Industrial Motor Controls

CARDINAL
AUTOMATION

Order No: 23006

First Edition

Revision level: 01/2023

By Cardinal Automation, LLC

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Printed in United States

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Lab 02 - Motor Wiring

Introduction

While the process of wiring an industrial motor can seem daunting, it all comes down to understanding the characteristics of the motor being wired. Lab 1 covered how to read and understand the motor nameplate data. In this Lab, that information will be used to aid in the installation of the motor in a circuit.

Disclaimer

Remember to follow the wiring rules below to complete the circuit.

- Never wire on an energized board. The trainer should be locked-out while wiring.
- All control circuit wires shall be as follows:
    - 24V control wires shall be blue.
    - 0V control wires shall be white or white/blue stripes.
    - A minimum of 18-gauge wires shall be used on the control circuit.
- All motor circuit wires shall be as follows:
    - Motor circuit wires shall be colored.
        - L1 – Red
        - L2 – White
        - L3 – Black
        - Ground - Green
    - A minimum of 14-gauge wires shall be used on the motor circuit.
- All wires should be labeled at each termination point.

Task

Perform the steps listed below to complete the installation of an AC Induction Motor.

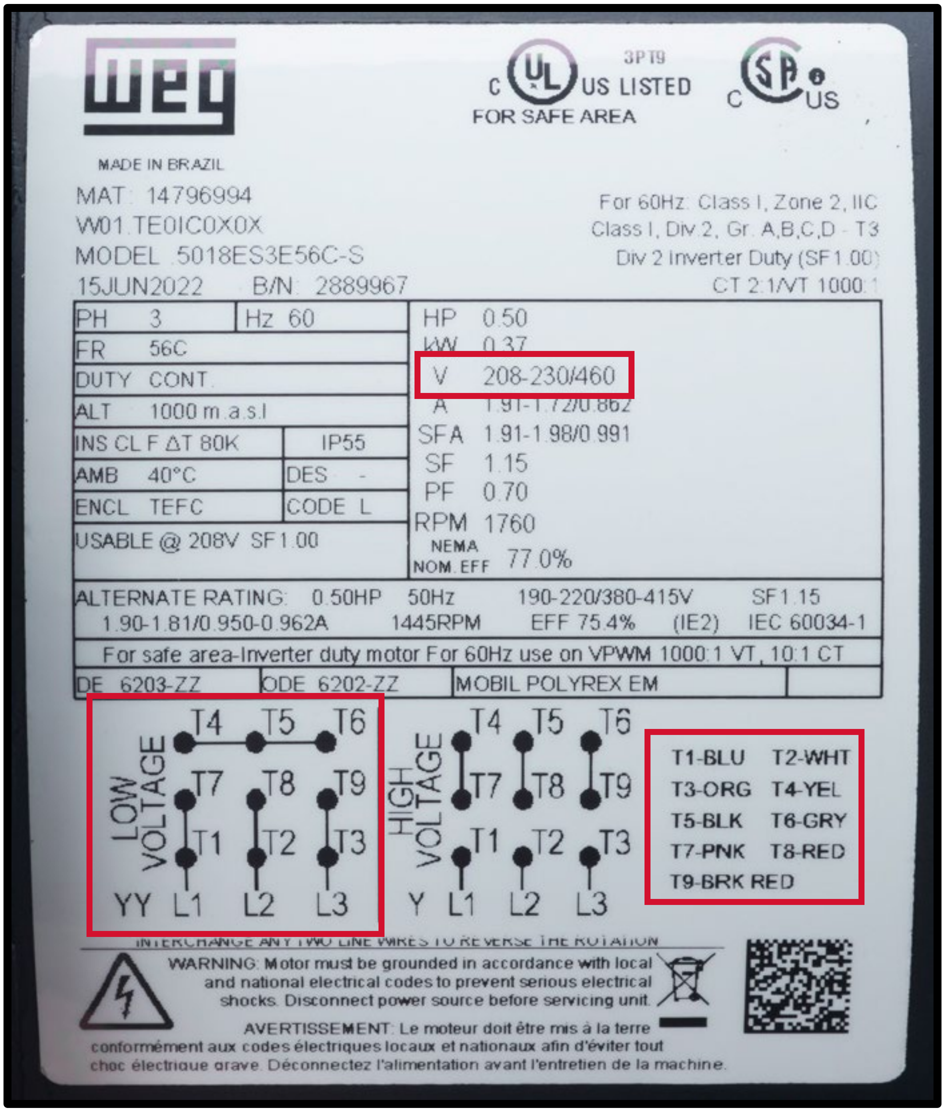
1. **Ensure that all power to the circuit is turned off and locked out.**

It is a good practice to check the components with a multimeter to ensure there is no power supplied to the circuit being wired.

2. **Determine the Voltage of the motor to select the proper Field Wiring diagram.**

Many AC industrial motors come configured from the factory to accept dual voltages. The correct supply voltage must be determined from the Motor Nameplate to complete the wiring. If the motor is not set up to accept dual voltages, there will only be one Field Wiring diagram to choose.

For this walkthrough, the following motor will be used. This motor is set up to accept a 230VAC (Low Voltage) circuit and a 460VAC (High Voltage) circuit.



3. Select the proper conductor size (AWG) for the circuit.

It is important to ensure that any cable or wire used in the installation of the motor can handle the current load supplied during operation. If the incorrect conductor size is chosen, the conductor could become overloaded and damage the equipment or create an electrical fire.

The following chart can be used to select the appropriate conductor size for this walkthrough.

Power	FLA		Minimum Wire Size (AWG)	
HP	230V	460V	230V	460V
0.5	2.2	1.1	14	14
0.75	3.2	1.6	14	14
1	4.2	2.1	14	14
1.5	6.0	3.0	14	14
2	6.8	3.4	14	14
3	9.6	4.8	14	14
5	15.2	7.6	12	14
7.5	22	11	8	14
10	28	14	8	12

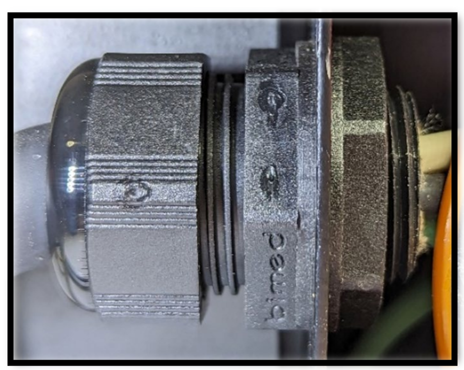
Note: It is always a good idea to reference both the manufacturers documentation and the NFPA charts when selecting conductors.

Since the motor used in this example is 0.5hp and can be wired in either 230VAC or 460VAC configurations, the recommended conductor size 14 AWG wire or cable. If the motor has a Horsepower rating of 5hp or larger, note that the conductor size is different between the two voltage options.

4. Prepare the cable and motor for wiring.

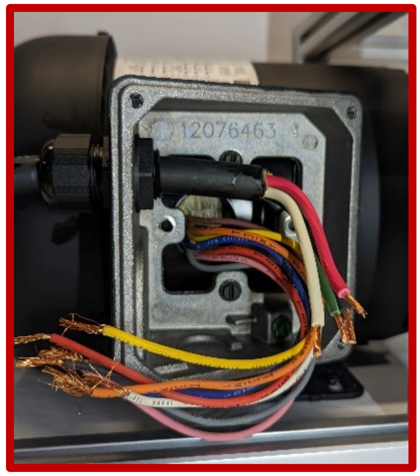
Once the proper conductor has been chosen, it is now time to prepare that conductor for installation. Trim back about six inches of the cables rubber insulation until each of the four wires are isolated. Be especially careful not to cut the insulation of the individual wires. If a wires insulation is cut, it is recommended to cut the wires flush and start over with step four.

Next, remove the motor’s electrical knock out by striking it with a hammer and punch. There are several electrical knockouts located on the motor. Select the knockout that best fits the application and proceed with its removal.



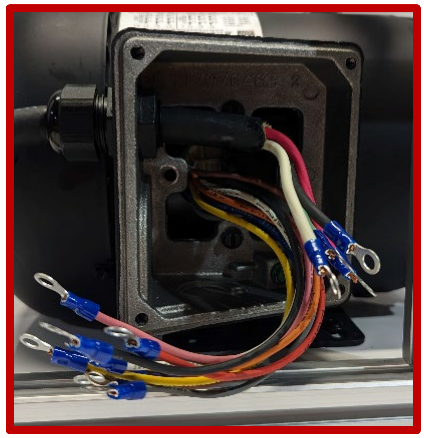
Once the knockout is removed, install a Cable Gland to ensure that the cable is properly secured into the motor housing. Cable Glands are used to provide a secure way to attach the cable to the motor housing and act as a seal to ensure the motor wiring is protected from the outside environment. The motor cable can now be fed into the motor housing and tightened down with the cable gland.

5. Wire Identification and Hookup



With the motor cover removed, the motor leads and the cable leads will be visible. It is important to identify the motor leads which are labeled T1-T9, and to isolate the cable leads so they can be labeled. The cable leads in this example are labeled as follows:

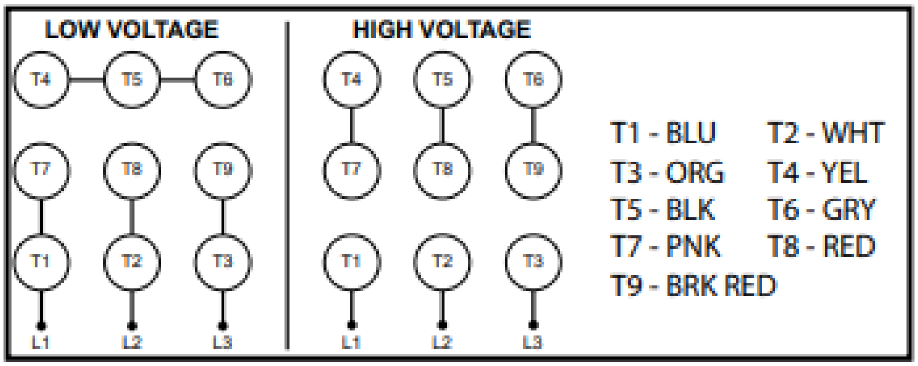
- Red ------- L1
- White ---- L2
- Black ----- L3
- Green ----- GND (Ground)



At this point, ring terminals should be installed on all motor and cable leads. It is often common to see field connections made with wire nuts. Over time, the vibrations of the motor can loosen the wire nuts and cause a wire to short, causing a dangerous situation. It is the suggestion of this walkthrough to install ring terminals, and to bolt the connections together to ensure a secure connection.

Once the ring terminals are installed, the green Ground wire can be screwed to the motor case.

The motor in this example is going to be wired for a 230VAC Low Voltage setup. With this determined, the Low Voltage Field Wiring diagram will be used.

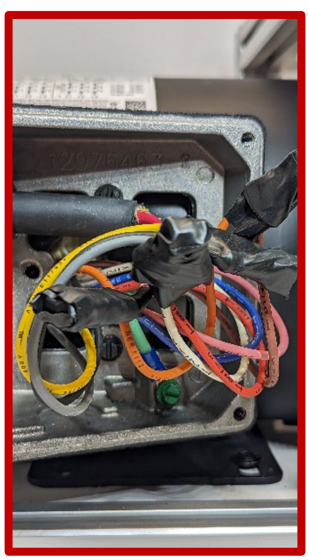


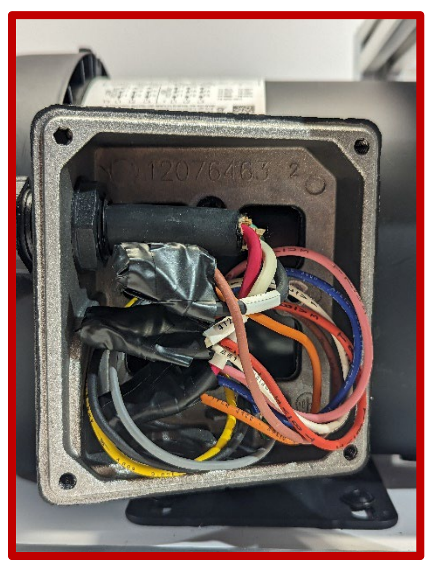
The following connections should be made to complete the Low Voltage wiring.

- L1 → (T1, T7)
- L2 → (T2, T8)
- L3 → (T3, T9)
- (T4, T5, T6)

Each of the field wiring connections should be bolted together and taped to ensure a secure connection and to insulate the connection inside the motor case.

It is important at this time to ensure that all the connections are tight and that the correct connections have been made. If any of the wires are crossed when power is applied, the motor could be damaged, and individuals could be injured.





Once the wiring is checked and verified correct, the motor and cable leads can be tucked back into the electrical box and the cover reinstalled.

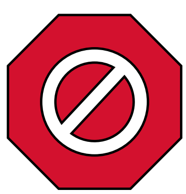
If the motor were to be wired for the 460VAC High Voltage option, the same steps would be followed to complete the installation, with the exception of the following connections.

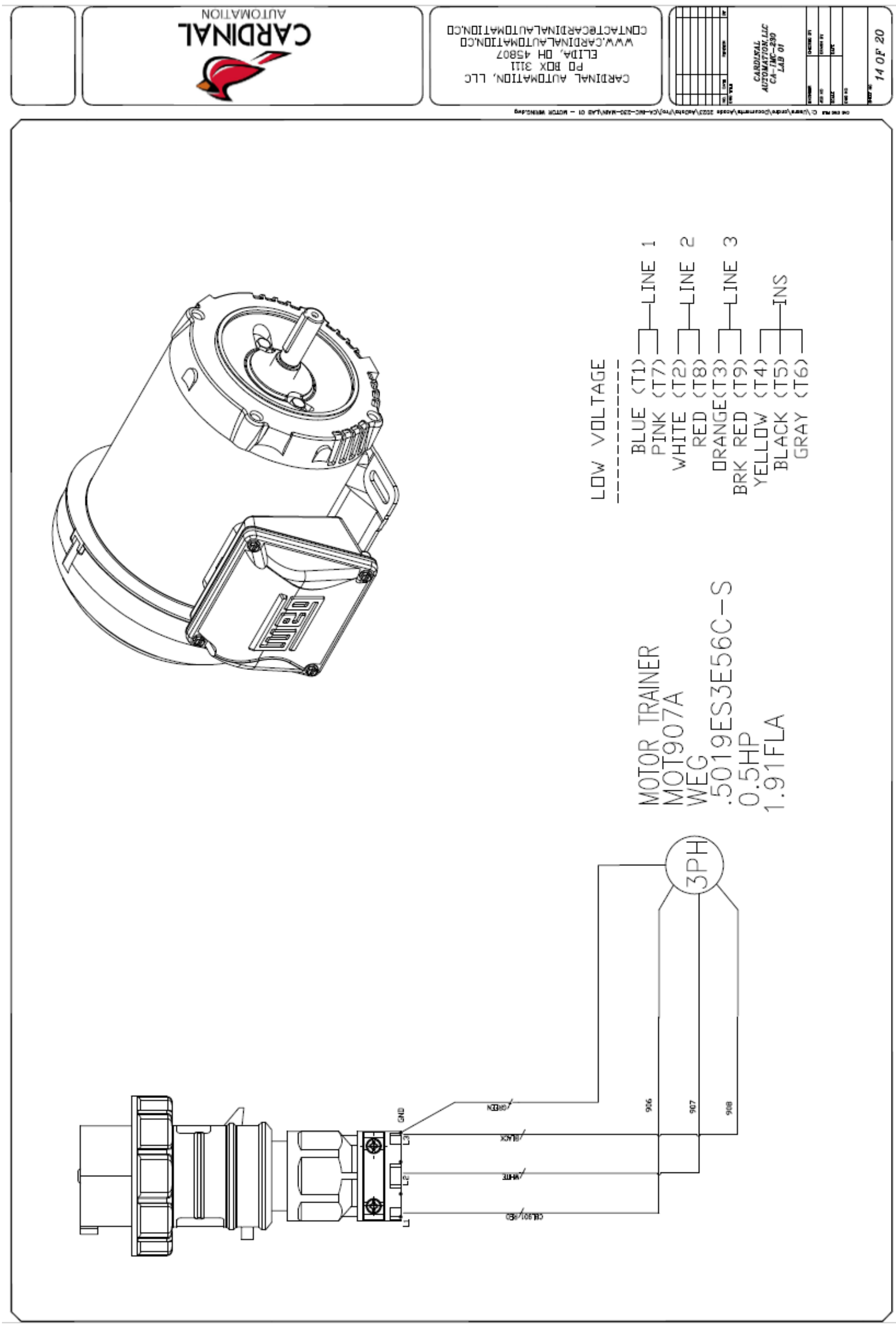
- L1 → (T1)
- L2 → (T2)
- L3 → (T3)
- (T4, T7)
- (T5, T8)
- (T6, T9)

Wiring Diagram

The following page has the wiring diagram to assist with the lab.

Before power is applied to the circuit, be sure the instructor has verified the wiring.

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LOW VOLTAGE
BLUE (T1)
PINK (T7)
WHITE (T2)
RED (T8)
ORANGE(T3)
BRK RED (T9)
YELLOW (T4)
BLACK (T5)
GRAY (T6)
LINE 1
LINE 2
LINE 3
INS
MOTOR TRAINER
MOT907A
WEG
.5019ES3E56C-S
0.5HP
1.91FLA
3PH
906
907
908
GND
L1
L2
L3

Lab 03 – Wiring Safety Relay

Introduction

A safety relay is an electrical device that is used to monitor and control safety-critical applications. It is designed to ensure that machines and systems operate safely, preventing accidents and protecting personnel and equipment from harm.

Key Terms

Power Terminals (A1, A2): *These are the terminals that supply 24VDC to the safety relay module.*

Input Terminals (S11-S12, S52, S21-S22): *These are the terminals on the safety relay that receive signals from sensors or switches that monitor the machine or equipment.*

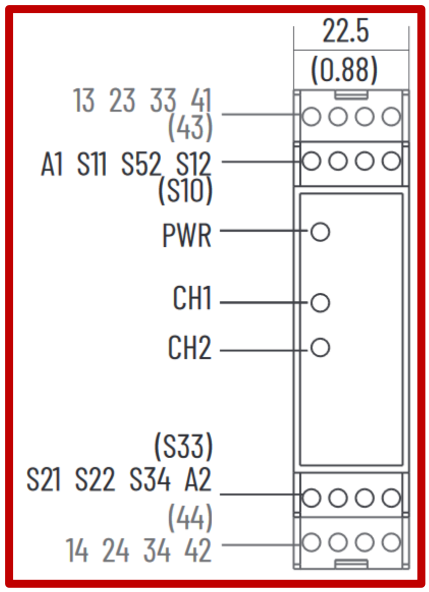
Output Terminals (13-14, 23-24, 33-34): *These are the terminals on the safety relay that control the power to the machine or equipment.*

Auxiliary Terminals (41-42): *These are the terminals on the safety relay that are used for external feedback to other devices. (Ex: PLC, Visual Indicators)*

LED Diagnostics

When Safety Relay in Operation, Green Indicators will be on to display the following information:

Indicator	Description
Power	Power is applied to device.
Reset	Reset circuit is closed.
CH1	External switch input 1 closed.
CH2	External switch input 2 closed.
K1	Internal relay safety output contacts closed.
K2	Internal relay safety output contacts closed.



Circuit Overview

- When the control line inputs are closed **(S11-S12, S21-S22)** and the **Start/Reset** condition has been met the safety output contacts close.
- The safety relay outputs **(13-14, 23-24, 33-34)** open when the inputs are deactivated or if there is a power failure. **13-14** are going to the **Emergency Stop Relay coil**. This will be used in later labs to stop the control circuit in case of an emergency stop situation. **23-24** are going to the **VFD Safe Torque-Off Relay coil**, which will be used to stop the VFD in case of an emergency stop situation that will be used later labs.
- When operating in the monitored manual reset configuration the **Reset Button** must perform a make-then-break action before the safety relay will activate.
- The auxiliary contacts are going to the **Reset Button LED, and Emergency Stop LED**, to provide the operator with visual indicators to know the safety circuit has been tripped.

Disclaimer

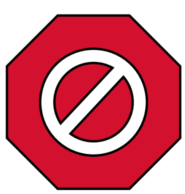
Remember to follow the wiring rules below to complete the circuit.

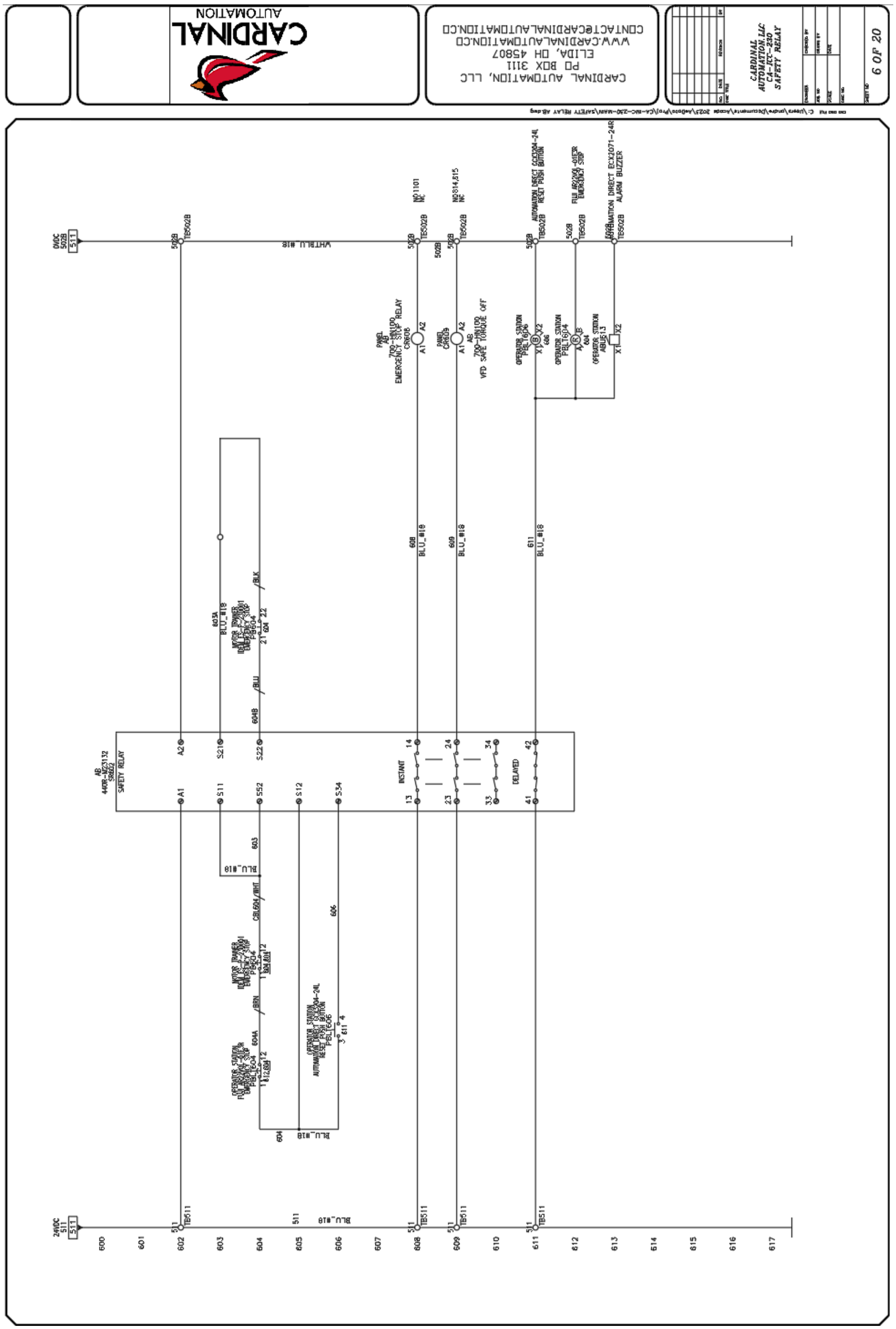
- Never wire on an energized board. The trainer should be locked-out while wiring.
- All control circuit wires shall be as follows:
  - 24V control wires shall be blue.
  - 0V control wires shall be white or white/blue stripes.
  - A minimum of 18-gauge wires shall be used on the control circuit.
- All motor circuit wires shall be as follows:
  - Motor circuit wires shall be colored.
    - L1 – Red
    - L2 – White
    - L3 – Black
    - Ground - Green
  - A minimum of 14-gauge wires shall be used on the motor circuit.
- All wires should be labeled at each termination point.

Wiring Diagram

The following page has the wiring diagram to assist with the lab.

- **Before power is applied to the circuit, be sure the instructor has verified the wiring.**

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Lab 04 – Simple START Circuit

Introduction

It is now time to test the functionality of the motor circuit completed in Lab 2. A simple start circuit will be used to energize the forward contactor. By energizing the coil, the motor contacts will close, and power will be supplied to the motor. With the motor powered on and rotating, the direction of rotation can be noted and changed if needed.

Key Terms

Overload Contact: *A series of contacts located on the overload relay that are used to interrupt the circuit in an overload situation. While most overload contacts are Normally Closed, Normally Open contacts are sometimes used to initiate an indicating device.*

E-STOP: *Emergency Stop (E-STOP) devices are used to halt machine functions in an emergency situation.*

Circuit Overview

- When the **FWD START** button is pressed, the circuit closes and energizes the motor contactor coil **(M1123)**. The circuit will remain closed while the **FWD START** button is pressed.
- While the motor contactor coil **(M1123)** is energized, the **Green Stacklight** will light to signify normal running conditions.
- If at any time during the operation of the motor an overload occurs, the **Overload Contact** would de-energize the coil. This action helps protect the motor from damage.
- If the **E-STOP** is pressed at any point of the operation, the circuit will de-energize and return to its normal off state.
- If the **E-STOP** is pressed, the **Red Stacklight** will light to signify the motor is in a faulted state. The **Red Stacklight** will stay lit until the fault condition is reset.

Note: This circuit will utilize the integrated safety circuit constructed in **Lab 3**.

Disclaimer

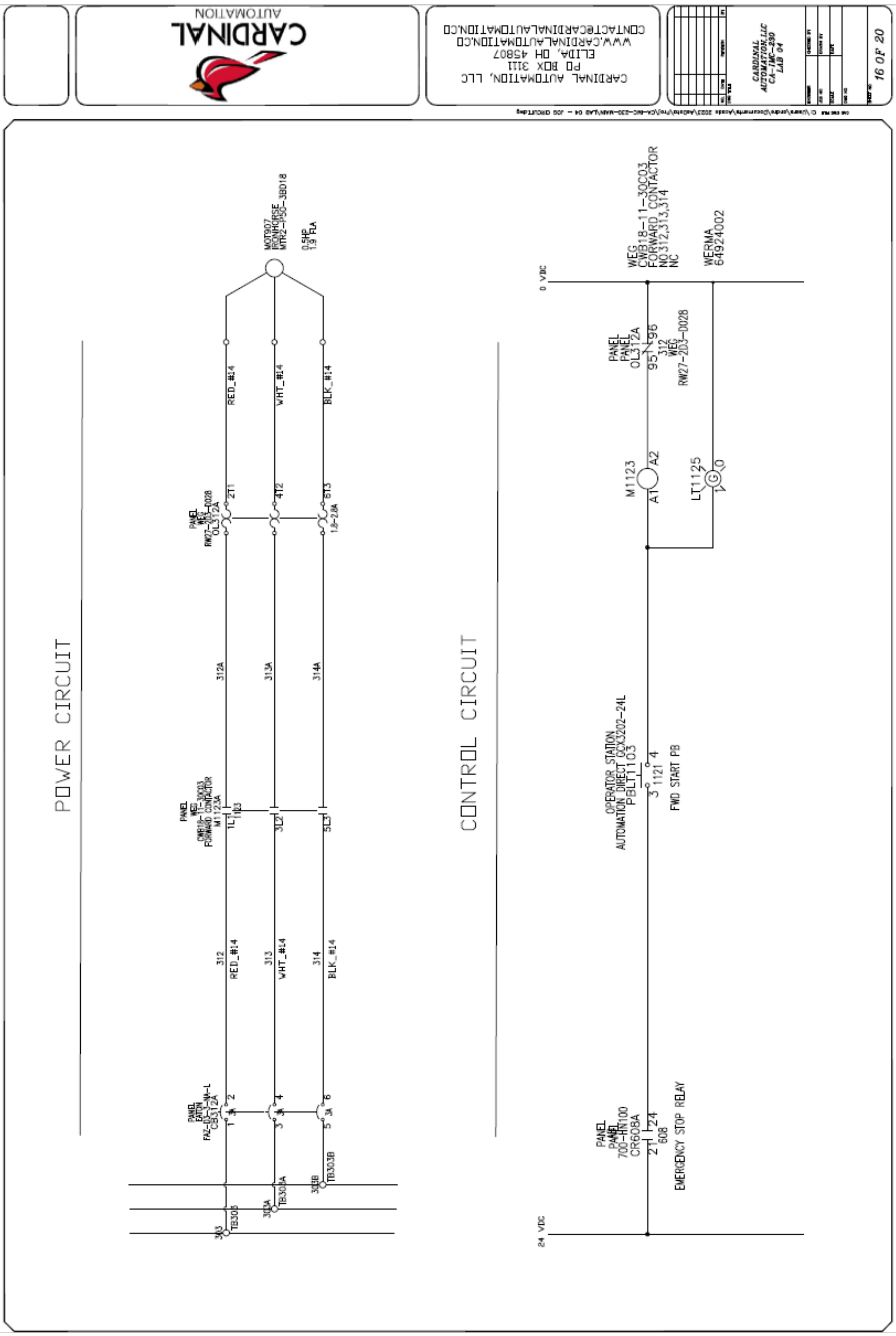
Remember to follow the wiring rules below to complete the circuit.

- Never wire on an energized board. The trainer should be locked-out while wiring.
- All control circuit wires shall be as follows:
    - 24V control wires shall be blue.
    - 0V control wires shall be white or white/blue stripes.
    - A minimum of 18-gauge wires shall be used on the control circuit.
- All motor circuit wires shall be as follows:
    - Motor circuit wires shall be colored.
        - L1 – Red
        - L2 – White
        - L3 – Black
        - Ground - Green
    - A minimum of 14-gauge wires shall be used on the motor circuit.
- All wires should be labeled at each termination point.

Wiring Diagram

The following page has the wiring diagram to assist with the lab.

Before power is applied to the circuit, be sure the instructor has verified the wiring.



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LAB 04
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POWER CIRCUIT
CONTROL CIRCUIT
MOT907
IRONHORSE
MTR2-P50-3BD18
0.5HP
1.9 FLA
RED_#14
WHT_#14
BLK_#14
PANEL
WEG
RW27-2D3-D028
OL312A
2T1
4T2
6T3
1.8-2.8A
312A
313A
314A
PANEL
WEG
CWB18-11-30C03
FORWARD CONTACTOR
M1123A
1L1
3L2
5L3
312
313
314
PANEL
EATON
FAZ-D3-3-NA-L
CB312A
TB303
TB303A
TB303B
0 VDC
24 VDC
WEG
CWB18-11-30C03
FORWARD CONTACTOR
NO 312,313,314
NC
WERMA
64924002
PANEL
PANEL
OL312A
95 96
312
WEG
RW27-2D3-D028
M1123
A1
A2
LT1125
OPERATOR STATION
AUTOMATION DIRECT GCX3202-24L
PBLT1103
1121
FWD START PB
PANEL
PANEL
700-HN100
CR608A
21 24
608
EMERGENCY STOP RELAY

Appendix

Motor Maintenance & Troubleshooting

Once the motor is installed, there will come a time that the motor will need service. To perform service on the motor, it will be important to understand how to diagnose the issue. This section will cover troubleshooting tools and techniques used to diagnose motor issues.

Troubleshooting Tools

Note, it is important that individuals do not work on live circuits unless they have been properly trained or are supervised by a trained individual.

Amp Clamp

Amp Clamps or Clamp Meters are primarily used to measure currents over 1A in AC circuits. They allow technicians the ability to troubleshoot the circuit without disconnecting or deenergizing the circuit.

Depending on the model of Amp Clamp used, they range from 90-99% accurate on measured readings. When measuring motor current it is common to all three power leads together to get a total amperage reading as well as individual to ensure each lead is providing equal amounts of current.

Megohmmeter

Meggers or Megohmmeters are used to test insulation on a motor's generator, windings, and wire through a resistance test. This test is performed by sending a high voltage signal from the megohmmeter to the motor being tested. In most cases, if a resistance over 10 megohms is read, the insulation in the motor is good. If the test yields a lower resistance and fails, the motor will need to be replaced or repaired.

Motor Insulation failures can be a result of the following issues:

- High Current Draw
- Inconsistent Power Draw
- Motor Overheating
- Motor Vibration

Digital Multimeter

Digital Multimeters are the combination of several meter types. They are designed to perform the actions of an ammeter, ohmmeter, and voltmeter all in one handheld device. Depending on the model of the meter used, there may be several additional functions included in the meter.

Most industrial grade digital multimeters on the market will read the following values:

- AC Amperage/Voltage
- DC Amperage/Voltage
- Capacity
- Conductance
- Continuity
- Duty Cycle
- Frequency
- Inductance
- Resistance
- Temperature

Insulated Tools

Insulated tools are used when working and troubleshooting live circuits. The tools are manufactured to cover the maximum amount of exposed metal to mitigate the risk of arcing the tool across a live circuit. Most insulated tools have a minimum rating of 1000 volts, and that rating should be printed on the tool. This means that the tool should not conduct electricity up to 1000 volts.

It is important to inspect all insulated tools before use. If a tool is damaged, or has a nick in the coating, that tool should no longer be trusted. Most tool manufacturers will replace a tool if the damage is due to normal use.

Motor Troubleshooting Guide

Motor Fails to Run After Installation

- Does the motor have power?
    - Check the incoming power source with a multimeter.
- Was the motor wired properly?
    - Review the motor wired as compared to the field wiring diagram.

Motor Direction is Incorrect on Startup

- Was the motor wired properly?
    - If the motor is running in the reverse direction, rewire the motor and switch the L1 and L3 cable leads.

Motor Fails to Start After it has Run

- Has an Overload Protection device been tripped?
    - Check all fuses and circuit breakers in line with the motor.
- Does the motor have power?
    - Check the incoming power source with a multimeter.
- Is the motor jammed or overloaded?
    - Inspect the motor coupling to ensure the motor is not bound up.

Motor Runs at a Slower Speed

- Has the Motor Been Overloaded?
    - Check that the motor is rated from the attached load. Consider installing a motor with a higher horsepower rating if the load cannot be changed.
- Is the motor running at its rated voltage?
    - Check the incoming voltage source with a multimeter.

Motor does not Accelerate in the Allotted Timeframe

- Has the Motor Been Overloaded?
    - Check that the motor is rated from the attached load. Consider installing a motor with a higher horsepower rating if the load cannot be changed.
- Is the motor running at its rated voltage?
    - Check the incoming voltage source with a multimeter.
- Does the motor have failing bearings?
    - Check the motor shaft for play and rough motion.

Motor Starts but Dies Shortly After

- Has an Overload Protection device been tripped?
    - Check all fuses and circuit breakers in line with the motor.
- Does the motor have power?
    - Check the incoming power source with a multimeter.
- Is the motor jammed or overloaded?
    - Inspect the motor coupling to ensure the motor is not bound up.

Motor Vibrates During Operation

- Does the motor have failing bearings?
  - Check the motor shaft for play and rough motion.
- Is the motor shaft misaligned with the load?
  - Check the motor coupling and realign it if necessary.
- Is the motor shaft bent or damaged?
  - Ensure that the motor shaft has not been damaged or bent during operation. If damage has occurred, replace the motor.
- Is the motor winding damaged?
  - Perform a continuity test on each of the motors winding to ensure the winding has not become damaged. If the winding is faulty, Replace the motor or have the motor rewound.

Motor is Overheating on a Thermal Scan

The following issues should be checked if a motor is overheating.

- Improper Conductor Size
  - Industrial motors require a minimum conductor size used in the installation. If the conductor is too small, a voltage drop can occur which can generate heat and damage the motor.
- Mechanical Issues
  - Worn Bearings
  - Damaged Windings
- Poor Ventilation
  - Motors installed in a poorly ventilated area can become overheated due to dust and debris accumulating on the motor case. This accumulation will create a thermal layer on the case which in turn can raise the internal temperature of the motor.
- Unbalanced Supply Voltages
  - Due to the multiple leads on a 3-Phase motor, it is possible for one or all of the leads to have an unbalanced voltage. This unbalance leads to excess heat buildup in the motor.
  - Voltage imbalance is often caused by the following:
    - Malfunctioning Transformer
    - Damaged Motor Windings
    - Poor Facility Voltage Supply

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AUTOMATION

About Us

Cardinal Automation, LLC was created by former university instructors and industry professionals to provide custom automation training and equipment to meet the needs of your program.

Cardinal Automation, LLC is committed to providing a quality training platform to those looking to expand their knowledge in industrial automation.

- Our courses offer a concise curriculum taught online and in-person through step-by-step guides to teach real-world industrial equipment.
- We provide custom training options to assist the employees in your facility.
- The automation trainers we build are constructed with industrial grade components that will bridge the gap to industry.

Reach Us

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