Data Sheet

Strain gauges and load cells

Strain gauges

Two ranges of foil strain gauges to cover general engineering requirements for strain analysis. All gauges have 30mm integral leads to alleviate damage to the gauges due to excessive heat being applied during soldering and installation.

Miniature gauges can be used for precise point measurement of instrumentation of small components. The polyimide backing of the gauges can withstand temperatures up to 180°C making them ideal for higher temperature applications.

The larger size of the standard gauges will not only make these gauges suitable for larger components, but is useful to assess the average strain over the area covered by the gauge thus reducing the possibility of incorrect readings due to stress concentrations.

Gauges temperature compensated for aluminium match materials with a coefficient of thermal expansion of 23.4 x 10^{-6}/°C and are indicated by blue colour coding of the backing material.

Gauges temperature compensated for mild steel match materials with a coefficient of thermal expansion of 10.8 x 10^{-6}/°C and are indicated by red colour coding of the backing material.

All gauges are intended for uniaxial strain measurements only.

General specification (all types)

Measurable strain	2 to 4% max.
Thermal output 20 to 160°C	±2 micro strain/°C*
160°C to 180°C	±5 micro strain/°C*
Gauge factor change with temperature	± 0.015%/°C max.
Gauge resistance	120Ω
Gauge resistance tolerance	±0.5%
Fatigue life	>10^5 reversals @ 100 micro strain*
Foil material	copper nickel alloy

* 1 micro strain is equivalent to an extension of 0.0001%

Specification (Standard polyester backed types)

Temperature range	-30°C to +80°C
Gauge length	8 mm
Gauge width	2 mm
Gauge factor	2.1
Base length (single types)	13.0 mm
Base width (single types)	4.0 mm
Base diameter (rosettes)	21.0 mm

Specification (Miniature polyimide backed type)

Temperature range	-30°C to +180°C	
Gauge length	2 mm	5mm
Gauge width	1.6 mm	1.8mm
Gauge factor	2.0	2.1
Base length (single types)	6.0 mm	9.0 mm
Base width (single types)	2.5 mm	3.5 mm
Base diameter (rosettes)	7.5 x 7.5 mm	12 x 12mm

Construction and principle of operation

The strain gauge measuring grid is manufactured from a copper nickel alloy which has a low and controllable temperature coefficient. The actual form of the grid is accurately produced by photo-etching techniques. Thermoplastic film is used to encapsulate the grid, which helps to protect the gauge from mechanical and environmental damage and also acts as a medium to transmit the strain from the test object to the gauge material.

The principle of operation of the device is based on the fact that the resistance of an electrical conductor changes with a ratio of ΔR/R as a stress is applied such that its length changes by a factor ΔL/L, where ΔR is change resistance from unstressed value, and ΔL is change in length from original unstressed length.

The change in resistance is brought about mainly by the physical size of the conductor changing and an alteration of the conductivity of the material, due to changes in the materials structure.

Copper nickel alloy is commonly used in strain gauge construction because the resistance change of the foil is virtually proportional to the applied strain i.e.

$\Delta R/R = K.E$,

where K is a constant known as a gauge factor, and K

$$= \frac{\Delta R/R}{\Delta L/L}$$

And $E = \text{strain} = \Delta L/L \therefore K = \frac{\Delta R/R}{E}$

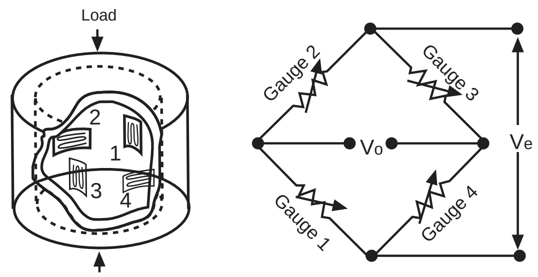
The change in resistance of the strain gauge can therefore be utilised to measure strain accurately when connected to an appropriate measuring and indicating circuit e.g. Strain gain amplifier RS stock no. 846-171 detailed later in this data sheet.

Applications

When strain gauges are used in compressive load transducer applications, which normally require more stringent accuracy requirements, a full bridge circuit is used with active gauges in all four arms of the bridge, (Figure 1).

The load transducer shown in Figure 1 utilises four strain gauges attached to the cylinder. The gauges are connected into the bridge circuitry in such a manner as to make use of Poisons ratio i.e. the ratio between the relative expansion in the direction of force applied and the relative contraction perpendicular to the force, to increase the effective gauge factor and thus the sensitivity.

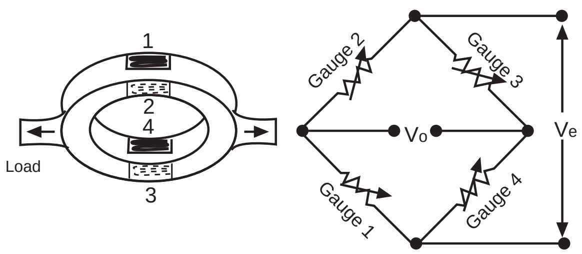
Figure 1 Compressive load transducer



To measure tensile loads, a ring with gauges attached as shown in Figure 2 may be used.

Under the action of a tensile load, the curvature of the ring in Figure 2 is deformed such that the inner gauges undergo tension while the outer gauges experience compressive forces.

Figure 2 Tensile load transducer



Instructions for mounting of strain gauges

In order to obtain the best possible results from a strain gauge, it is important to thoroughly prepare the gauge and the surface of the specimen to which the gauge is to be attached, prior to bonding with the adhesives recommended in paragraph 3 below.

1. Specimen surface preparation

An area larger than the installation should be cleared of all paint, rust etc., and finally smoothed with a fine grade emery paper or fine sand blasting to provide a sound bonding surface.

The area should now be degreased with a solvent such as RS PCB solvent cleaner, RS stock no. 496-883, and finally neutralised with a weak detergent solution. Tissues or lint free cloth should be used for this operation, wetting the surface and wiping off the clean tissues or cloth until the final tissue used is stain free. Care must be taken not to wipe grease from a surround-ing area onto the prepared area or to touch the surface with the fingers.

This final cleaning should take place immediately prior to installation of the gauge.

2. Strain gauge preparation

By sticking a short length of adhesive tape along the upper face of the gauge it may be picked up from a flat clean surface. Holding both ends of the tape, orientate the gauge in the desired location and stick the end of the tape furthermost from the tags to the specimen. Bend the other end of the tape back on itself thereby exposing the back of the gauge.

3. Adhesives and strain gauge installation

Two basic types of adhesive are recommended:

a) RS cyanoacrylate

b) RS 'quick-set' epoxy.

When using epoxy adhesive coat the back of the gauge with adhesive and gently push down into position, wiping excess adhesive to the two outside edges of the gauge, to leave a thin film of adhesive between gauge and sample. Stick the whole length of tape to hold the gauge in position. Care should be taken that there is an even layer of adhesive and no air bubbles are left under the grid. Cover the gauge with cellophane or polyethylene etc., and apply a light weight or clamp as required until adhesive has set. Remove tape by slowly and very carefully pulling it back over itself, staring at the end furthermost from the tags. Do not pull upwards.

If cyanoacrylate adhesive is to be used stick one end of the tape down to the specimen completely up to the gauge. Drop a fillit of adhesive in the 'hinge' point formed by the gauge and the specimen. Starting at the fixed end, with one finger push the gauge down at the same time pushing the adhesive along the gauge in a single wiping motion until the whole gauge is stuck down. Apply pressure with one finger over the whole length of the gauge for approximately one minute. Leave for a further three minutes before removing tape.

4. Wiring

The RS strain gauges are fitted with 30 mm leads to enable the gauge to be soldered. The lead out wires are fragile and should be handled with care.

Installation protection

RS strain gauges are encapsulated and therefore are protected from dust and draughts etc. If however, additional protection from humidity, moisture, and mechanical damage is required RS silicone rubber compound, RS stock no. 555-588, may be used. This should be carefully spread over the installation using a spatula.

Connecting to strain gauges

The following bridge circuits are shown with connection referring to the basic amplifier circuit, Figure 7. All resistors, precision wire wound 0.1% 5 ppm. (For precision resistors see current RS Catalogue).

Note: The expressions are assuming that all gauges are subjected to the same strain. Some configurations produce different strain in different gauges, and allowance must be made.

Figure 3 Full bridge

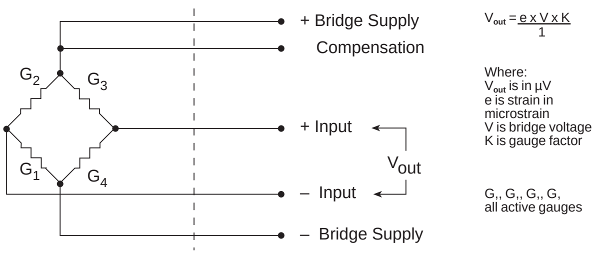


Figure 4 Half bridge

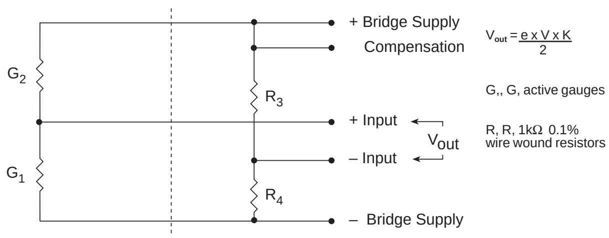
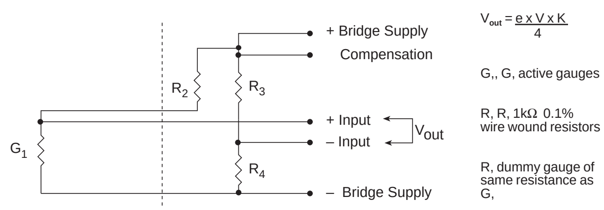


Figure 5 Quarter bridge (3 wire)



Strain gauge amplifier (**RS** stock no. 846-171) and printed circuit board (**RS** stock no. 435-692)

Description and operation

The strain gauge amplifier is a purpose designed hybrid, low noise, low drift, linear dc amplifier in a 24 pin DIL package, specifically configured for resistive bridge measurement and in particular the strain gauges detailed earlier in this data sheet.

Foil strain gauges when attached to a specimen, produce very small changes in resistance (typically 0.24mΩ in 120Ω per microstrain), and are thus normally connected in a Wheatstone bridge. Overall outputs of less than 1mV on a common mode voltage of 5 volts may be encountered, requiring exceptional common mode rejection which cannot be provided by conventional means.

The strain gauge amplifier overcomes the problem of common mode rejection by removing the common mode voltages. This is achieved by controlling the negative bridge supply voltage in such a manner that the voltage at the negative input terminal is always zero. Thus for a symmetrical bridge, a negative bridge supply is generated equal and opposite to the positive bridge supply, hence zero common mode voltage.

The advantages of such a system are:

- No floating power supply needed.
- Bridge supply easily varied with remote sense if necessary.
- Wire remote sense system.
- Freedom from common mode effects.
- Very high stability dc amplifier enables numerous configurations to be assembled.
- Low noise.
- High speed (at low gains).

Figure 6 Pin connections

+ Bridge Voltage	1	24	+ V_S
N/C	2	23	N/C
Compensation	3	22	-Vs
N/C	4	21	N/C
N/C	5	20	Bridge Ref Input
+ Input	6	19	N/C
N/C	7	18	Feedback
N/C	8	17	N/C
N/C	9	16	Output
- Input	10	15	N/C
N/C	11	14	N/C
- Bridge Voltage	12	13	Zero Adjust

Top view

Specification

(At 25°C ambient and ±12V supply unless otherwise stated.)

Supply voltage	±2 to ±20Vdc
Input offset voltage	200μV max.
Input offset voltage/temperature	0.5μV/°C max.
Input offset voltage/supply	3μV/V max.
Input offset voltage/time	0.3μV/month max.
Input impedance	>5MΩ min.
Input noise voltage	0.9μVp.p max.
Band width (unity gain)	450kHz
Output current	5mA
Output voltage span	±(V_s-2)V
Closed loop gain (adjustable)	3 to 60,000
Open loop gain	>120dB
Common mode rejection ratio	>120dB
Bridge supply voltage/temperature	20µV/°C
Maximum bridge supply current	12mA
Power dissipation	0.5W
Warm up time	5 mins
Operating temperature range	-25°C to + 85°C

Figure 7 Basic circuit for printed circuit board **RS** stock no. 435-692 (gain approx. 1000)

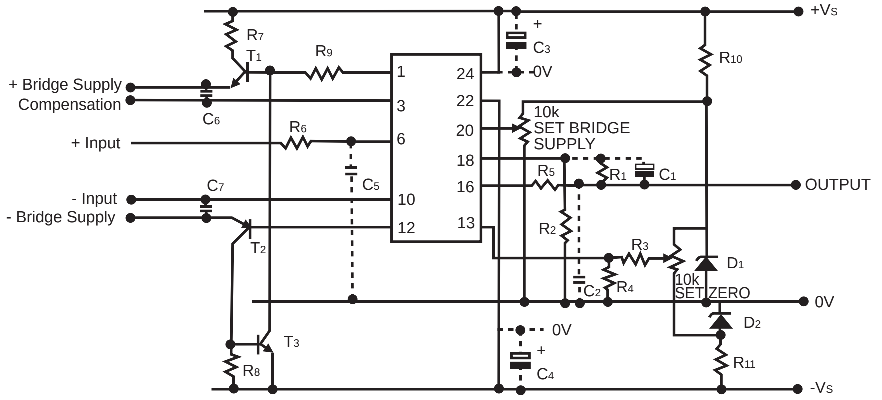
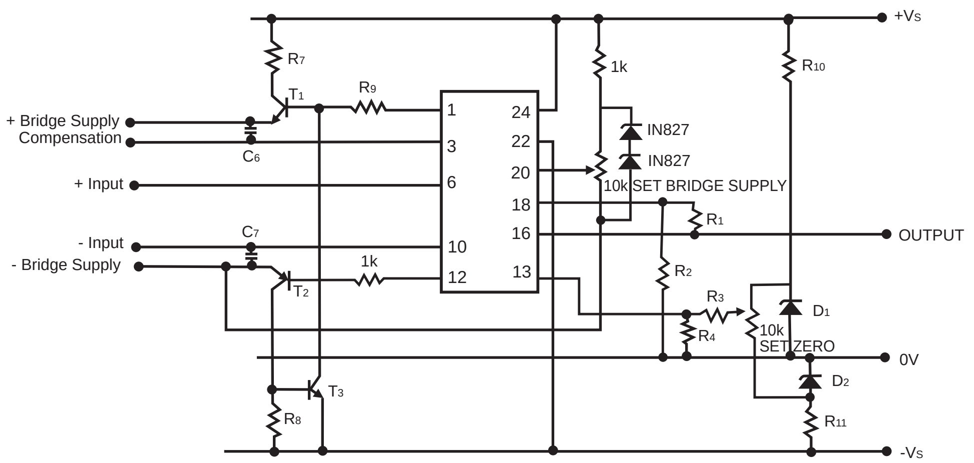


Figure 8 Circuit for semiconductor gauges and transducers



Component values (Figures 7 and 8)

R_1 100k	R_7 47R	C_2, C_5 10n (typ.)
R_2 100R	R_8 10R	C_3, C_4 10μ (tant.)
R_3 100k*	R_9 1k0	T_1 BD 135
R_4 68R*	R_{10} 680R	T_2 BD 136
R_5 10R	R_{11} 680R	T_3 BC 108
R_6 100R(typ.)	C_1, C_6, C_7 100n (typ.)	D_1, D_2 1N827

A glass fibre printed circuit boar, RS stock no. 435-692 is available for the basic circuit as given in Figure 7.

The board is 46 × 98 mm in size and is complete with screen printed component identification and a solder mask.

Only typical values are given for certain components, as adjustment of these values may be necessary in specifics applications to obtain optimum noise reduction (see Minimisation of Noise later in this data sheet).

*R_3 and R_4 values may be adjusted to alter the zero adjustment range when compensating for bridge imbalance.

Notes: 1. Gain is defined as $1 + \frac{R_1}{R_2}$

2. Zero adjustment range $\pm 6.2 \times \frac{R_4}{R_3 + R_4}$ Volts

Total bridge supply = 2 x bridge ref input (pin 20)

C_5 may be omitted for input lead lengths of less than 10 metres

T_1 and T_2 provide bridge currents up to 60mA and should be kept away from amplifier.

Provided stabilised power supplies are being used, zero and bridge supply reference may be taken direct from the power rails.

The high output of some semiconductor strain gauges may cause large amounts of asymmetry to the bridge. In correcting for the common mode change, the negative bridge voltage will change, causing a span error. This may be calibrated out or the arrangement above used to eliminate the cause of the error. Some semiconductor strain gauge transducers are temperature compensated by the use of series arm compensation. Thus the common mode voltage changes the with temperature, and hence the arrangement above should be used. This operates by referencing the positive bridge supply to the negative supply, thus varying the common mode but not the overall bridge supply.

Minimisation of noise

1. Inherent white/flicker noise in amplifier.
To keep this to a minimum use high quality (metal film) resistors and protect the amplifier from excessively high temperatures. The inherent noise level may be further reduced from its already low value by fitting C_1 and C_2 to reduce the operating bandwidth.

2. Supply frequency (or harmonics) inference.
If at 100Hz then the cause is almost likely to be from power supply rails, so use stabilised lines. If at 50Hz then it is generally caused by the location of the supply transformer, and/or the wiring. Relocate the supply transformer, screen and input leads to the amplifier, and if possible reduce the operating bandwidth by fitting C_1 and C_2.

3. Power supply transient interference.
It is good practice to decouple the supply lines to the amplifier, by fitting C_3 and C_4, as close to it as possible. If a particular nuisance then fit a mains suppressor.

4. Electromagnetic interference

This may be picked up by input leads, output leads, supply leads or direct into the circuit. Minimisation involves a combination of screening, decoupling and reducing operating bandwidth. Screening. The shield should be connected to only one earth potential at the receiving monitoring equipment end. Try not to earth any of the dc power lines (e.g. 0V). If the shield at the sensor end is earthed then earth the shield at the receiving end and if possible connect this earth potential to the strain gauge amplifier circuit shield. Decouple the power supply leads by fitting C_3 and C_4, decouple the input leads with R_6 and C_5 (note a similar action on the input is not possible). Remove any pickup from the output leads by fitting R_5 and C_2. Fit C_5 if input leads are more than 10m long and fit C_6 if remote sense is longer than 10m. Reduce the operating bandwidth by fitting C_1 and C_2.

Load cells

Introduction

Load cells are basically a beam or other shaped member arranged so that an applied load will cause a proportional strain at certain fixed points on the device.

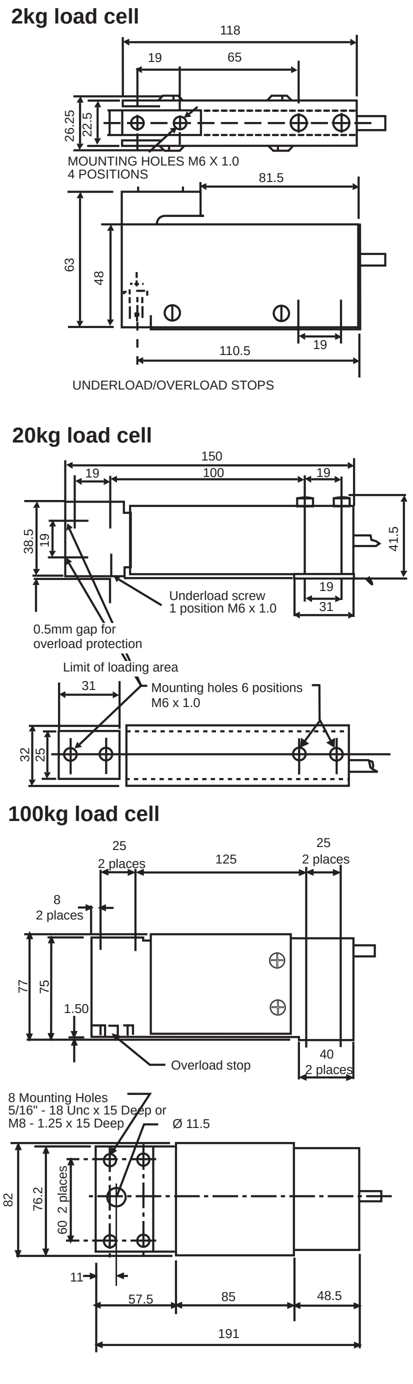
The strain can be detected in several ways, the most common being an arrangement of strain gauges. These gauges convert the strain into an electrical signal which can then be displayed, used as a control signal, etc.

Single point load cells

This RS range of load cells comprise of centre type (2kg, 20k & 10kg oil damped) in which a double beam is used. Also in this range is a 100kg low profile off-centred load cell designed for direct mounting of the weighing platform. They are supplied complete with a full bridge of four strain gauges fitted and calibrated ready to connect to any suitable amplifier.

Three sizes of standard units are available for weighing up to 2kg, 20kg and 100kg. Although physically different, the cells are 100kg similar in method of operation and construction.

Figure 9 Dimensions



When used in weighing scales a platform up to the maximum size given in the specification can be used without loss of performance.

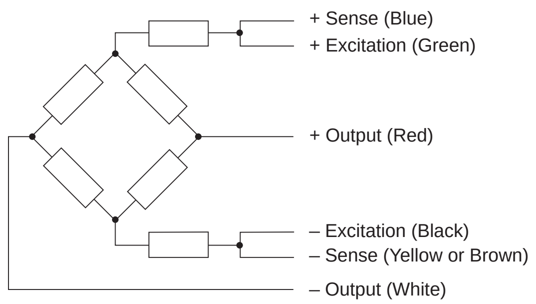
Electrical connections

The cells use a six wire full bridge system for the most accurate results. The lead to the cell is screened and the cores are colour coded as shown in Figure 10.

The RS strain gauge amplifier RS stock no. 846-171 can be used with these load cells. Use the circuit shown in Figure 7, connecting bridge supply to excitation and compensation to sense (Figure 10). In this circuit a five wire system is employed so that the -ve sense wire shown in Figure 10 is not used and should be connected to the -ve supply.

Other amplifiers can be used but to achieve good results an accurate low drift amplifier is required.

Figure 10 Internal wiring single point types



Mechanical fixings

The 2 and 2kg cells are fixed by M6 x 1 set screws and the bodies of the cells are drilled and tapped to a depth of 10mm. The 100kg cell is fixed by M8 x 1.25 set screws with the body drilled and tapped 15mm deep.

Care must be exercised when handling these devices - do not pull the lead or drop the device and ensure that the cell is not subjected to excessive vibration.

A platform, hopper, or any other fixture can be attached to the top or front face of these cells but it must be noted that the weight of these attachments must be taken into account. For example if a 1kg hopper is attached to the 2kg load cell for weighing out polystyrene granuals for injection moulding the cell will only weigh 1kg of the material because of the weight of the hopper.

These load cells must be mounted on a flat rigid base which is level and will not deflect under loading.

The fixing bolts must be tightened to the correct torque of 7Nm. Do not use a ratchet of ‘click stop’ torque spanner on the 2kg cells as this may damage it.

Overload stops

It is vital that overload protection is provided and it is recommended that under load protection is incorporated where possible.

While these load cells can be subjected to overloads of 150% (200% for 100kg unit) without permanent damage the use of this safety factor cannot be recommended. An overload in excess of 150% (200% for 100kg unit) will cause permanent damage to the cell.

An underload is simply a load which raises rather than depresses the load face. The RS cells are capable of measuring these types of load.

On the 2kg load cell both over and under load stops are built into the device and therefore the cell will be protected if correctly mounted on a flat and rigid base.

With the 20kg cell the base of the beam is machined so that it will deflect and touch any flat base used at rated load. Using a flat rigid base will, therefore, automatically provide overload protection.

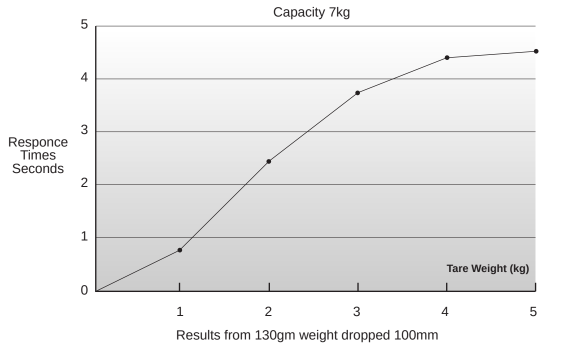
An extra M6 x 1 tapped hole is provided in the base for an underload stop. A mechanical stop should be provided with a no load clearance of 0.5mm so that the load face of the load cell can be only be raised by 0.5mm which is equivalent to the full rated load of the unit.

Single point - oil damped

Principles of operation

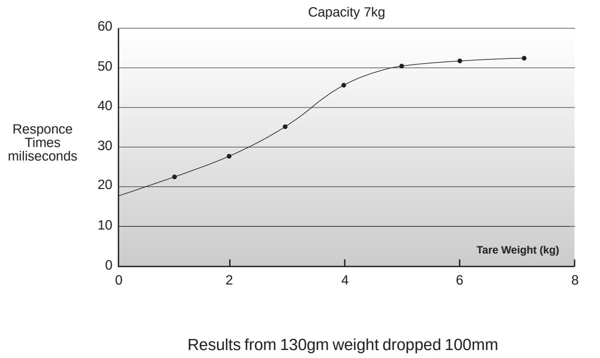
An undamped cantilever load cell can behave like a very stiff spring. Consequently when pre-loaded with a weight and shock excited by another weight, the unit "rings" for an appreciable time. A settling time of several seconds may be acceptable in platform scale applications but it is not acceptable for high speed repetitive weighing (Figure 11).

Figure 11 Typical response times (undamped)



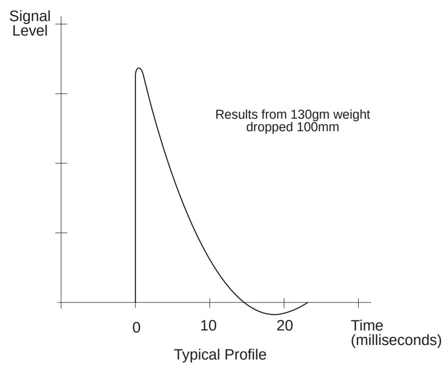
As can be seen tare weight increases settling time and should be kept at a minimum.

Figure 12 Typical response times (damped)



With the damped load cell it can be that the settling time is drastically reduced from more than 1 second to less than 100ms. (Figure 12 and 13).

Figure 13 Capacity 7Kg



Mounting

The precision obtainable from the unit can only be realised by careful attention to the mechanical mounting. It will be appreciated that if the full scale deflection of the Cell is 0.4mm and the scale is divided into 4000 divisions, one division on the scale is the result of a deflection of 0.0001mm. So, any, force, from whatever source, which brings about such a deflection will introduce an error into the system.

It is for this reason that the baseplate is solid and has a machined surface for mounting. Ensure, therefore that the mounting support is correspondingly flat and rigid. Holding down bolts must be equally torqued to 35-40 Nm (or 25-30 Ib ft). Also it is important that the Load Cell be level and that the level should not change significantly when the system is loaded. The initial level should be within 1 degree of the horizontal (check with spirit level) and the deflection under load should not exceed 0.1 degrees.

Vibration

It is sometimes assumed that because the Load Cell is damped it is impervious to external vibration. This is not so. It is damped against its own natural vibration when loaded. If however, the Load Cell is oscillated by external forces, such as adjacent vibrating machinery, it may provide output signals corresponding to these forces because heavy structures tend to oscillate at around 0.1 to 10Hz. It is impossible to damp the Load Cell adequately to eliminate these effects and maintain coherent performance. The design aim must therefore be to attach the unit to a firm flat, level base and to ensure that this base is free from vibration. The main sources of vibration are likely to be rotating machinery on the weigh structure, vibration from the floor etc. Each of these must be nullified, preferably by physical separation, but if that is not possible, by shock absorbers, anti-vibration mounts or similar devices.

Applying the load

The load must be applied via the bearing surface which is uppermost on the load applicator (Figure 14). Both holes must be used, evenly torqued to 7 Nm (51b/fft) so that the load is evenly distributed.

It is usual to use a flat bar or other load spreading member between the applicator and the weigh platform, table or live superstructure. The mating section and the substructure, must be rigid, otherwise the latter will oscillate and superimpose on the Load Cell output, depending on the frequency and amplitude generated. The supporting member must be flat. The load should be transported on to the weigh platform in such a way that it creates the minimum disturbance. If the load traverses across the platform, it should, if possible, avoid knocking the platform edge (i.e. no step). If the load is lowered on to the platform it should be controlled placement, not a dropped load, if possible. For optimum performance the line of action of the applied load should act as near as possible to the centre line of the Load Cell - in both horizontal planes-to minimise eccentricity effects.

Effect of temperature

Variations in temperature will affect the viscosity of the damping fluid and consequently the settling time of the Load Cell. The standard unit is damped for ambient working temperatures (around 20°C).

It is recommended that the Load Cell temperature be within 10°C of the specified working temperature if the settling time is to be within 50 milliseconds.

Unstable reading

If the repeated application of a load gives a steady but inconsistent reading, or the readings steady at around, but not quite, zero between weighings, then the Load Cell is probably reflecting some form of mechanical interference or "stiction". Check that the platter is not fouling and that dirt etc. has not accumulated somewhere in the scale mechanism. Remove the source of interference and normal weighing should result. Inspect the Load Cell load applicator: this should not be binding on the cover of the unit. Do not unbolt the base unless absolutely necessary. If this has to be done, be sure to follow the bolting down procedure described earlier.

Outline dimensions

Figure 14

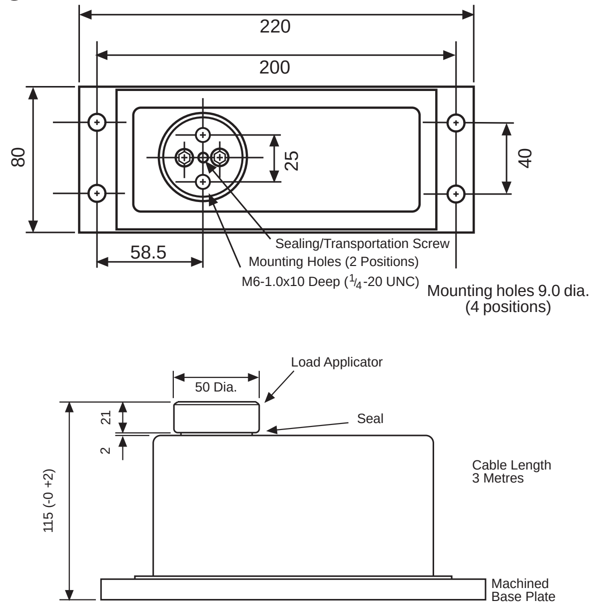


Figure 15 Mounting

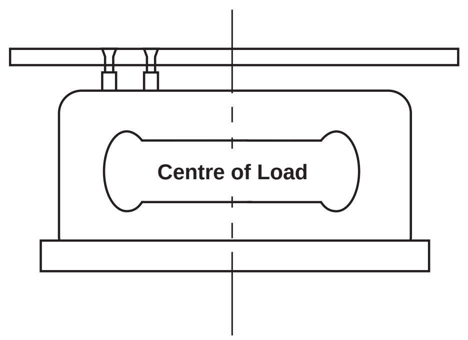
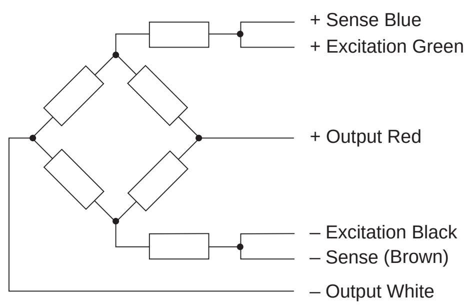


Figure 16 Wiring schematic



Tension/compression load cells

These general purpose load cells are for force measurement with loads up to 500kg. Mechanical connections are by M12 x 1.75 threads in the body of the device (1/2 x 20 UNF on 500kg unit) and electrical connections are via a 3m 5-core screened cable.

These cells can be used for weighing but are ideally suited for the measurement of tensile, or compressive forces by using the cell to replace the structural member under investigation. The 500kg unit is constructed using stainless steel & the 250kg utilises aluminium.

Other applications include, e.g. determining the power output of a motor be replacing the mounting with the cell and measuring the torque reaction produced.

Figure 17 250kg load cell dimensions

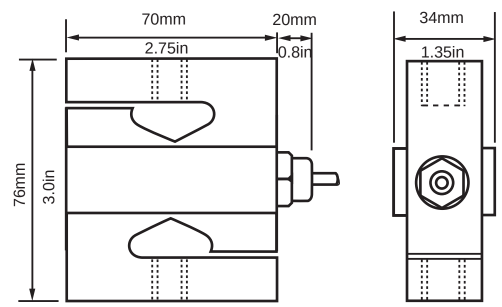


Figure 18 500kg load cell dimensions

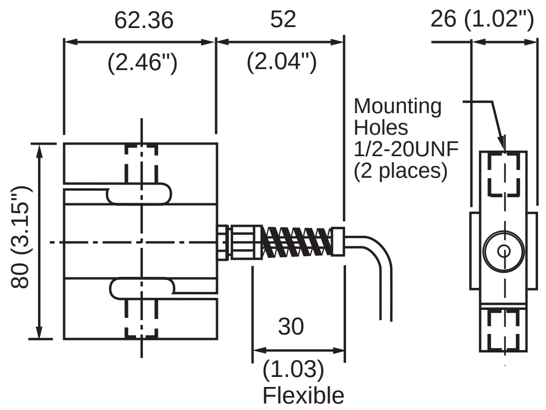
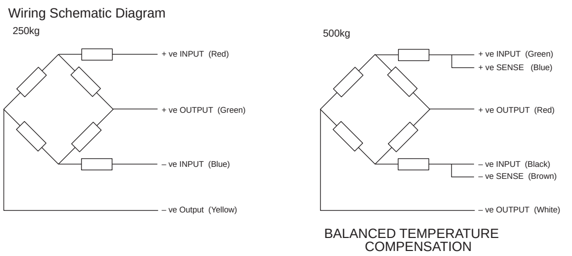


Figure 19



Shear beam load cells

These shear beam load cells are available in stainless steel (500kg & 1000kg) construction or in aluminium (500kg only) construction. All are low profile units providing a high level of environmental protection whilst featuring 6 wire output for temperature compensation. Both types of unit are of rugged construction but the stainless steel products are hermetically sealed to enable the cells to function in harsh environments whilst maintaining its operating specifications.

Typical applications for these products would be in low profile platforms, pallet truck weighers, tanks and silos etc.

Figure 20 Outline dimensions, stainless steel

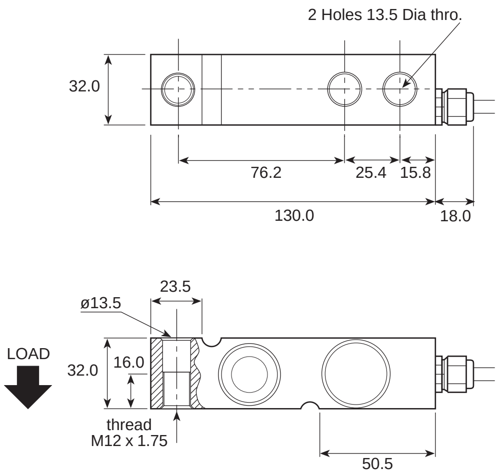
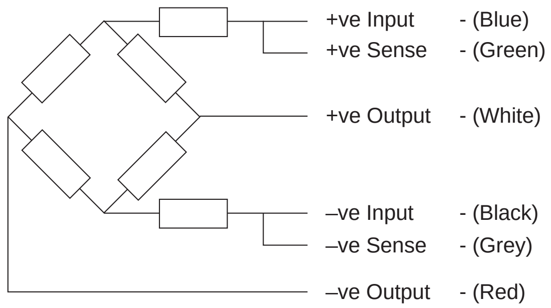


Figure 21 Wiring schematic diagram



Balanced temperature compensation

Figure 22 Outline dimensions, aluminium

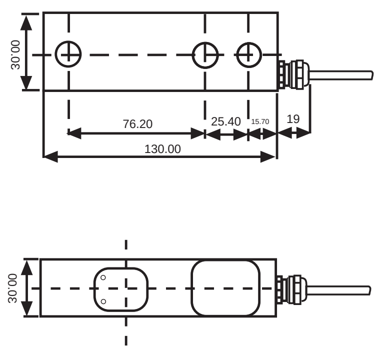
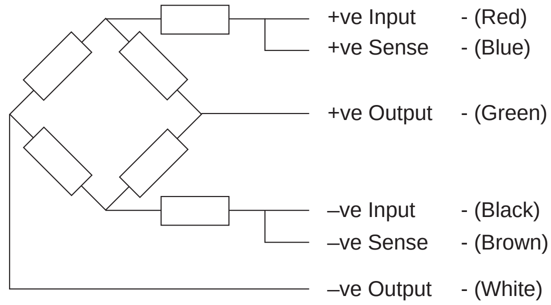


Figure 23 Wiring schematic diagram



Balanced temperature compensation

Contilever load cells

These load cells are available in 100kg and 250kg options. They are of welded, bending beam, stainless steel construction and hermetically sealed to enable functionally in harsh environments.

The low profile construction and high accuracy of these products make them ideal for applications such as platform scales, weighing and packing machines and for mechanical scale conversions.

Figure 24 Outline dimensions

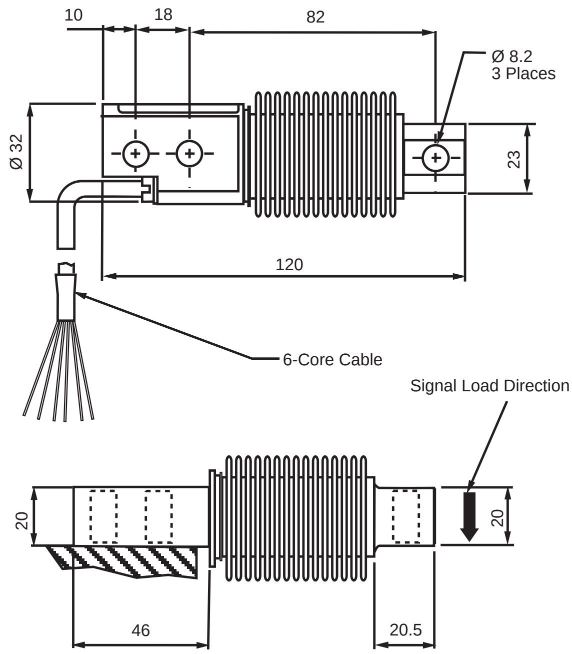
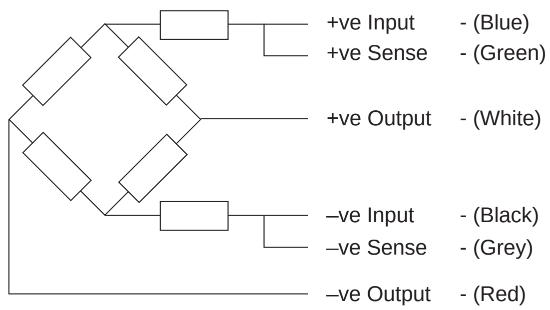


Figure 25 Wiring schematic diagram



Balanced temperature compensation

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