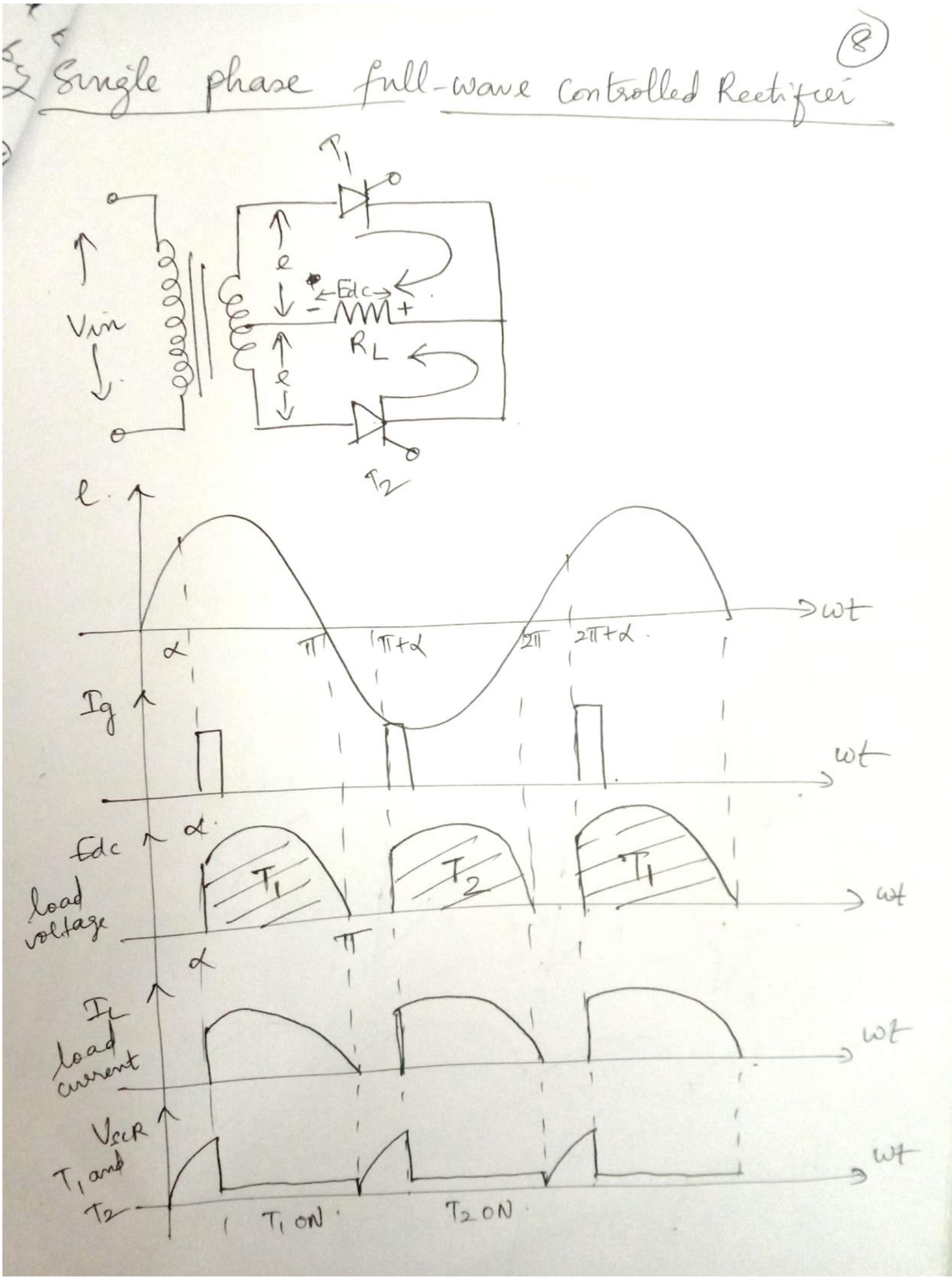
1. **Derive the expression for E_{dc} and E_{rms} for full wave controlled rectifier with R Load. Also draw the relevant circuit diagram and waveforms.**

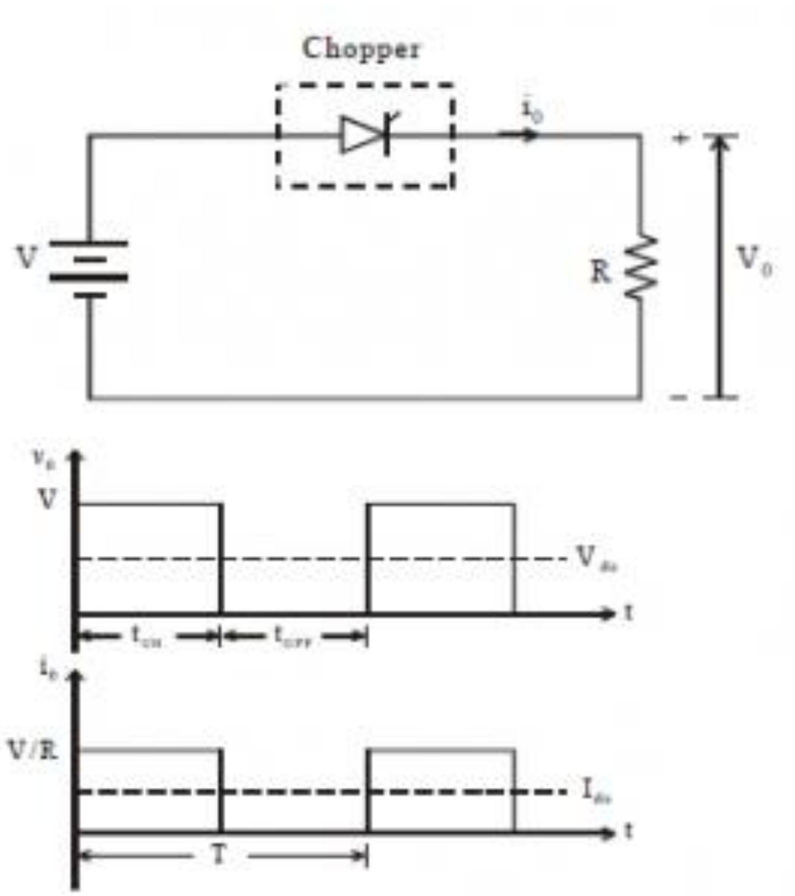


2. **Derive the expression for step down and step up chopper circuit**

Step Down Chopper

Step down chopper for R load

Figure below shows the Circuit Diagram andÂ Waveform of resistive load step down chopper.



The thyristor in the circuit acts as a switch.
When thyristor is ON, supply voltage appears across the load
When thyristor is OFF, the voltage across the load will be zero.

The average output voltage is given as,

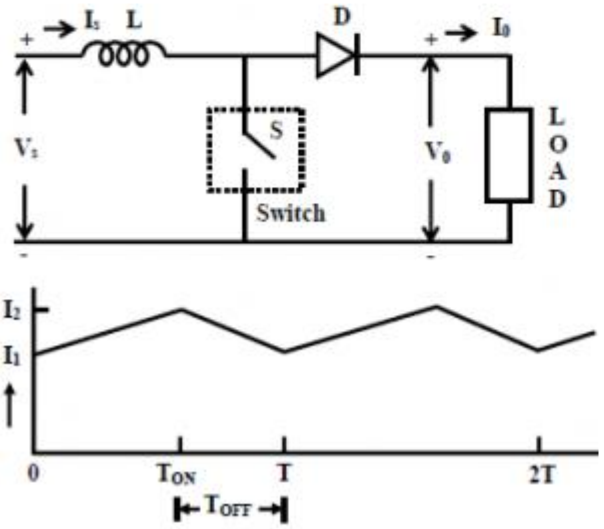
$$V_0 = \frac{1}{T}\int_0^{T_{ON}} V_s\, dt$$

$$= \frac{V_s T_{ON}}{T}$$

$$= DV_s$$

Step up chopper

Figure below shows the Circuit Diagram and Waveform of step up chopper.



Step-up chopper is used to obtain a load voltage higher than the input voltage V.
The values of L and C are chosen depending upon the requirement of output voltage and current.
When the chopper is ON, the inductor L is connected across the supply. The inductor current rises and the inductor stores energy during the ON time of the chopper, tON.
When the chopper is off, the inductor current I is forced to flow through the diode D and load for a period, tOFF.
The current tends to decrease resulting in reversing the polarity of induced EMF in L.
Therefore voltage across load is given by,

$$V_0 = V + L\frac{dI}{dt}$$

3. **What is a Strain Gauge? Find out the expression for Gauge factor.**

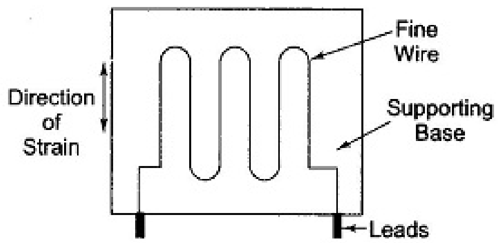


Fig. 13.4 Bonded resistance Wire Strain Gauge

A fine wire element about 25 μm (0.025 in.) or less in diameter is looped back and forth on a carrier (base) or mounting plate, which is usually cemented to the member undergoing stress. The grid of fine wire is cemented on a carrier which may be a thin sheet of paper, bakelite, or teflon. The wire is covered on the top with a thin material, so that it is not damaged mechanically. The spreading of the wire permits uniform distribution of stress. The carrier is then bonded or cemented to the member being studied. This permits a good transfer of strain from carrier to wire.

A tensile stress tends to elongate the wire and thereby increase its length and decrease its cross-sectional area. The combined effect is an increase in resistance, as seen from the following equation

$$R = \frac{\rho \times l}{A}$$

where
ρ = the specific resistance of the material in Ωm.
l = the length of the conductor in m
A = the area of the conductor in m^2
As a result of strain, two physical parameters are of particular interest.

1. The change in gauge resistance.

2. The change in length.

The measurement of the sensitivity of a material to strain is called the gauge factor (GF). It is the ratio of the change in resistance Δ R/R to the change in the length Δl/l

$$\text{GF } (K) = \frac{\Delta R/R}{\Delta l/l}$$

where

K= gauge factor

Δ R= the change in the initial resistance in Ω's

R = the initial resistance in Ω (without strain)

Δ l= the change in the length in m

l = the initial length in m (without strain)

Since strain is defined as the change in length divided by the original length,

$$\text{i.e.} \qquad \sigma = \frac{\Delta l}{l}$$

Eq. (13.1) can be written as

$$K = \frac{\Delta R / R}{\sigma} \tag{13.2}$$

where σ is the strain in the lateral direction.

The resistance of a conductor of uniform cross-section is

$$R = \rho \frac{\text{length}}{\text{area}}$$

$$R = \rho \frac{l}{\pi r^2}$$

$$r = \frac{d}{2} \quad \therefore \quad r^2 = \frac{d^2}{4}$$

$$R = \rho \frac{l}{\pi d^2/4} = \rho \frac{l}{\pi/4\, d^2} \tag{13.3}$$

where

ρ= specific resistance of the conductor

l = length of conductor

d= diameter of conductor

When the conductor is stressed, due to the strain, the length of the conductor increases by Δl and the simultaneously decreases by Δd in its diameter. Hence the resistance of the conductor can now be written as

$$R_s = \rho \frac{(l + \Delta l)}{\pi/4(d - \Delta d)^2} = \frac{\rho(l + \Delta l)}{\pi/4\,(d^2 - 2d\,\Delta d + \Delta d^2)}$$

Since Δd is small, Δd^2 can be neglected

$$R_s = \frac{\rho\,(l + \Delta l)}{\pi/4\,(d^2 - 2d\,\Delta d)}$$

$$= \frac{\rho\,(l + \Delta l)}{\pi/4 d^2\left(1 - \frac{2\Delta d}{d}\right)} = \frac{\rho\,l\,(1 + \Delta l/l)}{\pi/4 d^2\left(1 - \frac{2\Delta d}{d}\right)} \tag{13.4}$$

Now, Poisson's ratio μ is defined as the ratio of strain in the lateral direction to strain in the axial direction, that is,

$$\mu = \frac{\Delta d/d}{\Delta l/l} \tag{13.5}$$

$$\frac{\Delta d}{d} = \mu\,\frac{\Delta l}{l} \tag{13.6}$$

Substituting for Δd/d from Eq. (13.6) in Eq. (13.4), we have

$$R_s = \frac{\rho\,l\,(1 + \Delta l/l)}{(\pi/4)\,d^2\,(1 - 2\,\mu\,\Delta l/l)}$$

Rationalising, we get

$$R_s = \frac{\rho\,l\,(1 + \Delta l/l)}{(\pi/4)\,d^2\,(1 - 2\,\mu\,\Delta l/l)}\,\frac{(1 + 2\,\mu\,\Delta l/l)}{(1 + 2\,\mu\,\Delta l/l)}$$

$$R_s = \frac{\rho l}{(\pi/4)\,d^2}\left[\frac{(1 + \Delta l/l)}{(1 - 2\,\mu\,\Delta l/l)}\,\frac{(1 + 2\,\mu\,\Delta l/l)}{(1 + 2\,\mu\,\Delta l/l)}\right]$$

$$R_s = \frac{\rho l}{(\pi/4)\,d^2}\left[\frac{1 + 2\mu\,\Delta l/l + 2\,\Delta l/l + 2\mu\,\Delta l/e\,\Delta l/l}{1 - 4\mu^2\,(\Delta l/l)^2}\right]$$

$$R_s = \frac{\rho l}{(\pi/4)\,d^2}\left[\frac{1 + 2\mu\Delta l/l + \Delta l/l + 2\mu\Delta l^2/l^2}{1 - 4\mu^2\,\Delta l^2/l^2}\right]$$

Since Δl is small, we can neglect higher powers of Δl.

$$R_s = \frac{\rho l}{(\pi/4)\,d^2}\;[1 + 2\,\mu\,\Delta l/l + \Delta l/l]$$

$$R_s = \frac{\rho l}{(\pi/4)\,d^2}\;[1 + (2\,\mu + 1)\,\Delta l/l]$$

$$R_s = \frac{\rho l}{(\pi/4)\,d^2}\;[1 + (1 + 2\,\mu)\,\Delta l/l]$$

$$R_s = \frac{\rho l}{(\pi/4)\,d^2} + \frac{\rho l}{(\pi/4)\,d^2}\;(\Delta l/l)\,(1 + 2\,\mu)$$

Since from Eq. (13.3),

$$R = \frac{\rho l}{(\pi/4)\, d^2}$$

$$R_s = R + \Delta R \tag{13.7}$$

$$\Delta R = \frac{\rho l}{(\pi/4)\, d^2}\ (\Delta l/l)\ (1 + 2\ \mu)$$

The gauge factor will now be

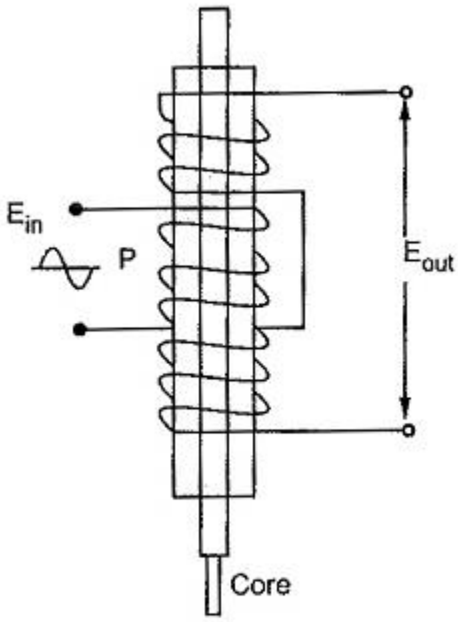
$$K = \frac{\Delta R/R}{\Delta l/l} = \frac{(\Delta l/l)(1+2\mu)}{\Delta l/l}$$

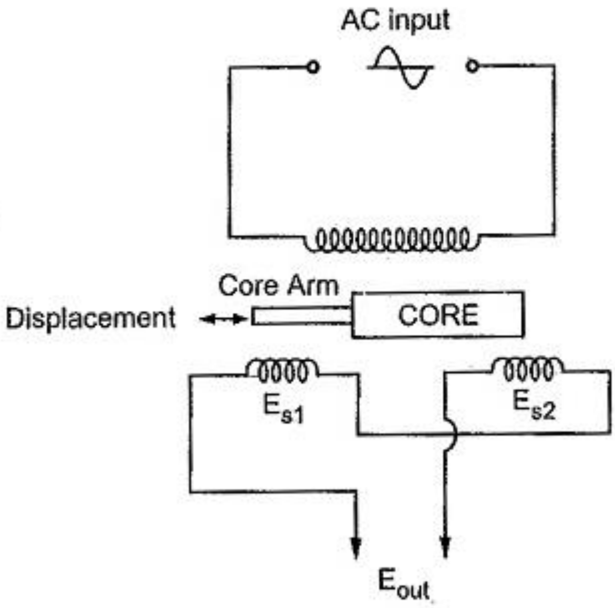
$$= 1 + 2\ \mu$$

$$K = 1 + 2\ \mu \tag{13.8}$$

4. **With neat diagram explain the working of LVDT**

LVDT is an another type of transducer often used to measure force, pressure or position. The Fig. 15.35 shows the basic structure of LVDT. As illustrated in the Fig. 15.35, the linear variable differential transformer consists of a single primary winding P_1 and two secondary windings S_1 and S_2 Wound on a hollow cylindrical former. The secondaries have an equal number of turns but they are connected in series opposition so that the emfs induced in the coils oppose each other. The primary winding is connected to an ac source, whose frequency may range from 50 Hz to 20 kHz. A movable soft iron core slides inside the hollow former The position of the movable core determines the flux linkage between the ac excited primary winding and each of the two secondary windings. The core made up, of nickel-iron alloy is slotted longitudinally to reduce eddy current losses. The displacement to be measured is applied to an arm attached to the core. With the core in the center, or reference, position, the induced emfs in the secondaries are equal, and since they oppose each other, the output voltage will be zero volt.



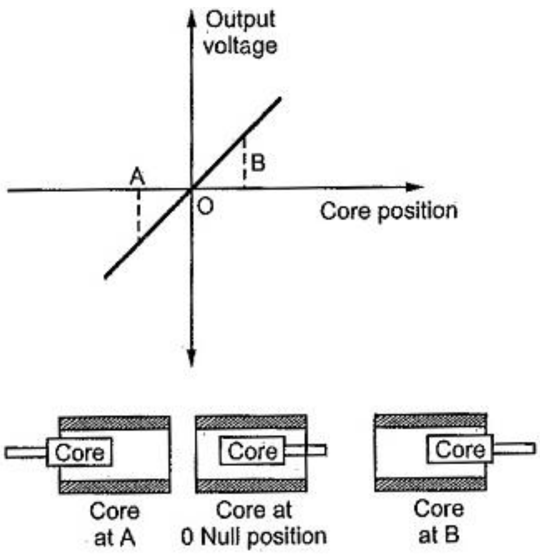


When an externally applied force moves the core to the left-hand position, more magnetic flux links the left-hand coil than the right-hand coil. The emf induced in the left-hand coil, E_{s1}, is therefore larger than the induced emf of the right-hand coil, E_{s2}.

The magnitude of the output voltage is then equal to the difference between the two secondary voltages and it is in phase with the voltage of the left-hand coil.

Similarly, when the core is forced to move to the right, more flux links the right-hand coil than the left-hand coil and the resulting output voltage, which is the difference between E_{s2} and E_{s1}, is now in phase with the emf of the right-hand coil.

Thus the LVDT output voltage is a function of the core position. The amount of a voltage change in either secondary winding is proportional to the amount of movement of the core. By noting which output is increasing or decreasing, the direction of motion can be determined. The output ac voltage inverts in phase as the core passes through the central null position. Further as the core moves from the center, the greater is the difference in value between Es1 and Es2 and consequently the greater the output voltage. Therefore the amplitude of the output voltage is a function of the distance the core moves, while the polarity or phase indicates the direction of the motion.



The amount of output voltage of an LVDT is a linear function of the core displacement within a limited range of motion.

5. Derive an expression for the output voltage of an instrumentation amplifier using transducer bridge.

Figure 14.25 shows a simplified circuit of a Differential Instrumentation Amplifier 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 $(R_T \pm \Delta R)$.

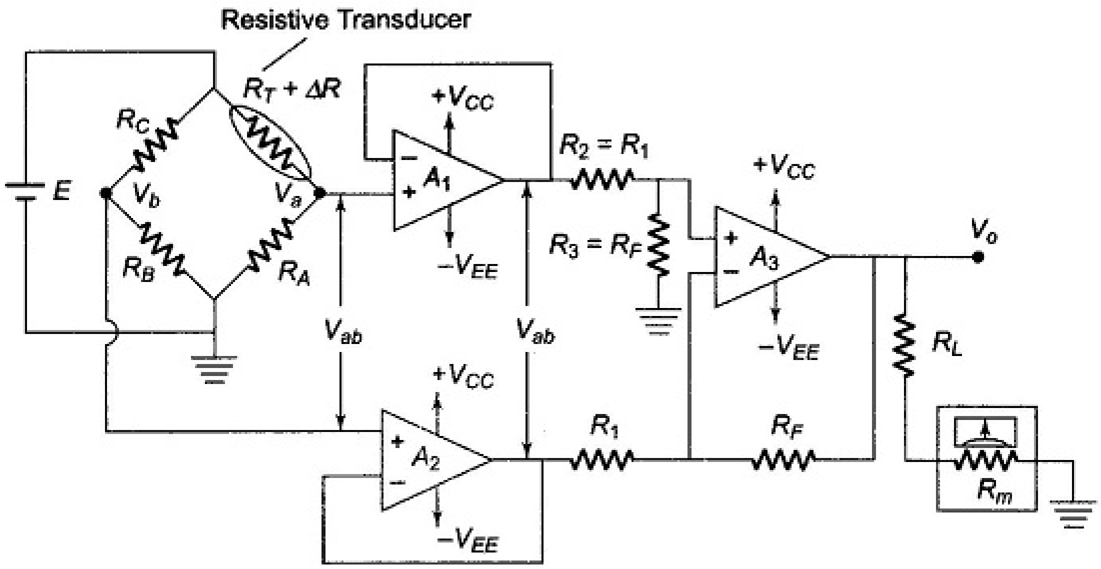


Fig. 14.25 Differential Instrumentation Amplifier using Transducer Bridge

The condition for bridge balance is Vb = Va, i.e. the bridge is balanced when Vb = Va, or when

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

$$\text{Therefore,} \quad \frac{R_c}{R_B} = \frac{R_T}{R_A}$$

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. (The value of the physical quantity normally depends on the transducers characteristics, the type of physical quantity to be measured, and the desired applications.)

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 # Va). 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,

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

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

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

$$V_{ab} = E\left(\frac{2R - 2R - \Delta R}{2(2R + \Delta R)}\right) = \frac{-\Delta R(E)}{2(2R + \Delta R)} \qquad (14.15)$$

The output voltage Vab of the bridge is applied to the Differential Instrumentation Amplifier Transducer Bridge through the voltage followers to eliminate the loading effect of the bridge circuit. The gain of the basic amplifier is (RF/R1) and therefore the output voltage Vo of the circuit is given by

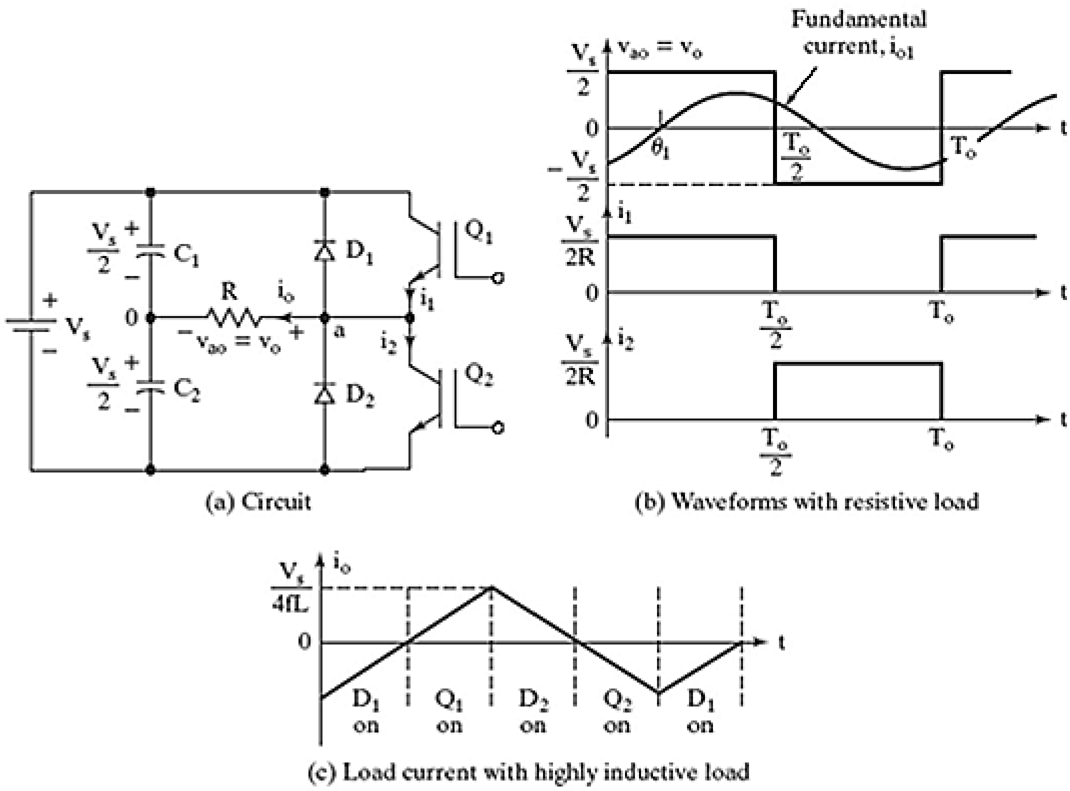
$$V_o = V_{ab}\left(\frac{R_F}{R_1}\right) = \frac{-\Delta R(E)}{2(2R+\Delta R)} \times \frac{R_F}{R_1} \qquad (14.16)$$

It can be seen from the Eq. (14.16) that Vo 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.

6. Explain the working of a half bridge inverter using Resistive load.

For the half-bridge inverter circuit, the centre-tap of the DC supply is used as one of the load terminals. The centre-tap is created by the two series-connected equal-valued capacitors across the DC supply. The dc rail voltages are thus at $+V_s/2$ and $-V_s/2$ with respect to some fictitious ground potential.

The two switches, Q1 and Q2, are switched alternately, in a complementary fashion, at the desired output frequency, f_o.



(a) Circuit

(b) Waveforms with resistive load

(c) Load current with highly inductive load

Single-Phase Half-Bridge Inverter

1. When Q1 is ON, Q2 is OFF and the voltage at the terminal a of the load is $+V_s/2$ with irrespective of the direction of current through the load. Similarly, when Q2 is ON, the Q1 is OFF and the potential at point a is $-V_s/2$.

2. The load voltage is a square-wave of amplitude $V_s/2$. For a resistive load the current waveform follows the voltage waveform (as shown). For an inductive load the current waveform lags the voltage waveform by an angle which is, approximately, the load power factor angle.

8. What is a Programmable Logic Controller? Explain the structure, operation, relays and registers.

The PLC Structure mainly consists of a CPU, memory areas, and appropriate circuits to receive input/output data as shown in Fig. 21.22. A PLC can be considered as a box full of hundreds of thousands of separate relays, counters, timers and data storage locations. (These counters, timers, etc. really do not exists physically but rather they are simulated and can be considered software counters, timers, etc). These internal relays are simulated through bit locations in registers.

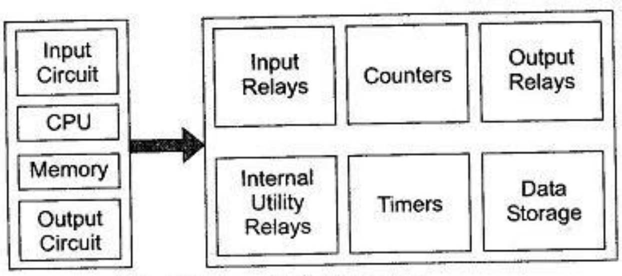


Fig. 21.22 PLC structure

The PLC structure consists of the following

Input Relays: (Contacts) These are connected to the outside world. They physically exist and receive signals from switches, sensors, etc. Typically they are not relays but are transistors.

Internal Utility Relay: (Contacts) These do not receive signals from the outside world nor do they physically exist. They are simulated relays and are what enables a PLC to eliminate external relays. There are also some special relays that are dedicated to performing only one task. Some are always ON while some are always OFF. Some are ON only once during Power-on and are typically used for initializing data that was stored.

Counters: These again do not physically exist. They are simulated counters and they can be programmed to count pulses. Typically these counters can be up-count, down count or both. Since they are simulated they are limited in their counting speed. Some manufacturers also include high speed counters that are hardware based.

Timers: These also do not physically exist. They come in many Varieties and increments. The most common type is an ON-delay type. Others include OFF-delay and both retentive and non-retentive types. Increments vary from 1 ms — ls.

Output Relays: (Coils) These are connected to the outside world. They exist physically and send ON/OFF signals to solenoid, lamps, etc. They can be transistors, relays or triacs depending upon the type selected.

Data Storage: Typically there are registers assigned simply to store data. They are usually used as temporary storage for math or data They can also be used to store data in case of a power failure. These registers ensure that there is no loss of contents owing to disconnection of power.

PLC System Operation:

A PLC System Operation works by continually scanning a program. This scan cycle can be considered as made up of three important states as shown in Fig. 21.23. In addition there are also more than three states and these are used for checking the system and updating the internal counter and timer values.

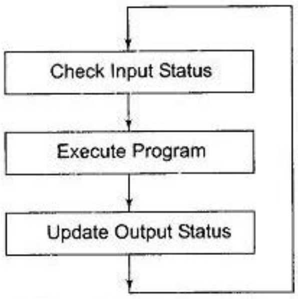


Fig. 21.23 PLC Operation Diagram

Step 1: Check Input Status: First the PLC takes a look at each input to determine if it is ON or OFF. In other words, it checks and senses whether the sensor connected to the first input is ON, to the second input is ON, to the third input is ON… It records this data into its memory to be used during the next step.

Step 2: Execute Program: The PLC System Operation next executes the program, one instruction at a time. For example, if the program says that if the first input was ON then it should turn ON the first output. Since it already knows which inputs are ON/ OFF from the previous step, it will be able to decide whether the first output should be turned ON based on the state of the first input. It will store the execution results for use later during the third step.

Step 3: Update Output Status: Finally the PLC updates the status of the outputs. It updates the outputs based on which inputs were ON during the first step and the results of executing the program during the second step. Based on example in step 2, it would now turn ON the first output because the first input was ON and the program said to turn ON the first output when this condition is true.

After the third step, the PLC System Operation goes back to step one and repeats the steps continuously. The time taken to execute the above three steps or one instruction cycle is defined as the scan time.

Relays Definition:

The main purpose of a PLC is to replace real world relays. A Relays Definition is basically an electro-magnetic switch. When a voltage is applied to the coil, a magnetic field is generated. This magnetic field attracts the contact of the relay in, causing them to make a connection. These contacts act like a switch and allow current to flow between 2 points thereby closing the circuit.Let us consider the following example in which we will simply turn ON a bell, whenever the switch is closed. A switch, relay and a bell is connected as shown in Fig. 21.28.

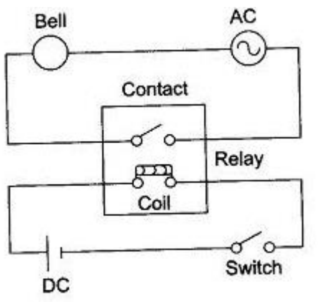
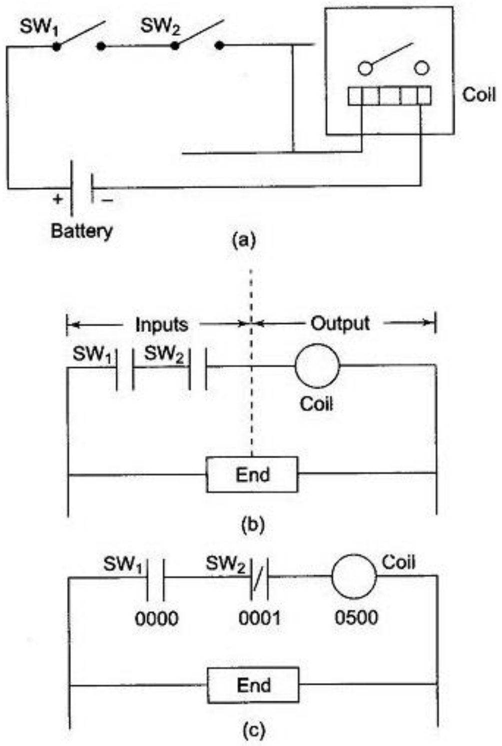


Fig. 21.28 Bell Circuit Diagram

When the switch closes, current is applied to a bell causing it to sound. In Fig. 21.28, it is seen that it consists of two separate circuits. One circuit is the dc part and the other circuit is the ac part.

PLC Register:

PLC Register – Let us consider a simple example and compare the ladder diagram with its real world external physically connected relay circuit. In Fig. 21.32 (a), the coil circuit will be energized when there is a closed loop between the '+' and '—' terminals of the battery. The same circuit can be drawn using ladder diagram. A ladder diagram consists of individual rungs. Each rung must contain one or more inputs and one or more outputs. The first instruction on a rung must always be an input instruction and last instruction on a rung should always be an output coil. The ladder diagram of Fig. 21.32(a) is shown in Fig. 21.32(b).



The PLC Register in use can be explained by using Fig. 21.32(b) and changing SW2 from normally open to normally closed as shown in Fig. 21.32(c).