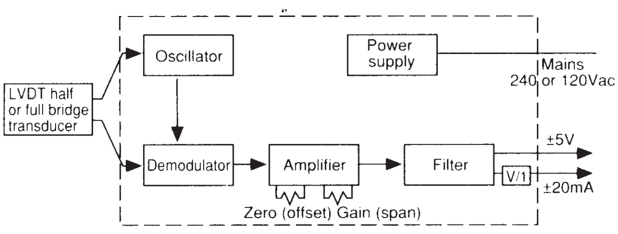


Figure 48 **OD5 block diagram**



Features

- 100% offset adjustment
- 0.1% accuracy
- 120 or 240V ac supply
- Zero and span controls
- Robust construction
- Current or voltage output
- Short circuit protection.

Electrical specification

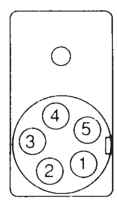
Power supply	240 or 120V ac 50/60Hz
Transducer drive	3V rms at 2.5kHz or 5kHz switchable sinusoid max rated 20mA
Oscillator protection	Open and short circuit protected
Range of zero control	0-100% adjustable
Output voltage	±5V into 10kΩ
Output current	±20mA into 100Ω max
Output protection	Open and short circuit protected
Output ripple	<10mV p to p at 10kHz (typical)
Output filter	Cut off frequency -3dB at 250/150Hz second order
Non-linearity	<0.1%
Operating temperature range	0°C to +60°C
Storage temperature range	-40°C to +80°C
Temperature coefficient	Zero (offset), better than 0.02% fro/°C Gain (span), better than 0.02% fro/°C
Termination	5 pin DIN connector

Mechanical specification

Weight	400g
Mounting	2 fixing straps and screws
Accessories included	Pre- plug, mountings

Figure 49 **External connections**

1 Red - input to demodulator
2 Blue - input to demodulator
3 NC - no connection
4 White - output from oscillator
5 Green - ouput from oscillator



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