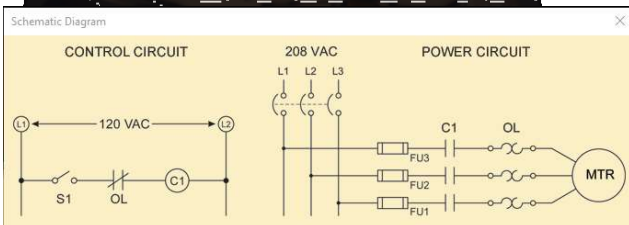
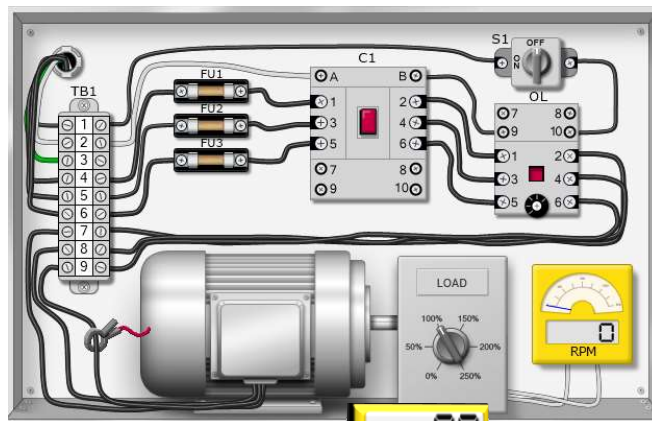




Training:
Electrical Industrial Troubleshooting
REFERENCE MANUAL





It is recommended that individuals using the products of Texas CPD Labor Training LLC be properly trained and certified to practice the profession and hold the NFPA 70E Arc Flash certification. This book is not responsible for the use of this book by any individual who acquires it.

TexasCPDLabor_training



I am a technician who has more than 12 years of experience as an industrial electromechanic:I am certified as an Arc flash trainer NFPA70E trainer, providing repair services and working in other jobs as an electrician. I have also been certified as Logix5000 Maintainer Certificate.

1. Safety First 🛡️

- ✔️ Use the appropriate PPE (gloves, safety glasses, helmet, etc.).
- ✔️ Apply the LOTO (Lockout/Tagout) procedure if necessary.
- ✔️ Ensure the work area is safe and free from electrical or mechanical hazards.

2. Identifying the Problem 🔍

- 🔗 Talk to the operator: Ask about the symptoms before the failure.
- 🔗 Observe the machine: Does it make strange noises? Overheat? Have leaks?
- 🔗 Check the HMI or PLC interface: Note any error codes or alarms.
- 🔗 Consult manuals and electrical schematics: Helps understand the system.

3. Visual and Basic Inspection 🔧

- 🔧 Check connections: Look for loose, burned, or corroded wires.
- ⚡ Verify fuses and breakers: If they are blown or tripped, investigate the cause.
- ⚙️ Mechanical inspection: Look for wear in belts, gears, and bearings.

4. Testing with Measurement Tools 📏

- 💎 Multimeter: Measures voltage, continuity, and resistance in electrical components.
- 💎 Clamp meter: Checks current consumption in motors and transformers.
- 💎 Megohmmeter: Evaluates the insulation condition of electrical windings.
- 💎 Oscilloscope (if applicable): Detects voltage spikes or interference.

5. Diagnosis and Repair 🔧

- ✔️ Electrical issue: Check contactors, relays, sensors, and power supplies.
- ✔️ Mechanical issue: Replace bearings, adjust belts, or gears.
- ✔️ Control issue: Reprogram parameters in PLC or VFD if necessary.

6. Testing and Validation ✔️

- 🔗 Reconnect and test the machine under normal conditions.
- 📊 Monitor its operation to ensure the problem is resolved.
- 📝 Log the intervention in the maintenance records.

Electrical formulas

Electrical Formulas

| Variable | Word Formula w/Units | Simplified Formula |
|--------------------------|---|--|
| Resistance - R | Ohms = Volts/Amperes | $R = \frac{E}{I}$ |
| Amperes- I | Amperes = Volts/Ohms | $I = \frac{E}{R}$ |
| Volts - E | Volts = Amperes x Ohms | $E = I \times R$ |
| % Efficiency - %Eff | $\%Eff = \frac{746 \times \text{Output Horsepower}}{\text{Input Watts}}$ | $\%Eff = \frac{746 \times \text{HP}_{Out}}{W_{In}}$ |
| Single Phase | | |
| Kilowatts - KW | $KW = \frac{\text{Volts} \times \text{Amperes} \times \text{Power Factor}}{1000}$ | $KW = \frac{E \times I \times PF}{1000}$ |
| Amperes - I | $I = \frac{746 \times \text{Horsepower}}{\text{Volts} \times \text{Efficiency} \times \text{Power Factor}}$ | $I = \frac{746 \times \text{HP}}{E \times \%Eff \times PF}$ |
| % Efficiency - %Eff | $\%Eff = \frac{746 \times \text{Horsepower}}{\text{Volts} \times \text{Amperes} \times \text{Power Factor}}$ | $\%Eff = \frac{746 \times \text{HP}}{E \times I \times PF}$ |
| Power Factor - PF | $PF = \frac{\text{Input Watts}}{\text{Volts} \times \text{Amperes}}$ | $PF = \frac{W}{E \times I}$ |
| Three Phase | | |
| Kilowatts - Kw | $KW = \frac{\text{Volts} \times \text{Amperes} \times \text{Power Factor} \times 1.732}{1000}$ | $KW = \frac{E \times I \times PF \times 1.732}{1000}$ |
| Volt-Amperes - VA | $VA = \text{Volts} \times \text{Amperes} \times 1.732$ | $VA = E \times I \times 1.732$ |
| Amperes - I | $I = \frac{746 \times \text{Horsepower}}{\text{Volts} \times \text{Efficiency} \times \text{Power Factor} \times 1.732}$ | $I = \frac{746 \times \text{HP}}{E \times \%Eff \times PF \times 1.732}$ |
| % Efficiency | $\%Eff = \frac{746 \times \text{Horsepower}}{\text{Volts} \times \text{Amperes} \times \text{Power Factor} \times 1.732}$ | $\%Eff = \frac{746 \times \text{HP}}{E \times I \times PF \times 1.732}$ |
| Power Factor - PF | $PF = \frac{\text{Input Watts}}{\text{Volts} \times \text{Amperes} \times 1.732}$ | $PF = \frac{W}{E \times I \times 1.732}$ |
| Horsepower | | |
| Horsepower (1 Ph) | $HP = \frac{\text{Volts} \times \text{Amperes} \times \text{Efficiency} \times \text{Power Factor}}{746}$ | $HP = \frac{E \times I \times \%Eff \times PF}{746}$ |
| Horsepower (3 Ph) | $HP = \frac{\text{Volts} \times \text{Amperes} \times 1.732 \times \text{Efficiency} \times \text{Power Factor}}{746}$ | $HP = \frac{E \times I \times 1.732 \times \%Eff \times PF}{746}$ |
| Power DC Circuits | | |
| Watts (W) | Watts = Volts x Amperes | $W = EI$ |
| Amperes - I | Amperes = Watts / Volts | $I = W/E$ |
| Horsepower - HP | $HP = \frac{\text{Volts} \times \text{Amperes} \times \text{Efficiency}}{746}$ | $HP = \frac{E \times I \times \%Eff}{746}$ |

The 80% rule is a safety guideline in electrical systems. It essentially means that a circuit's breaker or fuse should be rated to handle *no more than 80% of its continuous current capacity*. This is to prevent overheating and potential fires.

Why 80%?

Continuous Loads: Electrical loads that run for 3 hours or more are considered "continuous." These loads generate heat, and the 80% rule allows for a safety margin.

Safety Margin: Even non-continuous loads can have brief surges or spikes in current. The 80% rule provides a buffer to prevent nuisance tripping (the breaker tripping when it shouldn't).

Steps to Choose the Right Fuse or Breaker

Calculate the Load Current:

$$\text{Amps (I)} = \text{Watts (P)} / \text{Volts (V)}$$

Example: Let's say you have a load of 1200 watts on a 120-volt circuit.

$$I = 1200 \text{ watts} / 120 \text{ volts} = 10 \text{ amps}$$

Apply the 80% Rule:

Divide the load current by 0.8 (or multiply by 1.25) to find the minimum breaker/fuse rating.

Example:

$$10 \text{ amps} / 0.8 = 12.5 \text{ amps (or } 10 \text{ amps} * 1.25 = 12.5 \text{ amps)}$$

Choose the Next Higher Standard Breaker/Fuse Size:

Breakers and fuses come in standard sizes. You can't use a 12.5 amp breaker. You need to round *up* to the next standard size.

Standard Sizes: Common sizes are 15A, 20A, 25A, 30A, 40A, 50A, 60A, etc.

Example: Since 12.5 amps isn't standard, you'd choose a 15-amp breaker or fuse.

Formula Summary

Load Current (Amps) = Watts / Volts

Minimum Breaker/Fuse Rating = Load Current / 0.8 (or Load Current * 1.25)

Select the Next Higher Standard Breaker/Fuse Size

Important Notes

Wire Size: The wire size must also be rated for the breaker or fuse you choose. Using too small of a wire can create a fire hazard. Consult a wiring chart or a qualified electrician.

Local Codes: Always follow local electrical codes and regulations.

Professional Help: If you're unsure about any aspect of electrical work, consult a licensed electrician. Electricity can be dangerous if not handled properly.

Let's do another example:

Load: 1800 watts, 120 volts (continuous load)

Load Current: 1800 watts / 120 volts = 15 amps

80% Rule: 15 amps / 0.8 = 18.75 amps (or 15 amps * 1.25 = 18.75 amps)

Breaker/Fuse Size: You'd need to choose a 20-amp breaker or fuse.

In Simple Terms:

To make sure your electrical stuff is safe, you need to use a fuse or breaker that can handle a bit more power than your stuff actually uses. This extra capacity helps prevent things from getting too hot and causing problems.

Question

- What is the 80% rule in electrical systems, and why is it important?
- How do you apply the 80% rule when selecting a fuse or breaker?
- Why is it necessary to consider wire size and local codes when applying the 80% rule?

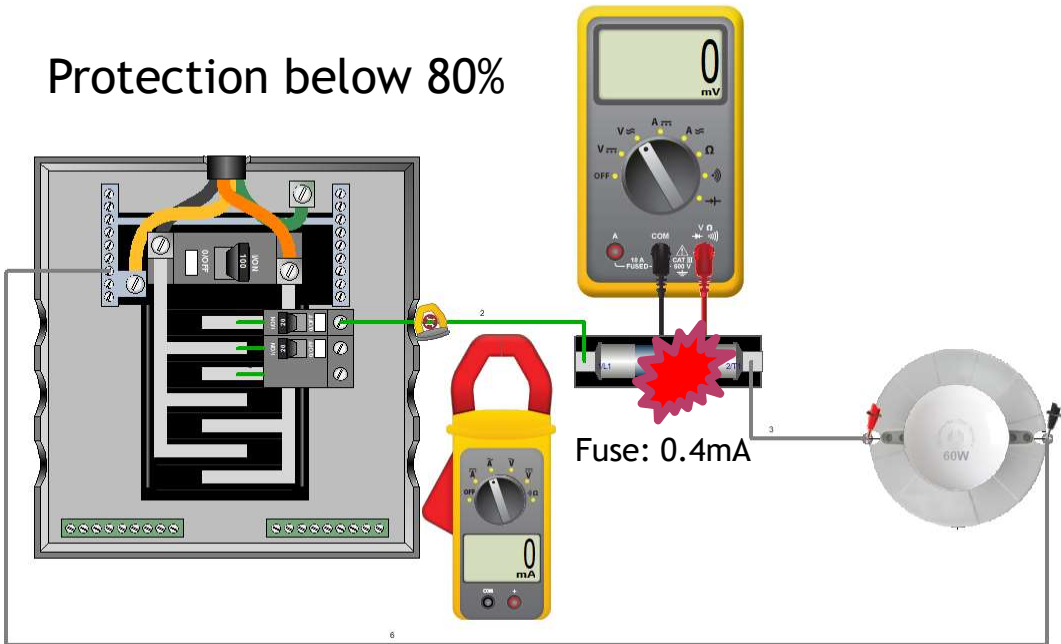
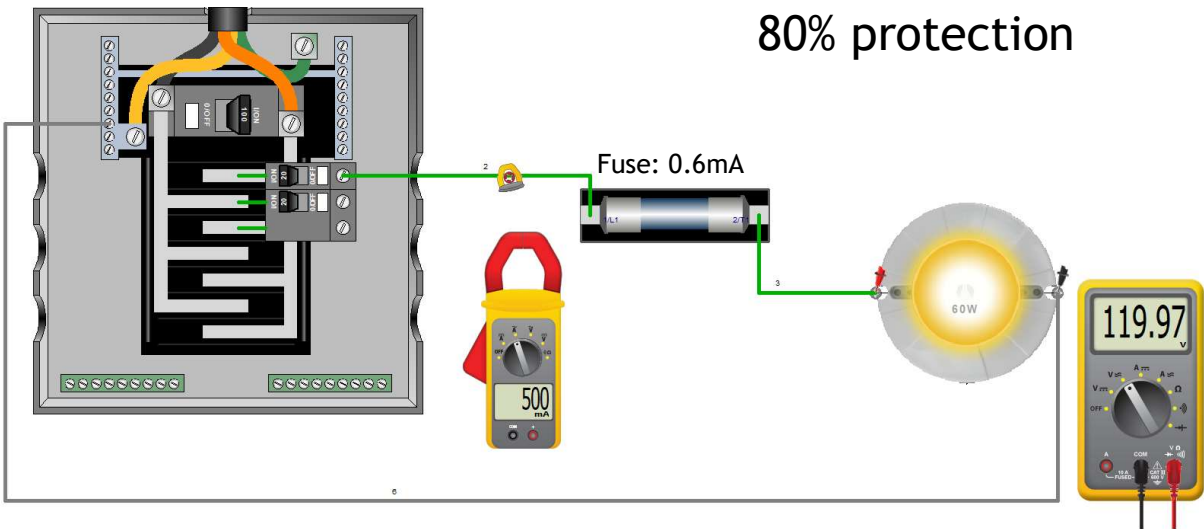


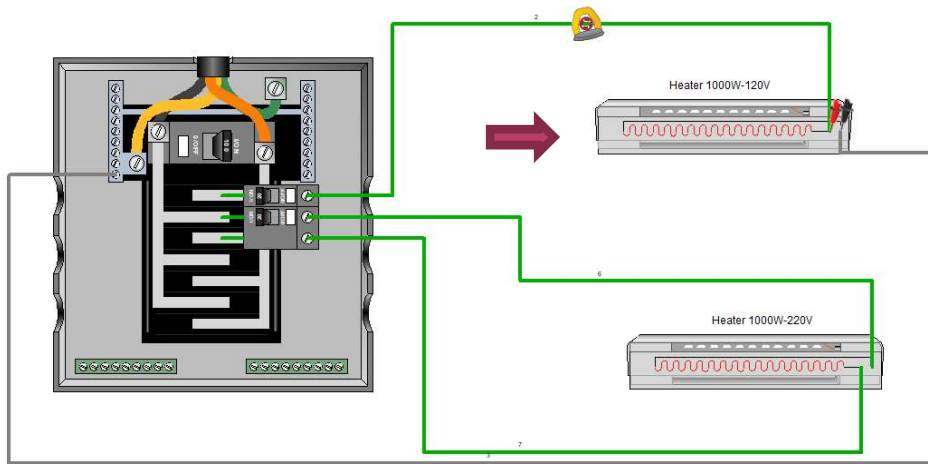
Answer

- The 80% rule is a safety guideline stating that a circuit's breaker or fuse should handle no more than 80% of its continuous current capacity. This prevents overheating and potential fire hazards. It provides a safety margin for both continuous and non-continuous loads, ensuring electrical systems operate safely.
- To apply the 80% rule when selecting a fuse or breaker:
- Calculate the load current using the formula: Amps (I) = Watts (P) / Volts (V).
- Divide the load current by 0.8 (or multiply by 1.25) to determine the minimum breaker/fuse rating.
- Choose the next higher standard breaker/fuse size available.
- Example: If a load is 1800 watts on a 120V circuit, the load current is 15A. Applying the 80% rule:
 - $15A / 0.8 = 18.75A$
 - The next standard size is 20A, so you would use a 20-amp breaker or fuse.
- Wire size must match the breaker or fuse rating to prevent overheating and potential fire hazards.
- Local electrical codes ensure compliance with safety regulations and proper installation.
- Consulting a qualified electrician helps avoid electrical hazards and ensures correct sizing of wires and breakers.
- Considering wire size and local codes is crucial because:
 - Wire size must match the breaker or fuse rating to prevent overheating and potential fire hazards. Local electrical codes ensure compliance with safety regulations and proper installation. Consulting a qualified electrician helps avoid electrical hazards and ensures correct sizing of wires and breakers.



Visual Example:

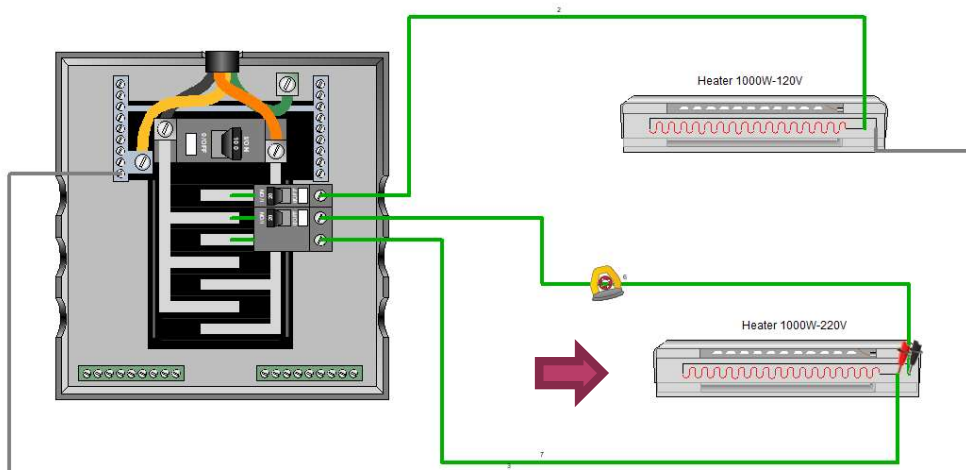




120VAC



When comparing two circuits, one at 120VAC and the other at 220VAC, the 220VAC circuit will draw less amperage for the same power consumption



220VAC



The original statement is partially correct, but it needs an important clarification: **the reduction in amperage occurs when comparing power consumption (watts) between the two circuits.** Here's why:
Relationship between voltage, amperage, and power:

Power (watts) is the result of multiplying voltage (volts) by amperage (amps): **Power (W) = Voltage (V) x Amperage (A).**

This means that, for a fixed amount of power, if the voltage increases, the amperage must decrease, and vice versa.

Application to the example:

If a device consumes the same amount of power (for example, 1000 watts) in both circuits:

In the 120VAC circuit, the amperage will be higher.

In the 220VAC circuit, the amperage will be lower.

This is because the higher voltage in the 220VAC circuit allows the same amount of power to be supplied with less current.

In summary:

Voltage and amperage have an inverse relationship when dealing with the same amount of power.

A higher voltage circuit will draw less amperage as long as the power consumption is the same.

VOLTAGE DROP CALCULATIONS
INDUCTANCE NEGLIGIBLE

- Vd = Voltage Drop
 I = Current in Conductor (Amperes)
 L = One-way Length of Circuit (Ft.)
 Cm = Cross Section Area of Conductor (Circular Mils) (page 72)
 K = Resistance in ohms of one circular mil foot of conductor

K = 12.9 for Copper Conductors @75°C
K = 21.2 for Aluminum Conductors @75°C

NOTE: K value changes with temperature.
 See NEC chapter 9, Table 8, Notes

*** SINGLE PHASE CIRCUITS:**

$$Vd = \frac{2K \times L \times I}{Cm} \quad \text{or} \quad Cm = \frac{2K \times L \times I}{Vd}$$

*** THREE PHASE CIRCUITS:**

$$Vd = \frac{1.73K \times L \times I}{Cm} \quad \text{or} \quad Cm = \frac{1.73K \times L \times I}{Vd}$$

| CONDUCTOR PROPERTIES | | | | | | | | |
|-----------------------|----------------------|---------------|--------------|--------------|-------------------------|-------------------------------|-------------------|-------------|
| Size AWG/ kcmil | Area Cir. Mils | Conductors | | | | DC Resistance at 75°C (167°F) | | |
| | | Stranding | | Overall | | Copper | | Aluminum |
| | | Quan- tity | Diam. In. | Diam. In. | Area In ² | Uncoated ohm/kFT | Coated ohm/kFT | ohm/ kFT |
| 18 | 1620 | 1 | ---- | 0.040 | 0.001 | 7.77 | 8.08 | 12.8 |
| 18 | 1620 | 7 | 0.015 | 0.046 | 0.002 | 7.95 | 8.45 | 13.1 |
| 16 | 2580 | 1 | ---- | 0.051 | 0.002 | 4.89 | 5.08 | 8.05 |
| 16 | 2580 | 7 | 0.019 | 0.058 | 0.003 | 4.99 | 5.29 | 8.21 |
| 14 | 4110 | 1 | ---- | 0.064 | 0.003 | 3.07 | 3.19 | 5.06 |
| 14 | 4110 | 7 | 0.024 | 0.073 | 0.004 | 3.14 | 3.26 | 5.17 |
| 12 | 6530 | 1 | ---- | 0.081 | 0.005 | 1.93 | 2.01 | 3.18 |
| 12 | 6530 | 7 | 0.030 | 0.092 | 0.006 | 1.98 | 2.05 | 3.25 |
| 10 | 10380 | 1 | ---- | 0.102 | 0.008 | 1.21 | 1.26 | 2.00 |
| 10 | 10380 | 7 | 0.038 | 0.116 | 0.011 | 1.24 | 1.29 | 2.04 |
| 8 | 16510 | 1 | ---- | 0.128 | 0.013 | 0.764 | 0.786 | 1.26 |
| 8 | 16510 | 7 | 0.049 | 0.146 | 0.017 | 0.778 | 0.809 | 1.28 |
| 6 | 26240 | 7 | 0.061 | 0.184 | 0.027 | 0.491 | 0.510 | 0.808 |
| 4 | 41740 | 7 | 0.077 | 0.232 | 0.042 | 0.308 | 0.321 | 0.508 |
| 3 | 52620 | 7 | 0.087 | 0.260 | 0.053 | 0.245 | 0.254 | 0.403 |
| 2 | 66360 | 7 | 0.097 | 0.292 | 0.067 | 0.194 | 0.201 | 0.319 |
| 1 | 83690 | 19 | 0.066 | 0.332 | 0.087 | 0.154 | 0.160 | 0.253 |
| 1/0 | 105600 | 19 | 0.074 | 0.372 | 0.109 | 0.122 | 0.127 | 0.201 |
| 2/0 | 133100 | 19 | 0.084 | 0.418 | 0.137 | 0.0967 | 0.101 | 0.159 |
| 3/0 | 167800 | 19 | 0.094 | 0.470 | 0.173 | 0.0766 | 0.0797 | 0.126 |
| 4/0 | 211600 | 19 | 0.106 | 0.528 | 0.219 | 0.0608 | 0.0626 | 0.100 |
| 250 | ---- | 37 | 0.082 | 0.575 | 0.260 | 0.0515 | 0.0535 | 0.0847 |
| 300 | ---- | 37 | 0.090 | 0.630 | 0.312 | 0.0429 | 0.0446 | 0.0707 |
| 350 | ---- | 37 | 0.097 | 0.681 | 0.364 | 0.0367 | 0.0382 | 0.0605 |
| 400 | ---- | 37 | 0.104 | 0.728 | 0.416 | 0.0321 | 0.0331 | 0.0529 |
| 500 | ---- | 37 | 0.116 | 0.813 | 0.519 | 0.0258 | 0.0265 | 0.0424 |
| 600 | ---- | 61 | 0.099 | 0.893 | 0.626 | 0.0214 | 0.0223 | 0.0353 |
| 700 | ---- | 61 | 0.107 | 0.964 | 0.730 | 0.0184 | 0.0189 | 0.0303 |
| 750 | ---- | 61 | 0.111 | 0.998 | 0.782 | 0.0171 | 0.0176 | 0.0282 |
| 800 | ---- | 61 | 0.114 | 1.030 | 0.834 | 0.0161 | 0.0166 | 0.0265 |
| 900 | ---- | 61 | 0.122 | 1.094 | 0.940 | 0.0143 | 0.0147 | 0.0235 |
| 1000 | ---- | 61 | 0.128 | 1.152 | 1.042 | 0.0129 | 0.0132 | 0.0212 |
| 1250 | ---- | 91 | 0.117 | 1.289 | 1.305 | 0.0103 | 0.0106 | 0.0169 |
| 1500 | ---- | 91 | 0.128 | 1.412 | 1.566 | 0.00858 | 0.00883 | 0.0141 |
| 1750 | ---- | 127 | 0.117 | 1.526 | 1.829 | 0.00735 | 0.00756 | 0.0121 |
| 2000 | ---- | 127 | 0.126 | 1.632 | 2.092 | 0.00643 | 0.00662 | 0.0106 |

Absolutely! Let's break down this image about voltage drop calculations in a simple way.

What is Voltage Drop?

Imagine electricity flowing through a wire like water flowing through a pipe. As the water moves, it loses some pressure due to friction with the pipe walls. Similarly, electricity loses some "pressure" (voltage) as it travels through a wire. This loss is called **voltage drop**.

Why is Voltage Drop Important?

Too much voltage drop can cause problems:

Lights dim: If the voltage reaching a light bulb is too low, it won't shine as brightly.

Motors run slow: Motors need a certain voltage to operate correctly. A low voltage can make them run slower or even overheat.

Appliances malfunction: Some appliances are sensitive to voltage changes and may not work properly with low voltage.

This Image Shows How to Calculate Voltage Drop

The image gives you formulas to calculate voltage drop in electrical circuits, specifically when the inductance (a property related to magnetic fields) is negligible (meaning it's so small we can ignore it).

Let's break down the parts:

Vd = Voltage Drop: This is what we want to find - how much voltage is lost.

I = Current: This is the amount of electricity flowing through the wire, measured in Amperes (amps). Think of it as the "speed" of the water in our pipe analogy.

L = Length: This is the distance the electricity travels along the wire, measured in feet. Longer wires mean more voltage drop.

Cm = Circular Mils: This is a measure of the wire's thickness. Thicker wires have less resistance and therefore less voltage drop.

K = Resistance Factor: This number depends on the type of wire material (copper or aluminum) and temperature. It tells you how much the wire resists the flow of electricity.

The Formulas

The image gives you two sets of formulas: one for **single-phase circuits** (like in most homes) and one for **three-phase circuits** (common in industrial settings).

Single-Phase Example

Let's say you have a copper wire (K=12.9) that's 100 feet long (L=100) and carries 20 amps (I=20). You want to find the voltage drop (Vd) if the wire has a cross-sectional area of 41,740 circular mils (Cm=41,740).

Using the formula:

$$Vd = (2 * K * L * I) / Cm$$

$$Vd = (2 * 12.9 * 100 * 20) / 41,740$$

$$Vd = 1.23 \text{ volts}$$

This means you'll lose 1.23 volts along that wire.

Three-Phase Example

Now, let's say you have an aluminum wire (K=21.2) in a three-phase circuit. The wire is 50 feet long (L=50), carries 30 amps (I=30), and has a cross-sectional area of 26,240 circular mils (Cm=26,240).

Using the formula:

$$Vd = (1.73 * K * L * I) / Cm$$

$$Vd = (1.73 * 21.2 * 50 * 30) / 26,240$$

$$Vd = 2.10 \text{ volts}$$

You'll lose 2.10 volts in this case.

Important Note: The image also shows how to rearrange the formulas to calculate the required wire size (Cm) if you know the desired voltage drop.

Question

1. What is voltage drop, and why does it occur in electrical circuits?
2. How do you calculate voltage drop in a single-phase and three-phase circuit?
3. Why is it important to consider voltage drop when designing electrical systems?



Answer

1. Voltage drop is the reduction in voltage as electric current flows through a conductor due to its resistance. It occurs because wires have inherent resistance, causing energy loss in the form of heat as electricity travels through them. The longer and thinner the wire, the greater the voltage drop.

2. To calculate voltage drop:

- For a single-phase circuit:

$$Vd = \frac{2 \times K \times L \times I}{Cm}$$

- For a three-phase circuit:

$$Vd = \frac{1.73 \times K \times L \times I}{Cm}$$

Where:

- Vd = Voltage drop
- I = Current in amperes
- L = Wire length in feet
- Cm = Circular mils (wire size)
- K = Resistance factor based on wire material (e.g., 12.9 for copper, 21.2 for aluminum)



3. Voltage drop is crucial in electrical system design because excessive drop can cause:

- Dimming lights, reducing illumination quality
- Motors running inefficiently, leading to overheating and failure
- Malfunctioning appliances that require stable voltage
- Increased energy losses and operational inefficiencies

Proper wire sizing and voltage drop calculations ensure safe and efficient electrical distribution.

What are Electrical Meter Category Ratings?

Electrical meter category ratings (CAT ratings) are safety standards that classify how safe it is to use a multimeter or other electrical test equipment in different electrical environments. These ratings indicate the meter's ability to withstand transient overvoltages (sudden spikes in voltage) that can occur in various electrical systems.

Why are CAT Ratings Important?

- Safety:** CAT ratings help protect you from electrical shock and arc flash hazards when taking measurements.
- Overvoltage Protection:** They ensure your meter can handle the voltage spikes that can occur in different electrical systems without failing catastrophically.

The Different CAT Ratings

The most common CAT ratings are:

- CAT I (Measurement Category I):**
 - For measurements performed on circuits NOT directly connected to mains (building wiring).
 - Examples: Protected electronic circuits, signal-level circuits, low-energy circuits.
 - Lowest overvoltage protection level.
- CAT II (Measurement Category II):**
 - For measurements performed on circuits directly connected to mains at receptacle outlets.
 - Examples: Appliances, portable tools, standard household circuits.
 - Medium overvoltage protection level.
- CAT III (Measurement Category III):**
 - For measurements performed on building installations at the distribution level.
 - Examples: Distribution boards, circuit breakers, wiring, permanent installations.
 - Higher overvoltage protection level.
- CAT IV (Measurement Category IV):**
 - For measurements performed at the origin of the installation.
 - Examples: Overhead power lines, underground cables, primary supply lines.
 - Highest overvoltage protection level.

Understanding the Numbers

In addition to the CAT rating, you'll often see a voltage rating (e.g., CAT III 600V or CAT IV 1000V). This voltage rating indicates the maximum transient overvoltage the meter can safely handle within that category.

Example

A multimeter rated CAT III 600V is designed to handle higher transient overvoltages than a CAT II 600V meter. This is because CAT III environments are more likely to experience larger voltage spikes.

In Simple Terms

Think of CAT ratings like a safety rating for your electrical tester. The higher the CAT rating, the safer it is to use in environments where there might be big, sudden jumps in voltage.

- If you're working on simple electronics, CAT I might be fine.
- If you're plugging into a wall outlet, you need CAT II.
- If you're working in a breaker panel, you need CAT III.
- If you're working on power lines, you need CAT IV.

Key Takeaway

Always choose a multimeter with a CAT rating that's appropriate for the electrical environment where you'll be taking measurements. Using a meter with an insufficient CAT rating can be extremely dangerous.

Because you are in Garland Texas, it is important that any work done on your home or business electrical systems be done by a licensed electrician, that is well versed in the NEC (National Electrical Code) and any and all local electrical codes.

Questions:

1. What are electrical meter category (CAT) ratings, and what do they indicate?
2. How do CAT ratings help ensure safety when using electrical test equipment?
3. What is the difference between CAT I, CAT II, CAT III, and CAT IV ratings?



Answers:

1. Electrical meter category (CAT) ratings are safety classifications that indicate the meter's ability to withstand transient overvoltages in different electrical environments. These ratings help determine how safe a multimeter or other test equipment is for various applications, from low-energy circuits to high-voltage power lines.
2. CAT ratings help ensure safety by:
 - Protecting users from electrical shock and arc flash hazards.
 - Ensuring the meter can handle sudden voltage spikes without failing.
 - Providing appropriate overvoltage protection for different electrical environments.
 - Reducing the risk of catastrophic failure when testing electrical systems.
3. Differences between CAT ratings:
 - CAT I: Used for low-energy circuits, such as protected electronic devices (lowest overvoltage protection).
 - CAT II: Suitable for household appliances, wall outlets, and portable tools (medium overvoltage protection).
 - CAT III: Designed for distribution panels, circuit breakers, and building wiring (higher overvoltage protection).
 - CAT IV: The highest rating, meant for power lines, underground cables, and primary supply lines (maximum overvoltage protection).

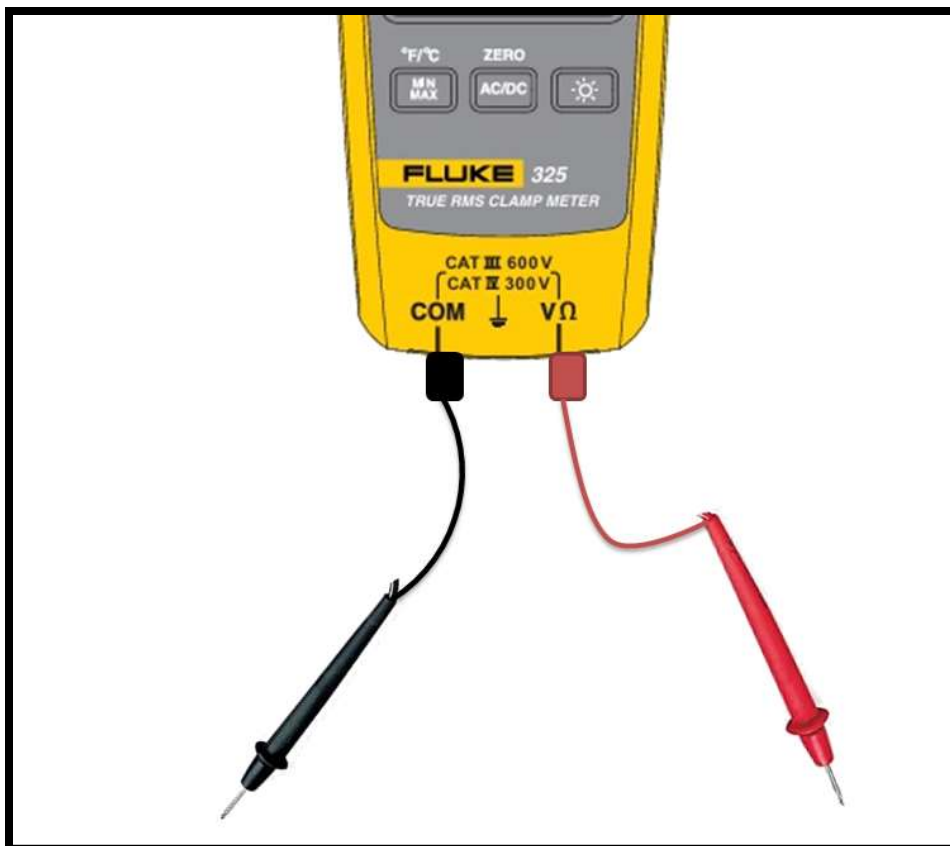
Always choose a multimeter with the appropriate CAT rating for the electrical system you're working on to avoid serious hazards.



How to Place the Multimeter Probe Connections

Category III applies to distribution wiring, including main buses, feeders, and branch circuits with permanently installed loads.

Category IV, the highest category, is used for installations at the point of origin of the power supply or at the utility level. Our devices are rated for **600 V in Category IV**, and for applications between **600 V and 750 V**, they are rated in **Category III**.



exercises

1

Schematic Diagram

2

Wiring Diagram

Practice Fault

"In this photo, you are looking at an example machine demonstrating how we will solve a problem that occurs in the electrical circuit using the following:

- 🔧 **1 Schematic diagram:** This will help us locate the control and actuation logic of the circuit.
- 🔧 **2 Wiring diagram:** This will show us how the wiring sequence follows through to the components and terminals."

Troubleshooting Skills Series V4

DEMO

TROUBLESHOOTING MOTOR CIRCUITS

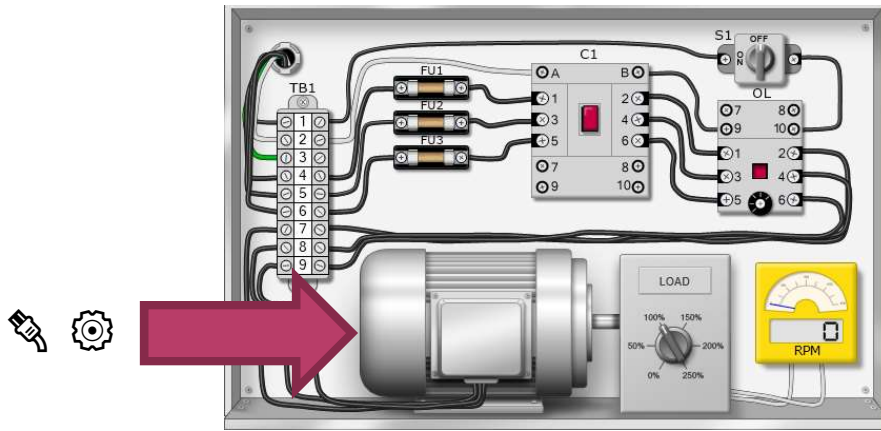
Start

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For practice, we will use the demo of this program.



Texas CPD Labor Training LLC does not own the software used in this presentation. A demonstration version obtained from the vendor's website was used. For complete information, please contact the software owner directly.



Troubleshooting Procedure for an Electric Motor with Transmission, Magnetic Contactor, and Breaker

Check the Power Supply:

- Verify that the main breaker is in the ON position.
- Use a multimeter to check for voltage at the breaker output.
- Ensure there is no blown fuse or tripped circuit breaker.

Inspect the Magnetic Contactor:

- Check if the contactor is receiving the correct voltage at the coil terminals.
- Listen for a clicking sound when the contactor is activated.
- If the contactor does not engage, check the control circuit, including push buttons, relays, and overloads.

Examine the Control Circuit:

- Verify that emergency stop buttons and safety switches are not engaged.
- Check for loose or damaged wiring in the control circuit.
- Ensure the control transformer (if applicable) is supplying the correct voltage.

Check the Overload Relay:

- If the overload relay has tripped, reset it and test again.
- Measure the current draw of the motor to ensure it is within the rated limits.

Test the Motor Windings:

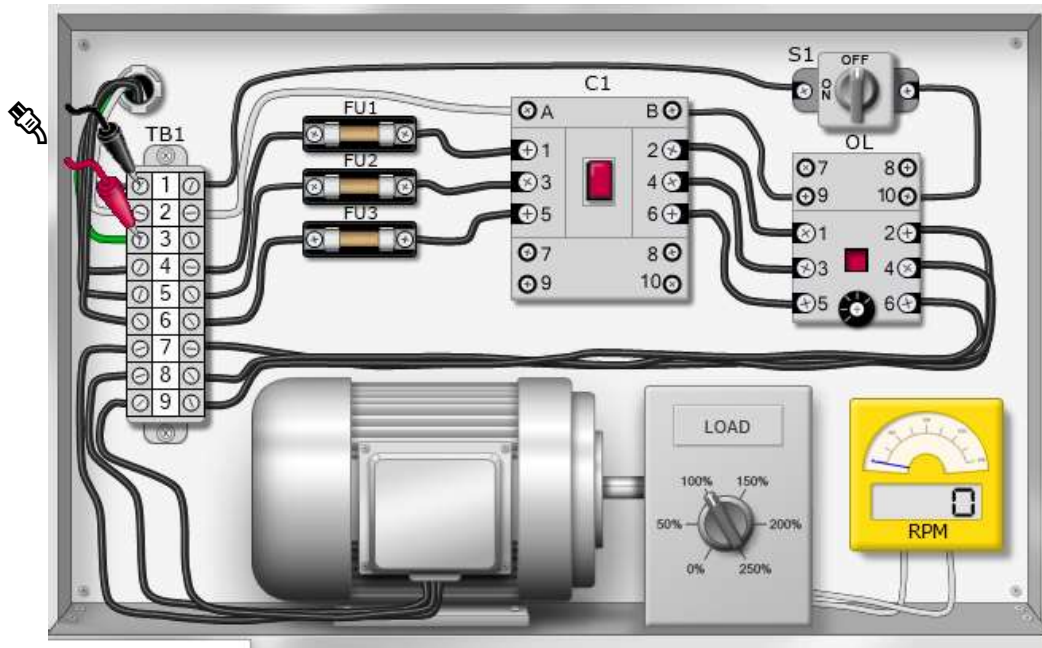
- Use a multimeter to measure resistance between motor windings (phase-to-phase).
- Check for continuity between each winding and ground to detect possible short circuits.
- If the resistance is too high or infinite, the motor windings may be open.

Inspect the Mechanical System:

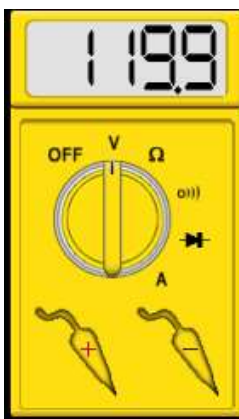
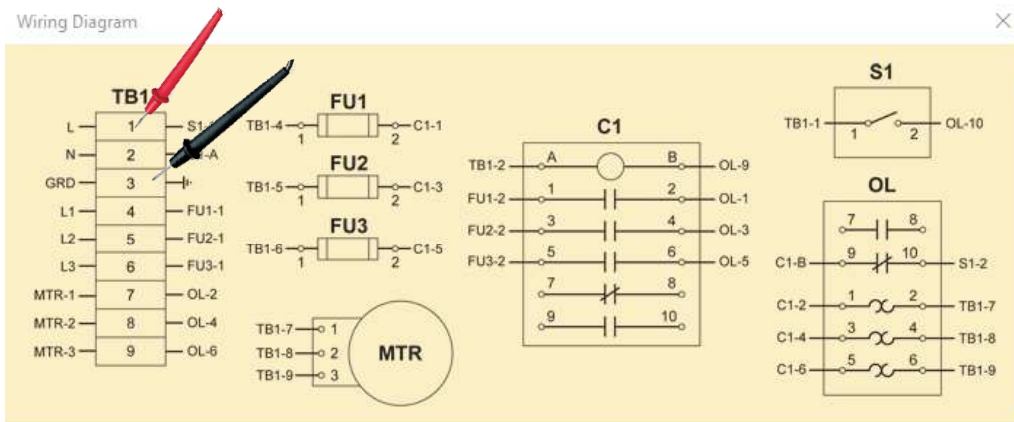
- Ensure the motor shaft is free to rotate manually (if safe to do so).
- Check for any mechanical obstructions in the transmission system.
- Verify that the coupling or belt is not jammed or broken.

Final Testing:

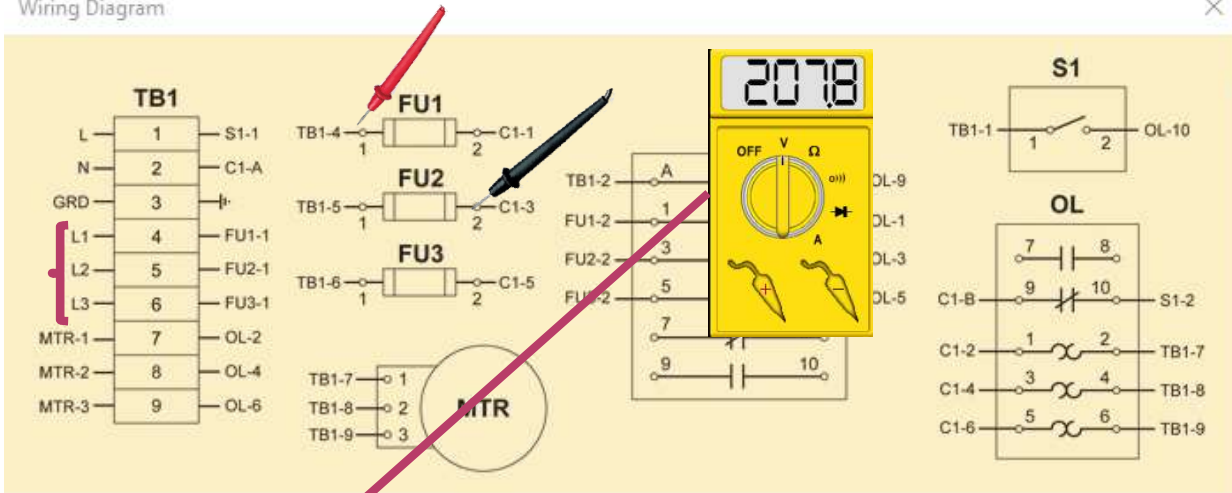
- If all electrical and mechanical components check out, attempt to start the motor again.
- Monitor voltage and current readings during startup.
- If the problem persists, further investigation may be needed on the motor or control circuit.



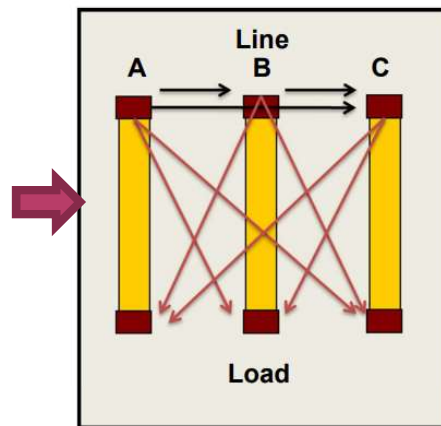
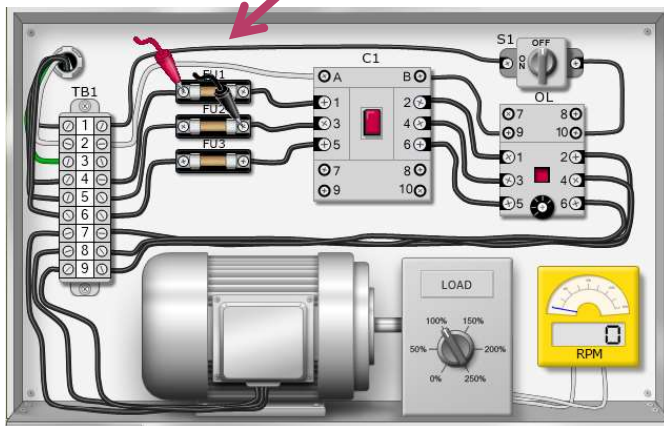
Wiring Diagram



You can also measure to ground, and it should read 120V AC. The measurement from line to neutral and from line to ground should always be 120V AC; otherwise, there is an issue with the connection.



Instructor to explain the Cross Checking Method



In a 208V three-phase system, a blown fuse occurs when one of the phase fuses is open or defective, causing abnormal voltage readings.

Measuring Between Phases (Lines A, B, and C)

Measure the voltage between Line 1 (A) and Line 2 (B): It should read approximately 208V AC.

Measure the voltage between Line 1 (A) and Line 3 (C): It should read approximately 208V AC.

Measure the voltage between Line 2 (B) and Line 3 (C): It should also read approximately 208V AC.

Detecting a Blown Fuse

If a fuse in one phase is open, you may notice incorrect or lower readings between some line combinations.

For example, if the fuse on Line 1 (A) is open, measuring between Line 1 (A) and Line 2 (B) or Line 1 (A) and Line 3 (C) may result in a lower voltage or even zero, depending on the connected load.

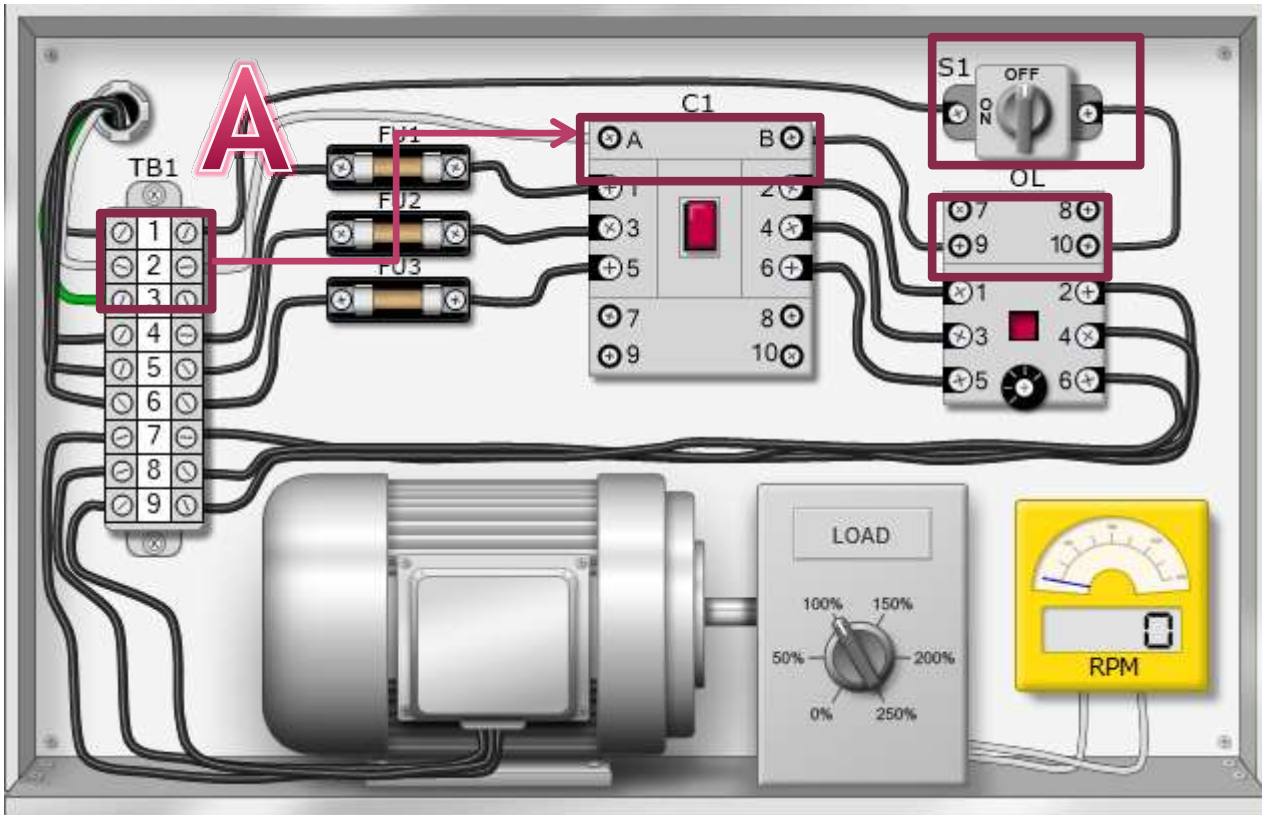
Checking with Ground and Neutral

Measure the voltage between Line 1 (A) and Ground: It should read 120V AC.

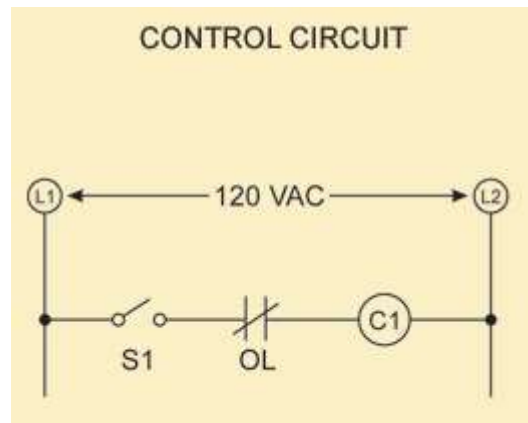
Measure the voltage between Line 2 (B) and Ground: It should read 120V AC.

Measure the voltage between Line 3 (C) and Ground: It should read 120V AC.

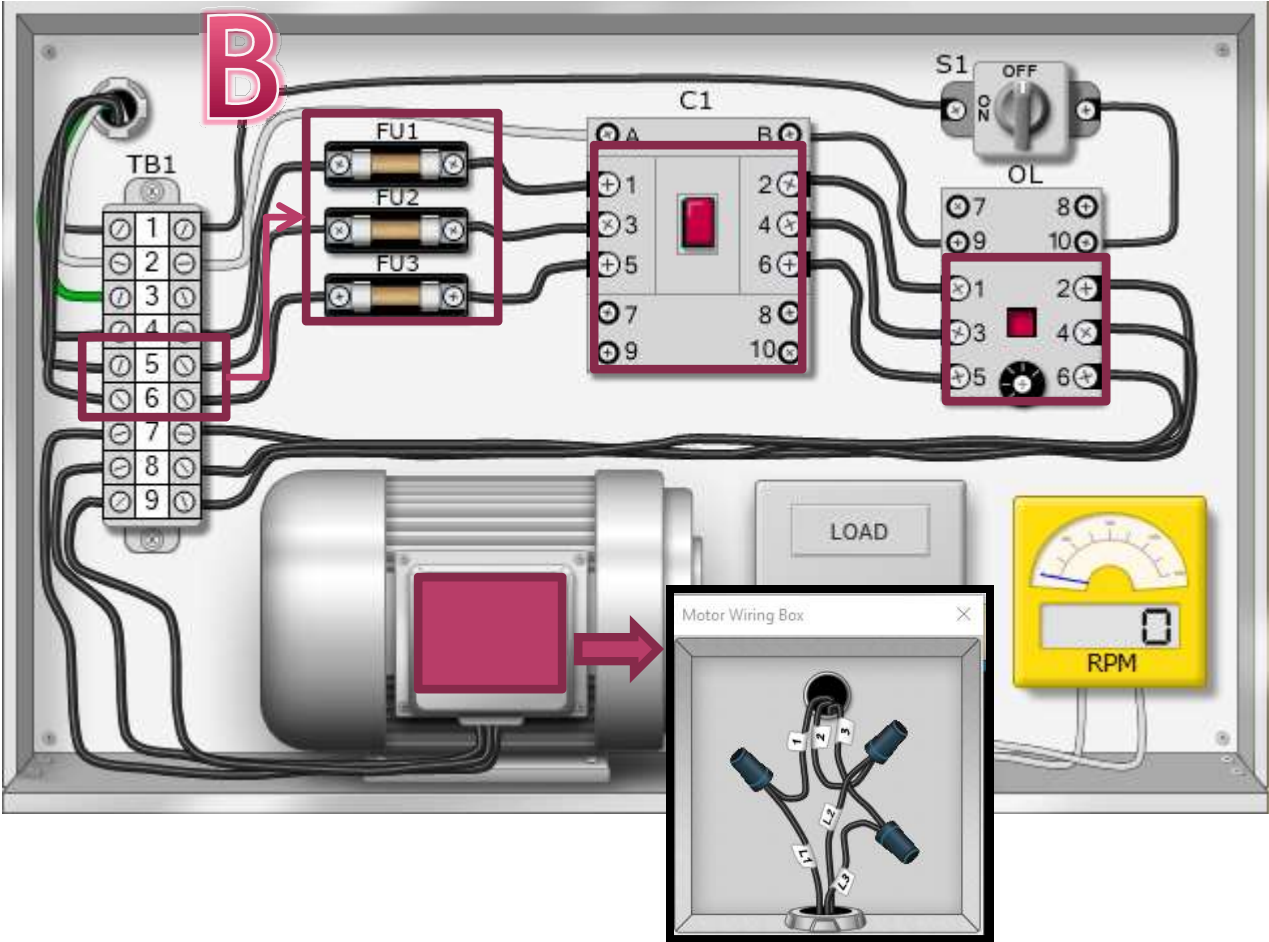
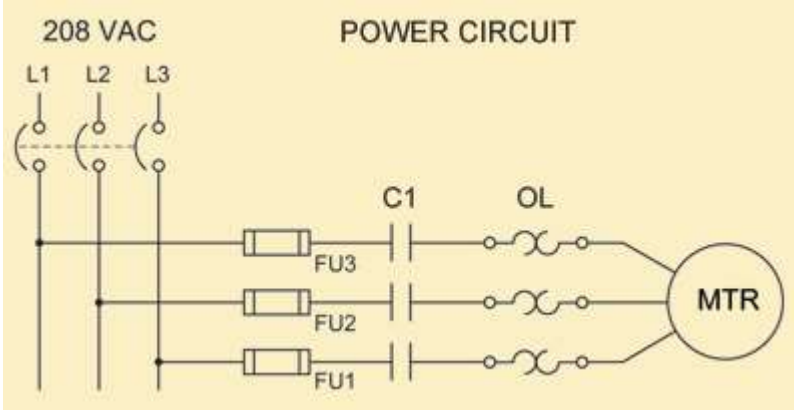
If any of these readings are zero or significantly reduced, a fuse may be open.



The "A" is the control voltage that activates the contactor coil, allowing the passage of line voltage 1, 2, and 3. These 208V lines power and control the electric motor.



Circuit B is responsible for allowing power flow when the motor is activated; it operates at high voltage and controls the actuation.





Main Disconnect Switch: Importance, Function, and Safe Handling

What is a Main Disconnect Switch?

The Main Disconnect Switch is a crucial electrical safety device designed to completely shut off power to a system, panel, or equipment. It serves as a primary point of isolation, ensuring that electrical circuits can be safely maintained or repaired without risk of electrocution or arc flash incidents.

Why is it Important?

Emergency Shutdown - Allows quick power disconnection in case of fire, short circuits, or maintenance.

Worker Safety - Prevents accidental energization while technicians are working on electrical components.

Compliance with Regulations - Required by NFPA 70E, OSHA, and NEC standards for industrial and commercial electrical systems.

How to Handle it Safely?

Pre-Operation Checks:

Verify that you are authorized and trained to operate the disconnect switch.

Wear appropriate PPE (Personal Protective Equipment), including arc-rated gear if necessary.

Use a voltage tester to confirm the circuit is de-energized.

Safe Operation Steps:

Notify affected personnel before shutting down power.

Stand to the side while operating the switch to avoid direct exposure to potential arc flash.

Use the proper technique - firmly grip the switch handle and operate it in a single, decisive motion.

Lockout/Tagout (LOTO) - If working on the circuit, apply a lock and tag to prevent accidental re-energization.

Post-Operation Safety:

Double-check that power is completely off before proceeding with work.

Keep the disconnect area clear and labeled for easy access in emergencies.

Follow re-energization procedures carefully when restoring power.

Common Mistakes to Avoid

X Operating the switch without wearing proper arc flash protection.

X Failing to verify power is off before starting maintenance.

X Ignoring LOTO procedures, which can lead to severe accidents.

By following these guidelines, the Main Disconnect Switch ensures electrical safety and prevents workplace hazards. Always respect safety protocols to protect yourself and others!

This is a thermal overload relay, a device used to protect motors from overheating due to excessive current. It's typically mounted under a contactor in a motor control circuit.

🔗 Key Components & Functions

1️⃣ AMP Adjustment Selector 🔄

This dial lets you adjust the current rating of the relay, so it trips at the correct level to protect your motor.

2️⃣ TEST Button (Red Button) ●

Pressing this button simulates a trip, just like an overload condition. It also triggers the auxiliary contact, allowing you to test your circuit without actually overloading the motor.

3️⃣ RESET Selector Switch (Blue Button) ●

Two modes:

H (Hand/Manual): You must press the reset button to restore normal operation after a trip.

A (Auto): The relay automatically resets once it cools down after an overload.

4️⃣ Parallel Access Point for Auxiliary Contact ⚡

This allows for external connections to monitor the relay's status or trigger alarms when a trip occurs.

⚡ How does it work?

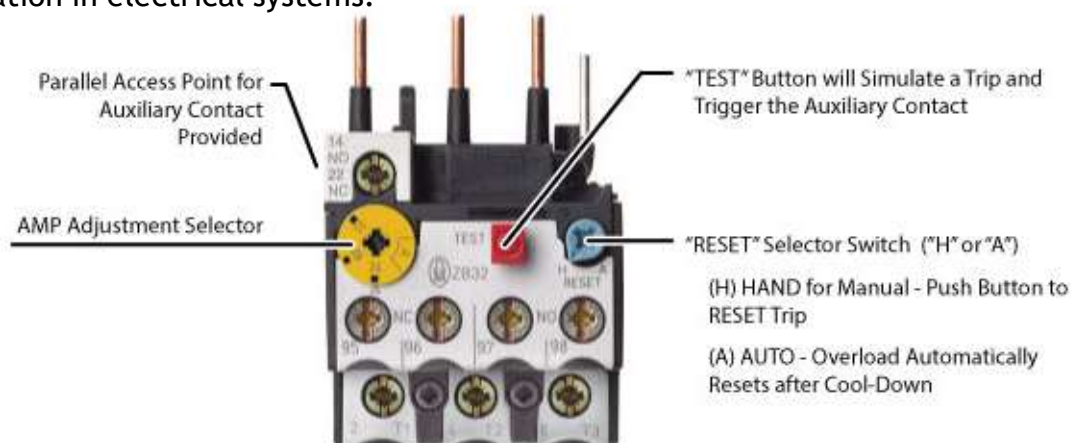
1️⃣ The relay is connected to the motor circuit.

2️⃣ If the motor draws too much current for too long, the relay trips to protect it.

3️⃣ Depending on the RESET mode, you either manually reset it or let it reset automatically.

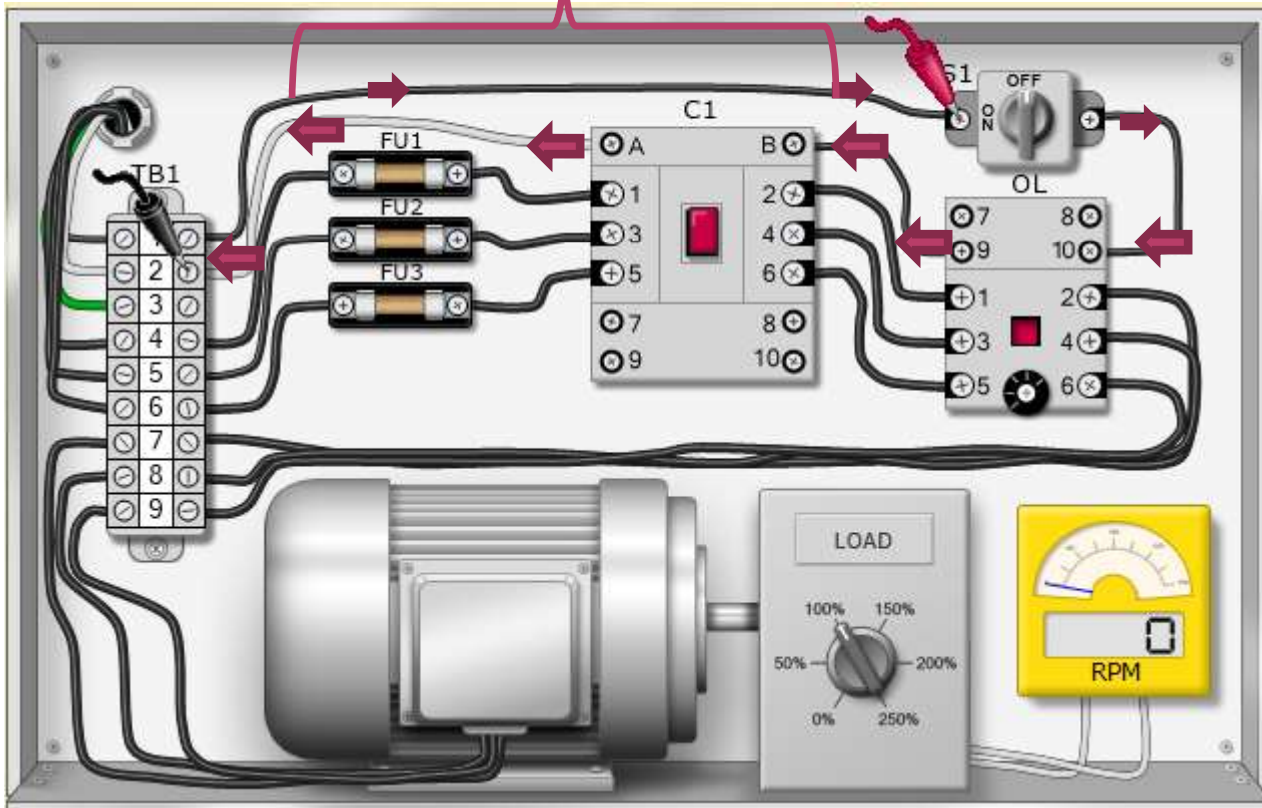
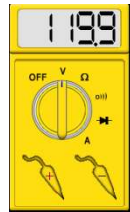
4️⃣ You can use the TEST button to simulate a trip and check if everything is working properly.

This relay is essential for preventing motor damage and ensuring safe operation in electrical systems.



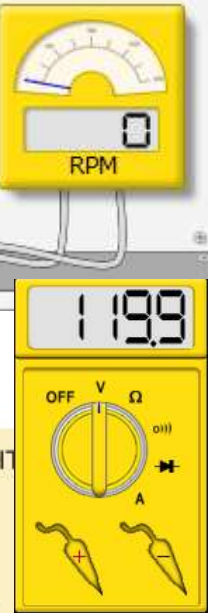
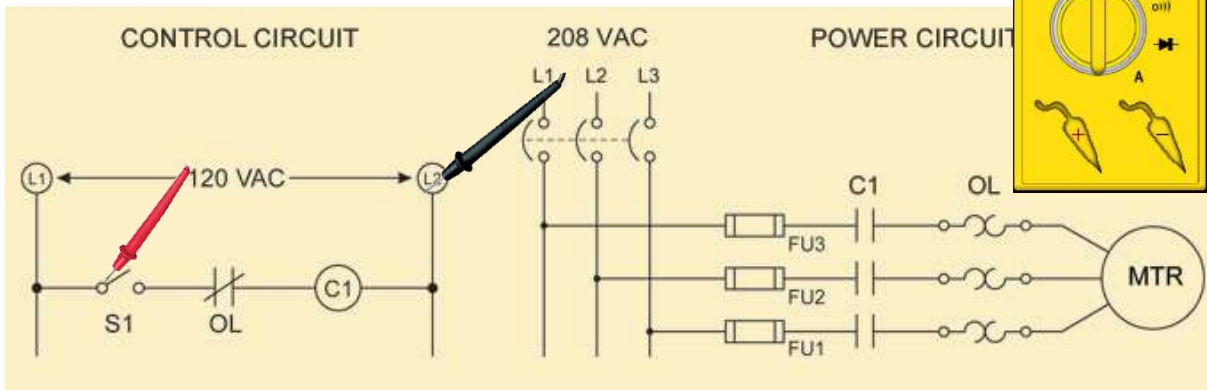


In the example we will see, we will perform a voltage test before the actuator that controls the voltage flow to the magnetic contactor coil.

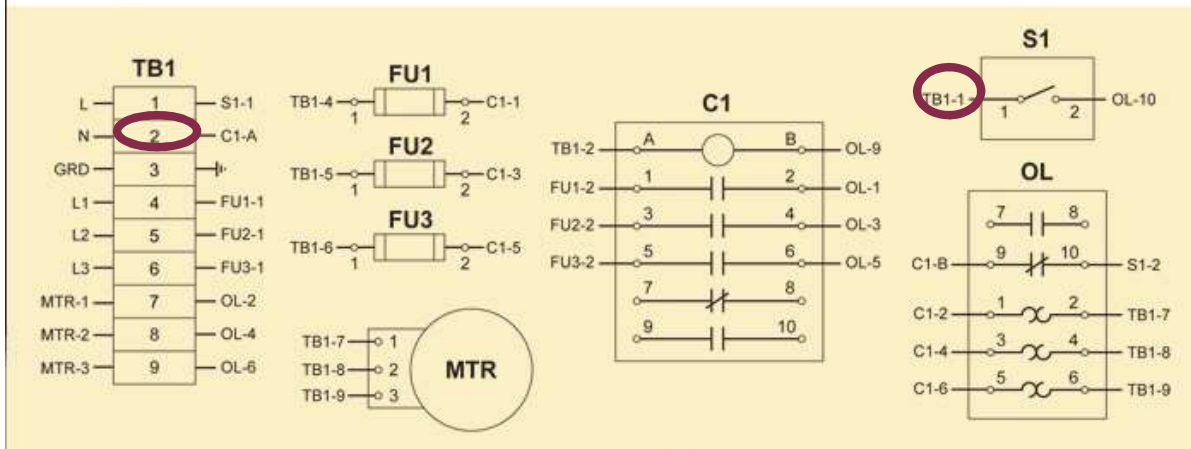


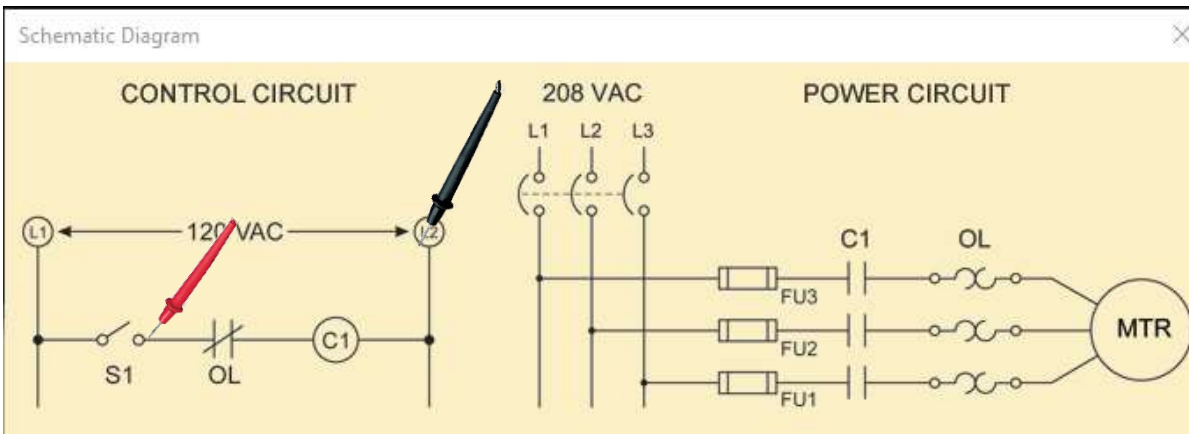
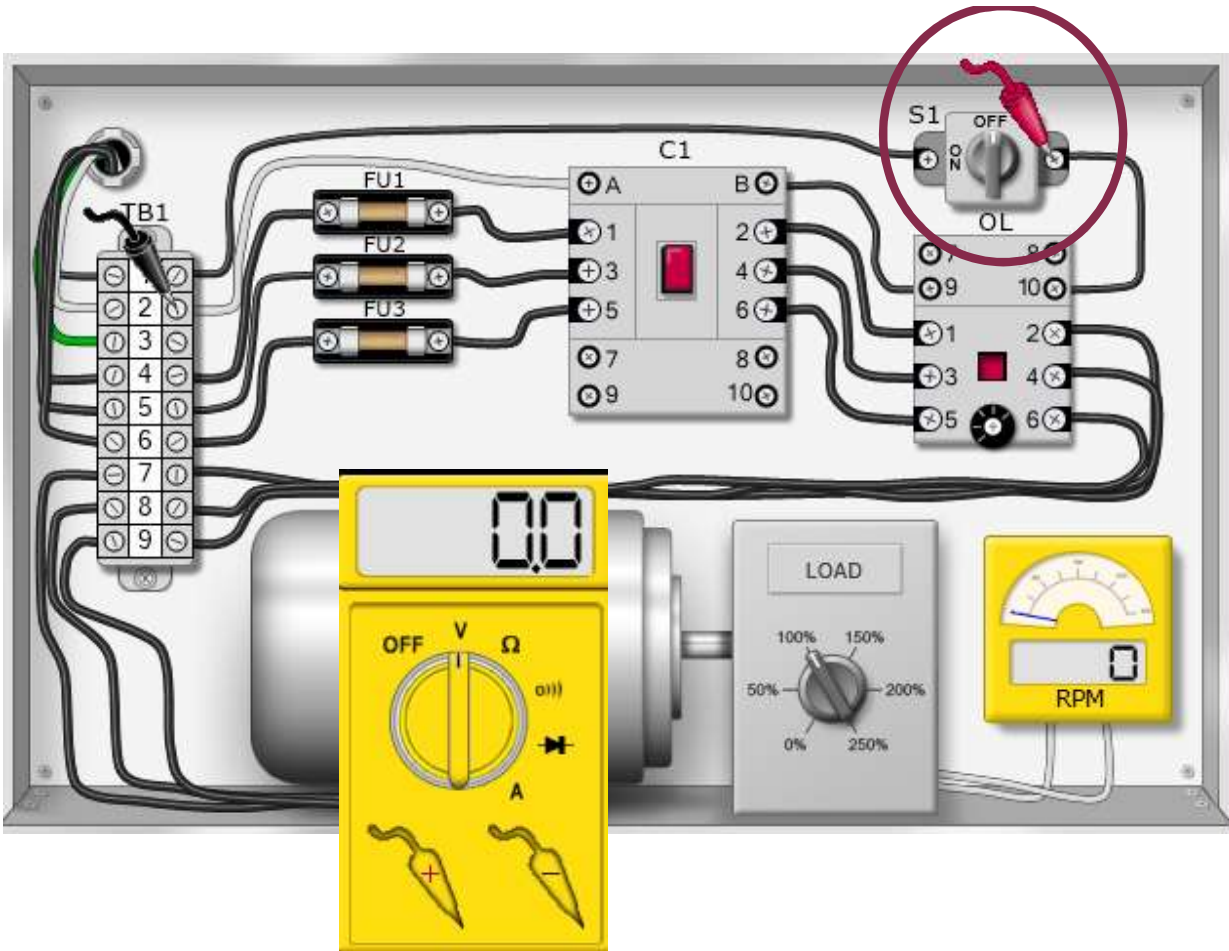


Schematic Diagram

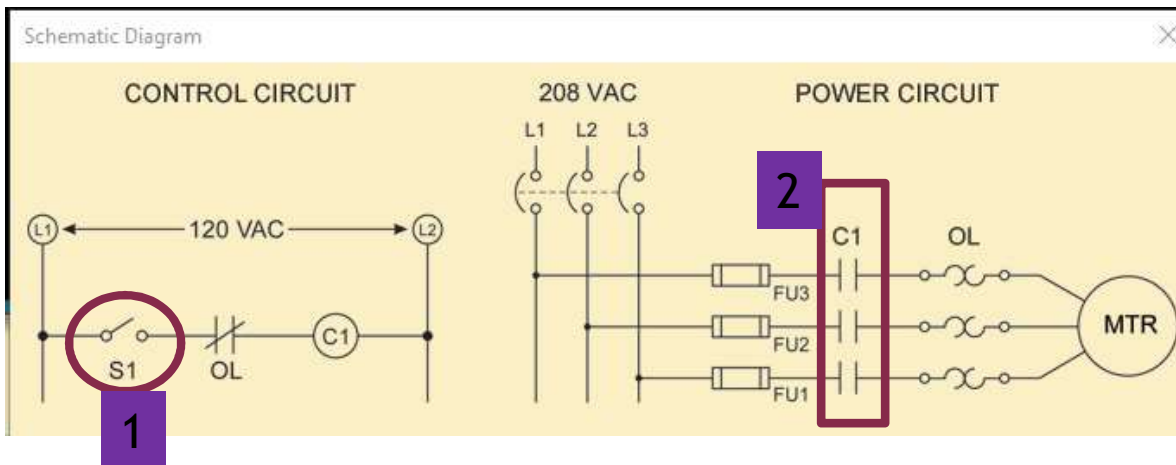
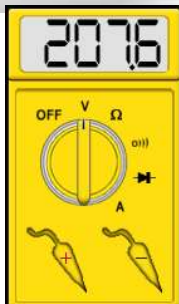
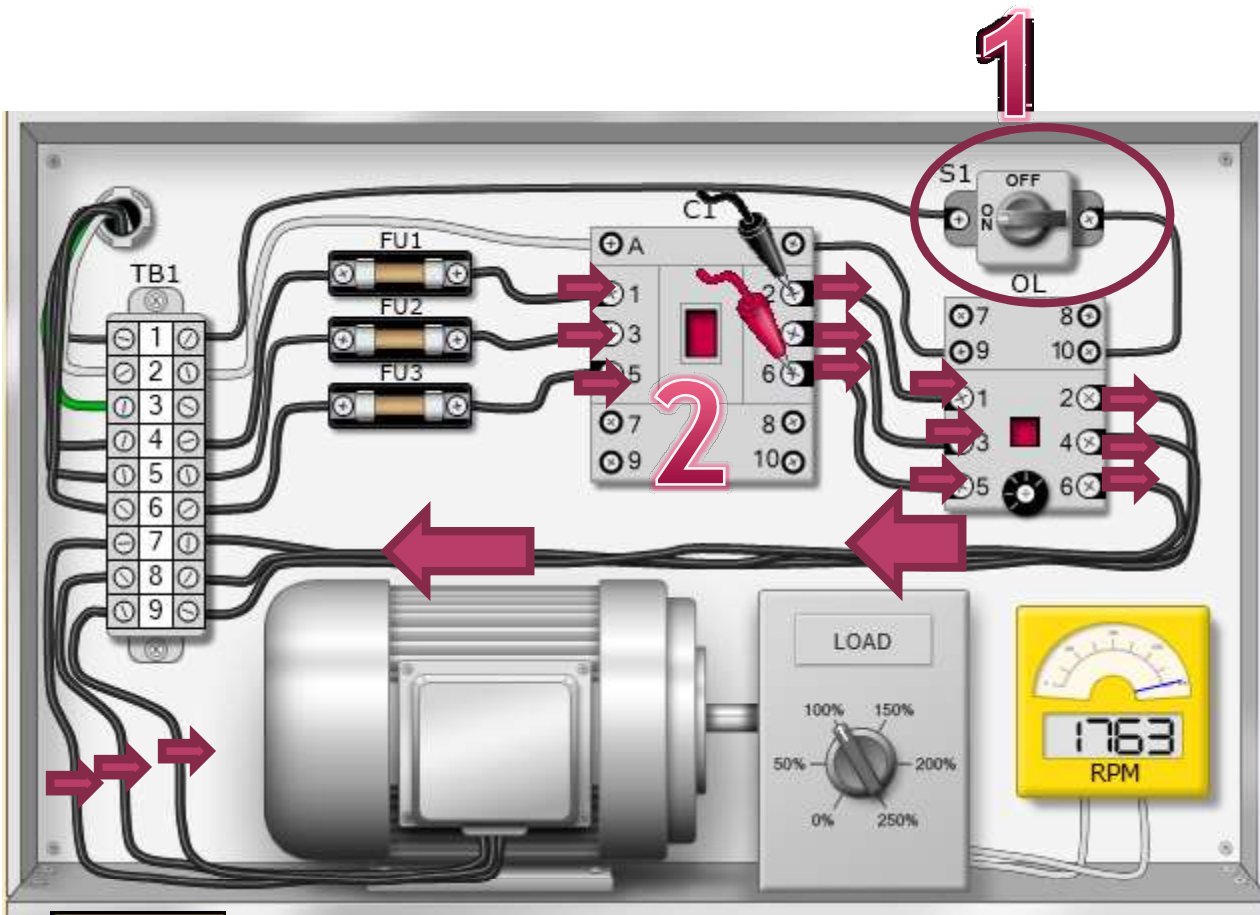


Wiring Diagram





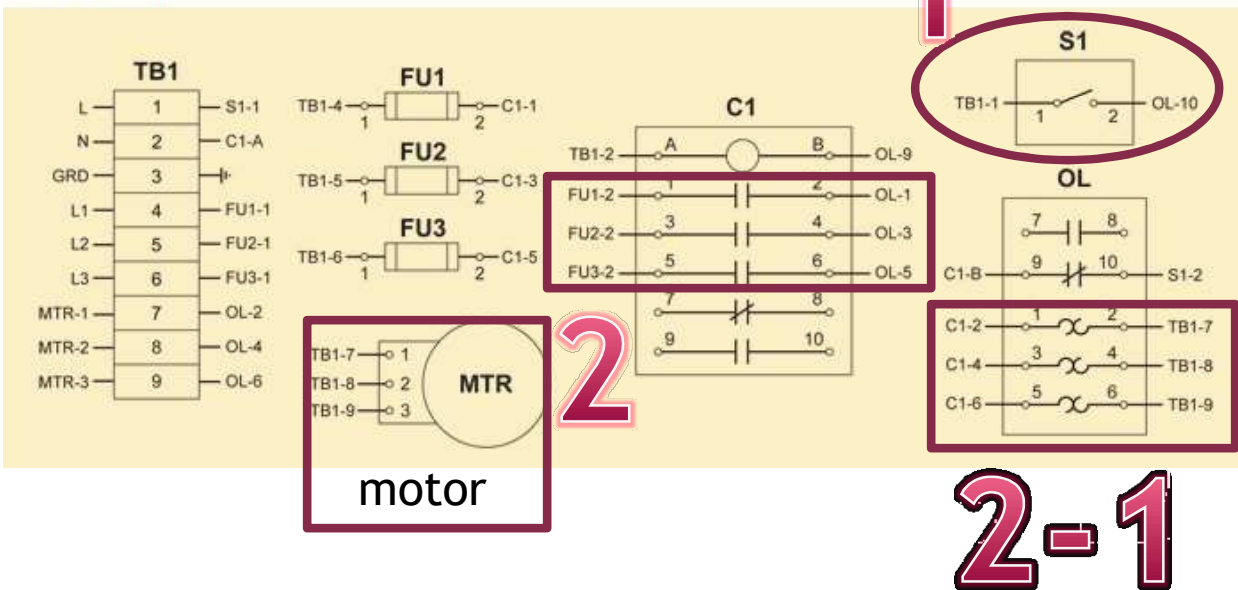
When the switch is in the OFF position, no voltage will be supplied to the contactor coil(C1)terminals (A&B)





When (1) the switch is activated, (2) the contactor closes the 3 terminals to pass through the Overload (OL,2-1) protection, which safeguards the circuit from excessive current. At the same time, it supplies power to the 3 voltage lines, number (2), that feed the electric motor.

Wiring Diagram



Types of industrial sensors/Controls

What Is a Micro Switch?

The micro-switch is a switch that operates rapidly with a very small amount of force. The micro-switch is also called a miniature snap-action switch. It is extremely reliable, fast, and efficient to operate, and is also known as a miniature snap-action switch. It is impossible to create smart appliances without micro switches. They are used in many modern-day smart applications. Microswitches are often used as safety devices because of their reliability and sensitivity. They are used to prevent the closing of doors when something or someone is in the way and other similar applications.

The micro switch has three pins: Common (C), Normally Closing (NC), and Normally Opening (NO). Here, the Common pin is an input pin, the NC pin is Output 1, and the NO pin is Output 2.

With its tiny contact gap, The micro switch is a snap-action precision switch for logic-level and power-duty loads. The switch has options like SPDT, SPNO, or SPNC, and offers power-duty switching through silver alloy contacts. Different electrical terminations are available, and logic-level control can be achieved by silver alloy or gold-plated contacts.

How Does a Micro Switch Work?

A micro switch is equipped with an actuator that lifts a lever when pressed to move the contacts into the proper position when depressed. When pressed, micro switches often make a “clicking” sound. Often, micro switches have mounting holes so they can be quickly mounted and secured into place. Due to their long life, they rarely need to be replaced and require little maintenance since they are such a simple switch.

The working principle of a micro switch is that when it touches an object, the contacts change position. Thus, the principle of operation of this switch is mainly as follows.

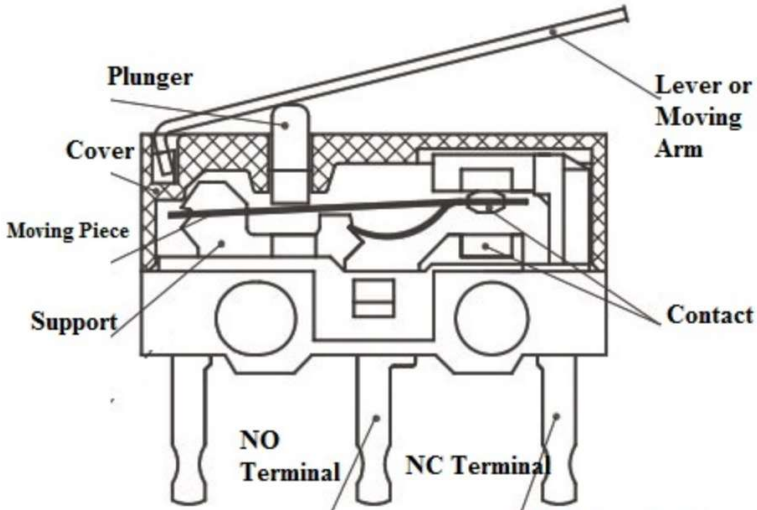
The normally closed pin of the circuit is opened and the normally open pin is closed when you press the lever of the switch. In the same way, when you open the lever of the switch, then the normally closed or NC pin of the circuit will carry the current, while the normally open or NO pin of the circuit can isolate electrically.

The tipping point mechanism is also the basic feature of the micro switch. So, this feature will help to generate certain tripping points and reset points wherever the contacts will change the state.

Micro Switch Circuit

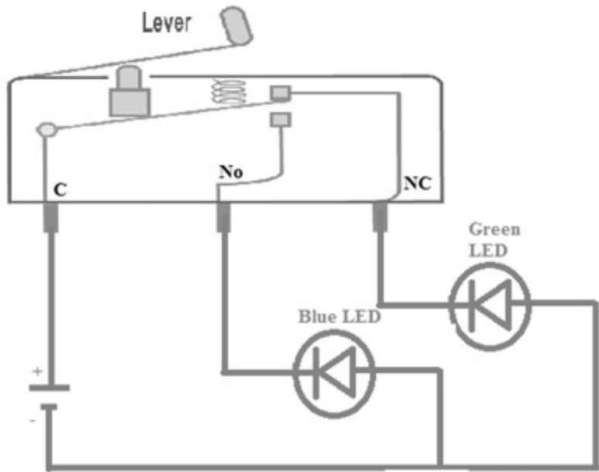
Following is the circuit diagram for the micro switch. The circuit shown below uses a micro switch to control two LEDs with a battery. The micro switch has three terminals, which are C, NO, and NC. This circuit can be connected in the same way as the circuit shown below.

Micro Switch



Micro Switch Circuit

Following is the circuit diagram for the micro switch. The circuit shown below uses a micro switch to control two LEDs with a battery. The micro switch has three terminals, which are C, NO, and NC. This circuit can be connected in the same way as the circuit shown below.



Safety Relays

Introduction

A safety relay is an electromechanical or electronic device designed to reduce risk and implement safety functions, particularly in industrial environments. Its primary goal is to shut down power and remove risk safely and reliably. It reduces the risk of hazards and decreases the chance of damage, injury, or death.

It's important to note that a safety relay is not a stand-alone device. Still, we install it as part of a more extensive control and safety circuit inside a machine. It's an interface between safety devices and the machine components.

Unlike regular relays, we build safety relays to meet stringent safety standards, incorporating fail-safe principles that guarantee operational safety in critical conditions. A safety relay helps to check for losses in safety functions and detect internal failures, including faults with its inputs and outputs.

Safety relays are essential in protecting workers from hazardous machinery or preventing system failures in automation. While installing a safety relay is not obligatory, it simplifies safety circuit design, increases the machine's safety level, and helps detect faults.

History of the Safety Relay

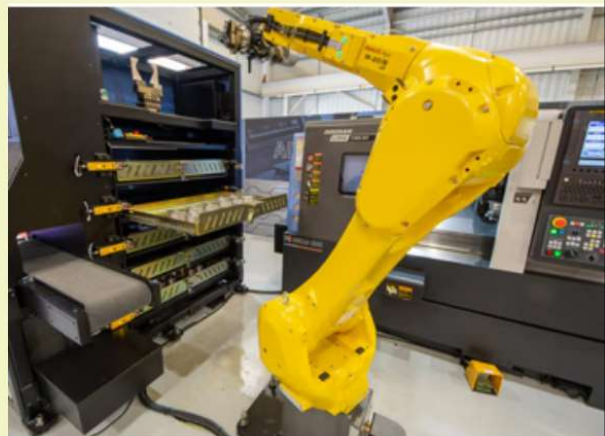
The German automation manufacturer Pilz developed the first safety relay and patented the PNOZ brand emergency stop relay in 1987.

Various manufacturers now produce safety relays with a range of different functions and features. For example, a [two-hand safety relay](#) is an example of a function-specific safety relay.

Risk Assessments

You should base the safety relay and overall safety system you choose on the results of a risk assessment for the machinery.

Although I won't cover the details here, it's essential to understand performance levels (PL), safety categories, and Safety Integrity Level (SIL) when selecting the appropriate safety system. Suppose you connect a low-PL component to a high-PL component. In that case, the entire system will be downgraded to the lowest PL.



Basic Construction of a Safety Relay

A safety relay will have several safety inputs and outputs depending on its type. These are terminals where you can connect your wires or cables.

So, if we start on the input side, we will connect a safety device to the safety relay. An example of a device that connects to the input of a safety relay is a safety interlock switch, an emergency stop button, or a light curtain. You can even connect the outputs of one safety relay to the inputs of another safety relay. (This is a way to “daisy-chain” safety relay modules.)

An essential aspect of the safety inputs of many safety relays is that they have dual-channel redundancy features.

Dual-Channel and Redundancy

Signal redundancy ensures that a single fault on a line will not compromise the safety function. We will discuss this in more detail later, but it’s essential to wire up the safety relay correctly to maintain redundancy with these devices. You will always have two wires for each safety input on a safety relay.

Now, this is not the case for all safety circuits. Depending on the risk assessment, a single-channel device could also connect to a specific safety relay that accepts single-channel inputs. However, a single-channel safety relay would not be able to detect all the faults that a two-channel safety relay could detect.

Similarly, for the output side of a safety relay, these terminals will connect to another safety relay or a device such as a contactor. As with the inputs, the outputs are also redundant and are monitored periodically to check the status of the signals.

Usually, a compact DIN-rail-mounted unit contains all these input and output terminals. We install these units inside a machine’s control or electrical cabinet. The safety relay should also have a couple of indicator lights on its face to show its output status. Sometimes, you can diagnose a fault by seeing which indicator light of a safety input is not resetting.

Finally, the safety relay’s “brain” or internal components are a function-specific microcontroller or other circuit. It verifies and continuously checks safety functions and itself. Therefore, the safety relay has redundant circuits with built-in self-monitoring. If a component inside the safety relay fails, it will remain operational.

There are several essential things to note about the electrical schematic above.

Power—The safety relay and contactors are powered by a 24VDC power supply connected directly to the A1 and A2 terminals.

The Emergency Stop Button (E-Stop)—Notice that the emergency stop button has two normally closed contacts that are mechanically connected. This is part of the redundancy-centric nature of safety systems. A pulsed signal from terminal S11 passes through both e-stop contacts before reaching terminals S12 and S14. When the E-Stop is depressed, both contacts are forced open, which cuts the signal to terminals S12 and S14.

Safety Outputs—Terminals 14 and 24 are the input side of the safety outputs section of the safety relay. These two are connected directly to the power supply. When all safety conditions are met, the relay will close a set of force-guided and redundant relays. This will send power to terminals 13 and 23, which will power the two contactors.

Contactors—The safety outputs provide a dual-channel, redundant signal connected to two contactors. These contactors will then be connected in series to control a motor.

Feedback Loop - The feedback loop monitors the contactors. In their normal state, a force-guided, normally closed contact will inform the relay of faults within the contactor, such as welded or stuck contacts. The input for these contacts comes from the safety relay as a pulsed signal. The two contacts are wired in series and returned to the safety relay on terminal S21.

Reset Button—If the safety relay is tripped, this button resets the relay to its regular operation once all safety conditions are met. In this case, the signal goes through the feedback loop of the contactors.

How Does a Safety Relay Work?

A safety relay monitors one specific safety function or a safety device, such as a light curtain. The safety relay will electronically evaluate inputs and control its outputs based on these evaluations.

Term: OSSD

OSSD Stands for Output Signal Switching Device. An electronic circuit sends out a unique pulse, recognized as a safety signal. OSSD signals prevent accidental or intentional bypassing of safety devices. The OSSD signal is not a steady 24V DC current, but rather a coded signal transmitted over a pair of wires that are out of phase with each other.

Safety Relay Functions

On a basic level, the safety relay has one or more of the following functions:

A safety relay will still function if an internal fault is detected, allowing the system to stop or shut down due to the built-in redundancy and self-monitoring.

The safety relay will monitor input faults such as shorts between conductors, stuck contacts, and shorts to the ground.

It has at least two inputs that receive signals from an OSSD or dry contacts, such as those found in an emergency stop button.

A safety relay sends test pulses along its inputs and outputs to detect faults in the wires, such as shorts.

A safety relay detects if dual-channel inputs change state simultaneously. This is to detect potentially failed contacts on an external safety device. Sometimes, a coded magnetic interlock that closes too slowly can cause the safety relay to think there is a fault because the two channels do not close simultaneously.

It has at least two safety outputs, and many safety relays have more than two.

These safety outputs use positively guided contacts to ensure that the contact sets move as a single unit.

It allows for monitoring of output devices such as contactors. This is called EDM or External Device Monitoring.

To restore a safety relay to normal operating condition after a fault has occurred, it must be power cycled or reset.

A safety relay may have a built-in time delay or other functions such as speed or frequency monitoring.

It provides electrical isolation between the safety devices and the power control circuit.

Proper Wiring is Important!

One crucial thing to consider is that for a safety relay to work as expected and reduce risk, it must be wired correctly. I have seen interlock switches wired to a safety relay's A1/A2 power input terminals, effectively removing and deactivating power. Not only is this the wrong way to connect a safety relay, but it also effectively bypasses the safety relay, making it useless in the circuit.

A typical use of a safety relay is to interconnect a safety interlock switch mounted on a guard with the contactors that power a motor.

The safety relay checks and turns on the motor contactors when all safety conditions are met.

Typical Applications & Usage Examples

We commonly find safety relays in industrial environments on machinery such as production lines, robots, and other devices where a higher safety level and risk reduction are required.

Here are examples of standard safety devices that we can connect to the input terminals of a safety relay:

- Light curtains
- Safety Mats
- Two-hand button control
- Safety guarding interlocks
- Emergency stop buttons

On the output side of a safety relay, a standard connection is made to contactors, which, in turn, connect back to the safety relay's inputs for monitoring the contactor's electrical contacts. In addition to contactors, we can connect a second safety relay, or we can connect to special OSSD inputs of VFDs or drives.

Examples of machinery and equipment that make use of safety relays:

- Elevators
- Cranes
- Robots
- Stamping Presses
- Cutting Machines
- Printing Machinery
- Production Machinery
- Relevant Standards

OSHA 1910.211(d)(62) - **Safety system** means the integrated total system, including the pertinent elements of the press, the controls, the safeguarding and any required supplemental safeguarding, and their interfaces with the operator, and the environment, designed, constructed and arranged to operate together as a unit, such that a single failure or single operating error will not cause injury to personnel due to the point of operation hazards.

ANSI B11.19 & ANSI B11.20 - Control Reliability



How Does a Proximity Sensor Work? 🚀

A proximity sensor is a device that detects the presence of an object without physical contact. It works by emitting a signal (electromagnetic, infrared, or ultrasonic) and analyzing how it interacts with nearby objects. These sensors are widely used in industrial automation, automotive systems, and consumer electronics.

⚡ Types of Proximity Sensors & How They Work

◆ Inductive Proximity Sensor (For Metal Objects)

Creates a magnetic field around its sensing area.

When a metallic object enters this field, it disrupts the field, triggering the sensor.

Used in: Machinery, metal detection, position sensing in automation.

◆ Capacitive Proximity Sensor (For Any Material)

Generates an electrostatic field.

Detects objects by sensing changes in capacitance (how the field is affected).

Used in: Plastic, wood, liquid level detection, and non-metallic materials.

◆ Ultrasonic Proximity Sensor (For Distance Measurement)

Emits high-frequency sound waves.

Measures the time it takes for the sound to bounce back after hitting an object.

Used in: Parking sensors, obstacle detection, and robotics.

◆ Photoelectric Proximity Sensor (For Light-Based Detection)

Uses a light beam (infrared or laser).

Detects objects when the beam is interrupted or reflected back.

Used in: Conveyor belts, automatic doors, and packaging systems.

🔧 How to Use a Proximity Sensor Safely?

✔ Mount the sensor at the correct distance for accurate detection.

✔ Avoid interference from external signals or metallic surfaces (especially for inductive and capacitive types).

✔ Regularly clean the sensor to prevent dust or dirt from affecting its performance.

✔ Test the sensor output before integrating it into a control system.

⚠ Common Issues & Solutions

✗ False triggers - Ensure proper sensor placement and shielding.

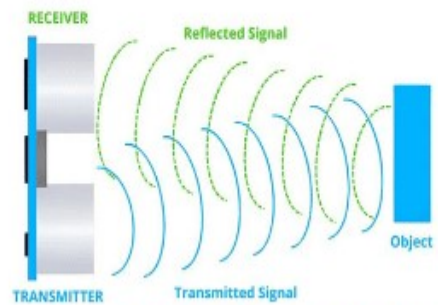
✗ Short detection range - Check power supply and sensor alignment.

✗ Interference from other devices - Use filters or shielding for electromagnetic-sensitive sensors.

TYPES OF PROXIMITY SENSORS



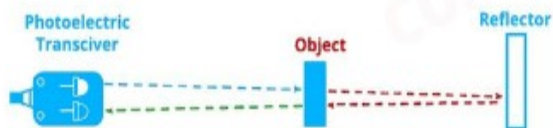
CAPACITIVE PROXIMITY SENSOR



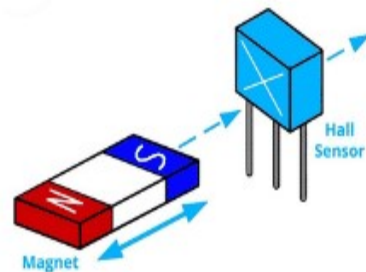
ULTRASONIC PROXIMITY SENSOR



INDUCTIVE PROXIMITY SENSOR



PHOTOELECTRIC PROXIMITY SENSOR



MAGNETIC PROXIMITY SENSOR

⚡ TYPES OF PROXIMITY SENSORS

1️⃣ CAPACITIVE PROXIMITY SENSOR

How it works? Detects objects by sensing changes in electrical capacitance.
What can it detect? Both metallic & non-metallic objects (plastic, liquid, wood, etc.).

Common uses: Detecting liquid levels in tanks, touch sensors, and food packaging lines.

2️⃣ INDUCTIVE PROXIMITY SENSOR

How it works? Creates a magnetic field and detects disturbances caused by metal objects.

What can it detect? Only metal objects (iron, aluminum, copper, etc.).

Common uses: Detecting metal parts in machinery, conveyor systems, and safety mechanisms.

3️⃣ ULTRASONIC PROXIMITY SENSOR

How it works? Sends sound waves (ultrasound) and detects objects based on the reflected signal.

What can it detect? Any solid object (metal, plastic, wood, glass).

Common uses: Distance measurement, parking sensors, and liquid level detection.

4️⃣ PHOTOELECTRIC PROXIMITY SENSOR

How it works? Uses light beams (LED or laser) to detect objects when they interrupt the beam.

What can it detect? Any material that blocks light.

Common uses: Object counting, package detection, and automation lines.

5️⃣ MAGNETIC PROXIMITY SENSOR

How it works? Uses a magnet and a Hall-effect sensor to detect magnetic fields.

What can it detect? Magnetic materials (permanent magnets).

Common uses: Door sensors, security systems, and speed detection in motors.

🔗 Final Thoughts

Each sensor type has its own strengths depending on the material and the application.

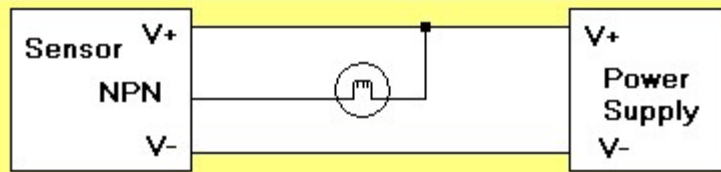
💡 Need to detect metal? → Use Inductive Sensors

💡 Want to detect any material? → Use Capacitive or Ultrasonic Sensors

💡 Need long-range detection? → Go for Ultrasonic or Photoelectric Sensors

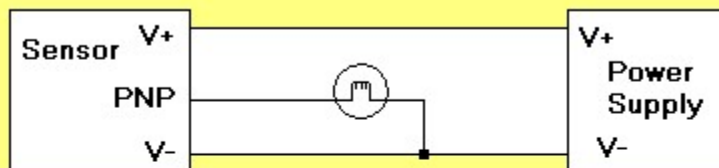
💡 Working with magnets? → Choose Magnetic Sensors

Now you're ready to pick the right sensor for your project!



SINKING

Sinking (NPN) - When actuated, the sensor will connect to ground, or pull the input low. If this is the case you need to use an output that normally stays high, true, floats high, etc.

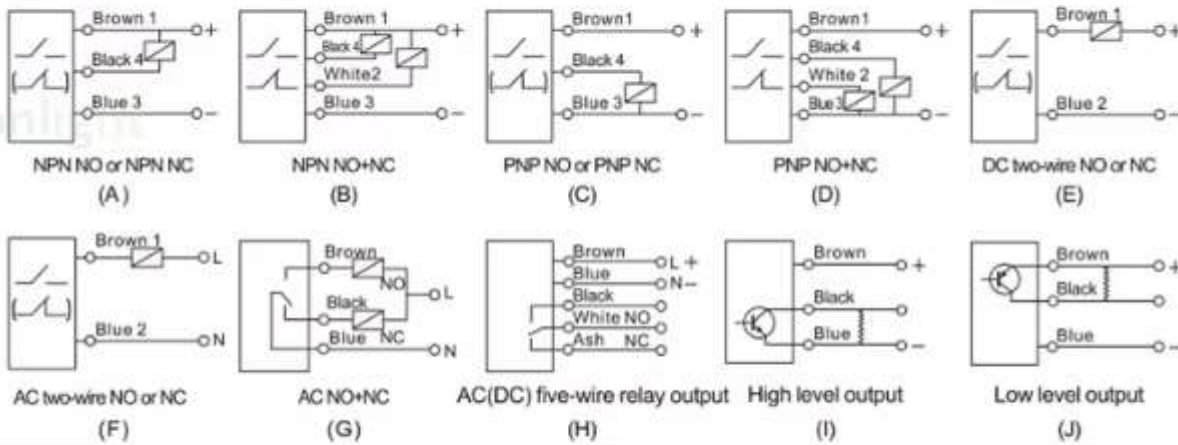


SOURCING

- Sourcing (PNP) - When actuated, the sensor will connect to $V+$, or pull the input high. If this is the case you need to use an output that normally stays low, false, floats low, etc.

Wiring diagram

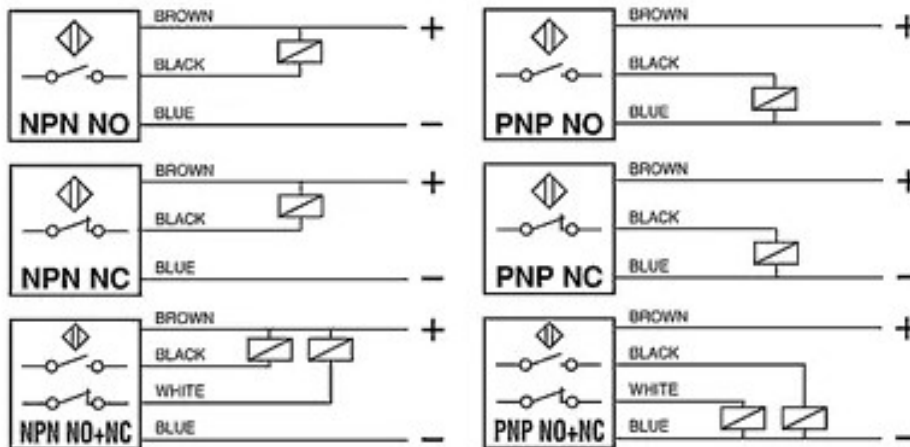
● Wiring diagram:



Brown:(sign plus) +

Blue:(minus sign) -

Black:(signal)



Color Codes for Proximity Sensor Connections

In this image, the color codes refer to the wiring of proximity sensors, which are electronic devices that detect the presence of nearby objects without physical contact. The color of the wires indicates their function in the circuit. Here's a breakdown:

Brown Wire:

Function: Brown (Marrón) indicates the positive power supply (+). It carries the voltage that powers the sensor.

Note: The image labels it as "Brown (sign plus) +".

Blue Wire:

Function: Blue (Azul) represents the negative power supply (-). It provides the return path for the electrical current.

Note: The image labels it as "Blue (minus sign) -".

Black Wire:

Function: Black (Negro) is the signal wire. It carries the output signal from the sensor, indicating whether an object has been detected or not.

Note: The image labels it as "Black (signal)".

Additional Wire Colors in the Diagram

The diagram also includes:

White Wire:

Function: In some sensor configurations, a white (Blanco) wire might be used for a normally closed (NC) output. This means the output is active when no object is detected.

Ash Wire:

Function: Ash (Ceniza) is another color that can be used for a normally closed (NC) output in certain sensor types.

Understanding the Wiring Diagrams

The image shows various wiring diagrams labeled A through J. These illustrate different configurations for connecting the proximity sensor, depending on the type of sensor (NPN, PNP, AC, DC) and the desired output (normally open (NO), normally closed (NC), or a combination).

NPN/PNP: These refer to the type of transistor used in the sensor's output stage.

NO/NC: Normally open and normally closed describe the default state of the sensor's output.

AC/DC: Indicates whether the sensor operates on alternating current (AC) or direct current (DC).

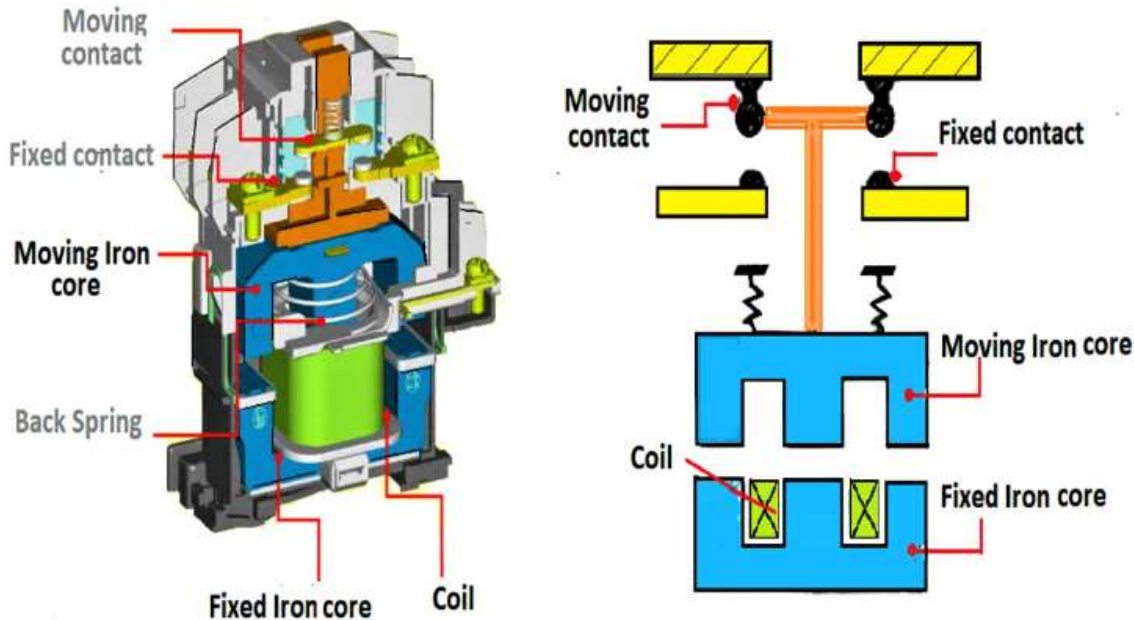
Key Points

Standard Colors: These color codes (brown, blue, black) are generally standard for many industrial proximity sensors.

Consult Documentation: Always refer to the specific sensor's documentation for accurate wiring information, as color codes can vary slightly between manufacturers.

Safety First: When working with electrical connections, ensure power is disconnected and follow proper safety procedures.

magnetic contactor is essentially an electrically controlled switch. Think of it as a heavy-duty relay designed to handle high-current loads. It's used to repeatedly establish or interrupt an electrical power circuit. Contactors are typically used to control electric motors, lighting systems, heating systems, and other high-power electrical loads.



- **Moving Contact:** This is the part of the contactor that physically moves to make or break the electrical connection.
- **Fixed Contact:** These are the stationary parts that the moving contact connects to.
- **Moving Iron Core:** This is the movable part of the electromagnet. When the coil is energized, this core moves.
 - **Fixed Iron Core:** This is the stationary part of the electromagnet.
- **Coil:** This is the electromagnet that, when energized, creates a magnetic field.
- **Back Spring:** This spring returns the moving contact to its original position when the coil is de-energized.

Schematic Diagram:

- Moving Contact and Fixed Contact:** The diagram clearly shows how these parts connect to complete the circuit.
- Springs:** The springs are shown to illustrate how the contacts are returned to their open position.
- Moving Iron Core, Fixed Iron Core, and Coil:** This shows how the electromagnet works to move the contacts.

How does it work?

Energizing the Coil: When an electrical current is passed through the coil, it creates a magnetic field.

Attracting the Core: The magnetic field attracts the moving iron core.

Closing the Contacts: The movement of the core causes the moving contacts to connect with the fixed contacts, completing the electrical circuit.

De-energizing the Coil: When the current to the coil is stopped, the magnetic field disappears.

Opening the Contacts: The back spring forces the moving contacts to return to their original position, breaking the circuit.

Why are they important?

Remote Control: Contactors allow you to control high-power circuits from a remote location.

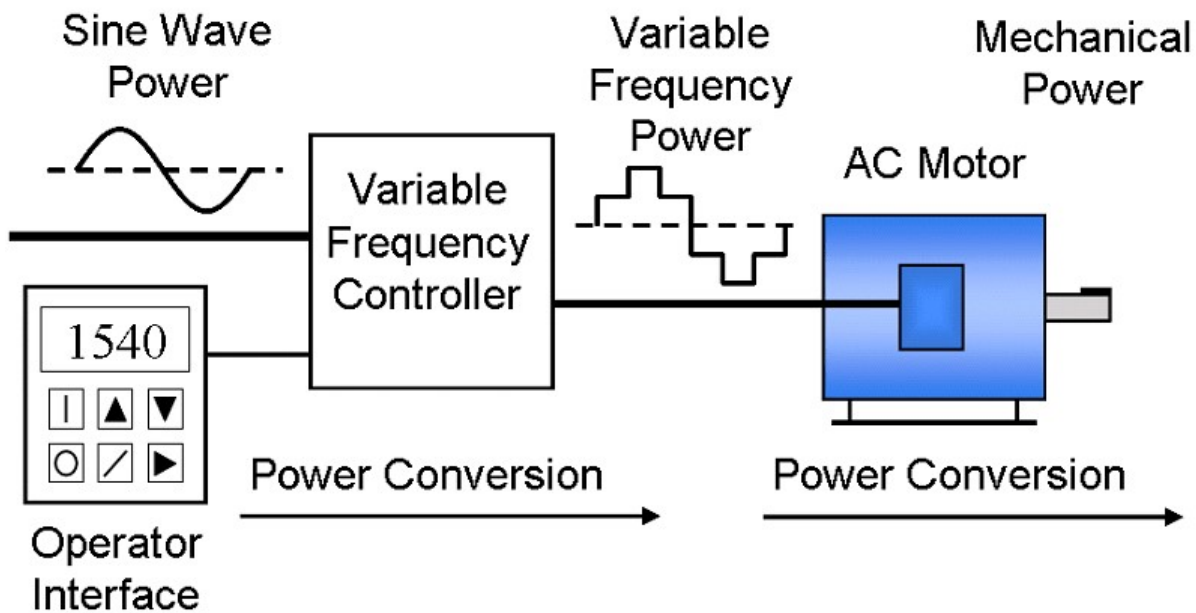
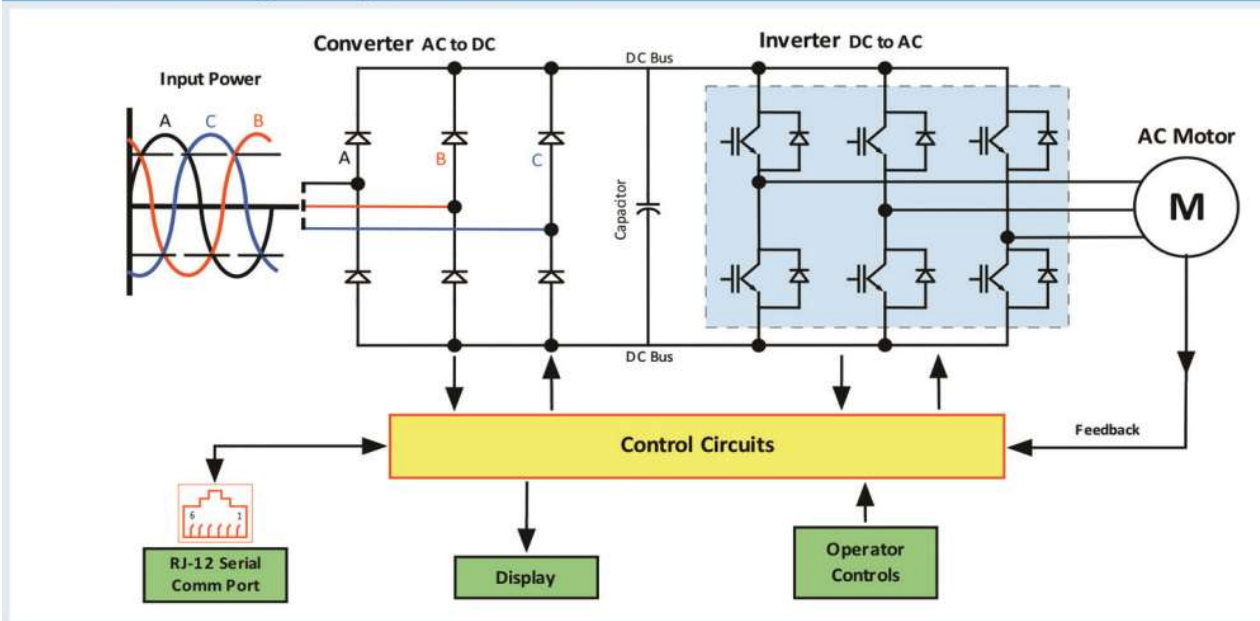
Automation: They are essential for automating electrical systems.

Safety: They provide a safe way to switch high-power loads.

Durability: They are designed to withstand frequent switching.

In summary: A magnetic contactor is a robust electrical switch that uses an electromagnet to control high-power circuits, enabling remote control, automation, and safety in various electrical applications.

Variable Frequency Drive (VFD)



Variable Frequency Drive (VFD)

This diagram shows the working principle of a Variable Frequency Drive (VFD), a device used to control the speed and torque of an AC motor by varying the frequency and voltage of the power supply.

🔗 How It Works:

- 1☐ Input Power (AC Supply): The VFD receives three-phase AC power (Labeled A, B, C).
- 2☐ Converter (AC to DC): Uses diodes to rectify AC into DC.
- 3☐ DC Bus & Capacitors: Smooths out the rectified DC voltage.
- 4☐ Inverter (DC to AC): Uses transistors (IGBTs) to create a controlled AC output at the desired frequency.
- 5☐ Control Circuits: The brain of the VFD, it manages power conversion, feedback, and user input.
- 6☐ Feedback Loop: The system monitors motor performance and adjusts output accordingly.
- 7☐ User Interfaces: Includes RJ-12 Communication Port, Display, and Operator Controls for programming and monitoring.

⚡ VFD Troubleshooting Tips 🛠️

If your VFD is not working properly, follow these steps to diagnose and fix the issue:

✔️ 1. Check Power Supply

Ensure the input voltage matches the VFD's rating.
Verify that all three phases are present and balanced.

✔️ 2. Inspect the Display & Error Codes

Most VFDs display fault codes; refer to the manufacturer's manual for troubleshooting.

✔️ 3. Test the DC Bus Voltage

Measure the DC bus voltage; a low or unstable voltage could indicate bad capacitors or rectifiers.

✔️ 4. Inspect the Output to the Motor

Use a multimeter to check if the VFD is outputting the correct voltage and frequency.

Look for unbalanced or missing phases.

✔️ 5. Check for Overloads or Overheating

Ensure the motor is not exceeding its current rating.
Clean or improve cooling and ventilation around the VFD.

✔️ 6. Examine the Control Circuit & Settings

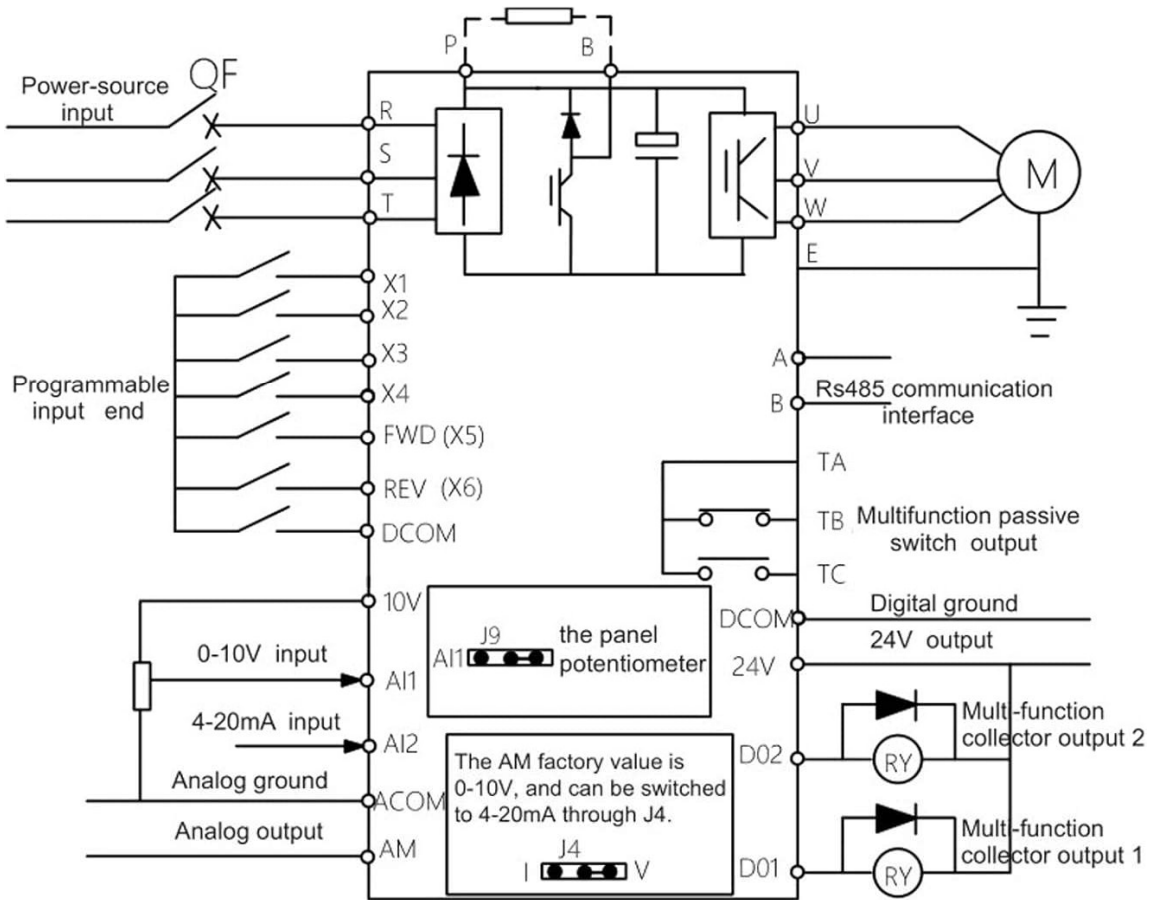
Verify that the operator controls are correctly configured.
Reset the VFD to factory defaults if needed.

✔️ 7. Inspect the Motor & Cables

Look for loose connections, damaged wiring, or short circuits.
Test motor windings with a megohmmeter to check for insulation issues.

✔️ 8. Communication & Feedback Issues

If the VFD is controlled remotely, check communication settings and cables.
Verify that the feedback sensor (encoder, tachometer) is functioning properly.



When P0-03=2, the AI1 external potentiometer or the panel potentiometer is selected by J9 to speed, and the factory value is the panel potentiometer.

Key Sections:

Power Input (QF, R, S, T): This is where your main power supply comes in. Think of it as the electricity coming from the wall.

Motor Output (U, V, W, E): These terminals connect to your motor. The VFD sends the adjusted power here.

Control Inputs (X1-X6, AI1, AI2, etc.): These are for signals that tell the VFD what to do. You can connect switches, potentiometers (dials), or other control devices.

Outputs (RY, TA, TB, TC etc): The VFD can send out signals to other devices, indicating its status or controlling other processes.

Communication (A, B): Rs485 communication interface, this is used for communication with other devices like computers or PLC's.

Diving into the Details

Power Input:

QF: This represents a circuit breaker or disconnect switch. It's a safety feature to cut power to the VFD.

R, S, T: These are the three phases of your AC power supply (if it's a 3-phase VFD).

Motor Output:

U, V, W: These connect to the three windings of your 3-phase motor.

E: This is the ground connection.

Control Inputs:

X1-X6: These are programmable digital inputs. You can connect push buttons or switches to them for functions like start, stop, or changing speeds.

FWD (X5) & REV (X6): dedicated forward and reverse digital inputs.

AI1 (0-10V input) and AI2 (4-20mA input): These are analog inputs. You can connect a potentiometer (dial) or a sensor that outputs a voltage or current signal to control the motor speed. The diagram also explains that there is a jumper (J4) that allows the AI2 input to be switched from 0-10V to 4-20mA.

ACOM: Analog common ground.

AM: Analog output.

Outputs:

RY (D01 & D02): Multi-function collector outputs. These can be used to signal when the motor is running, or if there's a fault.

TA, TB, TC: Multifunction passive switch outputs.

24V: 24V DC output to power external devices.

Potentiometers:

There is a section of the diagram that explains how to wire in an external potentiometer, and how the jumper J9 is used to select between the external potentiometer, and the panel potentiometer.

Communication:

A, B: Rs485 communication interface, this is for communication with other devices.

Dynamic Points to Consider

Flexibility: VFDs are incredibly flexible. The programmable inputs and outputs let you customize them for various applications.

Safety: The diagram includes safety features like the circuit breaker (QF) and ground connection (E).

Control: You have multiple ways to control the motor speed, from simple switches to analog signals.

Communication: The Rs485 communication allows the VFD to be integrated into larger control systems.

Jumpers: The diagram gives information about the jumpers J4 and J9, and how they change the function of certain inputs.

In essence, this diagram is a roadmap for wiring a VFD, enabling precise motor control and integration into industrial or automation systems.

🔍 What is a Relay?

A relay is an electrically operated switch that controls a circuit by opening and closing contacts in response to an electrical signal. It allows a low-power signal to control a high-power circuit, making it a key component in automation, control systems, and electrical protection.

🔧 How Does a Relay Work?

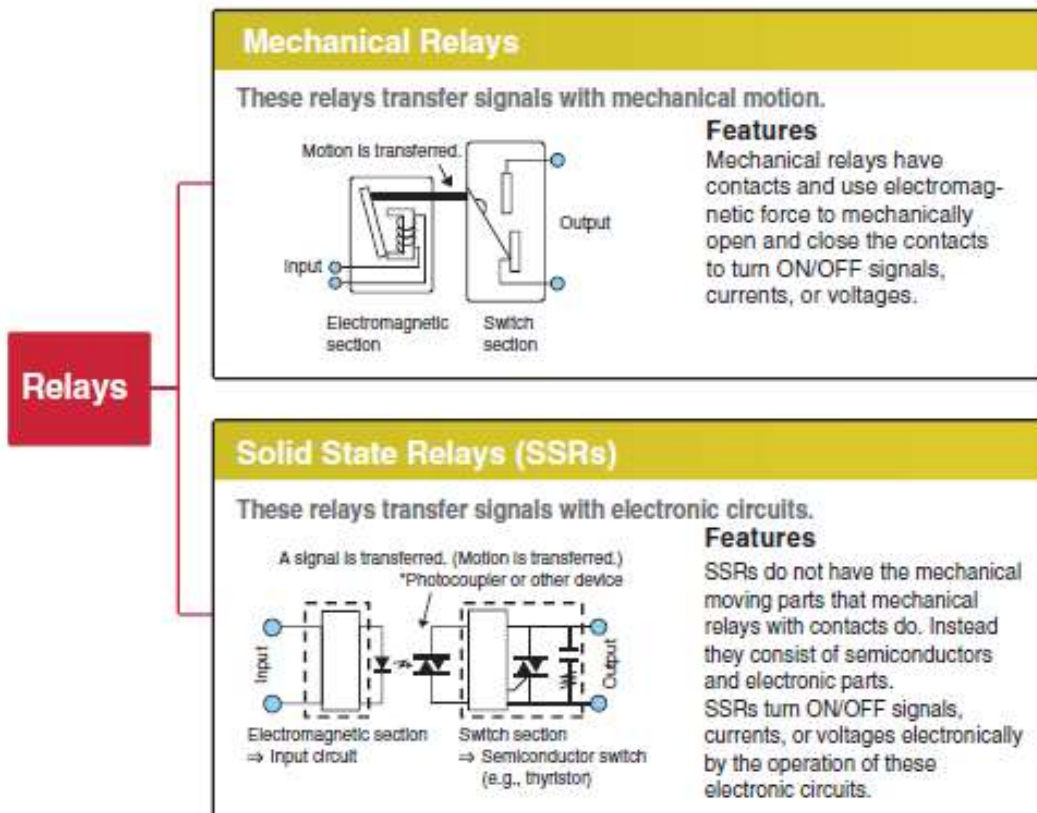
A relay typically consists of:

- 1️⃣ **Coil** - When energized, it creates a magnetic field.
- 2️⃣ **Contacts** - These switch the circuit ON or OFF.
- 3️⃣ **Spring & Armature** - Moves when the coil is activated, switching the contacts.

- ◆ When power is applied to the coil, it generates a magnetic force that pulls the armature, closing or opening the contacts.
- ◆ When power is removed, the spring returns the armature to its original position.

⚡ Types of Relays

- ◆ **Electromechanical Relay (EMR)**: Uses physical moving parts.
- ◆ **Solid-State Relay (SSR)**: Uses electronic components, faster and more durable.
- ◆ **Time-Delay Relay**: Activates after a set time.
- ◆ **Overload Relay**: Protects motors from excessive current.



How Do Relays Work?

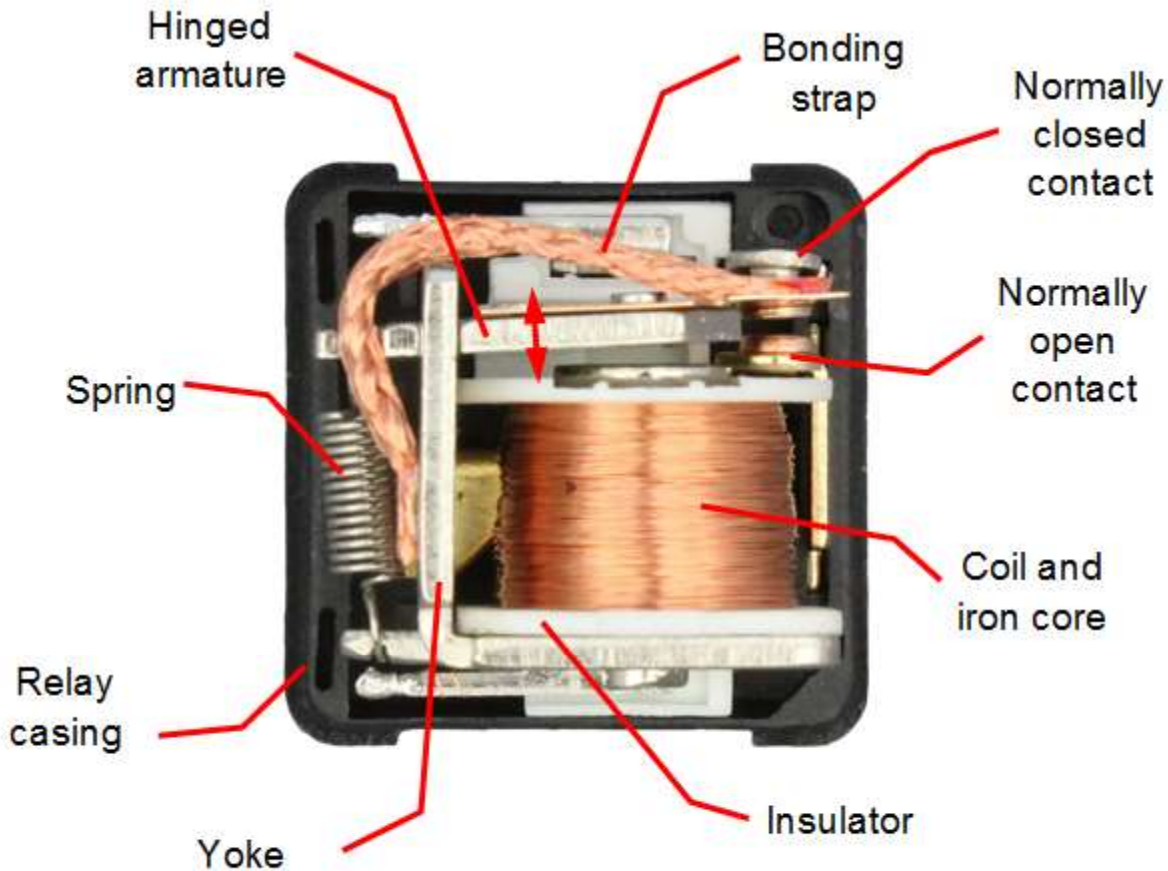


Image Courtesy of 12 Volt Planet

Here's a step-by-step look at how a basic automotive relay operates:

Low Power Input: A low-current signal (often from a switch or control module) is sent to the relay's coil.

Electromagnetic Field: This current energizes the coil, creating an electromagnetic field.

Switching Action: The electromagnetic field pulls a metal arm (or switch) to close or open a set of contacts.

High Power Output: Once the contacts close, they allow a higher current to flow through, powering devices like lights, fans, or fuel pumps.

Deactivation: When the low-current signal stops, the magnetic field collapses, and the contacts open again, turning off the high-power device.

Types of Relays

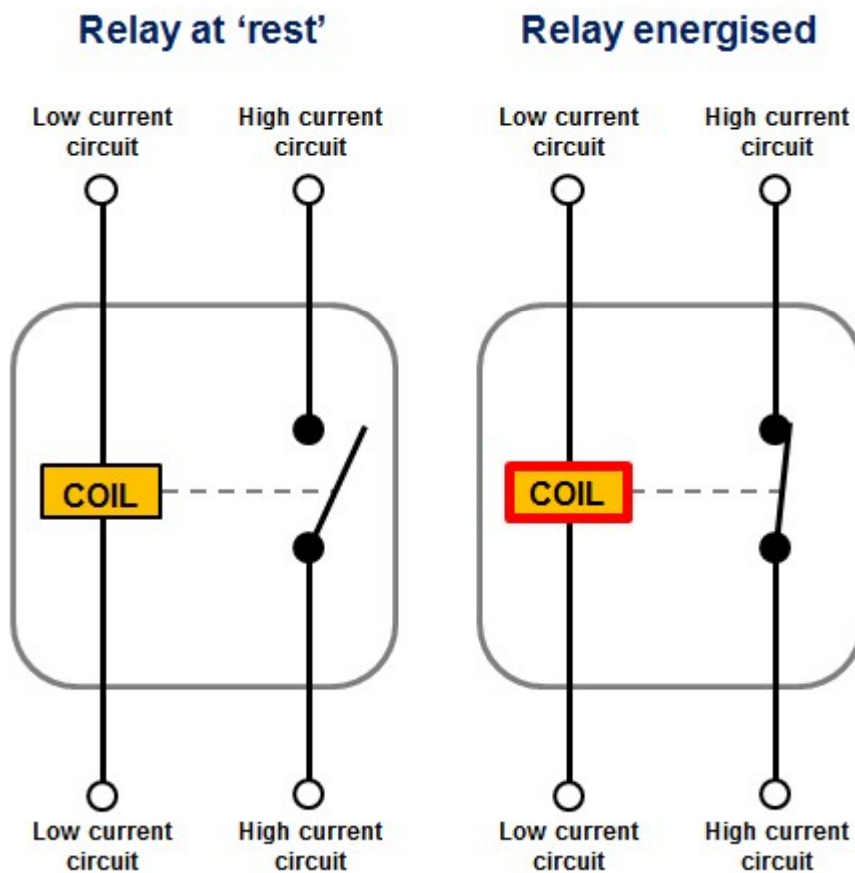
Normally Open (NO): The relay's default state is "off" (the circuit is open). When the relay is energized, it closes the circuit.

Normally Closed (NC): The relay's default state is "on" (the circuit is closed). Energizing the relay opens the circuit.

SPST (Single Pole Single Throw): This is the simplest relay type, controlling just one circuit with one output.

SPDT (Single Pole Double Throw): This relay has one input and can toggle between two different outputs.

DPDT (Double Pole Double Throw): Controls two independent circuits, useful for complex systems.



RELAY



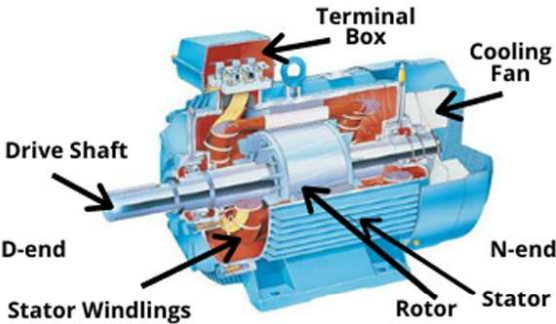
- Used in circuit with lower ampacity (Max 20A)
- Consists of at least two NO/NC contacts.
- Smaller in size.
- Max used in control, automation circuit, protection circuits and switching small electronics circuits.

CONTACTOR

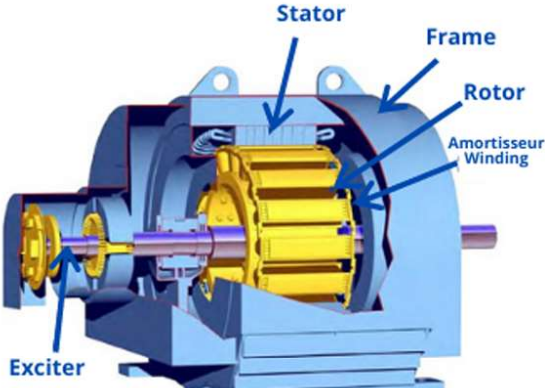


- It can be used for switching load up to 12500 Amps.
- Consists of a set of 3 phase power contacts and in some cases, additional auxiliary contacts are also available.
- Contactors have arc suspension arrangement inside
- It is used for switching motor, capacitor, light, etc that drain very high current.

Electric motor:



Induction Motor



Synchronous Motor

•**Synchronous Motors:**

A synchronous motor is an AC motor that operates at a constant speed, called synchronous speed. This speed is determined by the supply frequency and the number of poles in the motor. The rotor in a synchronous motor rotates in sync with the stator's rotating magnetic field. These motors are commonly used where precise speed control is essential. They require an external power source (like a DC supply) to excite the rotor and maintain synchronization with the stator field. Synchronous motors can either be self-excited or separately excited.

•**Asynchronous Motors (Induction Motors):**

An asynchronous motor, also known as an induction motor, is an AC motor where the rotor does not rotate at the same speed as the stator's magnetic field. The rotor speed is always slightly less than the synchronous speed, resulting in "slip," which is necessary for torque generation. These motors are simple in construction, reliable, and cost-effective, which makes them widely used in industrial applications. They do not require external excitation because the current in the rotor is induced by the stator's magnetic field.

Synchronous Motors:

Large Generators in Power Plants:

Synchronous motors are often used as generators in power plants. These generators need to maintain a constant speed to ensure the stability of the electrical grid, and synchronous motors provide that stability.

Clock Motors:

Synchronous motors are commonly used in clocks and timers. Since they run at a fixed speed, they ensure that timekeeping is accurate.

Electric Subways/Trains:

Some electric trains and subway systems use synchronous motors to ensure precise control of speed and minimize fluctuations in energy consumption.

High-precision CNC Machines:

Synchronous motors are sometimes used in machinery where precise and constant speed control is needed, such as in CNC (Computer Numerical Control) machines.

Asynchronous (Induction) Motors:

Household Appliances:

Many household appliances, like fans, refrigerators, washing machines, and air conditioners, use asynchronous (induction) motors due to their simplicity and efficiency.

Industrial Pumps and Fans:

Induction motors are widely used in industrial applications, such as driving pumps, compressors, and ventilation fans, because they can easily handle variable loads and are robust.

Electric Motors for Conveyors:

Induction motors are commonly used in conveyor belts in factories or warehouses, where they can handle continuous running and varying loads.

Electric Vehicles (EVs):

Some electric vehicles use induction motors because of their efficiency and durability, particularly in smaller or budget-friendly models.

Motor Nameplate Information

| AC MOTOR | | | | MADE IN USA | |
|------------|----------------|----------------|--------------------|-------------|------|
| ① FRAME | ② TYPE (ENCL.) | ③ INSUL. CLASS | IDENTIFICATION NO. | | |
| 324T | TEFC | F | 8779787246 | | |
| ④ HP | ⑤ RPM | ⑥ VOLTS | ⑦ FLA | ⑧ HZ. | ⑨ SF |
| 25 | 1760 | 230 / 460 | 60 / 30 | 60 | 1.15 |
| ⑩ CODE LTR | ⑪ PHASE | ⑫ DUTY | ⑬ AMB. | ⑭ BEARINGS | |
| H | 3 | CONT. | 40°C | DE | ODE |
| | | | | 6312 | 6311 |

Motor Nameplate Explanation

This nameplate provides essential specifications for an AC (Alternating Current) motor, made in the USA. Here's a breakdown of each numbered item:

- 1.FRAME:** This indicates the motor's frame size, which is a standardized dimension that determines the motor's mounting dimensions, shaft size, and overall physical size. In this case, it's a **324T** frame.
- 2.TYPE (ENCL.):** This refers to the motor's enclosure type. **TEFC** stands for Totally Enclosed Fan Cooled. This means the motor is designed to prevent outside air from circulating inside, and it has an external fan to cool it.
- 3.INSUL. CLASS:** This indicates the insulation class of the motor's windings. **F** represents a temperature rating of 155°C (311°F). This tells you the maximum temperature the motor's insulation can withstand during operation.
- 4.HP:** This is the horsepower rating of the motor, which is a measure of its power output. This motor is rated at **25 HP**.
- 5.RPM:** This is the motor's revolutions per minute, indicating its speed. This motor operates at **1760 RPM**.
- 6.VOLTS:** This indicates the voltage the motor is designed to operate on. This motor can be wired for either **230 volts or 460 volts**.
- 7.FLA:** This stands for Full Load Amps, which is the amount of current the motor draws when operating at full load. This motor draws **60 amps at 230 volts or 30 amps at 460 volts**.
- 8.HZ:** This is the frequency of the power supply, measured in Hertz. This motor is designed for a **60 Hz** power supply.
- 9.SF:** This is the service factor, which is a multiplier that indicates how much overload the motor can handle for short periods. This motor has a service factor of **1.15**, meaning it can handle a 15% overload.
- 10.CODE LTR:** This is the locked rotor kVA code letter, which indicates the inrush current the motor draws when starting. **H** falls within a specific range of kVA per horsepower, helping determine the appropriate starter and circuit protection.
- 11.PHASE:** This indicates the number of electrical phases the motor operates on. This is a **3-phase** motor.
- 12.DUTY:** This specifies the motor's operating duty cycle. **CONT.** stands for continuous duty, meaning the motor is designed to operate continuously.
- 13.AMB.:** This is the maximum ambient temperature the motor is designed to operate in. **40°C** (104°F) is the limit.
- 14.BEARINGS:** This specifies the bearing types used in the motor. **DE** stands for Drive End, and **ODE** stands for Opposite Drive End. The bearings are **6312** on the drive end and **6311** on the opposite drive end.

Additional Notes:

- MADE IN USA:** This simply states the motor was manufactured in the United States.
- IDENTIFICATION NO.:** This is a unique identification number for the motor.

Polarization Index (PI) Test on an Electric Motor

The Polarization Index (PI) test evaluates the insulation quality of a motor by measuring insulation resistance at two different time intervals.

Required Materials:

Megohmmeter (insulation resistance tester)

Insulated gloves

Safety lockout devices (locks, tags)

Multimeter (to verify absence of voltage)

Step-by-Step Procedure:

De-energize and Lockout

Ensure the motor is completely disconnected from the power supply.

Use a multimeter to verify the absence of voltage.

Apply lockout devices to prevent accidental reconnection.

Prepare the Megohmmeter

Select the appropriate test voltage:

Motor ≤ 600 V \rightarrow 500 V DC

Motor 600 V - 5 kV \rightarrow 1000 V DC

Motor > 5 kV \rightarrow 2500 V or 5000 V DC

Connect the megohmmeter leads:

Positive (+) lead to the motor winding.

Negative (-) lead to the motor casing (ground).

Measure the Insulation Resistance

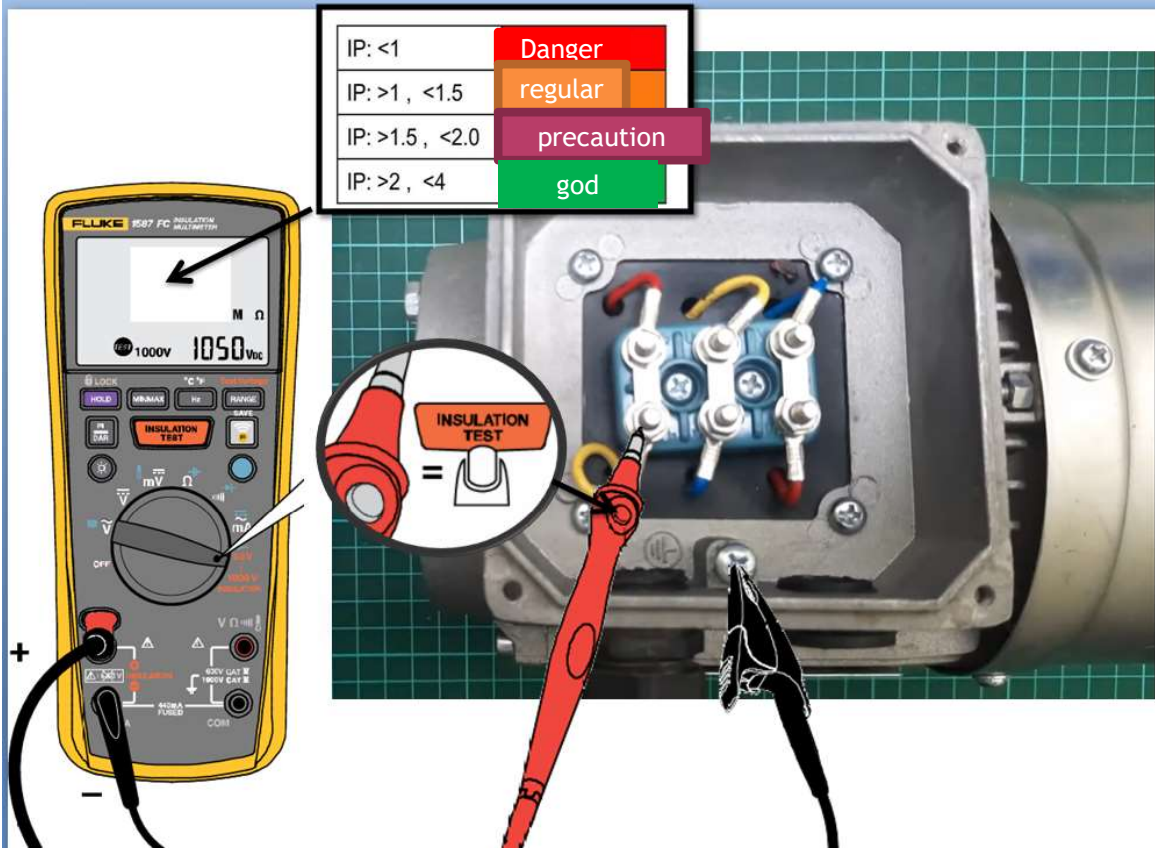
First reading (R_1): Take a resistance reading after 1 minute.

Second reading (R_{10}): Take another reading after 10 minutes.

Calculate the Polarization Index (PI): $PI = \frac{R_{10}}{R_1}$

5. Interpret the Results:

| Polarization Index (PI) | Insulation Condition |
|-------------------------|--|
| < 1.0 | Defective or contaminated insulation |
| 1.0 - 1.5 | Significant deterioration, requires inspection |
| 1.5 - 2.0 | Moderately acceptable, monitor condition |
| 2.0 - 4.0 | Good insulation |
| > 4.0 | Excellent insulation |



How to Use This Chart

This troubleshooting chart is designed to help you quickly diagnose and resolve common electric motor issues. Follow these steps:

Identify the Problem: Look for symptoms such as failure to start, overheating, vibration, or unusual noises.

Check Possible Causes: Find the potential reasons for the issue in the second column.

Apply Solutions: Follow the recommended actions to fix the problem.

Verify and Test: After implementing the solution, test the motor to ensure it operates correctly.

| Problem | Possible Causes | Solutions |
|--------------------------------|---|---|
| Motor fails to start | - No power supply- Blown fuse or tripped breaker- Overload relay tripped- Faulty start switch- Open winding | - Check power supply and connections- Replace fuse/reset breaker- Reset overload relay- Inspect and replace faulty switch- Test and repair windings |
| Motor runs but overheats | - Overloaded motor- Poor ventilation- High ambient temperature- Bad bearings- Incorrect voltage | - Reduce load- Clean cooling vents- Ensure proper ventilation- Replace faulty bearings- Check voltage supply |
| Motor hums but does not start | - Low voltage- Faulty capacitor (single-phase)- Rotor locked or stuck- Loose wiring | - Verify and correct voltage- Replace capacitor- Inspect and free rotor- Tighten or repair wiring |
| Motor vibrates excessively | - Misalignment- Unbalanced rotor- Loose mounting- Worn bearings | - Align motor properly- Balance rotor- Secure mounting- Replace worn bearings |
| Motor runs intermittently | - Loose connections- Overload relay trips repeatedly- Faulty control circuit | - Tighten connections- Identify and reduce overload cause- Inspect and repair control circuit |
| Motor makes unusual noises | - Bearing failure- Foreign objects in motor- Loose or damaged rotor/stator- Electrical arcing | - Replace bearings- Remove foreign objects- Inspect and repair rotor/stator- Check for insulation breakdown |
| Motor runs at incorrect speed | - Incorrect voltage or frequency- Defective winding- Faulty variable speed drive | - Check and correct power supply- Test and repair winding- Inspect and replace VFD if necessary |
| Motor trips breaker frequently | - Short circuit in winding- Ground fault- Excessive load | - Test and repair windings- Check insulation resistance- Reduce load or resize motor |

Electric Motor Frame Dimensions (Inches) Chart

The **Electric Motor Frame Dimensions Chart** provides key measurements for various NEMA (National Electrical Manufacturers Association) motor frame sizes. These measurements help determine compatibility when replacing or installing motors.

Here's what each column represents:

NEMA Frame Size: The standardized designation that defines motor size, mounting, and shaft specifications.

Shaft Diameter (inches): The width of the motor's shaft, which determines coupling or pulley compatibility.

Mounting Hole Spacing (inches): The distance between the motor's mounting holes, ensuring proper alignment with mounting bases.

Motor Length (inches): The overall length of the motor body, crucial for fitting into available space.

Electric Motor Frame Dimensions (Inches)

| NEMA Frame Size | Shaft Diameter (in) | Mounting Hole Spacing (in) | Motor Length (in) |
|-----------------|---------------------|----------------------------|-------------------|
| 48 | 0.625 | 3.00 x 5.00 | 10.00 |
| 56 | 0.625 - 0.875 | 3.50 x 5.88 | 12.00 |
| 143T/145T | 0.875 | 4.00 x 6.50 | 14.00 |
| 182T/184T | 1.125 | 5.00 x 7.50 | 16.00 |
| 213T/215T | 1.375 | 5.50 x 9.00 | 20.00 |
| 254T/256T | 1.625 | 6.50 x 10.00 | 24.00 |
| 284T/286T | 1.875 | 7.50 x 12.00 | 28.00 |
| 324T/326T | 2.125 | 8.50 x 14.00 | 32.00 |

Electric Motor Frame Letter Designations

| Letter | Meaning |
|--------|--|
| T | Standard integral horsepower motor frame (post-1952) |
| U | Older standard frame (pre-1952) |
| C | Face-mounting motor (direct-coupled applications) |
| D | Flange-mounted motor |
| H | Indicates a frame with a specific dimension change |
| Z | Non-standard shaft dimensions |
| Y | Special mounting configurations |
| S | Short shaft motor |

Electric Motor Insulation Classes

| Insulation Class | Maximum Temperature (°C) | Typical Applications |
|------------------|--------------------------|---|
| A | 105°C | Small appliances, fans, older motors |
| B | 130°C | Standard industrial motors, generators |
| F | 155°C | High-performance motors, heavy-duty industrial applications |
| H | 180°C | Extreme environments, high-temperature applications |

Two common connection configurations for three-phase electric motors: **Star (Y) and Delta (Δ).**

Star Connection (Y)

In this configuration, one end of each winding is connected to a common neutral point, forming a "Y" shape.

The other ends are connected to the three-phase supply lines **L1, L2, and L3.**

The **winding terminals U1, V1, and W1** connect to the power supply, while the other ends **U2, V2, and W2** meet at the neutral point.

The associated terminal connection diagram shows the wiring pattern when connected in Star.

Delta Connection (Δ)

In this configuration, the windings are connected in a closed loop, forming a triangle (Delta).

Each phase line (**L1, L2, and L3**) is connected at the junction of two windings.

The **winding terminals U1, V1, and W1** connect to the power supply, while the opposite ends (**U2, V2, and W2**) interconnect, forming a continuous loop.

The associated terminal connection diagram shows the necessary bridging connections for a Delta configuration.

Terminal Connectors

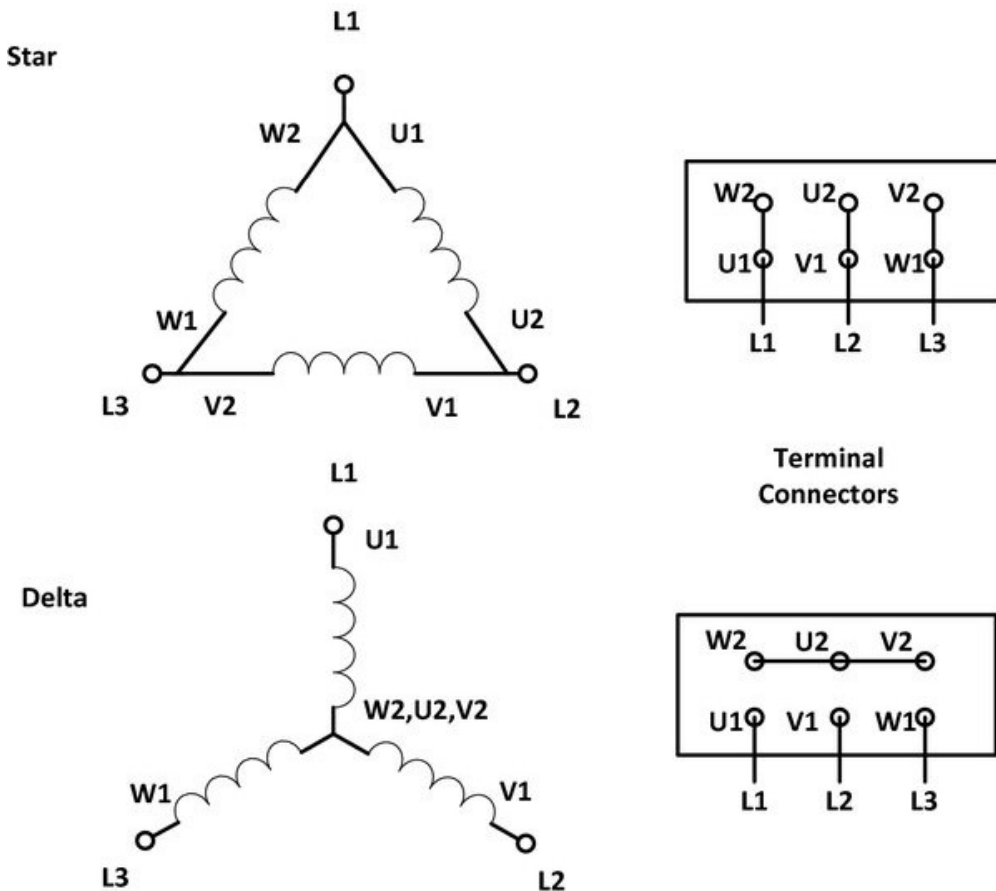
The **Star** connection diagram shows three independent terminals connected to the supply phases.

The **Delta** connection diagram includes bridging connectors that link **W2, U2, and V2** together, forming the closed-loop characteristic of the Delta connection.

These configurations affect the voltage and current distribution in the motor windings:

Star (Y): Lower phase voltage, higher phase current.

Delta (Δ): Higher phase voltage, lower phase current.



PLC (Programmable Logic Controller) is an **industrial digital computer** designed to control and automate electromechanical processes in **manufacturing plants, assembly lines, robotic systems, and other industrial applications.**

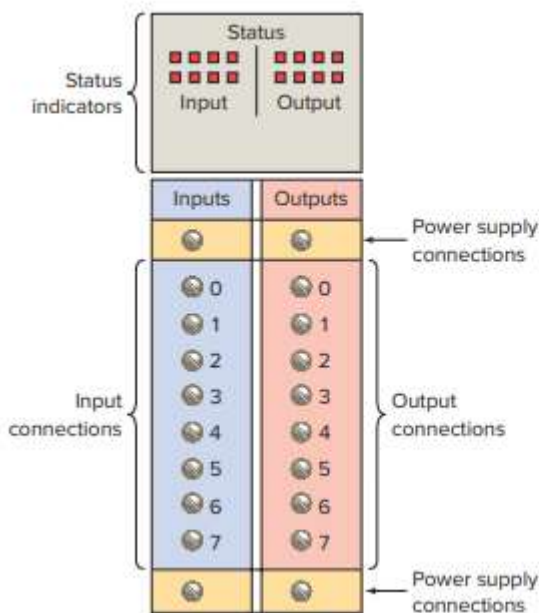
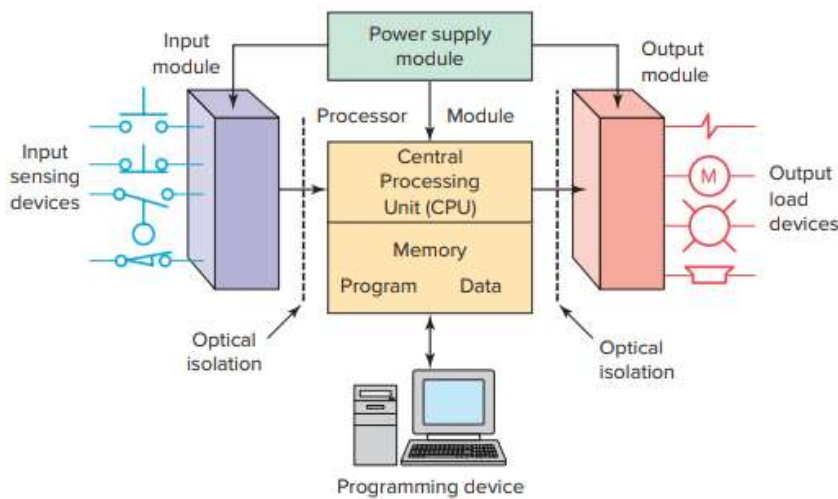
Key Features of a PLC:

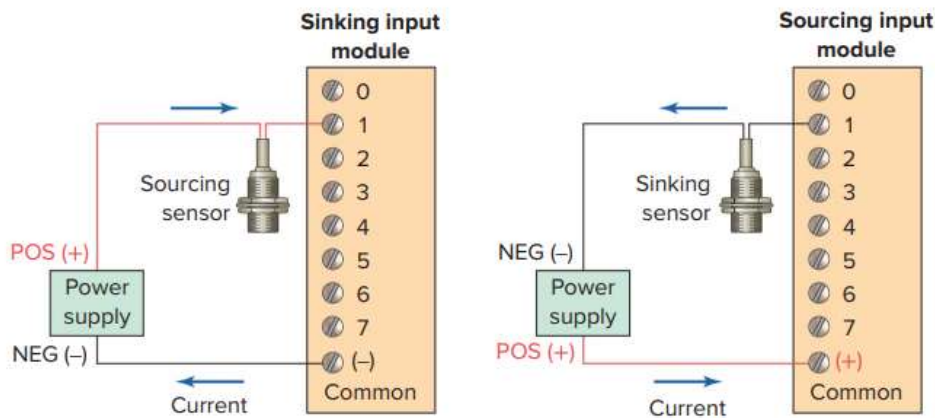
- Programmable:** Uses logic-based programming (e.g., Ladder Logic, Structured Text) to automate processes.
- Rugged & Reliable:** Built to withstand harsh industrial environments (temperature, dust, vibration).
- Real-time Processing:** Quickly processes inputs from sensors and executes outputs to control devices (motors, relays, valves, etc.).
- Modular & Scalable:** Can be expanded with additional input/output (I/O) modules for different applications.

How a PLC Works:

- 1.Inputs:** Receives signals from sensors, switches, and other devices.
- 2.Processing:** Executes the programmed logic to make decisions.
- 3.Outputs:** Sends control signals to actuators, motors, or other machines.

PLCs are widely used in **industrial automation**, replacing traditional relay-based control systems for better efficiency, flexibility, and reliability.





Left Side: Sinking Input Module

Power Supply:

The positive (+) terminal of the power supply is connected to the **sourcing sensor**.

The negative (-) terminal is connected to the **common** of the PLC input module.

Sourcing Sensor:

When the sensor is activated, it **supplies current** (sources) to the PLC input.

The current flows from the **positive supply** → through the sensor → into the **PLC input**.

Current Flow:

The PLC input "sinks" current, meaning the current enters the input module and exits through the **common (-) terminal**.

Right Side: Sourcing Input Module

Power Supply:

The negative (-) terminal of the power supply is connected to the **sinking sensor**.

The positive (+) terminal is connected to the **common** of the PLC input module.

Sinking Sensor:

When the sensor is activated, it **allows current to flow** from the **PLC input module** to ground (negative).

The current flows from the **PLC input** → through the sensor → into the **negative (-) power supply**.

Current Flow:

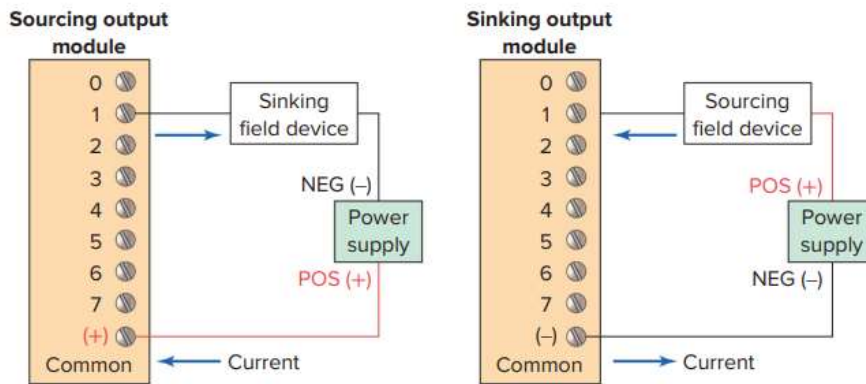
The PLC input "**sources**" current, meaning the current exits the input module and flows towards the sensor and ground.

Key Differences

Sinking input modules require **sourcing sensors** (current flows into the PLC).

Sourcing input modules require **sinking sensors** (current flows out of the PLC).

This concept is crucial in PLC wiring to ensure compatibility between sensors and input modules.



Left Side: Sourcing Output Module

Power Supply:

The **positive (+) terminal** of the power supply is connected to the **common** of the PLC output module. The **negative (-) terminal** is connected to the **sinking field device**.

Sinking Field Device:

The device is connected between the **output terminal of the PLC** and the **negative (-) of the power supply**.

When the PLC output turns **ON**, it provides a **positive voltage** to the field device.

Current Flow:

The current flows from the **positive supply** → through the PLC output module → through the field device → into the **negative (-) of the power supply**. The PLC **"sources"** current to the field device.

Right Side: Sinking Output Module

Power Supply:

The **negative (-) terminal** of the power supply is connected to the **common** of the PLC output module. The **positive (+) terminal** is connected to the **sourcing field device**.

Sourcing Field Device:

The device is connected between the **positive (+) of the power supply** and the **output terminal of the PLC**.

When the PLC output turns **ON**, it allows current to flow to the field device, completing the circuit.

Current Flow:

The current flows from the **positive supply** → through the field device → into the **PLC output module** → into the **negative (-) of the power supply**. The PLC **"sinks"** current from the field device.

How This Work Order Functions

This work order is used to document and track the troubleshooting and repair process of a malfunctioning system. Here's how it works:

Technician Information & Location

The document includes the **technician's name** and the **location** of the issue.

This helps identify who is responsible for the repair and where the problem is occurring.

Operator's Trouble Report

This section describes the issue reported by the operator.

In this case, nothing works—neither light turns on, and the "On" and "Off" buttons have no effect.

This gives the technician a starting point for troubleshooting.

Repair Status Section

The technician will **check one of the boxes** depending on the outcome:

Repairs Completed - The issue has been fixed.

Parts Ordered - The technician needs replacement parts.

Repairs Incomplete - Work has started but is not finished.

Unable to Determine Problem - The issue could not be identified.

Technician's Repair Report

This is a blank field where the technician writes details about the troubleshooting process and any repairs performed.

If parts were ordered or further steps are needed, that information should be recorded here.

Final Actions

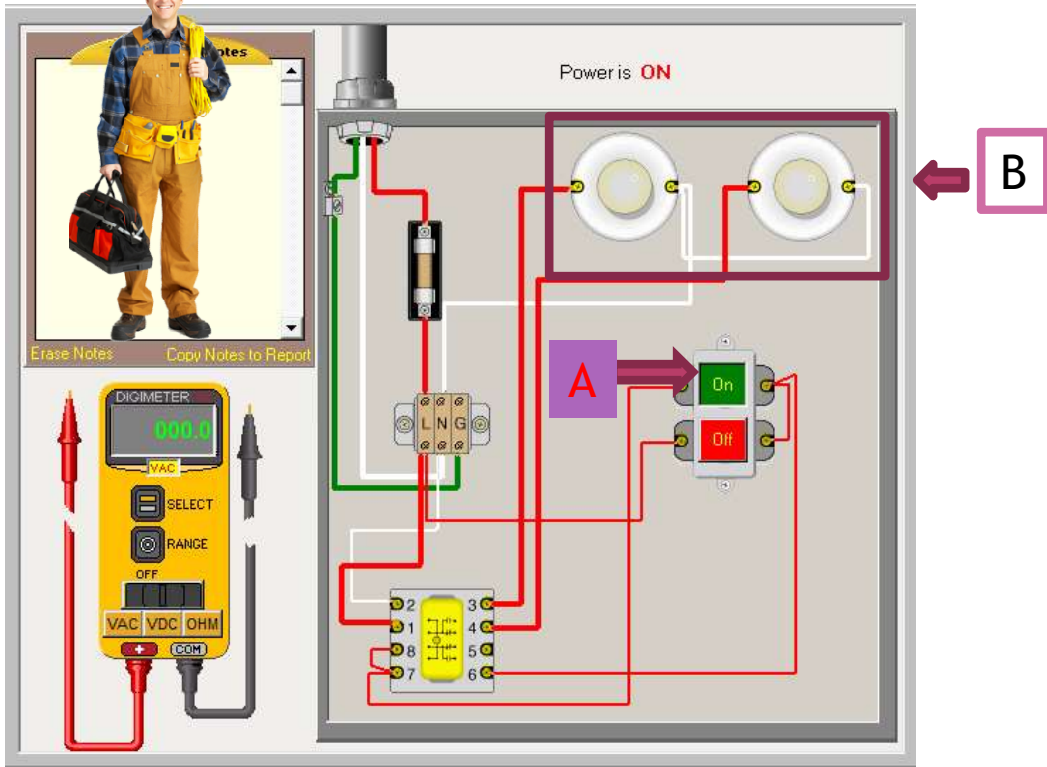
The technician can **print** the work order if needed.

Once everything is completed, they can **close the work order** to mark it as resolved.

Purpose

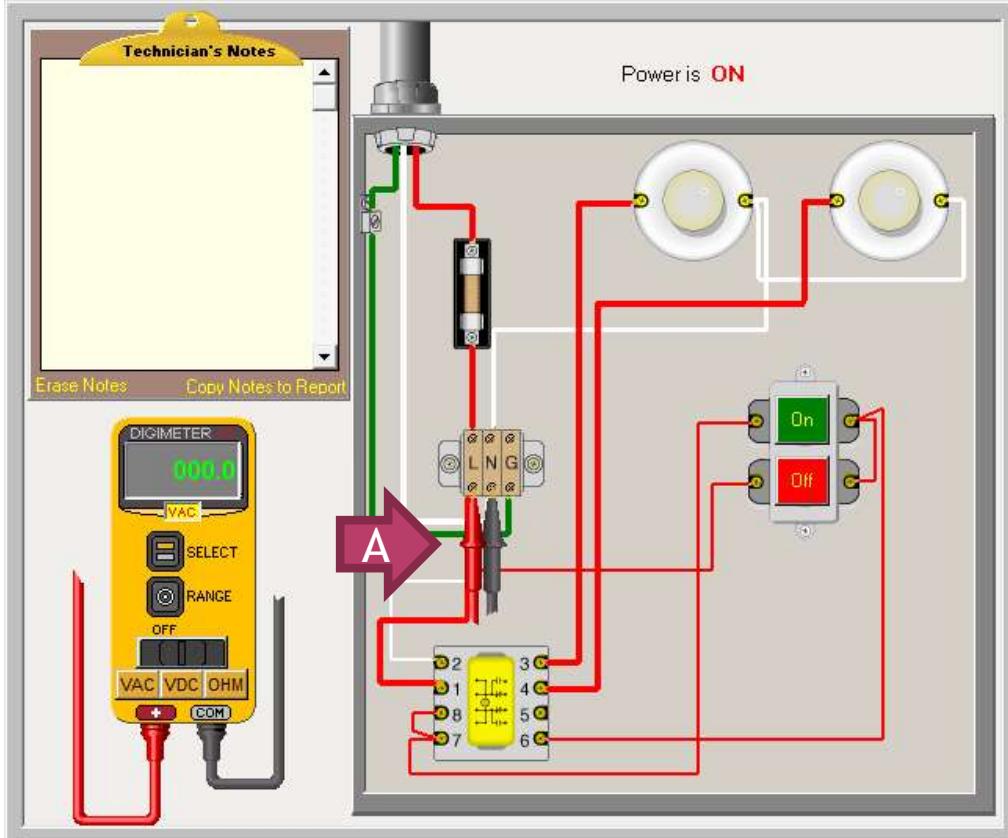
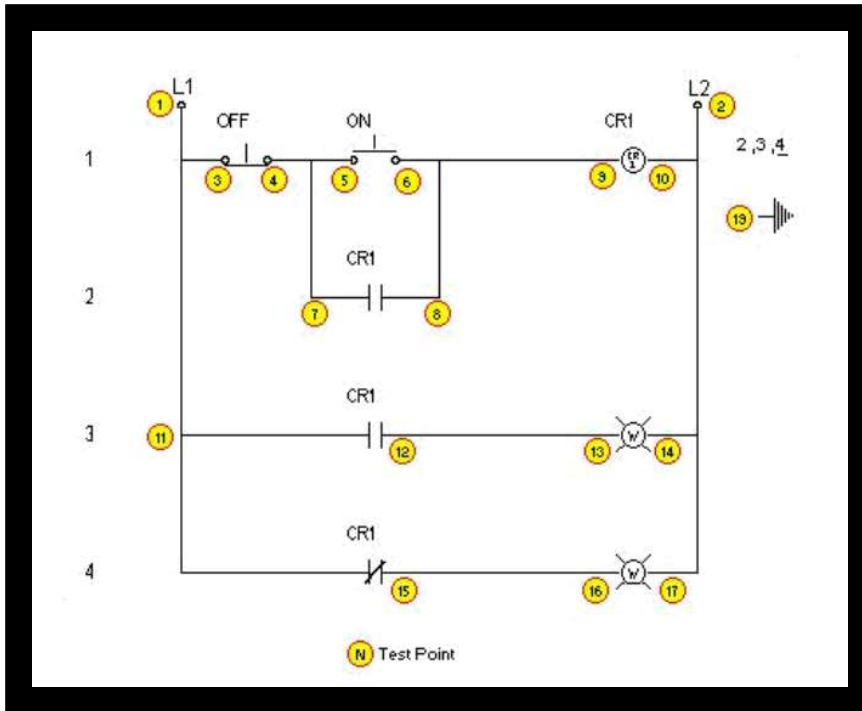
This work order ensures proper documentation, allowing for organized repairs, accountability, and a clear record of what actions were taken to resolve the problem. 🚀

The screenshot shows a web-based work order form. At the top right, there is a 'Print Work Order' button with a printer icon. Below this, the form contains several sections: 'Date: 03 16 2025', 'Time: 11:16:07 AM', and 'Technician Name:' followed by a redacted name. The 'Location:' is 'Loading Dock'. The 'Operator's Trouble Report:' section contains the text: 'Nothing works. Neither light will operate. Pushing the "On" or "Off" button has no effect.' To the right of these fields is a 'Repair Status' section with four checkboxes, all of which are currently unchecked: 'Repairs Completed - See Repair Report', 'Parts Ordered - See Repair Report', 'Repairs Incomplete - See Repair Report', and 'Unable to Determine Problem - See Repair Report'. Below the trouble report is the 'Technician's Repair Report:' section, which is a large empty text area. At the bottom right, there is a 'Close Work Order' button.



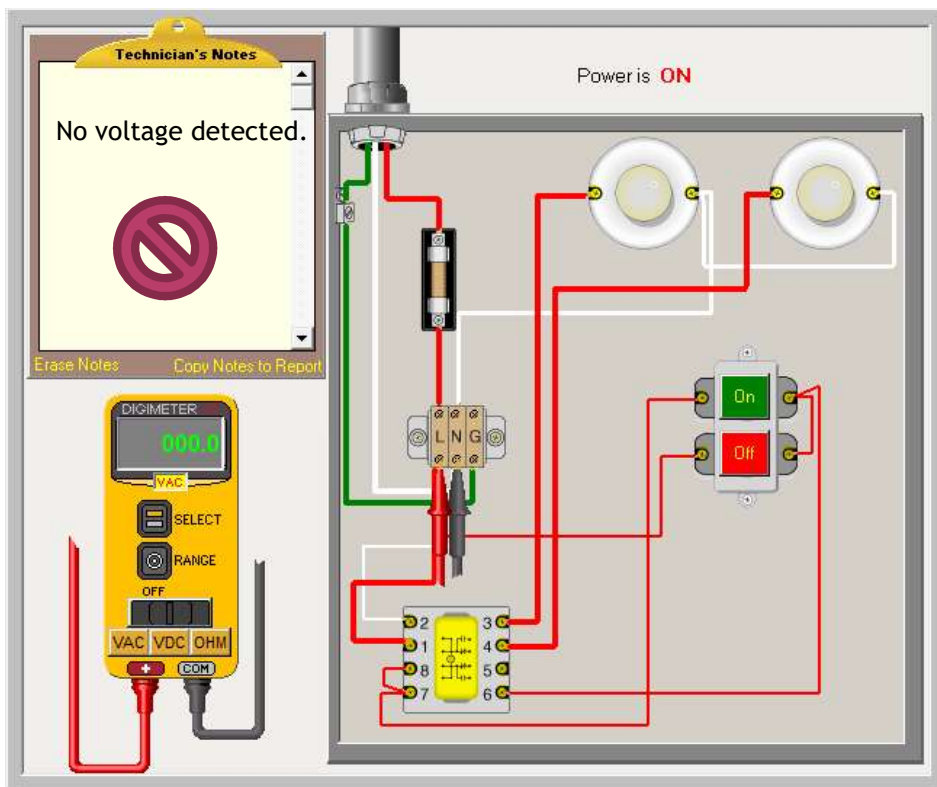
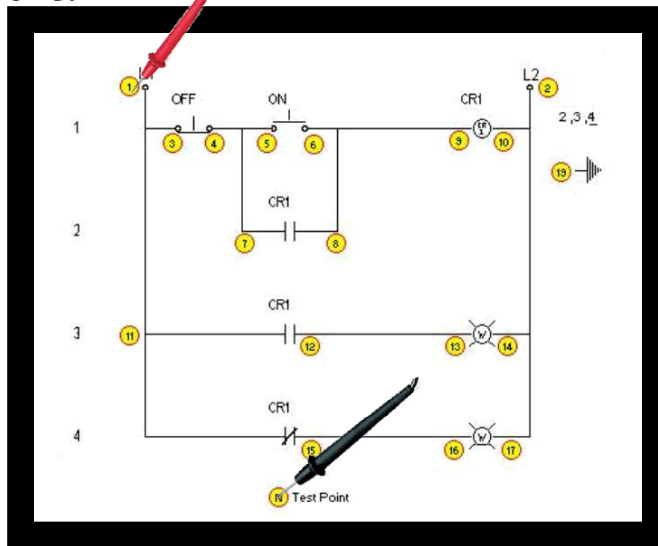
When you press 'Start' located in area (A), one light bulb should turn on while another one in area (B) should turn off

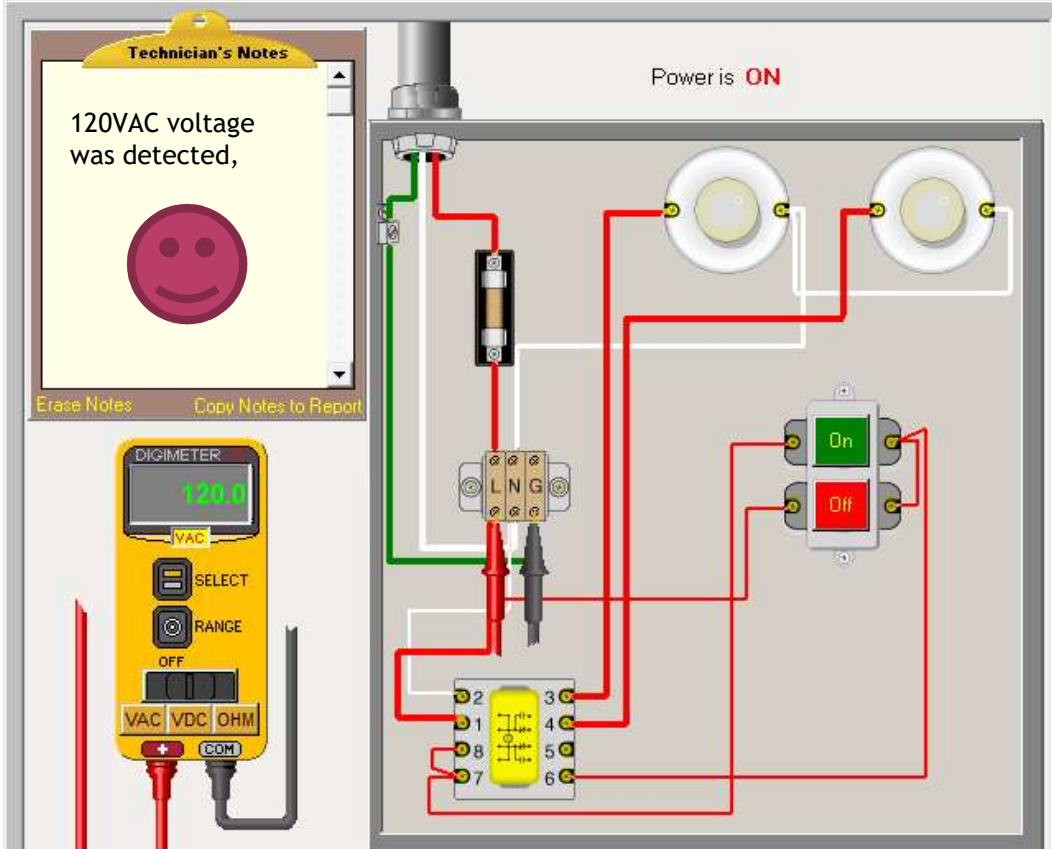
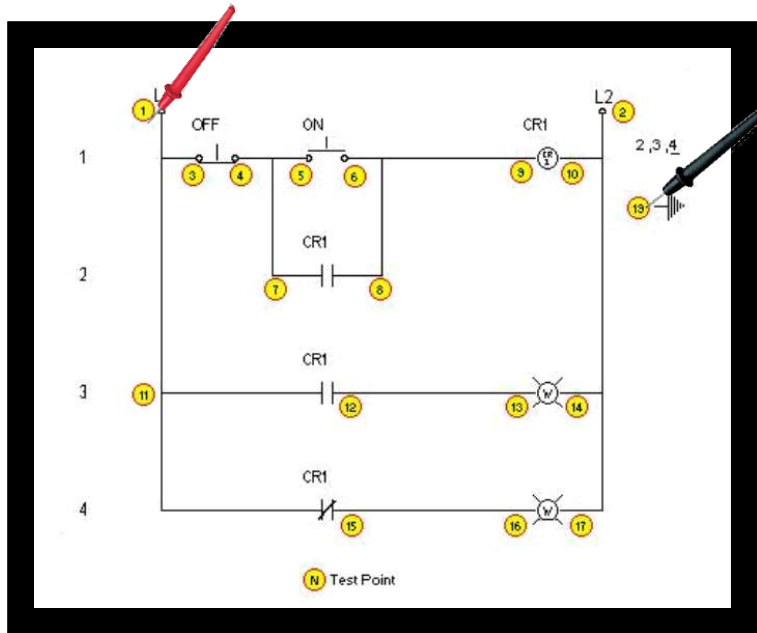
120 VAC circuit

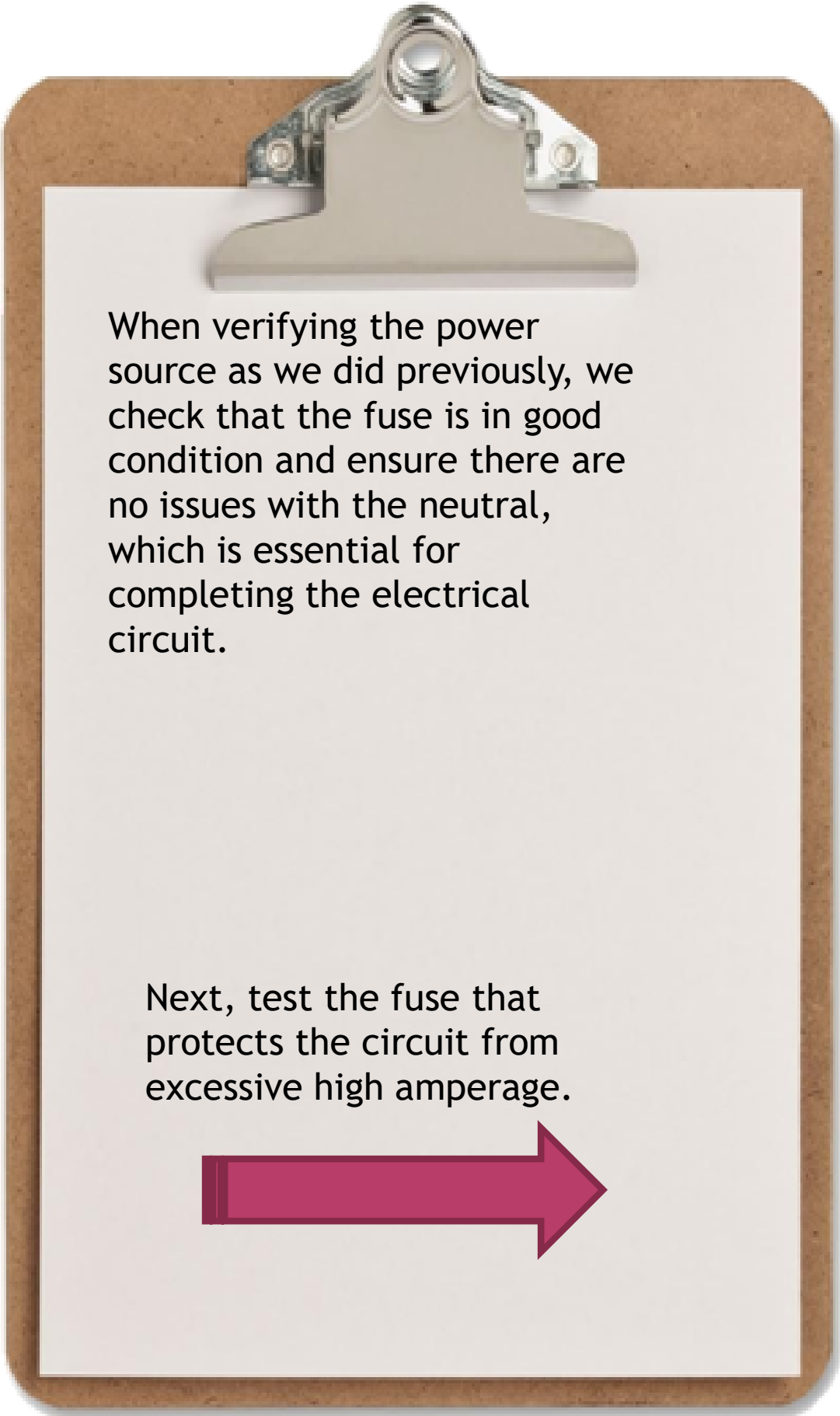




Place the red electrode on the line and the black electrode on neutral. Test these terminals, as they supply voltage to the circuit.







When verifying the power source as we did previously, we check that the fuse is in good condition and ensure there are no issues with the neutral, which is essential for completing the electrical circuit.

Next, test the fuse that protects the circuit from excessive high amperage.



What is a Continuity Test with a Multimeter?

A continuity test checks if electricity can flow through a circuit or component. It helps find broken connections or faulty parts.

Example with a Fuse:

Good Fuse:

Set the multimeter to continuity mode (look for the soundwave or diode symbol).

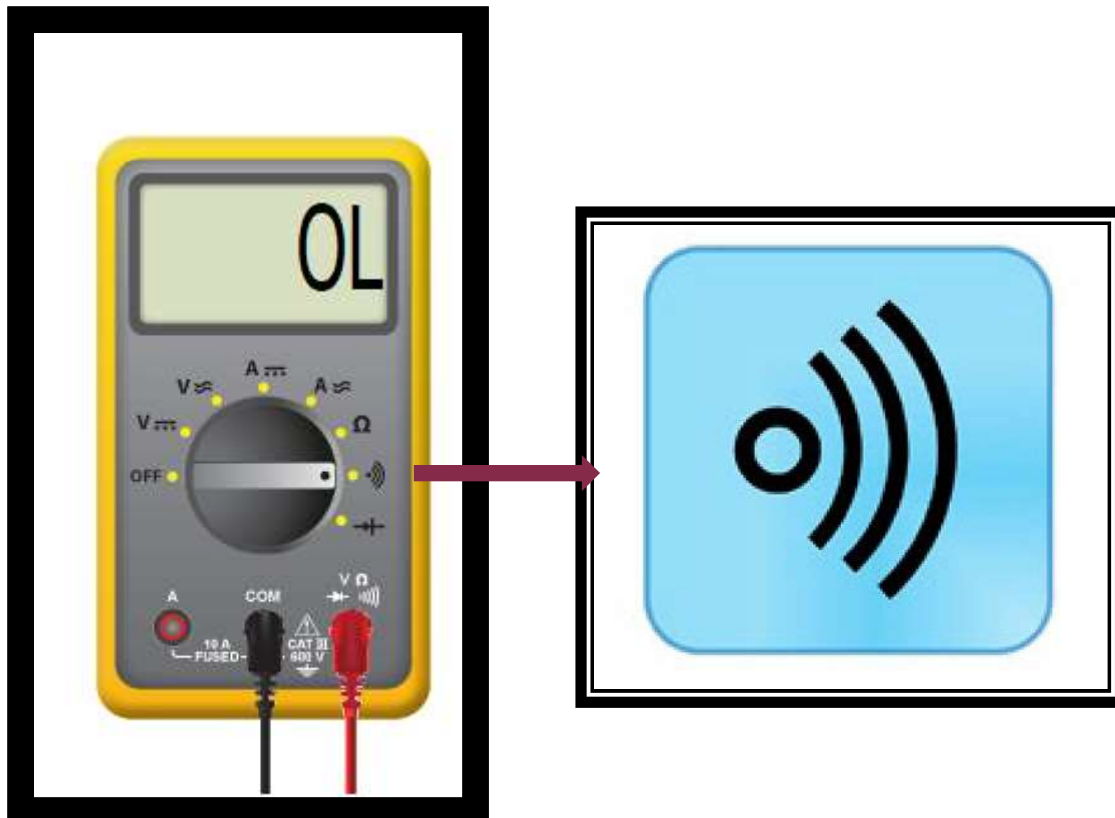
Touch both multimeter probes to the fuse terminals.

If the multimeter **beeps** or shows a low resistance (close to zero), the fuse is good.

Bad Fuse:

If there is **no beep** or the screen shows "OL" (open loop), the fuse is blown and must be replaced.

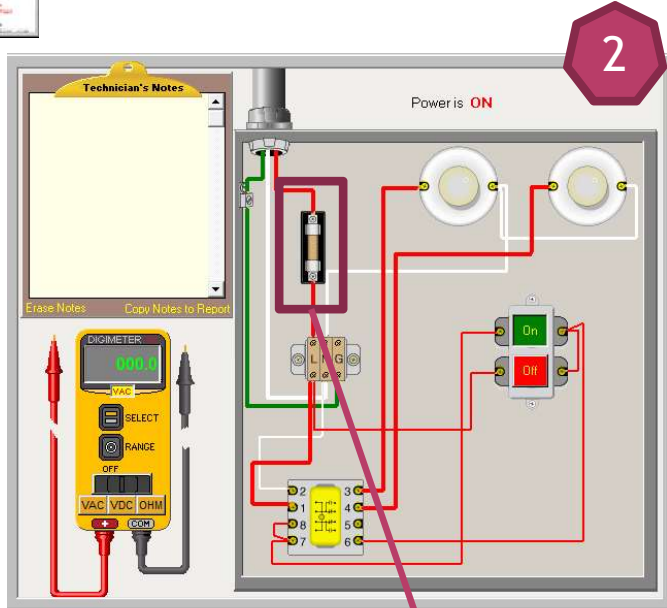
This test is useful for checking fuses, wires, and switches in electrical circuits.





1

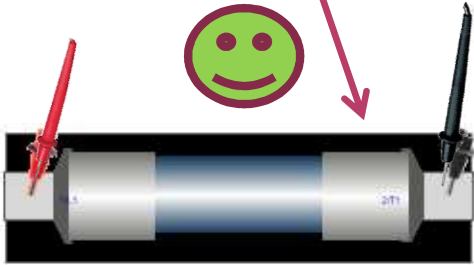
the main disconnecter is turned off.



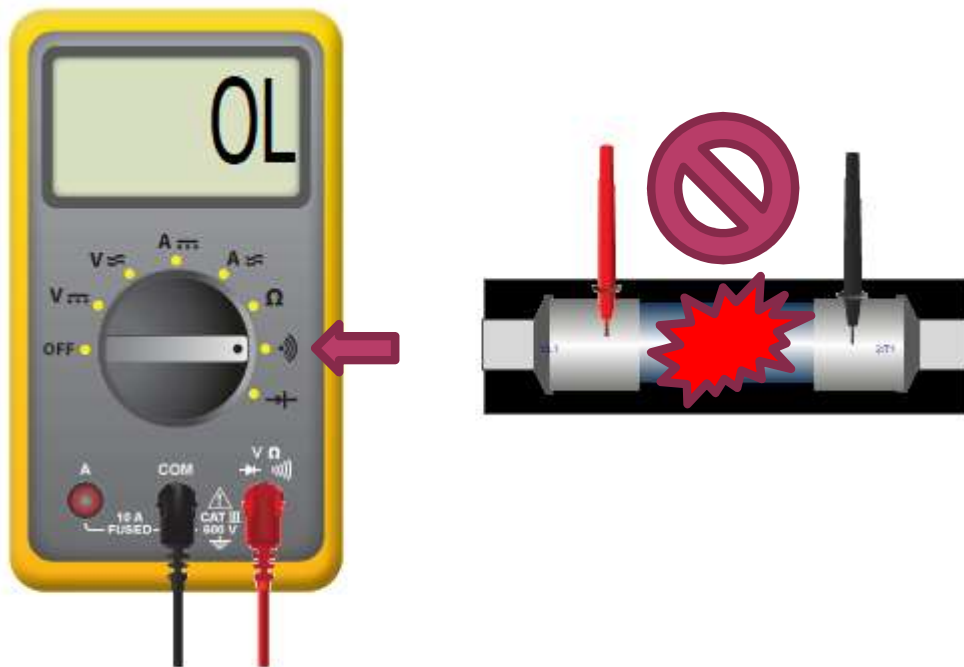
2

3

If the continuity test detects resistance, the fuse is still functioning but is beginning to degrade.



The fuse is removed and a continuity test is performed as shown in the photo.



If you see this reading during the continuity test, it means the fuse is damaged and needs to be replaced.

Date: 03 16 2025

Time: 1:50:18 PM

Technician Name:
zzz

Location:
Loading Dock

Operator's Trouble Report:

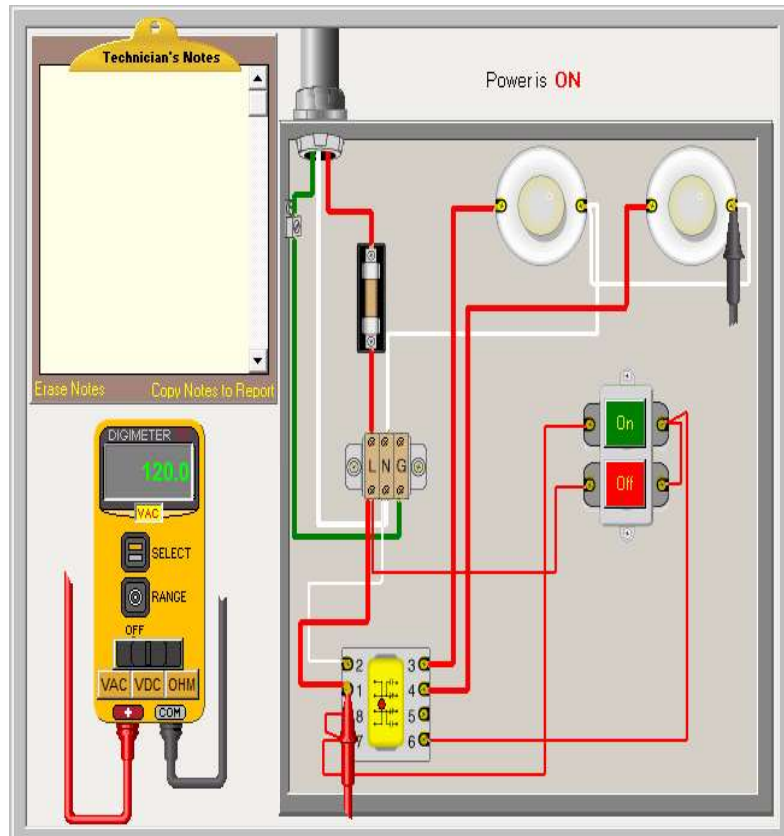
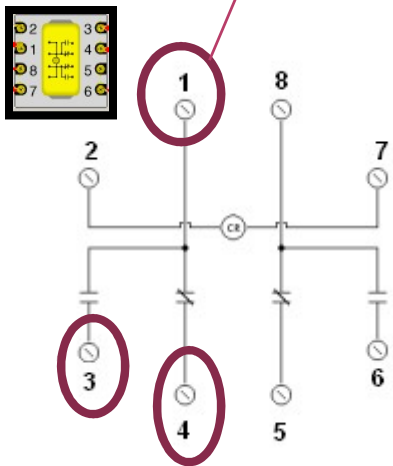
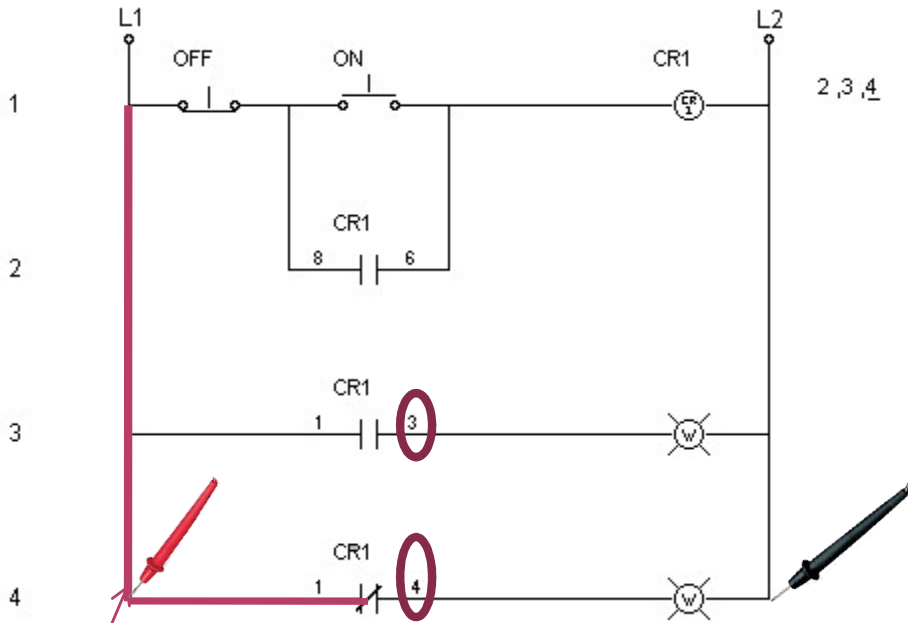
The light on the left side does not operate at all. The other light works properly.
May be a bad bulb.

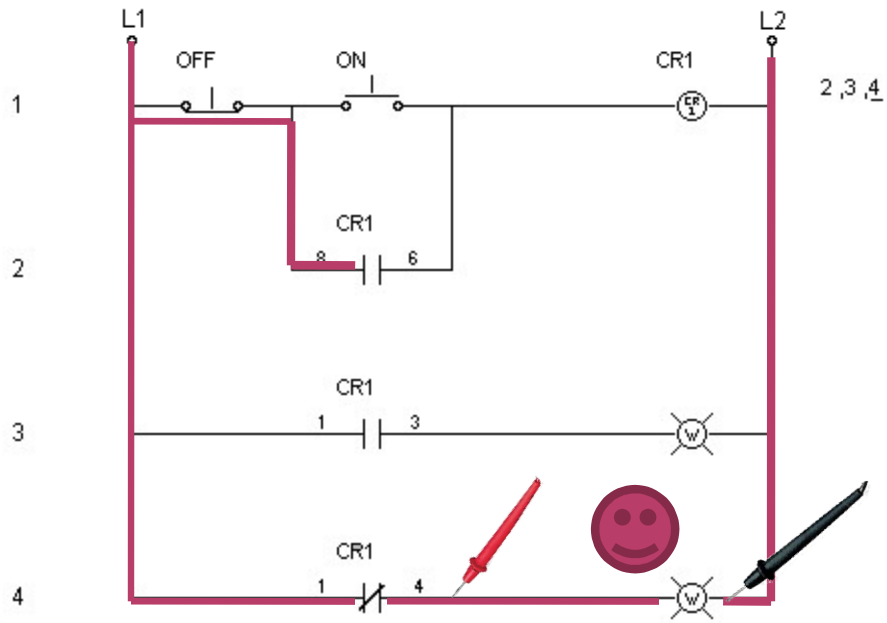
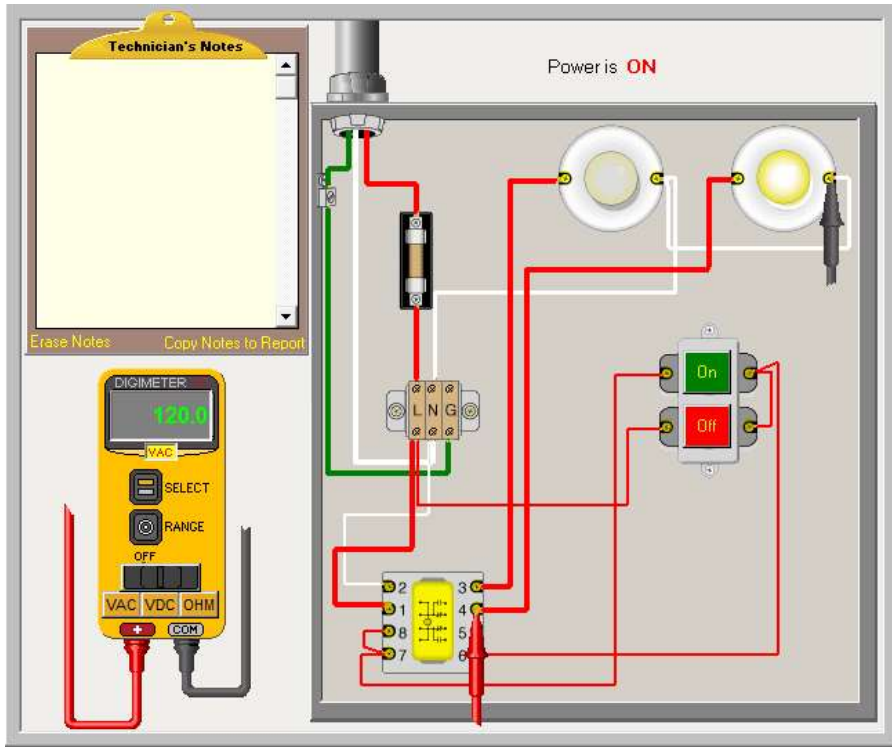
| Repair Status |
|--|
| <input type="checkbox"/> Repairs Completed - See Repair Report |
| <input type="checkbox"/> Parts Ordered - See Repair Report |
| <input type="checkbox"/> Repairs Incomplete - See Repair Report |
| <input type="checkbox"/> Unable to Determine Problem - See Repair Report |

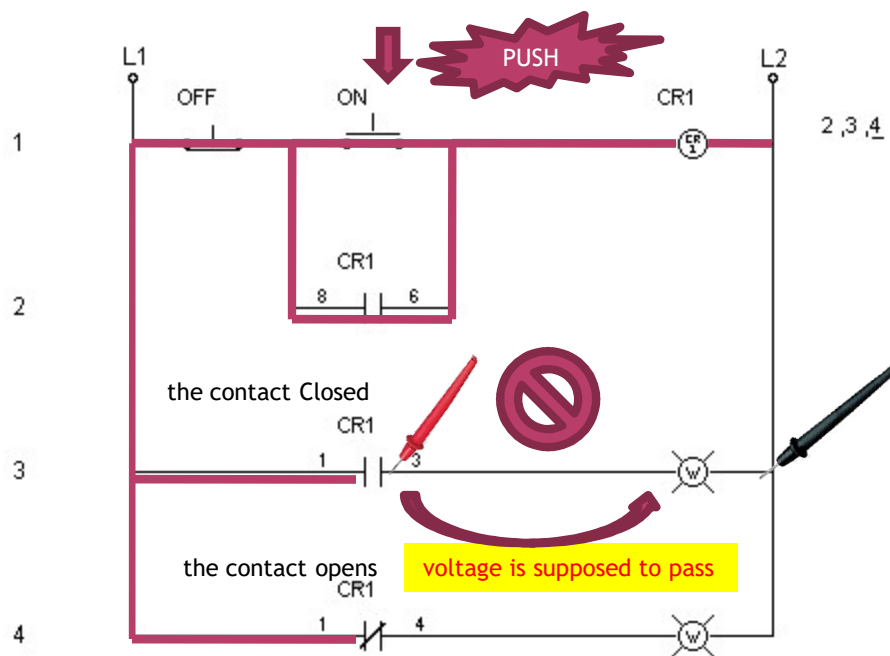
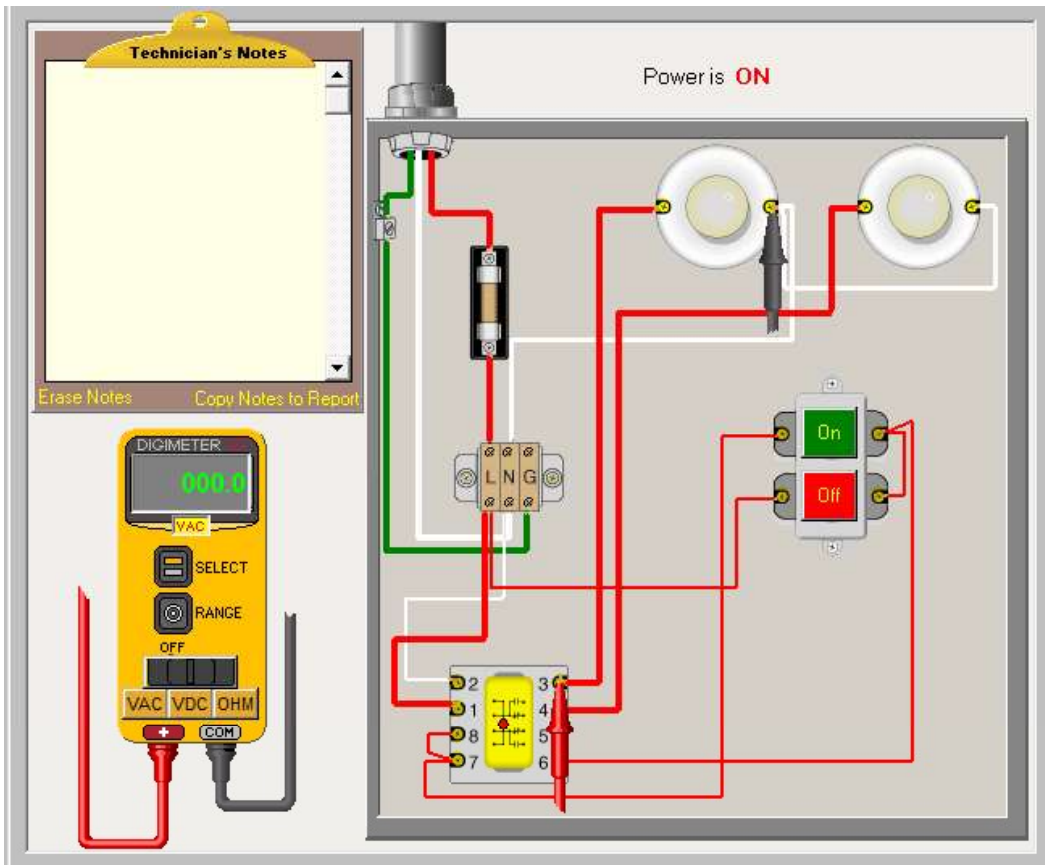
Technician's Repair Report:

Close Work Order

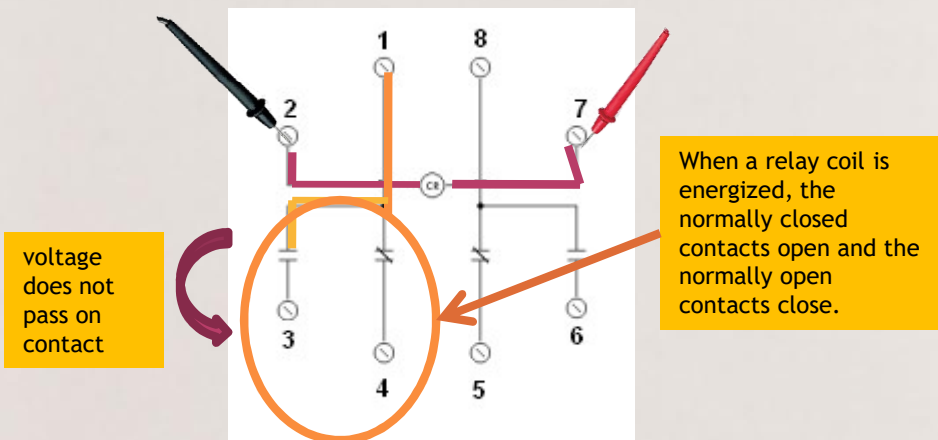
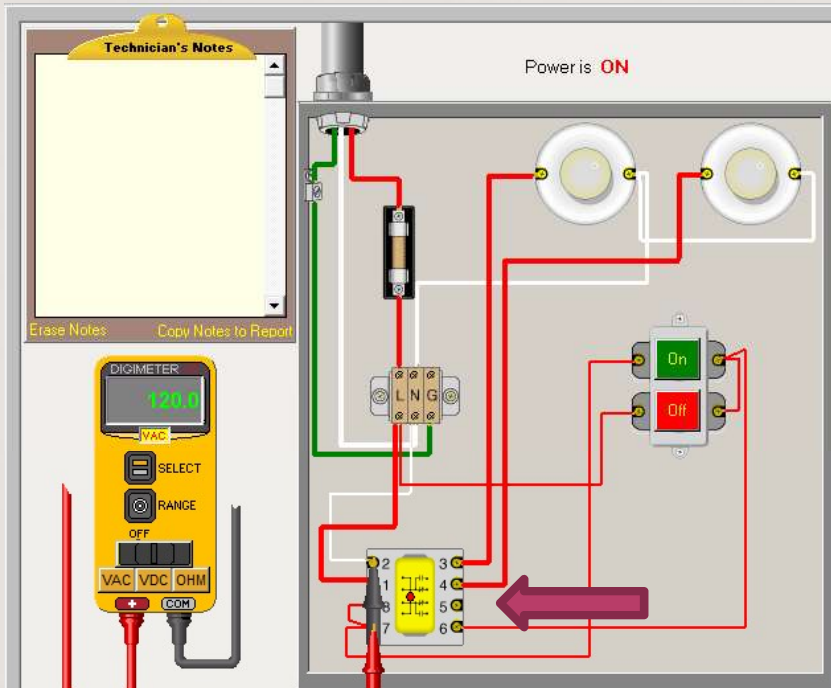
In this issue, the power supply is working correctly because part of the circuit is functioning. We need to find where the voltage is interrupted

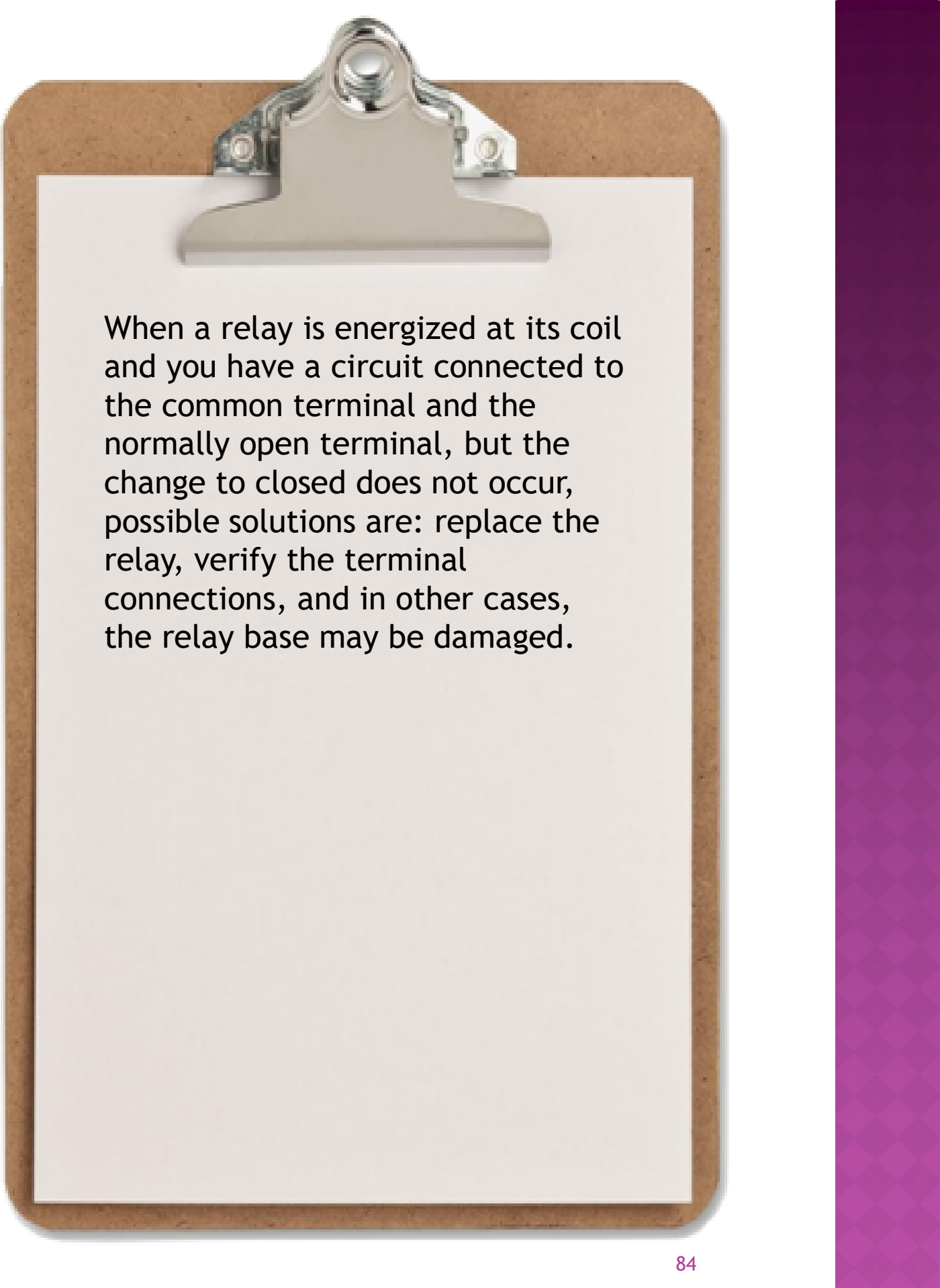






When the start button is pressed, it is observed that the





When a relay is energized at its coil and you have a circuit connected to the common terminal and the normally open terminal, but the change to closed does not occur, possible solutions are: replace the relay, verify the terminal connections, and in other cases, the relay base may be damaged.

Date: 03 16 2025

Time: 5:57:18 PM

Technician Name:
ZZZ

Location:
Index Table

Operator's Trouble Report:

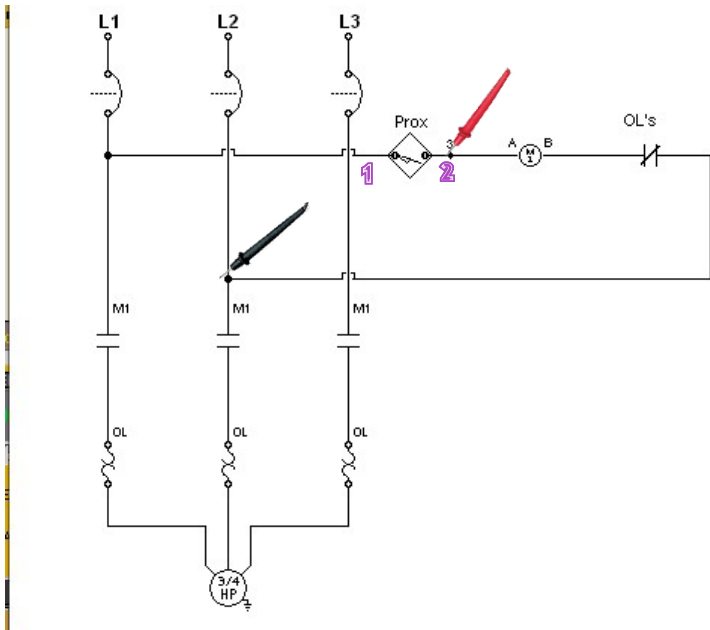
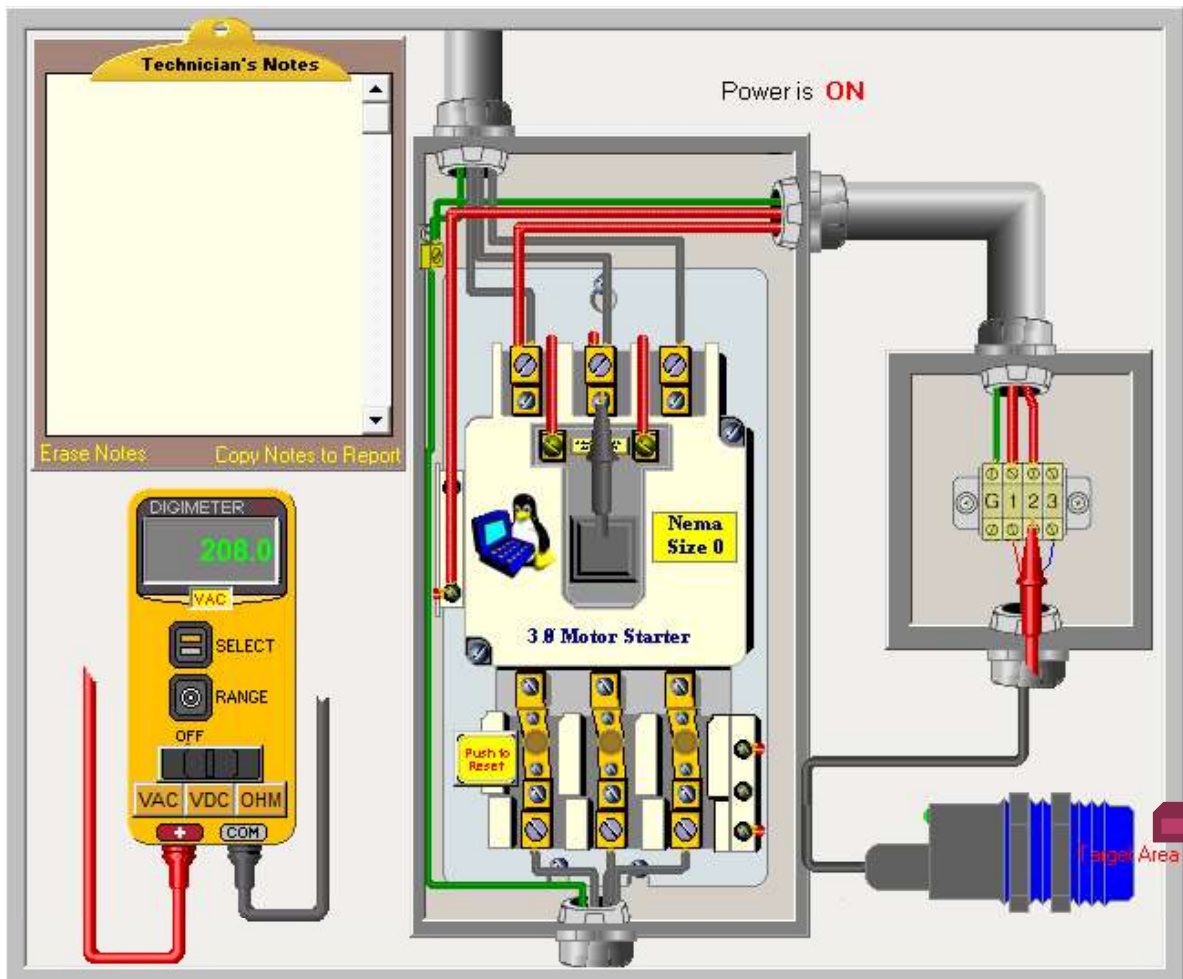
When a part is detected, the motor does not start.

Repair Status

- Repairs Completed - See Repair Report
- Parts Ordered - See Repair Report
- Repairs Incomplete - See Repair Report
- Unable to Determine Problem - See Repair Report

Technician's Repair Report:

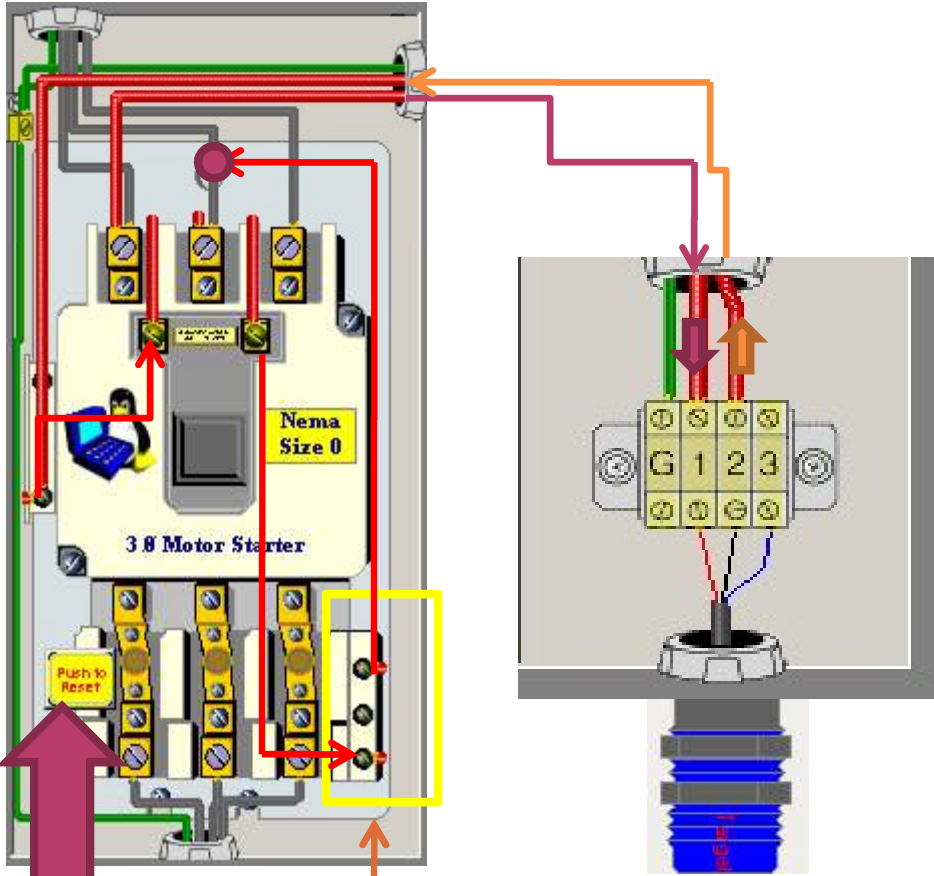
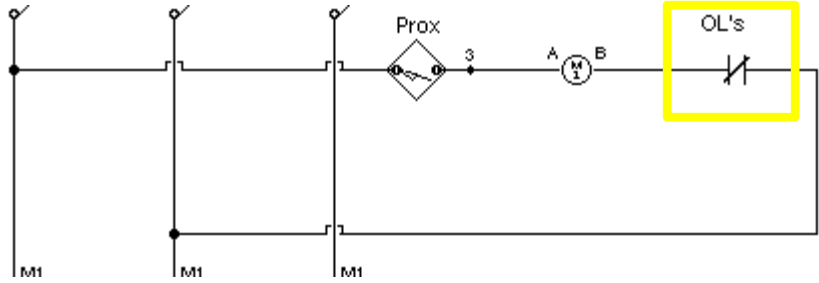
Close Work Order



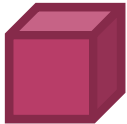
the sensor is passing voltage when it detects a box.

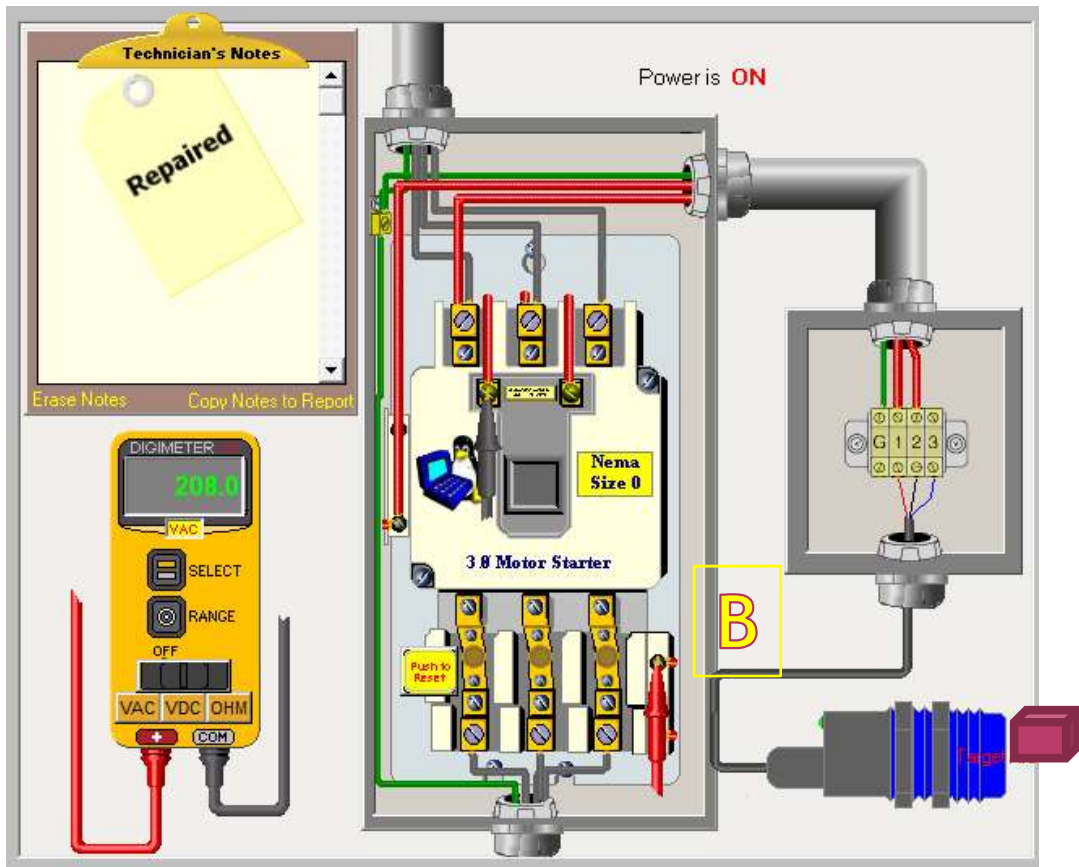
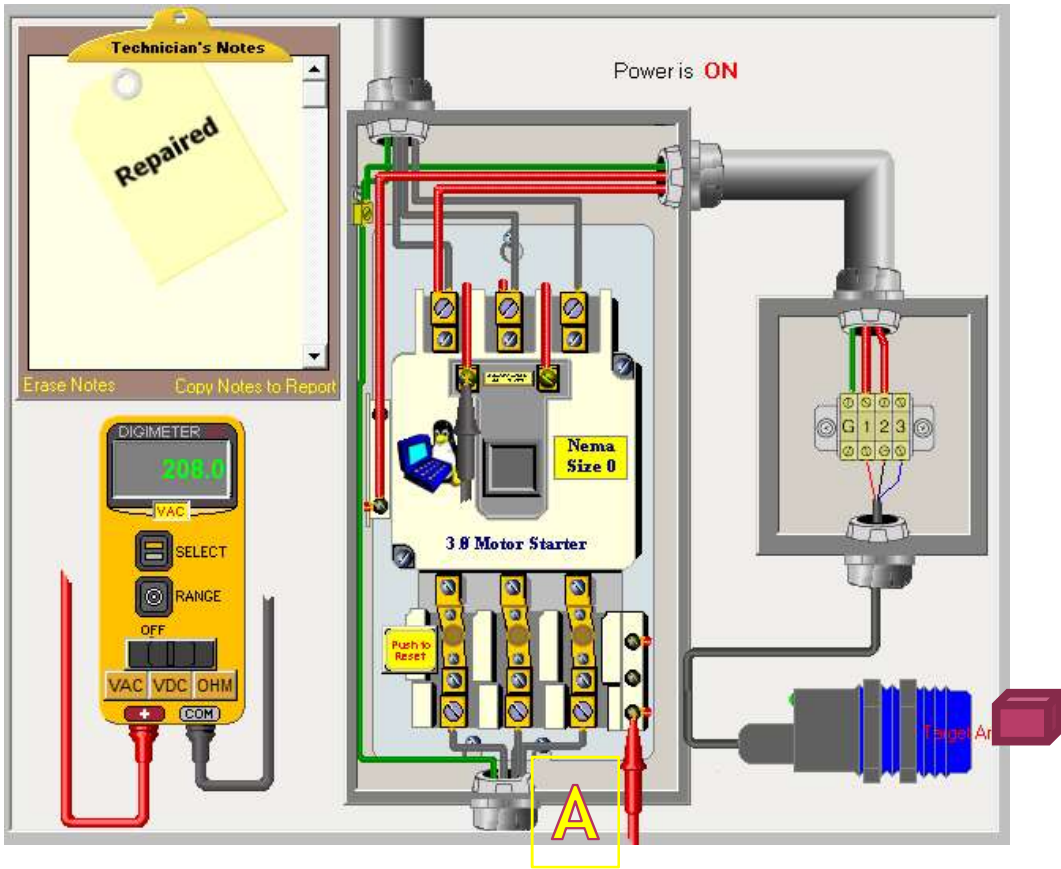


voltage flow in control circuit.



The thermal protector is open and does not allow the coil that activates the motor connection mechanism to be activated.





Improved Reasons for Evaluating Overload Protection in a Three-Phase Motor:

When an overload relay trips in a three-phase motor, it indicates that the motor has been drawing more current than it is designed to handle. It is crucial to evaluate the reasons behind this trip to prevent motor damage and ensure system safety. Here are some improved reasons to evaluate:

Mechanical Overload:

This occurs when the load connected to the motor requires more torque than the motor can provide. This can be due to a sudden increase in load, a mechanical blockage, or a problem with the driven machinery.

It is important to check for blockages, misalignments, or any other mechanical issues causing the overload.

Electrical Problems:

Voltage Imbalance: An imbalance in phase voltage can cause the motor to draw more current to compensate, leading to an overload.

Low Voltage: If the voltage supplied to the motor is too low, it will draw more current to maintain the same power.

Insulation Faults: Deterioration of the motor's insulation can cause current leakage and overheating, triggering the overload relay.

Starting Problems:

Excessive start-up time or frequent starts can overload the motor, especially if the load inertia is high. The starting equipment should be checked to verify that it is functioning correctly.

Environmental Problems:

High ambient temperatures or inadequate ventilation can hinder the motor's heat dissipation, increasing the risk of overheating and overload.

The space where the motor is located should be checked to verify that the ventilation is correct.

Incorrect Overload Relay Setting:

If the overload relay is not configured correctly, it may trip even when the motor is operating within its normal limits.

The relay settings should be checked to ensure they are correct, to avoid unnecessary trips.

Inadequate Maintenance:

Lack of lubrication, dirt accumulation, and component wear can increase friction and load on the motor, leading to an overload.

Importance of Evaluation:

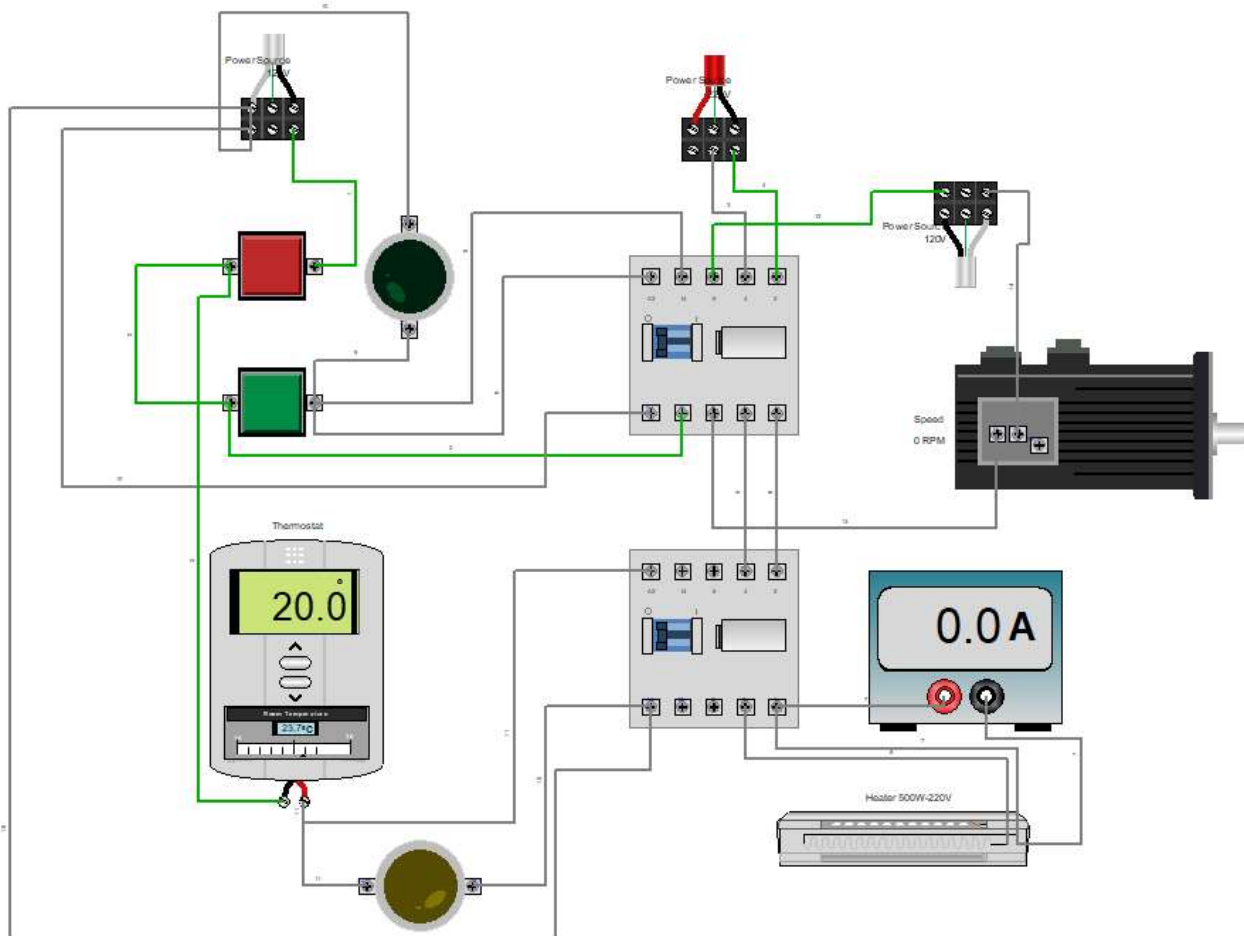
Motor Protection: Evaluation helps identify and correct the causes of overload, prolonging motor life.

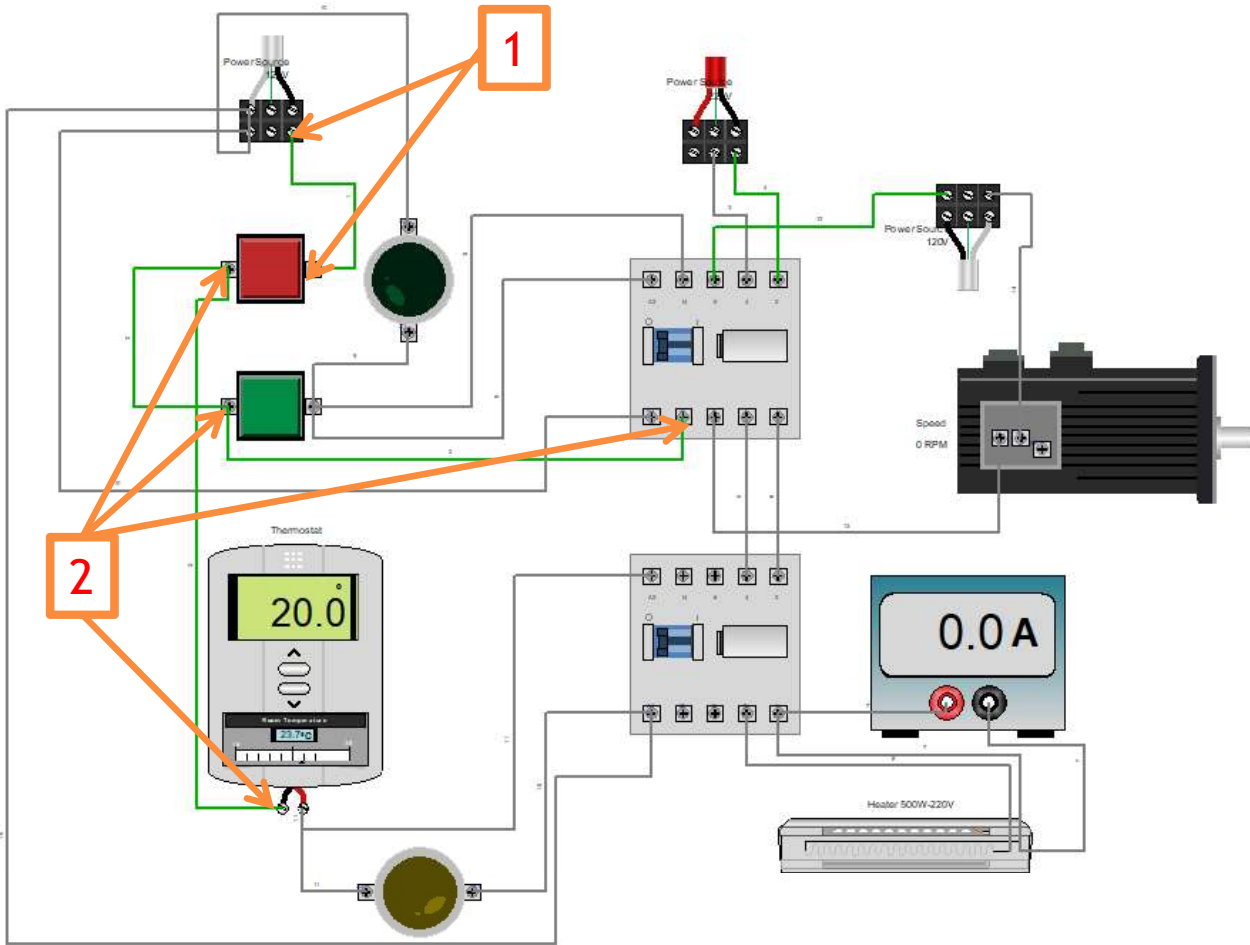
Safety: Prevents fire hazards and other dangers associated with motor overheating.

Efficiency: Ensures the motor operates efficiently and reliably.

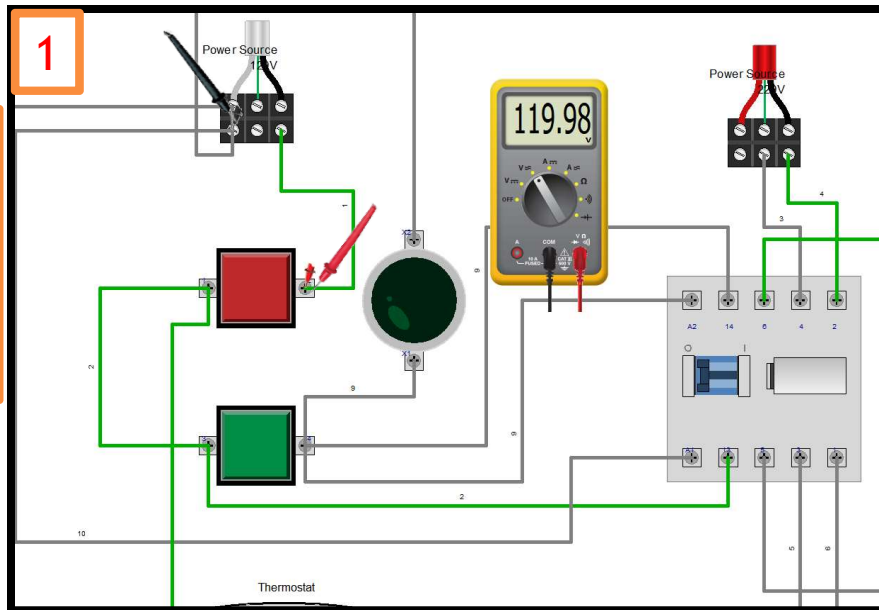
Reduced Downtime: Addressing the causes of overload minimizes downtime and improves productivity. By conducting a thorough evaluation, the root cause of the overload can be determined and necessary measures taken to prevent recurrence.

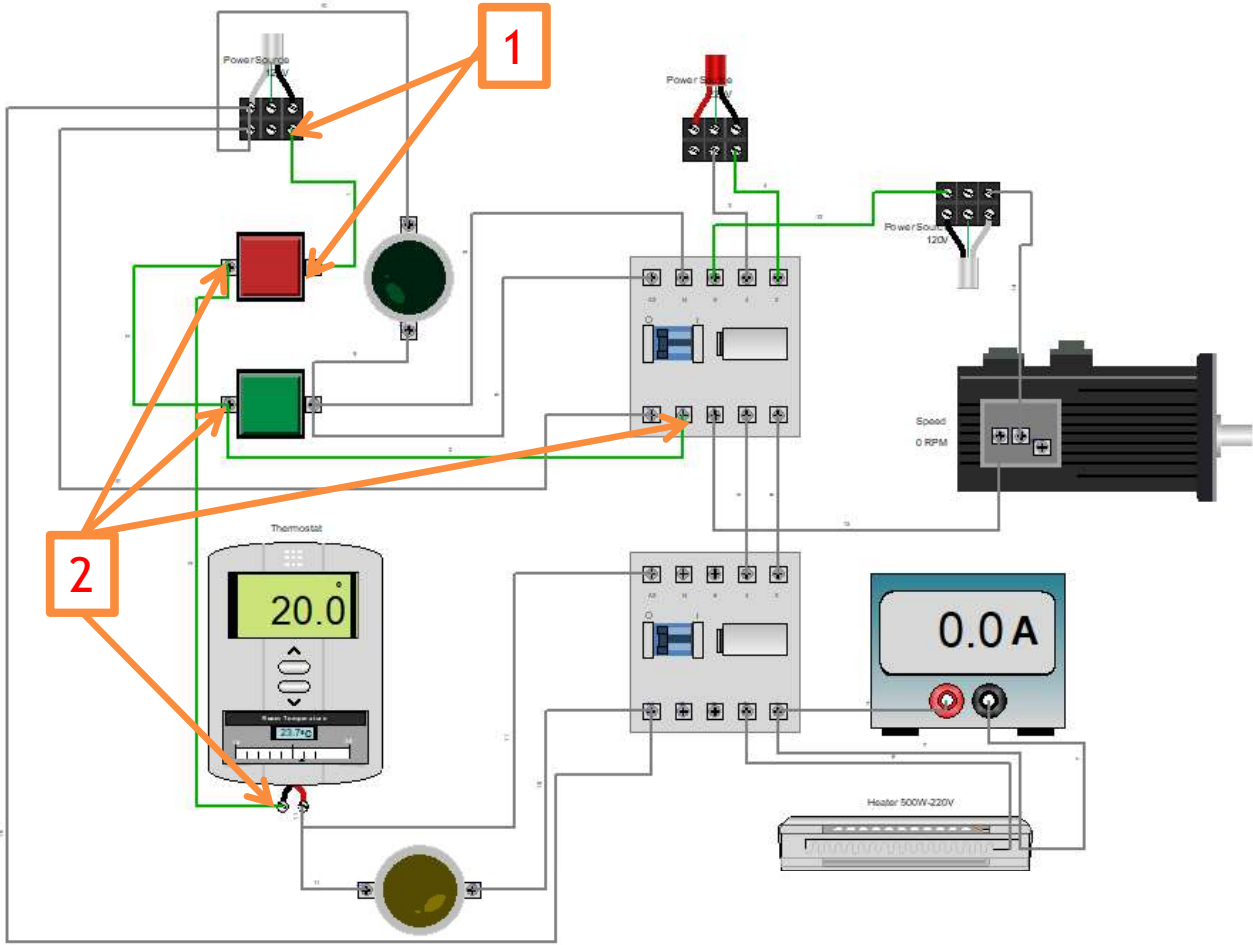
Let's take a look at the circuit of a water heater that's controlled by a recirculating water pump.





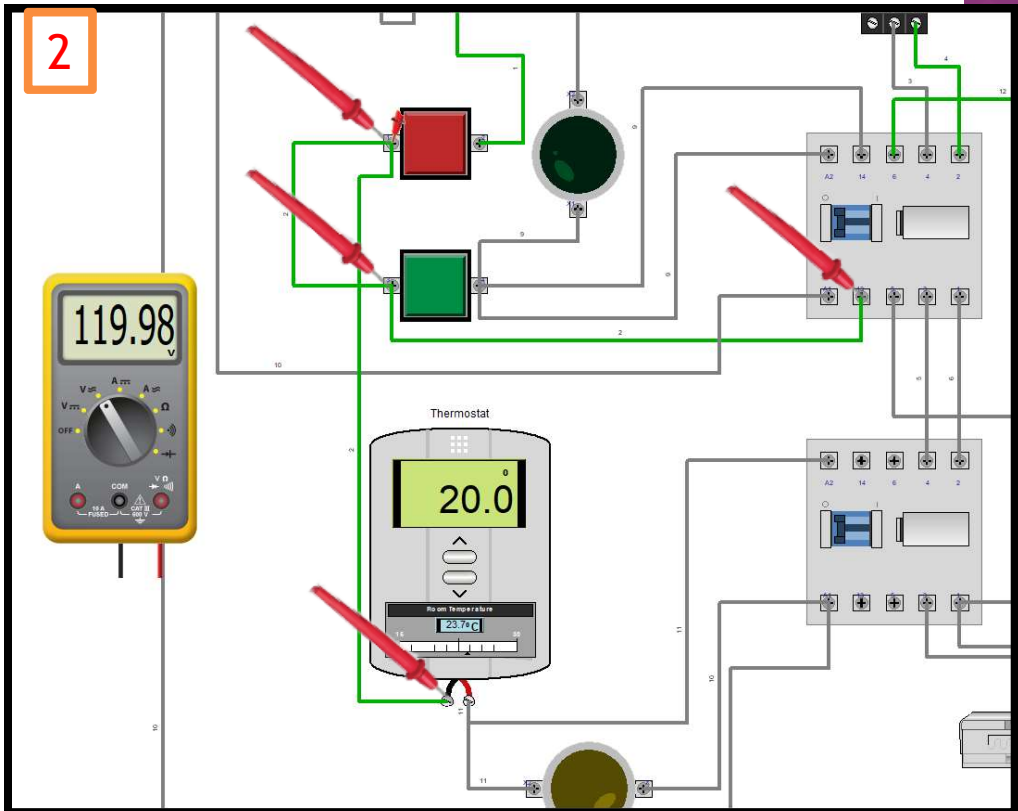
This test is to determine if the circuit upstream of the stop switch is energized, as it supplies power to the control circuit.





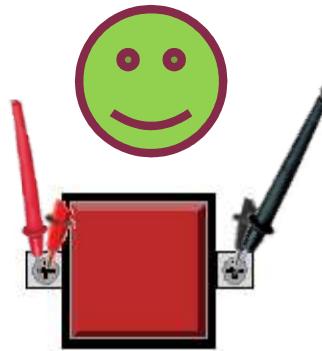
2

1

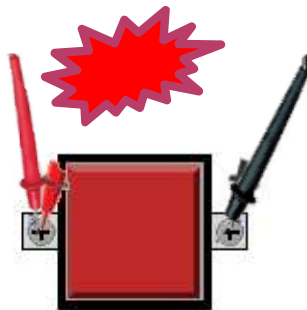



2





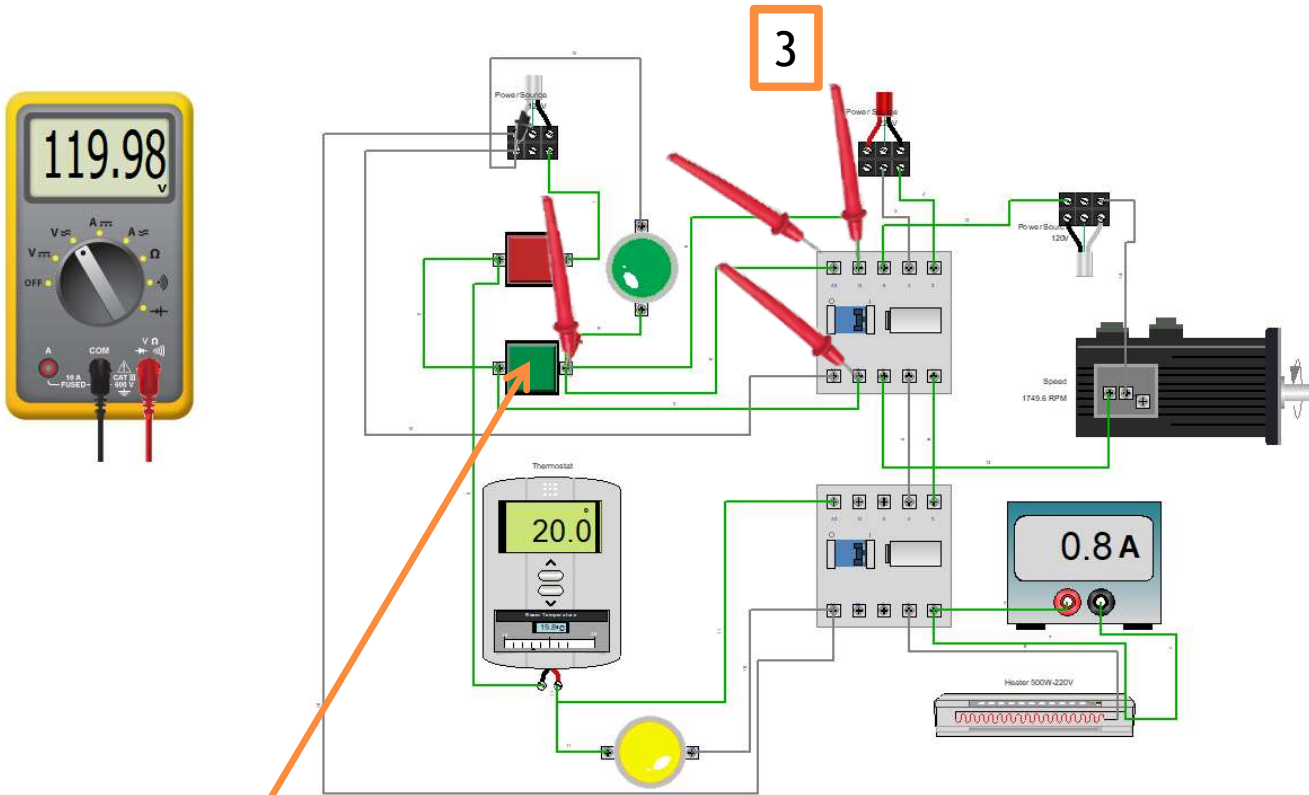
When it exhibits high conductivity, it can suppress the voltage.




To perform continuity tests, the electrical circuit must be de-energized and secured with a lockout/tagout (LOTO) for safety.

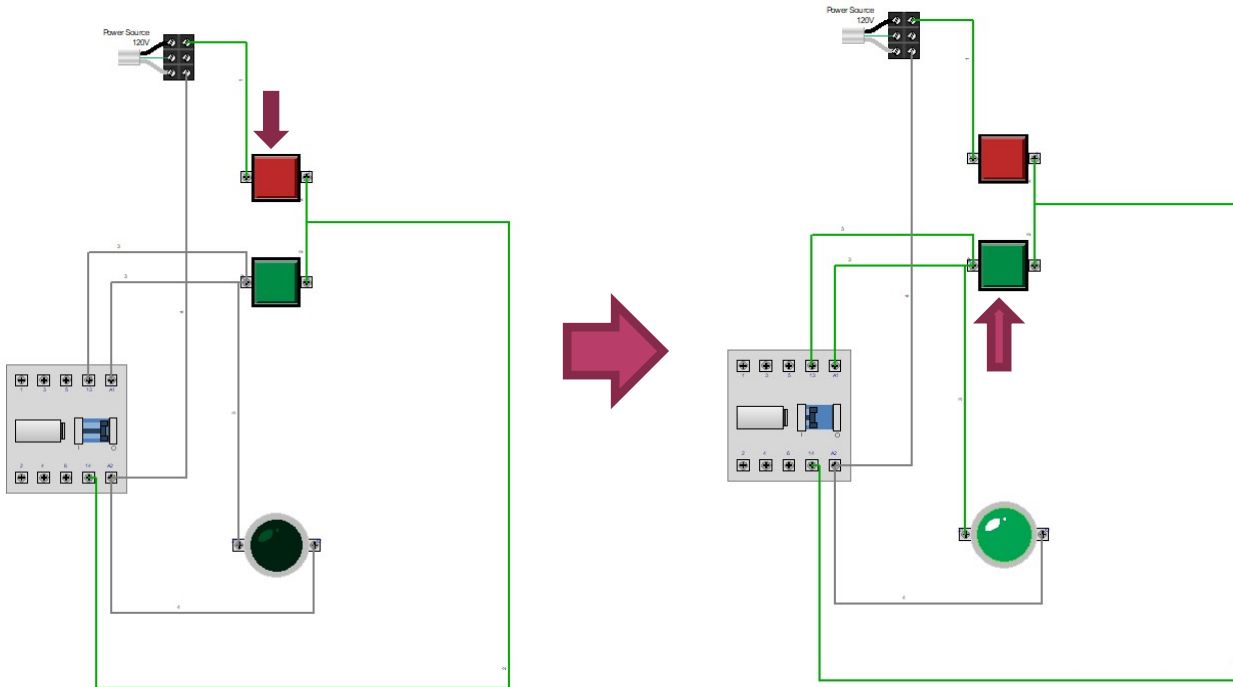
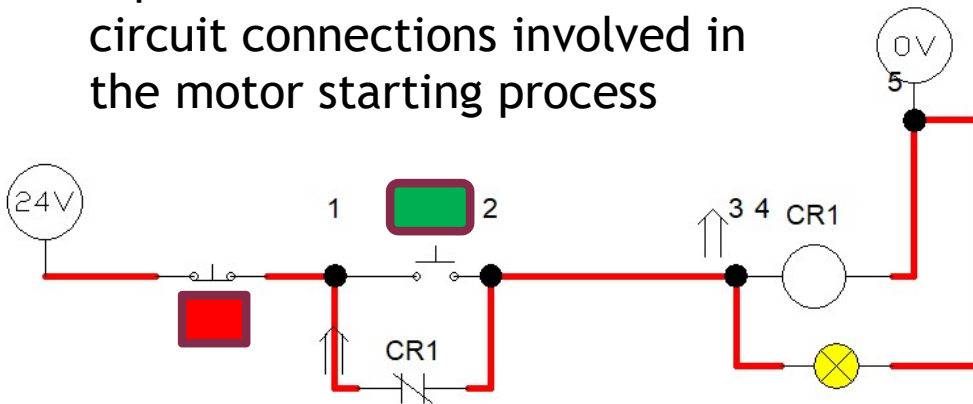
Damaged electric button

It must be normally closed at all times



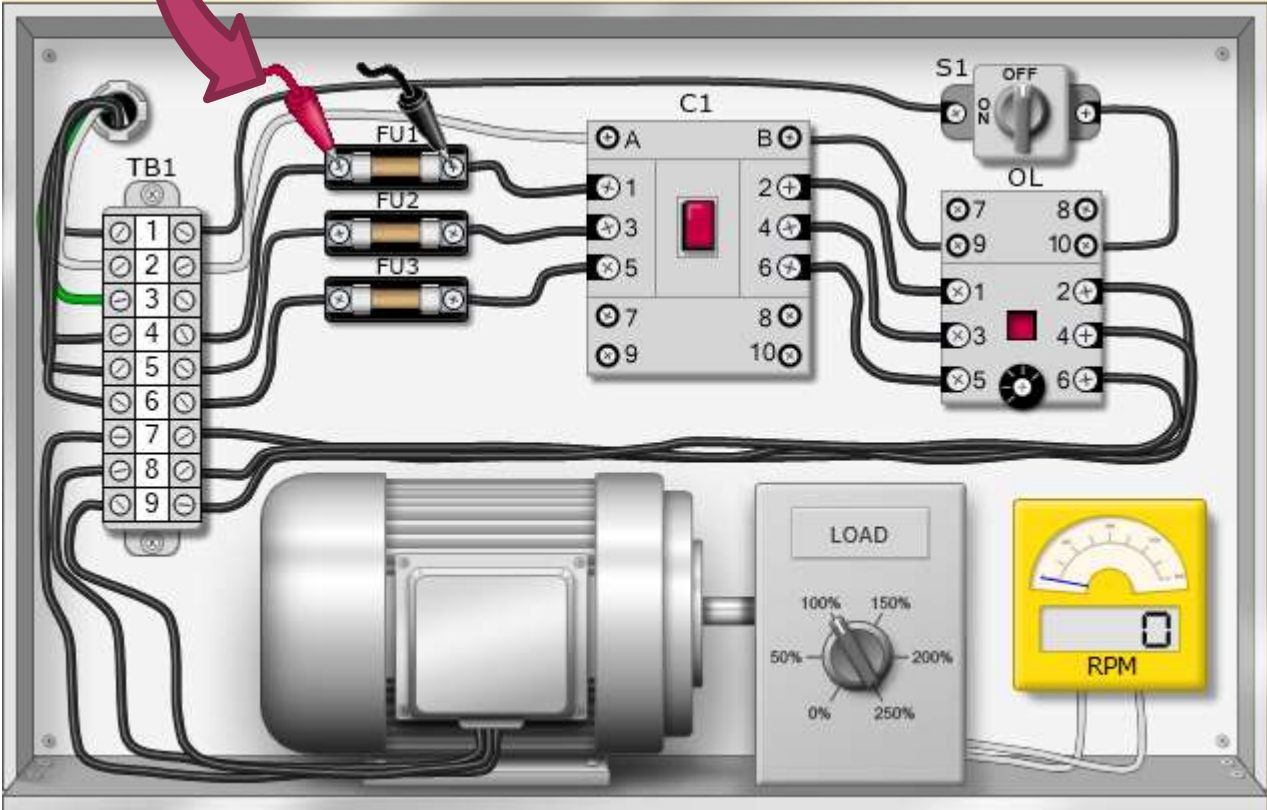
Once the start button is pressed, the green light activates a latching configuration within the circuit to maintain the contactor signal energized

This is a simplified representation of the control circuit connections involved in the motor starting process



Practice exercises using the demo simulator

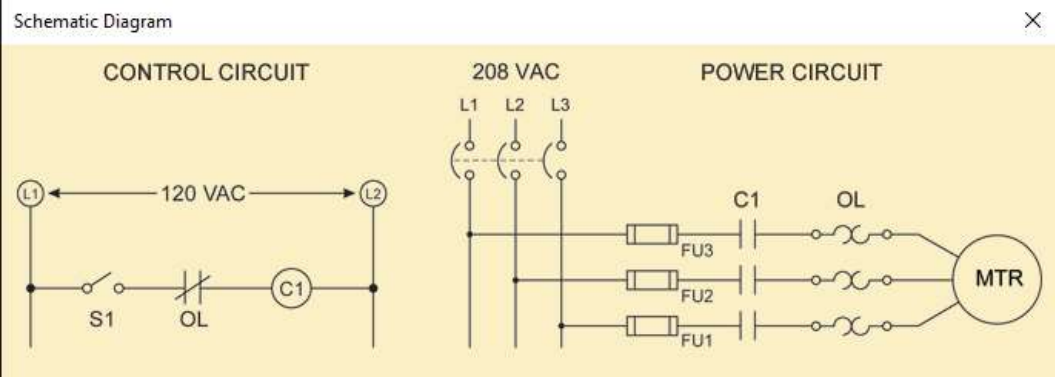
Turn off the main switch

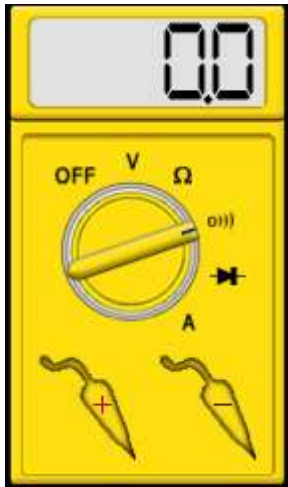


Perform the continuity test as observed

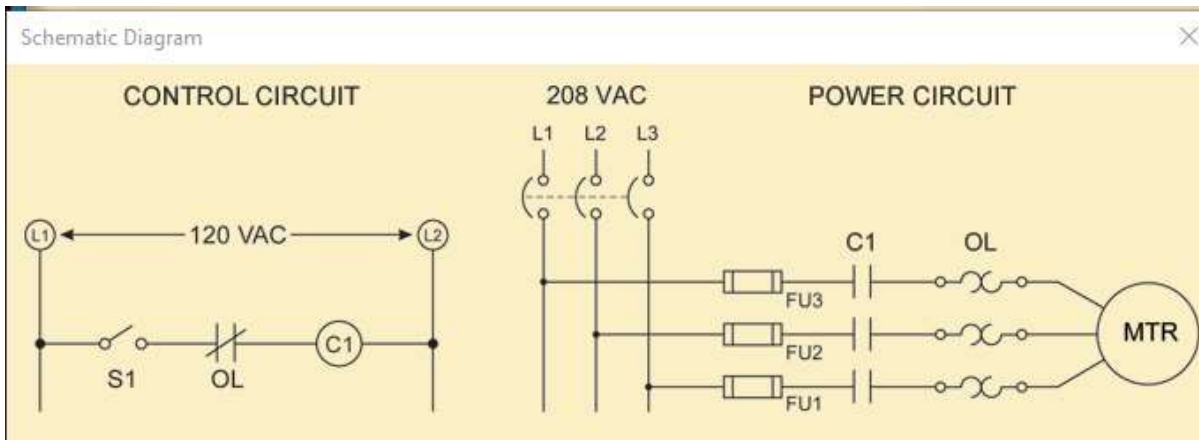
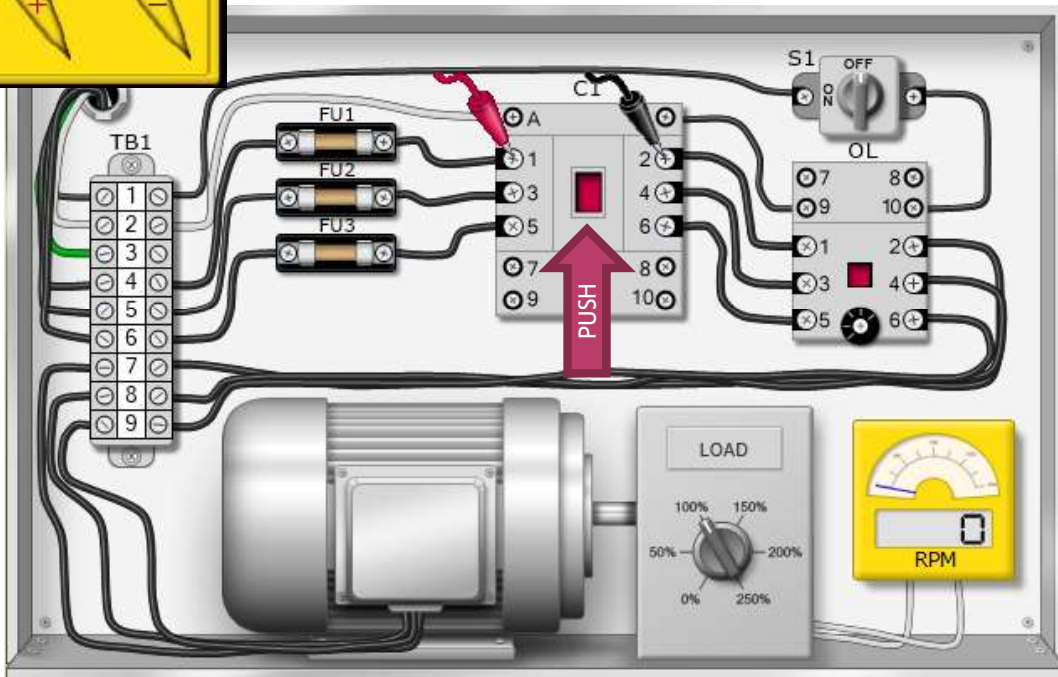
1)When I connected the multimeter in series for a continuity test, my result was _____.

2)What are the main fuses?





Measures the three input and output voltage lines of the magnetic contactor that supplies power to the motor.



Terminals 1 to 9, which component and its contacts are connected?

