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PRELIMINARY STUDY OF THE PRESSURE TRANSDUCER PROJECT

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ABSTRACT

A feasibility study of the application of several commercially available pressure transducers for incorporation in a dynamic baro-switch tester or for use in a baro-switch application.

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PRELIMINARY STUDY OF THE PRESSURE TRANSDUCER PROJECT

I. INTRODUCTION

The initial objective of the project was to study the feasibility of using one of several commercially available pressure transducers as a pressure standard in a dynamic baro-switch tester. This objective was later expanded to include the possibility of using a transducer in a baro-switch application.

Three types of transducers were chosen for this project. These three were considered to be the most sensitive commercial transducers then obtainable:

1. The "Equibar" of Transonics, Inc.
2. The "Model S-3" of Ultradyne Engineering Labs., Inc.
3. The "Clark Transducer" of Clark Engineering Co.

The "Equibar" is a variable capacitive type device consisting of a diaphragm mounted between two fixed electrodes. These elements are enclosed within a pressure chamber having suitable ports to either side of the diaphragm. Electrical connections to the capacitive elements are made through insulated and sealed headers. Unbalances in pressure on the two sides of the diaphragm will be reflected as inverse variations of capacitance between the diaphragm and the two fixed electrodes.

The "Model S-3" of Ultradyne, Inc., is an inductive device in which the impedance of the coils varies with the position of the diaphragm, the coil on the high pressure side of the diaphragm having the lower inductance.

The "Clark Transducer" is an inductance device having two excitation coils, two pickup coils, and a diaphragm. Details of its construction were not available at this writing. Pressure changes are reflected as changes in the output of the pickup coils.

The Equibar was used with several methods of indication using bridge circuits and the Decker Delta Unit to indicate specified pressure altitude points on a barometer. The sensitivity obtained with each method was adequate or more than adequate for the intended application. The sensitivity and repeatability were evaluated for each of the methods of using the Equibar. The Ultradyne was used with null indicating circuits and phase sensitive circuits to indicate specified pressure-altitude points on a barometer. Sensitivity was more than adequate, and repeatability was well within the readability of the Hass barometer used for monitoring purposes. The Clark transducer was not completely evaluated, but its sensitivity was found to approximate that of the other two systems.

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II. EVALUATION OF THE EQUIBAR

The Equibar was evaluated by using it in conjunction with the following circuits:

A. Bridge Circuit Using a Leeds & Northrup Co. Campbell-Shackleton Shielded Ratio Box as Shown in Fig. 1

In addition to the use of an oscilloscope as a detector, an amplifier and relay circuit to actuate indicating lights was also used. That is, a green light indicated the null point, and a red light indicated when the system was out of null.

Static response tests made using the setup illustrated indicated that the Equibar transducer exceeded in sensitivity and repeatability the Hass barometer against which it was referenced. The Hass barometer can be read accurately to 0.1 mm of mercury, which corresponds, at this altitude, to approximately 4 feet of altitude. It was noted that a change of a foot or two in altitude of the Equibar was sufficient to produce relay actuation of the detector. This sensitivity could not, however, be utilized in practice, without undue complexity, because of thermal effects upon the circuitry involved.

B. Decker Delta Unit

This is a novel device which utilizes a principle discovered fairly recently (1938) and only developed to practical use in the last several years. Refer to Fig. 2.

By exposing a gas discharge tube containing two electrodes to a high frequency electric field formed between a sliding ring and the electrodes, it was found that a DC potential was developed between the electrodes. The magnitude of this voltage varied with the ring position, giving from about 60 volts positive when the ring was close to one electrode, to 60 volts negative when the ring was close to the other electrode.

A variation of this principle is used in the "Delta Unit", Fig. 3.

Since the system is electrically balanced when $C_1 = C_2$, no DC output is obtained. If, however, C_1 increases or C_2 decreases or both values change inversely and at the same time, a comparatively large DC output is obtained. Since the circuit is phase sensitive, the sign of the DC output voltage will depend upon the direction of change.

The Equibar transducer was used in place of capacitors C_1 and C_2, and the system tested for sensitivity and repeatability. Results indicated that repeatability and sensitivity were within the readability limits of the Hass barometer. There was, however, a hysteresis between off and on of approximately 70 feet, which is entirely attributed to the relay circuit and could undoubtedly be decreased if desired.

An experiment was conducted for the purpose of determining the dynamic characteristics of the BS-5 baro switch with respect to the dynamic characteristics of the Equibar transducer. The experiment confirmed the belief that the response of the Equibar to dynamic pressure changes was much faster than the larger volume BS-5 baro switch.

III. THE ULTRADYNE TRANSDUCER

This device possesses the advantage of low impedance, so that effects from noise or external pickup are minimized.

The transducer was specifically designed for use in a bridge-type circuit, and all attempts to utilize it in a different electrical configuration have been to little avail. The circuit designed for its use is shown in Fig. 4.

It was felt desirable to produce a system, using the Ultradyne transducer, that approached in sensitivity the system using the Equibar transducer. The transducer purchased from Ultradyne was the most sensitive they then manufactured. This unit encompasses a pressure range of ± 1 psi. To produce the desired sensitivity with this unit requires that its output be amplified considerably. In practice, an amplifier with a voltage gain of at least 10,000 is needed to actuate a relay circuit acting as an indicator. Initially, a General Radio type 1231-B "Amplifier and Null Detector" was used for this purpose. Later, in an attempt at miniaturization, transistorized amplifiers were used to replace the General Radio amplifier. Further, the oscillator supplying excitation to the bridge circuit was transistorized. The circuit is illustrated in Fig. 5. A relay circuit was added to the output of the amplifier to provide a simple visual indication of null.

Runs with this system indicated its sensitivity and repeatability were superior to the Hass barometer against which it was checked.

It was felt, however, that a null type of output characteristic would be desirable for weapon application. If the pressure, being detected, were to change rapidly enough, the system might pass through null so fast that the relay circuit would fail to detect the null. Therefore, it was deemed desirable to actuate the relay circuit by some means other than amplitude sensing.

A study was conducted to determine the feasibility of using phase detection to operate a relay circuit. A phase detector circuit was built and connected to the output of the amplifier. The output of the phase detector was fed to a polarity sensitive circuit which in turn operated the relay circuit. This is illustrated in Fig. 6.

The advantage of the phase detector is that its output will be of one polarity above the pressure balance point of the transducer, at balance zero, and below balance its output will be of opposite polarity. This avoids possible failure of relay closure due to rapid pressure changes and thus eliminates the danger inherent with the null type of system whose output is always of the same polarity when the transducer is unbalanced and of zero or low output at balance.
Typical output curves versus pressure for the two types of outputs are shown in Fig. 7.

Runs made with the phase detector circuit were comparable to those with the null type operation.

IV. THE CLARK TRANSDUCER

Efforts were made to use the Clark pressure transducer in a manner similar to the Ultradyne, but these were not successful. It was not designed to be incorporated in bridge circuitry, and the tests confirmed this. Unfortunately a residual signal of approximately 20 millivolts remained at null. With a null of this amplitude, the sensitivity of the Clark could not be expected to approach that of the other two units. And since the transducer seemed to have a considerable drift, the tests were discontinued.

V. CONCLUSIONS

Results indicate that a transducer of the type considered in this project could be used as a pressure-sensing instrument in a dynamic baro-switch tester. Considerable time has been devoted to the development of just such a tester using the Equibar transducer. This tester is now being utilized by Organization 1651-2. There is no reason to believe that a tester using the Ultradyne could not be constructed, although its sensitivity may be less than the Equibar.

For weapons application, the Equibar unit would seem more desirable because of the possibility of using it in conjunction with a "Delta Unit". This could possibly provide a comparatively simple system.

A. J. ELDRIDGE - 1652-1

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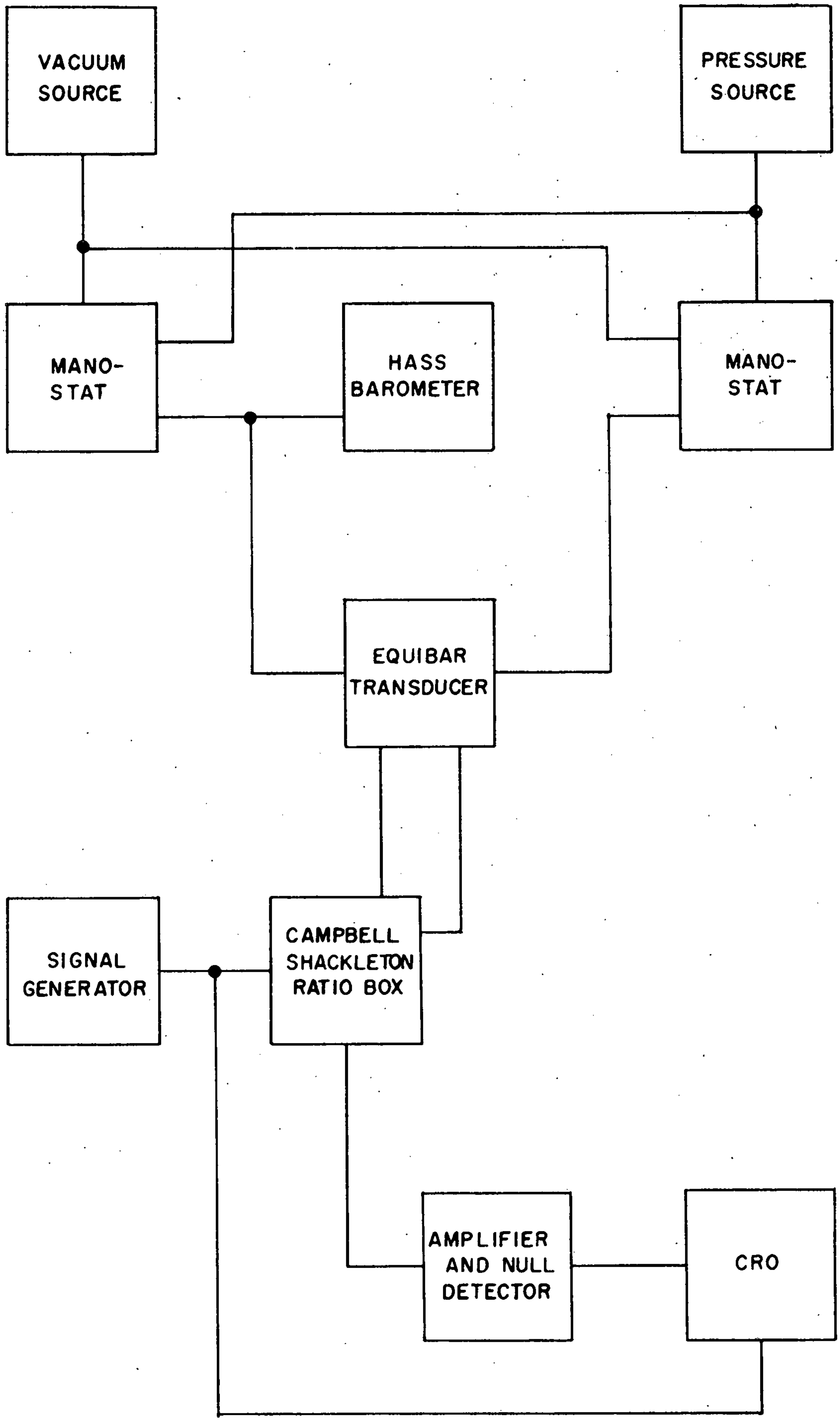

FIG 1. INITIAL SETUP FOR EVALUATION OF THE EQUIBAR TRANSDUCER

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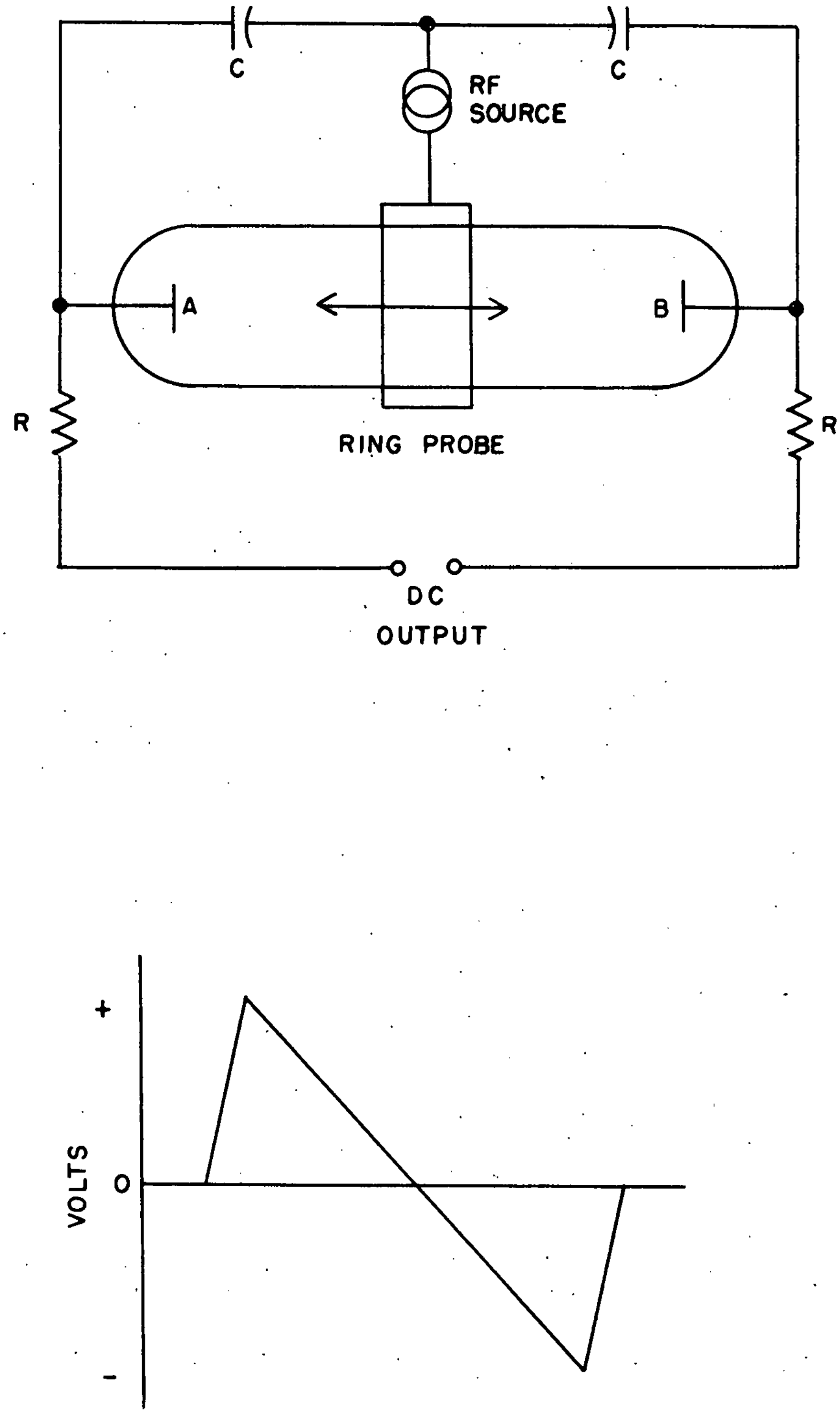

OUTPUT VOLTAGE VERSUS
DISPLACEMENT OF PROBE

FIGURE 2

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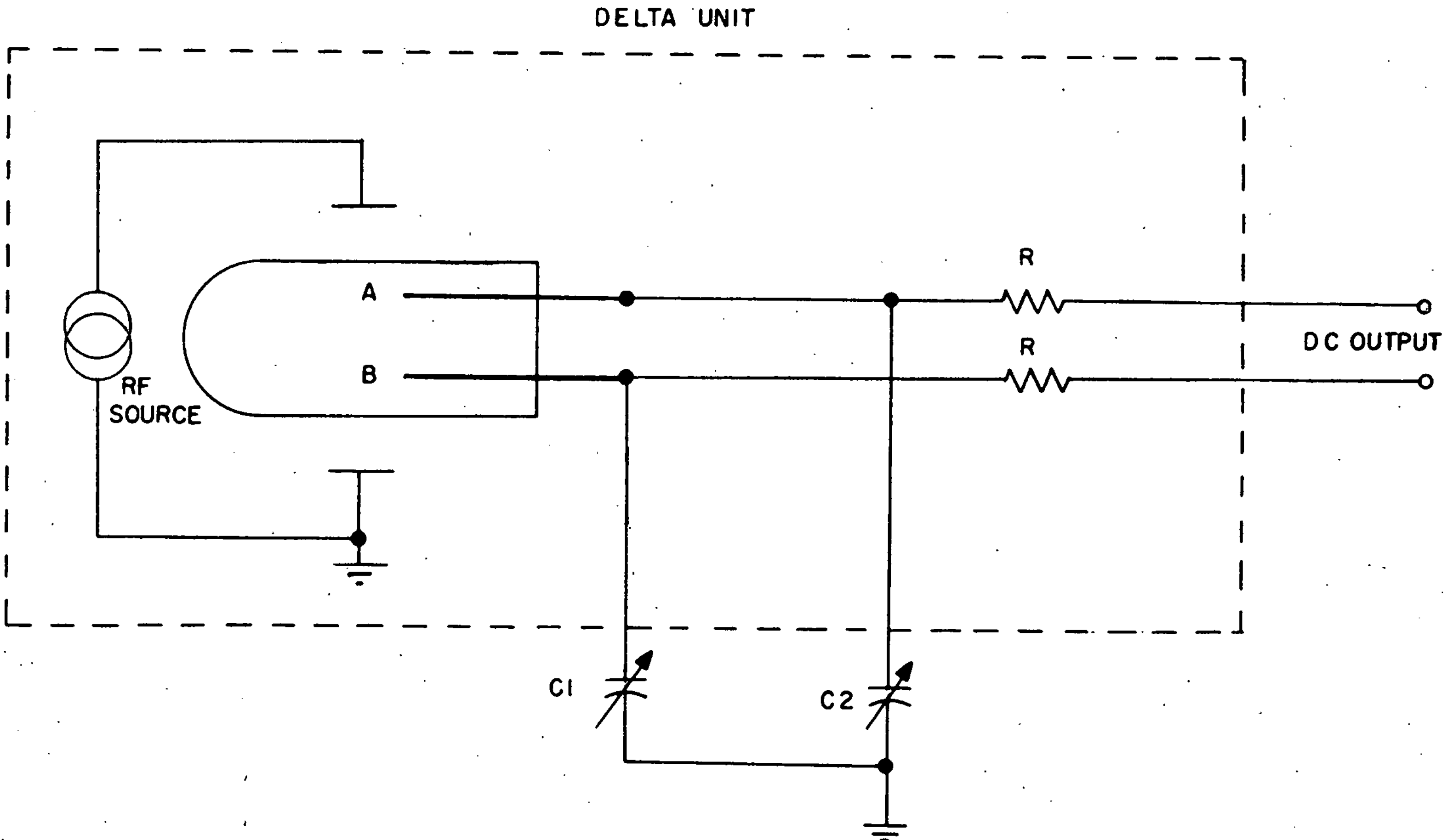

FIGURE 3. CONFIGURATION USED WITH DELTA UNIT

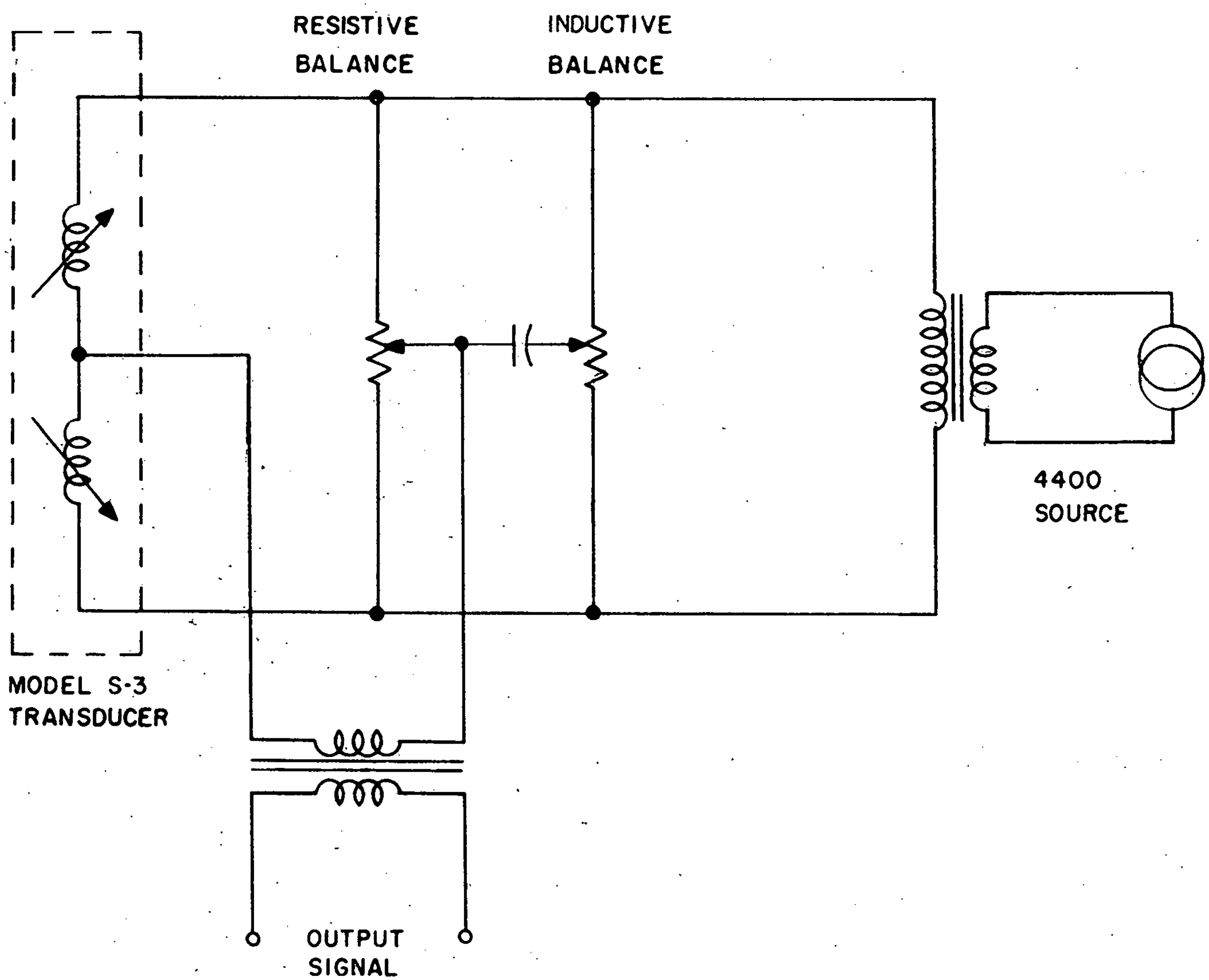

FIGURE 4. BRIDGE CIRCUIT FOR ULTRADYNE TRANSDUCER

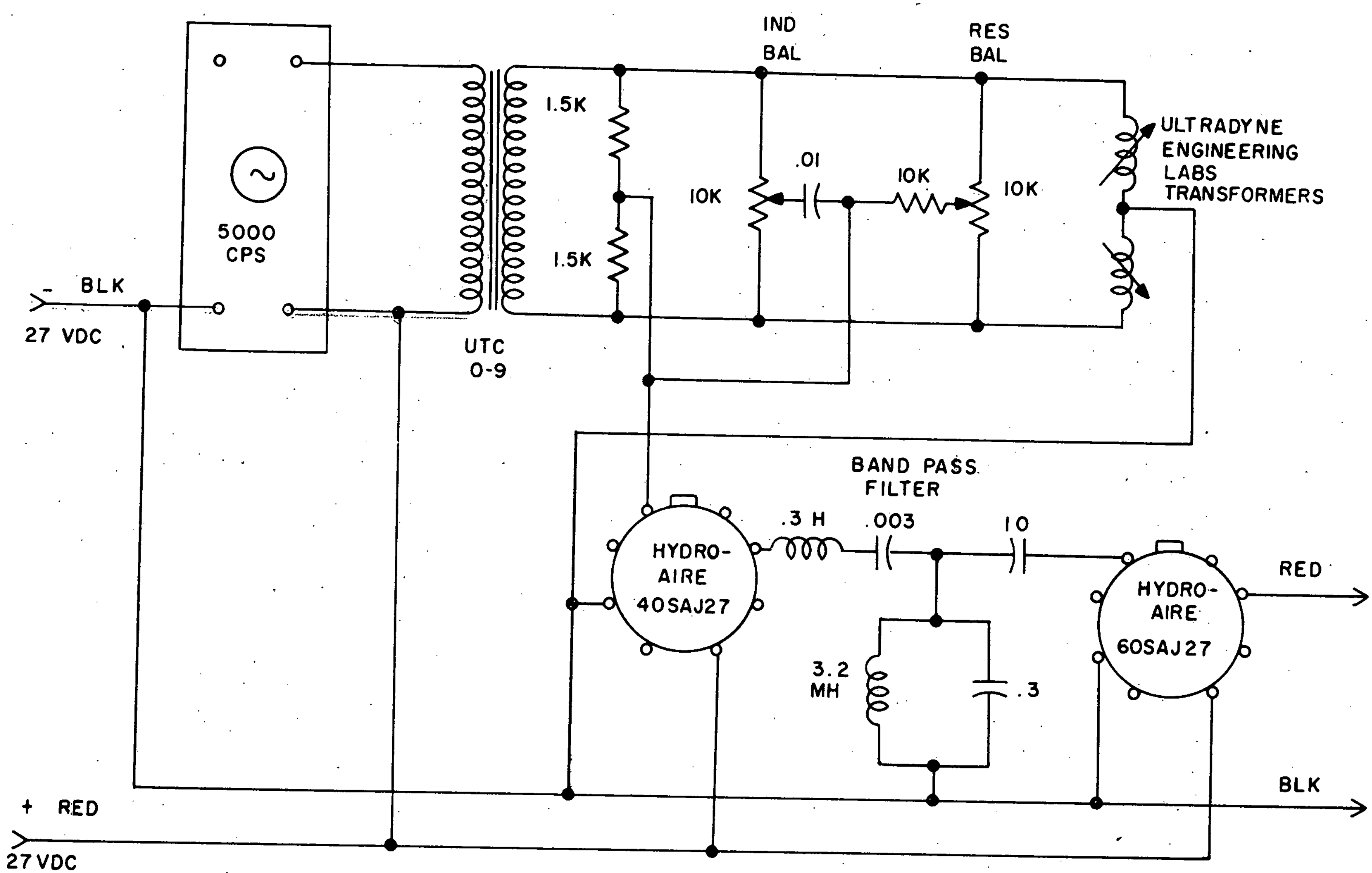

FIGURE 5
DYNAMIC PRESSURE TRANSDUCER

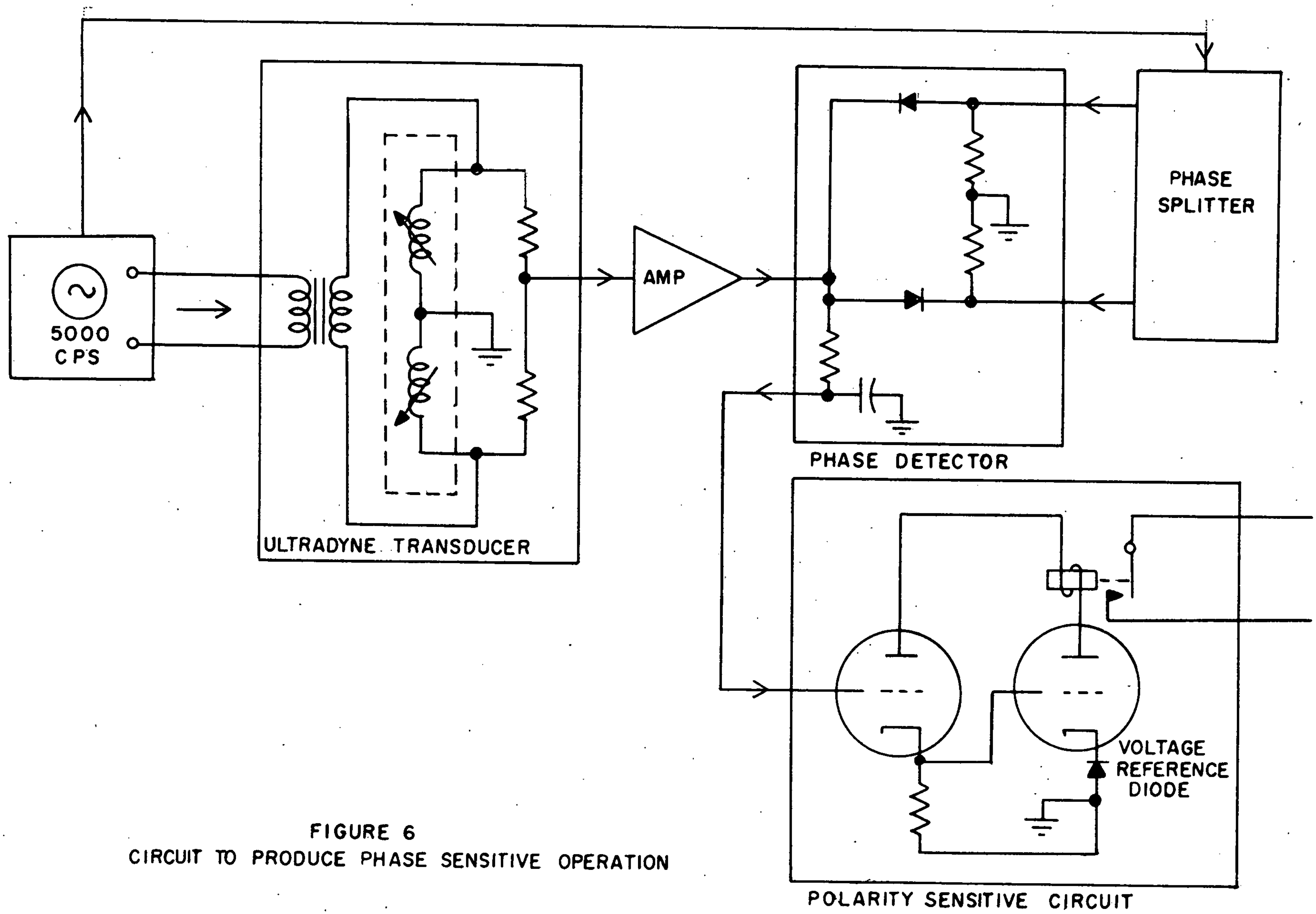

FIGURE 6
CIRCUIT TO PRODUCE PHASE SENSITIVE OPERATION

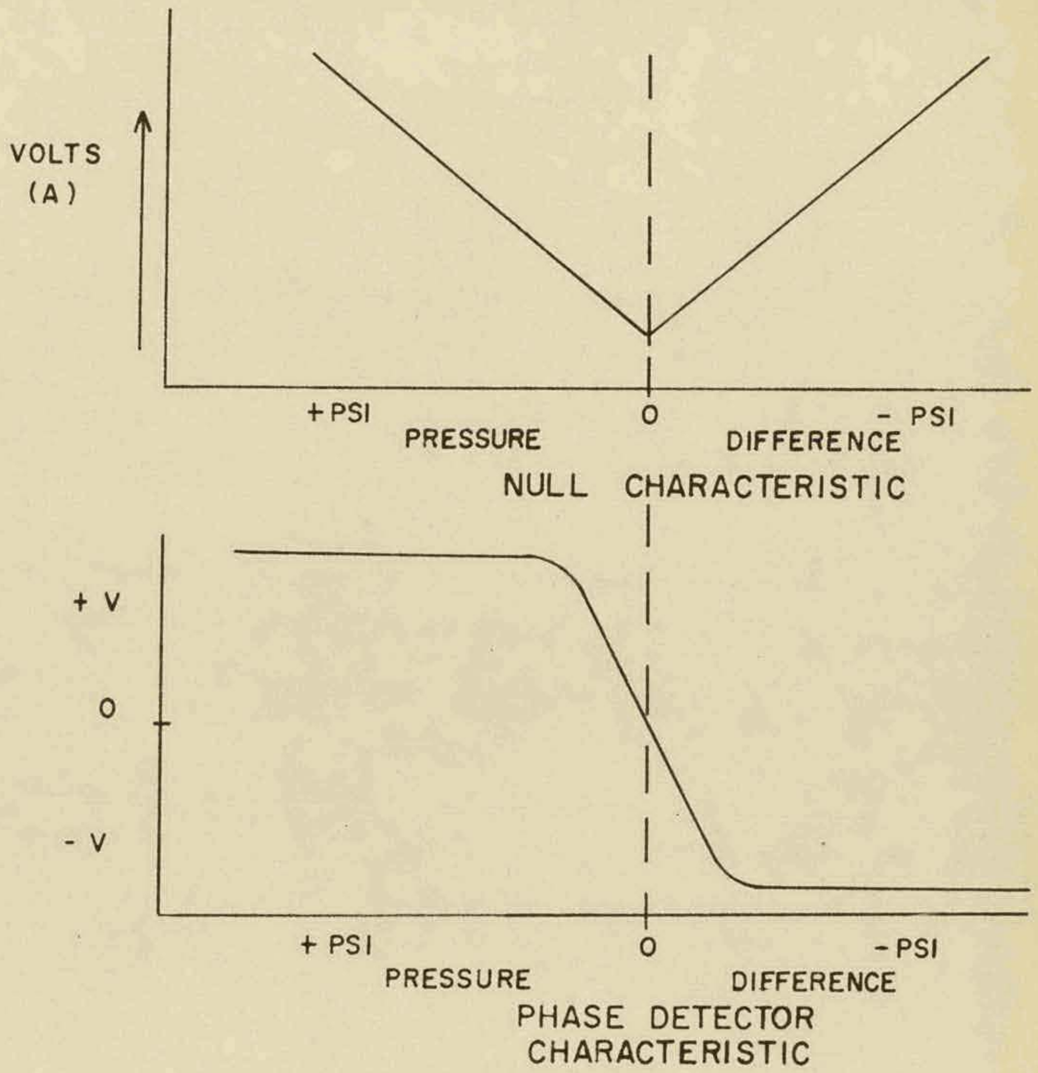

FIGURE 7. VOLTAGE OUTPUT VERSUS PRESSURE DIFFERENCE

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