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User's Manual

POTENTIOMETRIC ERROR DETECTOR

Model: PED-01

(Rev : 01/04/2010)

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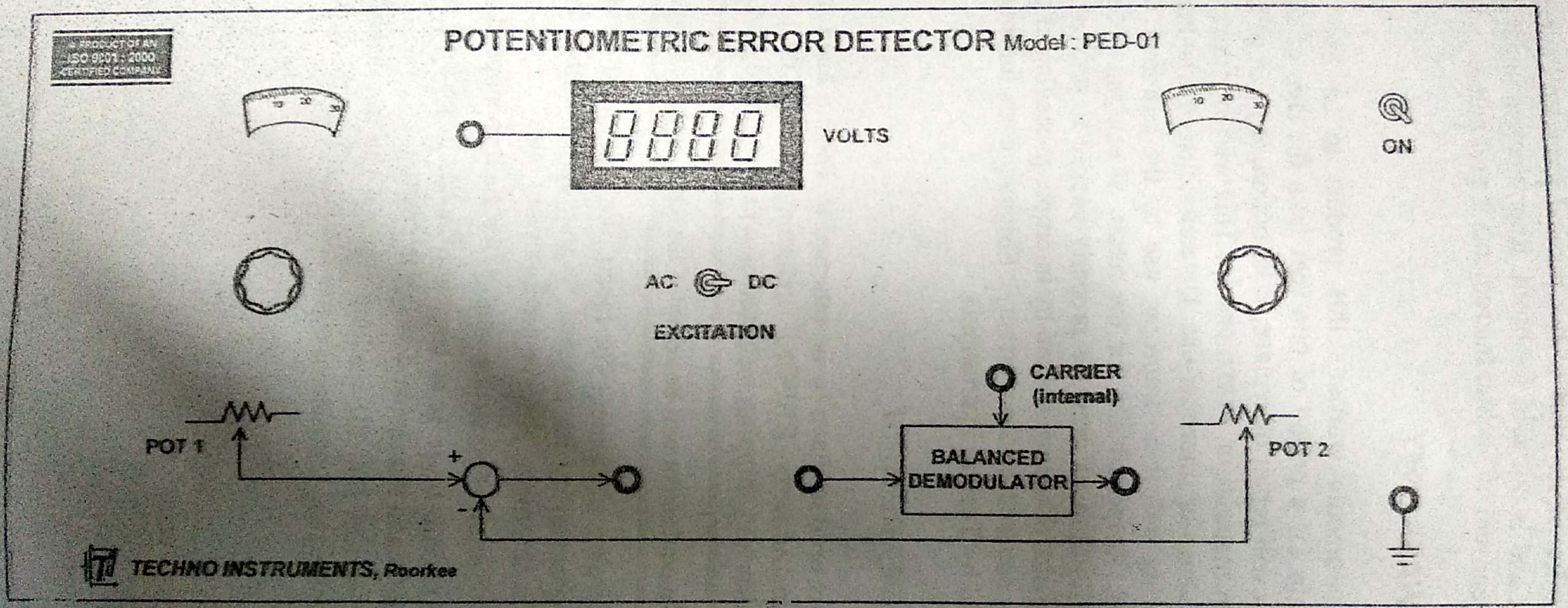
EQUIPMENT RETURN

Should this product have to be returned to Techno Instruments, for whatever reason, notify Techno Instruments BEFORE returning the product. Upon notification, the return authorization and shipping instructions will be promptly issued.

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

POTENTIOMETRIC ERROR DETECTOR

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.

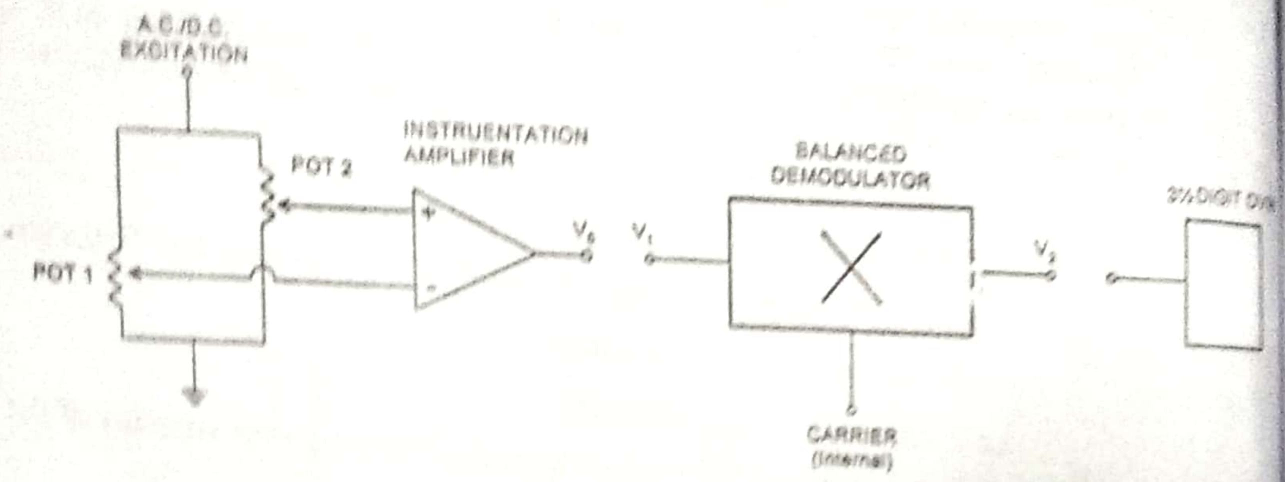


Fig. 1 Schematic Diagram

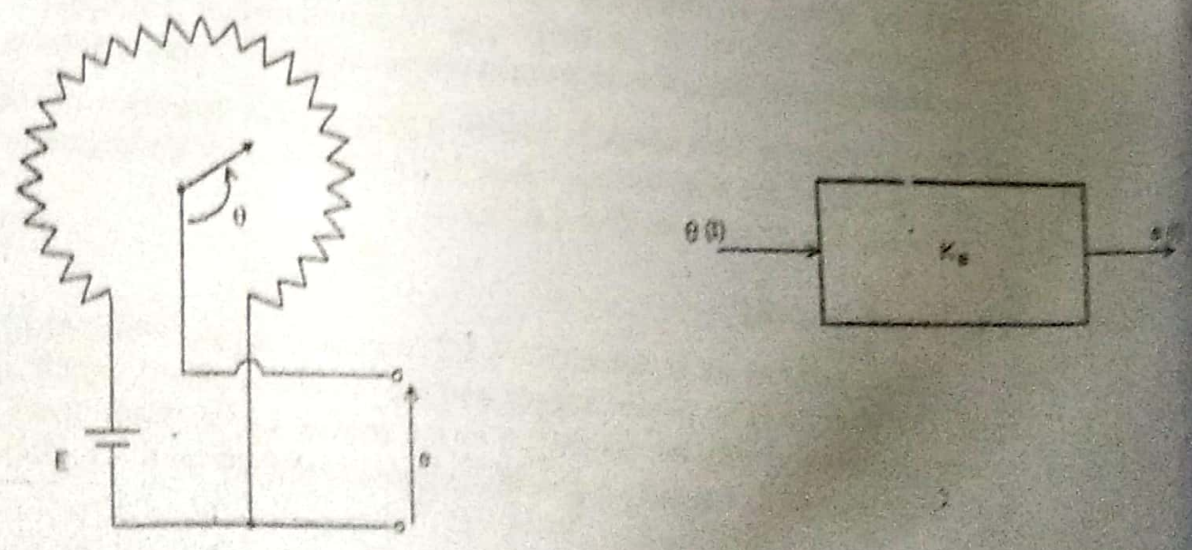


Fig. 2 Potentiometer Presentation

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:

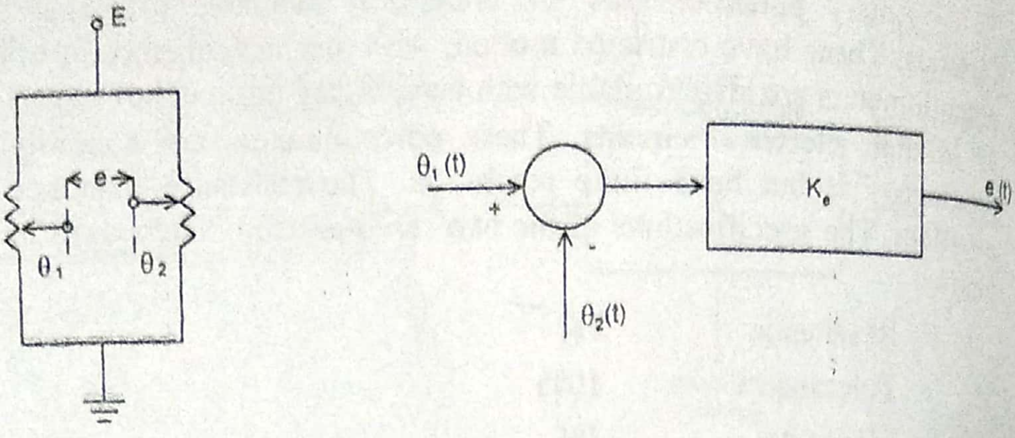


Fig. 3 Error Detector Configuration

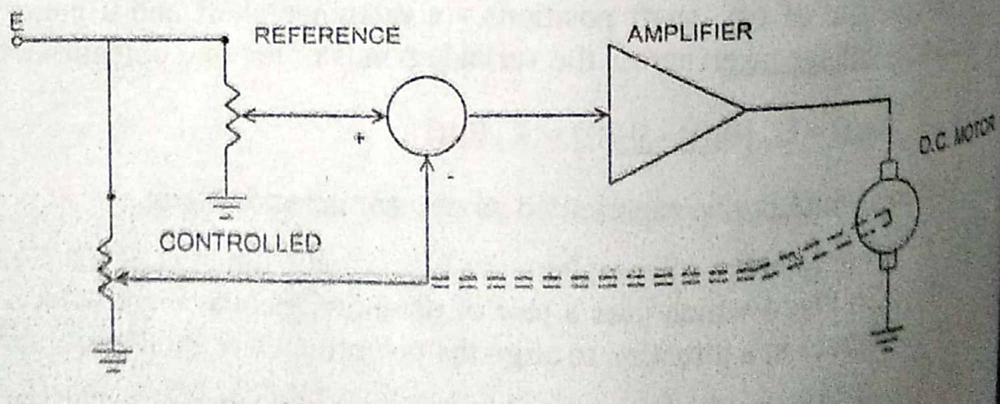


Fig. 4 D.C. Position Control System

(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

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

where θ_e is the angular error between reference and controlled potentiometers.

It may be seen from above that whenever θ_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

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

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 θ_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,

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

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

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

$$e_0(t) = \frac{K_s VV'}{2} \theta_e \qquad \dots \quad (7)$$

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 θ_2
- Turn POT 1 in steps of 20° (at 1° interval when there is a sudden change in voltage). Record angular position θ_1 and the output V_o (use DVM on panel).
- Plot V_o vs θ_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 θ_e. Note that the information about the sign of θ_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 θ_e. Note that the information about the sign of θ_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).

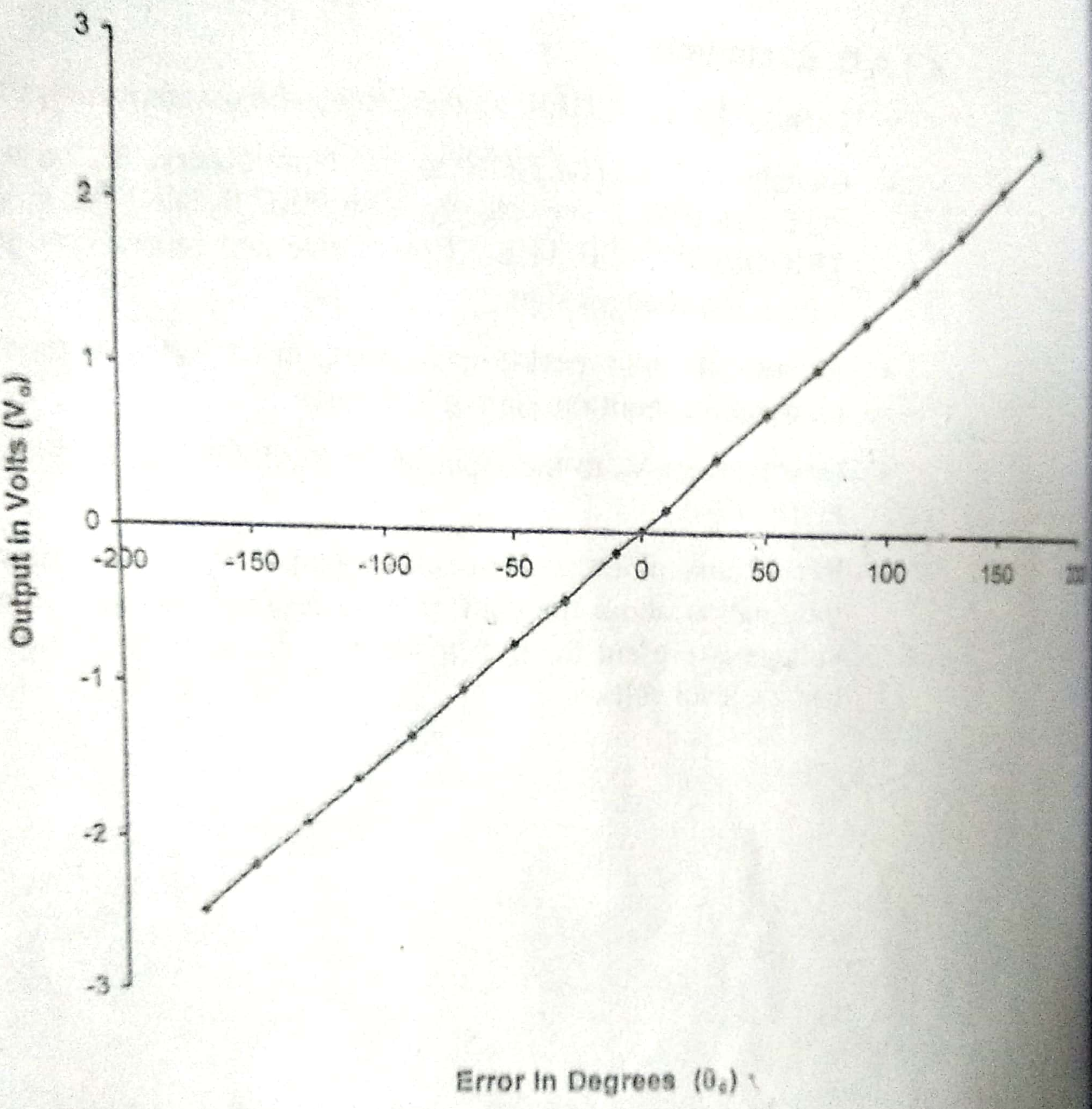


Fig. 5 Error Vs. Output with D.C. Excitation

5. TYPICAL RESULTS

(a) Error detector with d.c. excitation

POT 2 fixed at 180° ($= \theta_2$)

S.No.	POT1 position θ_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 θ_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.

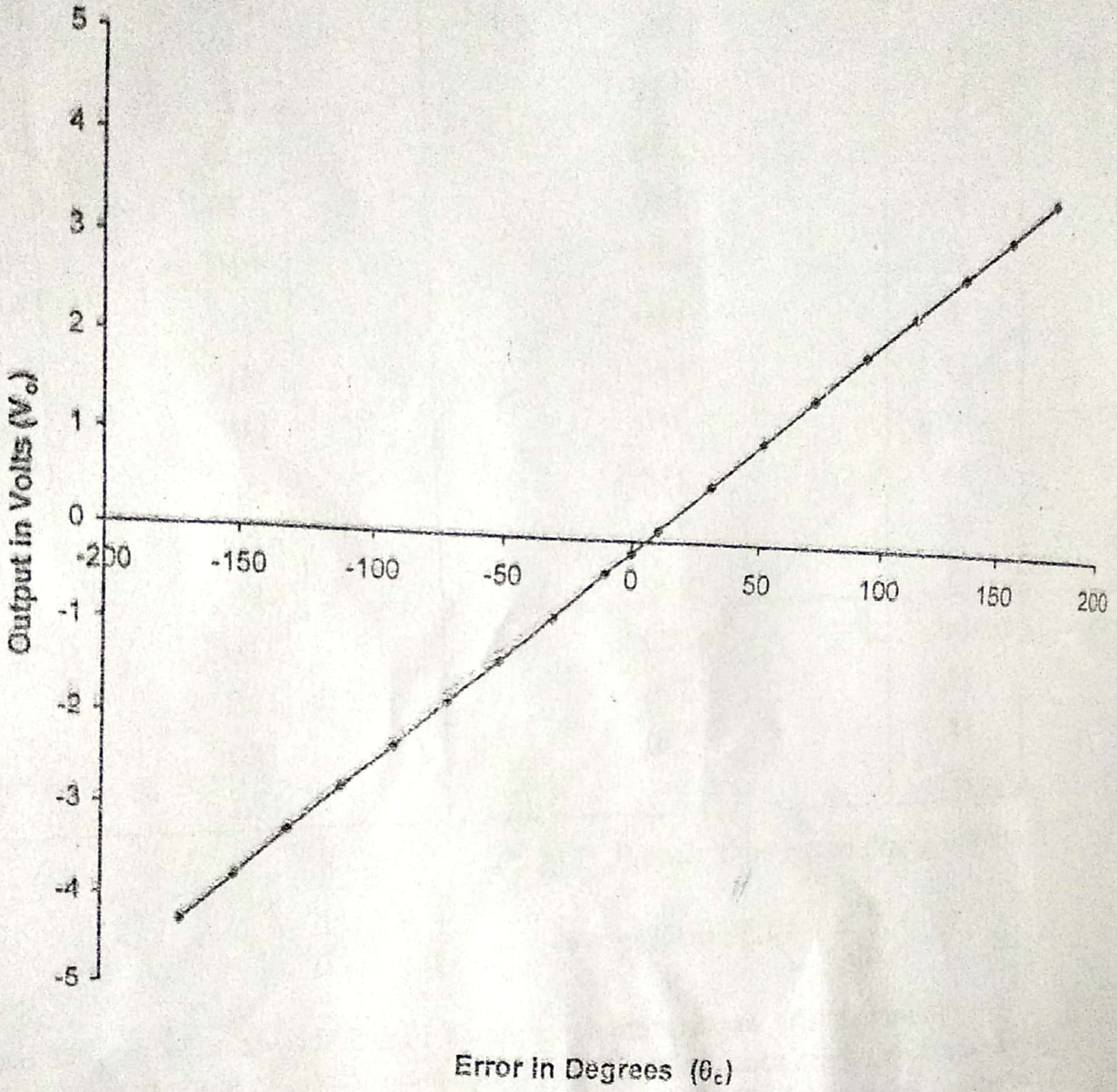


Fig. 6 Error Vs. Output with A C. Excitation

(b) Error detector with a.c. excitation

POT 2 fixed at 180° ($=\theta_2$)

S.No.	POT1 position θ_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