

# CONTENTS

<b>CHAPTER 1 – General Wiring, Lighting and Hazardous Locations</b> . . . . .	<b>1-1</b>
Ohm’s Law Diagram and Formulas . . . . .	1-2
Power Diagram and Formulas . . . . .	1-2
AC/DC Formulas for Calculating Amps, Horsepower, Kilowatts and kVA. . . . .	1-3
Circuit Characteristics . . . . .	1-4 – 1-7
Bending Conduit . . . . .	1-8
Back-to-Back Bending . . . . .	1-9
Offset and Saddle Bends. . . . .	1-10
Bending Stub-Ups . . . . .	1-11
Pull and Connection Points . . . . .	1-12
Wire-Bending Space . . . . .	1-13
Junction Box Calculations . . . . .	1-14
Conductor Volume Allowance . . . . .	1-14
Box Fill . . . . .	1-15
Enclosures in Wet Locations . . . . .	1-16
Grounded Conductor Color Code. . . . .	1-16
Grouped Conductors . . . . .	1-17
Paralleled Conductors . . . . .	1-17
Conductor Color Code. . . . .	1-18
Power Wiring Color Code . . . . .	1-18
Power-Transformer Color Code. . . . .	1-18
Basic Grounded Conductor Rules . . . . .	1-19 & 1-20
Minimum Size Conductors for Grounding Raceway and Equipment. . . . .	1-21

Underground Installation Requirements . . . . .	1-22 & 1-23
Minimum Cover Requirements for Underground Installations . . . . .	1-24 & 1-25
Family Room Receptacle Outlet Spacing . . . . .	1-26
Family Room with Split-Wired Receptacles and Switched Circuit . . . . .	1-27
Countertop Receptacle Outlet Spacing . . . . .	1-28 & 1-29
Kitchen Receptacles . . . . .	1-30
Bathroom Receptacles . . . . .	1-31
Wet Bar Receptacles . . . . .	1-32
Crawl Space Receptacles . . . . .	1-33
Unfinished Basement Receptacles . . . . .	1-34
Garage/Shop Receptacles . . . . .	1-35
Outdoor Receptacles . . . . .	1-36
Isolated Ground Receptacle . . . . .	1-37
GFCI . . . . .	1-37
Split-Wired . . . . .	1-37
GFCI Wiring Diagrams . . . . .	1-38
Wiring Diagrams for NEMA Configurations . . . . .	1-39 – 1-43
Wiring Diagrams for Switches . . . . .	1-44
Wiring Diagram of Split-Wired Receptacles and Switched Circuit . . . . .	1-45
Single Pole Switch Circuit . . . . .	1-46
Single Pole Operating a Light with Additional Independent Receptacle . . . . .	1-47
Double-Gang Switch – Each Controls a Light . . . . .	1-48
Double-Gang Switch – One Controls Receptacle, One Controls Light . . . . .	1-49

Three-Way Switches .....	1-50
Three- and Four-Way Switches.....	1-51
Three-Way Switch Circuit Operating One Outlet .....	1-52
Three-Way Switch Circuit Operating One Outlet From Two Locations.....	1-53
Three-Way Switch Circuit Operating Multiple Outlets.....	1-54
Wiring Diagram for Operating Lights from Four Locations .....	1-55
Typical Preheat Circuit .....	1-56
Typical Ballast.....	1-56
Rapid-Start Circuits .....	1-57
Classifications of Hazardous Locations .....	1-58
Standard and Optional Hazardous Location Systems.....	1-59
Division 1 Examples.....	1-60
Explosionproof Reducers.....	1-61
Conduit Seals .....	1-62
Dispensing Equipment Conduit Seals.....	1-63
Fuel Dispenser Hazardous Areas .....	1-64
Service Station Hazardous Areas .....	1-65
Dispensing Equipment Disconnecting Means .....	1-66
Hazardous Locations – Commercial Garages .....	1-67
Hazardous Locations – Pits.....	1-68
Hazardous Locations – Storage Tanks .....	1-69
Hazardous Locations – Vertical Tanks.....	1-70
Hazardous Locations – Vent Pipes .....	1-71
Hazardous Locations – Ventilation .....	1-72

<b>CHAPTER 2 – Low Voltage. . . . .</b>	<b>2-1</b>
Low-Voltage Circuits. . . . .	2-2 – 2-4
Low-Voltage Remote Control Circuit with Several Switches Controlling a Receptacle Outlet. . . . .	2-5
Remote Control Circuit from Various Locations Operating Two Different Circuits from the Same Switches. . . . .	2-6
Remote Control Circuit Controlling Three Separate Circuits with Outlets . . . . .	2-7
Common Low-Voltage Relay Wiring Diagram . . . . .	2-8
Wiring Diagram for a Nine Point Selector Switch. . . . .	2-9
Bell Circuit for One Door . . . . .	2-10
Bell Controlled from Several Locations. . . . .	2-10
Return Call Bell System. . . . .	2-11
Return Call Bell System Utilizing Double Contact Push-Button Switches. . . . .	2-11
Central Chime for Two Doors . . . . .	2-12
Three Tone Door Signal Systems . . . . .	2-12
Two Parallel-Wired Chimes . . . . .	2-13
Chime System with House Number Light and Transformer . . . . .	2-13
Closed Circuit Intruder Alarm . . . . .	2-14
Open Circuit Intruder Alarm. . . . .	2-15
Intruder Alarm Circuit with Annunciator and Relay . . . .	2-16
Unbalanced Audio Output. . . . .	2-17
Balanced Audio Output . . . . .	2-17
Intercom System with Two Remotes and One Master Unit . . . . .	2-18 & 2-19

Basic Annunciator Wiring Diagram . . . . .	2-20
Sequence System for Thermal Power Relays . . . . .	2-21
Residential Powerline Carrier System Using Normal Electric Circuits as Communication Lines. . . . .	2-22
Residential Hard-Wired Control System . . . . .	2-23
Common Telephone Connections. . . . .	2-24
Color Coding of Cables . . . . .	2-24
Standard Telecom Color Coding . . . . .	2-25
Modular Jack Styles. . . . .	2-26
Common Wiring Configurations . . . . .	2-26 & 2-27
25-Pair Color Coding/ISDN Contact Assignments. . . . .	2-28
Common Unshielded Twisted Pair Data and Voice Wiring Schemes . . . . .	2-29
Data and Voice Wiring Diagrams . . . . .	2-30 – 2-35
ISDN Assignment of Contact Numbers . . . . .	2-36
Typical Wiring Methods . . . . .	2-37
66 Block Wiring & Cable Color Coding. . . . .	2-38 & 2-39
150-Pair PIC Cable Core Arrangement. . . . .	2-40
Phantom Telephone Circuit . . . . .	2-41
Standard DTMF Pad and Frequencies . . . . .	2-41
Wiremapping . . . . .	2-42
EIA/TIA 568A Modular Pin Connections . . . . .	2-42
Modular Pin Connections – Reversed Pair . . . . .	2-43
Modular Pin Connections – Shorts and Opens . . . . .	2-43
Modular Pin Connections – Split Pairs . . . . .	2-44
Modular Pin Connections – Transposed or Crossed Pairs . . . . .	2-44

Balanced Pair Transmission . . . . .	2-45
Attenuation . . . . .	2-45
Next (Near End Crosstalk) . . . . .	2-46
Power Sum Next (Near End Crosstalk) . . . . .	2-46
ACR (Attenuation to Crosstalk Ratio) . . . . .	2-47
Delay Skew . . . . .	2-47
Neuron Chip Simplified Block Diagram . . . . .	2-48 – 2-51
Neuron Chip Block Diagram . . . . .	2-52
Basic HVAC Thermostat Circuit . . . . .	2-53
HVAC Twin-Type Thermostat . . . . .	2-54
HVAC Millivolt Control . . . . .	2-55
Connections for a Stoker Installation . . . . .	2-56
Connections for an Oil Burner Installation . . . . .	2-57
Damper-Control Low-Voltage Installation . . . . .	2-58
Gas Burner Controls . . . . .	2-59
Illustrating a Gas-Burner Installation . . . . .	2-60
Electric Heating Unit Diagrams . . . . .	2-61 – 2-64
Compound Metal Thermostat and Circuit . . . . .	2-65
Limit Switch Included in a Baseboard Heater . . . . .	2-66

## **CHAPTER 3 – Grounding . . . . . 3-1**

Basic Grounding Connections . . . . .	3-4
Minimum Sizes of Grounding Electrode Conductors for AC Systems . . . . .	3-5
Resistivities of Various Soils . . . . .	3-5
Adding Chemicals to Soil to Lower Ground Resistance . . . . .	3-6

Ground-Rod Testing . . . . .	3-7
Typical Equipment Grounding Conductor . . . . .	3-8
Grounded Conductor – Neutral . . . . .	3-9
Grounded Conductor – Not Neutral . . . . .	3-9
Grounding Different Types of Circuits . . . . .	3-10 & 3-11
Voltage Relationship on Grounded 4-Wire Systems . . .	3-12
Grounded Primary Distribution System . . . . .	3-13
Grounding a Basic Overhead Electrical Service . . . . .	3-14
Grounding a Basic Nonmetallic Underground Service Raceway . . . . .	3-15
Grounding Electrode Systems . . . . .	3-16 – 3-19
Grounding and Bonding a Typical Service Entrance . . .	3-20
Proper Bonding of a Water Meter . . . . .	3-21
Ufer Ground . . . . .	3-21
Grounding an Outdoor Antenna . . . . .	3-22
Grounding Separately Derived Systems in Multiple Floor Buildings . . . . .	3-23
Main Bonding Jumpers . . . . .	3-24
Bonding Service Equipment Methods . . . . .	3-25
Bonding Jumpers for Grounding Equipment Conductor Raceways . . . . .	3-26
Equipment Bonding Jumpers . . . . .	3-27
Grounding a Typical Residential Wiring System . . . . .	3-28 & 3-29
Grounding a Typical Commercial Wiring System . . . . .	3-30 & 3-31
Typical Low Voltage Services . . . . .	3-32

Grounding a Signal Loop . . . . .	3-33
Dedicated Instrumentation System Ground Bus . . . . .	3-33
Ground Loops May Develop in Non-Isolated Signal Loops. . . . .	3-34
A Signal Isolator Blocks Unwanted DC Ground Current . . . . .	3-35
Ground Fault Protection . . . . .	3-36 & 3-37
Lightning and Surge Protection. . . . .	3-38

## **CHAPTER 4 – *Motors and Controls* . . . 4-1**

Delta-Wound Motor for Use on 240/480 Volts . . . . .	4-3
Wye-Wound Motor for Use on 240/480 Volts. . . . .	4-3
Split-Phase Motors. . . . .	4-4
Split-Phase Motor Rotation . . . . .	4-5
Single-Voltage, 3 $\phi$ , Wye-Connected Motor . . . . .	4-6
Single-Voltage, 3 $\phi$ , Delta-Connected Motor . . . . .	4-6
Dual-Voltage, 3 $\phi$ , Wye-Connected Motors . . . . .	4-7
Dual-Voltage, 3 $\phi$ , Delta-Connected Motors . . . . .	4-8
Star-Connected, Polyphase Motor . . . . .	4-9
Reversing Three-Phase Motors. . . . .	4-9
Two-Phase, AC Motors . . . . .	4-10
Connections for a Two-Speed, Constant Horsepower, One Winding Motor . . . . .	4-11
Connections for a Two-Speed, Constant Torque, One Winding Motor . . . . .	4-12
Connections for a Two-Speed, Variable Torque, One Winding Motor . . . . .	4-13
Capacitor-Start-Capacitor-Run Motor. . . . .	4-14

Reversing a Capacitor-Start Motor . . . . .	4-14
Capacitor-Start Motor Voltage Connections. . . . .	4-15
Two-Speed Capacitor Motor . . . . .	4-15
Wound-Rotor Motor Schematic . . . . .	4-16
Reversing Split-Phase Motors. . . . .	4-16
Typical Motor Starter Diagram. . . . .	4-17
Step-Down Transformer Motor Control . . . . .	4-17
Motor Control Circuits . . . . .	4-18 – 4-59
DC Series-Wound Motor . . . . .	4-60
DC Shunt-Wound Motor . . . . .	4-60
DC Compound-Wound Motor. . . . .	4-60
DC Motor Connections . . . . .	4-61 – 4-69
DC Motor Control Circuits . . . . .	4-70 – 4-84

## **CHAPTER 5 – *Transformers*. . . . . 5-1**

Single-Phase Transformer Circuits . . . . .	5-2
Single-Phase Transformer Connections . . . . .	5-3 – 5-6
Two-Phase Transformer Connections. . . . .	5-7 & 5-8
Three-Phase AC Circuits . . . . .	5-9 & 5-10
Three-Phase Transformer Connections. . . . .	5-11 – 5-32
Current Transformer . . . . .	5-33
Testing a Transformer for Polarity . . . . .	5-33
Current-Voltage Relationship Between High Side and Low Side of a Transformer . . . . .	5-33
Split-Coil Transformer and an Additive-Polarity Transformer. . . . .	5-34
Secondary Ties. . . . .	5-35

Loads Connected Between Transformer Supply Points .....	5-35
Prohibited Connections on High-Voltage Lighting Transformers.....	5-36
Permissible Connection on High-Voltage Lighting Transformers.....	5-36
Tap Circuits Not Over 25 Feet Long .....	5-37
Transformer Feed Taps Not Over 25 Feet Long.....	5-38
Autotransformer .....	5-39
Autotransformer Dimmer Circuit .....	5-40
Autotransformer Voltage Booster .....	5-40
Autotransformer Connections .....	5-41
Star-Delta Connected .....	5-42
Delta-Delta Connected .....	5-43
Star-Star Connected .....	5-44

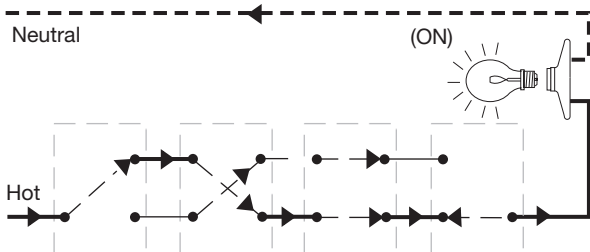
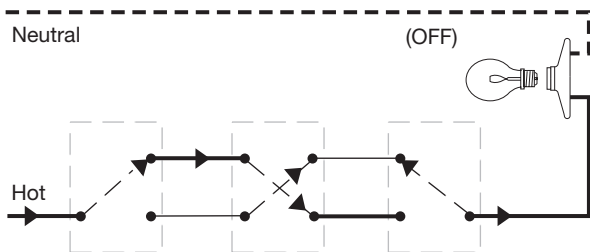
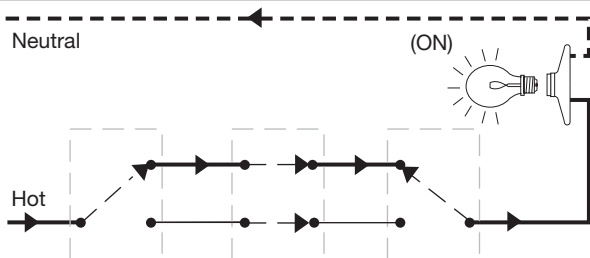
## **CHAPTER 6 – *Power Distribution* . . . . 6-1**

Multiwire System Voltages .....	6-2 & 6-3
4-Wire Circuits .....	6-4 & 6-5
High-Leg of 4-Wire Delta System .....	6-6
Phase Arrangement for Three-Phase Bus Bars .....	6-7
3-Wire Circuits .....	6-8 & 6-9
Branch Circuits .....	6-10
Branch Circuit Grounding .....	6-11
Circuit Breakers .....	6-12 – 6-14
Overcurrent Protection .....	6-15 & 6-16
Current and Voltage Transformer Connections .....	6-17

Tap Circuit .....	6-18
Minimum Service-Drop Clearance .....	6-19
Service Drop Attached to a Building or Other Structure .....	6-20
Service Lateral Extending from Point A to Point B ....	6-21
Principal Parts of an Electrical Service .....	6-22 & 6-23
Underground Service Conduit to Sidewalk Hand Hole and Underground Service Conductors .....	6-24
Bonding Flexible Metal Conduit in a Service Entrance .....	6-25
Pole-Mounted Service-Entrance Equipment for Mobile Home Use with the Feeder Cable Above Ground .....	6-26
Underground Service Lateral for Use with Mobile Home .....	6-27
Pole-Mounted Service-Entrance Equipment for Mobile Home Use with the Feeder Cable Buried ....	6-28
An Overhead Feeder-Cable Installation to Supply Power to a Mobile Home .....	6-29
120/240 V, 1 $\phi$ , 3-Wire Service .....	6-30
120/208 V, 3 $\phi$ , 4-Wire Service .....	6-31
120/240 V, 3 $\phi$ , 4-Wire Service .....	6-32
277/480 V, 3 $\phi$ , 4-Wire Service .....	6-33
200-Ampere Service with a 12 $\frac{1}{2}$ kVA Standby Alternator Arranged for Nonautomatic Switchover ..	6-34
Meter Diagrams .....	6-35 & 6-36
Let-Through Chart for a 1200A Class L Fuse .....	6-37
Single Low-Tension, Double High-Tension Bus .....	6-38
Single High-Tension Bus .....	6-39

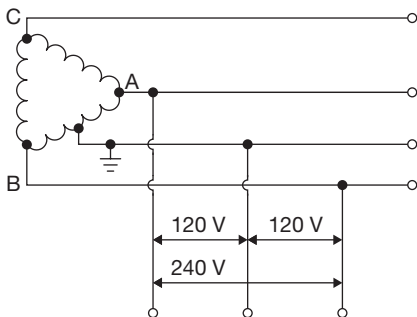
Double-Bus System with the Tie Bus in Dotted Line . .	6-40
Double-Bus, Double-Circuit Breaker System . . . . .	6-40
Ring-Bus System . . . . .	6-41
A Typical “H” System . . . . .	6-42 & 6-43
System Using Single Low- and Single High-Tension Bus . . . . .	6-44
Bus System Using Double Buses and Double Circuit Breakers . . . . .	6-45
Arrangement When Station Is At a Distance From the Lead Center . . . . .	6-46
Old Switchboard Being Fed From New Switchboard . .	6-47
Spare-Bus, Spare-Circuit-Breaker System . . . . .	6-48
Double-Bus and Single-Circuit-Breaker System . . . . .	6-49
Typical Large Commercial Building Service . . . .	6-50 & 6-51
Large Distribution System with Two Utility Feeds . . . . .	6-52 & 6-53
Large Distribution System with Four Utility Feeds . . . . .	6-54 & 6-55
ATS Arrangement with Solid Neutral . . . . .	6-56
ATS Arrangement with Switched-Neutral . . . . .	6-57
Isolation Transformer Installed in the Bypass Source . . . . .	6-58 & 6-59
Bypass Source . . . . .	6-60 & 6-61

## THREE- AND FOUR-WAY SWITCHES

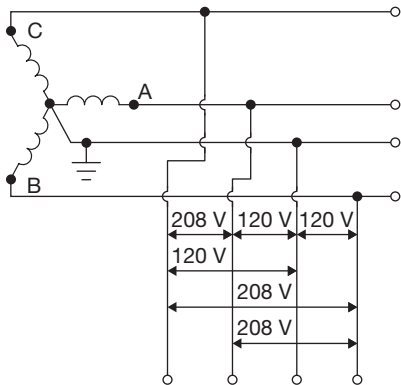


**Two 3-Way Switches and Two 4-Way Switches  
Showing One Operating Position and Current Flow**

## 4-WIRE CIRCUITS



**One type of multiwire circuit from a 4-wire delta system.**



**Multiwire circuit from a 4-wire wye system.**

# 120/240 V, 3 $\phi$ , 4-WIRE SERVICE

