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Electrical Basics Drawing Samples

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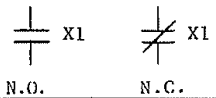
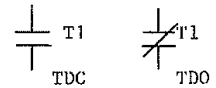
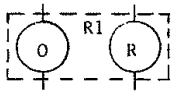
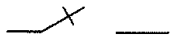
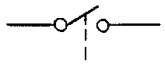
Handout References

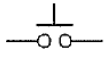
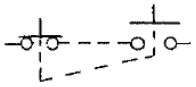
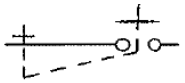
TYPICAL ELECTRICAL DRAWING SYMBOLS AND CONVENTIONS

ELECTRICAL SYMBOLS

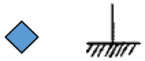
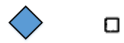
◆ Denotes common symbols we will encounter in the sample problems

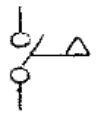
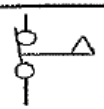
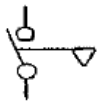
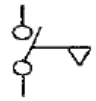
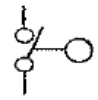
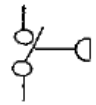
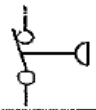
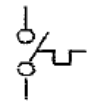
CONTACTS, SWITCHES, CONTACTORS AND RELAYS

SYMBOL	DESCRIPTION
	Relay contact - Shown with relay in de-energized or in reset position. (Show relay coil designation near contact.)
	Timing Relay Contact - TDC indicates contact closes at end of timing period. TDO contact opens at end of timing period.
	Coil - Relay, contactors, circuit breaker, solenoid etc. (Show device designation, X1)
	Coil - Timing Relay - TDPU indicates timing period starts when coil is energized. TDDO indicates timing period starts when coil is de-energized.
	Latching Relay or Mechanically-Held Contactor O=operate; R=reset; TC=trip coil; CC=closing coil. (Coils may be separated on diagram)
	Knife Switch, general. (If shown closed, terminals must be added.)
	Switch - General, single pole, single throw.
	Switch - One pole of multi-pole switch shown. Other poles shown elsewhere.

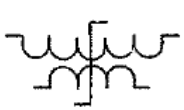
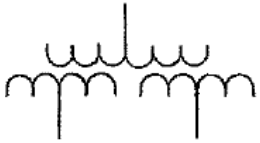
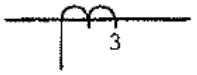
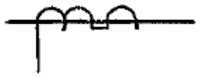
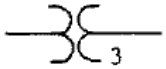
	Pushbutton - Momentary or spring return. Single Circuit (make)
	Pushbutton - Momentary or spring return. Single Circuit (break)
	Pushbutton - Momentary or spring return. Two Circuit
	Pushbutton - Maintained, two circuit
	Pushbutton - Maintained, single circuit
	Selector Switch - Two position, maintained (designate position shown; i.e. A=Auto; H=Hand)
	Selector Switch - Three position, SR indicates spring return from position so labeled. ("TRIP-(NORMAL)-CLOSE" position shown)
	Limit Switch - Normally open - Not applicable for Motor Operated Valves and Solenoid Valves.
	Limit Switch - Normally closed - Not applicable for Motor Operated Valves and Solenoid Valves.

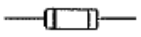
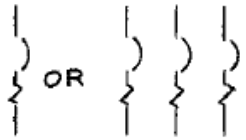
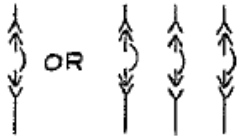
	Used with other symbols to indicate device is adjustable
+ (Positive) — (Negative)	Polarity markings - Direct current.
	Instantaneous Polarity Markings
	3-phase, 3-wire, delta
	3-phase, 3-wire, open delta grounded
	3-phase, 3-wire, wye
	3-phase, 3-wire, wye grounded neutral
	3-phase, 3-wire, zigzag

	3-phase, 3 wire zigzag, grounded neutral
	Connection to earth ground (may be plant grounding system)
	Connection to chassis or frame
	Terminal - may be added to any of the following symbols at connection points.
	Short circuit (not a fault)
	Terminal - Designates termination point of field run cables to main control board, emergency power board, main control board termination cabinet or emergency power board termination cabinet.

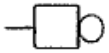
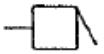
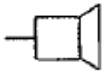
	Flow Switch - Closes on increase in flow at value shown
	Flow Switch - Opens on increase in flow at value shown
	Flow Switch - Closes on decrease in flow at value shown.
	Flow Switch - Opens on decrease in flow at value shown.
	Liquid Level Switch - Opens on rising level (Closes on low level)
	Liquid Level Switch - Closes on rising level (Opens on low level)
	Pressure or Vacuum Switch - Closes on rising pressure
	Pressure or Vacuum Switch - Opens on rising pressure (Closes on increase in vacuum)
	Temperature Switch - Closes on increasing temp.
 	Torque Switch - Opens on high torque

(Motor Operated Valves)

	Transductor - Control winding shown with 5 loops. Power winding shown with 3 loops.
	Transformer - General, two winding
	Autotransformer - General
	Transformer - General, three winding
	Current Transformer - number represents quantity (Add instantaneous polarity marks and ratio)
	Bushing Type Current Transformer
	Potential Transformer - number represents quantity (Show instantaneous polarity marks, voltage rating, vectors, etc.)

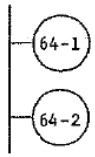
	Fuse - General
	High Voltage Primary Fuse Cutout
	Lightning Arrester - General Gap Type
	Lightning Arrester - Valve or film type
	Circuit Breaker - General
	Power Circuit Breaker - (Show location of operating mechanism)
	Circuit Breaker, 3-pole with magnetic - overload device in each pole. (Show rating)
	Circuit Breaker, 3-pole, drawout type (Used in metal clad switchgear groups) 

INDICATORS & ALARMS

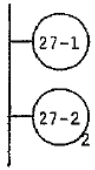
	Bell, electric
	Buzzer
	Horn - General
	Annunciator - General
	Indicating Light - General Use the following to specify color: A - Amber B - Blue C - Clear G - Green NE - Neon O - Orange OP - Opalescent P - Purple R - Red W - White Y - Yellow

RELAYS

The following methods are used on drawings to identify relays:

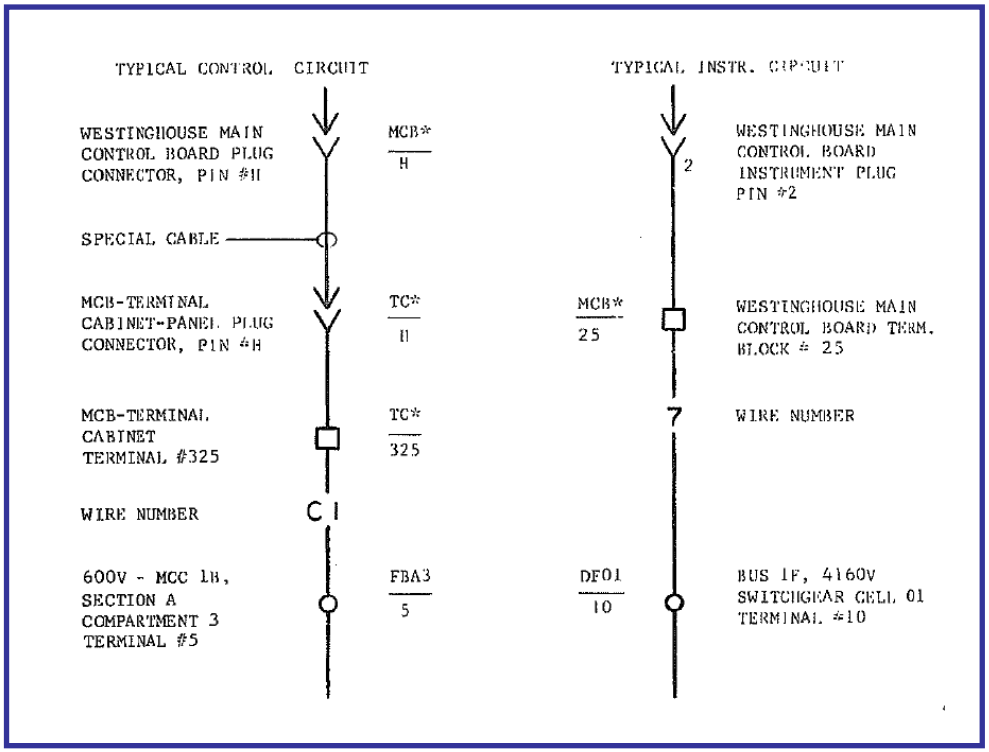
1) 

Two (2) 64 devices 64-1 and 64-2 in same cell.

2) 

Three (3) 27 devices 27-1, 27-2 and 27-3. The two (2) below the 27-2 device indicates there are two (2) 27 devices and their sequence numbers are in numerical order starting with -2.

ELEMENTARY DIAGRAM CONNECTIONS



*Abbreviation for equipment - The corresponding equipment number will appear in a table on the elementary diagram (e.g. MCB = Q1H12C005)

Understanding these general conventions will greatly help with understanding of how to work with schematic (elementary) diagrams

WIRE NUMBERING

WIRE NUMBERING SYSTEM

1. The following standard interconnecting wire numbers shall be used wherever applicable (for computer - schedule programming).

Wire Number	Purpose	Wire Number	Purpose
1	A - Phase Power	4	A - Phase Potential (See Notes 3 & 5)
2	B - Phase Power	5	A - Phase Current (See Notes 3 & 5)
3	C - Phase Power	6	B - Phase Potential (See Notes 3 & 5)
(Note 1)	Annunciator	7	B Phase Current (see Notes 3 & 5)
N	D. C. Negative (See Note 2)	8	C - Phase Potential (See Notes 3 & 5)
P	D. C. Positive (See Note 2)	9	C - Phase Current (See Notes 3 & 5)
U	115 volt A. C.-Ground Return (see Note 2)	0	Potential (or Current) Neutral (See Notes 4 & 5)
X	115 volt A. C. (See Note 2)		
C	Closing (See Note 2)		
T	Tripping (See Note. 2).		
O	Opening, MOV Only (See Note 2)		
F	Instrumentation (e.g. indicator, recorder, etc; See Note 2)		
H	Computer (See Note 2)		
M	General Control (Neither tripping nor closing; See Note 2)		
A	Amber Lamp (See Note 2)		
B	Blue Lamp (See Note 2)		
L	Green Lamp (See Note 2)		
R	Red Lamp (See Note 2)		
W	White Lamp (See Note 2)		

	Basic, Generator or Motor
	Field, Compensating, Generator or Motor
	Field, Series, Generator or Motor
	Field, Short or Separately Excited, Generator or Motor
	Field, Permanent Magnet, Generator or Motor
	1-phase
	2-phase
	3-phase, wye

	3-phase wye, grounded
	3-phase delta

ABBREVIATIONS

A	Ammeter
AH	Ampere-hour
C	Coulombmeter
CMA	Contact-making (or breaking) ammeter
CMC	Contact-making (or breaking) clock
CMV	Contact-making (or breaking) voltmeter
CRO	Oscilloscope or cathoderay oscillograph
DB	DB (decibel) meter: Audio level/meter
DBM	DBM (decibels referred to 1 milliwatt (meter)
DM	Demand meter
DTR	Demand-totalizing relay
F	Frequency meter
G	Galvanometer
GD	Ground detector
I	Indicating
INT	Integrating
UA	Microammeter
MA	Milliammeter
NM	Noise meter
OHM	Ohmmeter
OP	Oil pressure
OSCG	Oscillograph, string
PF	Power factor
PH	Phasemeter
PI	Position indicator
RD	Recording demand meter
REC	Recording
RF	Reactive factor
SY	Synchroscope
t^{O}	Temperature meter
THC	Thermal converter
TLM	Telemeter
TT	Total time: Elapsed time
V	Voltmeter
VA	Volt-ammeter
VAR	Varmeter
VARH	Varhour meter
VI	Volume indicator: Meter, audio level
VU	Standard volume indicator Meter, audio level
W	Wattmeter
WH	Watthour meter

ANSI/IEEE Standard Device Numbers

1 – Master Element
2 – Time delay Starting or Closing Relay
3 – Checking or Interlocking Relay
4 – Master Contactor
5 – Stopping
6 – Starting Circuit Breaker
7 – Rate of Change Relay
8 – Control Power Disconnecting Device
9 – Reversing Device
10 – Unit Sequence Switch
11 – Multi-function Device
12 – Overspeed Device
13 – Synchronous-speed Device
14 – Underspeed Device
15 – Speed – or Frequency, Matching Device
16 – Data Communications Device
17 – Shunting or Discharge Switch
18 – Accelerating or Decelerating Device
19 – Starting to Running Transition Contractor
20 – Electrically Operated Valve
21 – Distance Relay
22 – Equalizer Circuit Breaker
23 – Temperature Control Device
24 – Volts per Hertz Relay
25 – Synchronizing or Synchronize-Check Device
26 – Apparatus Thermal Device
27 – Undervoltage Relay
27s - DC under voltage Relay
28 – Flame detector
29 – Isolating Contactor or Switch
30 – Annunciator Relay
31 – Separate Excitation
32 – Directional Power Relay or Reverse Power Relay
33 – Position Switch
34 – Master Sequence Device
35 – Brush-Operating or Slip-Ring Short-Circuiting Dev
36 – Polarity or Polarizing Voltage Devices
37 – Undercurrent or Underpower Relay
38 – Bearing Protective Device
39 – Mechanical Condition Monitor
40 – Field (over/under excitation) Relay
41 – Field Circuit Breaker
42 – Running Circuit Breaker
43 – Manual Transfer or Selector Device
44 – Unit Sequence Starting Relay
45 – DC over voltage Relay
46 – Reverse-phase or Phase-Balance Current Relay
47 – Phase-Sequence or Phase-Balance Voltage Relay
48 – Incomplete Sequence Relay
49 – Machine or Transformer, Thermal Relay - OLR
50 – Instantaneous Overcurrent Relay
50G - Instantaneous Earth Overcurrent Relay (Neutral CT Method)
50N - Instantaneous Earth Overcurrent Relay (Residual Method)
50BF - Breaker failure
51 – AC Inverse Time Overcurrent Relay
51G - AC Inverse Time Earth Overcurrent Relay (Neutral CT Method)
51N - AC Inverse Time Earth Overcurrent Relay (Residual Method)
52 – AC Circuit Breaker
52a - AC Circuit Breaker Position (Contact Open when Breaker Open)
52b - AC Circuit Breaker Position (Contact Closed when Breaker Open)
53 – Exciter or DC Generator Relay
54 – Turning Gear Engaging Device
55 – Power Factor Relay
56 – Field Application Relay
57 – Short-Circuiting or Grounding Device
58 – Rectification Failure Relay
59 – Overvoltage Relay
60 – Voltage or Current Balance Relay.
61 – Density Switch or Sensor
62 – Time-Delay Stopping or Opening Relay
63 – Pressure Switch
64 – Ground Detector Relay
64R - Restricted earth fault
64S - Stator earth fault
65 – Governor
66 – Notching or Jogging Device
67 – AC Directional Overcurrent Relay
68 – Blocking Relay

ANSI/IEEE Standard Device Numbers

69 – Permissive Control Device
70 – Rheostat
71 – Liquid Level Switch
72 – DC Circuit Breaker
73 – Load-Resistor Contactor
74 – Alarm Relay
75 – Position Changing Mechanism
76 – DC Overcurrent Relay
77 – Telemetering Device
78 – Phase-Angle Measure Relay or "Out-of-Step" Relay
79 – AC Reclosing Relay (Auto Reclosing)
80 – Flow Switch
81 – Frequency Relay
82 – DC Reclosing Relay
83 – Automatic Selective Control or Transfer Relay
84 – Operating Mechanism
85 – Communications, Carrier, or Pilot-Wire Relay
86 – Lockout Relay/Master Trip
87 – Differential Protective Relay
88 – Auxiliary Motor or Motor Generator
89 – Line Switch
90 – Regulating Device
91 – Voltage Directional Relay
92 – Voltage and Power Directional Relay
93 – Field Changing Contactor
94 – Tripping or Trip-Free Relay (trip circuit supervision Relay)
95 – For specific applications where other numbers are not suitable
96 – Busbar Trip Lockout relay
97 – Specific applications where other numbers are not suitable
98 – Specific applications where other numbers are not suitable
99 – Specific applications where other numbers are not suitable
150 – Earth Fault Indicator
AFD – Arc Flash Detector
CLK – Clock or Timing Source
DDR – Dynamic Disturbance Recorder
DFR – Digital Fault Recorder
DME – Disturbance Monitor Equipment
HIZ – High Impedance Fault Detector
HMI – Human Machine Interface
HST – Historian
LGC – Scheme Logic
MET – Substation Metering
PDC – Phasor Data Concentrator
PMU – Phasor Measurement Unit
PQM – Power Quality Monitor
RIO – Remote Input/Output Device
RTU – Remote Terminal Unit/Data Concentrator
SER – Sequence of Events Recorder
TCM – Trip Circuit Monitor
LRSS - LOCAL/REMOTE SELECTOR SWITCH
SOTF - Switch On To Fault

DEVICE SUFFIX NUMBERS

A suffix letter or number may be used with the device number; for example, suffix N is used if the device is connected to a Neutral wire (example: 59N in a relay is used for protection against Neutral Displacement); and suffixes X,Y,Z are used for auxiliary devices.

Similarly, the "G" suffix can denote a "ground", hence a "51G" is a time overcurrent ground relay. The "G" suffix can also mean "generator", hence an "87G" is a Generator Differential Protective Relay while an "87T" is a Transformer Differential Protective Relay. "F" can denote "field" on a generator or "fuse", as in the protective fuse for a pickup transformer. Suffix numbers are used to distinguish multiple "same" devices in the same equipment such as 51-1, 51–2.

Common suffixes:
B – Bus
F – Field
T – Transformer
G – Ground or Generator
N - Neutral

Device numbers may be combined if the device provides multiple functions, such as the instantaneous/time-delay AC over current relay denoted as 50/51.

CIRCUIT ANALYSIS WORKSHEET

Component ID _____ Component Type _____

Component Description _____

Normal Position _____
Failed Electrical Position _____
Failed Air Position _____
Function State
Initial Position _____
Desired Position _____
BE Code _____

High Consequence Component Yes ☐ No ☐

Power Supplies _____ Breaker _____ Req'd ☐
_____ Breaker _____ Req'd ☐

Cable Analysis

Cable ID	Req'd?	MHS?	Fault Consequence	Comments

Cable ID	Req'd?	MHS?	Fault Consequence	Comments

Equipment Dependencies

Comments

Cable Analysis

Cable ID	Single or Double Break	Circuit Type	Power (AC or DC)	Grounded?	Insulation / Shield	Failure Mode(s)				7150 Table	P(x)
						Intra	Inter	GFEHS	Aggregate		
						☐	☐	☐	☐		
						☐	☐	☐	☐		
						☐	☐	☐	☐		
						☐	☐	☐	☐		
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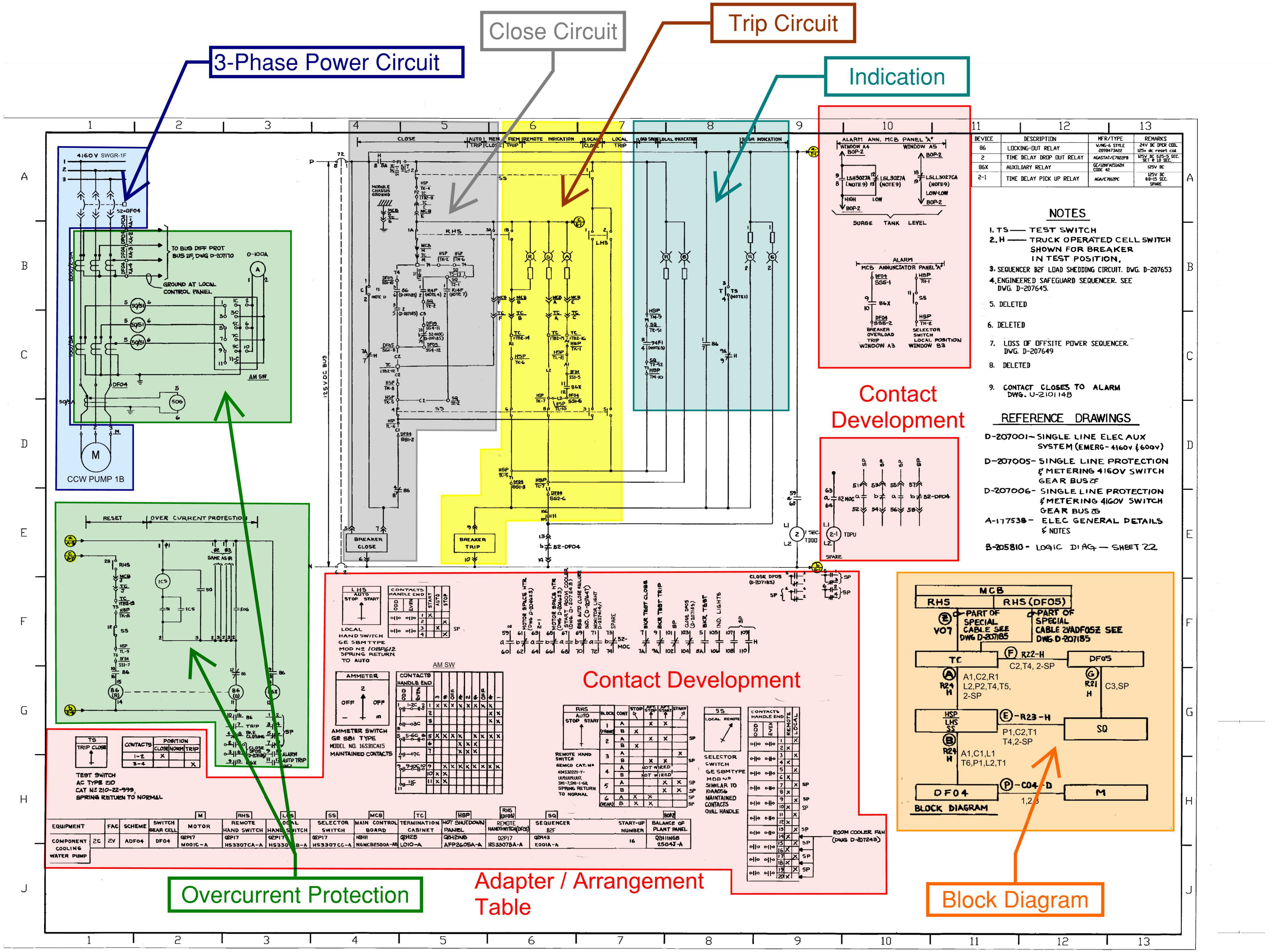


3-Phase Power Circuit
Close Circuit
Trip Circuit
Indication
Contact Development
Contact Development
Overcurrent Protection
Adapter / Arrangement Table
Block Diagram
CCW PUMP 1B
NOTES
1. TS — TEST SWITCH
2. H — TRUCK OPERATED CELL SWITCH SHOWN FOR BREAKER IN TEST POSITION.
5. DELETED
6. DELETED
8. DELETED
REFERENCE DRAWINGS
BLOCK DIAGRAM

Cable Selection /Circuit Analysis
Recommended Process for Task 3 & Task 9A

Preparation

1. Collect Drawings
2. Understand functional state requirements of the circuit
3. Decide on:

   Active functional state - Power is required to meet function state requirements

   or

   Passive functional state – Power is not required to meet function state requirements

Power Supply

4. Identify power supply and breaker/fuse for the circuit
5. Is power required to achieve/maintain functional state?
6. Determine requirement for “Alternate” power (if applicable)

Contact Positions / Cable-Conductor Markup

7. Mark up contact positions on drawings for “**Initial**” condition or state (*Don’t guess, use limit switch legends and switch developments*)
8. Highlight schematic (elementary) & block diagrams to show cable - conductor relationship

Hot-Probe Assessment

9. Using Hot-Probe and Ground-Probe technique, identify failure mode(s) for each conductor

   NOTE: Remember that this technique for Task 3/9A assumes a “source” conductor is present and does not distinguish between intra-cable and inter-cable hot short

10. Assign Fault Codes to the conductors
11. Roll up conductor failure modes to cable(s)

Off-Scheme Circuits / Dependencies

12. Assess each control contact from off-scheme circuits (auxiliary contacts) to decide if it can impact the function state:

    - Is contact needed for proper operation of a credited automatic function

- Could contact prevent automatic or manual operation
- Could contact by itself (or in conjunction with another circuit failure) cause a spurious operation

13. If contact could affect function state, then an “Equipment Dependency” exists with the contact’s circuit.

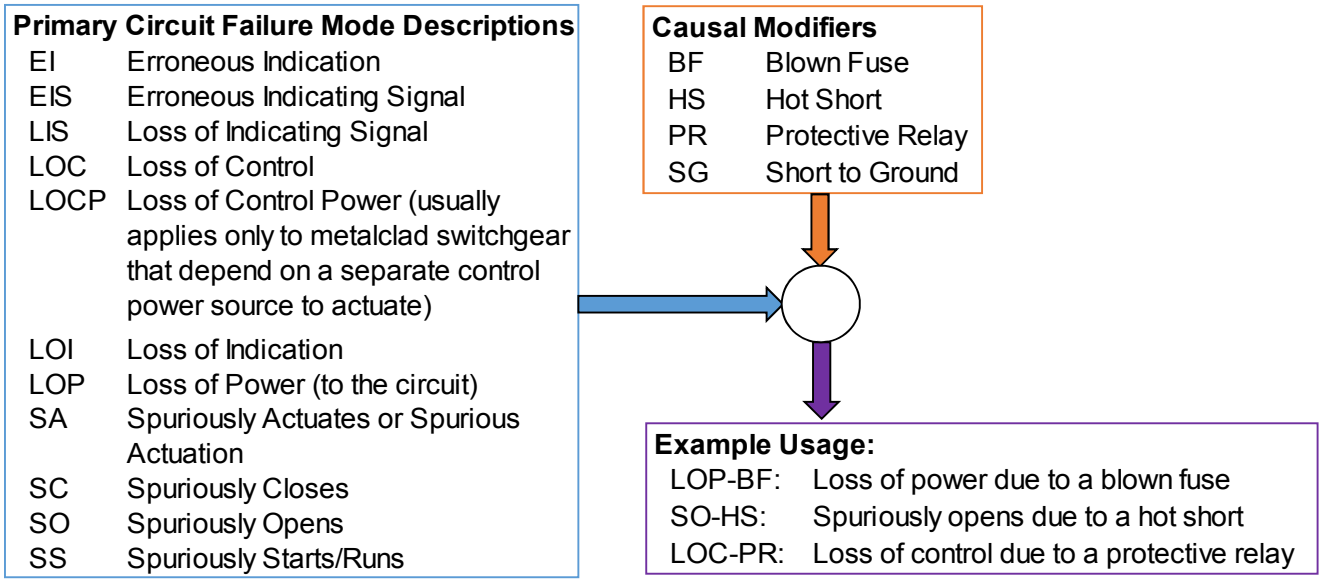
Document Analysis

14. Document analysis per established process

15. File all markup drawings and notes in component work package (Current “Best Practice” is create electronic work package)

16. Generate failure reports as required to support PRA quantification

Fault Codes



List of Circuit Analysis Exercises (2019 Course)

Example No.	Component	Description of Example	Function State
1A 1B	AOV-8879B	Easy AOV circuit with function states involving change of position and maintain energized position [Walkthrough Example]	Open - Closed Open - Open
2A 2B 2C	MOV-8112-A	Medium MOV circuit with interlock dependencies; various function states investigated [Walkthrough Example]	Closed - Open Closed - Closed Open - Closed
3A 3B	MOV-8888	Easy MOV circuit with function states involving change of position and maintain initial position	Open - Open Open - Closed
4A 4B	AOV-2869A	Medium difficulty AOV circuit with function states involving change of position and maintain position	Closed - Closed Closed - Open
5	MOV-11	DC MOV control circuit with desired change of state	Close - Open
6A 6B	MOV-15	Double pole DC motor control circuit with desired change of state – remote and local operation	Close - Throttled Close – Throttled (Local)
7A 7B	CCW Pump 1B	Medium difficulty 4.16 kV pump involving change of position and maintain position	Standby – On Off - Off
8	MCC-1B	480V MCC	Energized - Energized
9	LC-B	480V Load Center	Energized – Energized (Norm)
10	ANN-1	Annunciator Circuit	Available – Nonspurious
11	FCV-605A	Instrument control signal to flow control valve	Closed - Modulate
12	TTR2	Instrument loop – temperature indicator	Available – Available (FT-605A)
13	COMP-1	480 V Motor	Cycle - Cycle