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RESISTANCE MEASUREMENTS BY
RATIO EMPLOYING VOLTAGE TO
FREQUENCY CONVERTERS

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ABSTRACT

This report presents a method for measuring resistance in a range of a few milliohms to several hundred ohms by the use of Voltage to Frequency Converters.

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GENERAL

The resistance measurement circuit (Figure I) consists of one known resistance and one unknown resistance connected in a series loop to a Constant Current Power Supply, two Voltage to Frequency Converters and a Counter used as a Ratiometer.

RESISTANCE MEASUREMENT CIRCUIT (FIGURE I)

1. CONSTANT CURRENT SUPPLY. The constant current source furnishes a constant reference current through resistors "Rs" and "Rx" to produce a voltage drop across these resistors for comparison purposes. The current supplied through reference resistor "Rs" produces a voltage that is close to a full scale range voltage for No. 1 Voltage/Frequency Converter.

2. STANDARD INTERNAL REFERENCE RESISTOR Rs.

Reference resistor "Rs" is used to produce the constant voltage used as a reference by No. 1 Voltage/Frequency Converter. The resistor value is chosen to be an appropriate power of ten so the ratio of the Voltage/Frequency Converter outputs, "f1" to "f2", when displayed on the Counter/Ratiometer, will give a readout of the unknown resistance "Rx" that is directly in ohms.

3. RESISTOR Rd. This resistor represents the distributed resistance of the circuit wiring between resistors "Rs" and "Rx". This resistance is always present and in some cases can be controlled within certain limits by circuit design. The presence of resistor "Rd" means that the two Voltage/Frequency Converters must be floated above ground in order to avoid serious reading errors in the converters.
4. UNKNOWN EXTERNAL RESISTOR Rx. Unknown resistor "Rx" is the resistor whose value is to be determined. This resistor is connected in series with resistor "Rs" and resistance "Rd" to the constant current source. The voltage drop produced across unknown resistor "Rx" is applied to the input of No. 2 Voltage/Frequency Converter.
5. VOLTAGE TO FREQUENCY CONVERTERS. The input voltages for the Voltage/Frequency Converters are produced by the drop across resistors "Rs" and "Rx". The known voltage drop across reference resistor "Rs" is applied to the input of No. 1 Voltage/Frequency Converter and the voltage drop across unknown resistor "Rx" is applied to the input of No. 2 Voltage/Frequency Converter. No. 2 Voltage/Frequency Converter output supplies the EVENTS INPUT frequency (f2) for the Counter/Ratiometer and the No. 1 Voltage/Frequency Converter output supplies the EXTERNAL TIME BASE INPUT frequency (f1). It should be noted that No. 1 Voltage/Frequency Converter will only count the exact time selected,

.1, 1 or 10 seconds, if the external time base frequency is the same as the internal time base frequency. The Voltage/Frequency Converters used for this application will produce a continuous output frequency that is proportional to the input voltage. Regardless of the volts full scale range selected, the output frequency is the same for all full scale readings.

EXAMPLE:

If the full scale frequency is 100 KC, then on the 0.1 volt full scale range the output frequency will be 100 KC for an input voltage of 0.1 volt. On the 1.0 volt full scale range, the output frequency will be 100 KC for an input voltage of 1.0 volt.

6. COUNTER/RATIOMETER. Counters are universal in nature and are capable of performing several different functions. One function of a counter is to measure events per unit time. When a counter is used in this capacity, the events are a ratio to the internal time base frequency as indicated in Figure 2. If the S1 switch shown in Figure 2 is in the EXT TIME BASE position, the counter becomes a ratiometer as the ratio is taken with respect to the external time base frequency. The counter used in the resistance measurement circuit is used as a ratiometer in which the external time base input frequency is received from No. 1 Voltage/Frequency Converter output "f1" and the events input frequency is received from No. 2 Voltage/Frequency Converter output "f2".

CIRCUIT OPERATION

1. EXAMPLE:

The following example will illustrate the system:

A. Test Current - 1 amp

B. Rx value - 0.00499 ohms

C. Rs value - 0.1 ohm

D. $VR_s = I R_s = 1 (.1) = .1$ volt.

Select 0.1 volt full scale range for No. 1

V/F Converter. Full scale frequency

is 100 KC.

E. Select counter time base setting of .1 second.

F. $VR_x = I R_x = 1 (.00499) = .00499$ volts.

Select 0.1 volt full scale range for No. 2

V/F Converter. Output frequency will be

4.990 KC.

G. Upon actuation of the counter start button, the counter will gate on and count 10,000 "f1" pulses and stop. When the counter stops, the counter will display the number of "f2" pulses counted. The reading will be 00499. The 00499 count when converted to ohms is .00499 ohms.

This method of measuring resistances lends itself to automated testing. The readout is digital and hence eliminates operator error. The output of the counter can also be fed into a digital comparator and punch and/or printer for a permanent record and a go, no-go indication.

2. CALCULATIONS: Applying the given values from Example No. 1, the calculations of "Rx" resistance are as follows:

$$VR_s = R_s I \quad (1)$$

$$VR_x = R_x I \quad (2)$$

$$f_1 = VR_s (10^6 \text{ CPS/V}) \quad (3)$$

$$f_2 = VR_x (10^6 \text{ CPS/V}) \quad (4)$$

Since the counter performs f_1/f_2 then

$$\frac{f_1}{f_2} = \frac{VR_s (10^6 \text{ CPS/V})}{VR_x (10^6 \text{ CPS/V})} \quad (5)$$

Substituting equations 1 and 2 into equation 5

$$\frac{f_1 (\text{CPS})}{f_2 (\text{CPS})} = \frac{R_s (10^6)}{R_x (10^6)} \quad (6)$$

let $R_s = .1 \text{ ohm}$ and $R_x = .00499 \text{ ohms}$

$$\frac{f_1 (\text{CPS})}{f_2 (\text{CPS})} = \frac{100,000}{4990} \text{ or } \frac{f_1 (.1 \text{ CPS})}{f_2 (.1 \text{ CPS})} = \frac{10000}{499} \quad (7)$$

Since the counter displays only the 5 least significant digits of "f2", the 4990 CPS or 00499 reading when converted to ohms is .00499 ohms.

FIGURE 1 Resistance Measurement Circuit Block Diagram

FIGURE 2 Counter/Ratiometer Block Diagram