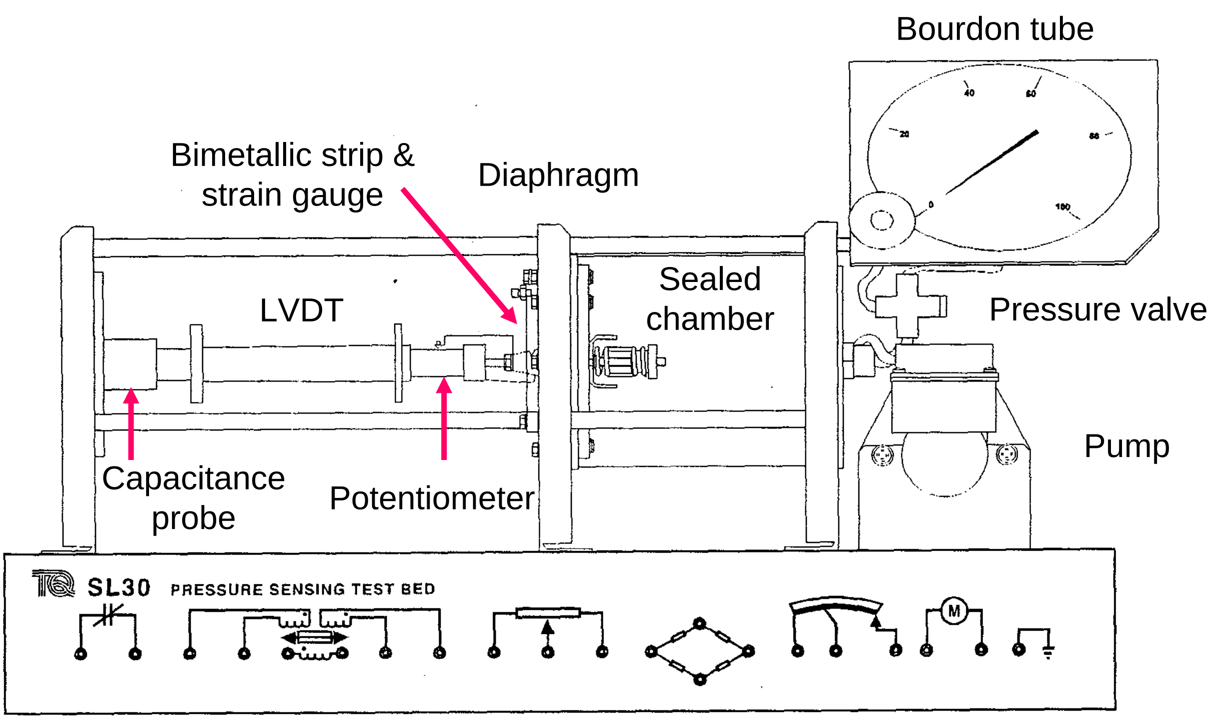
SL30 Pressure Measurement

ESS3271 Lecture



Experimental Setup

- A air compressor is used to pressurize the chamber at pressures up to approximately 100 kPa
- A Bourdon tube is provided to measure the chamber pressure and the scale on the meter is transparent so that the internal construction and operation of the meter can be clear seen
- A pressure valve is available to control the pressure in the chamber
- As pressure builds up in the pressure chamber, it distends a rubber diaphragm firmly clamped between the pressure chamber and the measurement chamber

Experimental Setup

- As the diaphragm distends it moves a column along which are various measurement transducers which give a measure of pressure related to the distension of the diaphragm
- A strain gauge transducer fixed to the surface of the diaphragm which is stretched as the diaphragm distends and therefore changes resistance
- A bimetallic heating sensing element which relies on the bending of the bimetallic strip and the contact it makes with a tapered carrier connected to the diaphragm
- A variable capacitance probe

Bourdon Tube

- Elliptical cross-sectional tube
- C-shape configuration
- Pressure applied to the inside of the tube
  - elastic deformation $\propto$ pressure
- Degree of linearity ~ quality of the gage
- End of the gage is connected to a spring-loaded linkage
  - amplifies the displacement
  - transforms it to an angular rotation of the pointer
- The linkage is constructed so that the mechanism may be adjusted for
  - a) optimum linearity and minimum hysteresis
  - b) compensate for wear

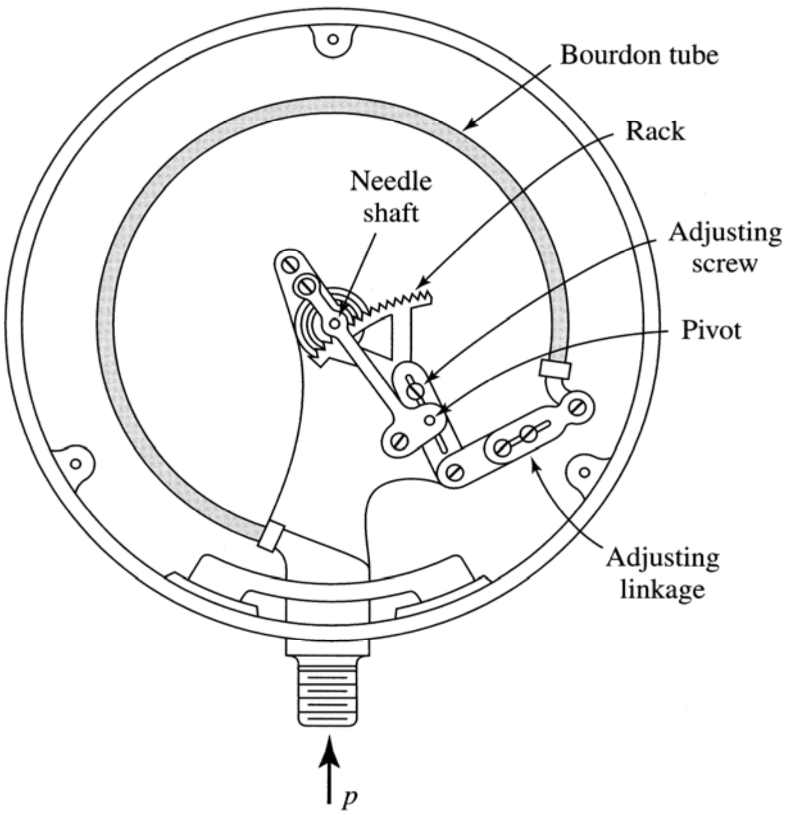


Figure 6.7 Schematic of a bourdon-tube pressure gage.

Diaphragm and Bellows Gages

- Elastic deformation devices
- Displacement
- Strain
- Capacitance
- Voltage – Transformer

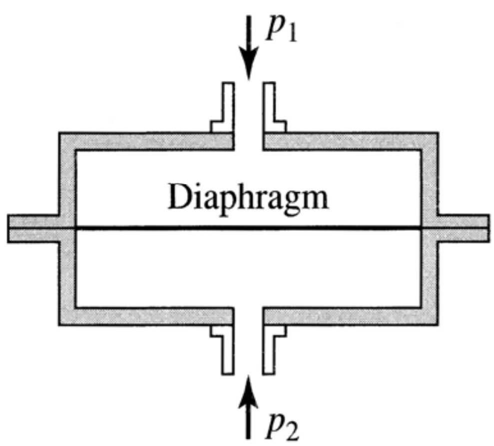
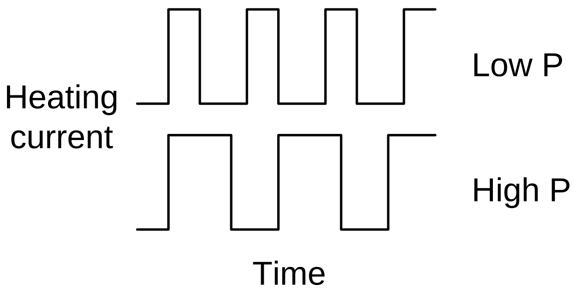


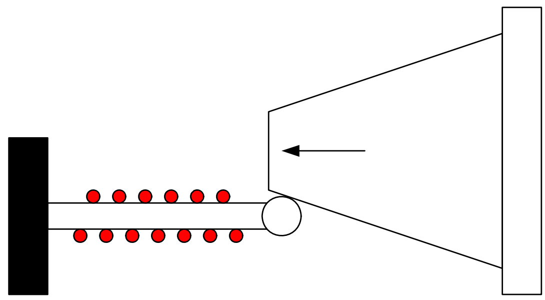
Figure 6.8 Schematic of a diaphragm gage.

•Differential pressure p_1 - p_2
•Diaphragm deflected => pressure differential
=> sensed by displacement transducer

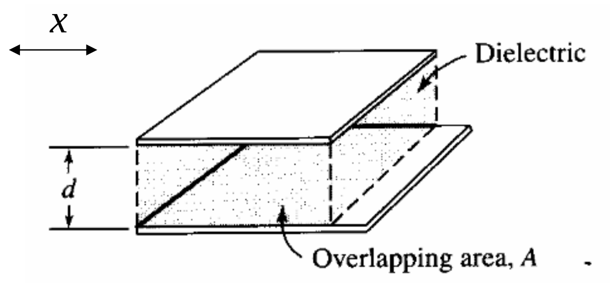
Bimetallic Strip

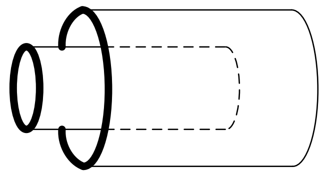
- While the spring contact is touching the cone, the heating circuit is completed, the coil heats up and the bimetallic strip bends.
- Eventually it bends sufficiently to break contact with the cone and the heating circuit is broken
- The bimetallic strip cools down until once again the contact is made and the system heats up again
- The length of time it takes for the contact to make is proportional to the displacement of the diaphragm





Capacitive Transducers





$$Capacitance\ C = 0.225\varepsilon\frac{A}{d}$$

where C is in pF, A in in^2, and d in in

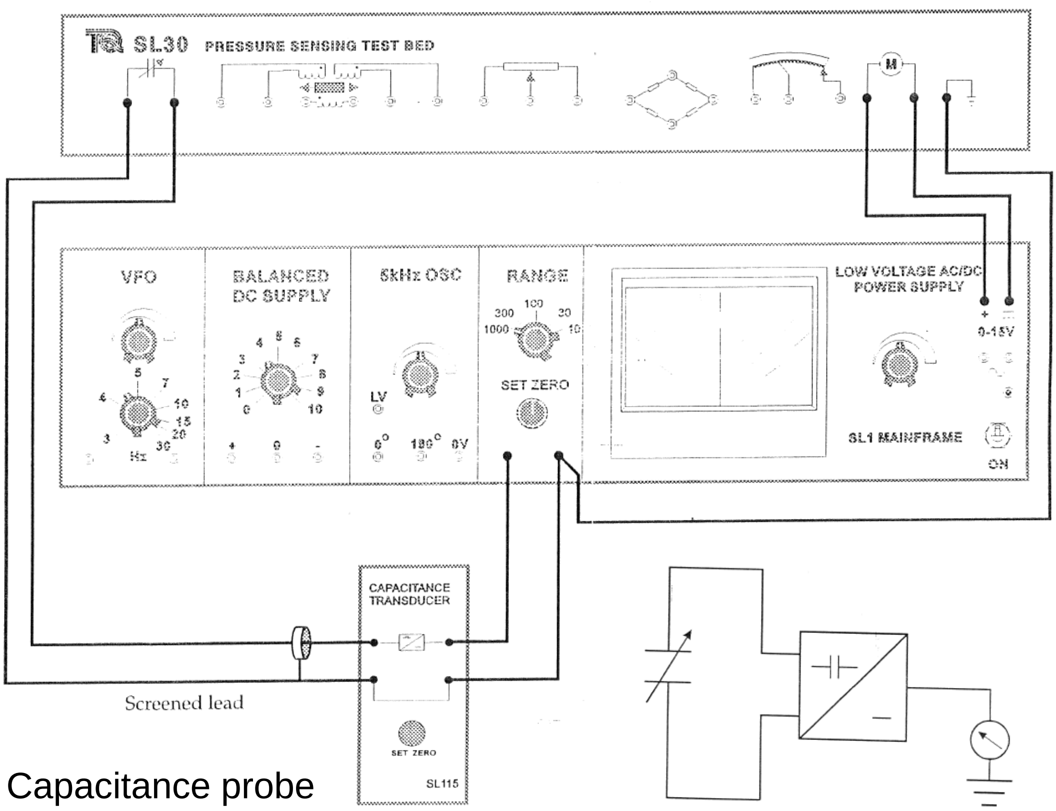
(the constant would be 0.0885 if cm^2 and cm are used for A ans d)

and ε is the relative dielectric constant ($\varepsilon = 1$ for air, 3 for plastics)

It can be shown that : $\frac{\Delta C}{C} = -\frac{\Delta d / d}{1 + (\Delta d / d)}, \quad \frac{\Delta C}{C} = \frac{\Delta A}{A} = (\frac{\Delta x}{x})$

Experiments

- 1. Capacitance probe
- 2. Bimetallic strip
- 3. Strain gage
- 4. Commercial sensor



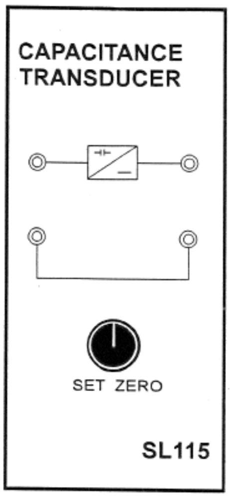
Capacitance probe

SL115 Capacitance Transducer

This module is intended for use in processing the output from the variable capacitance transducers.

The input from the capacitance probe is fed to the input sockets at the left of the module and the output is a DC voltage which can be fed into the SL1 Mainframe or other suitable monitoring equipment.

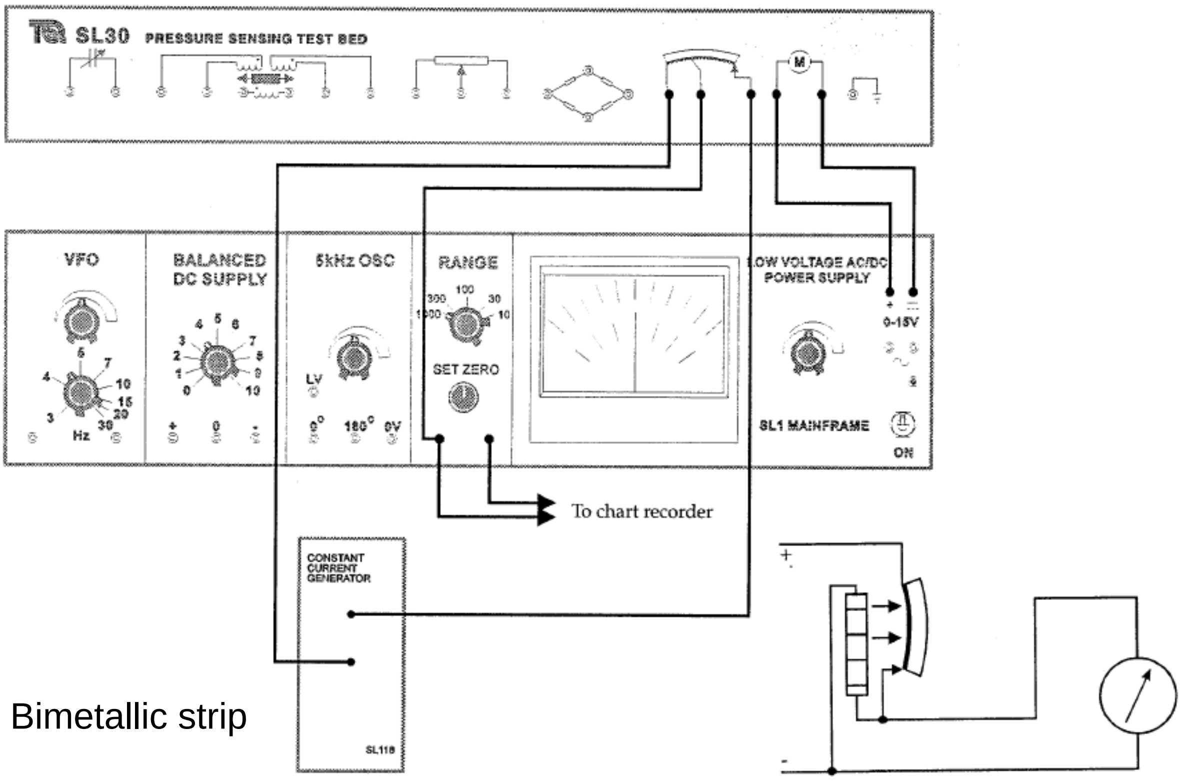
Connection between the input sockets on the transducer module and the transducer itself should be made via screened cable. The 'SET ZERO' control can be used to initialise the meter reading to zero at minimum capacitance. This module must be connected to the transducer by the screened lead provided with the Test Bed.



Experimental Results

Plot a graph of your results.

Pressure (kPa)	Meter Reading (mV)
100	
80	
60	
40	
20	
0	



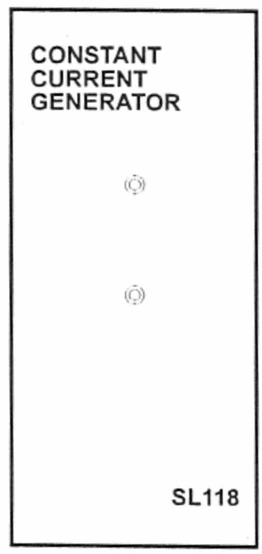
Bimetallic strip

SL118 Constant Current Generator

This module generates a stable constant DC current which will be useful in energising a number of different transducers.

The two sockets may be connected to an external load when the module will supply a constant current of 300mA ±3mA.

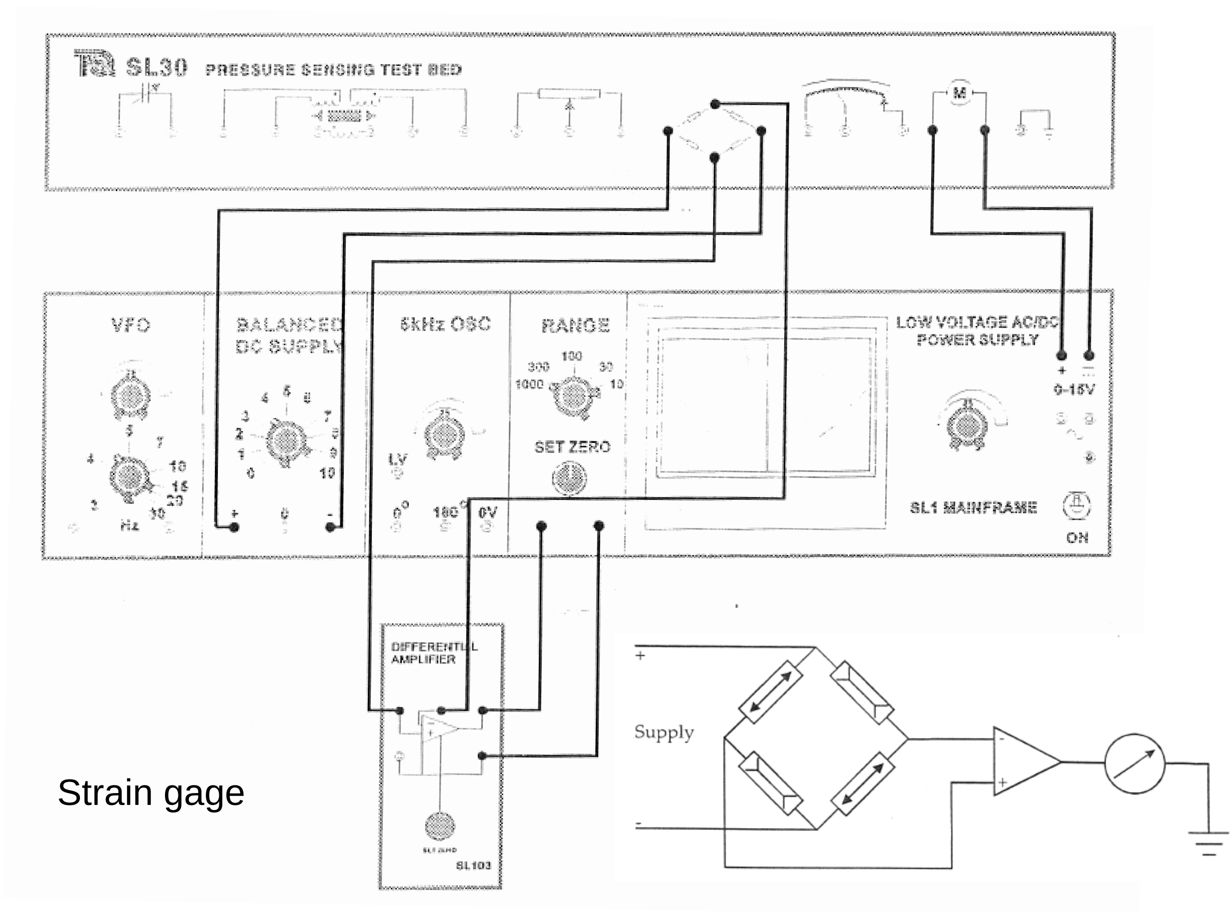
This constant current will be maintained with load resistance values up to approximately 50Ω.



Measure the average current flow by either:-

a) Measuring the length of time for which current flows t_c and then measuring the total cycle time from break to break t_p. Average current is proportional to t_c/t_p.

b) Using the chart recorder (suitable chart speed is 5mm/min and sensitivity for 1V full scale), record the cyclic signal. Measure the 'on' time and express as a percentage of total cycle time.



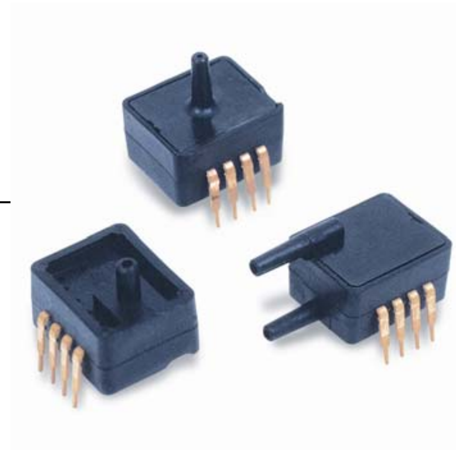
Strain gage

Commercial sensor

Honeywell

ASDX Series

Pressure Sensors
0 psi to 1 psi through
0 psi to 30 psi



DESCRIPTION

The ASDX Series is an amplified version of Honeywell's proven performer and industry leading SDX Series sensor. The ASDX sensor's footprint is slightly larger than the SDX; however, it offers a high level output (4.0 Vdc span) on a very cost-effective basis. This series is fully calibrated and temperature compensated with on-board Application Specific Integrated Circuitry (ASIC).

These DIP (Dual In-line Package) sensors are designed for use with non-corrosive, non-ionic working fluids; such as air and dry gases.

Sensors are available to measure absolute, differential and gage pressures. The absolute sensors have an internal vacuum reference and an output voltage proportional to absolute pressure. The differential sensors allow application of pressure to either side of the sensing diaphragm and may used for differential or gage measurements. Bidirectional versions are also available.

All ASDX Series sensors are accurate to within ±2.0% full scale and are designed for operation from a single 5.0 Vdc supply.

FEATURES

- ASIC-enhanced output
- Wide compensated temperature range 0 °C to 85 °C [32 °F to 185 °F]
- Available in absolute, differential and gage types
- Pressure ranges from 0 psi to 1 psi through 0 psi to 30 psi
- Accuracy ±2.0% max. V full scale
- Quantization step of 3 mV
- Response time of 8 ms

POTENTIAL APPLICATIONS

- Flow calibrators
- Ventilation and air flow monitors
- Gas flow instrumentation
- Dialysis equipment
- Sleep apnea monitoring and therapy equipment
- Barometry
- HVAC controls
- Pneumatic controls

ASDX Series

TABLE 1. GENERAL SPECIFICATIONS

Supply voltage (Vs)[1]	4.75 Vdc to 5.25 Vdc
Maximum supply voltage[1]	6.50 Vdc (max.)
Consumption current	6 mA (typ.)
Output current (sink)	2 mA (max.)
Output current (source)	2 mA (max.)
Lead temperature	2 s to 4 s at 250 °C [482 °F]
Compensated temp. range	0 °C to 85 °C [32 °F to 185 °F]
Operating temp. range	-20 °C to 105 °C [-4 °F to 221 °F]
Storage temp. range	-40 °C to 125 °C [-40 °F to 257 °F]
Vibration	10 g at 20 Hz to 2000 Hz
Shock	100 g for 11 ms
Life	1 million cycles minimum

Note:
1. The sensor is not reverse polarity protected. Incorrect application of excitation voltage or ground to the wrong pin can cause electrical failure. Application of supply voltage above the maximum can cause electrical failure.

TABLE 2. PRESSURE RANGE SPECIFICATIONS

Catalog Listing	Pressure Range	Burst Pressure[1]	Sensitivity
ASDX001	0 psi to 1 psi	5 psi	4.00 V/psi
ASDX005	0 psi to 5 psi	20 psi	0.80 V/psi
ASDX015	0 psi to 15 psi	30 psi	0.267 V/psi
ASDX030	0 psi to 30 psi	60 psi	0.133 V/psi

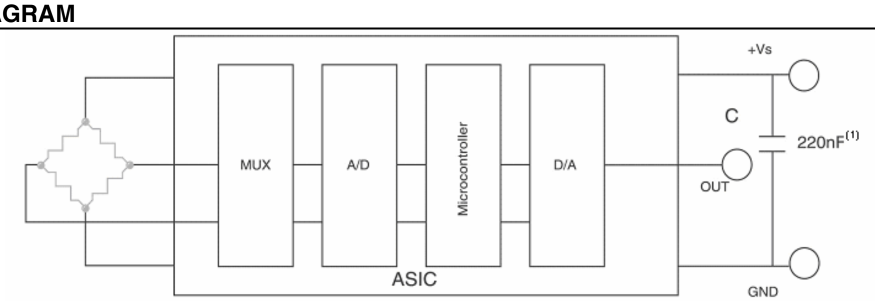
Note:
1. If the maximum burst pressure is exceeded, even momentarily, the package may leak or burst, or the pressure sensing die may fracture.

TABLE 3. PERFORMANCE SPECIFICATIONS[1]

Characteristic	Symbol	Min.	Typ.	Max.	Unit	Note
Zero pressure offset	Voff	0.420	0.500	0.580	Vdc	–
Full scale span	Vfss		4.00	–	Vdc	2
Output at FS pressure	Vfso	4.420	4.500	4.580	Vdc	–
Accuracy	–	–	–	±2.0	%V	3
Response time	–	–	8	–	ms	4
Quantization step	–	–	3	–	mV	5

Notes:
1. Reference conditions (unless otherwise noted): Supply voltage, V_S=5.0 ±0.01 Vdc; T_A=25 °C [77 °F]. Output is ratiometric within the supply voltage range (Vs).
2. Span is the algebraic difference between the output voltage at the specified pressure and the output at zero pressure. Span is ratiometric to the supply voltage.
3. Accuracy is the combined errors from offset and span calibration, linearity, pressure hysteresis, and temperature effects. Linearity is the measured deviation based on a straight line. Hysteresis is the maximum output difference at any point within the operating pressure range for increasing and decreasing pressure. Calibration errors include the deviation of offset and full scale from nominal values.
4. Response time for a 0 psi to full-scale pressure step change, 10% to 90% rise time.
5. The smallest change in the output voltage, given any change in pressure.

FIGURE 1. BLOCK DIAGRAM

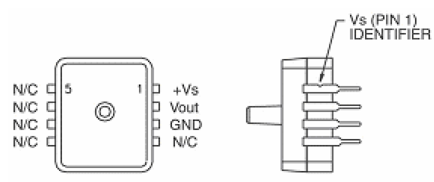


Note:
1. 220 nF capacitor is required between +Vs and GND. 15 nF capacitor between Vout and ground is optional.

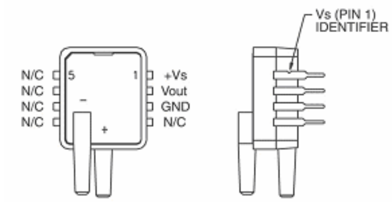
Pressure Sensors, 0 psi to 1 psi through 1 psi to 30 psi

FIGURE 2. PIN OUT[1, 2]

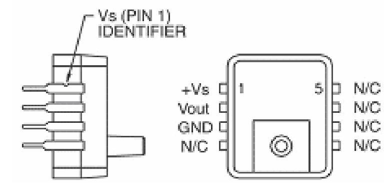
ASDXxxxA2



ASDXxxxD4



ASDXxxxG2



Notes:

1. N/C means no connection. Connecting to ground will damage the sensor.
2. Pins 4, 5, 6, 7 and 8 are internal connections and should not be connected to external circuitry or ground.

FIGURE 3. PERFORMANCE CHARACTERISTICS (Error Band Multiplier Over -20 °C to 105 °C [-4 °F to 221 °F])

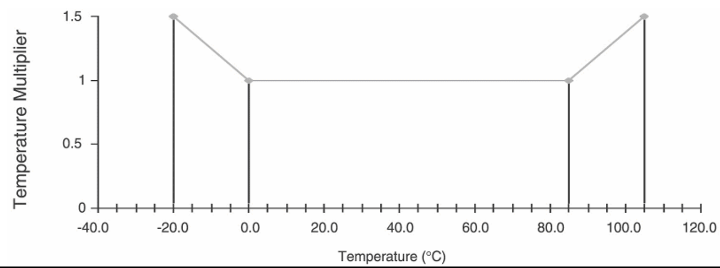
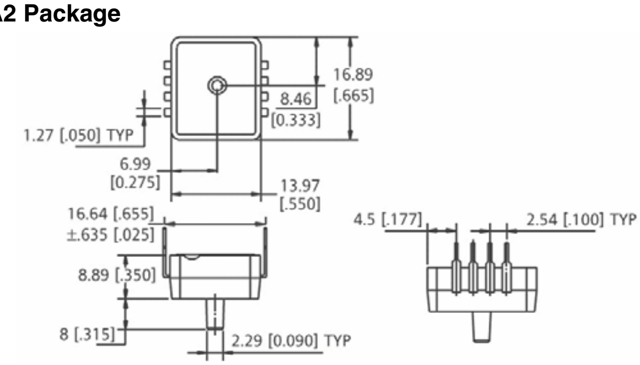
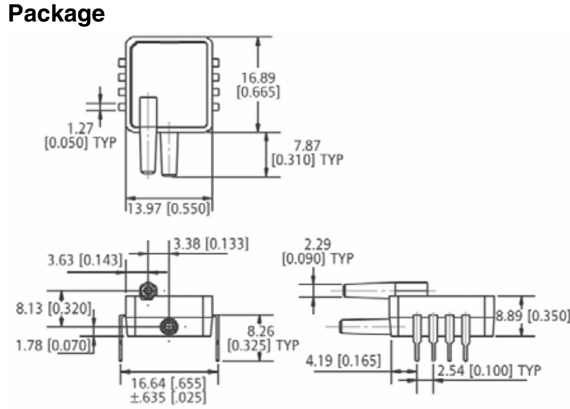


FIGURE 4. DIMENSIONAL DRAWINGS (For reference only: mm [in].)

A2 Package



D4 Package



G2 Package

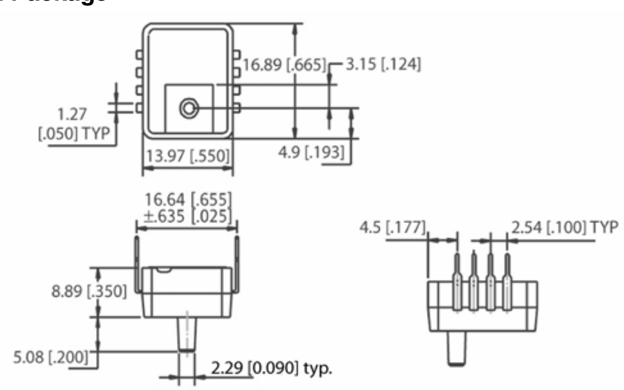


FIGURE 5. NOMENCLATURE TREE

ASDX XXX XX 4X

Series — ASDX

Pressure Range — XXX
001 = 0 psi to 1 psi (Differential, Gage)
005 = 0 psi to 5 psi (Differential, Gage)
015 = 0 psi to 15 psi (Absolute, Differential, Gage)
030 = 0 psi to 30 psi (Absolute, Differential, Gage)

Package Style and Type — XX
A2 = DIP, Absolute
D4 = DIP, Differential
G2 = DIP, Gage

Output — 4X
4R = 0.5 Vdc to 4.5 Vdc
4D = 2.5 ±2.0 Vdc
4H = 0.25 Vdc to 4.25 Vdc*
4M = 0.2 Vdc to 4.7 Vdc*

* Contact Honeywell for additional information.

ORDER GUIDE

Absolute Catalog LIsting	Differential[1] Catalog LIsting	Gage Catalog Listing	Bidirectional Catalog Listing	Pressure Range
–	ASDX001D44R	ASDX001G24R	ASDX001D44D	0 psi to 1 psi
–	ASDX005D44R	ASDX005G24R	ASDX005D44D	0 psi to 5 psi
ASDX015A24R	ASDX015D44R	ASDX015G24R	ASDX015D44D	0 psi to 15 psi
ASDX030A24R	ASDX030D44R	ASDX030G24R	ASDX030D44D	0 psi to 30 psi

Note:
1. May also be used in gage applications.

⚠ WARNING

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DO NOT USE these products as safety or emergency stop devices or in any other application where failure of the product could result in personal injury.
Failure to comply with these instructions could result in death or serious injury.

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Honeywell warrants goods of its manufacture as being free of defective materials and faulty workmanship. Honeywell's standard product warranty applies unless agreed to otherwise by Honeywell in writing; please refer to your order acknowledgement or consult your local sales office for specific warranty details. If warranted goods are returned to Honeywell during the period of coverage, Honeywell will repair or replace, at its option, without charge those items it finds defective. **The foregoing is buyer's sole remedy and is in lieu of all other warranties, expressed or implied, including those of merchantability and fitness for a particular purpose. In no event shall Honeywell be liable for consequential, special, or indirect damages.**

While we provide application assistance personally, through our literature and the Honeywell web site, it is up to the customer to determine the suitability of the product in the application.

Specifications may change without notice. The information we supply is believed to be accurate and reliable as of this printing. However, we assume no responsibility for its use.

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- Complete installation, operation, and maintenance information is provided in the instructions supplied with each product.

Failure to comply with these instructions could result in death or serious injury.

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Honeywell

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December 2007

Experimental Results

Plot a graph of your results.

Pressure (kPa)	Meter Reading (mV)
100	
80	
60	
40	
20	
0	

實驗原理

– Bourdon Tube + Capacitive Displacement Sensing

相關問題

– 請說明實驗中量測電容時為何需要使用特殊導線，其結構與作用為何？

– 請畫出bourdon tube的運動模式。

– 請比較 capacitance probe 和 strain gage 的實驗結果，並說明這兩種方式各自的優缺點。(準確度、靈敏度、線性度、適用範圍、、、)

實驗項目

4.2 Experiment 1: Capacitance Probe Pressure Transducer

Pressure is commonly measured by monitoring the movement of a diaphragm which is distended by a build up of pressure (or of vacuum). One way of monitoring diaphragm movement is to measure a change in capacitance of a system coupled to the diaphragm. In this case two concentric cylinders form a capacitance with the central cylinder coupled to the diaphragm.

This experiment illustrates the use of a variable capacitance fixed to a flexible membrane in pressure sensing.

Equipment Required

SL1 - Mainframe
SL30 - Pressure Sensing Test Bed
SL115 - Capacitance Transducer

Control Settings

Low Voltage Power Supply control to minimum
Meter to 100mV range.
Pressure release valve open

Procedure

Adjust the offset of the meter as follows:-

Switch on the SL1 Mainframe and then short together the input sockets of the meter on the SL1 and adjust the SET ZERO control until the meter indicates zero.

Set up the equipment as shown in Figure 4.2 and switch on.

The leads connecting the capacitance probe to the SL115 must be screened. Turn the SET ZERO control fully clockwise. Carefully rotate the control anti-clockwise until the meter pointer indicates zero. Close the pressure release valve.

Note: There are two possible zero settings. The above procedure ensures the correct one is used and therefore that the results are valid.

實驗紀錄

Increase the Low Voltage Power Supply until the pressure in the pressure chamber, as indicated by the meter, is 100kPa. Because there are inevitable small leaks within the pressure chamber system it will be necessary to increase the supply voltage to build up the pressure and then reduce the supply voltage to a low level so that the small amount of pressure being supplied by the pump balances the pressure losses to maintain a constant reading at 100kPa. Note the reading on the meter.

Using the pressure release knob reduce pressure to take readings at 80, 60, 40, 20 and 0kPa. Where necessary, maintain pressure at intermediate values by adjusting the supply voltage so that the pump supplies pressure losses.

Plot a graph of meter reading against pressure.

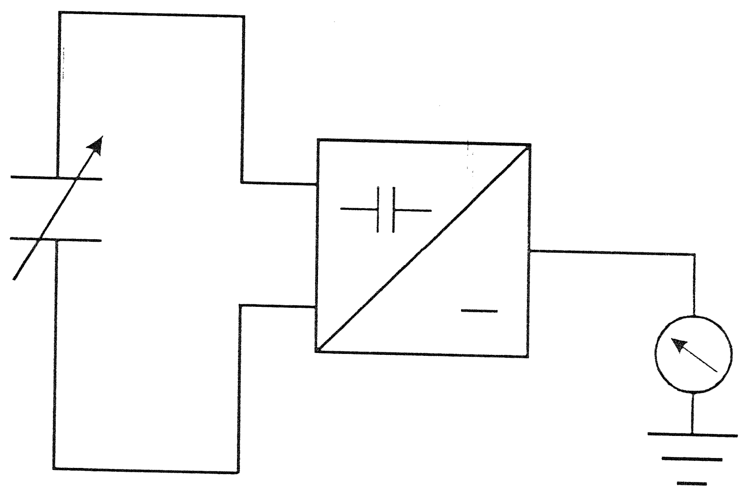

Figure 4.1

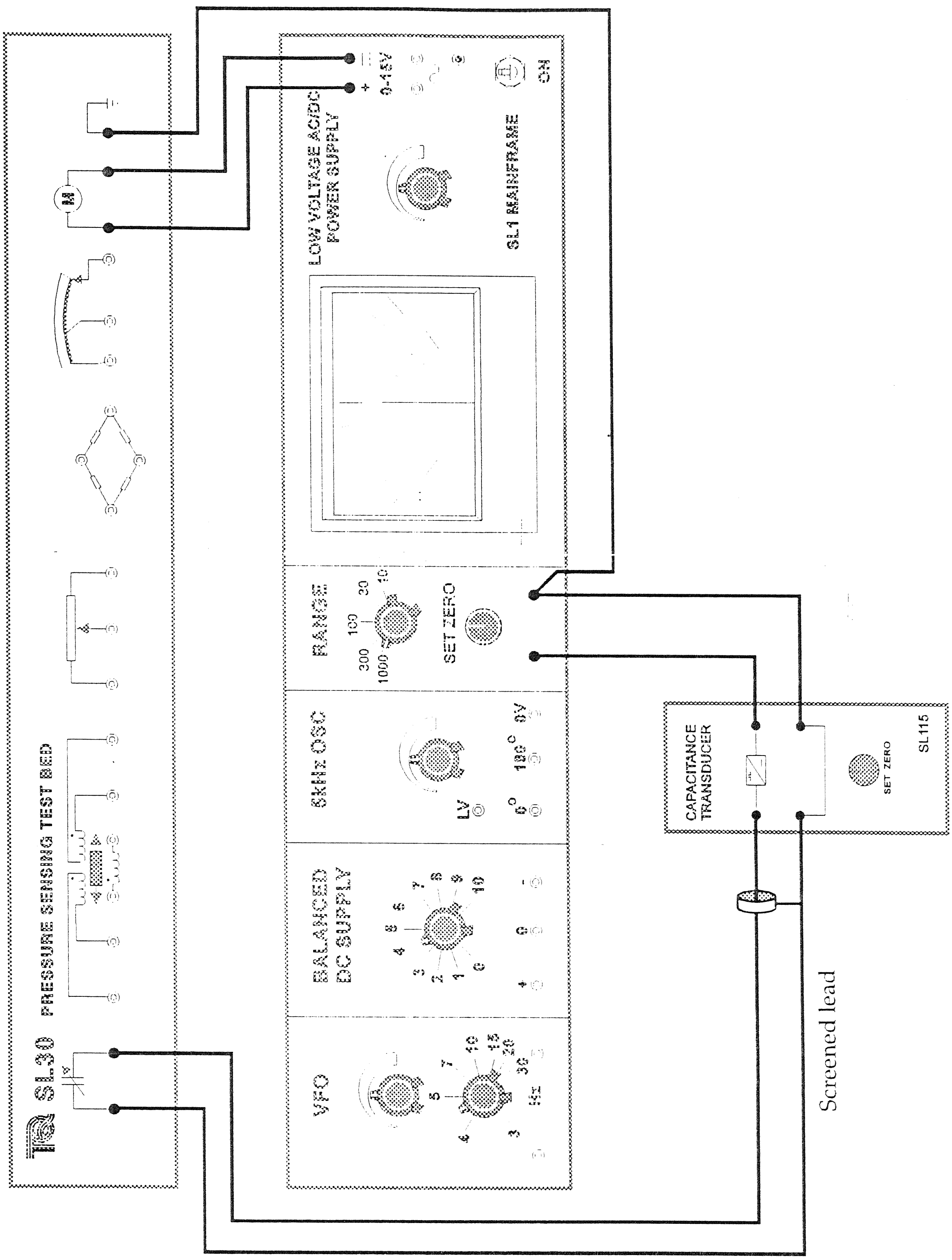

Figure 4.2 Capacitance Probe Pressure Transducer Wiring Diagram

實驗項目

4.3 Experiment 2: Bimetallic Pressure Transducer

Current passing through a heating coil will increase the temperature of a bimetallic strip which will then bend and open electrical contacts. This interrupts the current, causing the strip to cool down and the contacts to remake.

The rate at which the contacts open and close is dependent upon the tension in the strip initially. This may be varied by mounting the fixed contact on a cone moving in accordance to the state of the system being monitored.

This experiment illustrates the use of a bimetallic strip with heating coil and movable contact system in pressure measurement.

Equipment Required

SL1 - Mainframe
SL30 - Pressure Sensing Test Bed
SL118 - Constant Current Generator
Chart Recorder

Control Settings

Low Voltage Power Supply control to minimum
Meter to 1V range
Pressure release valve open

Procedure

Adjust the offset of the meter as follows:-

Switch on the SL1 Mainframe and then short together the input sockets of the meter on the SL1 and adjust the SET ZERO control until the meter indicates zero.

Set up the equipment as shown in Figure 4.4 and switch on. Close the pressure release valve.

Increase the Low Voltage Power Supply until the pressure chamber, as indicated by the meter, is 100kPa. Because there are inevitable small leaks within the pressure chamber system it will be necessary to increase the supply voltage to build up the pressure and then reduce the supply voltage to a low level so that the small amount of pressure being supplied by the pump balances the pressure losses to maintain a constant reading at 100kPa. Note the reading on the meter.

The system operates by current flowing through the heating coil while the contact is touching the cone attached to the diaphragm. The heat causes the bimetallic strip to bend until the contact moves away from the cone. This interrupts the current and the strip cools down until contact is made once again, when the cycle repeats.

The time for which current flows is related to the position of the diaphragm and therefore proportional to pressure.

實驗紀錄

Measure the average current flow by either:-

a) Measuring the length of time for which current flows t_c and then measuring the total cycle time from break to break t_p. Average current is proportional to t_c/t_p.

b) Using the chart recorder (suitable chart speed is 5mm/min and sensitivity for 1V full scale), record the cyclic signal. Measure the 'on' time and express as a percentage of total cycle time.

Using the pressure release knob reduce pressure to take readings at 80, 60, 40, 20 and 0kPa. Where necessary, maintain pressure at intermediate values by adjusting the supply voltage so that the pump supplies pressure losses.

Plot a graph of average current against pressure.

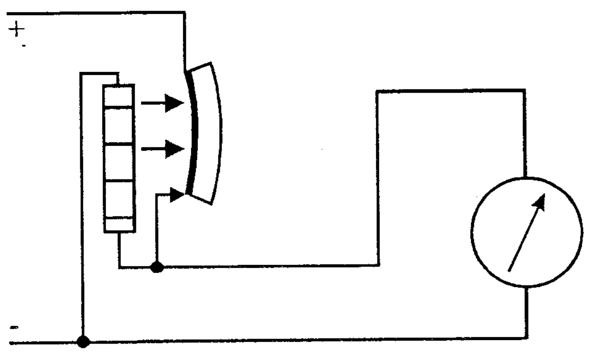

Figure 4.3

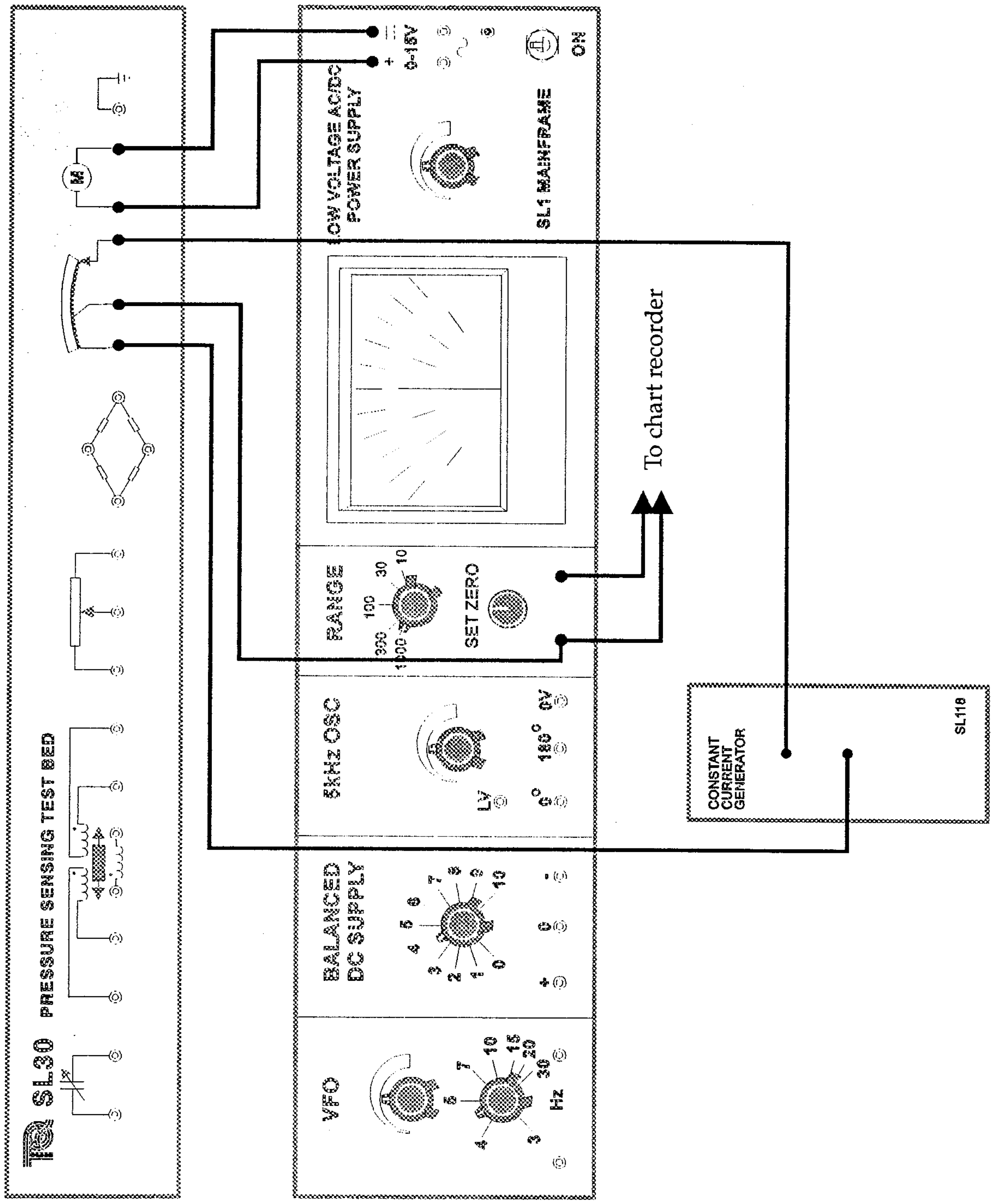

Figure 4.4 Bimetallic Pressure Transducer Wiring Diagram

實驗項目

4.6 Experiment 5: Strain Gauge Pressure Transducer

The resistance of a conductor is a function of its length and cross-sectional area. Stretching the conductor increases the length, reduces the area and so increases the resistance. Measuring the resistance of the conductor gives an indication of extension and also, therefore, of the force/pressure causing the extension.

This experiment illustrates the use of a strain gauge bridge in the measurement of pressure.

Equipment Required

SL1 - Mainframe
SL30 - Pressure Test Bed
SL103 - Differential Amplifier

Control Settings

Low Voltage Power Supply control to minimum.
Balanced DC supply to minimum
Meter to 30mV range.
Pressure release valve open.

Procedure

Connect the equipment as shown in Figure 4.10 and switch on the SL1.

Set the balanced DC supply to 5V. If necessary, zero the meter using the SL103 and meter SET ZERO's.

Use the SL1 Low Voltage Power Supply control and the SL30 pressure release valve to set the pressure to 100kPa, as indicated by the SL30 pressure gauge.

Reduce the pressure and record the corresponding values of pressure against meter reading, in steps as indicated in the table provided.

NOTE

If required, change the range of the meter.

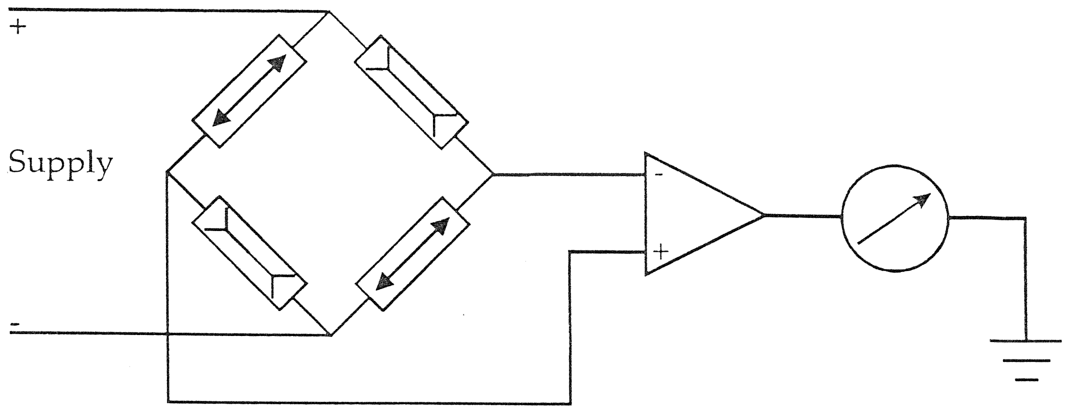

Figure 4.9

實驗紀錄

Plot a graph of your results.

Pressure (kPa)	Meter Reading (mV)
100	
80	
60	
40	
20	
0	

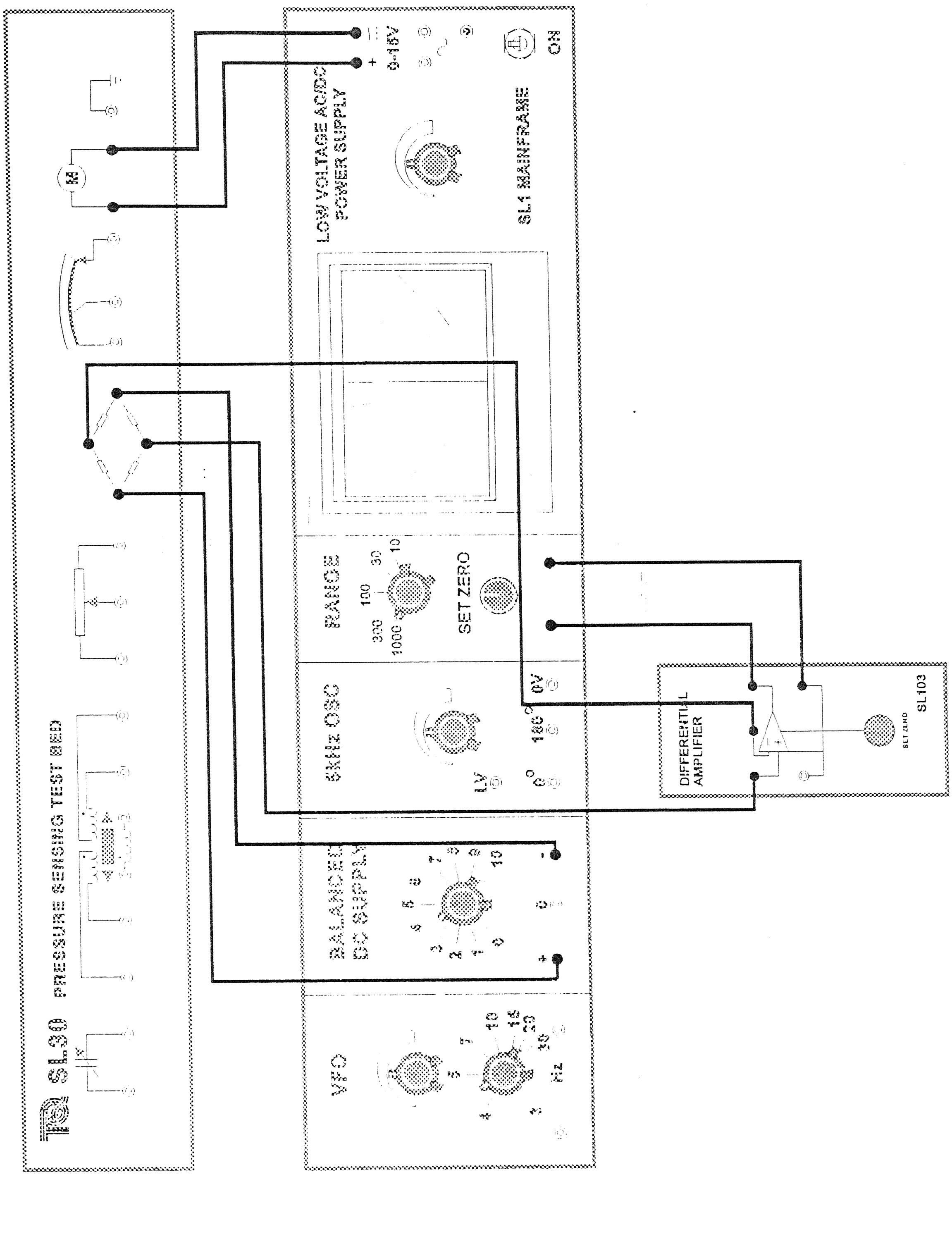

Figure 4.10 Strain Gauge Pressure Transducer

SECTION 2.0 SL30 PRESSURE SENSING TEST BED

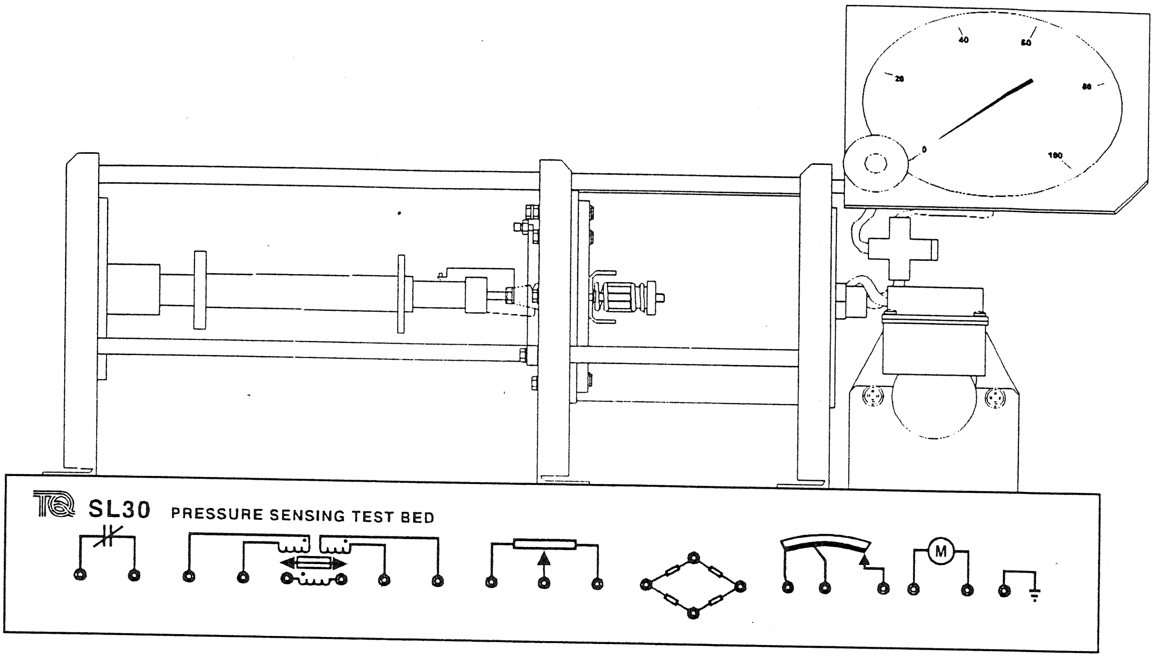

Figure 2.1 SL30 Pressure Sensing Test Bed

2.1 Introduction

The Systems Laboratory Pressure Sensing Test Bed, type SL30, is part of the modular system for teaching the use and application of transducers, measurement systems and signal processing techniques.

The Test Bed is intended for use with the Systems Laboratory Mainframe, SL1 and the user is referred to the SL1 manual for more details of the Mainframe itself.

The SL30 Pressure Sensing Test Bed illustrates techniques of pressure measurement. The component parts of the Test Bed are covered in more detail in later sections and the operation of this Test Bed can be briefly described as follows.

A variable speed pump is used to pressurise a transparent chamber at different pressures up to approximately 100kPa. An indicating meter is provided to measure the pressure of the chamber and the scale on the meter is transparent so that the internal construction and operation of the meter can be seen by the student. A pressure valve is available to control the pressure in the pressure chamber. As pressure builds up in the pressure chamber, it distends a rubber diaphragm firmly clamped between the pressure chamber and the measurement chamber.

Almost all pressure measurement devices rely to some extent on the distension of a diaphragm. This diaphragm may be made of plastic or rubber for low pressure, or of metal for medium and high pressures. In this Test Bed the diaphragm distends much more than would normally be the case in a commercial transducer in order to illustrate the technique more clearly to the student.

As the diaphragm distends it moves a column along which are various measurement transducers which give a measure of pressure related to the distension of the diaphragm The various transducers available are as follows:-

A strain gauge transducer fixed to the surface of the diaphragm which is stretched as the diaphragm distends and therefore changes resistance.

A bimetallic heating sensing element which relies on the bending of the bimetallic strip and the contact it makes with a tapered carrier connected to the diaphragm.

A linear wire wound potentiometer.

A linear variable differential transformer.

A variable capacitance probe.

All the connections to the various transducers are brought out to a series of 2mm sockets which are arranged on the front of the Test Bed, legends describe their various functions.

All signal connections are made via these sockets and no connections, power, signal or otherwise, are made automatically when the Test Bed is placed on the Mainframe. The Mainframe simply serves as a convenient mounting system for the Test Bed assembly which is itself totally self-contained.

This SL30 Pressure Sensing Test Bed forms a part of the Systems Laboratory complex which includes the SL1 Mainframe and various test beds. It covers several types of physical measurement systems for which plug-in signal processing modules can be selected and interchanged as appropriate to the measurement task in hand.

Later sections of this manual will describe in detail the function and operation of the parts of the SL30 Test Bed and those electronic signal processing modules which are necessary for use with the transducers in this measurement system.

2.2 Description of Parts

This description of the component parts of the SL30 Pressure Sensing Test Bed will consider the devices built into the Test Bed together with a description of where and how appropriate connections may be made. Later experimental sections of this manual will cover the practical use of these systems in making measurements.

Pressurising Pump and Pressure Chamber

The pressurising pump used in the SL30 Test Bed is a miniature single piston compression pump driven by a 12V DC motor. The pump is mounted at the extreme right of the Test Bed and the piston assembly is visible at the front of the pump. The DC supply to the pump can be provided via the motor sockets immediately below the pump itself. By varying the DC supply voltage to the pump from the SL1 Mainframe, it is possible to vary the speed of the DC motor and therefore the pressure in the chamber.

A pressure control valve is fitted to the pump in order to release pressure from the pressure chamber and a pressure relief valve is fitted to avoid excessive build up of pressure in the measurement system.

The pressure chamber itself is made up of the right hand section of the clear perspex tube mounted on top of the Test Bed. Between the pressure chamber and the measurement system is a rubber diaphragm which carries the different pressure measurement transducers.

Pressure within the chamber is indicated by a Bourdon type pressure gauge calibrated in kPa up to (100kPa = 1 standard atmosphere). In order to show the student the internal construction of a Bourdon gauge the dial is transparent.

As an optional accessory another type of pressure measurement gauge, based on a pressure diaphragm is available. This can be fitted adjacent to the Bourdon gauge and can be connected via a four-way adapter in the pressure feed system. The capsule gauge (cat. ref. no. SL31) also has a transparent dial.

Pressure Measurement Transducers

Strain Gauge

Fixed to the diaphragm itself is a strain gauge which changes in resistance as the diaphragm distends under pressure from the pressure chamber. The terminations of the strain gauge are brought out to two sockets in the central portion of the Test Bed front panel and pressure is related to the change in resistance.

Many pressure sensing transducers make use of strain gauge systems to measure distension of a diaphragm, although in practice there may be more than one strain gauge fixed to the diaphragm. Certainly the diaphragm would not usually distend as much as the example in the SL30 Test Bed.

Bimetallic Strip

Next in the pressure measurement system we have a bimetallic heating sensing element which is fixed to stationary reference member mounted on the left hand side of the measurement chamber. This consists of a bimetallic strip around which is wound a heating coil of fine wire. The heating circuit is complete through the fixed end of the bimetallic strip and then via a module contact which completes the circuit via the cone-shaped system fixed to the diaphragm.

The method of operation is very simple. While the spring contact is touching the cone, the heating circuit is completed, the coil heats up and the bimetallic strip bends. Eventually it bends sufficiently to break contact with the cone and the heating circuit is broken. Then the bimetallic strip cools down until once again the contact is made and the system heats up again. The length of time it takes for the contact to make is proportional to the displacement of the diaphragm.

Thus at low pressures, when the diaphragm is not distended, the contact only has to move a very small distance to break the circuit and the average current through the system is quite low. Under high pressure the cone moves relative to the contact and the bimetallic strip must bend a great deal further to break contact and the average heating current is, therefore, much greater.

The connection to this bimetallic sensing system is brought out to the set of three sockets adjacent to the motor sockets at the right of the Test Bed front panel.

Potentiometer

Attached to the fixed member of the measurement system is a wire wound resistance potentiometer with a slider attached to the diaphragm. This forms a linear potentiometer system where the position of the slider is proportional to pressure.

The appropriate connections are brought out to the potentiometer symbol in the centre of the Test Bed front panel. Because the potentiometer is wire wound, it is possible to show principles of minimum resolution as well as overall accuracy and linearity of the measurement system.

Linear Variable Differential Transformer

Next in the measurement system is a linear variable differential transformer LVDT. This is a triple coil assembly with a primary which can be excited by an HF signal and two secondaries, one alongside the other. The magnetic flux produced by the primary is linked with the two secondaries via a soft magnetic core which is connected to the diaphragm.

As the diaphragm moves outwards the magnetic flux is linked, more or less, with the two coils and therefore the output from the secondary coils varies in relation to the displacement. The connections to this measurement system are brought out to the six sockets to the left of the potentiometer on the front panel.

Further details of the operation of this measurement system are included in the experimental section.

Capacitance Probe

Finally, at the extreme left of the measurement chamber is a variable capacitance probe. This consists of two concentric co-axial cylinders with the centre portion being movable and fixed to the diaphragm. As the diaphragm, distends, the inner cylinder will mesh more with the outer cylinder and the capacitance will change. The change in capacitance can be related to the change in pressure. The connections to this device are brought out to the two sockets at the extreme left of the Test Bed front panel.

To eliminate spurious capacitance effects in the use of this device a screened lead is provided for use in connecting this probe to the Signal Processing Module (SL115). This lead **must** be used when making capacitance measurements. It is also necessary to connect the Test Bed **earth** socket to Mainframe signal ground.