

Unit III : Signal Conditioning
Module Name : Instrumentation amplifier using Transducer Bridge
 Chopped and Modulated DC Amplifier
Module No : 20

Instrumentation Amplifier Using Transducer Bridge

Fig, 1 shows a simplified circuit of a differential instrumentation amplifier using a transducer bridge.

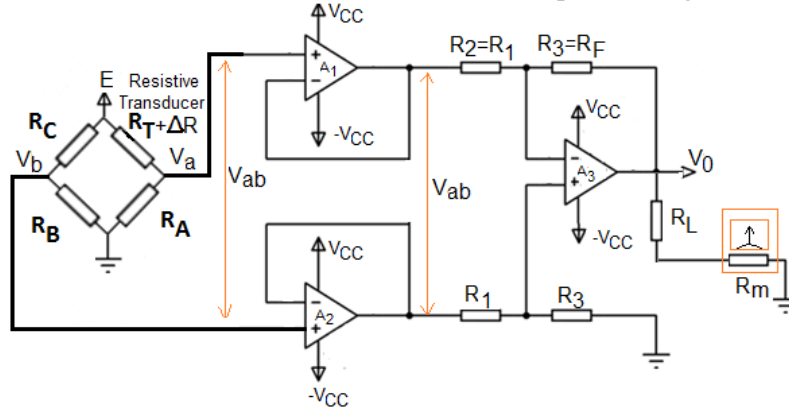


Fig. 1 Differential instrumentation amplifier using transducer bridge.

In this circuit a resistive transducer (whose resistance changes as a function of some physical energy) is connected to one arm of the bridge. Let R_T be the resistance of the transducer and ΔR the change in resistance of the resistive transducer. Hence the total resistance of the transducer is $(R_T \pm \Delta R)$. The condition for bridge balance is $V_b = V_a$, i.e. the bridge is balanced when $V_b = V_a$, or when

$$\frac{R_B(E)}{R_B + R_C} = \frac{R_A(E)}{R_A + R_T}$$

Therefore,
$$\frac{R_C}{R_B} = \frac{R_T}{R_A}$$

The bridge is balanced at a desired reference condition, which depends on the specific value of the physical quantity to be measured. Under this condition, resistors R_A , R_B and R_C are so selected that they are equal in value to the transducer resistance R_T .

Initially the bridge is balanced at a desired reference condition. As the physical quantity to be measured changes, the resistance of the transducer also changes, causing the bridge to be unbalanced ($V_b \neq V_a$). Hence, the output voltage of the bridge is a function of the change in the resistance of the transducer. The expression for the output voltage V_0 , in terms of the change in resistance of the transducer is calculated as follows.

Let the change in the resistance of the transducer be ΔR . Since R_B and R_C are fixed resistors, the voltage V_b is constant, however, the voltage V_a changes as a function of the change in the transducers resistance. Therefore, applying the voltage divider rule we have

$$V_a = \frac{R_A(E)}{R_A + (R_T + \Delta R)} \text{ and } V_b = \frac{R_B(E)}{R_B + R_C}$$

The output voltage across the bridge terminal is V_{ab} given by $V_{ab} = V_a - V_b$.

Therefore,
$$V_{ab} = \frac{R_A(E)}{R_A + (R_T + \Delta R)} - \frac{R_B(E)}{R_B + R_C}$$

However, if $R_A = R_B = R_C = R_T = R$, then

$$V_{ab} = \frac{R(E)}{2R + \Delta R} - \frac{R(E)}{2R} = E \left(\frac{R}{2R + \Delta R} - \frac{1}{2} \right)$$

$$V_{ab} = E \left(\frac{2R - 2R - \Delta R}{2(2R + \Delta R)} \right) = \frac{-\Delta R(E)}{2(2R + \Delta R)} \quad (1)$$

The output voltage V_{ab} of the bridge is applied to the differential amplifier through the voltage followers to eliminate the loading effect of the bridge circuit.

The gain of the basic amplifier is (R_F/R_1) and therefore the output voltage V_o of the circuit is given by

$$V_o = V_{ab} \left(\frac{R_F}{R_1} \right) = \frac{-\Delta R(E)}{2(2R + \Delta R)} \times \frac{R_F}{R_1}$$

It can be seen from the above that V_o is a function of the change in resistance ΔR of the transducer. Since the change is caused by the change in a physical quantity, a meter connected at the output can be calibrated in terms of the units of the physical quantity.

APPLICATIONS OF INSTRUMENTATION AMPLIFIERS

Temperature Indicators Using Thermistor

The Thermistor is a relative passive type of temperature resistance transducer. Most thermistors exhibit an NTC characteristic. An NTC type is one in which its resistance decreases with increase in temperature.

The temperature coefficient is expressed in ohms/°C. Since it is a thermally sensitive resistor, it has a high temperature coefficient of resistance and is therefore well suited for temperature measurement and control.

In the bridge circuit of Fig. 1 the thermistor is used as transducer and used as a temperature indicator. The output meter is then calibrated in °C or °F. The bridge is balanced initially at a desired reference condition. As the temperature varies, the resistance of the thermistor also changes, unbalancing the bridge, which in turn produces a meter deflection at the output. By selecting the appropriate gain for the differential instrumentation amplifier, the meter can be calibrated to read a desired temperature. In this circuit, the meter movement (deflection) depends on the amount of unbalance in the bridge, which is caused by a change in the value of thermistor resistance ΔR . The change ΔR for the thermistor can be determined as follows.

$$\Delta R = \text{temperature coefficient of resistance} \times [\text{final temperature} - \text{reference temperature}]$$

If the meter in this circuit is replaced by a relay, and if the output of the differential instrumentation amplifier drives the relay that controls the current in the heat-generating circuit, a temperature controller can be formed. A properly designed circuit should energise a relay when the temperature of the thermistor drops below a desired value, causing the heater unit to turn on.

Light Intensity Meter

In the bridge circuit of Fig. 1, the photocell is a transducer and used as a light intensity meter. Initially the bridge is balanced for the dark condition, therefore when exposed to light the bridge becomes unbalanced, to a degree depending upon the intensity of light. This unbalance causes the meter to deflect. To measure the change in light intensity, the meter is calibrated in terms of Lux or Lumen.

The light intensity meter can also be designed using a single input inverting or non-inverting opamp, but the light intensity meter using an instrumentation amplifier is more accurate and stable, because the common mode (noise) voltages are effectively cancelled by the differential mode.

Analog Weight Scale

Figure 1 can be converted into a simple analog weight scale by connecting strain gauges in the bridge circuit. These strain gauges are connected in all the four arms of the bridge. The strain gauge elements are mounted on a base of the specially made weight platform, on which an external force or weight is placed. One pair of strain gauge elements in opposite arms elongates, (i.e. RT1 and RT3 both increases in resistance) while the other pair compresses (RT2 and RT4 both decreases in resistance), and vice-versa. The bridge is balanced when no external force or weight is applied, i.e. $RT1 = RT2 = RT3 = RT4 = R$, and the output voltage of the weight scale is zero.

Suppose a weight is placed on the scale platform and RT1 and RT3 increases in resistance. Then RT2 and RT4 decrease in resistance by the same value ΔR and the bridge is unbalanced, thereby giving an unbalanced output voltage. This unbalanced voltage V_{ab} is given by

$$V_{ab} = +E \left(\frac{\Delta R}{R} \right).$$

where E – excitation voltage of the bridge.

$R = RT1 = RT2 = RT3 = RT4 =$ unstrained gauge resistance

ΔR – change in gauge resistance.

The differential instrumentation amplifier then amplifies the voltage V_{ab} , giving a deflection on the meter movement. As the gain of the amplifier is $(+ R_f/R_1)$, the output voltage V_o is given by

$$V_o = E \times \left(\frac{\Delta R}{R} \right) \times \left(\frac{R_f}{R_1} \right).$$

The gain of the amplifier is selected depending on the sensitivity of the strain gauge and on the full scale deflection requirements of the meter. The meter can be then calibrated in grams or kilograms

CHOPPED AND MODULATED DC AMPLIFIER

- A simple ac amplifier may be used to amplify a dc input through the use of additional circuit component known as chopper.
- In this circuit, the dc signal is first converted into ac signal, amplified by a standard amplifier, and finally converted back to a dc signal. The chopper can be electronic or mechanical.
- V_i is the input dc voltage, this voltage is alternately connected to terminals A and B.
- When the switch is in position A, the direction of current flow of the current is in one direction. When the switch is connected to position B, the current flows in the opposite direction.

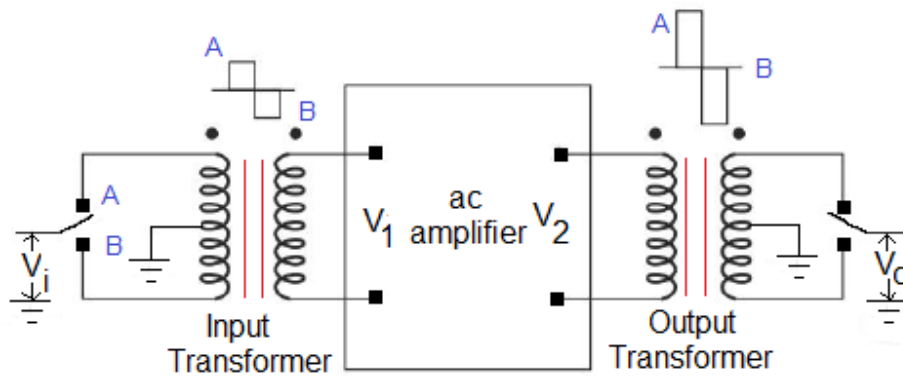


Fig 2. DC Chopper

- This means that an ac voltage will be induced in the secondary winding of the input transformer. For an ideal transformer, this voltage is of perfect square wave shape.
- The peak value of the induced voltage is proportional to the dc input.
- The ac signal is amplified by a standard ac amplifier. An amplified square wave appears at the primary winding of the output transformer.
- The ac signal is converted back to dc. The secondary winding of the output transformer is centrally tapped, with an output switch ganged (mechanically coupled) to the input switch.
- The input voltage across the primary winding of the output transformer and the output of the secondary winding is shown in the Fig 3

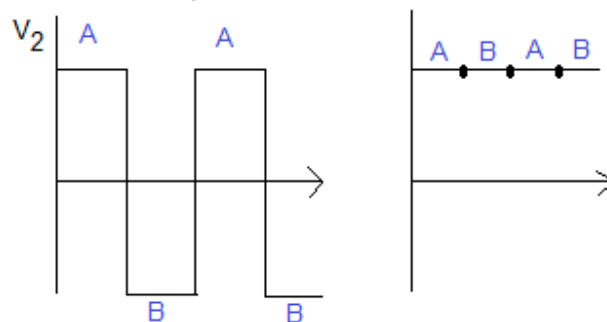


Fig 3. Input voltage across the primary winding of the output transformer and the output of the secondary winding.

- The amplifier is referred to as a chopper amplifier, since the dc input voltage is literally chopped to produce ac signal. The chopping action may be accomplished by either mechanical or electronic means.