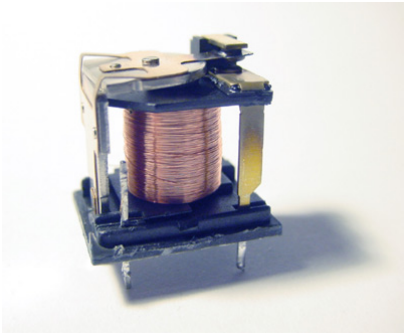
Chapter 11 - Control

11.1 Introduction

Machines are typically controlled with relay logic at the final contact. This allows the contact to operate at the voltage rating of the machine. However, the energizing signal to the coil for the relay can be a different, lower voltage.

11.2 Relay



A relay is another magnetic device. It consists of a coil that acts as a solenoid. When the coil is energized, a mechanical lever causes the contacts to change position and state.

Like any other inductor, the coil can be designed to operate at any voltage. Typical units us control level dc voltages of 5, 6, 12, or 24. The most common ac voltage is 120 Vac.

The mechanical contacts have a limit on the voltage they can break when switching and the amount of current they can conduct when closed. Smaller relays usually have a contact break rating of 120 V and current limit of 1 Amp. Large reclosers have a contact rating of 25,000 volts and current rating of 1000 Amps. Nevertheless, the mechanism is virtually identical.

A contact that open when the coil is de-energized is called normally open (NO) and a contact that is closed when the coil is de-energized is called normally closed (NC).

11.3 Logic

Every control circuit can be constructed using on three combinations of contacts. Standard logic using And, Or, and Not is employed. A series connection of contacts is And, while a parallel connection of contacts is an Or. A normally closed contact is a Not.

Boolean logic can be used to represent the circuit and to minimize the connections. A one “1” indicates a condition is true, while a zero “0” indicates a condition is false.

A true statement causes a normally-open switch to close. A false statement causes a normally-open switch to remain open.

Truth Table – AND

X	Y	X*Y
0	0	0
0	1	0
1	0	0
1	1	1

Truth Table – OR

X	Y	X*y
0	0	0
0	1	0
1	0	0
1	1	1

Truth Table – NOT

X	X’
0	1
1	0

AND: X*Y = XY = X AND Y = Z

z = 1, if x = 1 and y = 1

OR: X+Y = X OR Y = Z

z = 1, if x = 1 or y = 1

NOT: X’ = X NOT = Z

z = 1, if x = 0

Demorgan’s Theorem is used to complement or change the state of an equation. The complement of a function is the complement of each variable and change the operator.

Z = A * B

Z’ = A’ + B’

11.4 Ladder Diagram

The schematic is called a ladder diagram with the control hot or positive voltage on the left and the common or negative voltage on the right.

Inputs are represented by switches, controls by relay contacts, and outputs by a relay coil or lamp. Switches are illustrated with a connection that can be made from some mechanical device. A relay contact has two parallel bars in close proximity that have wire connections. Outputs are represented by a circle.

11.5 Control Symbols

Power	Symbol
Ground	
Ground chassis	
Fuse	
Circuit breaker	
Disconnect 3-phase	
Motor 1-phase	M
Motor 3-phase	M
Interlock safety	
Surge protector	
Light Pilot	

Relays	Symbol
Relay	
Relay Coil	
Thermal relay	
Relay Contact NO	
Relay Contact NC	
Label relay coil and contact with same notation, i.e. R1 or TD1	

Source	Symbol
Alternating current	AC
Direct current	DC
Battery	
Thermo-couple	

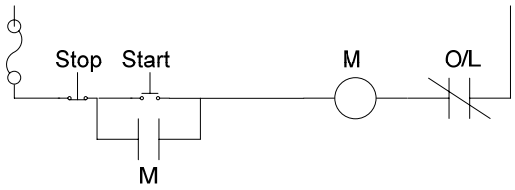
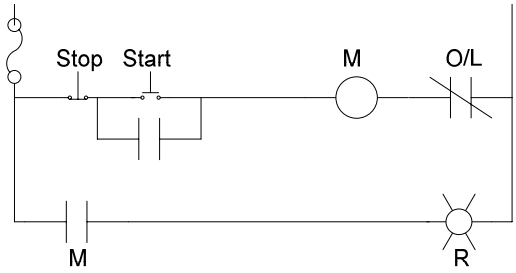
Switches	Symbol
Switch NO SPST	
Switch NO SPDT	
Switch NO DPST	
Pushbutton NO	
Pushbutton NC	
Pushbutton DPDT	
Switch selector	
HOA 3-position	

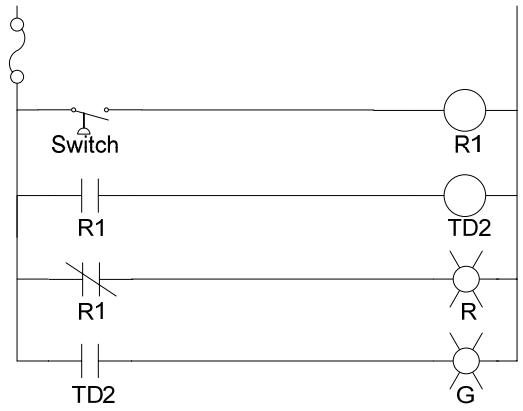
Operators	Symbol
Time delay NO	
Time delay NO	
Liquid level	
Gas flow	
Liquid flow	
Temperature	
Thermostat	

Abbrev	Description
NO	normally open
NC	normally closed
SPST	single pole single throw
SPDT	single pole double throw
DPST	double pole single throw
DPDT	double pole double throw

Elements	Symbol
Resistor	
Capacitor	
Inductor	
Transformer Air core	
Transformer Iron core	
Delta 3-phase	
Wye 3-phase	

11.6 Wiring Diagrams

Function	Diagram
Start / Stop Motor Control Press start to energize motor relay M. Contact M latches around start. Stop breaks circuit. Thermal overload relay O/L in motor circuit senses current. If high, then it opens contact O/L to stop.	
Start / Stop With Indicator Press start to energize relay M. Contact M latches around start. Stop breaks circuit. Thermal overload relay O/L senses current. If high, then it opens contact O/L to stop. Another contact M turns on red indicator	

Switch Time Delay	
Normally closed contact R1 energizes indicator light Red. Closing Switch energizes relay R1. Contact R1 energizes time delay relay TD2. NC contact R1 opens to turn off red light. After time delay, contact TD2 closes to turn on Green indicator.	

Chapter 11 Problems

Problem 11-1

SITUATION:

A plant mixes peanut butter (P) and chocolate (C). When the peanut butter level and the chocolate level is not low, the mixer (M) runs. When the peanut butter level is low or the chocolate level is low, an alarm light (L) is activated. After a time delay (T) the alarm turns on an annunciator (A).

REQUIREMENTS:

a) Write the Boolean equations for the situation.

b) Draw a ladder diagram schematic.

SOLUTION: