NEW APPROACHES TO TRANSDUCER EXCITATION AND CONDITIONING

Edward J. Price
System Engineering Manager
Aydin Vector Division
Newtown, Pennsylvania 18940

William G. Ricker
Senior Design Engineer
Aydin Vector Division
Newtown, Pennsylvania 18940

ABSTRACT

Transducer excitation and conditioning has continually influenced the size, power consumption, complexity, and weight of miniature data acquisition and multiplexing systems. Here we examine a new approach to the excitation and conditioning of transducers which have traditionally been formed into a wheatstone bridge configuration. This approach has been successfully utilized in new miniature systems to reduce size, power, and weight while not adversely effecting the function or accuracy.

Thermocouple measurements have also presented a significant conditioning problem, in that reference junction compensation and a measurement offset temperature must be provided for each thermocouple measurement. We show here an approach which, through the use of a single reference junction compensation and offset amplifier, has achieved significant improvements in the collection of temperature data.

INTRODUCTION

In telemetry applications, signal conditioning may be considered as a separate requirement or as part of the multiplexing and transmitting system. When separate, the signal conditioning can follow more conventional schemes which allow for the greatest flexibility in interfacing to the circuit functions that follow. With single or multi-element resistive transducers, the conventional conditioning circuit is voltage excitation of a wheatstone bridge as shown in Figure 1. This circuit can also include precision resistors to complete the bridge when the transducer has less than four elements.

When space, power, and weight do not present a problem, inclusion of signal conditioning into the multiplexing system package can be accomplished by the use of the conventional circuit, in the multiple required to handle the desired number of channels. A single excitation voltage source could be used, but, if a single transducer becomes shorted, this will cause the loss of the entire measurement block.

With the advent of miniature data multiplexing systems and the increase in the number of measurements they can handle, the signal conditioning size, weight, and power consumption become critical.

Integration of the signal conditioning for large numbers of transducers into a miniaturized data acquisition system causes us to review the conventional methods and find solutions to these problems.

MULTIPLEXED BRIDGE EXCITATION

The first thrust in reduction of signal conditioning circuitry is to reduce the number of components by using common circuit elements for all measurements. Once the signal conditioner becomes part of the multiplexer, the channel selection can be moved in front of the signal conditioner amplifier as shown in Figure 2. This leaves the excitation supply as the major point of circuit duplication. As stated before, the use of a single supply to all active bridges can be considered at the risk of data loss on the whole block of transducers. The next consideration would be to multiplex the excitation voltage source as shown in Figure 3. The excitation multiplex switch can then be driven by the same digital command lines which drive the data multiplex switch. The main problem, which beomes evident with this method, is that the "on" resistance of the multiplex switch is high compared to the bridge impedance and is not stable over the normal temperature range. This switch resistance is therefore a major element in the network and makes the use of this circuit impractical. This takes us to our next consideration.

MULTIPLEXED CURRENT EXCITATION

Constant current excitation has been used for many years in single active gage measurements and has been recommended for new applications using transducers having two active elements.

We can multiplex a constant current source through high resistance switches. We need only be concerned with having voltage margin high enough to maintain control at the constant current source. A two element transducer can then be readily accommodated as shown in Figure 4. This figure also shows the balance circuit that would be used to adjust the system to the individual transducer. The control will introduce a sensitivity error depending on the value of the selected potentiometer. This error can be calibrated out by the use of dummy elements.

ADVANTAGES OF CONSTANT CURRENT EXCITATION

Using constant current excitation, the effects of lead resistance on signal balance are cancelled. Also, lead resistnace has no effect on transducer sensitivity since only the change in resistance in the active elements will be measured.

The constant current excited transducer output is linear since it is responding to a change in resistance not a change in the ratio of resistances. Since the transducer is operated from an infinite impedance source, the output for any given change in transducer resistance will be double that in the conventional circuit. The greatest advantage of constant current excitation is that it allows the multiplexing of excitation to the transducer at the rate equivalent to the channel sample rate.

THERMOCOUPLE SIGNAL CONDITIONING

The thermocouple presents another type of problem in signal conditioning. This problem rests mainly with the need to establish an accurate reference junction within the system, so as to accurately determine the temperature at the measuring thermocouple. Each transducer basically is made up of two thermocouple junctions of the same type. The first is the one formed by the two specified metals and is used as the measuring device (see Figure 7). The second is formed when the two specified metals connect to the common system metal. This forms the reference junction. Thermocouple tables are established based on the difference in temperature between these two junctions when the reference junction is held at 0° celsius or 32° fahrenheit. It is impossible to hold the reference junctions, which are usually located in the data acquisition system, at 0° celsius when the system is installed in an airborne vehicle exposed to a temperature range of 100° celsius or more. For singular measurements, a cold junction compensator which consists of a calibrated bridge network can be used. This network contains a thermister and a reference junction which are held at a common temperautre. See Figure 8. In this configuration, the reference junction and the thermister (see arrows) are mounted in a common assembly which is at or near the system ambient temperature. When a large number of measurements are to be made and multiplexed, using time division, it is not necessary to provide continuous compensation. and it would consume valuable space to do so.

MULTIPLEXED THERMOCOUPLE COMPENSATION

The solution to the above problem is to establish a common isothermal block for the entire system. All thermocouple wires would be terminated in this block after entering the system. The temperature of this block would then be monitored using a semiconductor device such as the analog devices AD 590. This device is capable of an accurate output over the full range of temperatures to which an airborne data acquisition system might be exposed. This device outputs 1 micro amp per degree kelvin and is accurate up to ±0.5° celsius, depending on the type selected. The current from the device can then be readily used to generate an offset voltage to compensate for the thermocouple error. See Figure 9. R_5 in the figure is used to minimize power dissipation in the thermal measuring device. R_F is set to provide the specific correction desired (nominally 51.8µ volts per degree celsius for iron constatan) from amplifier U_2. The negative reference, along with $_{Ro}$, sets the output to zero volts, at the desired temperature. If 0° celsius is to be the zero volt output point then the negative reference and R_o must provide -273.16µ amps, since the AD 590 operates to the Kelvin Scale. U_3 is set for inverted gain and should provide the gain necessary to match the gain of the instrumentation amplifier U_1.

HYBRIDIZATION

The approaches detailed above contribute to the generation of efficient hybrid circuits which provide improved power budget, reduced parts count, and the necessary circuit performance. Aydin Vector Division has incorporated these circuits into a high density, rugged, versatile, thick film hybrid package. These packages are directly compatible with the Aydin Vector MMP-600 and MMP-900 modular micro miniature pulse code modulation data encoders. These models feature a broad line of telemetry encoder capabilities.

ADVANTAGES OF MULTIPLEXED EXCITATION

Now that we have a practical method to multiplex the excitation to the transducer, we find there are several advantages. The power consumption in the system is greatly reduced since only one transducer will be powered at a time. This will reduce system size since the power supply requirements will be greatly reduced. The power supply reduction will obviously lead to a reduction in the system weight and power dissipation. The heat flow from the system due to this dissipation will not have to be considered. Since the transducer is only powered during the short period that a measurement is made, the transducer measurement accuracy will be affected much less by self heating.

CALIBRATION

Calibration of the individual measurement is only a matter of knowing the current being applied to the element. This, however, requires that the current be carefully set during system calibration. The individual “R” cal circuit commonly found in bridge signal conditioning would not be required but, if desired, could be used in this circuit. The gage factor commonly used to calculate strain in a strain gage transducer measurement is not directly applicable in this circuit, since gage resistance also becomes a factor in the calculation.

FOUR ELEMENT BRIDGES

Although we have only addressed the use of constant current multiplexing when working with two active element transducers, it has also been successfully used with transducers having two passive, wired-in, bridge completion resistors. The normal configuration is shown in Figure 5. When R_3 and R_4 are a multiple higher than R_1 and R_2, constant current excitation can be used. These elements can then be connected in parallel as shown in Figure 6, without a serious reduction in linear accuracy. Also note that R_1 - R_3 junction of the bridge becomes the negative output. A single resistive transducer can also be accommodated with the use of an equal resistor internal to the signal conditioner. This completion element could also be used as the balance adjustment.

CIRCUIT USE

This circuit can be effectively applied to several types of transducers, such as the following:

- Strain Gages
- Piezo Resistive Accelerometers
- Resistive Temperature Devices
- Potentiometers
- Resistive Pressure Transducers

The thermocouple multiplexer module will handle 16 channels of differential measurements and is packaged in a 1.5 inch x 1.75 inch x 0.25 inch housing. The interconnections to the module from the thermocouples is via an ITT Canno MDM series micro connector. All thermocouples pass through an isothermal block before entering the module as copper wire. This block is manufactured to accomodate all 16 thermocouple pairs and occupies approximately 1 cubic inch.

The bridge conditioner modules are also configured to handle 16 channels in the same size and type of packages. In addition to the multiplexer, the bridge conditioning requires 16 individual balance networks which require additional space of approximately 2.5 inches. The two types of signal conditioning, when configured into a complete multiplexer, require additional overhead circuit functions. These functions will typically require additional space of 8 cubic inches.

CONCLUSIONS

The approaches we have presented to excitation, compensation, and conditioning of signals has been applied to real telemetry system requirements. These applications have shown that the listed advantages will be effective in an airborne telemetry system.

Multiplexed current excitation of resistive transducers has been proven to have many advantages both in the use of the transducer and the configuration of the system. The only application found that could not be accomodated is a transducer requiring anti-aliasing filtering.

The thermocouple reference junction compensation approach will greatly improve channel density and is applicable to all standard types of thermocouples.

By the integration of these approaches into thick film hybrid circuitry, we have made maximum use of their several advantages and developed the standard hybrid pulse code modulation encoder into a more versatile tool in the development of airborne telemetry systems.

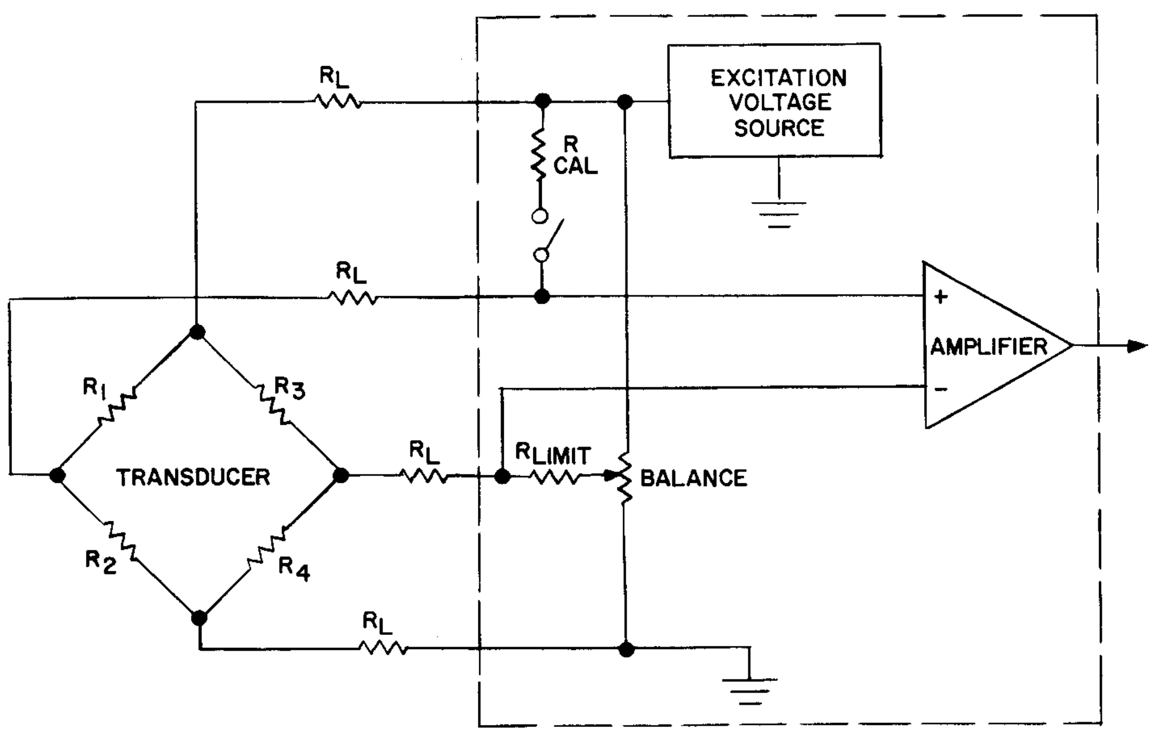

FIGURE 1
CONVENTIONAL BRIDGE CONDITIONER

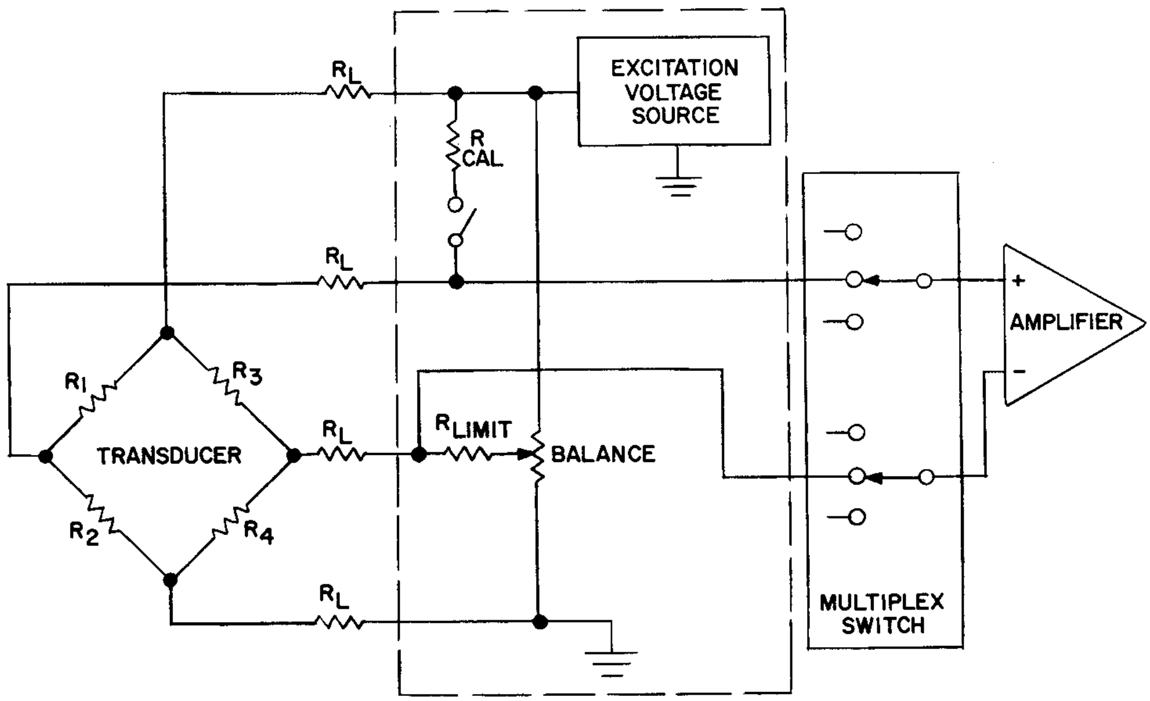

FIGURE 2
MULTIPLEXED SIGNAL CONDITIONING AMPLIFIER

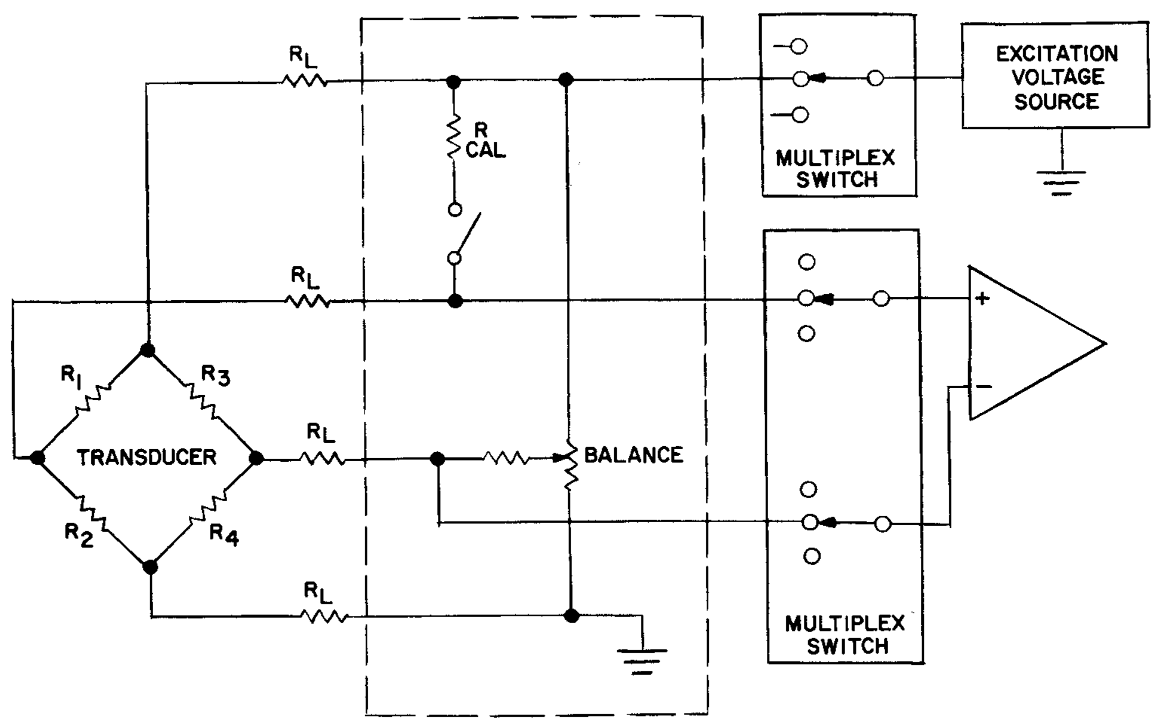

FIGURE 3
MULTIPLEXED SIGNAL CONDITIONING AMPLIFIER
AND EXCITATION VOLTAGE SOURCE

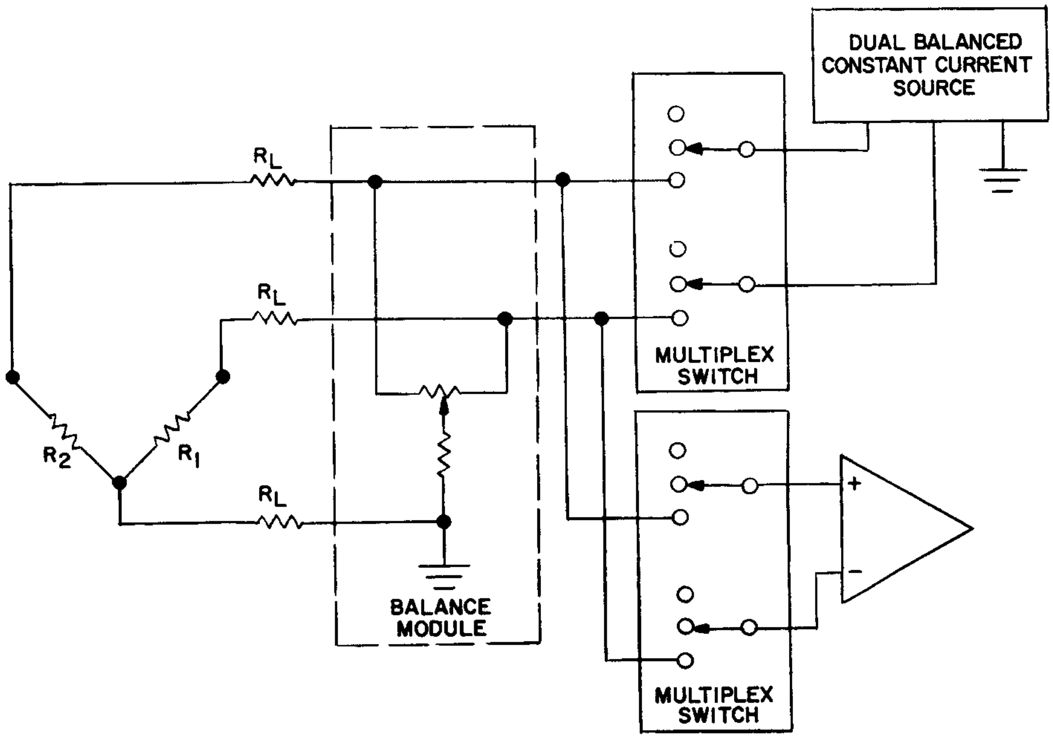

FIGURE 4
MULTIPLEXED SIGNAL CONDITIONING AMPLIFIER AND EXCITATION CURRENT SOURCE

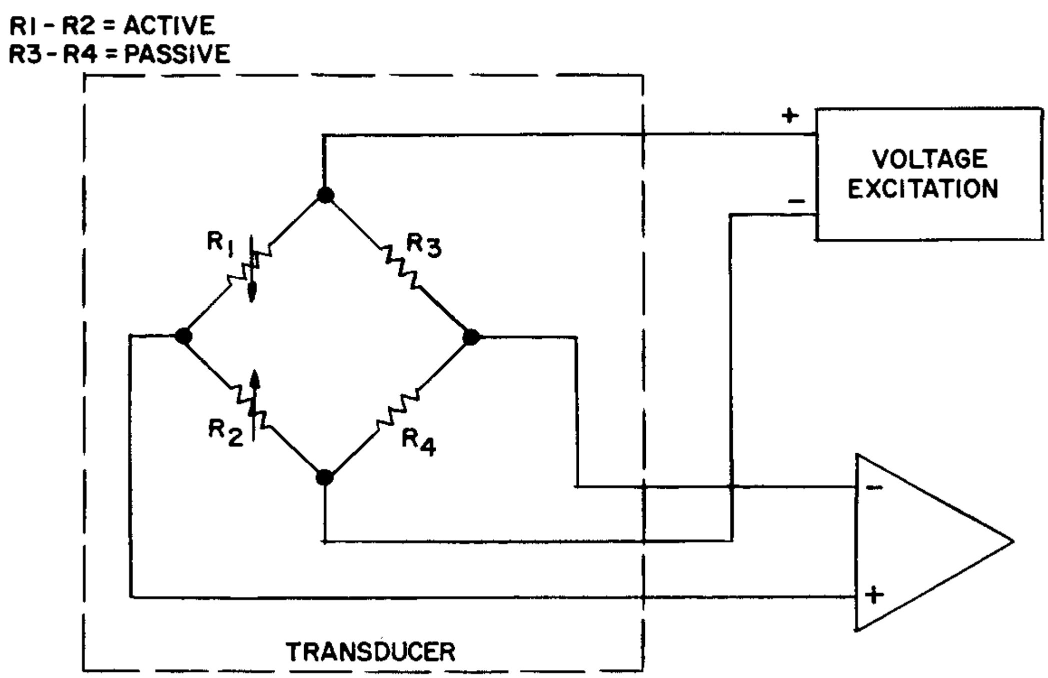

FIGURE 5
FOUR ELEMENT BRIDGE WITH TWO ACTIVE ELEMENTS USING CONSTANT VOLTAGE EXCITATION

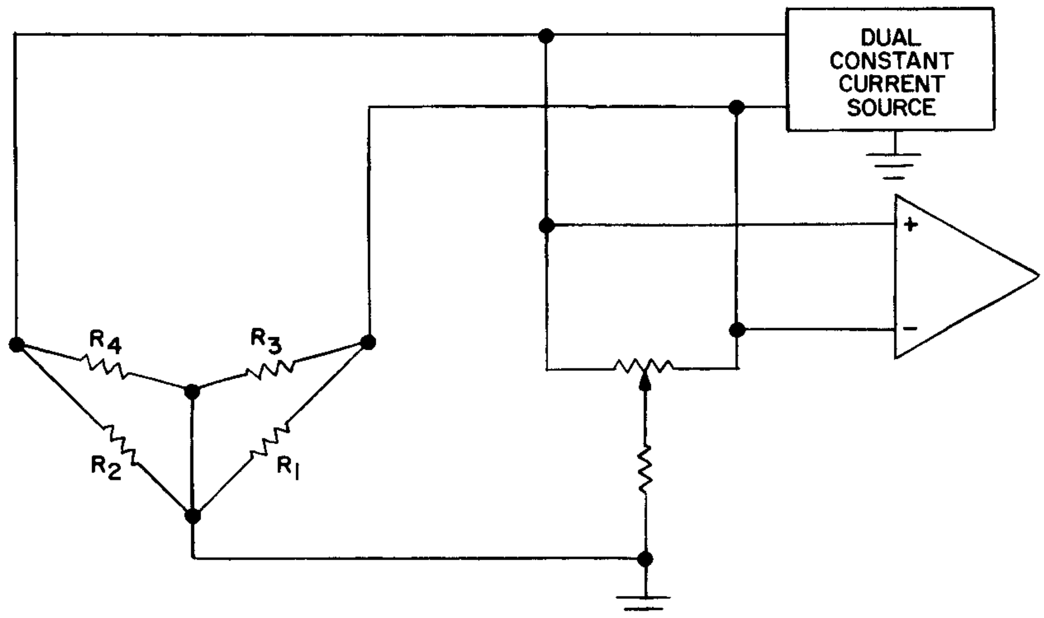

FIGURE 6
FOUR ELEMENT BRIDGE WITH TWO ACTIVE ELEMENTS USING CONSTANT CURRENT EXCITATION

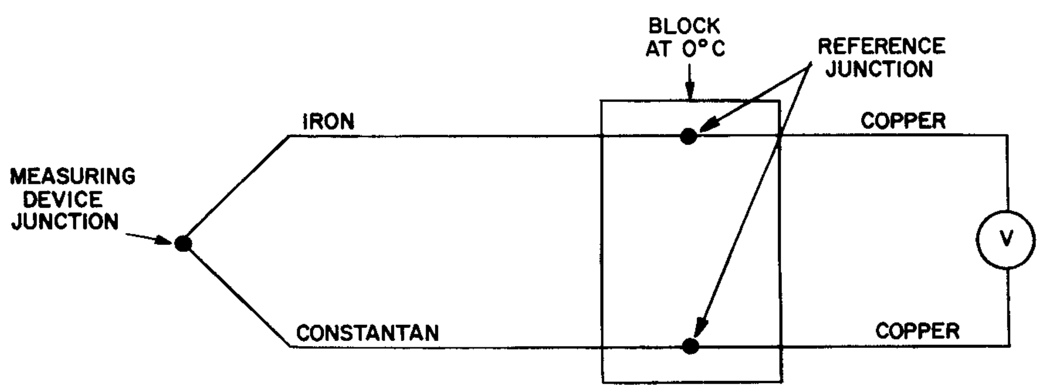

FIGURE 7
STANDARD THERMOCOUPLE MEASUREMENT CIRCUIT

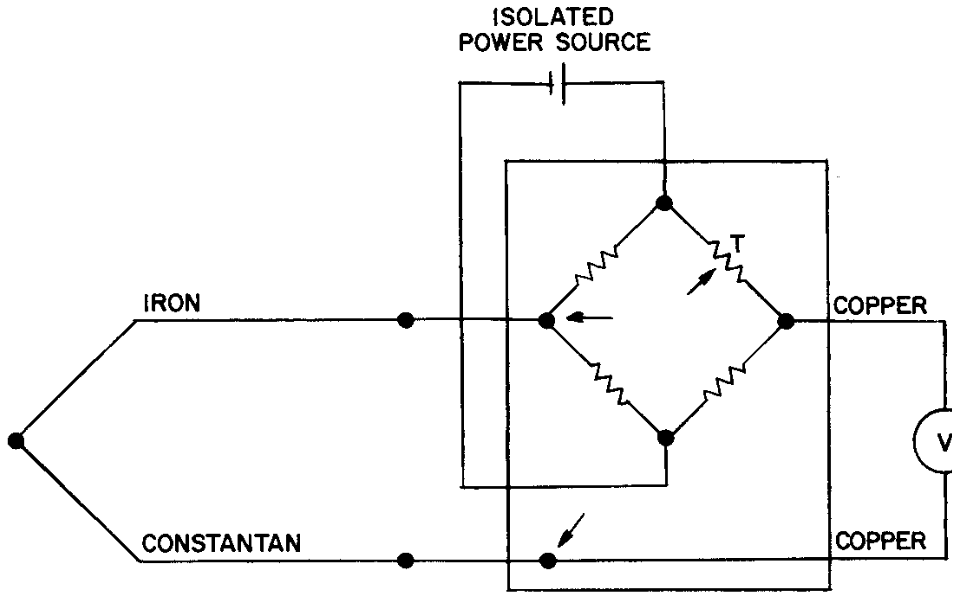

FIGURE 8
COLD JUNCTION COMPENSATION

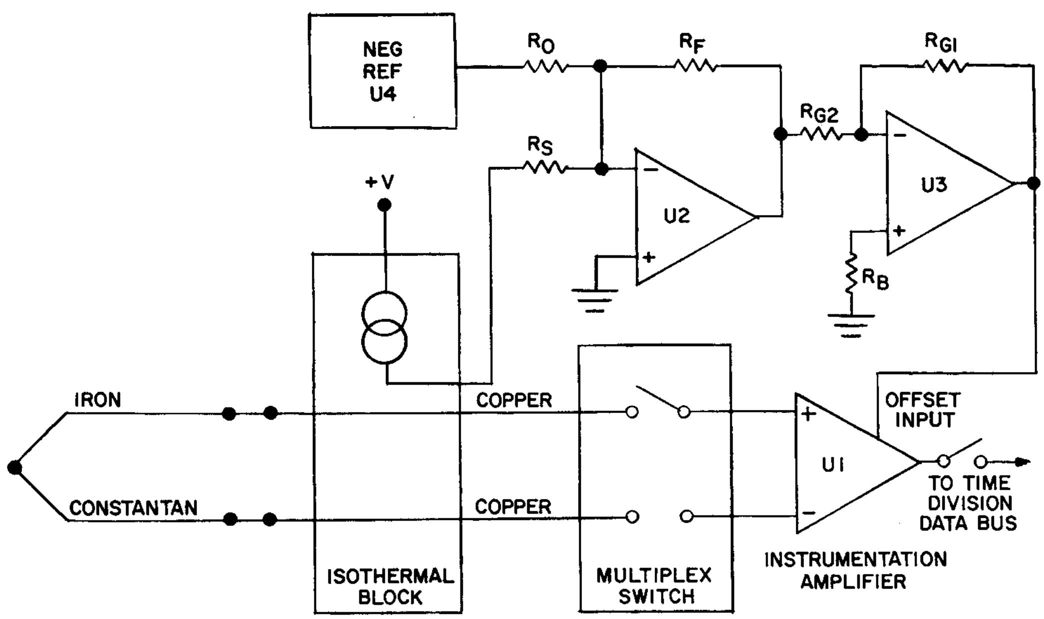

FIGURE 9
MULTIPLEXED THERMOCOUPLE COMPENSATION