EG553ME
Instrumentation and Measurement

Lab 7

Title: Variable capacitance transducers

Objective:
1) To investigate the output characteristics of variable area capacitor
2) To investigate the output characteristics of variable distance capacitor

Introduction:

A capacitor basically consists of two conducting plates separated by an insulator which is referred to as the dielectric. The capacitance of the device is directly proportional to the cross-sectional area that the plates overlap and is inversely proportional to the separation distance between the plates. A variable capacitor can therefore be constructed by varying either the area of plates overlapping or the separation distance.
Capacitance transducers can be used in systems where change in capacitance causes change in system parameters. a most common system is LC tuned circuit whose output frequency changes with the change in capacitance. Since frequency measurement is not simple, usually a complex electronic circuit is used to convert output frequency change into change in output voltage.

Relevant Equations

Capacitance of a capacitor is determined as:

$$C = \frac{\varepsilon_0 \varepsilon_r A}{d} \quad \text{(pF)}$$

Where, ε_o = 8.85 pF/m
ε_r = 1 for air
d = distance in m
A = area in m^2

The resonant frequency of inductance-capacitance circuit shown in figure below which is also called LC tuned circuit is determined as:

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

If a variable capacitor is added then,

$$f_r = \frac{1}{2\pi\sqrt{L(C + C_x)}}$$

It is seen from the above that if C_x is changed f_r will also change. This change in frequency is converted into voltage with the aid of an electronic circuit.

Lab Set-up

The equipment and accessories required for the lab are as follows:

1) TK294A Instrumentation module
2) TK294 Linear transducer test rig
3) TK294H Variable area capacitor sub-unit
4) TK294J Variable distance capacitor sub-unit
5) Power supply (Feedback PS446)
6) DC voltmeter/multimeter

Lab Procedure

Lab 7-1 Investigation of output characteristics of variable area capacitor

1) Assemble the TK294 and the TK294H units
2) Connect up the transducers and module as shown in figure 7-1. Keep the leads as short as possible in order to reduce stray capacitance.
3) Set the position of the slider corresponding to the rod being halfway into the capacitive transducer (about 42.5 mm on the scale)
4) The lower 'external tuning comp' socket is connected to 0V and should be connected to the left hand socket on TK294H, i.e. the capacitor body
5) Set switch SW9 to the 'C' position
6) Set the micrometer to read 10mm
7) Set the output voltage control on the oscillator to mid scale
8) Set the gain of the amplifier to 10
9) Switch on the power supply. An output should be visible on the meter.
10) Adjust the oscillator frequency control until the sharp transition from negative to positive (or vice-versa) of the output voltage is found. From this point slowly adjust oscillator frequency control until the meter indicates exactly zero volts. (Always remove your hands when taking readings to avoid the effects of stray capacitance)
11) Move the slider towards the transducer until either the rod is fully home or the meter reaches a positive maximum and adjust the oscillator output control until this reading is some convenient figure (e.g. 3V). Do not adjust the oscillator frequency control.
12) Record the output voltage for slider positions from 20mm to 65mm at 5mm intervals leaving micrometer setting at 10mm throughout
13) Switch off the power supply.

Observation Sheet

Slider position, mm	20	25	30	35	40	45	50	55	60	65
Output voltage, V										

Plot a graph of output vs. slider position. What shape is the graph? Which part of the graph (in volts) enables you to relate the output voltage to the position of the transducer?

Lab 7-2 Investigation of output characteristic of variable distance capacitor

1) Connect the circuit as shown in figure 7-1 except TK294H which should be replaced by TK294J
2) The lower of the 'external tuning comp' sockets is connected to 0V and should be connected to the lower socket on TK294J, i.e. the metal chassis.
3) Set the capacitor plates to about mid-separation (12.5mm on micrometer and about 30mm on slide scale)
4) Adjust the oscillator frequency for zero output voltage as in lab 7-1.
5) Adjust the micrometer until the meter indicates a positive maximum and adjust the oscillator output voltage control until this reading is a convenient figure (approx. 3V). Do not adjust the oscillator frequency.
6) Record the output voltage for micrometer settings between 10mm and 15mm at 0.5m intervals leaving the slide position unchanged
7) Switch off the power supply

Observation sheet

Micrometer setting, mm	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Output voltage, V											

Plot the graph of output voltage vs. micrometer settings. What shape is the graph over the central section? In your opinion, variable distance capacitor is better or variable area capacitor is better for linear position measurement?

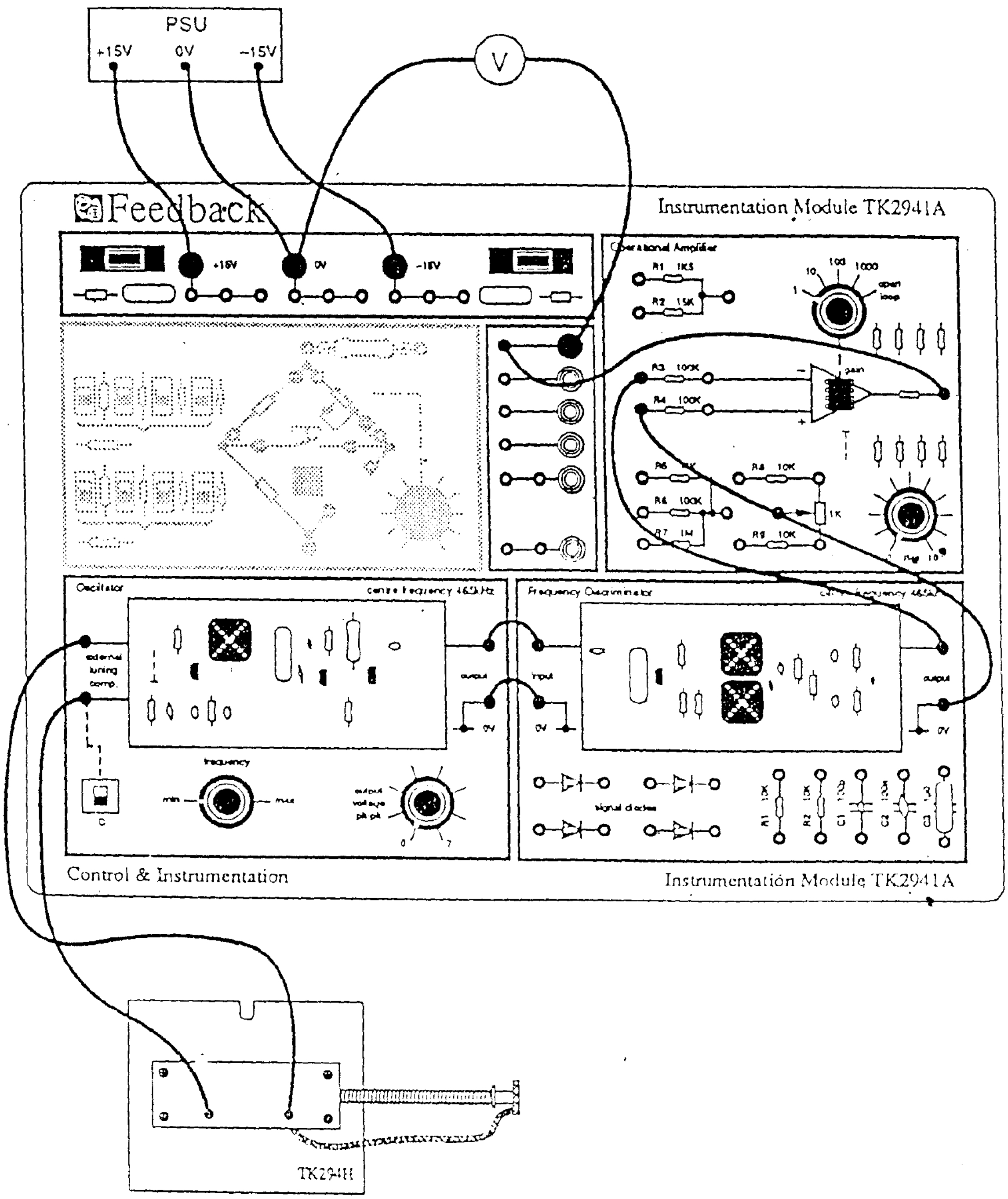

PSU
+15V
0V
-15V
V
Feedback
Instrumentation Module TK2941A
Control & Instrumentation
Instrumentation Module TK2941A
TK2941I

Figure 7-1

EG553ME
Instrumentation and Measurement

Lab 10

Title: Transducers for temperature measurement

Objective:
1) To calibrate a thermocouple
2) To calibrate a thermistor
3) To calibrate a platinum resistance thermometer

Introduction:

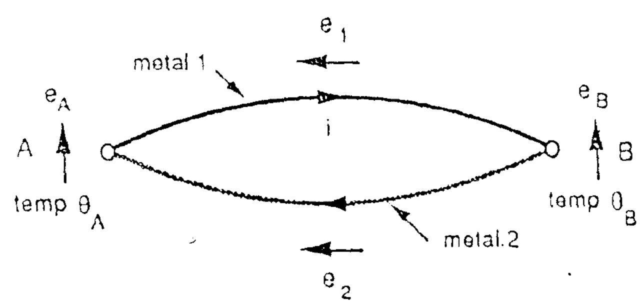
If two wires of dissimilar metals are in contact, an electromotive force exists whose magnitude is a function of several factors including temperature. Junctions of this sort, used to measure temperature are called thermocouples. According to 'Peltier effect', an emf is generated at each of two junctions which is dependent upon absolute temperatures of the junctions. Similarly, according to 'Thomson effect', each wire of the loop generates a small emf as a result of temperature difference between the ends.
Thermistors are thermally sensitive variable resistors made of oxides of metals like manganese, cobalt, nickel etc. Thermistors change their resistance by a large amount for small change in temperature which makes them very sensitive.
Apart from the above, some metals which change their resistance with temperature are also used for measuring temperature. Platinum, copper and nickel are most popular metals for constructing resistance thermometers. Among all the metals, platinum has most linear resistance-temperature relationship. The resistance-temperature relationship of resistance thermometers stay constant from one sample to another and over very long period of time. For this reason, resistance thermometers are used as sub-standards or even as standards of temperature.

Relevant Equations:

Peltier Effect:

$$e_A - e_B = P(\theta_A - \theta_B)$$

Where, P = Peltier coefficient



Thomson Effect:

$$e_1 = T_1(\theta_A - \theta_B)$$
$$e_2 = T_2(\theta_A - \theta_B)$$
$$e_2 - e_1 = (T_2 - T_1)(\theta_A - \theta_B)$$

Where, T_1 and T_2 = Thomson coefficients

Putting the two effects together,

$$(e_A - e_B) + (e_2 - e_1) = E = (P + T_2 - T_1)(\theta_A - \theta_B)$$

In practice, T1 and T2 are much smaller that P. Combining these three coefficients,

$$E = k(\theta_A - \theta_B)$$

Where, k = thermocouple constant

The resistance change of a thermistor is given by:

$$R = R_0 e^{\beta\left(\frac{1}{T} - \frac{1}{T_0}\right)}$$

Where,

β = temperature coefficient, 1/K
T_0 = reference temperature, K
T = working temperature, K
R_0 = resistance at T_0
R = resistance at T

The resistance change of resistance thermometer is given by:

$$R = R_0(1 + AT + BT^2)$$

Where,

R_0 = resistance at T_0
R = resistance at T
A,B = constants depending on materials

For platinum, A = 0.00398/°C and B = 0.588×10^{-6}/°C

Lab Set-up

In order to calibrate temperature sensors, temperature sources stabilised at various temperatures are required. This is achieved by a single heat bar shown in figure 10-1. The heat bar is heated at one end with electric heaters. The other end is connected to an extended surface exposed to surrounding. The heat bar consists of 20 notches. After reaching steady-state (it takes about an hour after the heater is turned on), each notch of the heat bar will have steady temperature. A calibration tank which is filled with water as shown in figure 10-2 is clamped to each notch. After the water temperature is steady, the temperature shown by thermometer is in effect, the temperature of that notch. If any other temperature is immersed in the tank, the changes in electric properties of the immersed sensor will correspond to the temperature shown by the thermometer. (The thermocouple used in the lab is of copper-constantan type and the thermistor has 2000 ohm at 20°C.) It is a good practice to start calibration from the least-temperature end of the heat bar.

Safety consideration: The heat bar may be hot (up to 100°C) and cause burns. Handle with care.

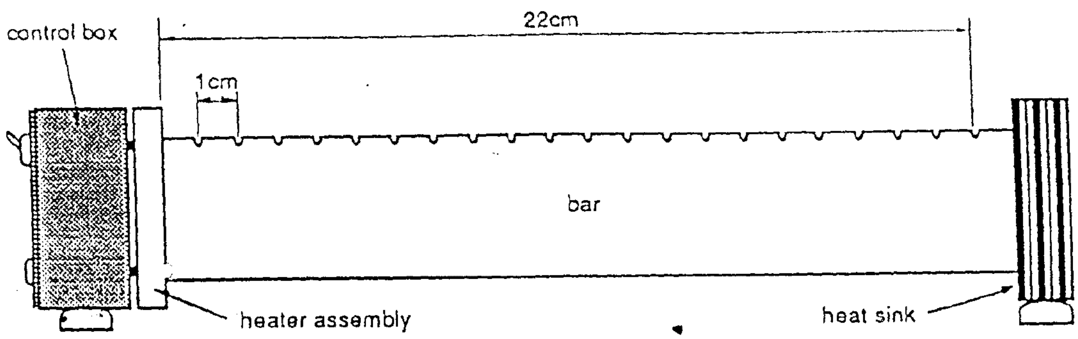


Figure 10-1 Heat bar

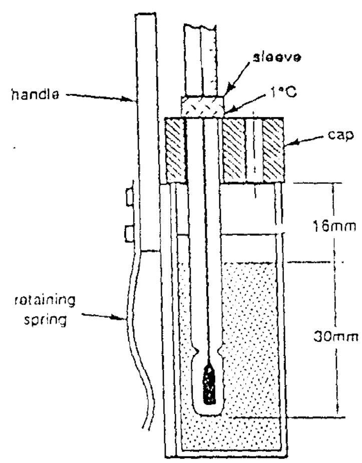


Figure 10-2 Calibration tank

The equipment and accessories required are as follows:

Thermocouple:

1) TK294A Instrumentation module
2) Heat bar
3) Thermometer
4) Calibration tank
5) Transducer-thermocouple and flying compensating lead (black sleeve)
6) Power supply (Feedback PS446)
7) Multimeter

Thermistor:

1) TK294A Instrumentation module
2) Heat bar
3) Thermometer
4) Calibration tank
5) Transducer-thermistor and flying compensating lead (white sleeve)
6) Power supply (Feedback PS446)

7) Multimeter
8) Decade resistance box

Platinum resistance thermometer:
1) TK294A Instrumentation module
2) Heat bar
3) Thermometer
4) Calibration tank
5) Transducer-Platinum resistance and flying compensating lead (yellow sleeve)
6) Power supply (Feedback PS446)
7) Multimeter
8) Decade resistance box

Lab Procedure:

Lab 10-1 Calibration of a thermocouple

1) The calibration tank has a white plastic cap with two holes in it. The larger hole is used for mercury-in-glass thermometer and the smaller is used for thermocouple. Remove the cap and fill the tank with water up to approximately 16mm from the top (see figure 10-2). If you look at the back of the thermometer, you will see that it is marked '30mm immersion'. This is the depth of immersion for which it was calibrated and should be adhered to for accurate measurements
2) Turn on the heat bar power supply
3) Connect the circuit with probe (black sleeve) as shown in figure 10-3. Switch on the power supply and place the probe near to the amplifier input so that all points are at the same temperature (the capacitor in the circuit is used to avoid the possible pick-up of signal from oscillator)
4) Use a thermometer to measure room temperature. This will be cold junction temperature and should be ideally be constant during experiment
5) Switch the gain on the operational amplifier to 1000.
6) Place the probe and the thermometer in the calibration tank and clip the tank on the heat bar at notch 20.
7) When the temperature is steady (it takes about 15 mins) note the thermometer reading and voltmeter reading. Repeat this for notches 18,16 etc up to the point where 100°C is reached. Enter your results into observation sheet for each notch.

Observation Sheet

Notch #	20	18	16	14	12	10	8	6	4	2
Tank temp, °C										
Room temp, °C										
Temp. Difference, °C										
Voltmeter reading, V										
TC emf, mV										

Calculate the temperature difference and TC emf which will be the meter reading divided by 1000 expressed in mV. Plot the TC emf against temperature difference. Is the graph straight line? If so, what is the slope in μV/°C?

Lab 10-2 Calibration of a thermistor

1) To calibrate the thermistor, we have to place it in the calibration tank with a mercury thermometer and heat he water to various temperatures, measuring the thermistor resistance at each point by means of Wheatstone bridge. For this set up the heat bar and calibration tank as in lab 10-1.
2) Set up the circuit as shown in figure 10-4. On the Wheatstone bridge set switches SW3 and SW6 'in' and all other switches 'out'
3) Switch on the power supply and set the potentiometer control on the operational amplifier to give 1Vdc (with a gain of 1000) across the bridge circuit
4) Insert the probe (white sleeve) and a mercury thermometer into the calibration tank. When the thermometer is steady, at room temperature, balance the bridge and note temperature and resistance
5) Clip the tank to heat bar at notch 20, wait about 5-10 minutes for the temperature to stabilise and rebalance the bridge to read the thermistor resistance. Note the result and thermometer reading. Repeat the process at notch 18,16 etc. until a temperature of about 100°C is reached.
6) Turn off the power supply/heat bar.

Observation Sheet

Notch #	20	18	16	14	12	10	8	6	4	2
Temperature, °C										
Resistance, ohm										

Plot the graph of resistance as a function of temperature. Is the curve linear? For linearization of curve, a resistance in parallel with the prove should be connected. For the thermistor used in this experiment, a value around 400 ohm is optimum. Compute total R for various values of thermistor resistance (from the graph or table) and plot them against corresponding temperature. How is the new graph? Is it linear? What is the slope in ohm/°C?

Lab 10-3 Calibration of Platinum resistance thermometer

1) To calibrate the thermistor, we have to place it in the calibration tank with a mercury thermometer and heat he water to various temperatures, measuring the thermistor resistance at each point by means of Wheatstone bridge. For this set up the heat bar and calibration tank as in lab 10-1.
2) Set up the circuit as shown in figure 10-4. On the Wheatstone bridge set switches SW3 and SW6 'in' and all other switches 'out'
3) Switch on the power supply and set the potentiometer control on the operational amplifier to give 1Vdc (with a gain of 1000) across the bridge circuit
4) Insert the probe (yellow sleeve) and a mercury thermometer into the calibration tank. When the thermometer is steady, at room temperature, balance the bridge and note temperature and resistance
5) Clip the tank to heat bar at notch 20, wait about 5-10 minutes for the temperature to stabilise and rebalance the bridge to read the thermistor resistance. Note the result and thermometer reading. Repeat the process at notch 18,16 etc. until a temperature of about 100°C is reached.
6) Turn off the power supply/heat bar.

Observation Sheet

Notch #	20	18	16	14	12	10	8	6	4	2
Temperature, °C										
Resistance, ohm										

Plot the graph of resistance as a function of temperature. Is the graph a straight line? What is the slope in ohm/°C?

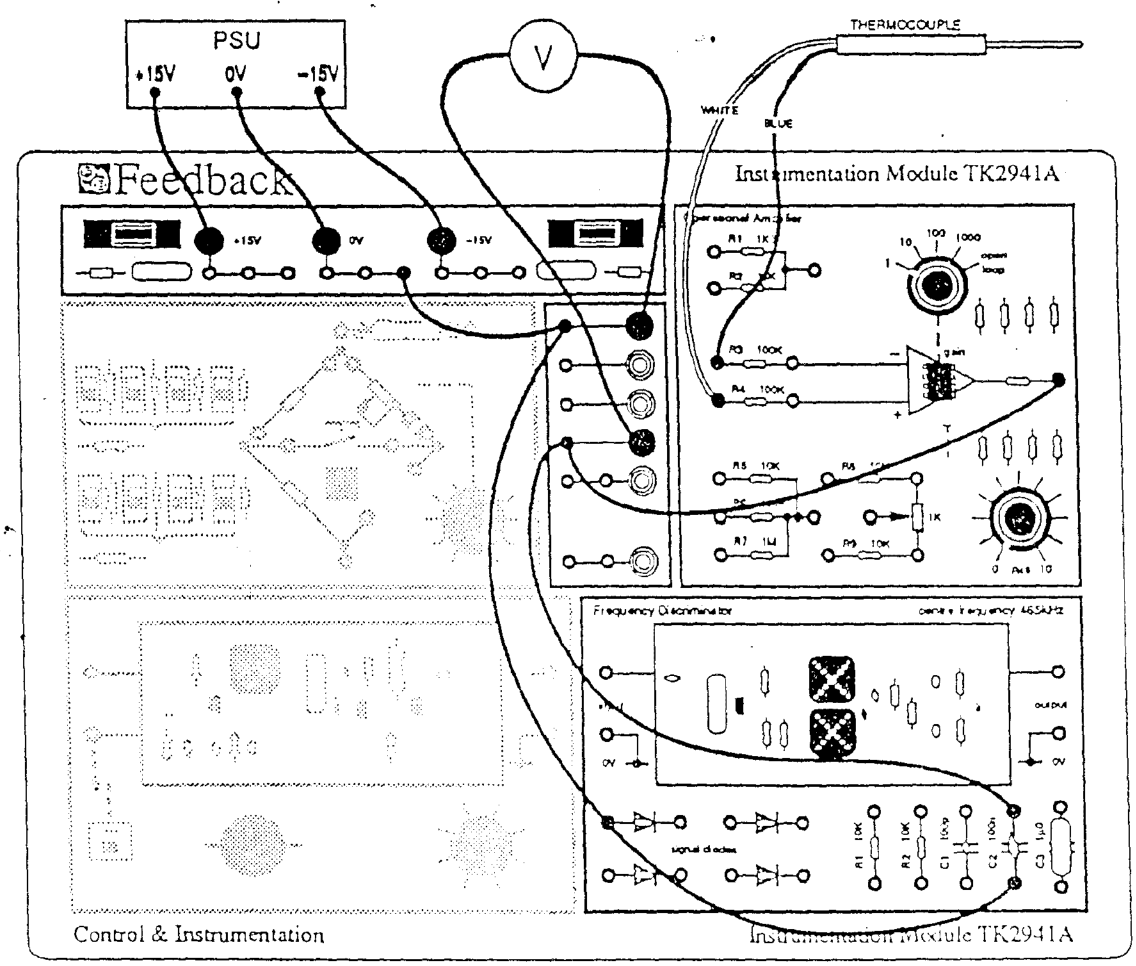

PSU
+15V
0V
-15V
V
THERMOCOUPLE
WHITE
BLUE
Feedback
Instrumentation Module TK2941A
+15V
0V
-15V
R3 100K
R4 100K
R5 10K
R7 1M
R9 10K
1K
Frequency Discriminator
output
0V
signal diodes
R1 10K
R2 10K
Control & Instrumentation
Instrumentation Module TK2941A

Figure 10-3

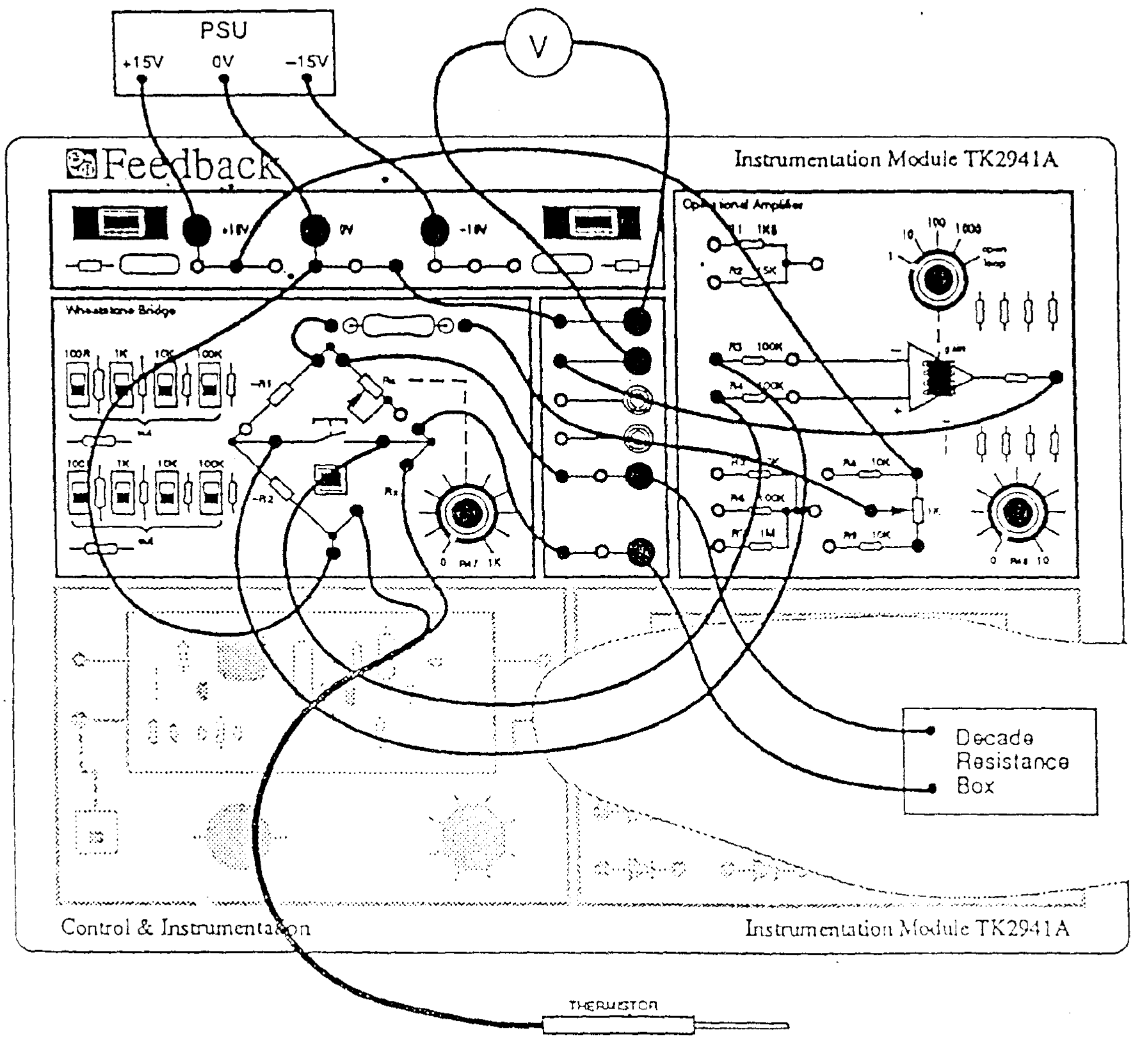

PSU
+15V
0V
-15V
V
Feedback
Instrumentation Module TK2941A
Decade
Resistance
Box
Control & Instrumentation
Instrumentation Module TK2941A
THERMISTOR

Figure 10-4