CANADA

DEPARTMENT OF TRANSPORT
METEOROLOGICAL BRANCH

DESIGN OF A SERVO POTENTIOMETER FOR USE IN A DATA ACQUISITION SYSTEM

BY

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ABSTRACT

The development of an automatic data acquisition system for radiation measurements led to the requirement for an accurate electronic potentiometer, having analogue and integrated digital output. The design of such a unit is described in this paper. Construction costs and service record are also included.

CONCEPTION D'UN SERVOPOTENTIOMÈTRE DEVANT SERVIR DANS UN SYSTÈME D'ACQUISITION DE DONNÉES

par

V. Marsh

RÉSUMÉ

La mise au point d'un système automatique d'acquisition de données pour les measures du rayonnement a fait apparaître la nécessité d'un potentiomètre électronique de précision ayant une sortie analogique et une sortie numérique intégrée. L'auteur décrit la conception d'un tel dispositif, en indique le coût de construction et traite de son comportement en service.

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by

Verne Marsh

(Manuscript Received January 11, 1966)

1. Introduction

The Meteorological Branch operates recorder-integrator systems for the measurement of solar radiation at various locations in Canada. Some time ago it became apparent that where five or more variables were to be measured simultaneously at a site, a more compact automatic system would result in capital and operating economies. The first requirement of this system was an accurate, serviceable electronic potentiometer meeting the requirements set out below. The development of this component of the system is detailed in this paper.

Requirements

(a) The unit should be of conventional electronic potentiometer design.

(b) It should use standard stock parts wherever possible.

(c) It should be of modular construction for ease of field maintenance.

(d) Accuracy of range need only be ± 1%; however, repeatability should be . 1% or ± one output pulse.

(e) The sensitivity should permit use of spans between 5 and 50 millivolts.

(f) Two forms of output should be provided. Digital output to be in the form of contact closures proportional in quantity, over a unit time, to the input variable. The hourly digital output at maximum should be about 1200 contact closures. Analogue output to be in the form of a variable resistance proportional to the input variable.

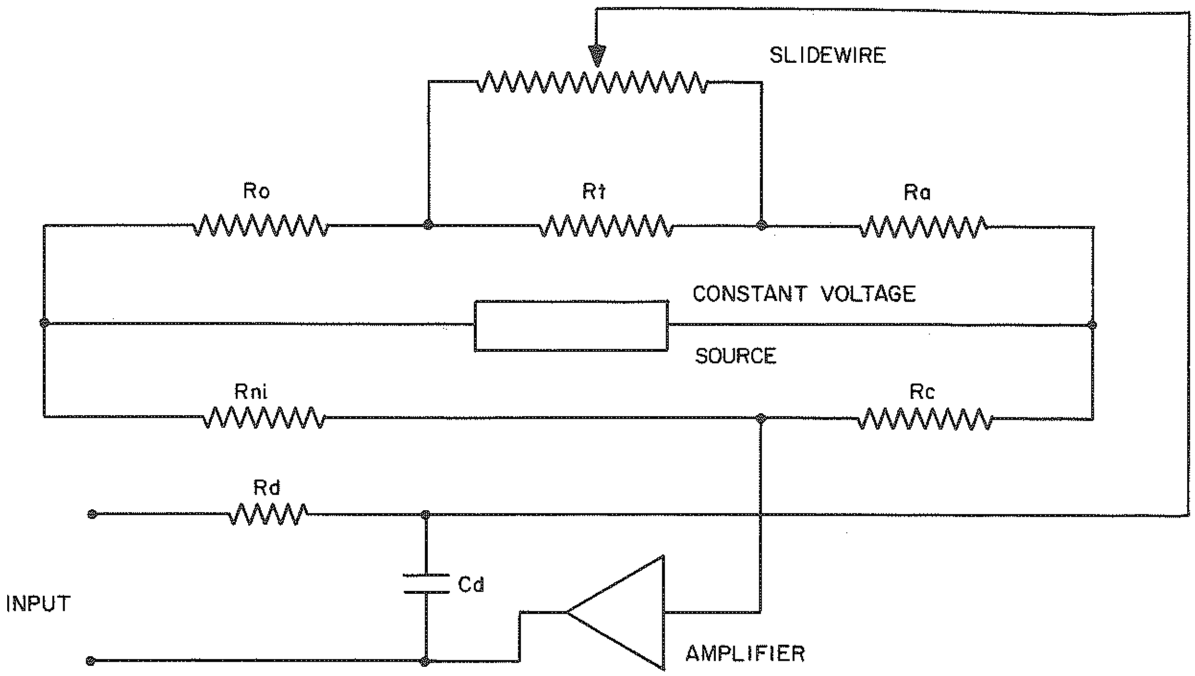

Figure 1
Measuring Circuit - Schematic

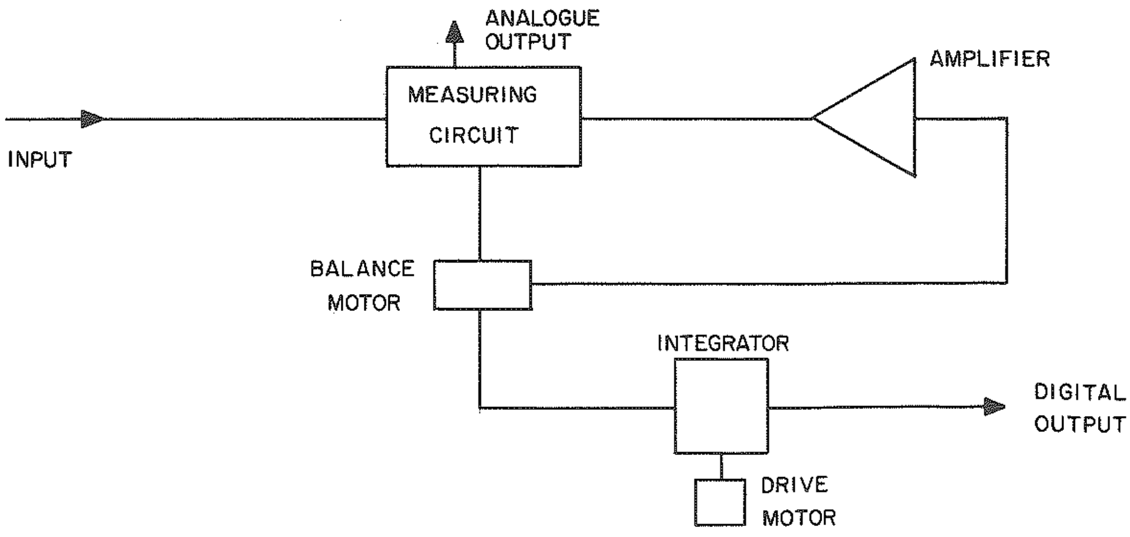

Figure 2
Block Diagram of Assembly

(g) The cost of the system should be as low as possible consistent with good design. Excluding the costs of jigs and templates the unit cost should not exceed \$1000.

2. Design

To meet the first three requirements, it was decided to adopt the Honeywell Continuous Balance System (Reference 1) and use Honeywell components of a type available in our stock as spare parts for recorders. A Honeywell Servo Amplifier, Servo Motor and Constant Voltage unit were selected for this purpose. Specifications for these parts are shown in the Appendix.

The measuring circuit is constructed along conventional lines according to the circuit in Fig. 1. Characteristics of the circuit and function of the components are described thoroughly in Reference 2.

Since range accuracy is not an important factor, (the unit as a whole, is calibrated, but no calibration adjustment is provided) 0.1% resistors are used in the measuring circuit. To provide the necessary stability and repeatability, manganin resistors with a temperature coefficient of 20 ppm and a temperature compensated double zener constant voltage source are used. The measuring circuit module is constructed in a Hammond utility case. It is designed with a three resistor range clip so that the range may be readily changed within the limits of the span.

The slidewire potentiometer and follower potentiometer (which provides the analogue output) are Helipot Model C, 3 turn potentiometers shunted to 20 ohms $\pm 0.1\%$.

A linear cam with a rise of .781" in 360°, affixed to the shaft driving the potentiometers is used to position the control rod of a ball and disc integrator. The integrator selected for this application is a Librascope Model 20 with a spring loaded ball carriage return and special mounting inserts. It is a stock model modified by the manufacturer to meet our special requirements. The integrator disc is driven with a Haydon timing motor and the output shaft is fitted with an Eclipse button magnet which gives 2 closures of a reed switch per revolution.

To calculate the output of the integrator, we use the equation

$$\text{Output} = S \cdot d \cdot 3.2 \cdot 2 \cdot t$$

where S is the rotational speed of the disk in rpm

d is the displacement of the ball carriage in inches

3.2 is the integrator constant

2 is the number of contact closures per output shaft revolution

t is the time in minutes.

The main drive gear is fitted with a stop limiting rotation to 320°. A cam rise of .781" in 360° provides a maximum displacement of the ball carriage of 0.695". This displacement results in a maximum hourly count of 1068. Where some other output maximum is desired, for example, in temperature or heat flow applications, a motor of appropriate speed may be substituted for the above listed type. The maximum integrator displacement is .750" and the minimum displacement is .05", the latter being necessary to prevent undue wear at zero due to lack of lubrication of the disc surface.

3. Theory of Operation

The unknown input voltage is compared in the measuring circuit with the calibration voltage and the difference (the error signal) is amplified and used to drive the balance motor to reduce the error signal to zero. At the same time the balance motor positions the analogue potentiometer and the integrand shaft of the integrator. The drive motor, through the integrator, drives the output shaft which operates the magnetic switch providing digital output. This arrangement is shown in Fig. 2.

4. Construction

The whole assembly was mounted in a Hammond utility drawer, (Fig. 3) suitable for rack mounting. The drawer was drilled and tapped according to a drill template. The gear housing assembly (Fig. 4) which contains the balance motor, 2 potentiometers, integrator and drive motor plus the cam and associated gearing was made to our design and specifications. Complete drawings of this assembly and circuit drawings of the wiring and measuring circuit are available.

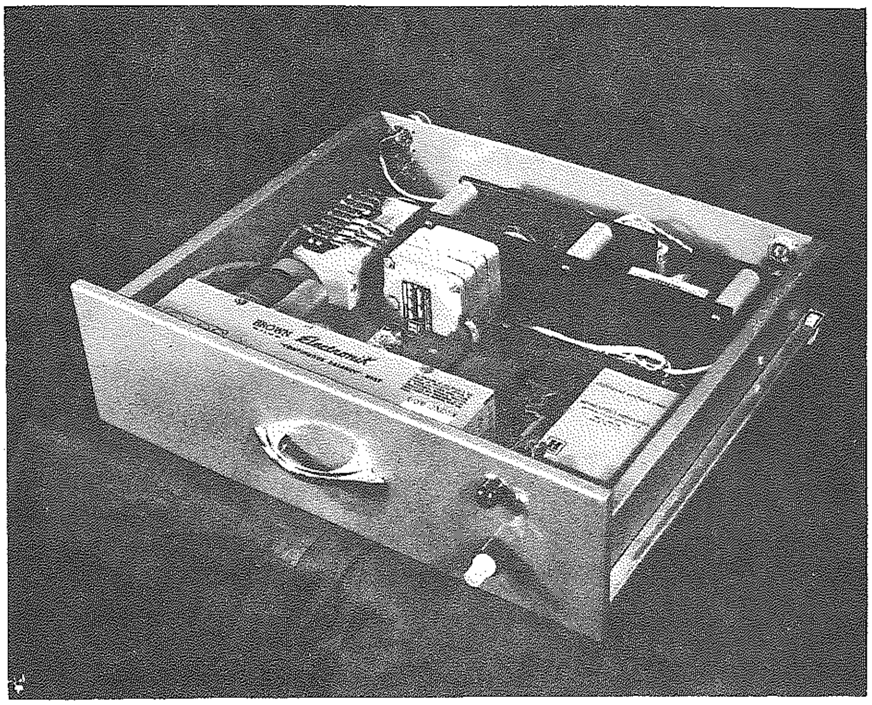

Figure 3
Servo Potentiometer

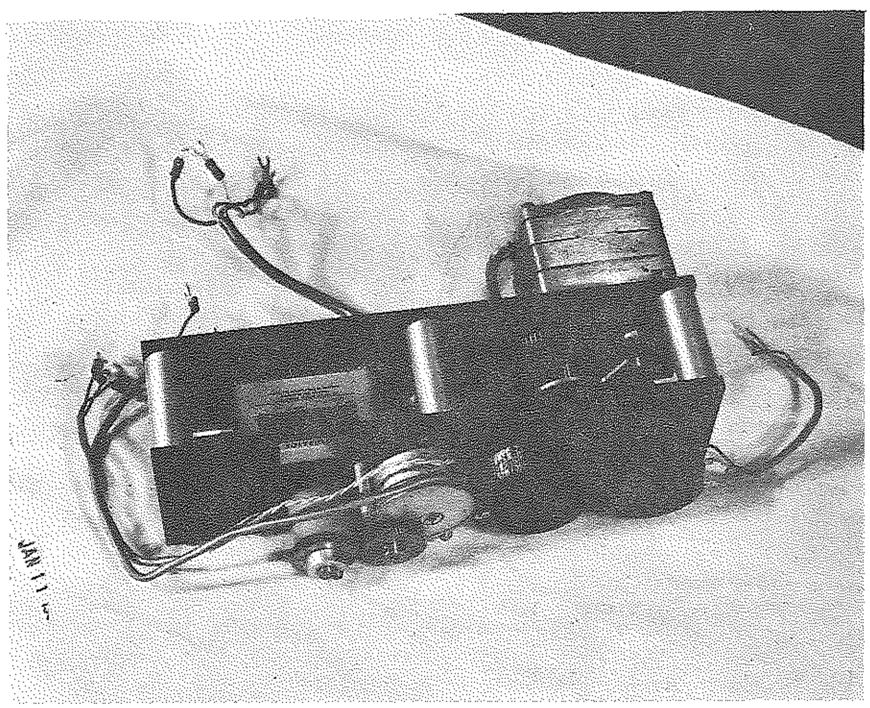

Figure 4
Gear Housing Assembly

5. Test Results

This system was built as a prototype and operated originally with an integrator of different manufacture. This integrator failed in service and was subsequently replaced with the Librascope model now in use. The following service record is of interest.

Integrators:

4 units in service 20 months - still operating.

5 units in service 15 months - still operating.

2 units failed in service on two occasions after 4 and 8 months use due to flat spots on ball bearings.

Potentiometers:

2 units have required cleaning and lubrication after up to 20 months service. No failures or replacements have been necessary.

Other Components:

There have been no failures in 20 months service of:

amplifiers

constant voltage units

integrator drive motors

measuring circuit parts

One Magnetic Reed Switch and one Balancing Motor Failed in service.

The only inherent defect noticed to date concerns the two integrators which failed after up to eight months service. Both these integrators were operated with fields where the variable was stable for long periods of time. This causes the lubricant to be forced off the disc surface which results in a flat spot developing on the ball bearing. Ball bearings may be replaced in fifteen minutes at a cost of 30 cents.

APPROVED,

J. R. H. Noble,
Director,
Meteorological Branch.

6. References

(1) Brown Electronik Continuous Balance System. Bulletin B15-6A.

(2) Characteristics of Measuring Circuits used in Brown Electronik Potentiometers. Bulletin B15-13.

Item	Description	Estimated Cost
Rack Drawer	Hammond 1409 B	$ 20.00
Servo Gear Housing	Meteorological Branch Instrument Workshop	$200.00
Servo Amplifier	Honeywell 356358-103	$280.00
Servo Motor	Honeywell 362479-503	$ 75.00
Constant Voltage Unit	Honeywell 365389-1	$ 60.00
Measuring Circuit Parts	1 - Hammond Case 1 - Jones Terminal Strip 5 - Precision Resistors 1 - Damping Capacitor 2 - Potentiometers	$ 50.00
Wiring Accessories	4 - Cannon Connectors 1 - Terminal Strip	$ 10.00
Integrator	Librascope Model 20-1-B-CD	$225.00
Integrator Drive Motor	Haydon KR42139	$ 10.00
Pulse Magnet, Switch & Indicators	Eclipse 822B Mounting Bushing Reed Switch Hamlin DRG1 Mounting Clamp Fuse Panel Lamp	$ 10.00
	Total approximate cost	$940.00

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