# *User's Manual*

## POTENTIOMETRIC ERROR DETECTOR

**Model: PED-01**

(Rev : 01/04/2010)

*Manufactured by:*

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## LIMITED WARRANTY

Techno Instruments warrants this product to be free from defects in materials and workmanship for a period of one year from the date of shipment to the customer. Techno Instruments will repair or replace, at its option, any part of the product which is deemed to be defective in material or workmanship. This warranty does not cover damage to the product caused by abuse or improper use. Determination of whether a product failure is the result of manufacturing defect or improper use by the customer shall be made solely by Techno Instruments. Responsibility for the return of equipment for warranty repair belongs to the customer. Equipment must be properly packed to prevent damage and shipped postage or freight prepaid. (Damage caused by improper packaging of the equipment for return shipment will not be covered by the warranty). Shipping costs for returning the equipment, after repair, will be paid by Techno Instruments.

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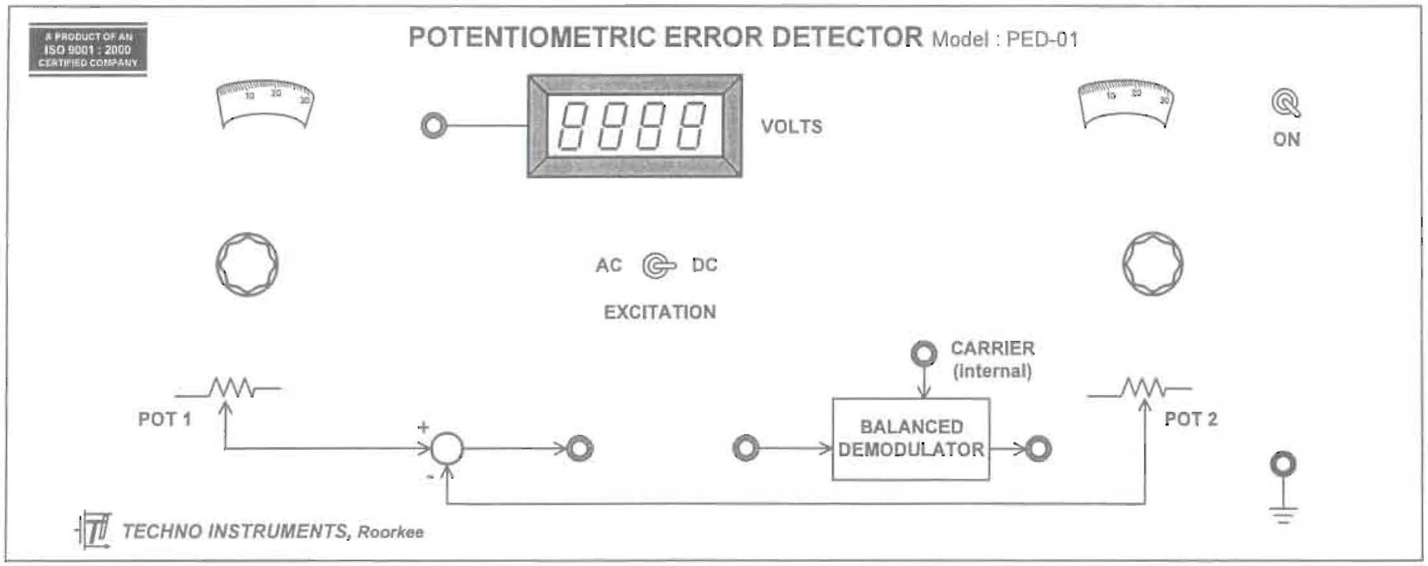
**Note :** No equipment will be accepted for return without an authorization.

When returning equipment for repair, the units must be packed properly. Carriers will not accept responsibility for damage by improper packing. To be certain the unit will not be damaged in shipment, observe the following rules:

1. The carton must be strong enough for the item shipped.
2. Make certain there is at least two inches of packing material between any point on the apparatus and the inside walls of the carton.
3. Make certain that the packing material can not displace in the box, or get compressed, thus letting the instrument come in contact with the edge of the box.




Panel Daigram of Potentiometric Error Detector, Model PED-01

## 1. OBJECTIVE

To study the performance characteristics of an angular position error detector using two potentiometers.

## 2. EQUIPMENT DESCRIPTION

Measurement of the output variable and its comparison with the command or reference input is a fundamental task to be performed in any feedback control system. In a position control system this is usually achieved by a pair of potentiometers (d.c. systems) or a synchro transmitter-control transformer set (a.c. systems). The present unit allows students to study the performance of an angular position error detector using high quality servo-potentiometers. In addition, facilities have been provided for a.c. studies as well. The schematic diagram of the system is shown in Fig.1.

### 2.1 Signal Sources

There are two built-in sources for operating the error detector. These are,

d.c. : I.C. regulated +5V (nominal)

a.c. : 400 Hz, 1.2V p-p (nominal)

Both these sources are derived from the internal power supplies of the system which again are stabilised using integrated circuits.

### 2.2 Measurement

A 3½ digit DVM is available on the panel for the measurement of d.c. signals. For a.c. measurements an external CRO will be required.

### 2.3 Building Blocks

*(a) **Error Detector** :* The basic error detector consists of two servo-potentiometers with calibrated dials of 1° resolution mounted on the panel. A common a.c./d.c. (selected by a switch) signal is internally connected to these, and the potentiometer outputs are permanently wired to a unity gain instrumentation amplifier. The output of the instrumentation amplifier is brought out on the panel. This constitutes the error detector.

*(b) **Demodulator*** : This block is needed during the a.c. operation of the potentiometer. The a.c. output of the potentiometer may be connected to the demodulator input and the output obtained is a phase-sensitive d.c. signal.

### 2.4 Power Supply

The unit has an internal ±12V I.C. regulated supply which is permanently connected to all the circuits. The power supply and the circuits are short circuit protected. No external a.c. or d.c. power may be connected to the sockets on the front panel. A good quality dual trace oscilloscope is the only external equipment required for this experiment.

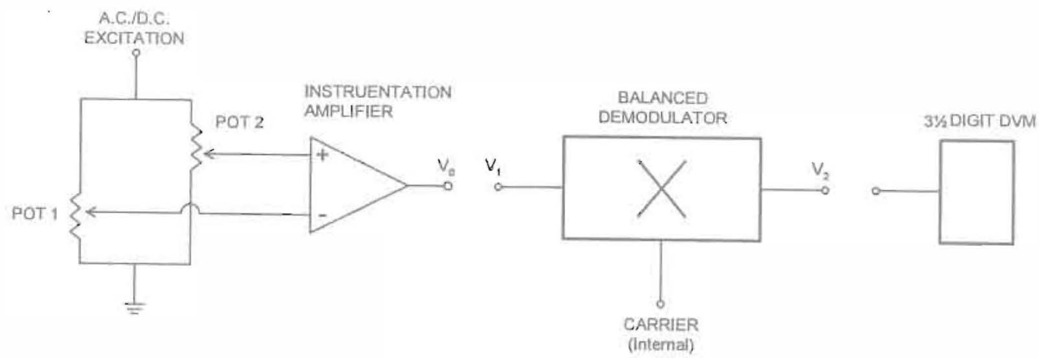



Fig. 1 Schematic Diagram

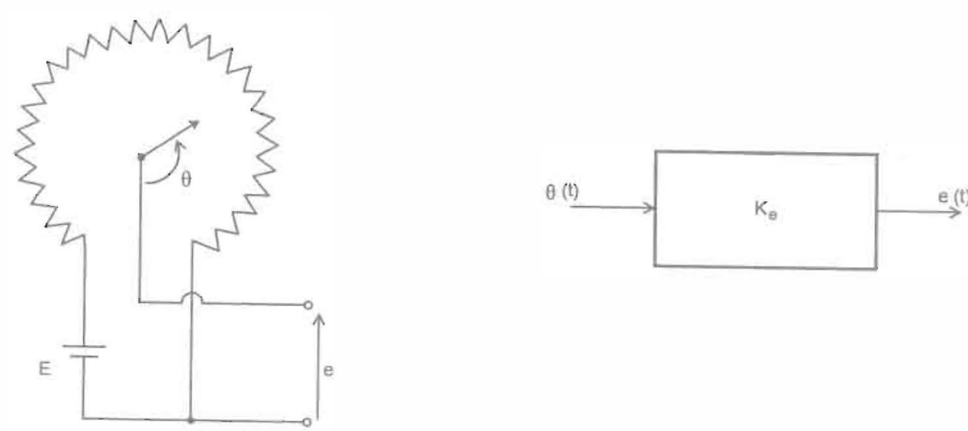



Fig. 2 Potentiometer Presentation

## 3. BACKGROUND SUMMARY

Potentiometer is an important component of a feedback position control system. Potentiometers are also used in open loop system for the purpose of monitoring the angular position of a shaft. Other devices which find similar application include optical encoders, synchros, electromagnetic transducers and specialised potentiometers like sine-cosine potentiometer etc., although a good quality linear potentiometer is perhaps the most common. Description of some specialised potentiometers may be seen in [2] pages 22-23.

A potentiometer is an electromechanical transducer which converts angular or linear displacement into a proportional electrical voltage. When a reference voltage is applied across the fixed terminals of the potentiometer, the output voltage measured at the variable terminal is proportional to the input displacement. Fig. 2 shows a schematic diagram and the block diagram of a potentiometer.

Rotary potentiometers are commonly available in single turn or 3 turn/10 turn varieties. These have restricted motion, with mechanical stops at both ends. Special servo - potentiometers are also available with unrestricted motion, however, they have a gap of about 5° in their electrical circuits. These potentiometers are normally wire wound for long rotational life but have finite resolution. The resistance tolerance and linearity are also excellent. The specifications of the two servo-potentiometers used in the unit are reproduced below :

| | |
|---|---|
| Resistance | 1K |
| Tolerance | 10% |
| Linearity | 1% |
| Power rating | 3W |
| Mechanical travel | 360° |
| Electrical travel | 355° |

Referring to Fig. 2, the output voltage e(t) may be written as

$$e(t) = K_e\theta(t) \qquad \ldots \qquad (1)$$

where $\theta(t)$ is the shaft position and $K_e$ is the constant of proportionality,

$$K_e = \frac{\text{Voltage applied, volts}}{\text{Maximum angular span, radians}} \qquad \ldots \qquad (2)$$

Use of two potentiometers in parallel, supplied from the same source, enables a comparison of two shaft positions - a reference shaft and a controlled shaft (Fig. 3). The output voltage taken across the variable points of the two potentiometers may be expressed as

$$e(t) = K_e\,[\theta_1(t) - \theta_2(t)] = K_e\,\theta_e(t) \qquad \ldots \qquad (3)$$

and the circuit is also represented as an error detector block.

For the sake of completeness, a schematic diagram of a d.c. position control system is shown in Fig. 4 which uses a pair of potentiometers as error detector. In this system the d.c. motor rotates in a direction to align the potentiometers and to minimize the error.

A system similar to the above is possible using a.c. excitation of the potentiometers, a.c. amplifier and a 2-phase a.c. servomotor to drive the load. The difference between the d.c. and a.c. position control systems essentially arises from the features of the amplifier and motor types used. Advantages of a.c. systems over d.c. systems are:

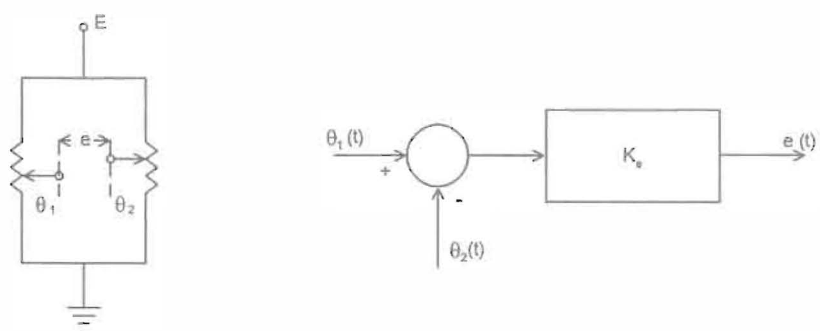



Fig. 3 Error Detector Configuration

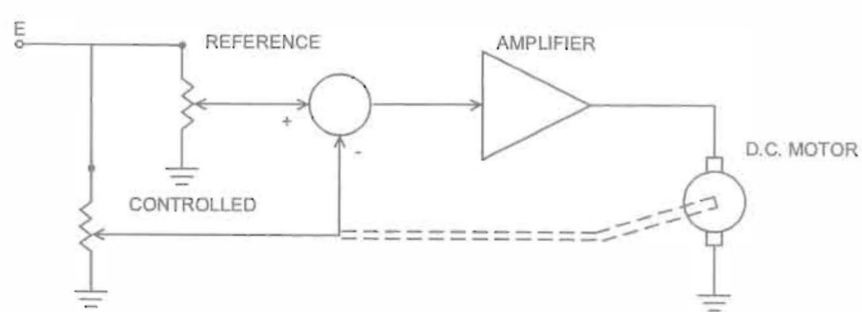



Fig. 4 D.C. Position Control System

(a) a.c. amplifiers are free from drift, and the transformer coupled output allows single supply operation, and

(b) 2-phase motors having no commutators and brushes are inherently more robust and maintenance free.

On the other hand, in potentiometer error detector supplied with a.c. signal (carrier). $v(t)=V \sin \omega_c t$, the error output is given by

$$e(t) = K_s \theta_e V \sin \omega_c t \qquad \ldots \qquad (4)$$

where $\theta_e$ is the angular error between reference and controlled potentiometers.

It may be seen from above that whenever $\theta_e$ changes sign there is a 180° phase shift in e(t). Again considering a sinusoidal angular error,

$$\theta_e(t) = \sin \omega_s t$$

e(t) may be represented as a suppressed carrier signal given by

$$e(t) = \frac{1}{2} K_s V [\text{Cos}(\omega_c - \omega_s)t - \text{Cos}(\omega_c + \omega_s)t] \qquad \ldots \qquad (5)$$

When the above signal is applied to a 2-phase servomotor, the motor acts as a demodulator and the direction of shaft movement is in accordance with the sign of $\theta_e$. A d.c. motor may be used instead, provided a balanced demodulator is used to extract the direction information from the signal of Eq. (5). An integrated circuit balanced modulator/demodulator type LM1496 has been used in the present unit for this purpose. In this circuit, the modulated signal $e(t) = K_s \theta_e V \sin \omega_c t$, is multiplied by the carrier signal of amplitude $V'$ to yield,

$$e'(t) = K_s \theta_e V \sin \omega_c t . V' \sin \omega_c t$$

$$= \frac{K_s V V'}{2} \theta_e [1 - \cos 2\omega_c t] \qquad \ldots \qquad (6)$$

The above signal is passed through a low pass filter to remove the $2\omega_c$ component to yield the output

$$e_0(t) = \frac{K_s V V'}{2} \theta_e \qquad \ldots \qquad (7)$$

This may then be amplified by a d.c. amplifier before feeding to a d.c. motor.

## 4. EXPERIMENTAL WORK

The critical features of a potentiometer type error detector are the linearity and range of the potentiometers used and the gain $K_e$ of the error detector. Given below are the steps for their determination. This is followed by a.c. studies with and without the demodulator.

### 4.1 Linearity and Range of the Potentiometer

The linearity of a potentiometer may be defined as the maximum percentage deviation of the output voltage from its ideal value. This may be better appreciated from a graph between the potentiometer output and shaft position. Again, the range of the potentiometer indicates the angle through which a proportional output is available in the potentiometer (electrical travel specification). Steps for conducting this experiment are:

- Set the excitation switch to DC

- Keep POT 2 fixed at any position and do not disturb its position. Let this position be $\theta_2$
- Turn POT 1 in steps of 20° (at 1° interval when there is a sudden change in voltage). Record angular position $\theta_1$ and the output $V_o$ (use DVM on panel).
- Plot $V_o$ vs $\theta_1$. Observe linearity and range.
- Repeat for another position of POT 2.

### 4.2 Error Detector Coefficient

From the readings of sec. 4.1, plot $V_o$ versus $\theta_e(=\theta_1-\theta_2)$. If this plot is not a straight line, draw a straight line approximation. Calculate the slope of this line as,

$$\text{Slope} = K_e = \frac{\text{Change in output voltage}}{\text{Change in shaft position}} = \frac{\Delta V_o}{\Delta \theta_e}$$

### 4.3 A.C. Excitation

- Display the 'CARRIER' on the CRO and measure its amplitude and frequency.
- Switch the 'EXCITATION' to AC Now observe $V_o$ on a CRO while turning either POT 1 or POT 2 very slowly. USE THE INTERNAL CARRIER FOR EXTERNAL TRIGGERING OF THE CRO. Notice and record how phase of $V_o$ changes when $\theta_e(=\theta_1-\theta_2)$ changes sign.
- Record and plot peak-to-peak (or r.m.s.) $V_o$ as a function of $\theta_e$. Note that the information about the sign of $\theta_e$ is lost.
- Next connect $V_o$ to the input of the 'BALANCED DEMODULATOR' and its output to the DVM.
- Record and plot the demodulator output $V_{DEM}$ as a function of $\theta_e$. Note that the information about the sign of $\theta_e$ is restored. (It may be noted that a non-zero d.c. voltage is present for $\theta_e = 0$ which in an actual application could be eliminated by using a level shifter).

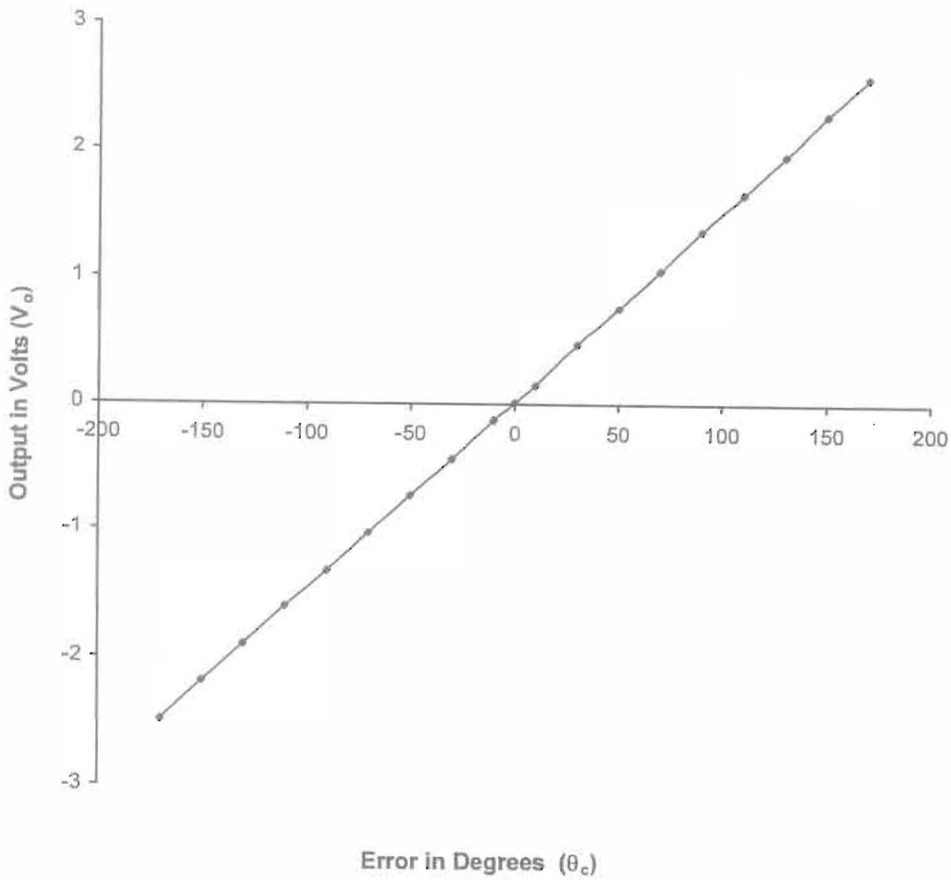



Fig. 5 Error Vs. Output with D.C. Excitation

## 5. TYPICAL RESULTS

### (a) Error detector with d.c. excitation

POT 2 fixed at 180° ($= \theta_2$)

| S.No. | POT1 position $\theta_1$, degrees | $\theta_e = \theta_2 - \theta_1$, degrees | Output $V_o$, Volts |
|---|---|---|---|
| 1. | 10 | +170 | +2.57 |
| 2. | 30 | +150 | +2.27 |
| 3. | 50 | +130 | +1.95 |
| 4. | 70 | +110 | +1.65 |
| 5. | 90 | +90 | +1.36 |
| 6. | 110 | +70 | +1.05 |
| 7. | 130 | +50 | +0.76 |
| 8. | 150 | +30 | +0.47 |
| 9. | 170 | +10 | +0.15 |
| 10. | 180 | 0 | 0.01 |
| 11 | 190 | -10 | -0.13 |
| 12. | 210 | -30 | -0.44 |
| 13 | 230 | -50 | -0.73 |
| 14. | 250 | -70 | -1.03 |
| 15. | 270 | -90 | -1.33 |
| 16 | 290 | -110 | -1.61 |
| 17. | 310 | -130 | -1.90 |
| 18. | 330 | -150 | -2.19 |
| 19. | 350 | -170 | -2.49 |

From the graph between $V_o$ and $\theta_e$ (Fig. 5)

$$K_e = \frac{\Delta V_o}{\Delta \theta_e} = 14.50 \text{ mV/degree}$$

*Linearity*: The experimental results of Fig. 5 show a near perfect linearity since the deviation in $V_o$ from ideal value, if any, is not measurable. In some cases, however, maximum deviations of upto 50mV may be observed which corresponds to 1% linearity specification of the potentiometers.

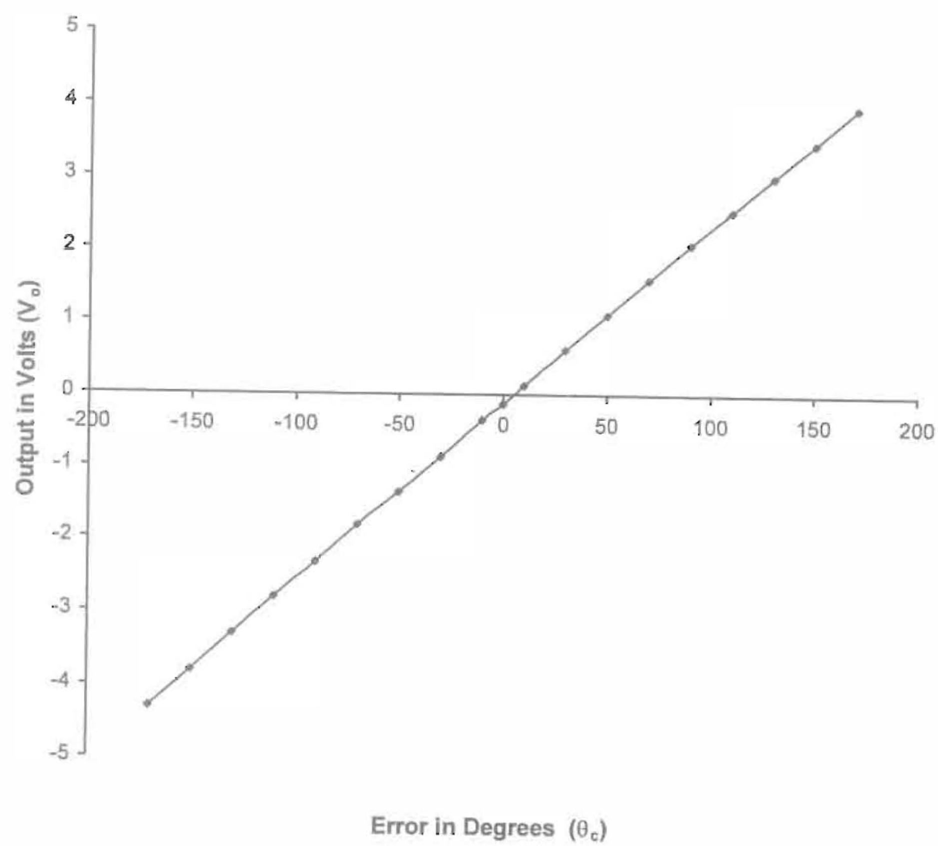



Fig. 6 Error Vs. Output with A.C. Excitation

### (b) Error detector with a.c. excitation

POT 2 fixed at 180° ( $=\theta_2$ )

| S.No. | POT1 position $\theta_1$, degrees | $\theta_e = \theta_1 - \theta_2$, degrees | $V_o$ (rms)* mV | $V_{DEM}$ from DVM, Volts |
|---|---|---|---|---|
| 1. | 10 | -170 | 195 | -4.30 |
| 2. | 30 | -150 | 172 | -3.80 |
| 3. | 50 | -130 | 147 | -3.30 |
| 4. | 70 | -110 | 123 | -2.80 |
| 5. | 90 | -90 | 101 | -2.33 |
| 6. | 110 | -70 | 76 | -1.82 |
| 7. | 130 | -50 | 52 | -1.35 |
| 8. | 150 | -30 | 29 | -0.86 |
| 9. | 170 | -10 | 5 | -0.35 |
| 10. | 180 | 0 | 0 | -0.13 |
| 11. | 190 | +10 | 3 | 0.12 |
| 12. | 210 | +30 | 27 | 0.61 |
| 13. | 230 | +50 | 50 | 1.09 |
| 14. | 250 | +70 | 74 | 1.57 |
| 15. | 270 | +90 | 98 | 2.07 |
| 16. | 290 | +110 | 121 | 2.53 |
| 17. | 310 | +130 | 144 | 3.00 |
| 18. | 330 | +150 | 167 | 3.46 |
| 19. | 350 | +170 | 190 | 3.95 |

Error Vs. Output with A.C. Excitation is shown in Fig. 6

## 6. REFERENCES


[1] B.C. Kuo, "Automatic Control Systems"- Fifth Edition, Prentice Hall of India Pvt. Ltd. 1990 pp 150-55.

[2] R.W. Miller, "Servomechanisms - Devices and Fundamentals", Reston Publishing Co. Inc., Reston, Virginia, pp 11-29.


* True RMS A.C. Millivoltmeter, Model: ACM-102 (Scientific Equipment & Services, Roorkee) or similar instrument may be used

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## To reach Techno Instruments

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    - Approximate age of the apparatus.
    - A detailed description of the problem/ sequences of events may please be sent by email or Fax.
* If your problem relates to the instruction manual, note;
  Model number and Revision (listed by month and year on the front cover).
  Have the manual at hand to discuss your questions.

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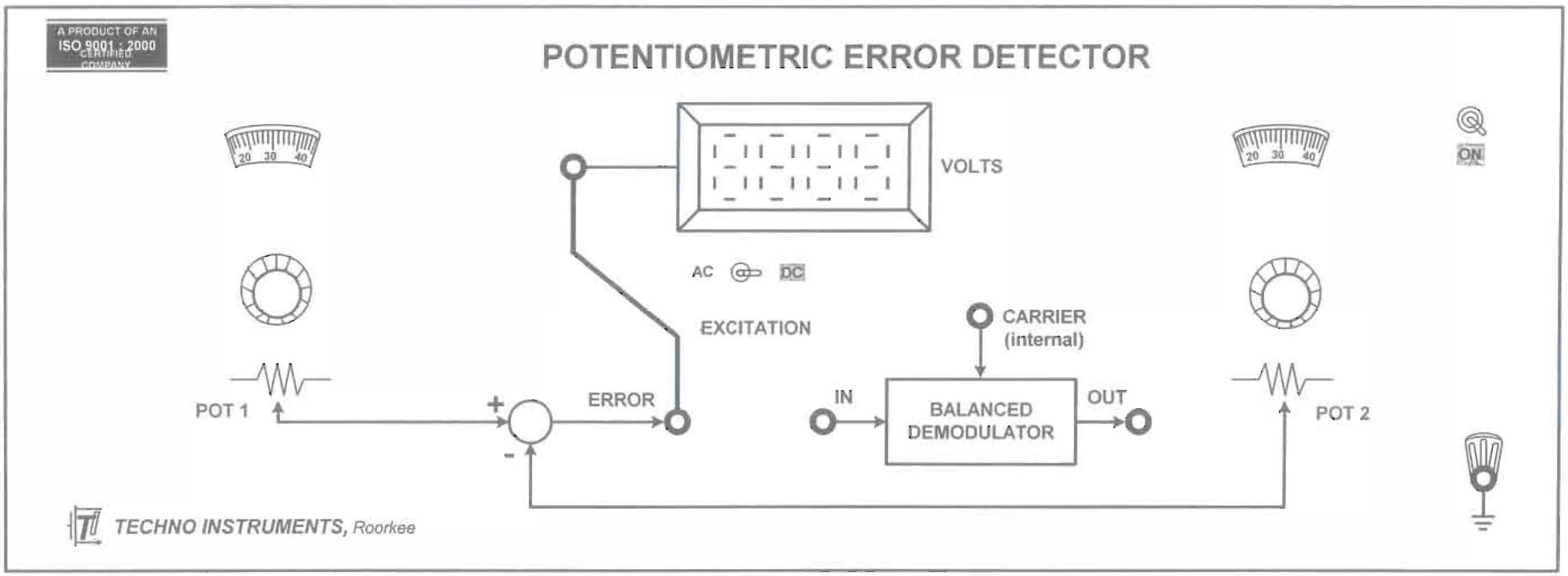
# CONNECTION DIAGRAM

## POTENTIOMETRIC ERROR DETECTOR
(D.C. STUDIES)



# CONNECTION DIAGRAM

## POTENTIOMETRIC ERROR DETECTOR
(A.C. STUDIES)