

PROTOTYPE MODEL OF MAGLEV TRAIN USING LINEAR RELUCTANCE MOTOR

Submitted by:-

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INTRODUCTION

- ◉ **Maglev** (magnetic levitation), is a system of transportation that suspends, guides and propels vehicles, predominantly trains, using magnetic levitation from a very large number of magnets for lift and propulsion.
- ◉ In **INDIA** a *maglev* was planned to implement in the route Delhi-Mumbai which would reduce the travel time from 22 hours to 3 hours that was further reduced to Pune-Mumbai in 2003 but due to high capital cost it is being delayed.

HISTORY

- ◉ The first commercial Maglev "people-mover" was officially opened in 1984 near Birmingham, England.
- ◉ The most well known implementation of high-speed maglev technology currently operating commercially is the Shanghai Maglev Train(German-built Transrapid train in Shanghai, China).
- ◉ The highest recorded speed of a Maglev train is 581 kilometres per hour (361 mph), achieved in Japan in 2003.

ADVANTAGES

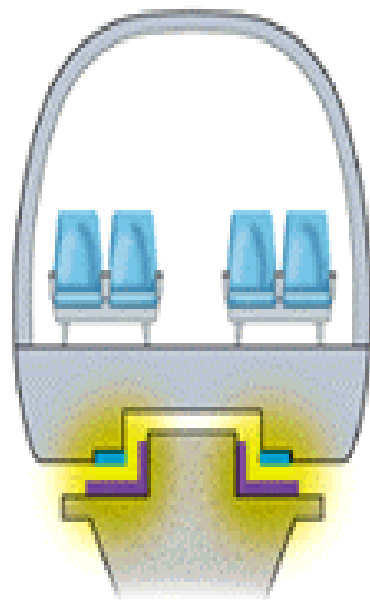
- ⦿ This method has the potential to be faster, quieter and smoother than wheeled mass transit systems.
- ⦿ The power needed for levitation is usually not a particularly large percentage of the overall consumption.
- ⦿ There is no friction between the track & train as they don't touch each other.
- ⦿ They have got high power efficiency.

DISADVANTAGES

- ◉ Magnet reliability at higher temperatures is a major disadvantage.
- ◉ EMS Maglev needs very fast-responding control systems to maintain a stable height above the track; this needs careful design in the event of a failure in order to avoid crashing into the track during a power fluctuation.
- ◉ Maglev trains currently in operation are not compatible with conventional track, and therefore require all new infrastructure for their entire route.

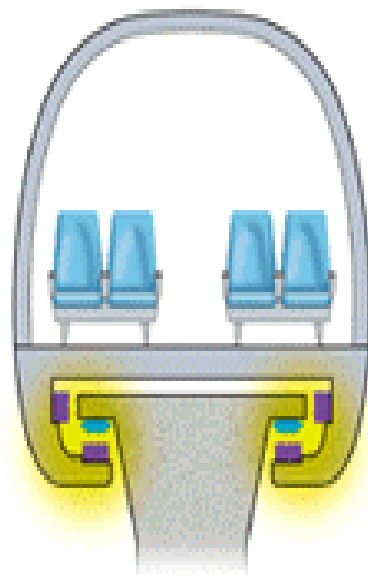
Levitation Techniques

ELECTRODYNAMIC



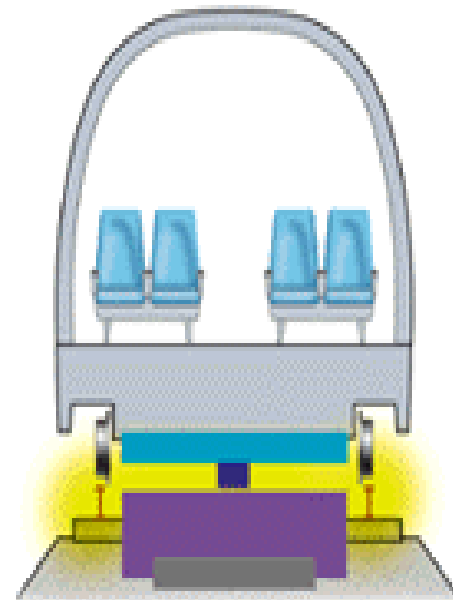
Electromagnets on the guideway levitate the car.

ELECTROMAGNETIC



Electromagnets on the cars lift the cars.

INDUCTRACK



Permanent magnets levitate over passive coils.

ELECTRO-DYNAMIC SUSPENSION

- ◉ EDS uses the repulsive force between superconducting magnets mounted in the vehicle and other conducting magnets in its "U"-shaped guideway to keep the vehicle levitating.

ELECTROMAGNETIC SUSPENSION

- ◎ It utilizes the attractive force of magnets by wrapping the bottom of the vehicle around the track and mounting magnets in the part of the vehicle that's below the track. This way, the electromagnets underneath are attracted to the track, made of a ferromagnetic substance and just enough energy is put into the electromagnets to keep the vehicle hovering around the track.

- ◉ A MagLev train using the EMS system pulls itself along the track with a linear synchronous motor, which uses the electromagnetic currents in the vehicle to attract it to the track ahead of it, so that the vehicle is drawn further along the track. The speed is adjusted by changing the frequency of the electromagnetic fields pulling the vehicle.

INDUCTRACK

- ◉ There is one final type of magnetic levitation technology that is used solely in the American version of MagLev, known as Inductrack.
- ◉ Inductrack employs an array, or a set of large, powerful bar magnets arranged very carefully, so that an enhanced magnetic field is generated below the array, but none above it.

- ◉ Also, the array of magnets acts like a coiled spring - as the distance between the array and the track decreases, the levitating force increases exponentially, so that no matter how heavy the cars are, they will still hover above the track.

SWITCHED RELUCTANCE MOTORS

- ⦿ Switched reluctance machines (LSRMs) are an attractive alternative to linear induction or synchronous machines due to lack of windings on either the stator or rotor structure.
- ⦿ A reluctance motor is an electric motor in which torque is produced by the tendency of its movable part to move to a position where the inductance of the excited winding is maximized OR the magnetic circuit tends to adopt a configuration of minimum reluctance.

CLASSIFICATION

- ◉ Based on the nature of motion they are classified as:
 - **Rotatory switched reluctance motor (RSRM)**
 - **Linear switched reluctance motor (LSRM)**
- ◉ Based on the direction of the flux path with respect to the axial length of the machine the SRMs are further differentiated as:
 - **Longitudinal flux configuration**
 - **Transverse flux configuration**

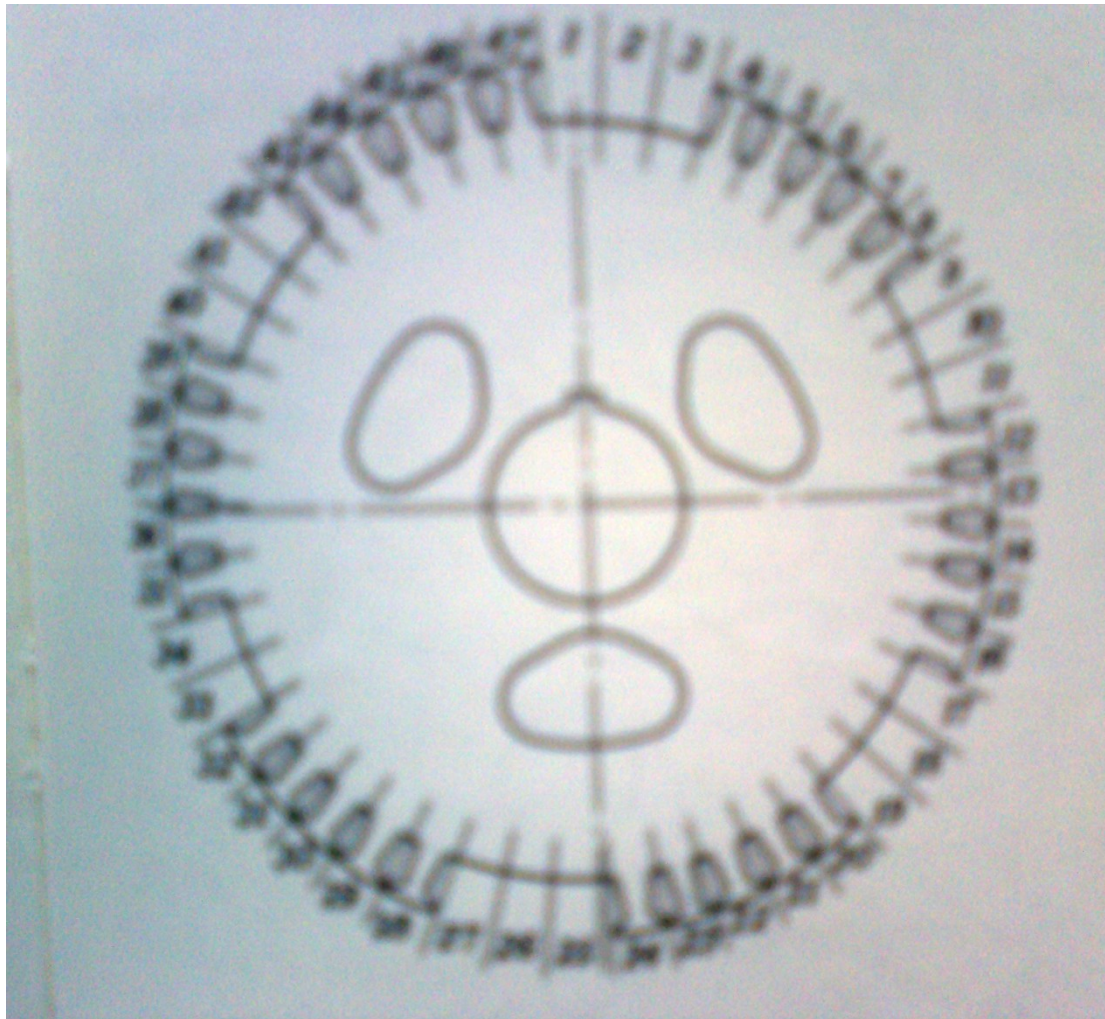
ADVANTAGES

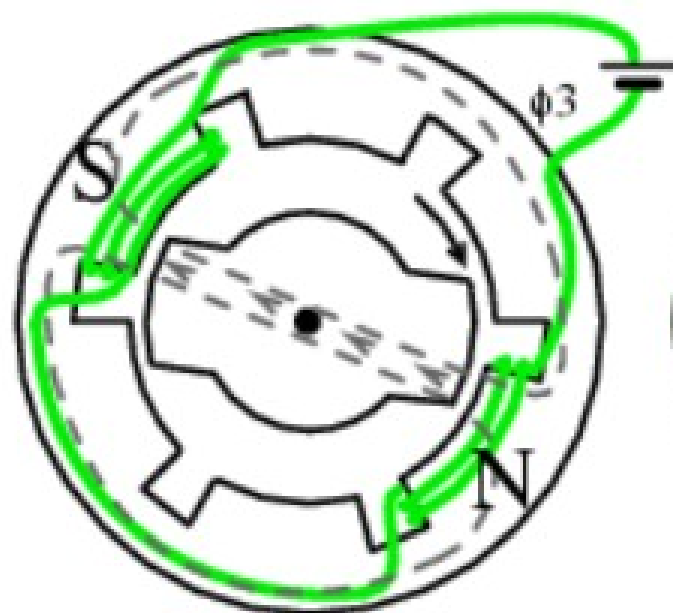
- ⊙ Lack of windings on either the stator or rotor structure.
- ⊙ Absence of mechanical gears.
- ⊙ Ideal for manufacturing and maintenance as the winding are concentrated rather than distributed.
- ⊙ Inexpensive secondary material.
- ⊙ Absence of significant heat sources during secondary operation and only one part of the secondary that is opposite to the primary is present in the magnetic field.

USES

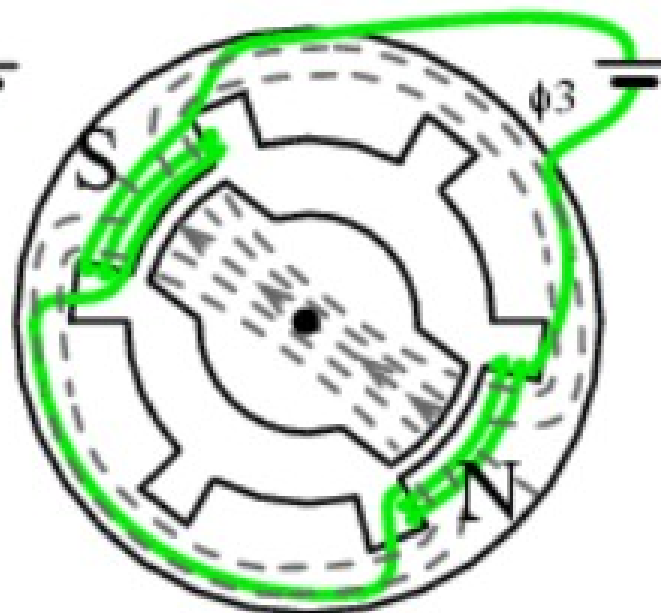
- ⦿ These motors are increasingly chosen for material-handling applications because they are quieter, more reliable, and less expensive than rotary electric motors.
- ⦿ Material handling systems, which require low speed operations.
- ⦿ Transporting materials inside a totally contained system.
- ⦿ Food processing plants, to move the items from one place to another during processing stage.

ROTATORY SWITCHED RELUCTANCE MOTOR (RSRM)

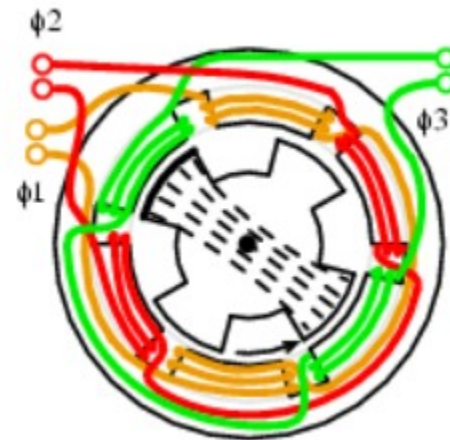
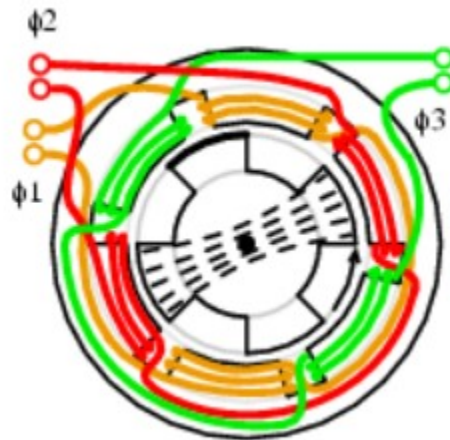
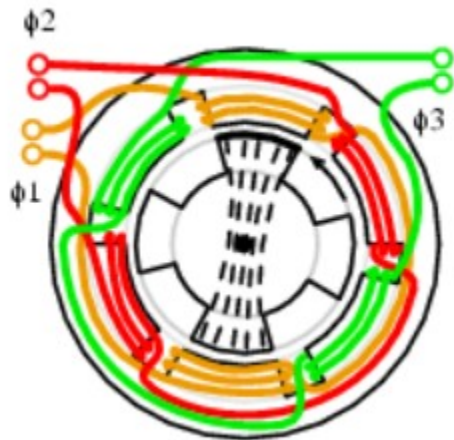
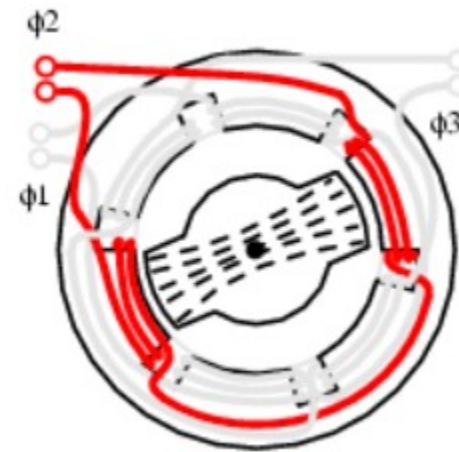
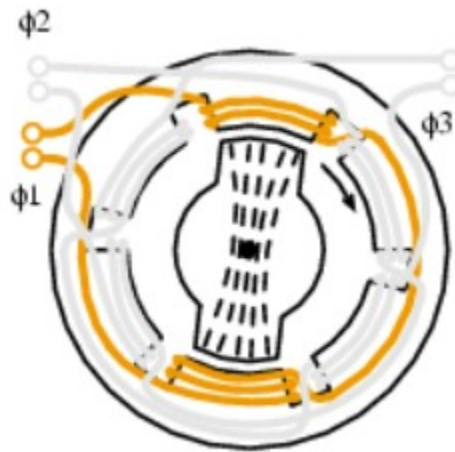
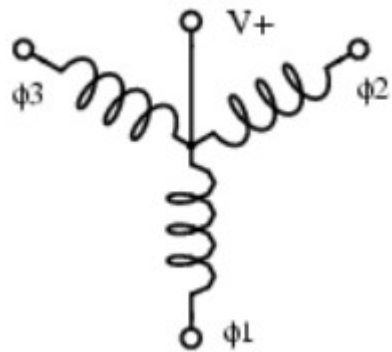


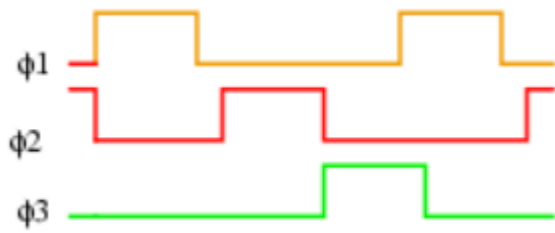


high reluctance



low reluctance

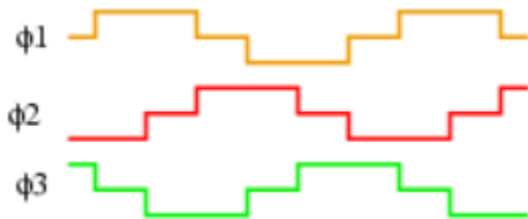




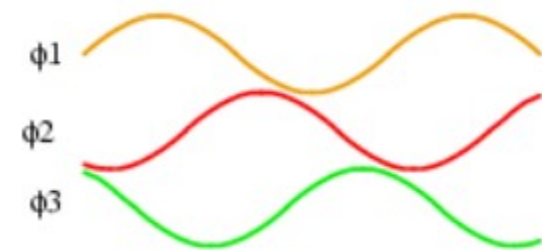
Unipolar wave



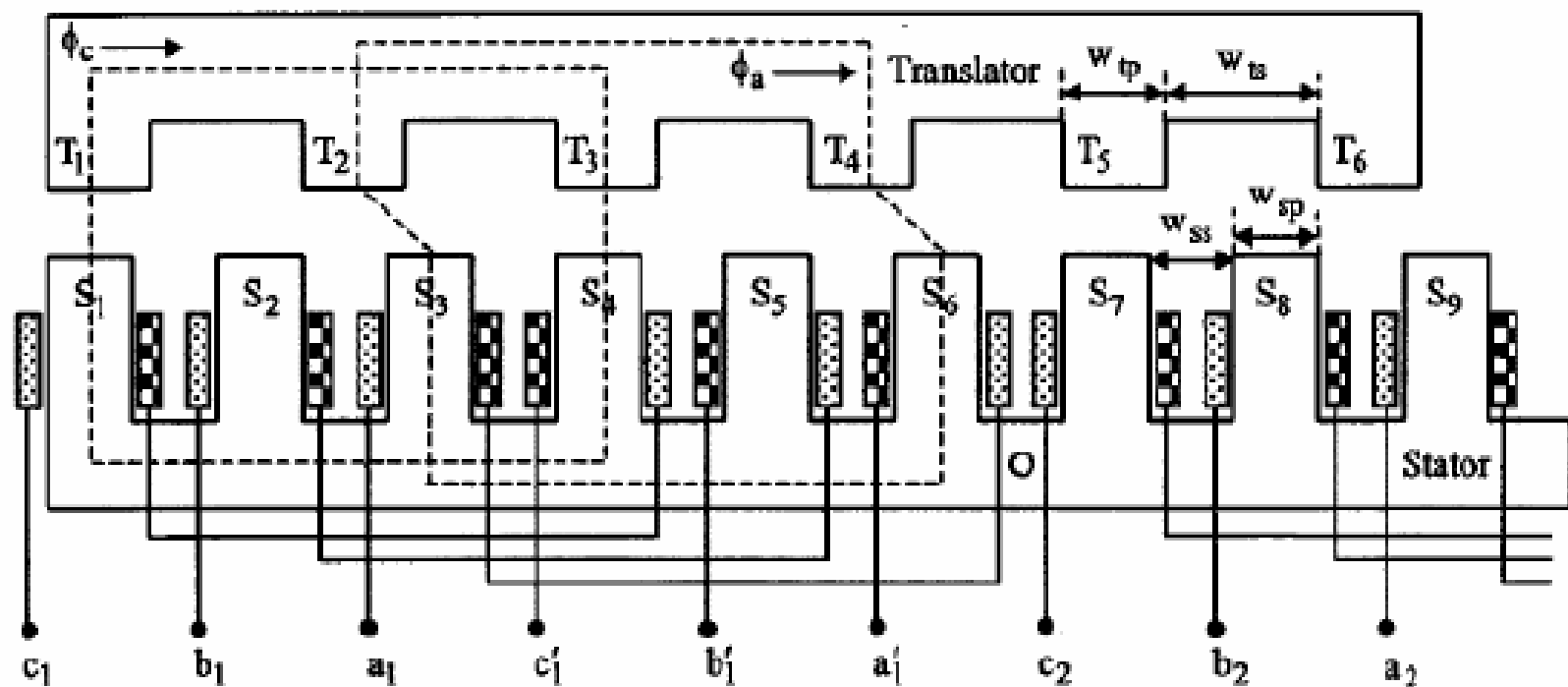
Bipolar full step



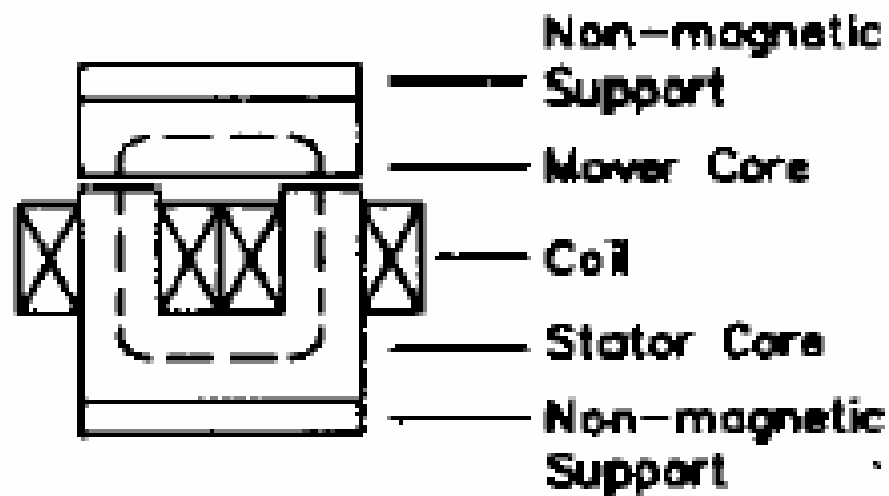
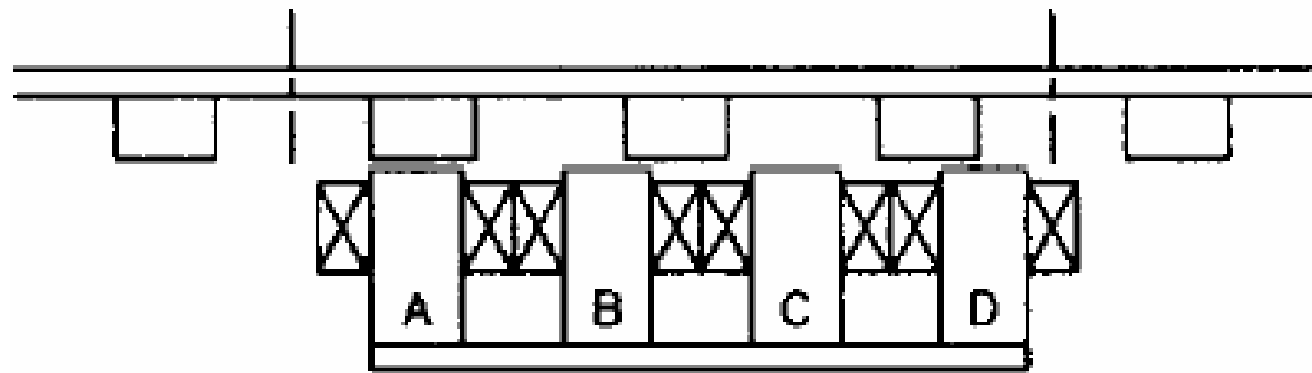
Bipolar 6-step



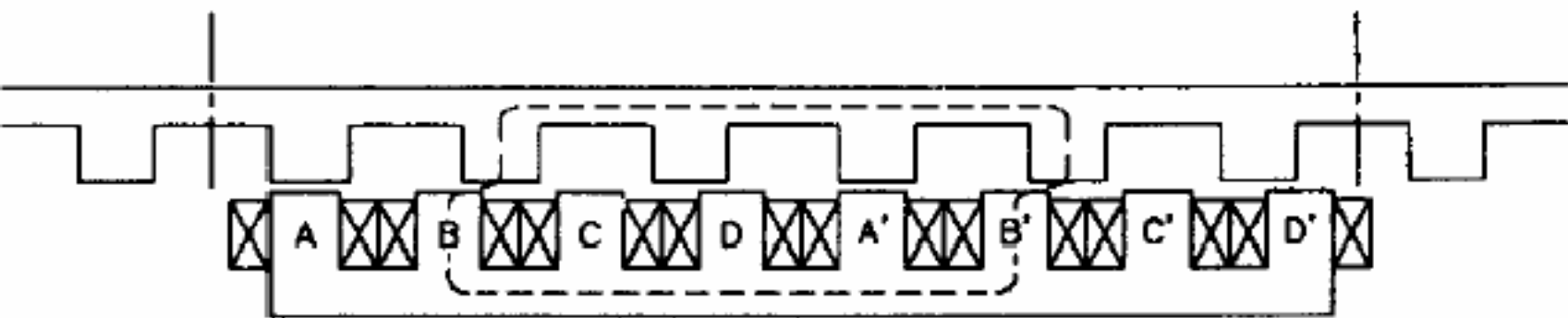
Sine-wave



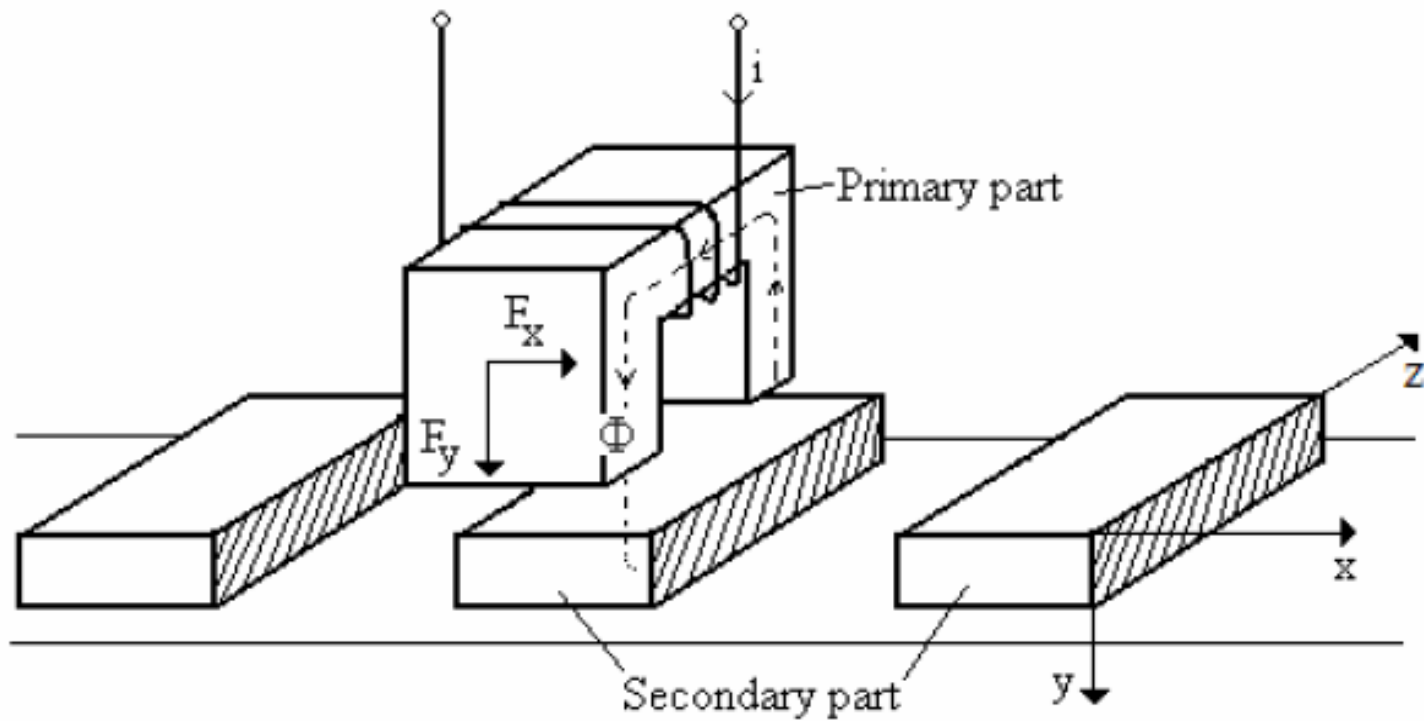
LINEAR SWITCHED RELUCTANCE MOTOR (LSRM)



TRANSVERSE FLUX CONFIGURATION OF LSRM



LONGITUDINAL FLUX CONFIGURATION OF LSRM



SINGLE-PHASE LINEAR RELUCTANCE MOTOR WITH U-SHAPED PRIMARY CORE

SINGLE PHASE RELUCTANCE MOTOR WITH U-SHAPED PRIMARY CORE

- ⊙ The motor consists of primary part that possesses the winding and secondary part.
- ⊙ The winding of the primary is supplied by the voltage v , *which causes the current i to flow.*
- ⊙ *The current produces the* magnetic flux φ that is closed through the path that is perpendicular to the direction of motion (axis x).
- ⊙ Due to the magnetic field, the primary part is affected by two forces: linear force and attraction force .

DERIVATION OF FORMULAE

⊙ We know , magnetic energy stored in coils is

$$E = 0.5 i^2 * dL$$

$$\text{or, } f_x dx = 0.5 i^2 * dL$$

$$\text{So, } f_x = 0.5 i^2 * dL/dx$$

Now magnetic energy density in air gap,

$$E_g/V = 0.5 B^2 / \mu_o$$

$$\text{Or, } F_y * 2g = (0.5 B^2 / \mu_o) * A_g * 2g$$

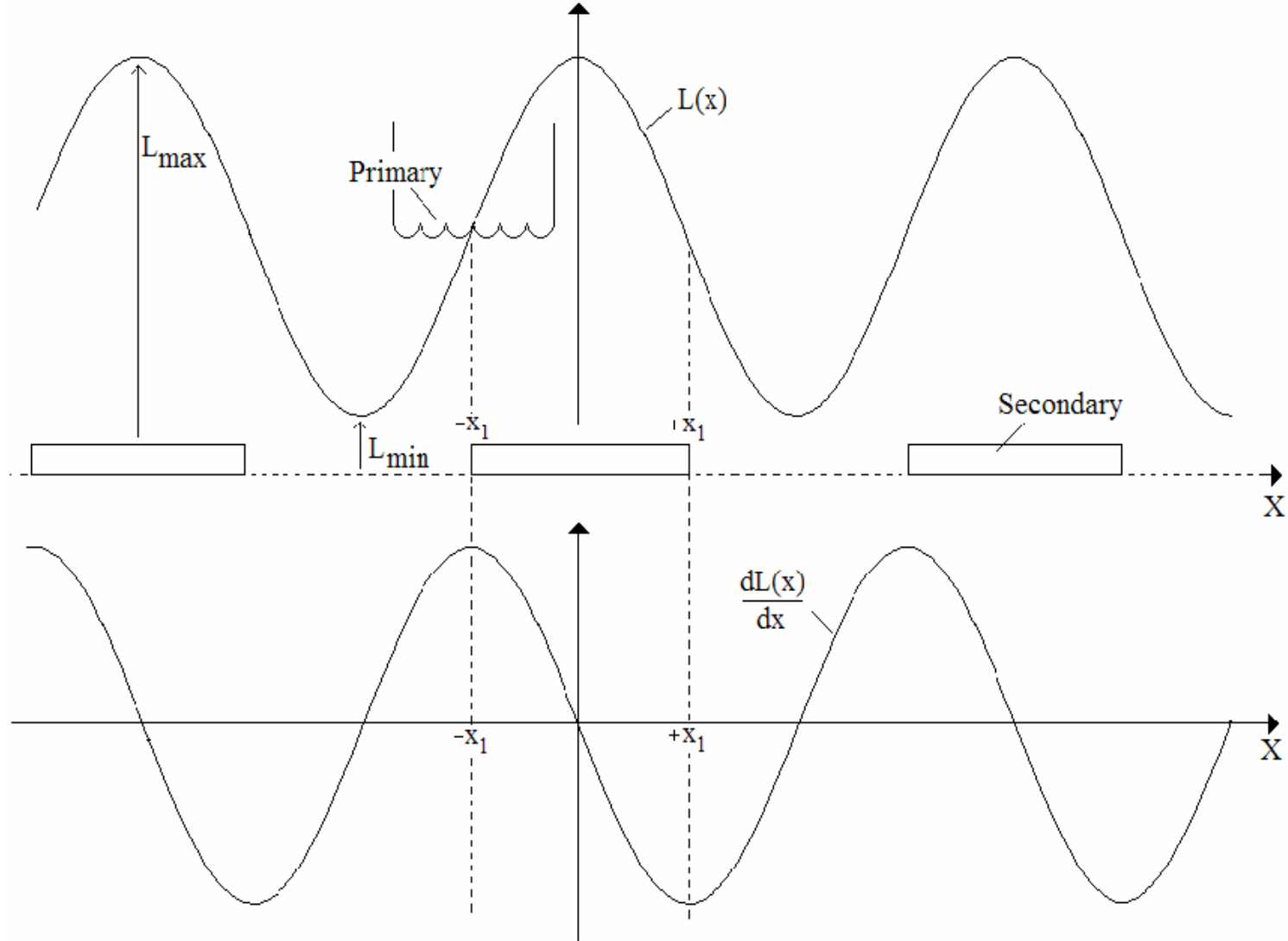
$$\text{So, } F_y = (0.5 B^2 / \mu_o) * A_g$$

- ⊙ The linear force, which is the driving force, is expressed by the formula:

$$f_x = \frac{1}{2} i^2 \frac{dL(x)}{dx}$$

where, $L(x)$ is the coil inductance which is expressed as the function of x co-ordinate.

The higher the value of $\frac{dL(x)}{dx}$ the stronger the driving force.



INDUCTANCE AND DERIVATIVE OF INDUCTANCE CHANGING

- ⊙ The primary is always affected (when coil is excited) by the attractive force, expressed by the equation:

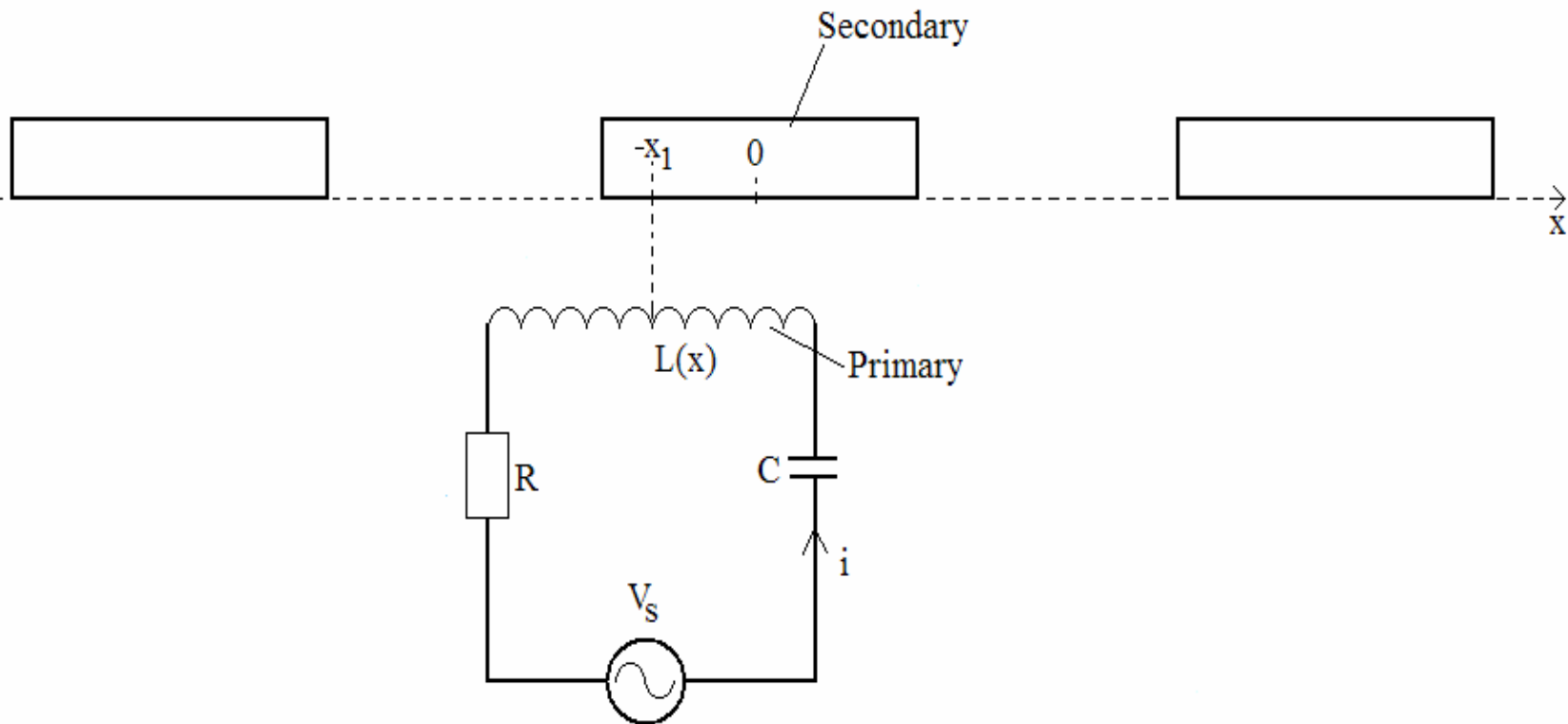
$$f_y = \frac{B^2}{2\mu_0} \cdot A_g$$

where, B is the magnetic flux density in the air-gap and A_g is the active area between the two motor parts.

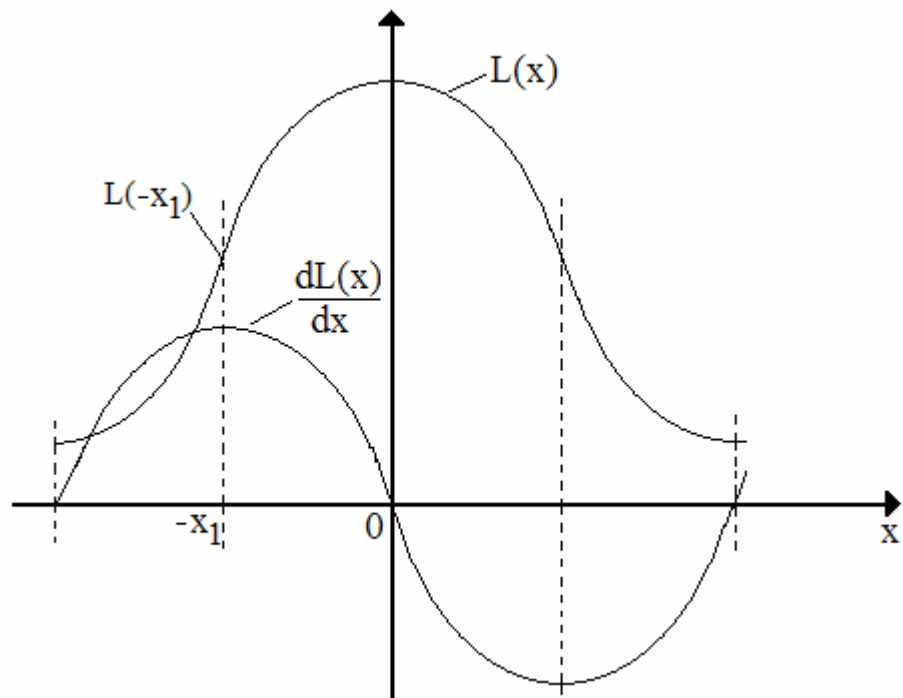
This force will also change during the primary part movement along x co-ordinate, due to the variation in B and A_g .

AC SUPPLY

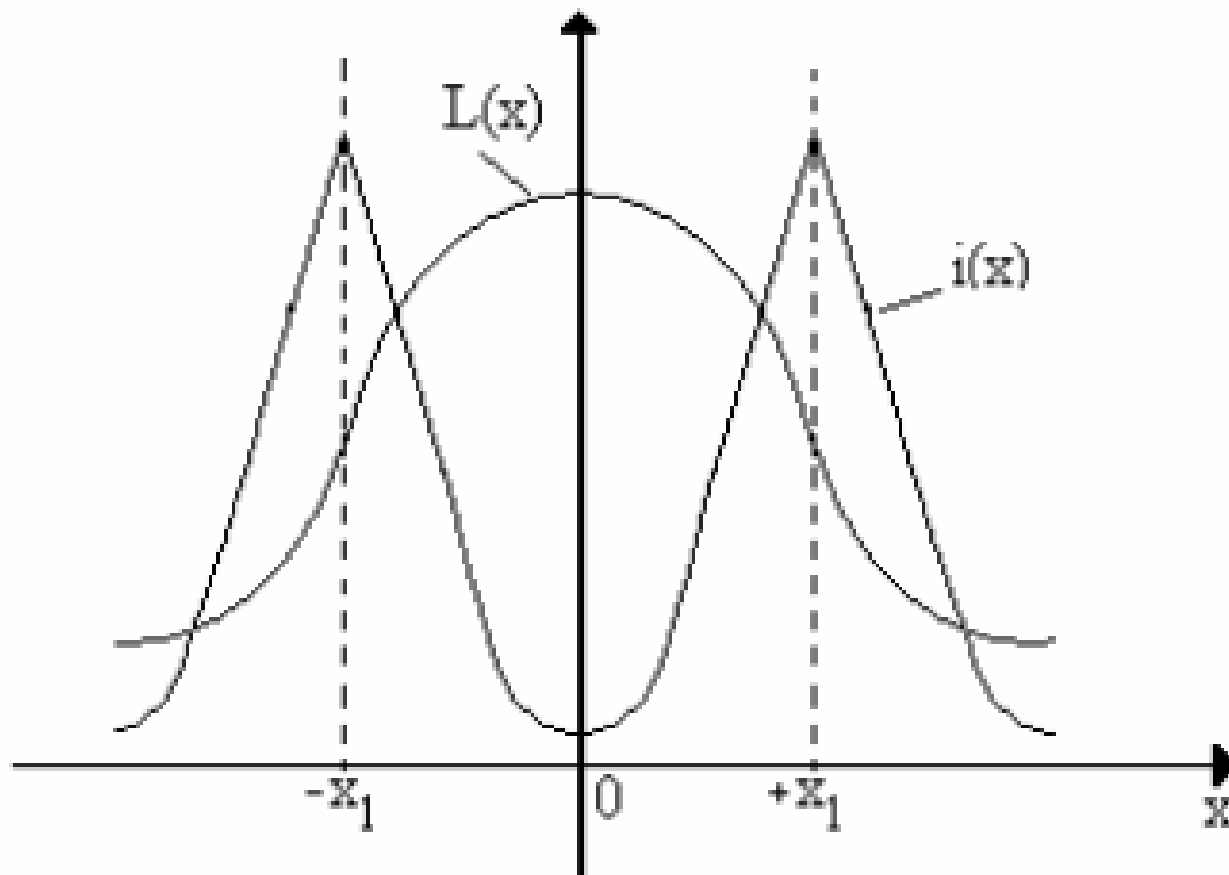
- The reluctance motor when supplied from AC source operates on the principle of resonance in RLC circuit of primary part.



- ⊙ The primary coil moves with respect to the secondary in the x *direction*. *During* this motion the inductance of the coil L *changes since it depends on the position of the* primary part with respect to the secondary part.
- ⊙ Suppose, the middle of the primary coil is placed at the distance then the inductance of the coil is equal to $L(-x_1)$.



INDUCTANCE AND THE DERIVATIVE OF INDUCTANCE
WAVE FORMS.



INDUCTANCE AND RESONANCE CURRENT AS A FUNCTION OF
DISPLACEMENT x

OUR MODEL

1.PRIMARY:-

MECHANICAL DESIGN:

- ◎ CORE-U SHAPED

- ◎ WEIGHT- 120 g

- ◎ DIMENSIONS-

POLE LENGTH-1cm

POLE WIDTH-1cm

POLE HEIGHT- 4 cm

PHYSICAL DESIGN-

$$E = 4.44 N f \Phi_m, \text{ where } \Phi_m = A * B,$$

where, A=area of cross section and
B=permissible magnetic flux density ,for
laminated steel is equal to 1.8 Tesla.

Here, $A = 1 \text{ cm}^2$

Therefore, $N = V / (4.44 f A B)$, $V = E(\text{approx.})$

By, this formula N comes out to be 300

ELECTRICAL DESIGN:

- ⊙ SUPPLY-14 Vac 50Hz
- ⊙ IMPEDANCE OF WINDING-46.9 ohm
- ⊙ RESISTANCE OF WINDING-3.0 ohm
- ⊙ MAX.CURRENT-1.90 A

MAGNETIC DESIGN:

- ⊙ NO. OF AMPERE-TURNS-570AT
- ⊙ INDUCTANCE-149mH

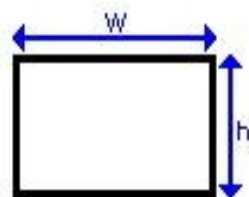
2.SECONDARY:-

MECHANICAL DESIGN:

- ⦿ MATERIAL USED:-SOFT IRON
- ⦿ DIMENSIONS:
- ⦿ LENGTH-5.8 cm
- ⦿ WIDTH-1 cm
- ⦿ THICKNESS-3 mm
- ⦿ SPACING BETWEEN CONSECUTIVE SECONDARY SEGMENTS-4.5 cm

Inductance Calculations: Rectangular Loop

Loop of wire with rectangular shape



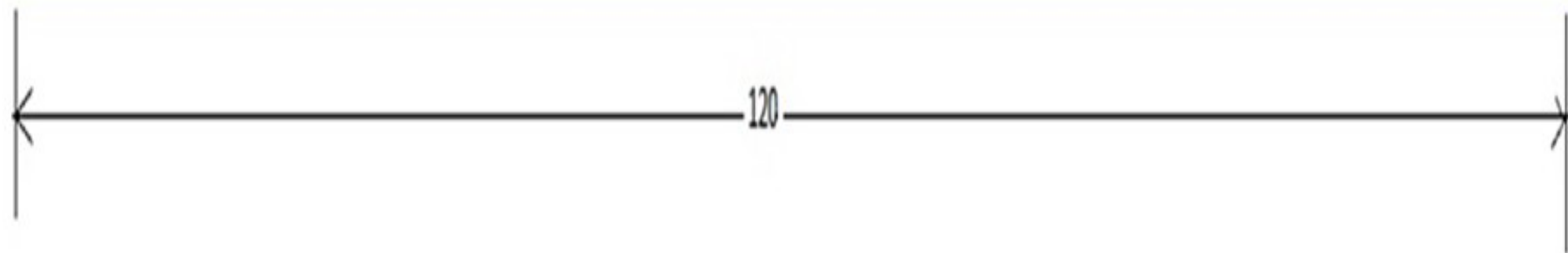
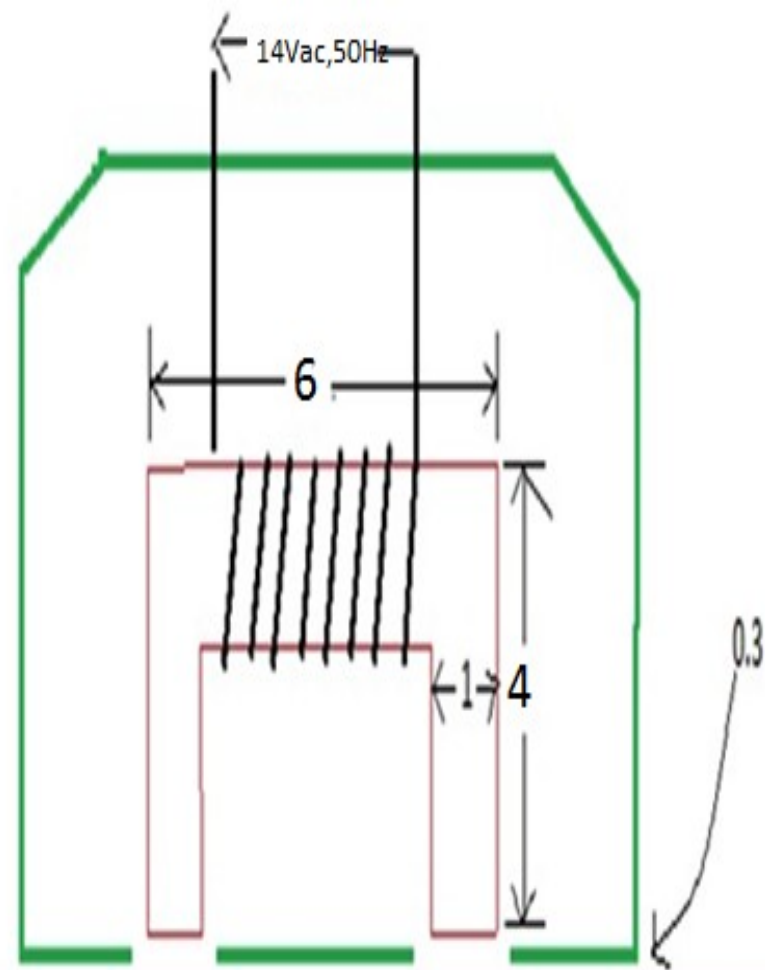
N	350	[]	number of turns
w	.01	[m]	width of the rectangle
h	.01	[m]	height of the rectangle
a	.001	[m]	wire radius
μ_r	100	[]	relative permeability of the medium
L	0.1498000803929392	[H]	Inductance

Calculate

Clear

NOTE: numbers are in scientific notation (e.g.: 1.427e-9 H = 1.1427·10⁻⁹ H = 1.427 nH)

$$L_{rect} \approx N^2 \frac{\mu_0 \mu_r}{\pi} \left[-2(w+h) + 2\sqrt{h^2 + W^2} - h \ln \left(\frac{h + \sqrt{h^2 + W^2}}{W} \right) - W \ln \left(\frac{W + \sqrt{h^2 + W^2}}{h} \right) + h \ln \left(\frac{2h}{a} \right) + W \ln \left(\frac{2W}{a} \right) \right]$$



3.LEVITATION SYSTEM:-

SPECIFICATIONS OF MAGNETS USED FOR
LEVITATION:-

DIMENSIONS-1cm * 1cm *0.2 cm

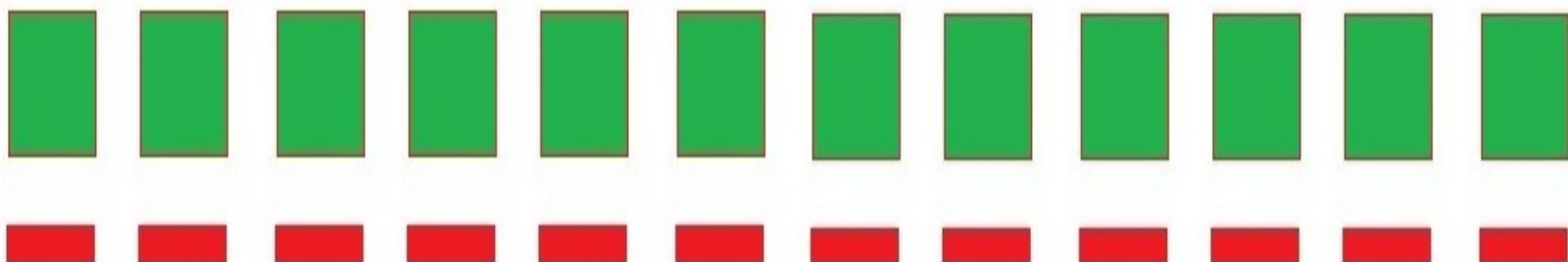
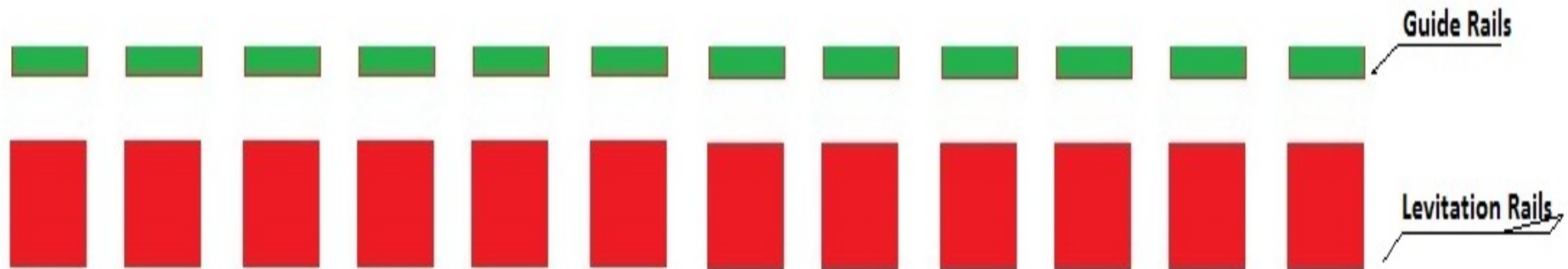
MAGNETIC PROPERTIES-

FACE TO FACE MAGNETIC STRENGTH = 0.53 Tesla

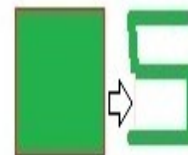
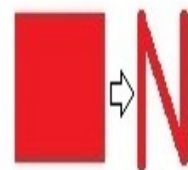
MAGNETIC STRENGTH AT 3MM- 0.42T

NO. OF MAGNETS USED-100

EXPECTED RELUCTANCE CLEARANCE- 3mm



Top View of Track



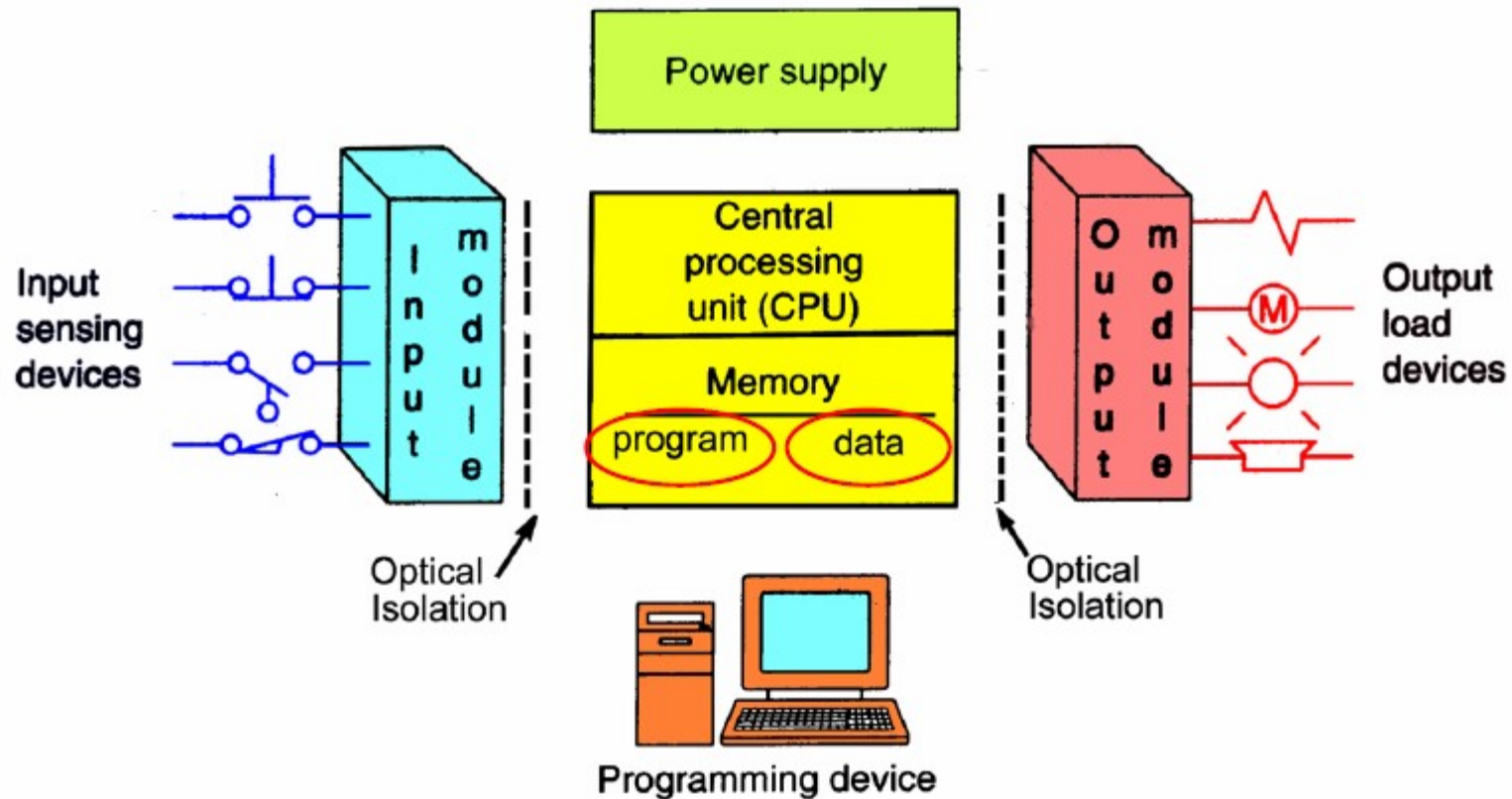
BASICS OF PLC PROGRAMMING

- ◉ The first Programmable Logic Controller (PLC) was developed by a group of engineers at General Motors in 1968, when the company were looking for an alternative to replace complex relay control systems.

The new control system had to meet the following requirements:

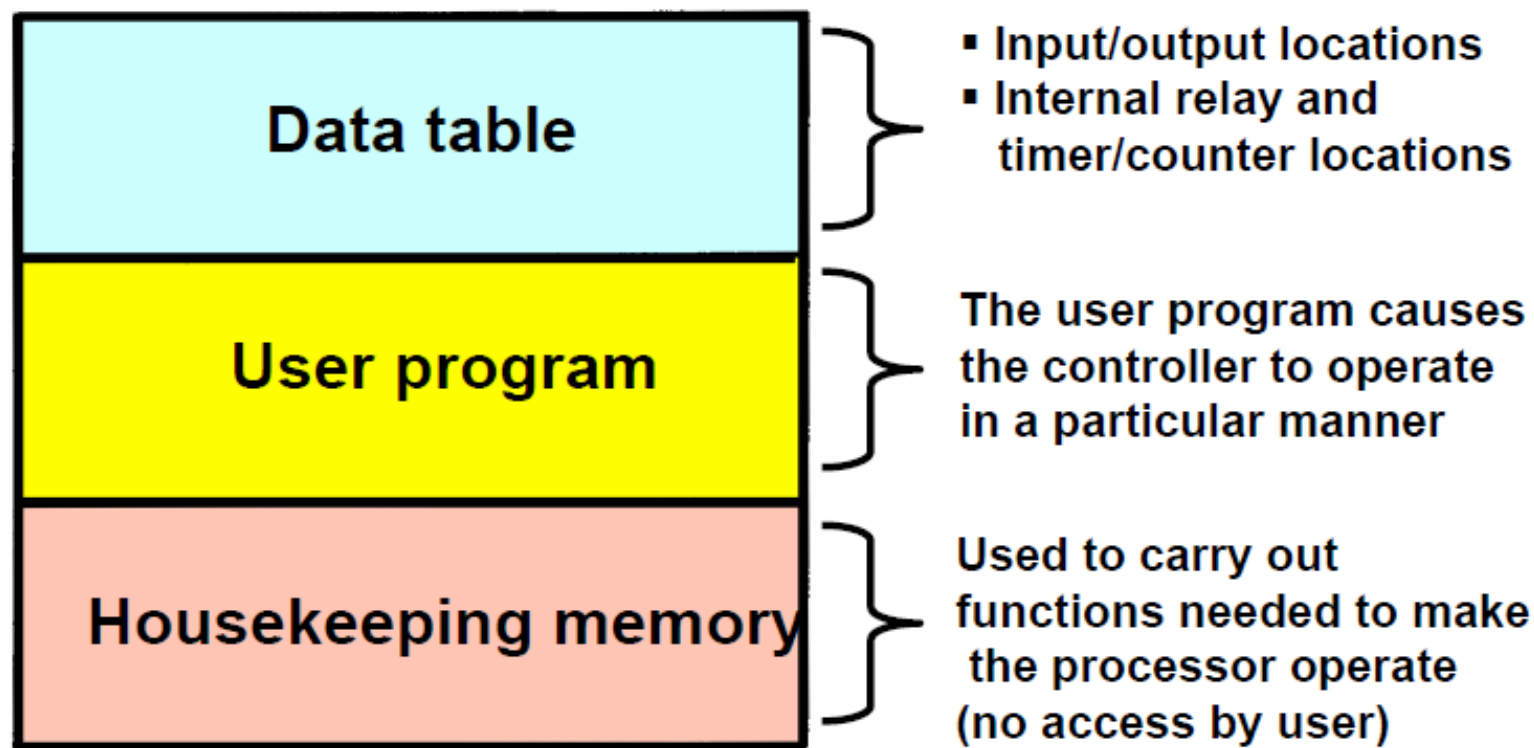
- ◉ Simple programming
- ◉ Program changes without system intervention (no internal rewiring)
- ◉ Smaller, cheaper and more reliable than corresponding relay control systems
- ◉ Simple, low cost maintenance

PLC System

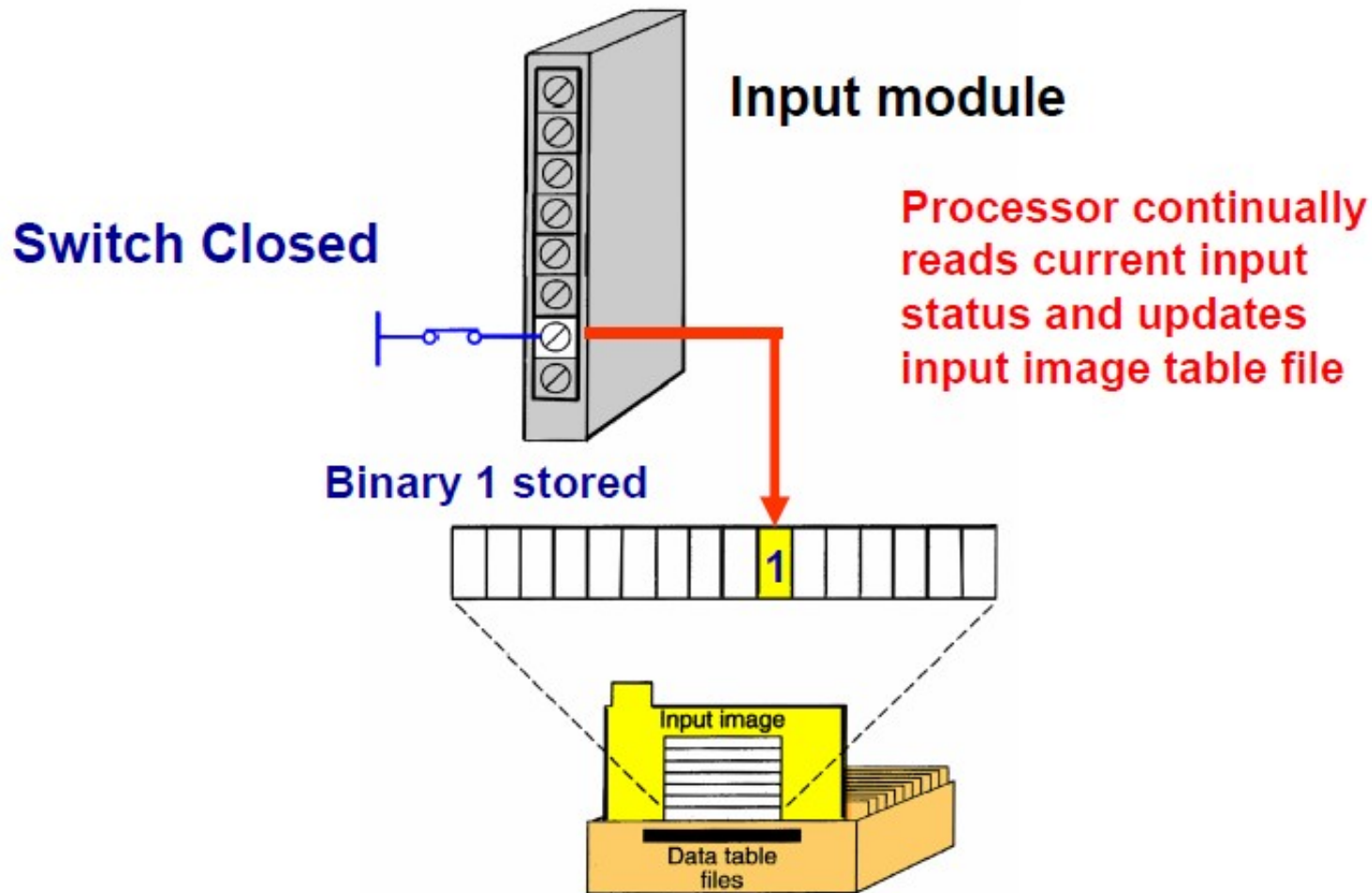


Memory Map

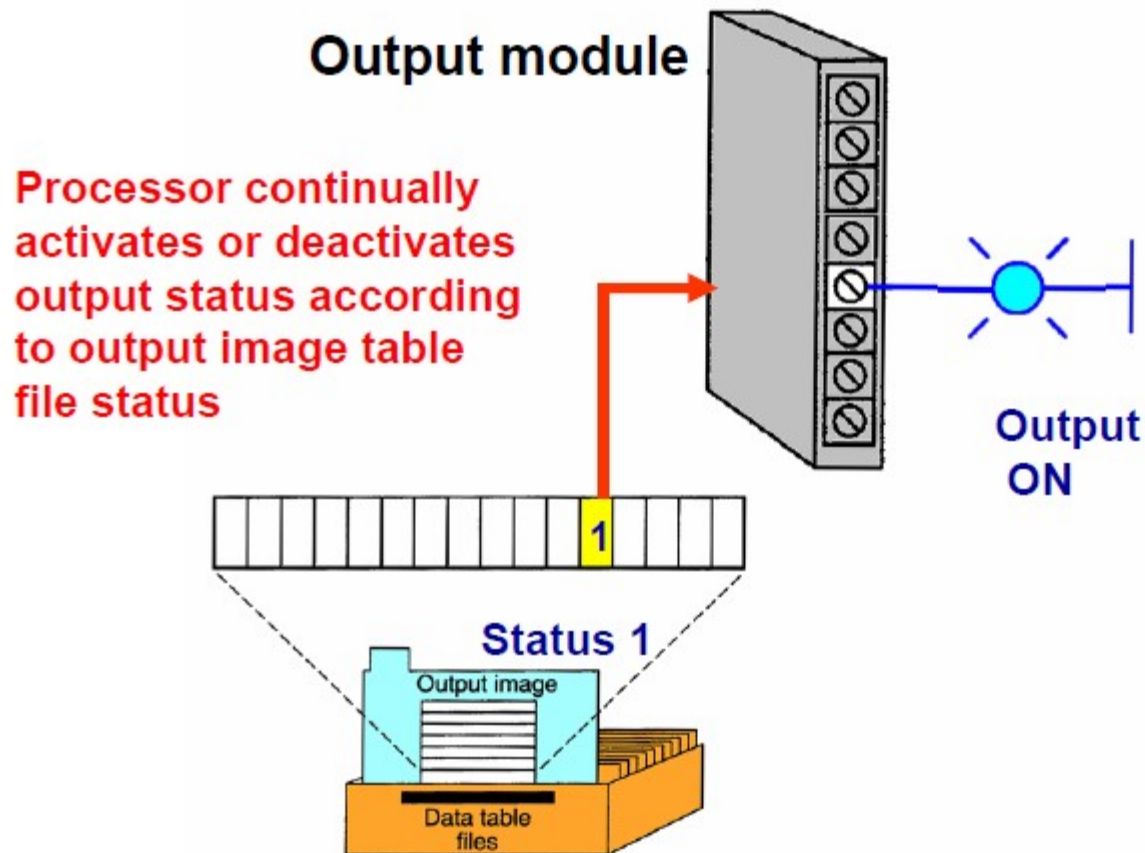
A memory map can be used to show how memory is organized in a PLC.



Input Table File Operation

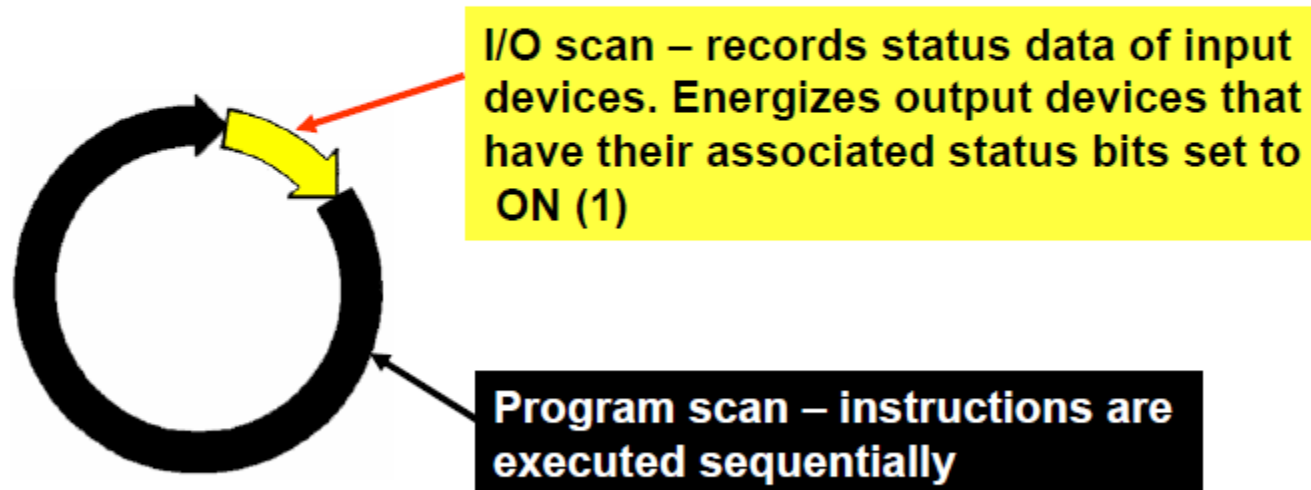


Output Table File Operation



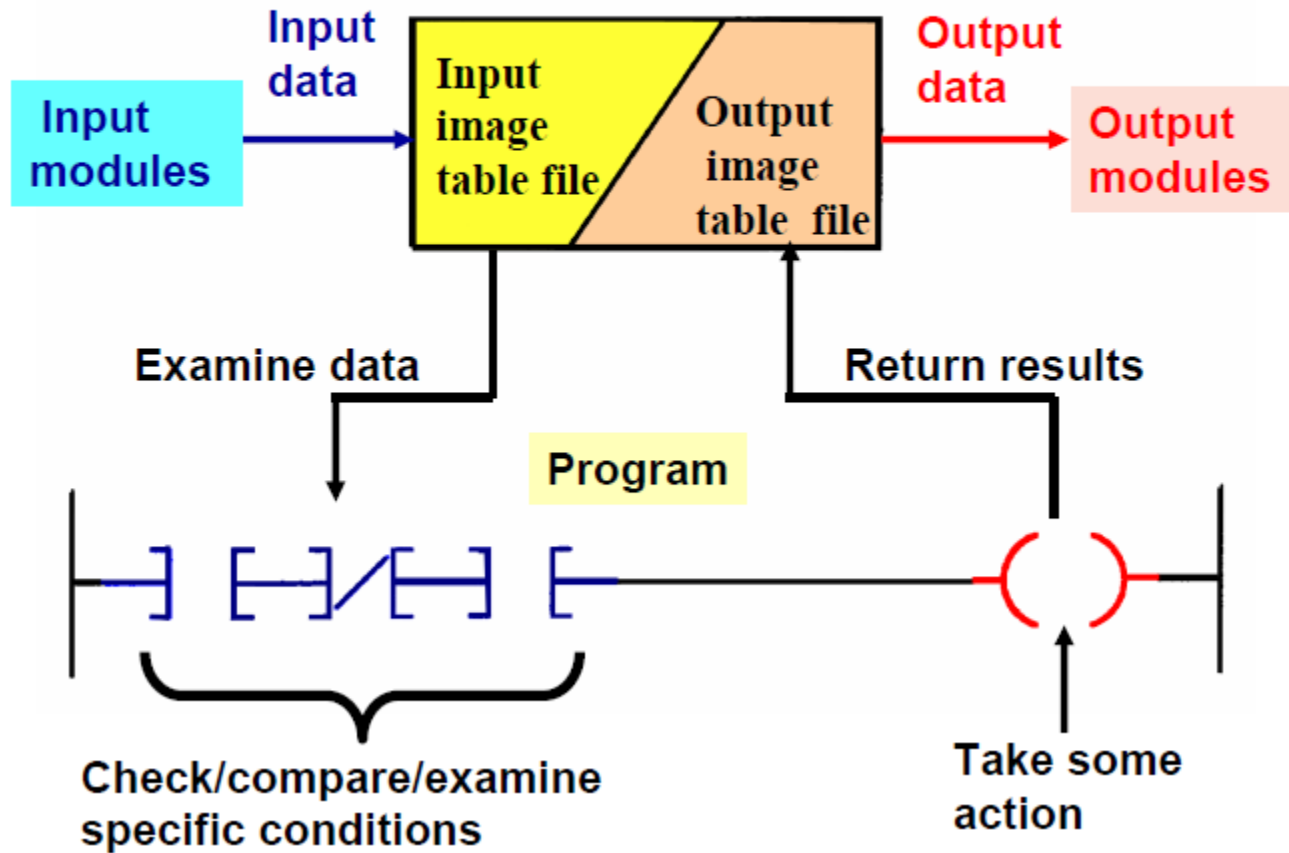
Program Scan

During each operating cycle, the processor reads all inputs, takes these values, and energizes or de-energizes the outputs according to the user program. This process is known as a *scan*.

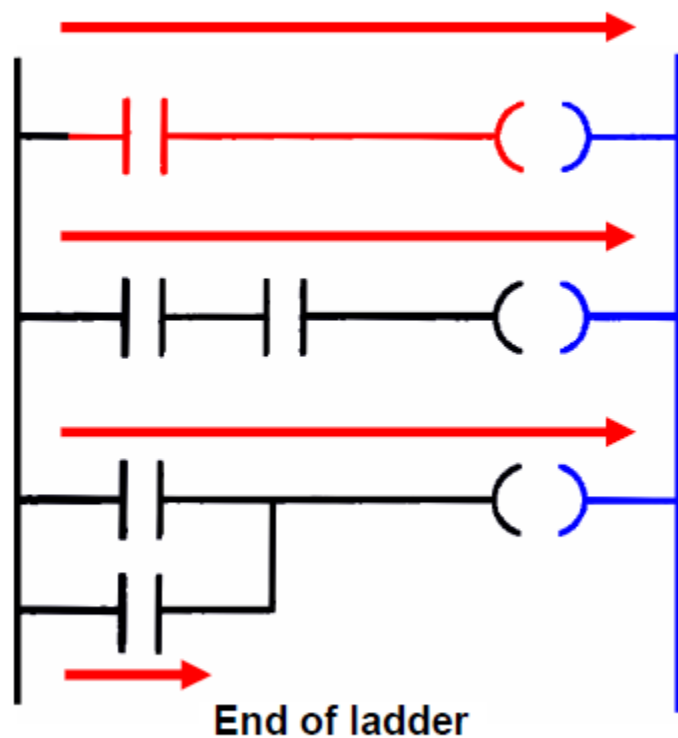


Because the inputs can change at any time, the PLC must carry on this process continuously.

Data Flow Overview



Scan Patterns



Horizontal Scanning Order

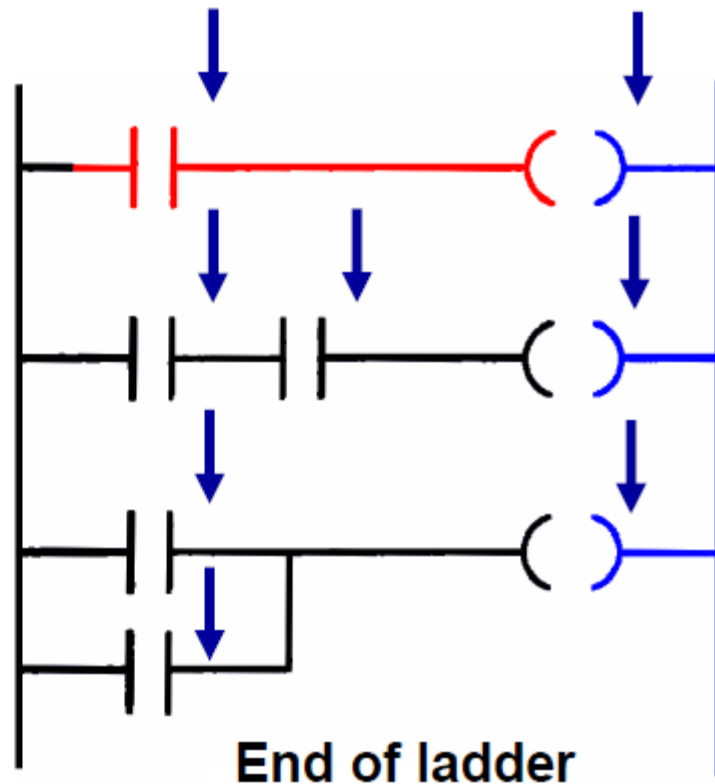
The processor examines input and output instructions from the first command, top left in the program, horizontally, rung by rung.

In addition to the program itself, the scan time is also dependent on the clock frequency of the processor!

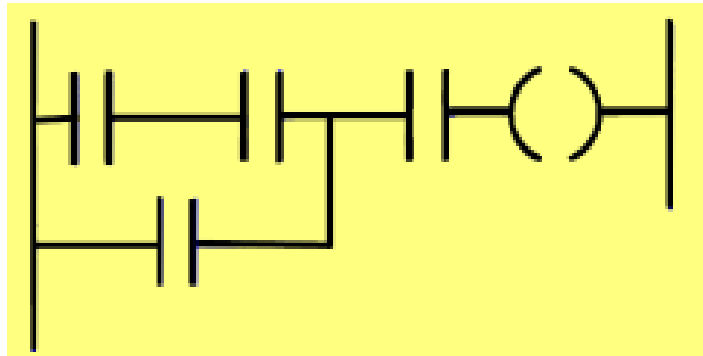
Scan Patterns

Vertical Scanning Order

The processor examines input and output instructions from the first command, vertically, column by column and page by page. Pages are executed in sequence.



Misunderstanding the way the PLC scans can cause programming bugs!

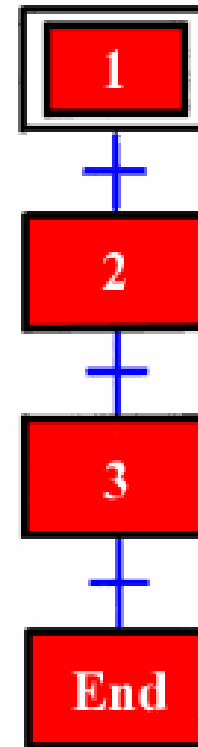


Ladder diagram language

START	PB1
AND	CR1
OR	LS1
AND NOT	CR2
OUT	SOL

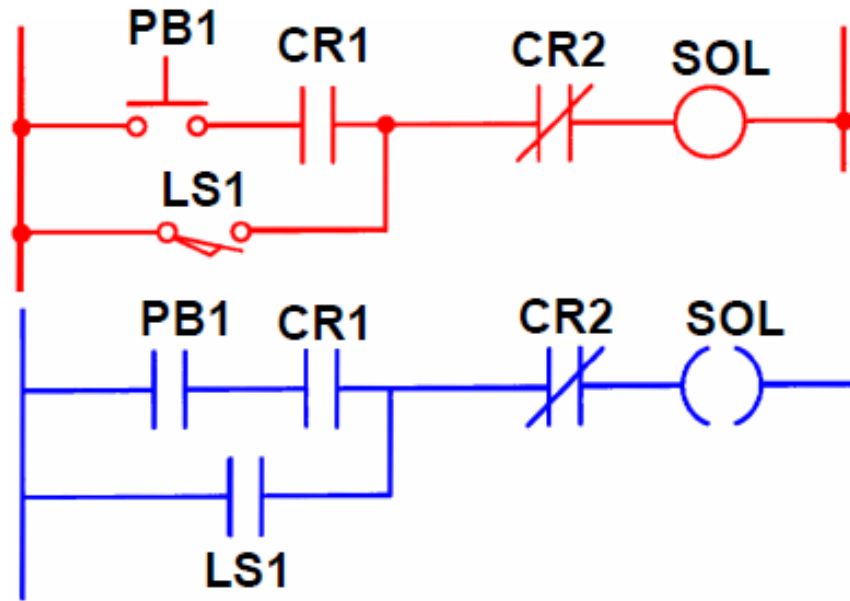
Boolean equation: $Y = [(AB) + C] \bar{D}$

Boolean language



Functional chart

Comparing Programming Language



Relay Schematic

Equivalent ladder diagram language

START	PB1
AND	CR1
OR	LS1
AND NOT	CR2
OUT	SOL

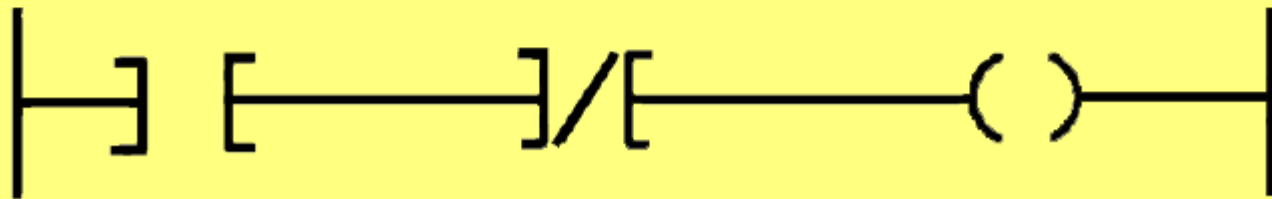
Equivalent Boolean language

Boolean equation: $Y = [(AB) + C] \bar{D}$

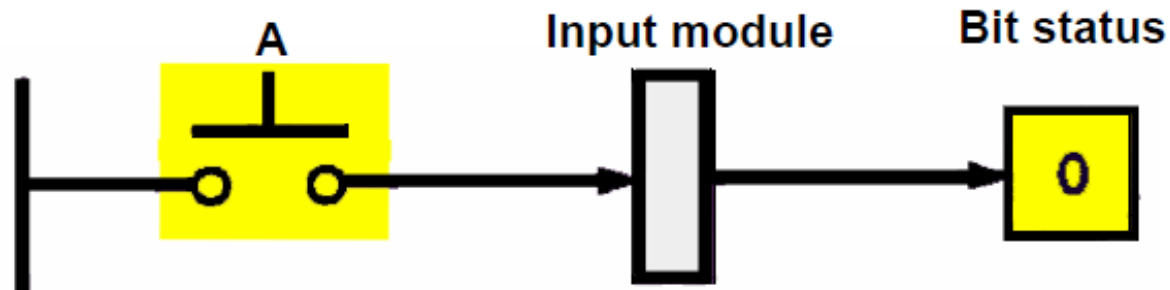
Relay-Type Instructions

The ladder diagram language is basically a *symbolic* set of instructions used to create the controller program.

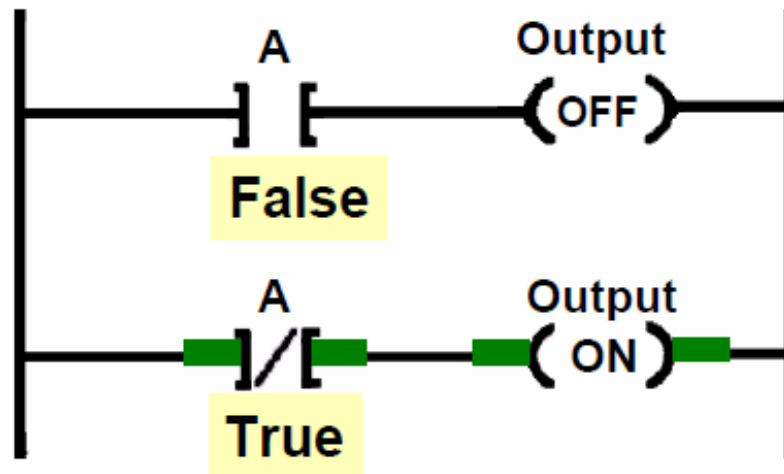
These ladder instructions symbols are arranged to obtain the desired control logic.



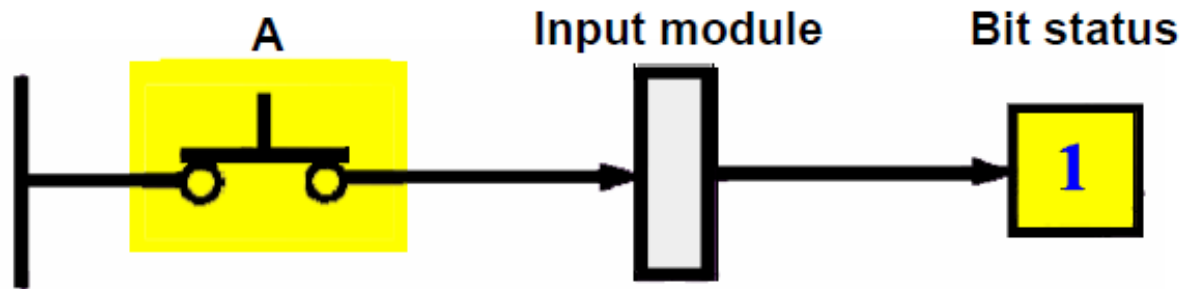
Status Bit Examples



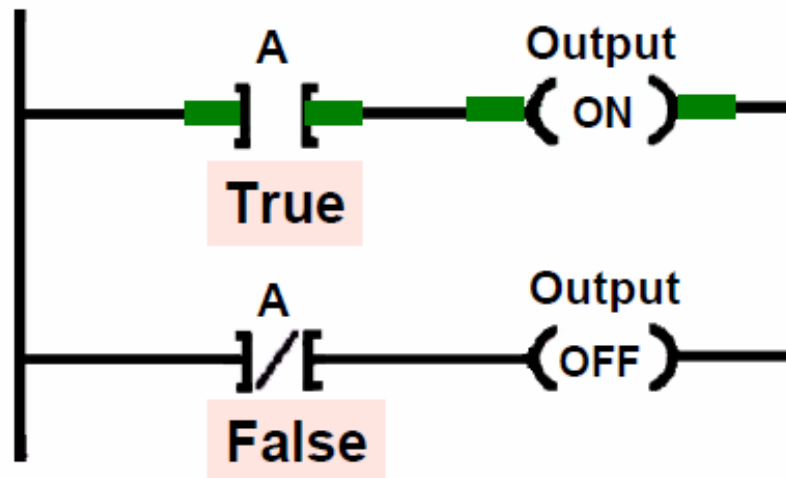
Button not actuated



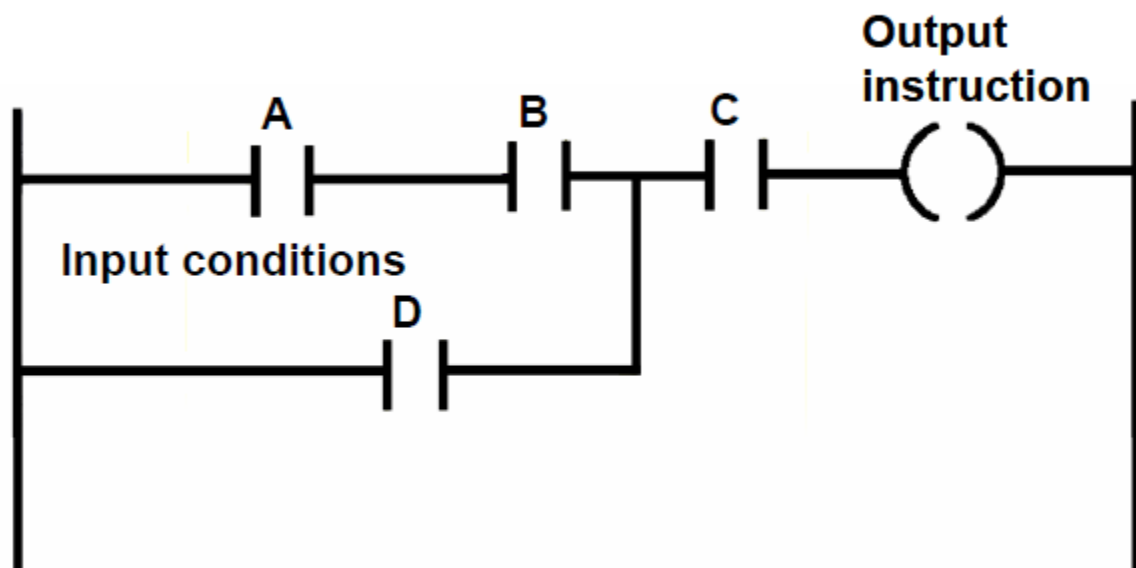
Status Bit Examples



Button actuated

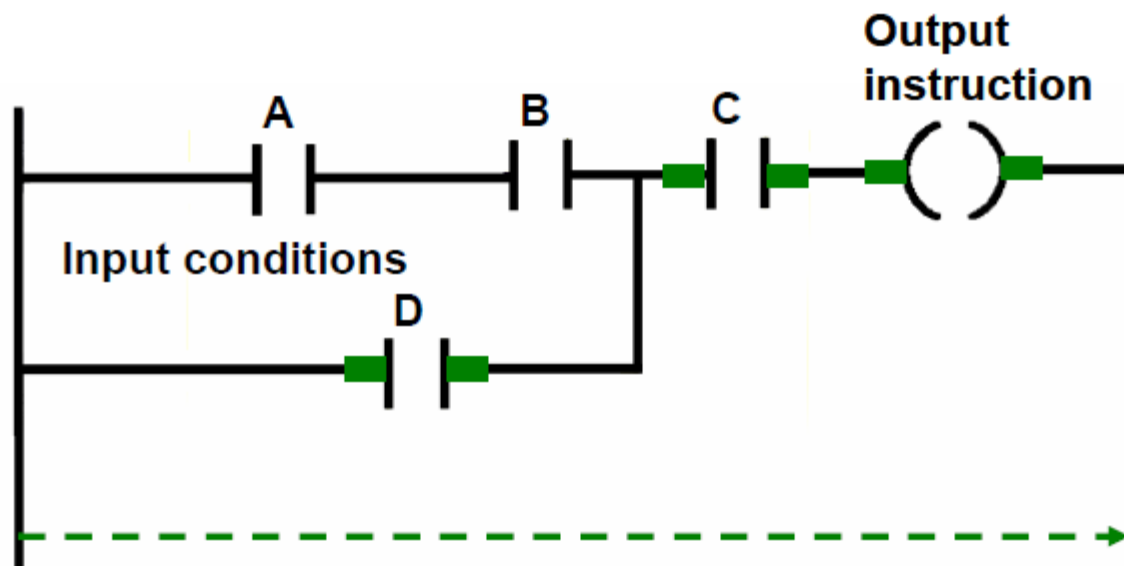


Ladder Rung



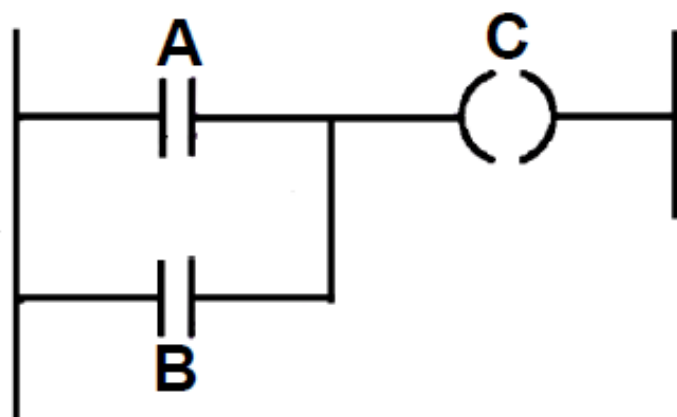
A ladder rung consists of a set of input conditions, represented by contact instructions, and an output instruction at the end of the rung, represented by the coil symbol.

Ladder Rung



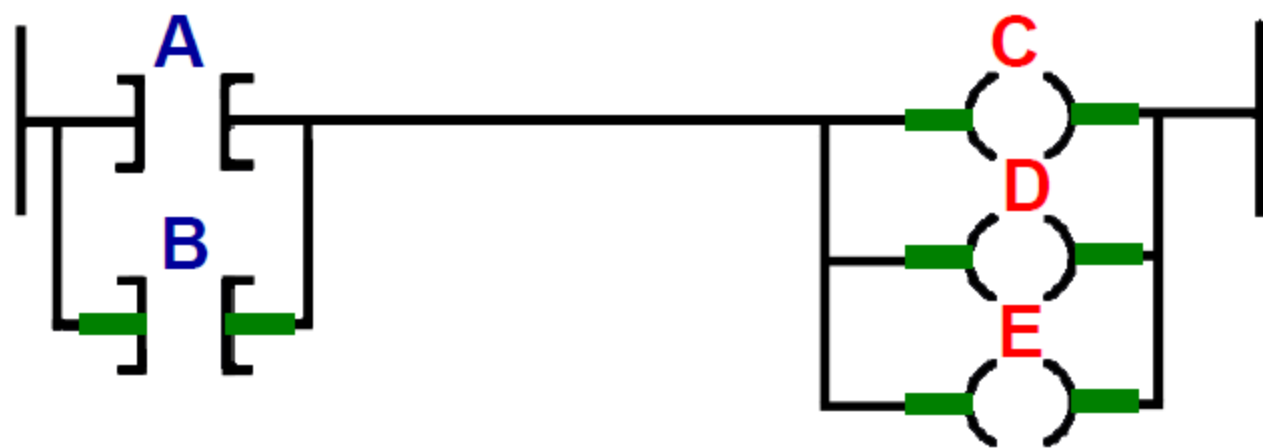
For an output to be activated or energized, at least *one* left-to-right path of contacts must be closed. A complete path is referred to as having *logic continuity*. When logic exists the rung condition is said to be **TRUE**.

Parallel Input Branch Instructions



Branch instructions are used to create parallel paths of input condition instructions. If at least one of these parallel branches forms a true logic path, the logic is enabled.

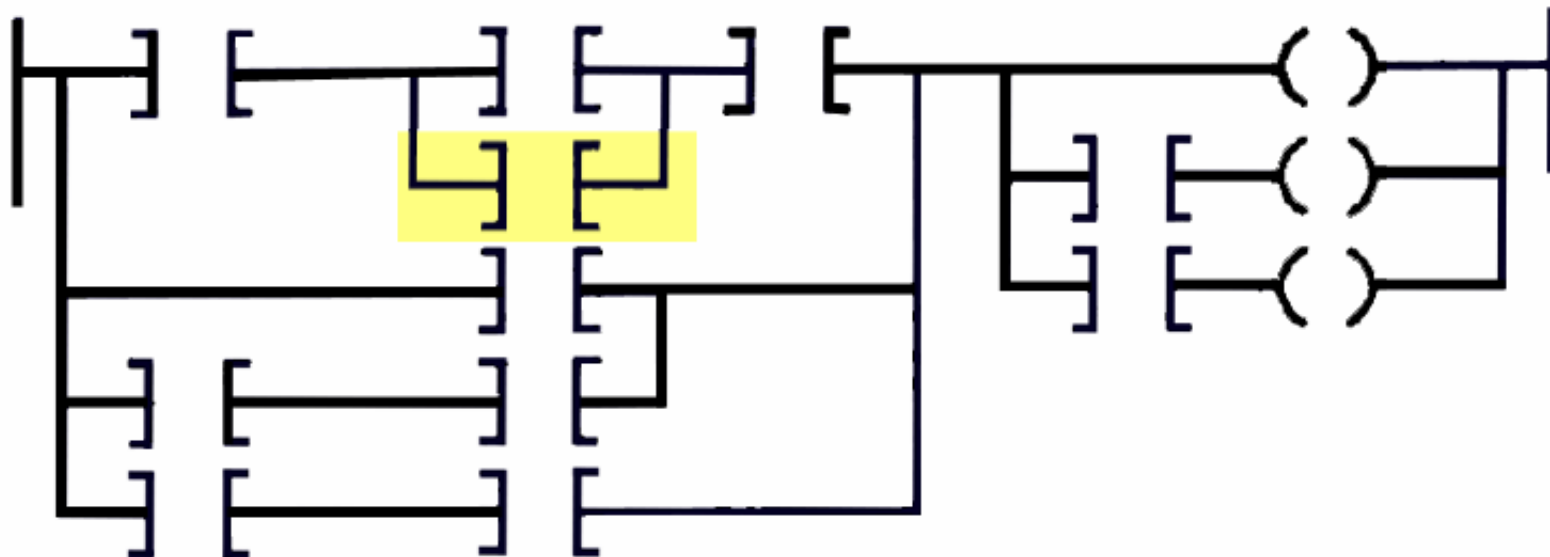
Parallel Output Branching



On most PLC models, branches can be established at both the input and output portion of the rung.

With output branching, you can program parallel outputs on a rung to allow a true logic path to control multiple outputs.

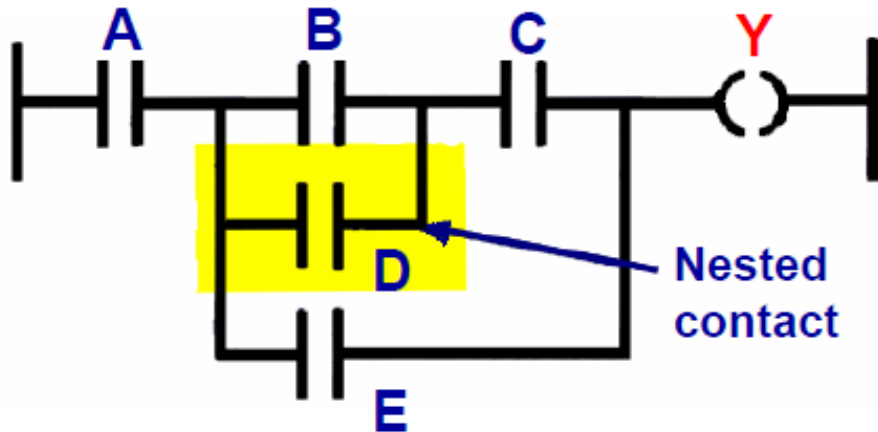
Nested Input and Output Branches



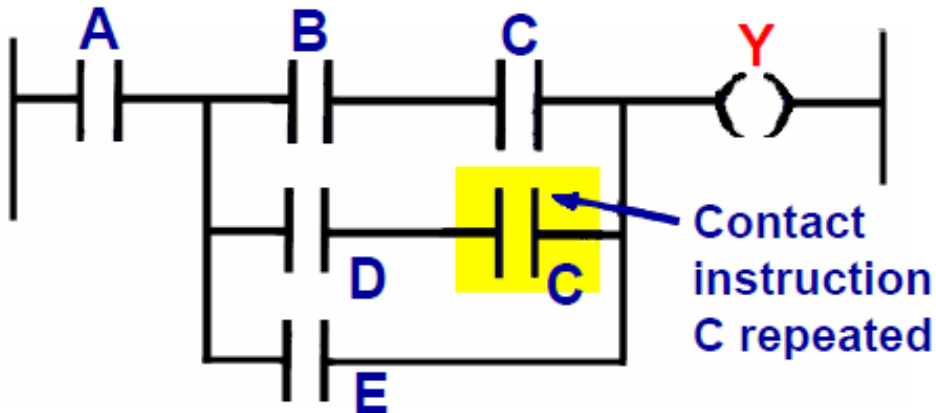
Input and output branches can be *nested* to avoid redundant instructions and to speed up the processor scan time.

A nested branch starts or ends within another branch.

Nested Contact Program

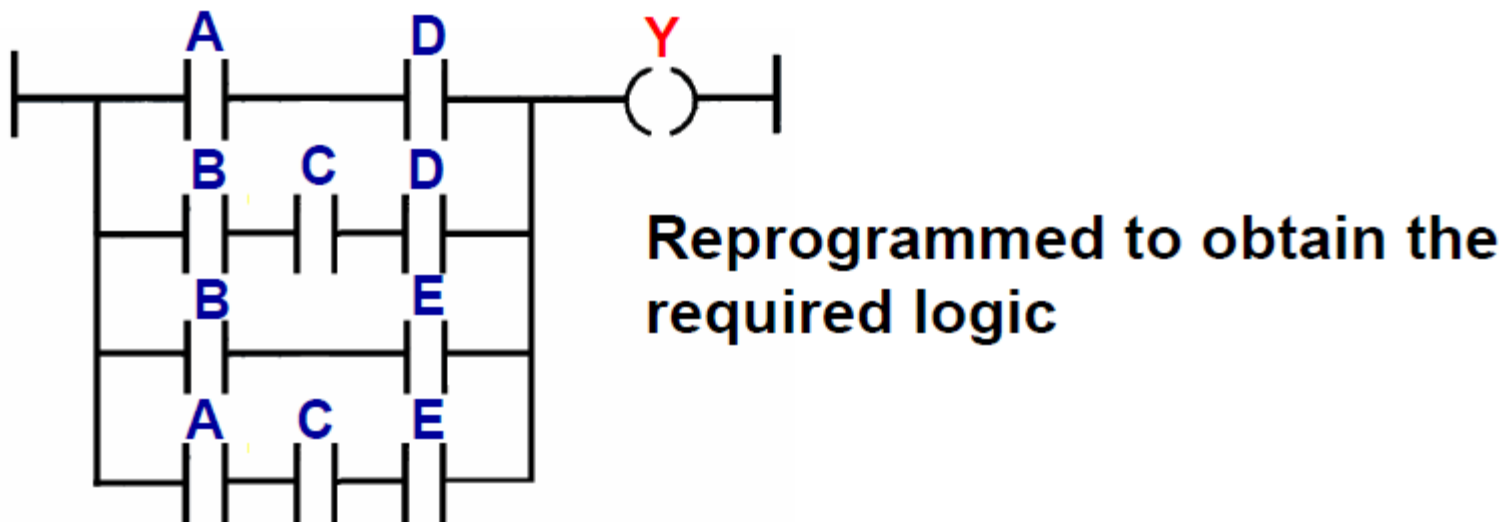
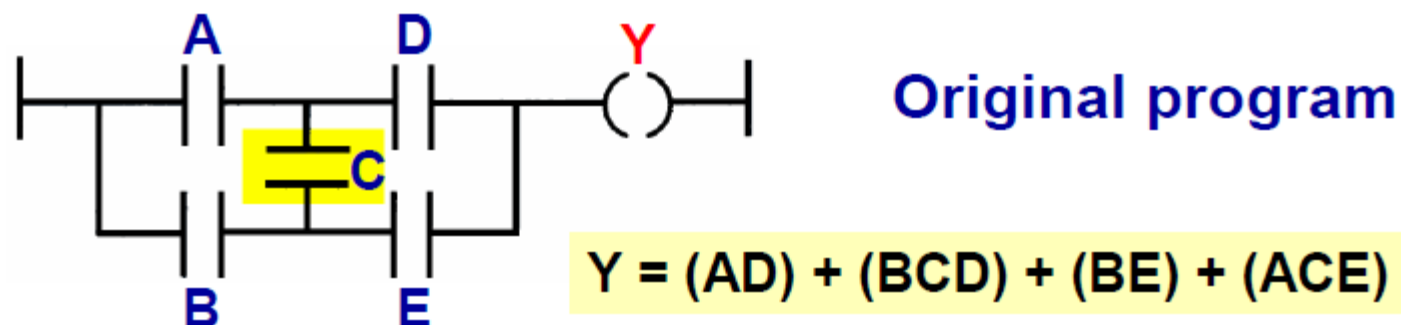


On some PLC models, the programming of a nested branch circuit cannot be done directly.

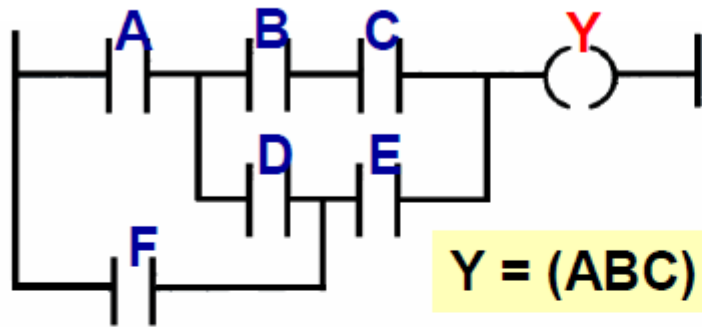


Reprogrammed to obtain the required logic.

Programming of Vertical Contacts

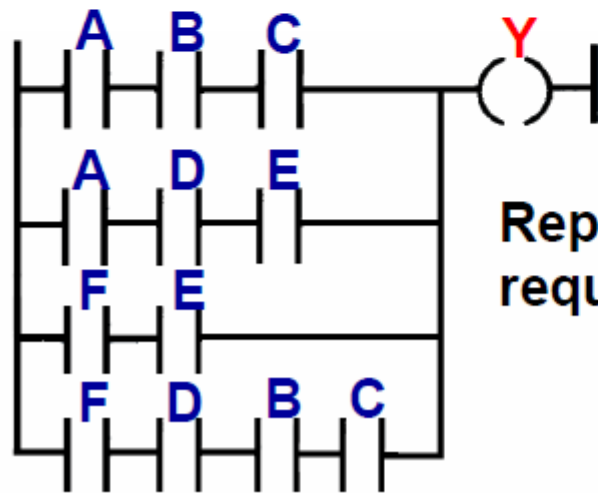


Programming for Different Scan Patterns



Original program

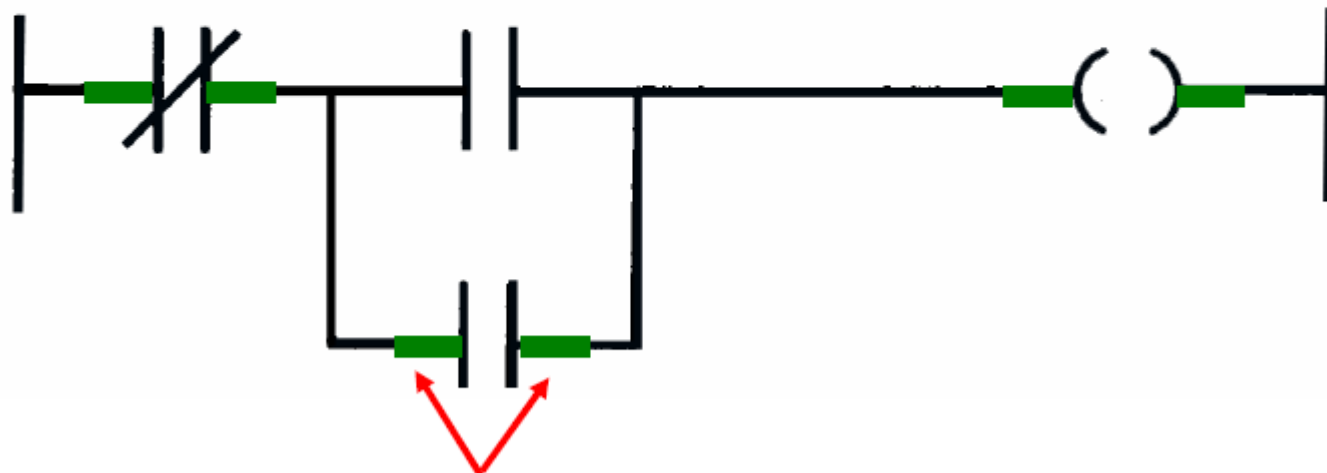
$$Y = (ABC) + (ADE) + (FE) + (FDEBC)$$



Reprogrammed to obtain the required logic

Monitoring a Ladder Logic Program

Operation of the logic is apparent from the highlighting of rungs of the various instructions on screen, which identifies the logic state in real time and has logic continuity.



Highlighted rungs indicate the instruction is true

PROGRESS TILL NOW

- ◉ The design of primary and secondary of the LRM was completed for a 24V,50Hz ac supply.
- ◉ The hard-work implementation of primary and secondary of the train is being undertaken.
- ◉ The study of basic principles of PLC is being undertaken.

FUTURE WORK

- ◉ To complete the remaining construction of primary & secondary.
- ◉ Assembling of the magnets for the levitation and guidance of the train.
- ◉ To understand the functioning of a PLC and to apply it for our specific purpose i.e. to control speed of LRM.

REFERENCES:

- ◉ Ganti S Devi; Linear reluctance motor, JNTU 2003
- ◉ Linear motion electric machines by S. A. Nasar
- ◉ Wikipedia: maglev_train
- ◉ For theoretical measurement of L
http://www.technick.net/public/code/cp_dp

THANK YOU