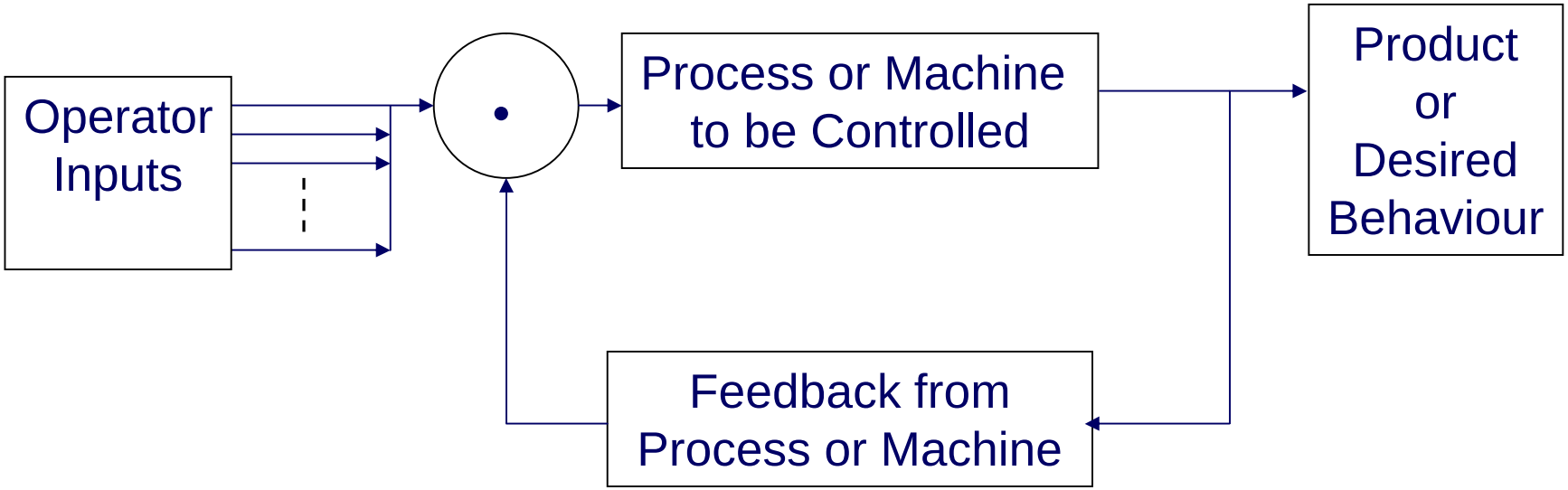
Ladder Logic Fundamentals

Industrial Control Systems
Fall 2006

Purpose of Industrial Controls

- In general, the purpose of an industrial control system is to control a process or mechanical system
- Examples include:
  - Beer brewing, camshaft machining, press loading, automobile body welding, tube cutting, foam curing, water pump assembly, automobile painting, truck frame coating, etc.

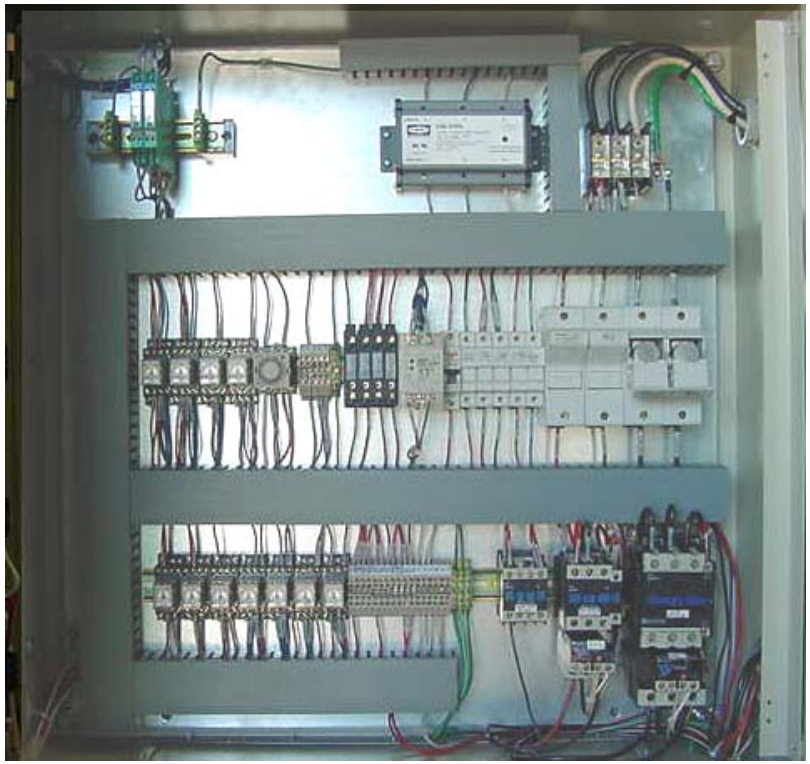
Components of Control



History

- Before the use of computers, industrial control systems were implemented as mechanical, pneumatic/hydraulic or electric circuits
- Hardwired switches and electromechanical relays implemented the desired control logic
- Today, relay panels are still used in applications with low complexity.
- More often, I/O devices interface with a PLC that implements the desired logic.

Relay Panel

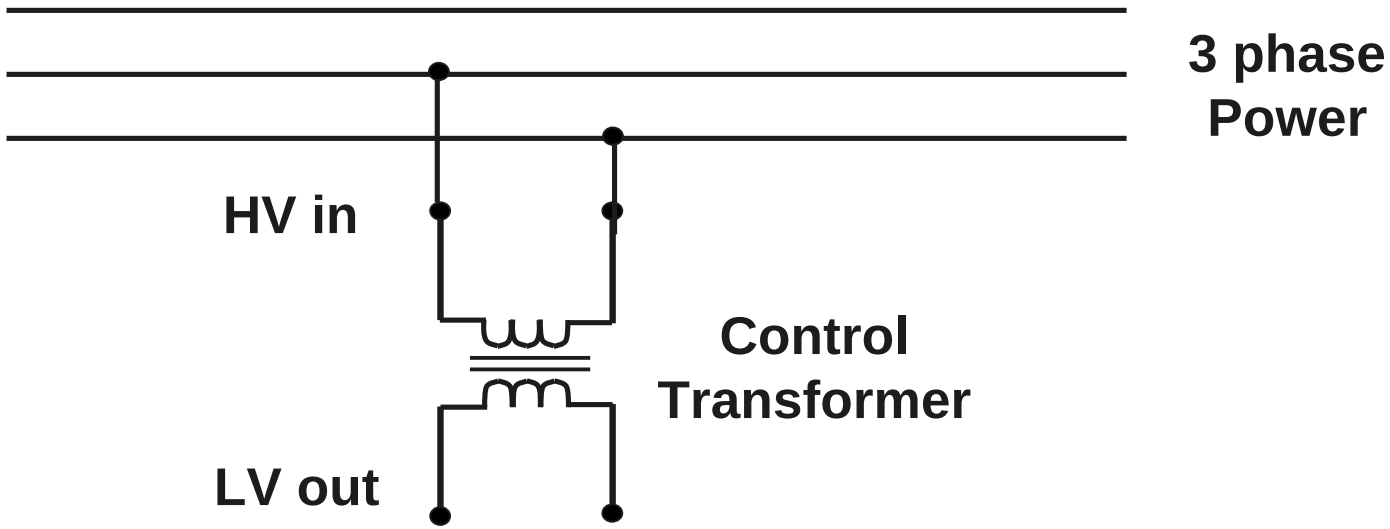


http://www.maple-leaf.ca/indrelaybasedcontrol.html

Control Supply Transformers

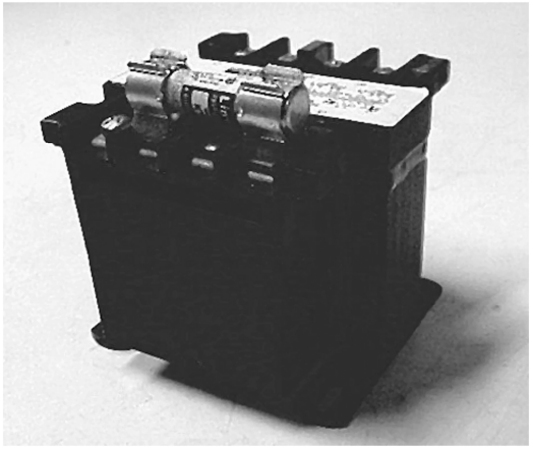
- Unlike high voltage (i.e. 240 VAC, 480 VAC, 575 VAC) output devices such as motors, the control systems are powered by lower voltage levels.
- Depending on the application, the control voltage can be 24 VDC or 120 VAC.
- The control logic supply is usually derived from the higher line voltages using a transformer.

Control Supply Transformers



Fuses

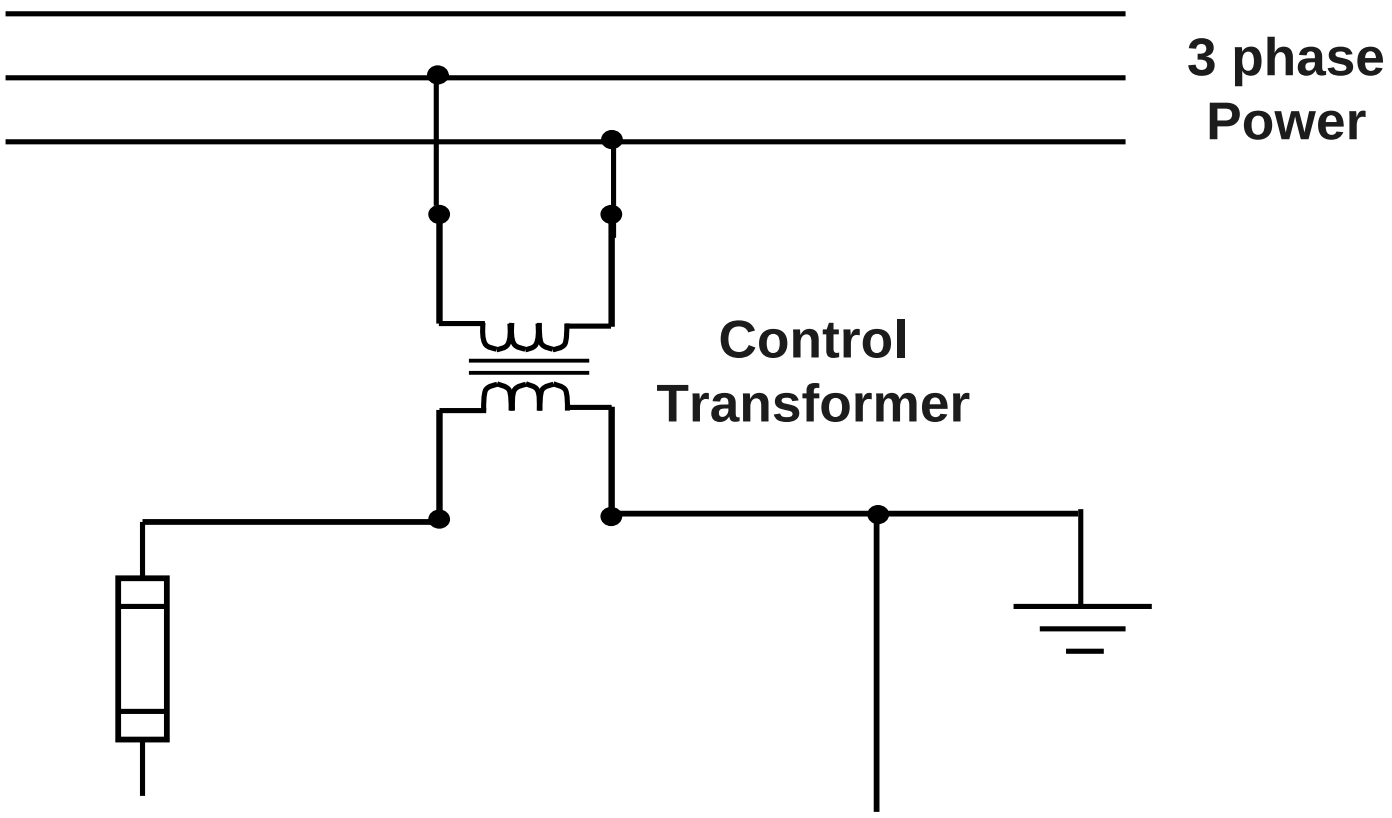
- Control circuits are always fuse protected
- This will prevent damage to the control transformer in the event of a short circuit



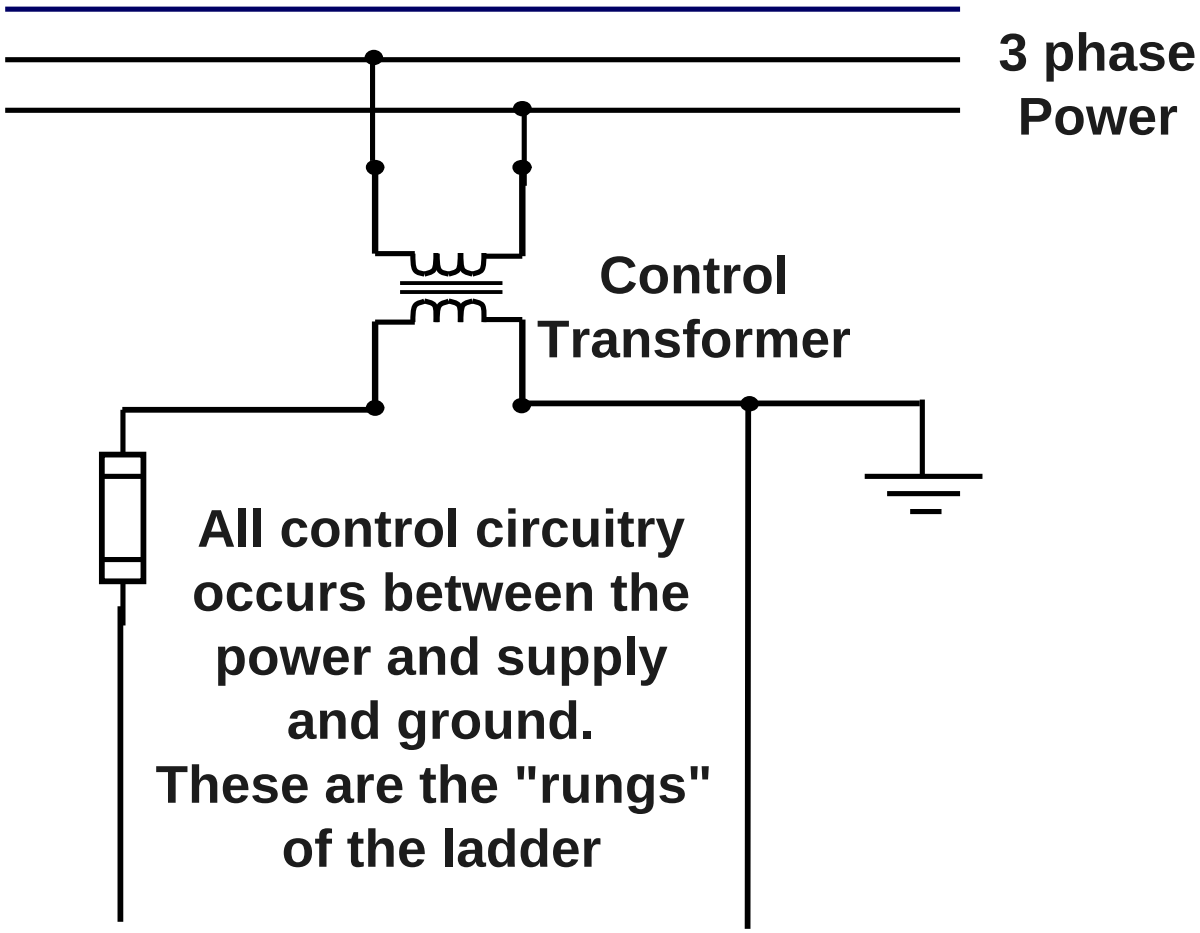
Fuses

- Fuses should be immune to current transients (slow blow)
- Must be rated at a current that is less than or equal to the rated secondary current of the control transformer
- The fusing of control circuits can be complex. There are many different fuse types with trip characteristics available.

Typical Diagram of Control Circuit Power



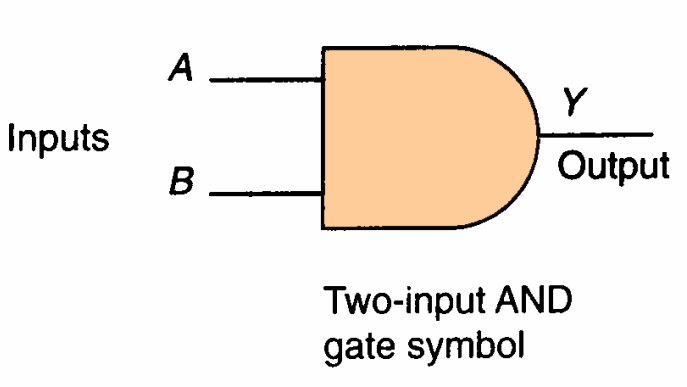
Ladder Logic



Boolean (combinational) Logic and Relay Logic

- Switches and relays in a machine perform some type of control operation "logical function" such as AND, OR, NOT as found in digital circuits
- Coils, N/O and N/C contacts can be wired to perform logical functions
- No storage of previous states

Ladder Logic - AND Function



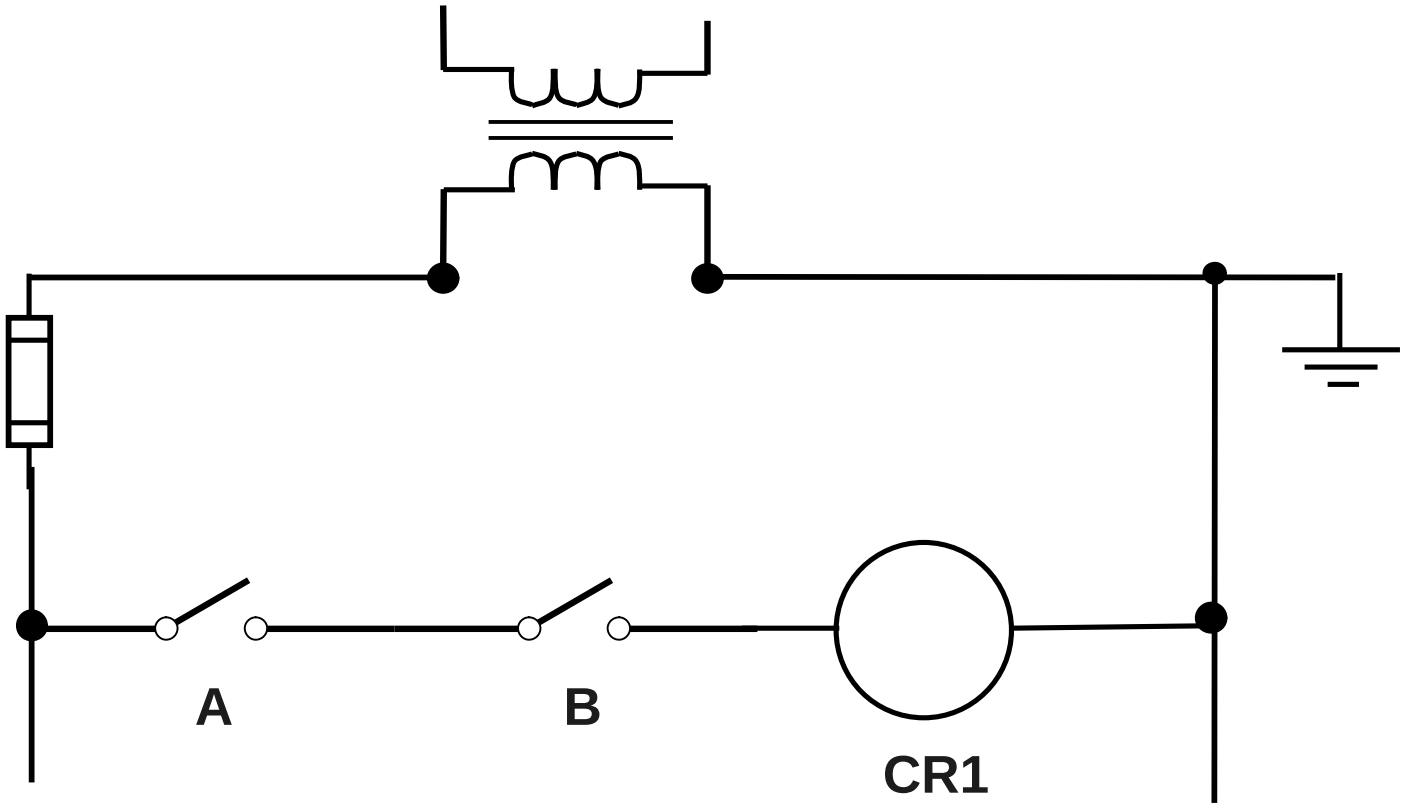
Two-input AND gate symbol

AND truth table

Inputs		Output
A	*B*	*Y*
0	0	0
0	1	0
1	0	0
1	1	1

- Binary 1 represents the presence of a signal or the occurrence of some event, while binary 0 represents the absence of the signal or nonoccurrence of the event.
- For example, the closing of a switch would represent a logic 1, while an open switch represents a logic 0.

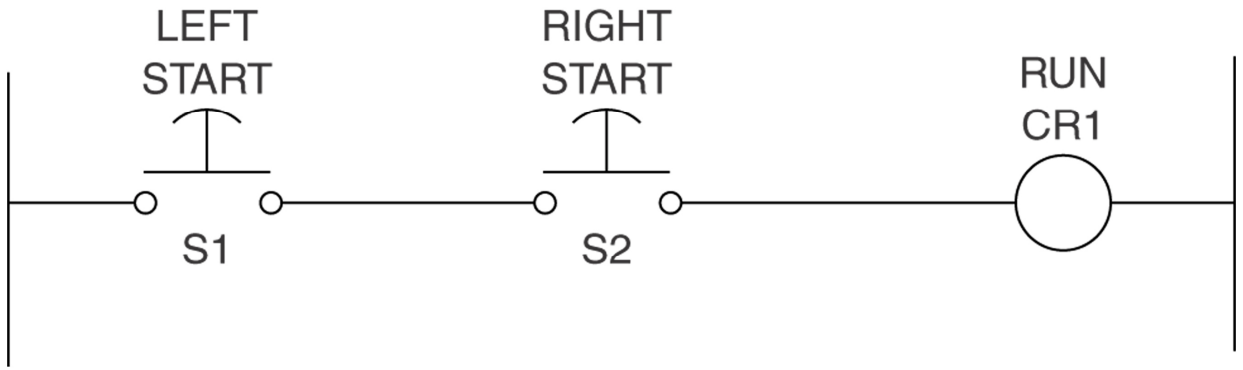
Ladder Logic – AND Function



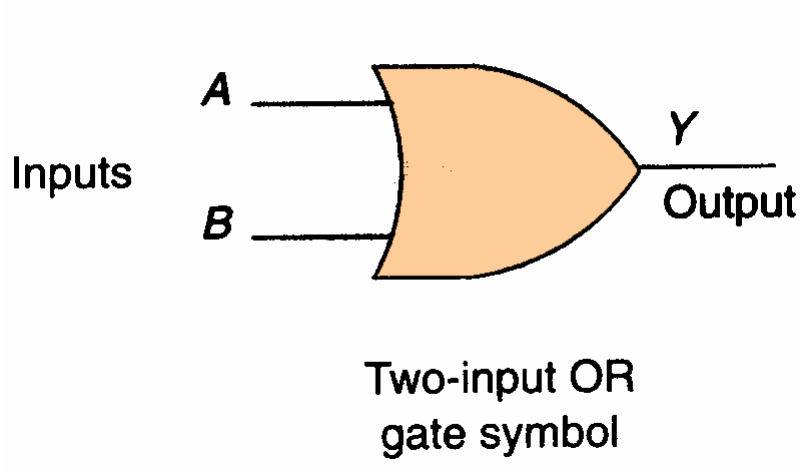
Both A AND B must be closed to energize CR1

Application of AND Logic

- Press operation
- The machine can be only cycled by pressing two switches simultaneously using two hands



Ladder Logic - OR Function

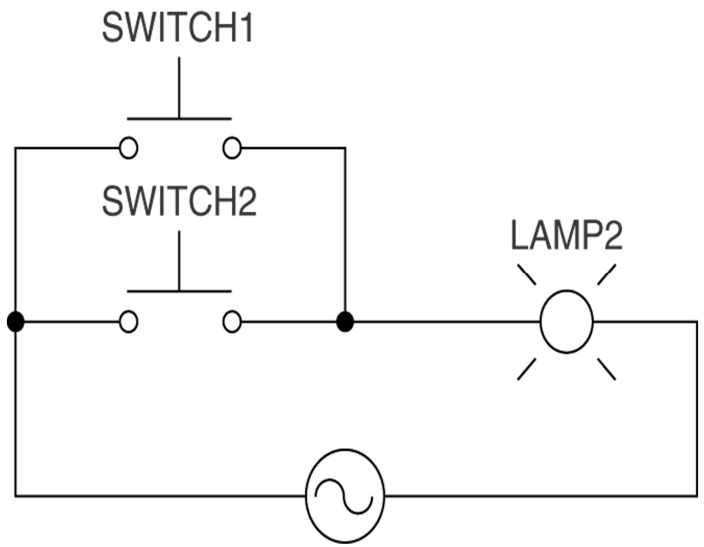


Two-input OR gate symbol

OR truth table

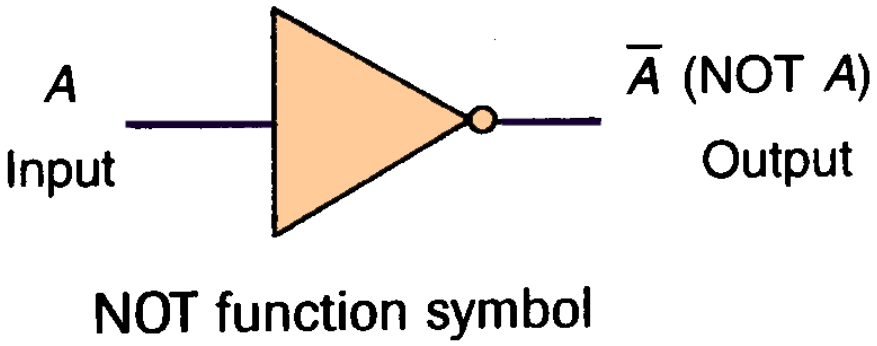
Inputs		Output
A	*B*	*Y*
0	0	0
0	1	1
1	0	1
1	1	1

Ladder Logic – OR Function



- The lamp is on if SWITCH1 OR SWITCH 2 is closed.

Ladder Logic – NOT Function



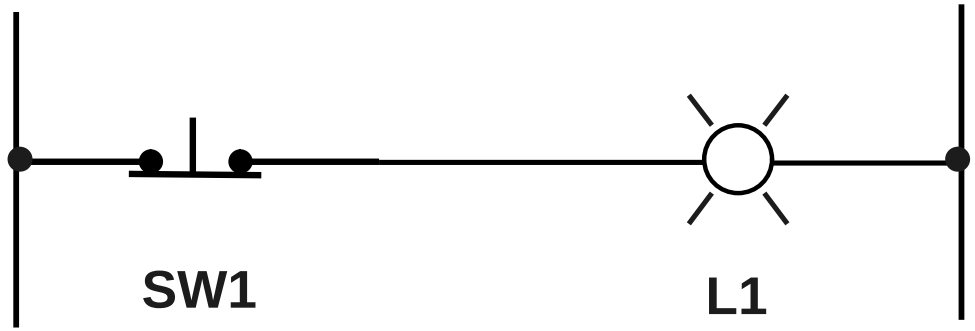
NOT function symbol

NOT truth table

A	NOT A
0	1
1	0

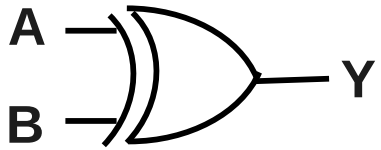
- The output is the inverse of the input

Ladder Logic – NOT Function



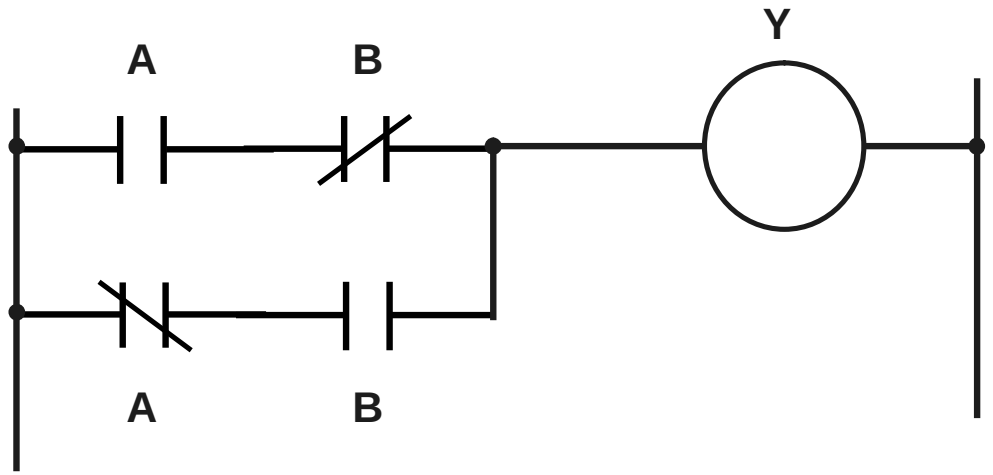
- The light is on when the switch is open

Ladder Logic – XOR Function



A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

Ladder Logic – XOR Function

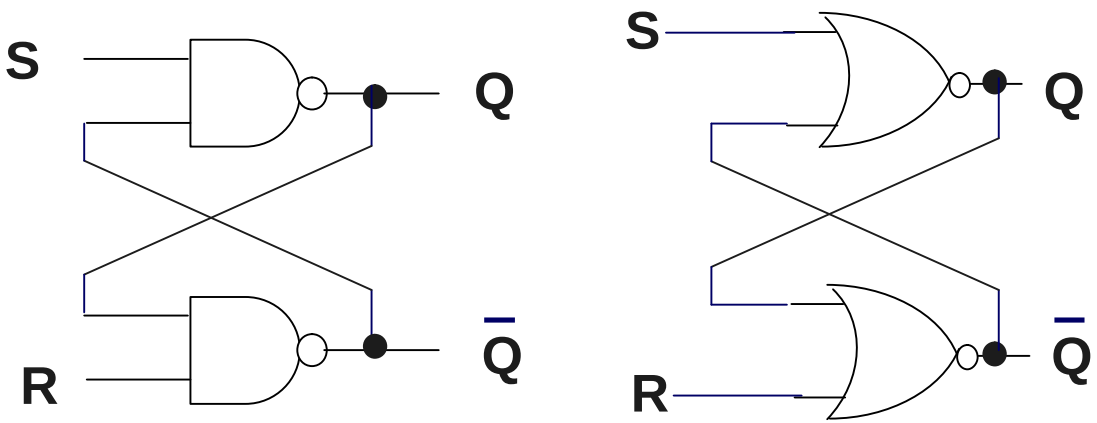


Sequential Logic

- Previous state used along with state present inputs to determine output. present state
- SR, D, and T flip flops

The SR Latch

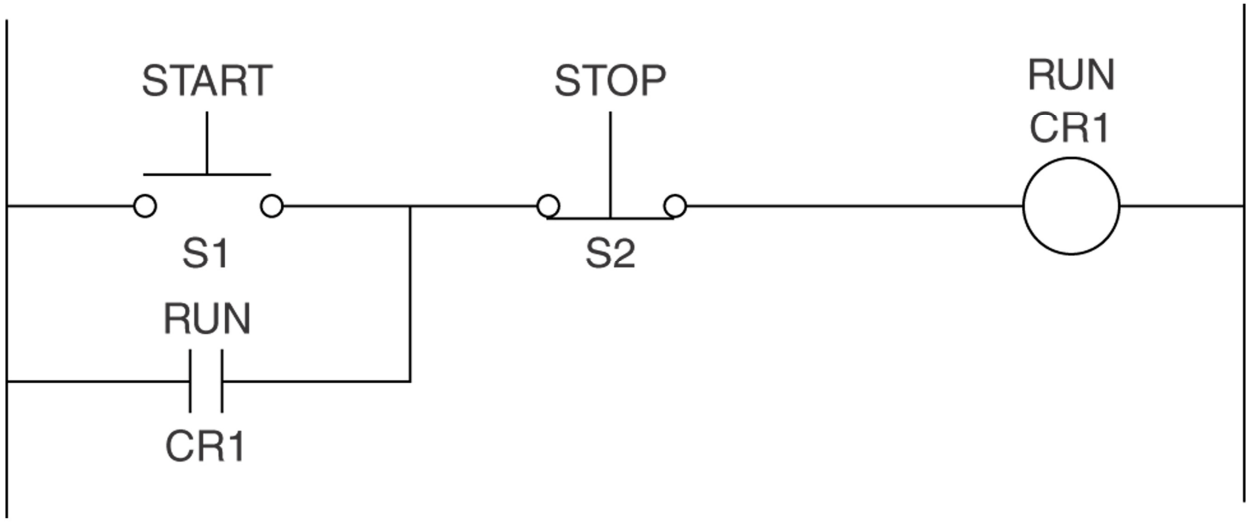
- The SR latch has 2 stable states, on and off
- The S, or set input is used to turn on the output. The R, or reset input is used to turn off the output.



S	R	Q
0	0	$Q_{(t-1)}$
0	1	0
1	0	1
1	1	Race

The SR Latch

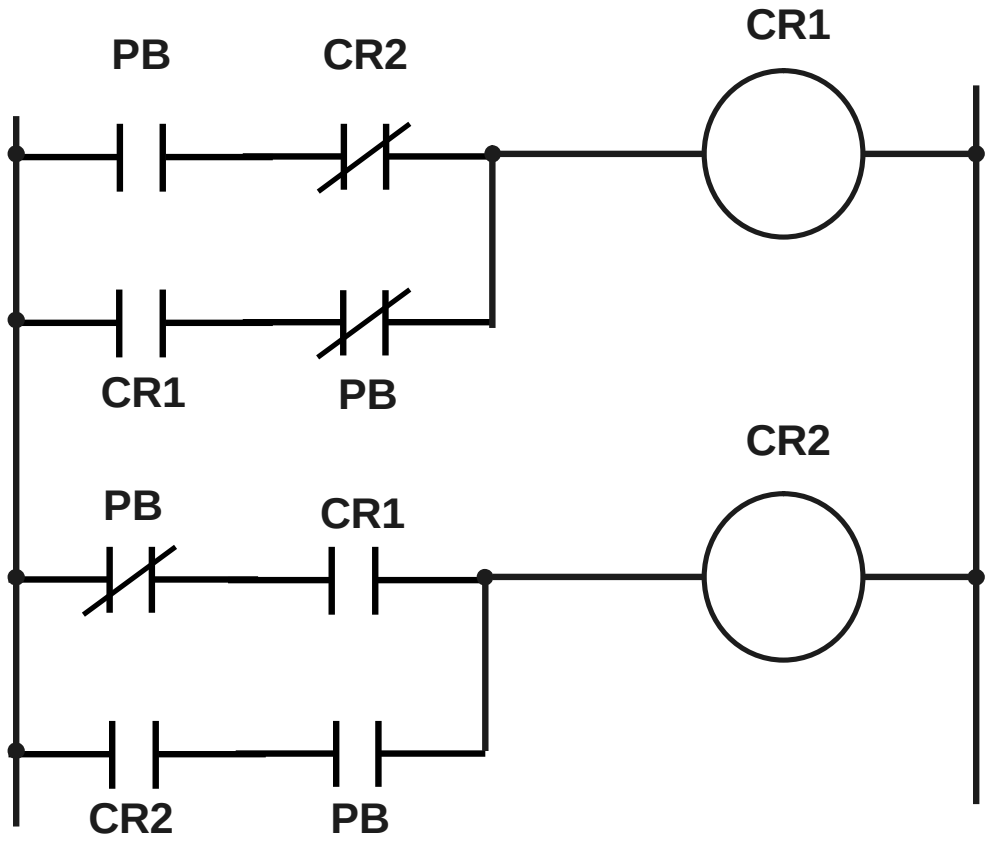
- Occasionally, it is necessary to latch a relay ON when the activating device goes OFF.
- An SR latch may be formed by a NO and NC switch.
- The start button is the set input, while the stop button is the reset input.
- The physical act of pushing the start or stop button is analogous to applying a logic 1 to the S, or R inputs respectively.



The T Flip Flop

- Sometimes it is useful to have a momentary contact switch the output on during the first switch contact, and switch the output off during the second switch contact.

T Flip-Flop Proposed Circuit



Output appears on CR2

T Flip-Flop

- Homework – Verify that the circuit on the previous page works through an analysis of the circuit states.
- Explain the operation of the circuit.

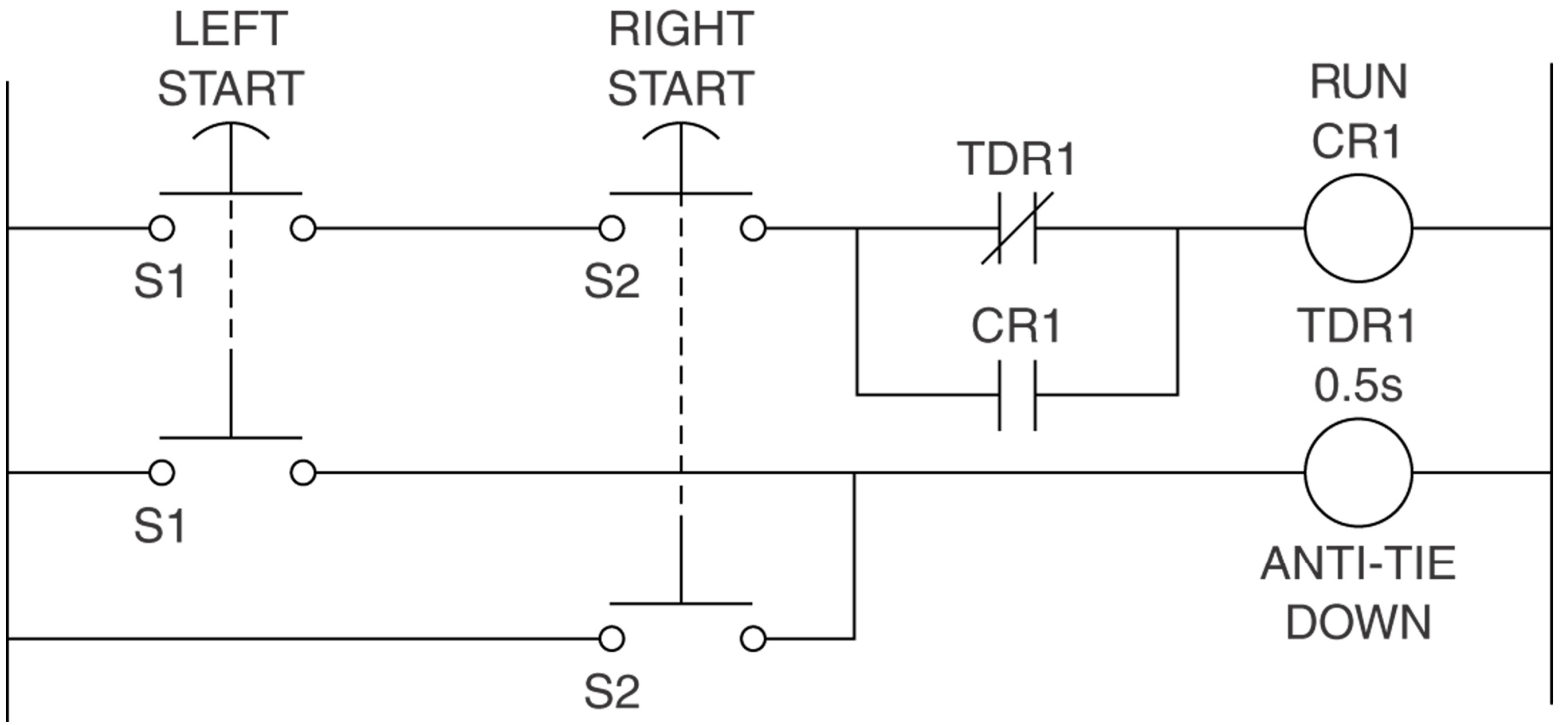
Anti-Tie Down and Anti-Repeat

- The machine must not have the capability to be cycled by tying down one of the two RUN switches and using the second to operate the machine
- In most cases this is an extremely hazardous practice
- Anti-tie down and anti-repeat solve this problem

Anti-Tie Down and Anti-Repeat

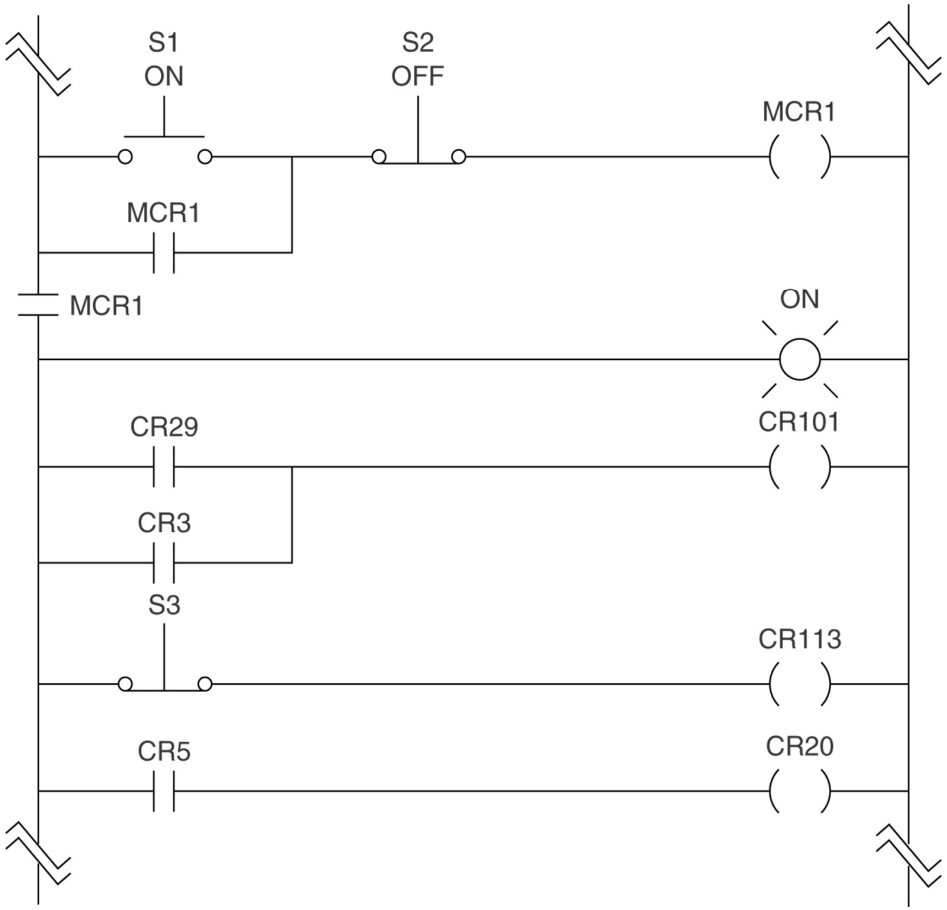
- Both switches must be pressed at the same time within small time window
- If one switch is pressed then the other is pressed after the time is expired, the machine will not cycle
- We need:
  - Two switches
  - TON relay

Anti-Tie Down and Anti-Repeat



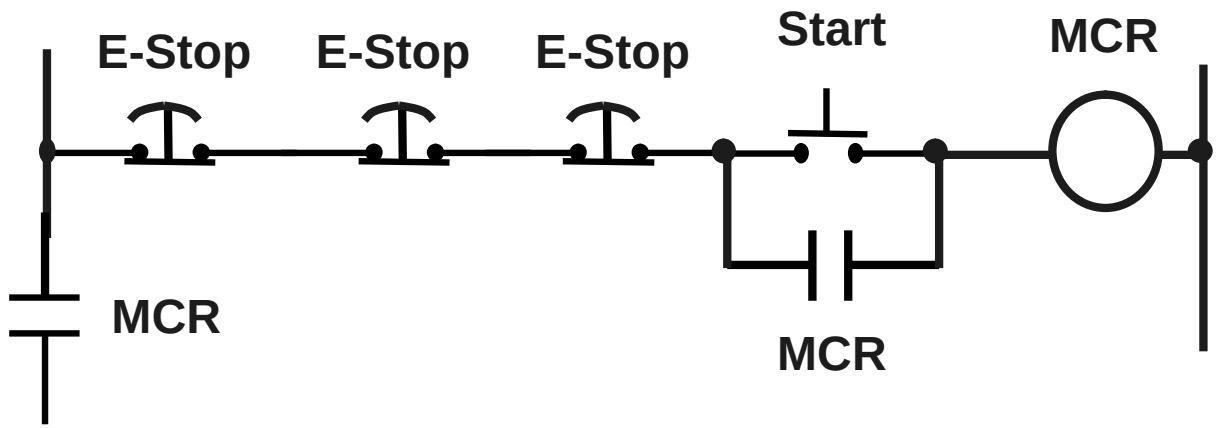
Master Control Relays (MCRs)

- Used to enable or disable entire sections of control circuit (rungs)



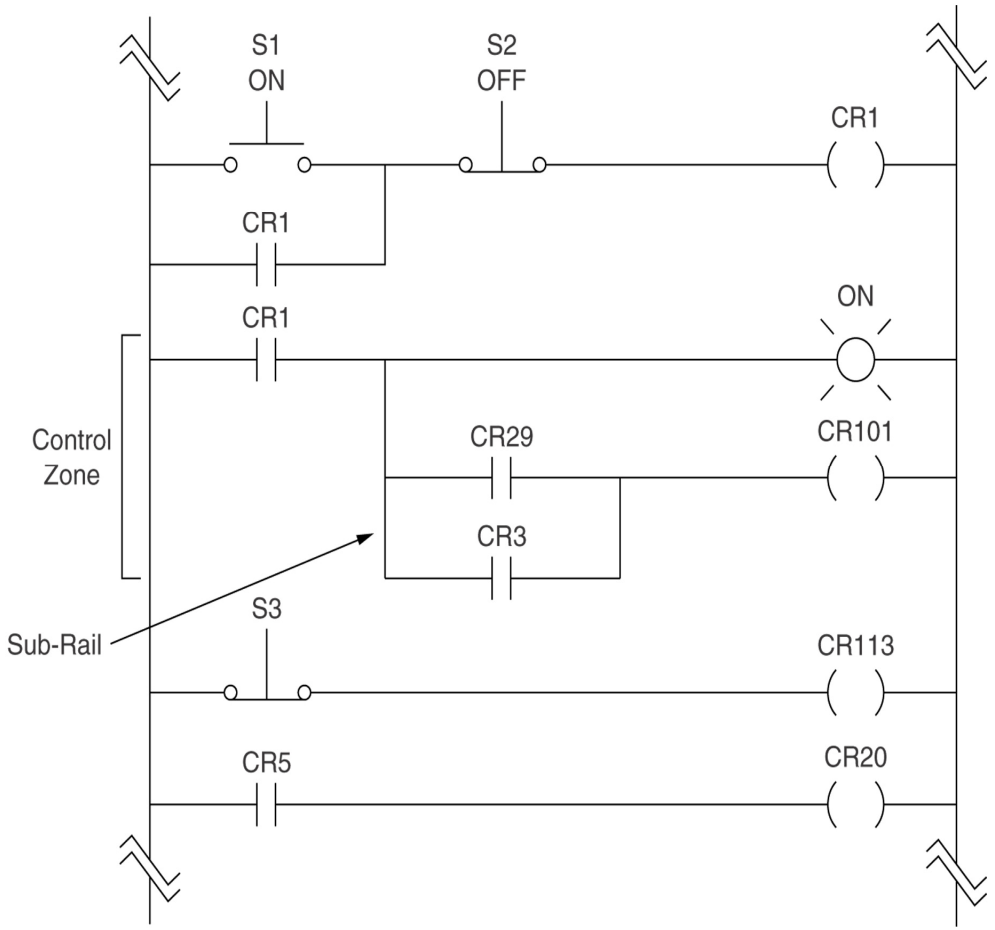
MCR's – Emergency Stops

- Typically, MCR's are used in Emergency Stop (E-Stop) circuits to disable power to a circuit or machine in the event of a fault, or an operator initiated stop.



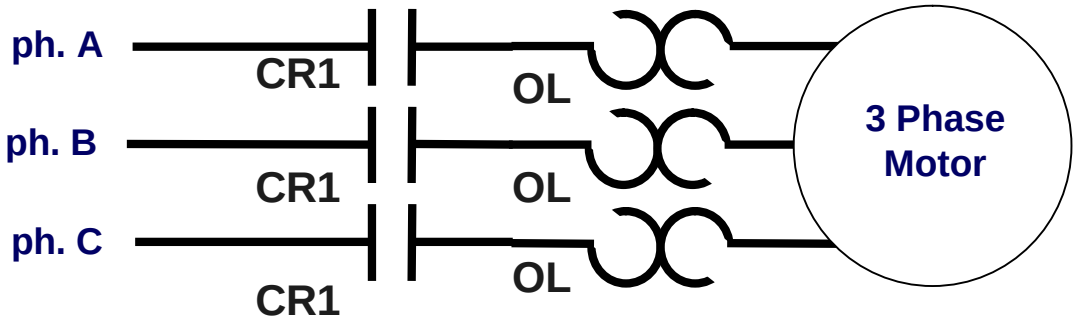
Control Zones

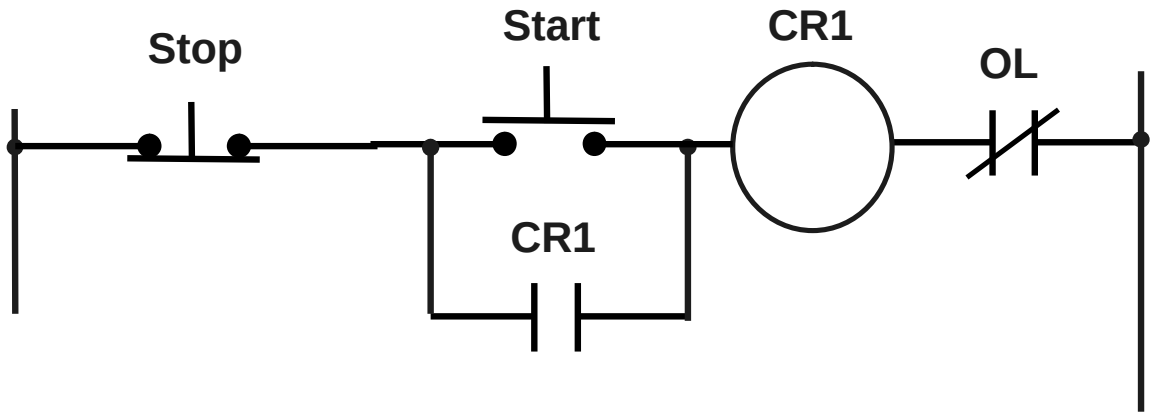
- Used to apply control to specific sections of the control circuitry



Motor Starter Wiring

- A 3 phase motor can be started in the following manner:





Motor Starter Wiring – Single Phase Motors

- Homework: Investigate how a three phase motor starter can be used to control a single phase motor.