Differential Instrumentation Amplifier 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.

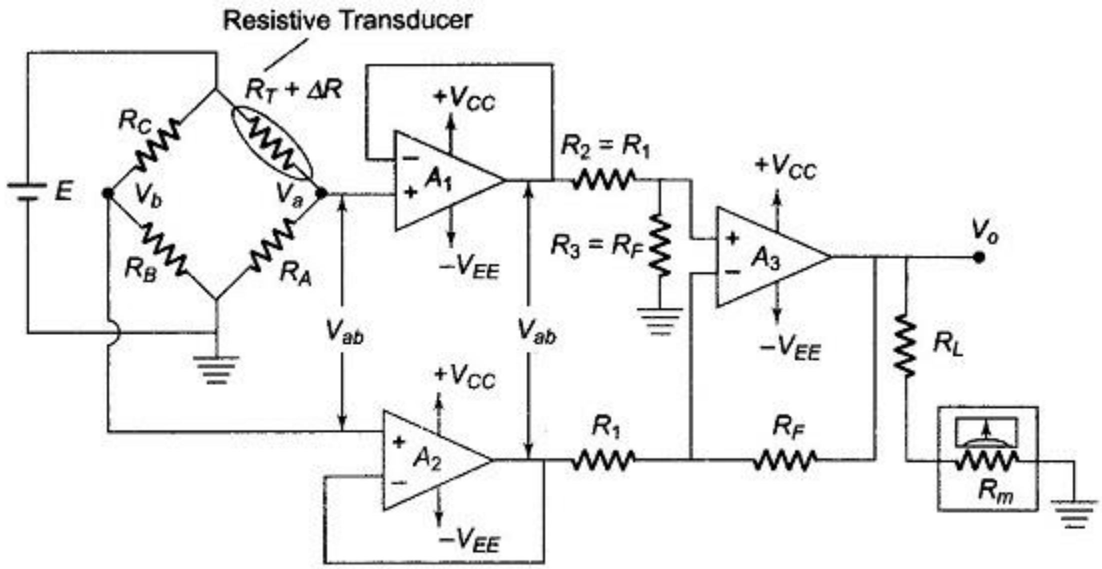


Fig. 14.25 Differential Instrumentation Amplifier using Transducer Bridge

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 Vb = Va, i.e. the bridge is balanced when Vb = Va, or when

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

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 RA, RB and RC are so selected that they are equal in value to the transducer resistance RT. (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 ($V_b \neq V_a$). Hence, the output volt-age 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,

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

$$R_A = R_B = R_C = R_T = R, \text{ then}$$

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

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

The output voltage V_{ab} of the bridge is applied to the Differential Instrumentation Amplifier Transducer Bridge through the voltage followers to eliminate the loading effect of the bridge cir-cuit. The gain of the basic amplifier is (R_F/R_1) 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.

Applications of Instrumentation Amplifier Transducer Bridge

We shall now consider some important applications of instrumentation amplifiers using resistance types transducers. In these transducers, the resistance of the transducer changes as a function of some physical quantity. Commonly used resistance transducers are thermistors, photoconductor cells, and strain gauges.

Temperature Indicators Using Thermistor:

The Thermistor is a relative passive type of temperature resistance transducer. They are basically semiconductors.

In many respects, a thermistor resembles a conventional resistor. It is usually a two-terminal device. It has resistance as its fundamental property. It is gener-ally installed and operated in the manner of an ordinary resistor. But its great difference is that it has a negative temperature coefficient (NTC) or positive temperature coefficient (PTC) type. Most thermistors exhibit an NTC charac-teristic. 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 coef-ficient of resistance and is therefore well suited for temperature measurement and control.

If in the bridge circuit of Fig. 14.25 the transducer used is a thermistor, the circuit can thus be 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 Transducer Bridge, 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.

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

If the meter in this circuit is replaced by a relay, and if the output of the Differential Instrumentation Amplifier Transducer Bridge drives the relay that controls the current in the heat-generating circuit, a temperature controller can be formed. A prop-erly designed circuit should energise a relay when the temperature of the ther-mistor drops below a desired value, causing the heater unit to turn on.

Analog Weight Scale:

Figure 14.25 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,as shown in Fig. 14.26. 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.

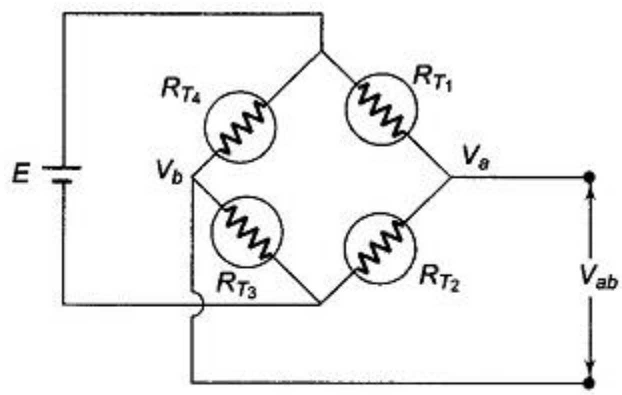


Fig. 14.26 Strain Gauge Bridge Circuit for Analog Weight Scale

The bridge is balanced when no external force or weight is applied, i.e. $R_{T1} = R_{T2} = R_{T3} = R_{T4} = R$, and the output voltage of the weight scale is zero.

Suppose a weight is placed on the scale platform and R_{T1} and R_{T3} increases in resistance. Then R_{T2} and R_{T4} 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 is the excitation voltage of the bridge.

$R = R_{T1} = R_{T2} = R_{T3} = R_{T4}$ = unstrained gauge resistance

ΔR is the change in gauge resistance.

The Differential Instrumentation Amplifier Transducer Bridge then amplifies the voltage V_{ab}, giv-ing a deflection on the meter movement. As the gain of the amplifier is (+ R_F/R_1), the output voltage Vo 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. For better accuracy and resolution, a micro based digital weight scale may be constructed. However, such a scale is much more complex and expensive then the analog scale.

PLC Definition (Programmable Logic Controller or Program-mable Controller):

PLC Definition – Programmable Logic Controller (PLC) or commonly simply called a Programmable Controller, is a solid state, digital, industrial computer. It is a device that was invented to replace the necessary sequential relay circuits for machine control. The PLC basically operates by looking at its inputs and depending upon their state, turning on/off its output. The user enters a program, normally through software, that gives the desired results.

PLCs are used in many real world applications such as machining, packaging, material handling, automated assembly, etc. Almost any applications that need some type of electrical control has a need for a PLC.

Let's assume that when a switch turns ON, we want to turn a solenoid ON for 10 seconds and then turn it OFF regardless of how long the switch is ON for. This can be done by a simple external timer. But if the process included 10 or more switches and solenoids, then we would need 10 or more external timers. But if the processes also needed to count how many times the switches individually turned ON, then a lot of external counters would be needed. As can be seen, the bigger the process, the more important is the need of a PLC. The PLC can be simply programmed to count its inputs and turn the solenoids ON for the specified time.

Since the PLC is a computer it should be told what to do. The PLC knows what to do through a program that is developed and then entered into its memory. The PLC however, without a set of instructions, is just a black box consisting of electronic components only.

A PLC can control devices such as limit switches, push button, proximity or photo-electric sensors, float switches or pressure switches, etc. to provide the incoming control signals into the unit. The incoming control signal is called the INPUT. These control signals or inputs, interact with the instructions specified in the user program, telling the PLC how to react to the incoming signals. The user program also directs the PLC on how to control field devices such as motor starters, pilot lamps and solenoids. A signal going out of the PLC control to a field device is called an OUTPUT.

PLC can also be defined as per National Electrical Manufacturer Association (NEMA) as a digitally operated electronic system, designed for use in industrial environment, which uses a programmable memory for internal storage of user-oriented instructions for implementing specific functions such as logic, sequencing, timing, counting and arithmetic to control, through digital or analog inputs and outputs, various types of machines or processes. Both the PLC Definition and its associated peripherals are designed so that they can be easily integrated into an industrial control system and easily used in all intended functions.

PLC Structure:

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.

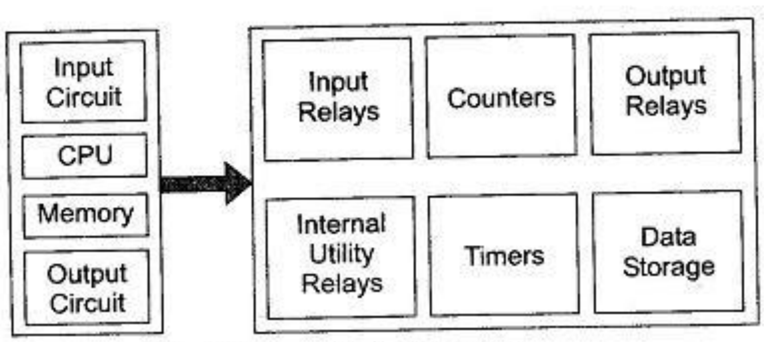


Fig. 21.22 PLC structure

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.

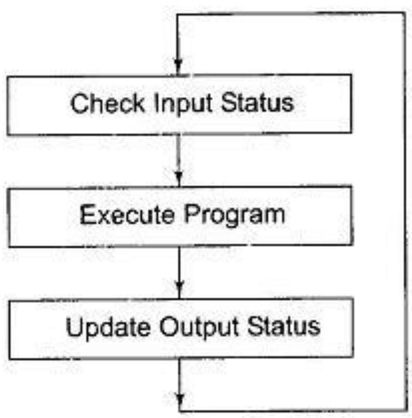


Fig. 21.23 PLC Operation Diagram

The Three important states are:

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:

The main purpose of a PLC is to replace real world relays. A Relays 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.

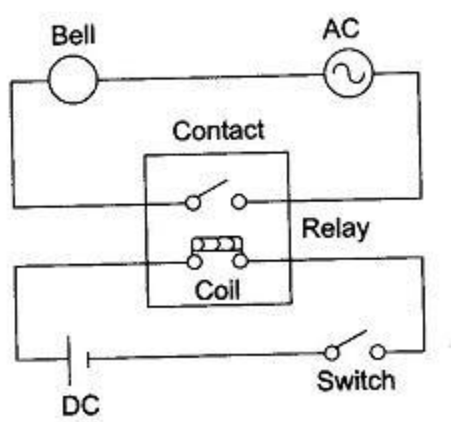


Fig. 21.28 Bell Circuit Diagram

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.

In this case we are using a dc relay to control an ac circuit. When the switch is open, no current flows through the coil of the relay. As soon as the switch is closed, current starts to flow through the coil causing a magnetic field to build up. This magnetic field causes the contacts of the relay to close. Hence, ac current flows through the bell and the sound of the bell can be heard.

Let us now replace the Relays Definition by a PLC. The first process is necessary to create what is called a ladder diagram.

A ladder diagram consists of vertical lines called the **bus bars** and within these vertical lines are placed various horizontal lines consisting of input contacts and output. These horizontal lines are called as **rungs**. We have to create a ladder diagram, but a PLC does not understand a schematic diagram. It only recognizes code. Fortunately most PLCs have software which convert ladder diagrams into code.

First step: We have to translate all of the items we are using into symbols the PLC understands. The PLC does not understand terms like switch, relay, bell etc. It prefers input, output, coil, contact, etc. It does not care what actual input or output device actually is. It only cares that it is an input or an output.

The batteries or power supply is replaced by a symbol. This symbol is common to all ladder diagrams. These are called the bus bars. These look like two vertical lines on either side and the input and output are placed within these bars. The left side can be considered as the voltage and the right side as the ground and the current flow from left to right.

The inputs and outputs each are also given a symbol. The input, that is, the switch will be connected by a symbol, shown in Fig. 21.29. This symbol can also be used as the contact of the Relays.

Only one output is normally used, e.g. a bell. The output that the bell will be physically connected in the circuit by the symbol is shown in Fig. 21.30. This symbol is used as the coil of a relay.

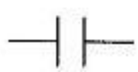


Fig. 21.29

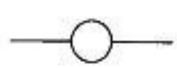


Fig. 21.30

The ac supply is an external supply hence it is not put in the ladder diagram. The PLC only knows and cares about which output it has to turn on.

The PLC must know where everything is located. In other words we have to give all the devices an address. The location where the switch is going to be physically connected to the PLC. Each inputs and outputs used have an address. The PLC has a lot of inputs and outputs but the PLC has to figure out which device is connected where.

The final step is to convert the schematic into a logical sequence of events. The program written tells the PLC what to do when certain events take place. The PLC should be told what to do when the operator turns ON the switch. The diagram shown in Fig. 21.31 is the final converted diagram. In Fig. 21.31, the input is called as ‘0000’ and output is called as ‘0500’.

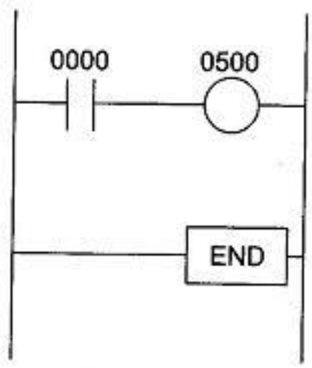
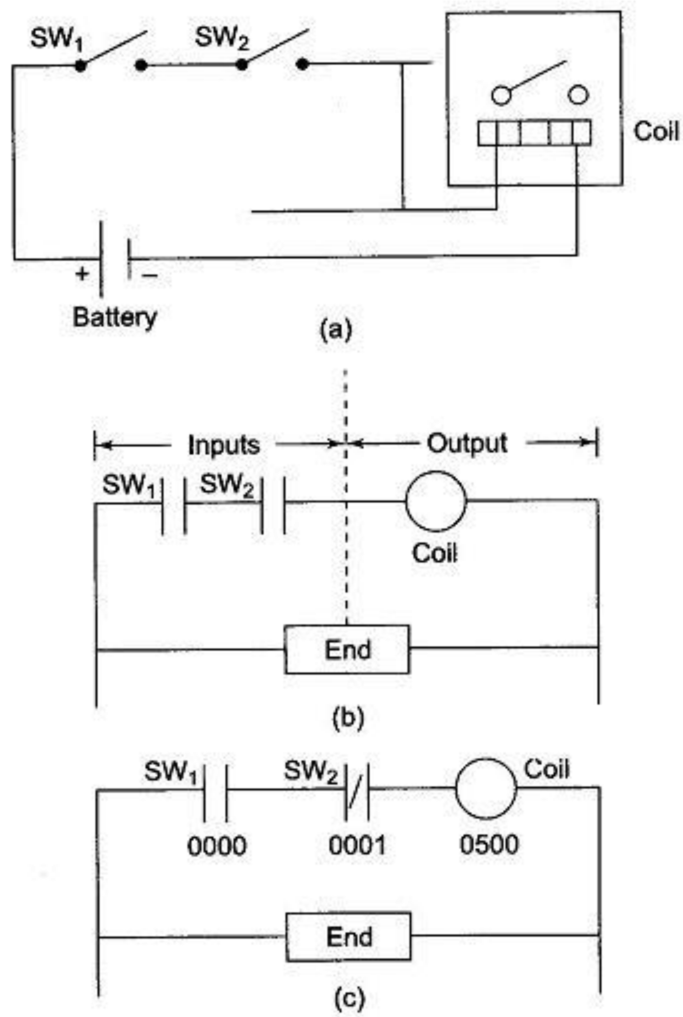


Fig. 21.31 Basic Ladder Diagram

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).

Hence, in Fig. 21.32(c), SW1 will be physically OFF and SW2 will be physically ON initially. Each symbol or instruction has been given an address. This address sets aside a certain storage area in the PLC data files so that the status of the instruction (i.e. true/false) can be stored. Most PLCs uses 16 slots or bit storage locations. In the example given above, two different storage locations or PLC Register are used.

15	14	13	12	11	10	Register 00									
15	14	13	12	11	10	09	08	07	06	05	04	03	02	01	00
														1	0
							Register 05								
15	14	13	12	11	10	09	08	07	06	05	04	03	02	01	00
															0

(d)

Fig. 21.32

In the tables of two registers 00 and 05 shown in Fig. 21.32(d), we can see that in register 00, bit 00 corresponding to input 0000 was a logic 0 and bit 01 corresponding to input 0001 was a logic 1. Register 05 shows that bit 00 corresponding to output 0500 was a logic 0. The logic 0 or 1 indicate whether an instruction is False or True.

The PLC will only energise an output when all conditions on the rung are TRUE. Hence, in the above example, SW1 must be logic 1 and SW2 must be logic 0, then and only then the output (coil) will be True, that is energized.

If any instruction on the rung before the output (coil) is false, then the output (coil) will be false (not energized).