

A blurred background image of an industrial robotic arm in a factory setting. The arm is metallic and has various cables and hoses attached to it. It is positioned over a work area with some machinery visible in the foreground and background.

AUTOMATED MACHINE CONTROL SYSTEM

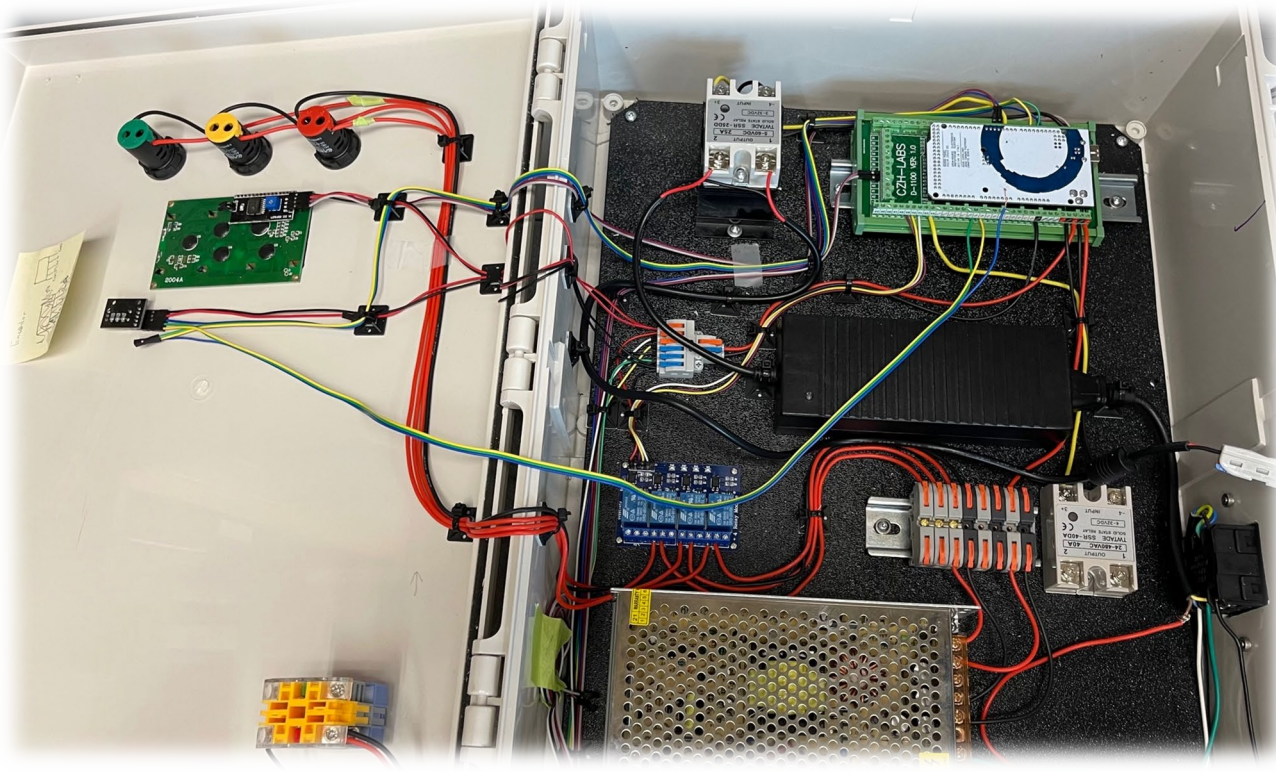
Imtehaze Heerah

Faculty, Mechanical Engineering

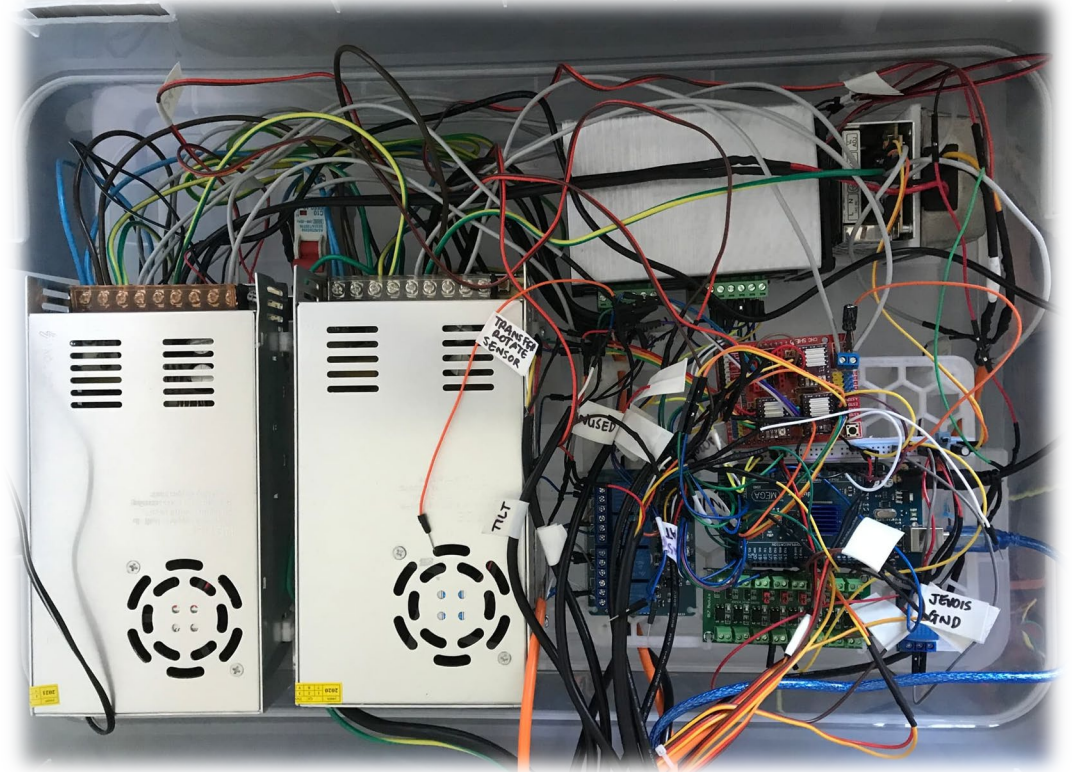
Camosun College

Control Cabinet Layout

<https://forum.arduino.cc/t/general-rules-for-limiting-inference/907998>

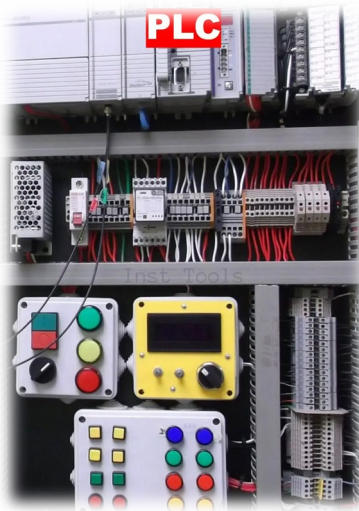
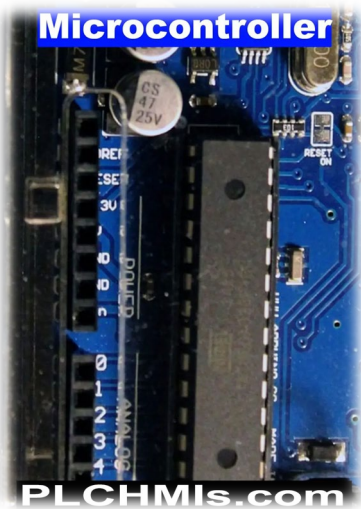


OK!



NOT OK!

Microcontroller v PLC



Feature / Criteria	Microcontroller (Arduino / ESP)	PLC (Programmable Logic Controller)
Ease of Use (Prototyping)	Very beginner-friendly, great for fast prototyping	Requires more setup and learning curve for beginners
Cost	Low (typically \$5–\$30 per unit)	Higher (typically \$100–\$500+ per unit)
Programming	C/C++ (Arduino IDE), Python, flexible	Ladder logic, structured text (less flexible for complex tasks)
I/O Flexibility	Digital/Analog I/O with add-on modules	Built-in industrial-grade I/O, highly reliable
Connectivity	Wi-Fi, Bluetooth (especially ESP), serial, etc.	Industrial Ethernet, Modbus, Profibus, etc.
Real-Time Reliability	Moderate – depends on code quality and power stability	High – designed for robust, real-time control
Environment Suitability	Good for lab/test environments	Rugged, suitable for harsh/industrial conditions
Expandability	High with shields/modules (sensors, motors, etc.)	High with I/O modules, HMI, SCADA systems
Maintenance & Support	Community-driven, limited formal support	Professional support, long-term vendor backing
Power Supply Requirements	5V/3.3V USB or external adapter	24V DC (standard in industrial setups)

Key Steps to Develop a Microcontroller-Based Control System

1. Define System Requirements

- Identify machine objectives and desired functionality.
- List sensors, actuators, motors, and other components.
- Determine I/O needs (number and type of signals).
- Identify timing, safety, power, and environmental constraints.

2. Select the Microcontroller Platform

- Choose a microcontroller that meets your I/O, memory, speed, and communication needs.
- Examples: **Arduino Uno**, **ESP32**, **STM32**, **Teensy**, etc.
- Evaluate compatibility with sensors, actuators, and expansion modules.

Selecting the right microcontroller

Consideration

Details / Questions to Ask

I/O Requirements

How many digital and analog I/O pins are needed? Are PWM or interrupt pins required?

Processing Power

Do you need fast data processing (e.g., for motor control or real-time logic)?

Memory (RAM/Flash)

How much program and variable storage is needed? Large programs or sensor data logs require more.

Communication Interfaces

Do you need Serial (UART), I2C, SPI, Ethernet, Wi-Fi, or Bluetooth?

Power Supply

What voltage and current are available? Does the controller need to be low-power or battery-powered?

Motor Control Capabilities

Does the microcontroller have timers, PWM channels, or support for encoder feedback?

Real-Time Control

Is real-time responsiveness critical? Consider real-time clocks or external interrupt handling.

Form Factor & Size

Does it need to fit in a tight space or on a specific mounting?

Development Ecosystem

Are libraries, community support, and tools (IDE, debuggers) available and mature?

Programming Language

Are you comfortable with the programming environment? (Arduino C++, MicroPython, etc.)

Shield/Module Compatibility

Are expansion modules or shields available for rapid development?

Environmental Tolerance

Will the system face vibration, heat, dust, or moisture? Does the controller need to be rugged?

Cost & Availability

What's the unit cost, and is it available in quantity? Are there long lead times?

Future Scalability

Will your system grow (e.g., more sensors or actuators)? Consider modularity and upgrade paths.

Key Steps to Develop a Microcontroller-Based Control System

3. Design the System Architecture

- Create a block diagram of the system:
 - Inputs: sensors, switches, encoders
 - Outputs: motors, relays, solenoids, indicators
 - Communication: displays, wireless modules, HMI
- Decide on power supply strategy and isolation needs.

4. Develop Hardware Interface

- Design schematics and prototype the circuit on a breadboard
 - Most scenarios can be prototyped using LEDs, switches and potentiometers to validate the system logic
- Ensure proper signal conditioning (e.g., voltage dividers, optocouplers, etc.).
- Plan for protection: fuses, etc.
- Mount components in a control enclosure (consider ventilation and maintenance access).

Key Steps to Develop a Microcontroller-Based Control System

5. Write the Control Program

- Structure your code into logical modules
 - Sensor reading
 - Control logic (State machines, PID control, etc.)
 - Actuator output
 - Communication
- Use interrupt handling for real time response where necessary.
- Use libraries and non-blocking codes (use `millis()` instead of `delay()` in Arduino).

6. Test & Debug

- Start with individual component testing (sensors, motors, etc.).
 - Integrate components step-by-step.
 - Use the Serial monitor, and/or LED indicators for debugging.
 - Verify/Validate logic under various operating conditions.

Key Steps to Develop a Microcontroller-Based Control System

7. Tune & Optimize

- Calibrate sensors and tune control parameters (e.g., PID gains).
- Optimize timing, memory usage, and loop efficiency.
- Include electrical noise management (software/hardware) to ensure predictable behavior.

8. Implement Safety & Fail-Safes

- Add emergency stop inputs, timeouts, limit switches, and current sensing, as needed.
- Ensure safe start-up and shutdown sequences.

Key Steps to Develop a Microcontroller-Based Control System

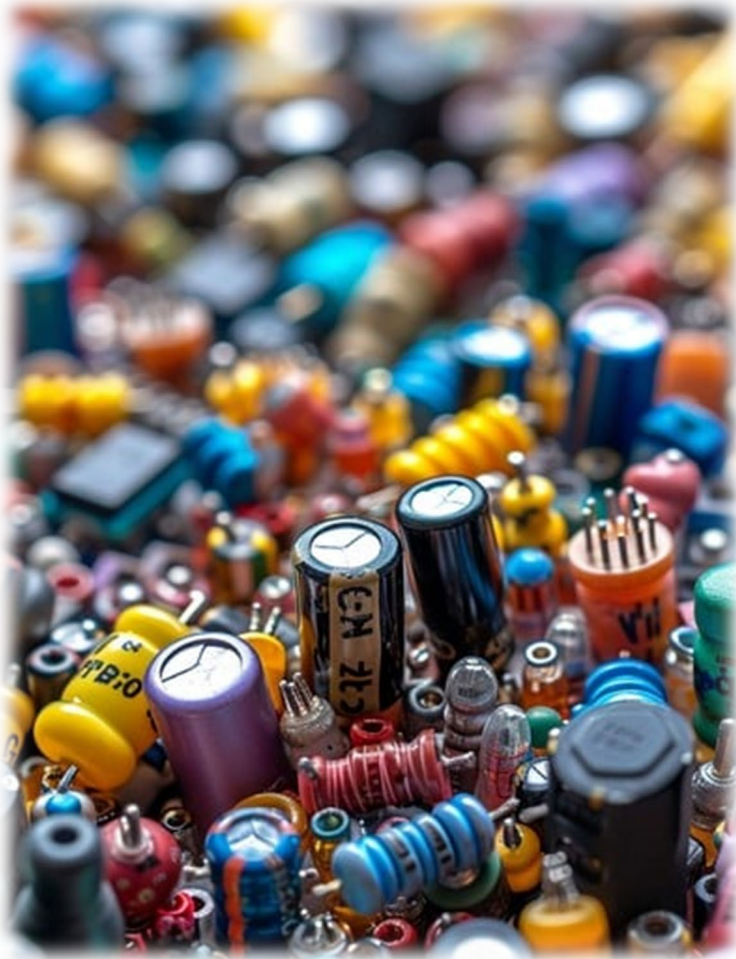
9. Finalize Control Cabinet

- Move from breadboard to a reliable layout (e.g., DIN rail, terminal blocks, wire ducts).
- Label all connections.
- Add documentation: wiring diagrams, user guides, maintenance instructions.

10. Deploy & Monitor

- Install the system on the machine.
- Run test cycles and monitor performance over time.
- Log data for offline analysis.

Where to source parts?



Digikey ([digikey.ca](https://www.digikey.ca))

Robotshop (ca.robotshop.com)

Abra Electronics (abra-electronics.com)

Mouser Electronics ([mouser.ca](https://www.mouser.ca))

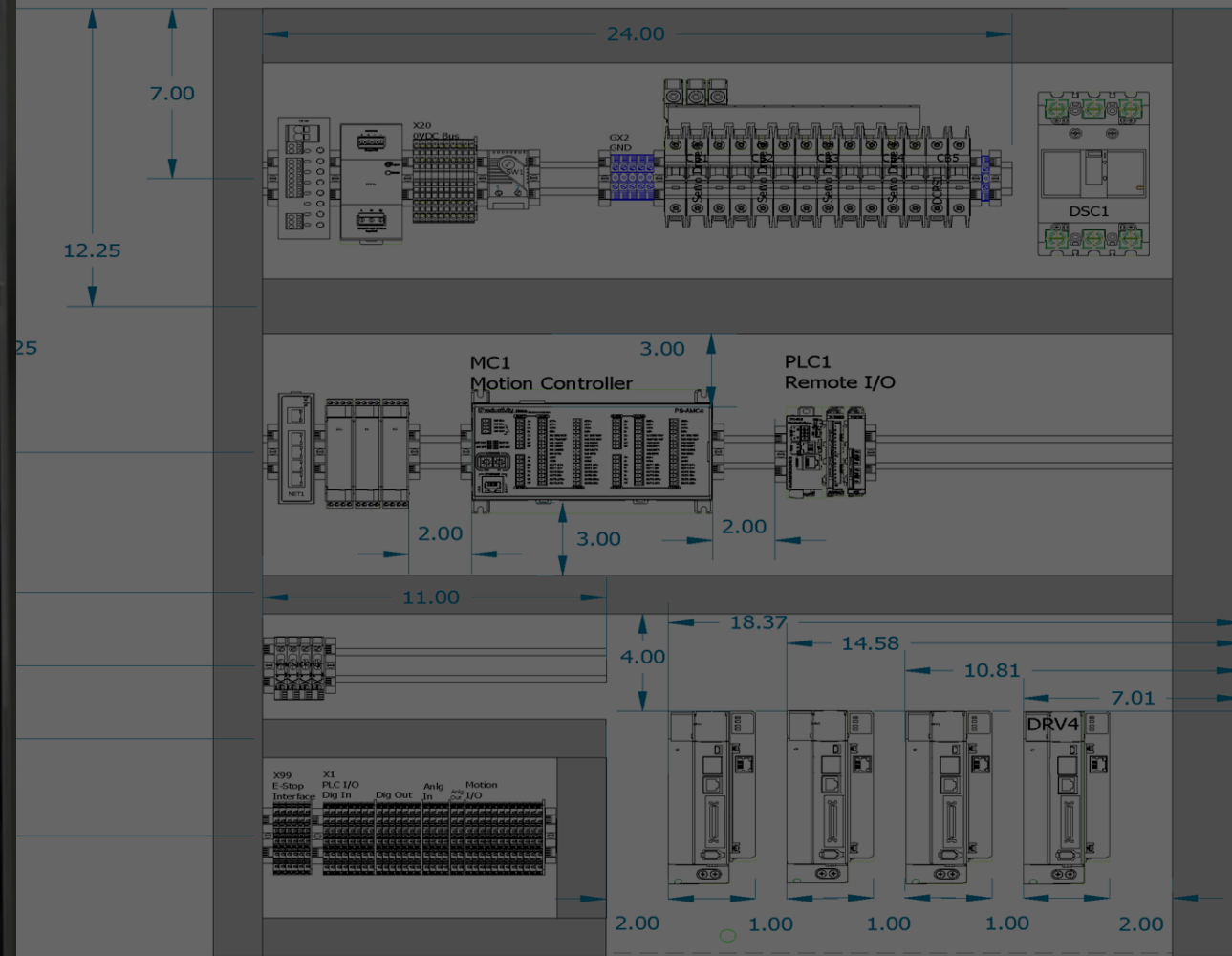
Amazon ([amazon.ca](https://www.amazon.ca))

Automation Direct ([automationdirect.com](https://www.automationdirect.com))

Sparkfun ([sparkfun.com](https://www.sparkfun.com))

Control Cabinet Design

Key Components



InformationDirect
105 Hutchinson Rd
Marietta, GA 30040
(800) 633-0405

Main Subpanel Layout
Dimensions in inches

LOCATION: L1 L1-SP

Cabinet Subpanel

REV.	DATE
0	6/18/20

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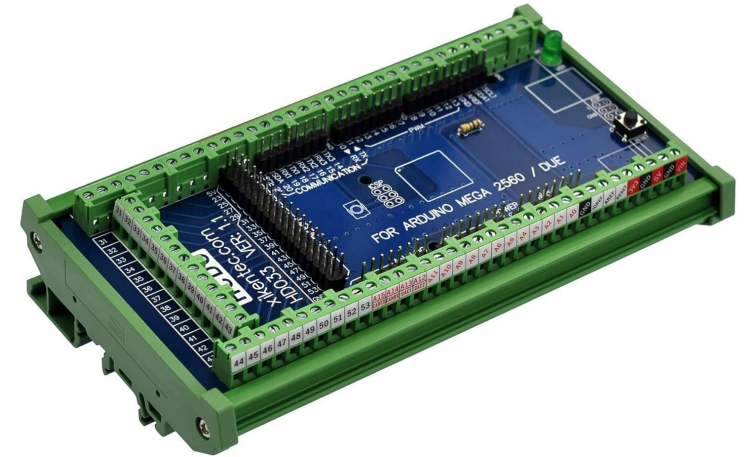
Common parts for a control cabinet



1. Control cabinet (IP rated)



2. DIN Rail



3. Arduino DIN rail mount



4. Sealed ON/OFF switch

Common parts for a control cabinet



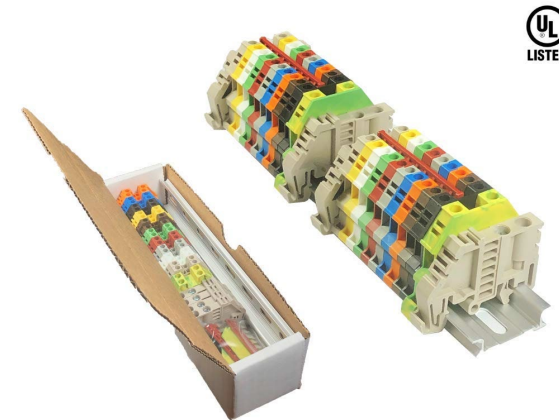
5. E-stop



7. Power supplies



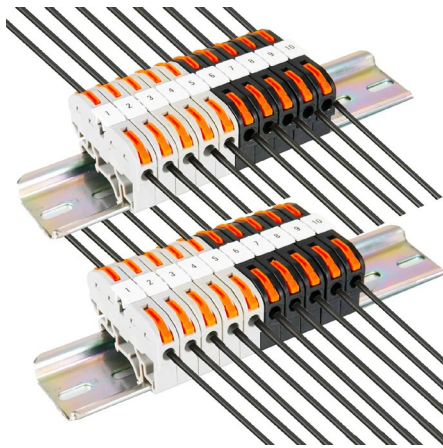
6. Waterproof cable gland



8. Power distribution terminal block



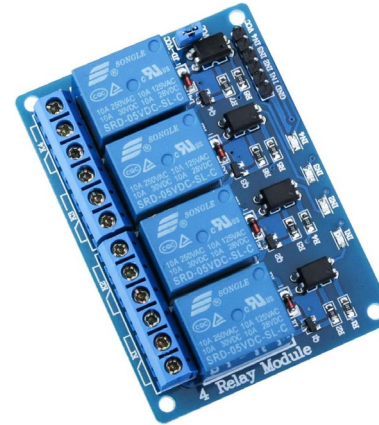
Common parts for a control cabinet



9. DIN rail terminal block



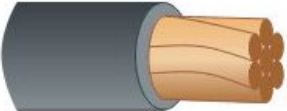
10. Stack light

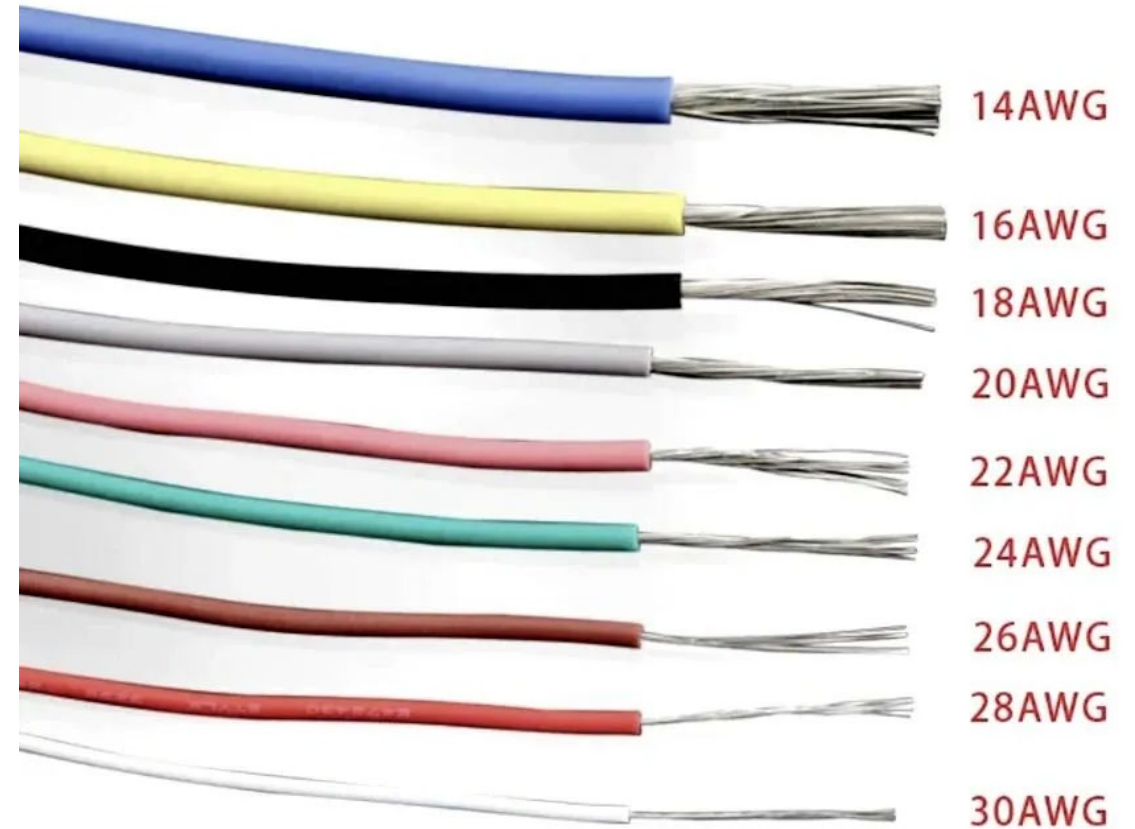


11. Relay module



12. Screen (LCD v Touch)

3/0 Gauge		200 Amps Service Entrance
1/0 Gauge		150 Amps Service Entrance and Feeder Wire
3 Gauge		100 Amps Service Entrance and Feeder Wire
6 Gauge		55 Amps Feeder and Large Appliance Wire
8 Gauge		40 Amps Feeder and Large Appliance Wire
10 Gauge		30 Amps Dryers, Appliances, and Air Conditioning
12 Gauge		20 Amps Appliance, Laundry and Bathroom Circuits
14 Gauge		15 Amps General Lighting and Receptacle Circuits



Wire gauge

Common wiring

1. Key Consideration when selecting Wire Gauge

- ❑ **Current** – Higher current requires thicker wire (lower AWG).
- ❑ **Voltage Drop** – Long wire runs may require thicker wire to reduce losses.
- ❑ **Voltage Level** – Safety clearances and insulation ratings vary.
- ❑ **Environment** – Ambient temperature, bundling, and conduit use
- ❑ **Wire Type** – Stranded vs solid

2. Typical Use Case – General guides

120 VAC Circuits

- ❑ **20A circuits (receptacles, outlets):** AWG 12
- ❑ **15A lighting/control circuits:** AWG 14
- ❑ **E-stop and interlock control (with relays):** AWG 16–14
- ❑ **Main panel feeds (30A+):** AWG 10–6

DC Circuits (5V, 12V, 24V)

- ❑ **Sensor and I/O wiring:** AWG 22–20
- ❑ **Microcontroller supply (e.g., 5V @ 1–2A):** AWG 22–20
- ❑ **24VDC power for relays, solenoids, small motors:** AWG 18–16
- ❑ **24VDC logic/control power distribution:** AWG 16–14
- ❑ **High current DC loads (10–30A):** AWG 12–10

Control cabinet components cost estimate

Components	Approximate cost (CAD)
Control cabinet	200
DIN rail kit (8")	30
Arduino DIN rail mount	60
Sealed ON/OFF switch	16
E stop	25
Waterproof cable gland	25
Power supplies (standard v DIN rail)	40 - 50
Power distribution terminal block	50
DIN rail terminal block	30
Stack light	40
Relay module (4 channel)	11
Screen (LCD or 3.5" touch screen)	18 - 35
Total (low estimate)	545 – 572



Notes:

1. The table only assumes a single controller and power supply
2. Electromechanical relays are estimated in the table, not solid-state relays (more expensive)
3. Not included:
 - a. Cost of wires
 - b. Sensors and actuators costs

Other Considerations

Components lead time

- How much time it takes for parts to arrive

Component source

- Purchases from the US need to cross the border and this may add to the lead time
- Order from local/Canadian sources as much as possible

Critical components

- Buy spares of critical components as the added lead times outweigh the additional costs
- Identify and order critical components early

Team collaboration

- Talk to other team members, also building electromechanical machines
- Some parts can only be ordered in kits or large qty (share the cost)

Programmable controllers
 Variable Frequency Drives
 Industrial Connectivity
 Motor Starters & Controls
 Surge Protection Devices
 Smart Relays

7.Circuit Breaker
 8.Safety Controllers
 9. Relays
 10.Power Supplies
 11.Manual Motor Starter
 12.Contacts & Connectors

13.Wires & Cables
 14.Fans & Fan Accessories
 15.DIN Rails

Control Cabinet Layout

[Main On/Off Switch]

[Circuit Breaker / Fuse]

[E-Stop Button]

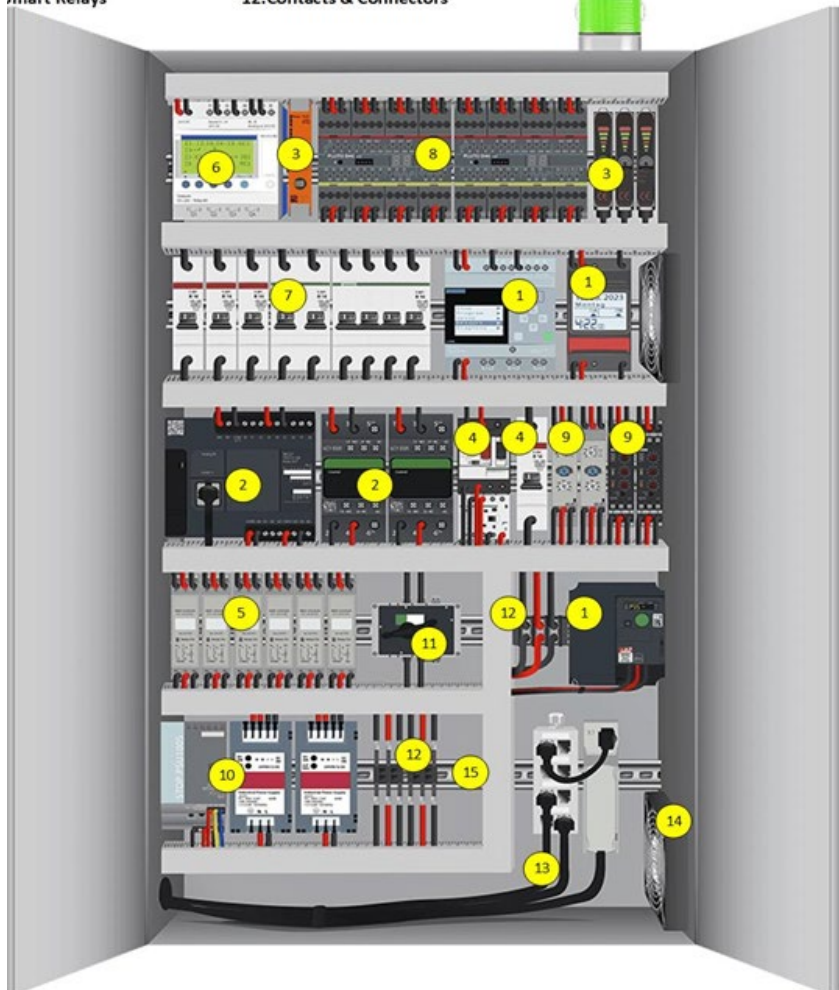
[AC → DC Power Supplies]

[24V / 12V / 5V Terminal Blocks]

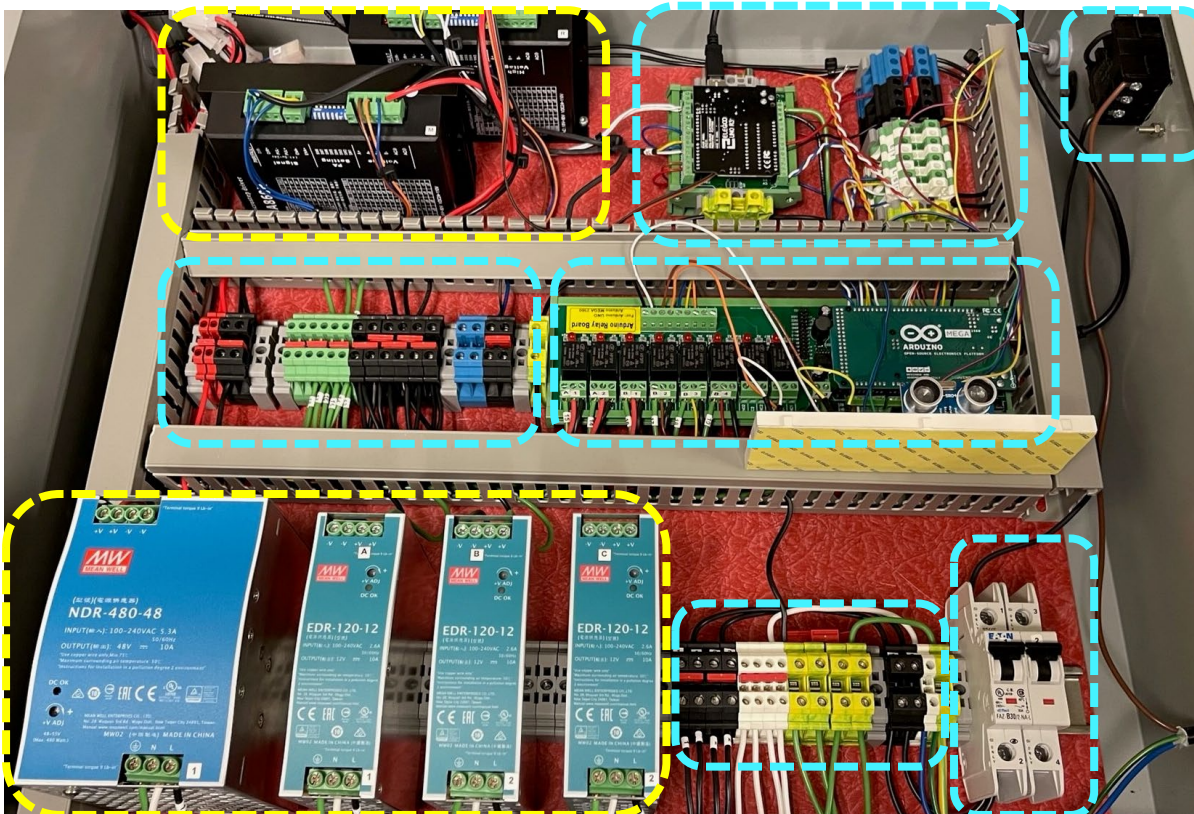
[Microcontroller / I/O Modules]

[Relays / Contactors / Output Devices]

[Wire Duct / Ground Bar]



Control Cabinet Layout



General Layout Philosophy

- Organize components into **zones**:
 - **High voltage (AC)** area (e.g., 120VAC mains input)
 - **Low voltage (DC)** area (5V, 12V, 24V)
 - **Control & signal section** (e.g., microcontroller, I/O modules, HMIs)
 - **Safety section** (e-stop, fuses, breakers)
- **Top-to-bottom flow** is common:
 - **Top:** Power entry
 - **Middle:** Power conversion & distribution
 - **Bottom:** Control electronics

Control Cabinet Layout



2. AC Power Section (Line Voltage: 120VAC)

- **Main disconnect or on/off switch:**
 - Should be easily accessible from outside or just inside the panel.
 - Label clearly.
- **Fuses or circuit breakers:**
 - Protects wiring and downstream components.
 - Must be rated appropriately for load and wire gauge.
- **E-stop:**
 - Positioned prominently on the cabinet or external panel.
 - Should **cut power to dangerous components** only, not necessarily all electronics.

Control Cabinet Layout



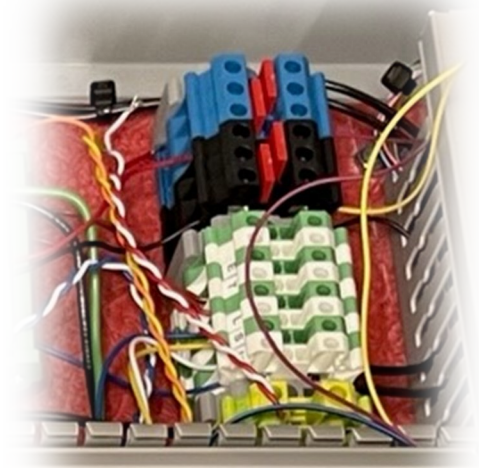
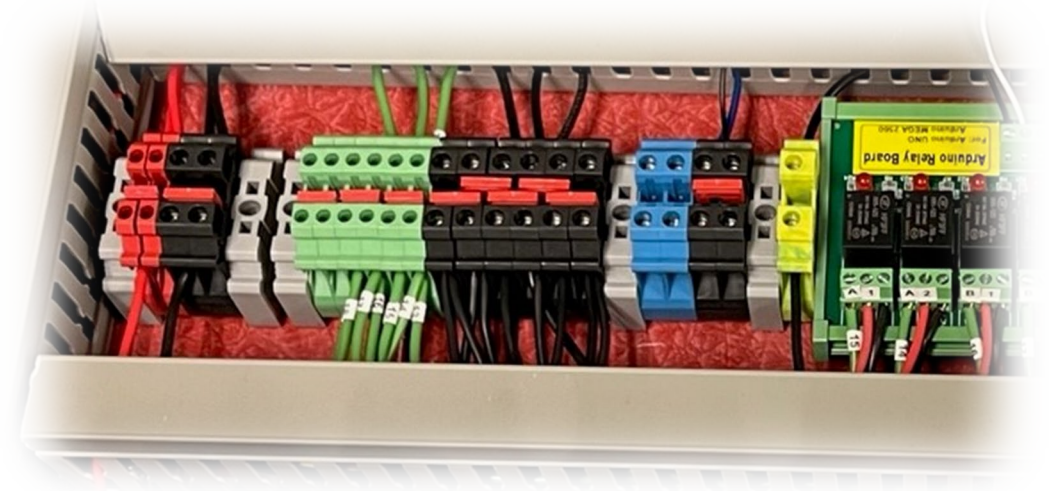
3. Power Supplies (AC to DC Conversion)

- Install DIN rail-mounted **power supplies** (120VAC → 24VDC, 12VDC, 5VDC).
- Power supplies should be mounted with adequate spacing (usually 20–50 mm) for heat dissipation.
- Mount vertically if recommended by the manufacturer.
- **24VDC is often the primary industrial control voltage.** Use step-down converters or buck regulators for 12V and 5V.

Control Cabinet Layout

4. DC Power Distribution (24VDC / 12VDC / 5VDC)

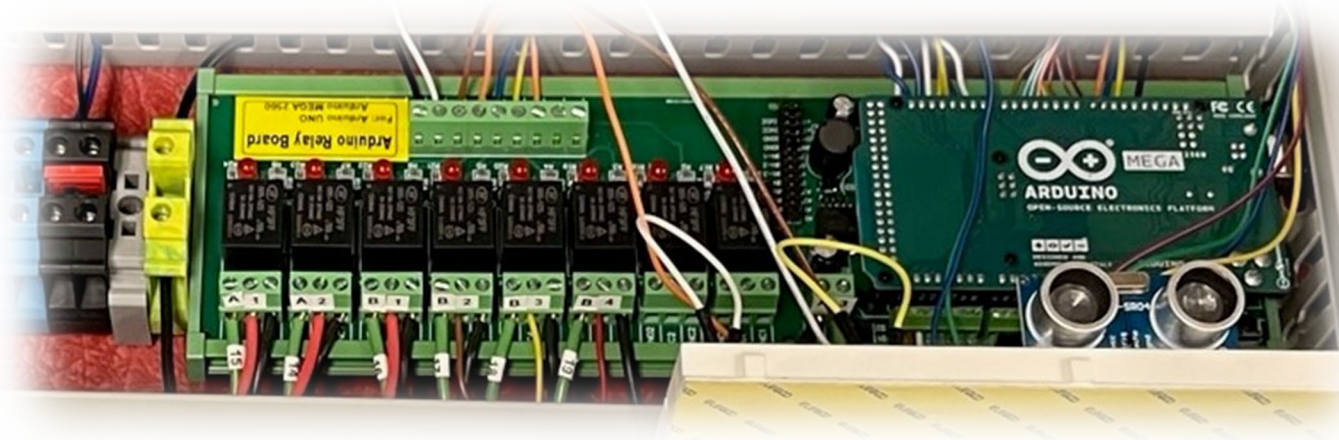
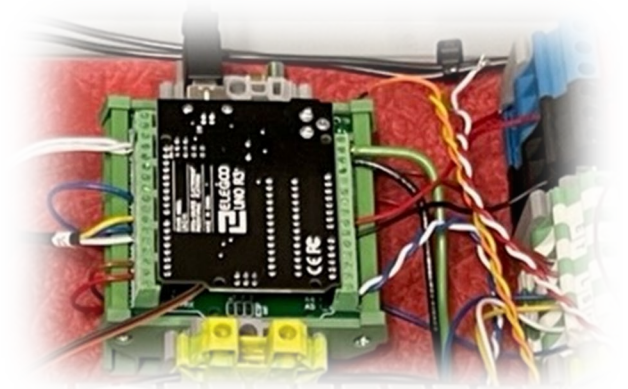
- Use **separate terminal blocks or bus bars** for each voltage level.
- Label all terminals clearly (e.g., 24V+, 24V-).
- Avoid routing 5V or signal lines near AC wiring to reduce noise/interference.



Control Cabinet Layout

5. Microcontroller & Logic Area

- Keep this section isolated (electrically and physically) from AC.
- Mount Arduino, ESP32, or PLC on **non-conductive standoffs** or DIN rail adapters.
- Use proper shielding for analog/digital I/O.



Control Cabinet Layout

6. DIN Rail & Terminal Block Layout

- Group terminal blocks by function (power, inputs, outputs, grounds).
- Use **color coding**:
 - Red = +24VDC
 - Black or Blue = DC Negative (or neutral)
 - Black = AC hot
 - White = Neutral
 - Green/Yellow = Ground
- Use **jumper bars** where needed and label each terminal.
- Leave room for wire ducts as needed.



Control Cabinet Layout

7. Wire Management

- Use **wire duct** with snap-on covers.
- Separate AC and DC wiring inside the duct (run on opposite sides if needed).
- Route **signal and communication wires** (e.g., I2C, UART) separately from power.
- Follow **minimum bend radius** and avoid sharp kinks.



Control Cabinet Layout

8. Safety & Grounding

- Always connect chassis ground (earth) to metal enclosure and all grounded terminals.
- Use a ground bar or terminal block for consistent grounding.

9. Labeling & Documentation

- Label:
 - Wires (both ends)
 - Terminal blocks
 - Components (use engraved tags or stickers)
- Maintain a panel wiring diagram inside the enclosure or attached in a weatherproof pouch.



Industrial Control Panel Resource

[https://www.youtube.com/
channel/UC5jmMHoUvdXg
9z77S4LFpVw](https://www.youtube.com/channel/UC5jmMHoUvdXg9z77S4LFpVw)

The screenshot shows the YouTube channel page for RSP Supply. At the top is a blue banner with the 'RSP SUPPLY EDUCATION Series' logo. Below the banner is the channel's profile picture, name 'RSP Supply', and handle '@RSPSupply'. It shows 91.2K subscribers and 276 videos. A description states they are an authorized distributor of industrial hardware, power, communication, and more, with links to 'rspsupply.com' and '4 more links'. A 'Subscribe' button is present. Navigation tabs for 'Home', 'Videos', 'Playlists', and 'Posts' are visible. The 'Our Playlists' section features five video thumbnails with titles: 'Terminal Blocks' (5 videos), 'Industrial Control Panels' (27 videos), 'Industrial Ethernet' (8 videos), 'Industrial Electrical' (50 videos), and 'Industrial Batteries' (4 videos). Each thumbnail includes a 'View full playlist' link. The 'Popular videos' section at the bottom shows a row of video thumbnails.

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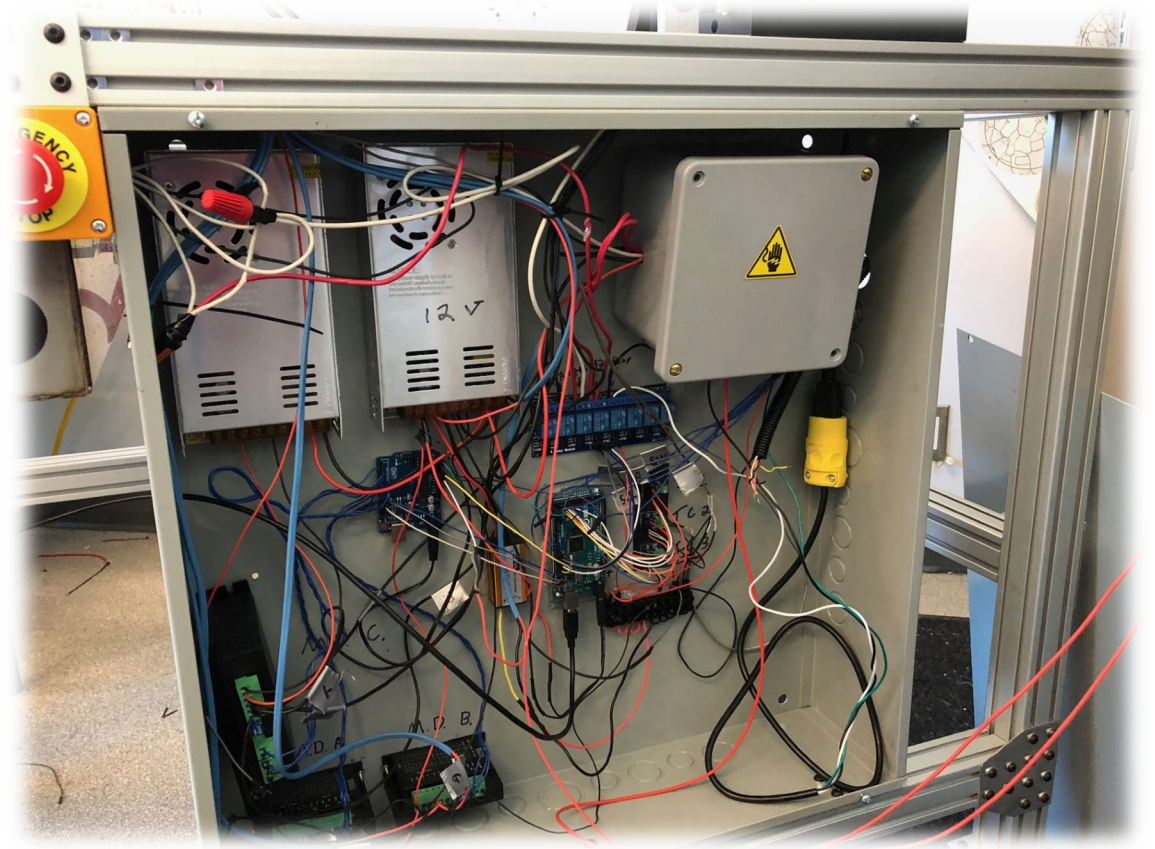
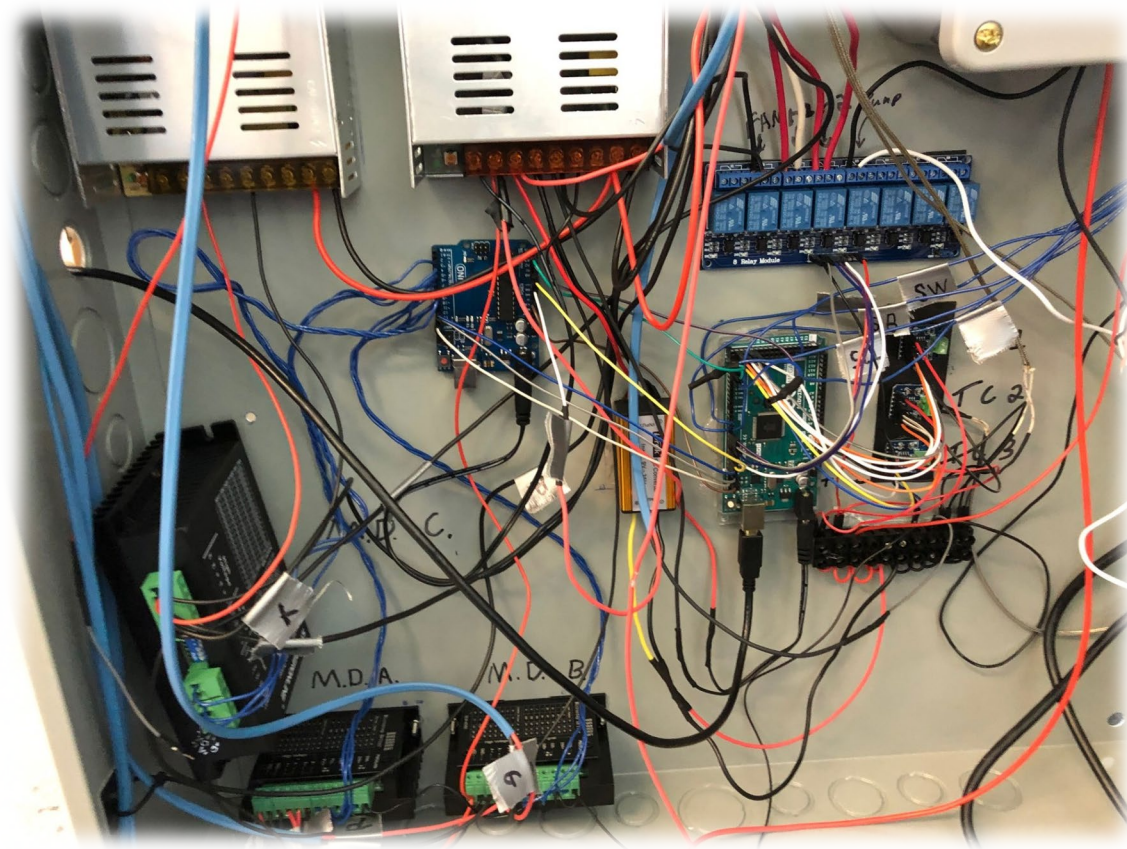
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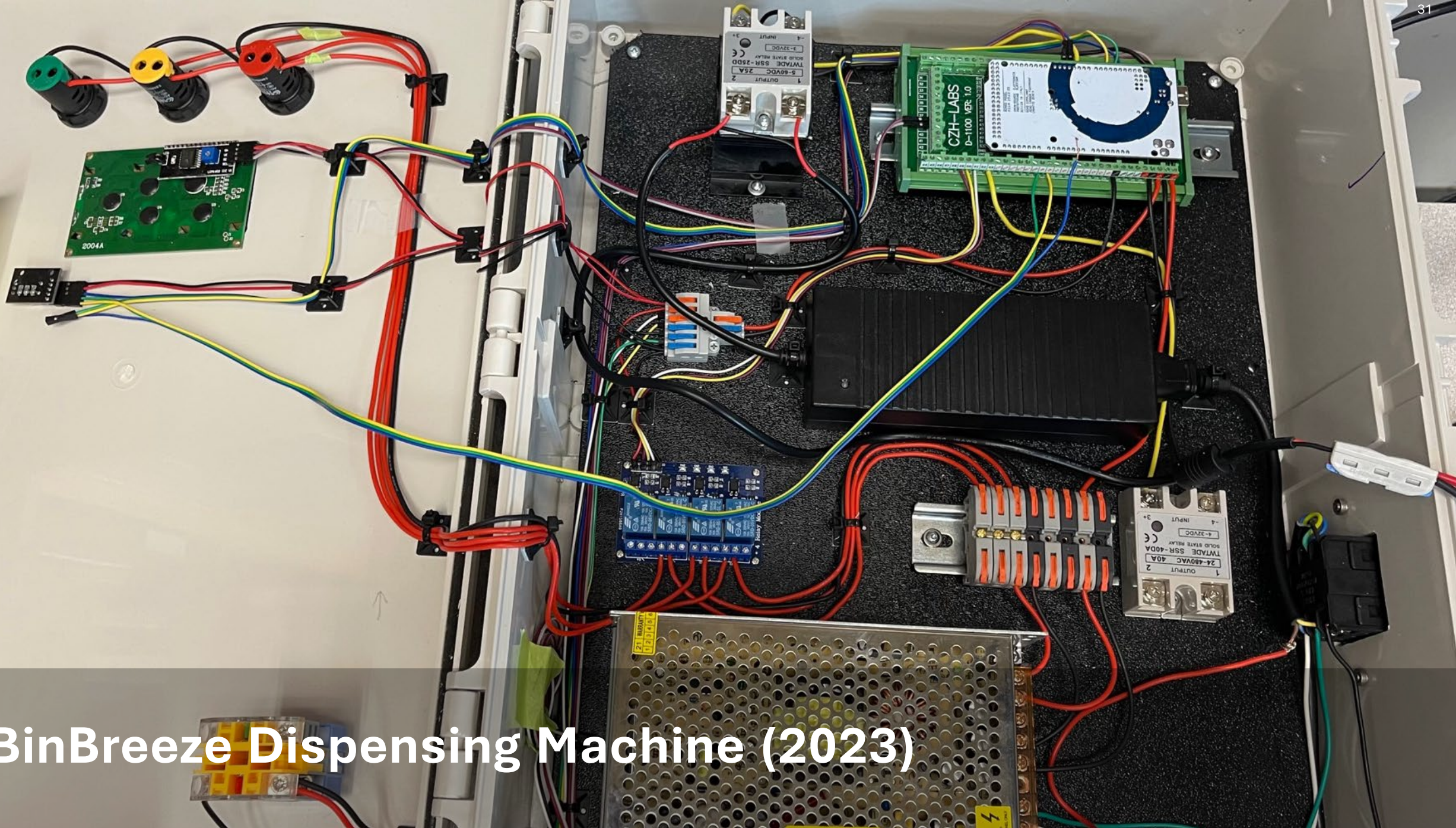


Nature Bee Fabric Waxing Machine (2019)

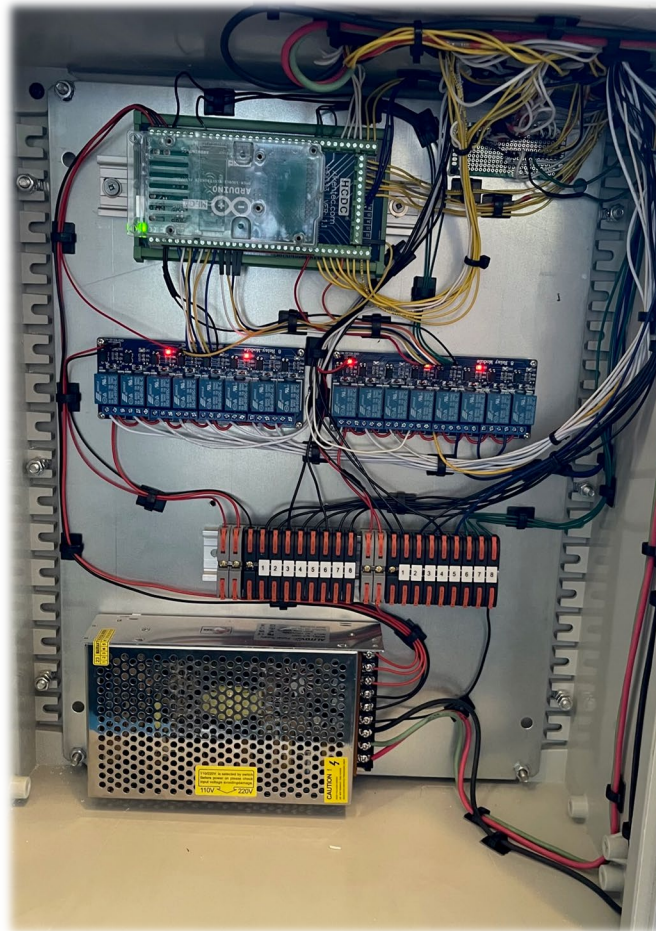
Nature Bee Fabric Waxing Machine (2023)



BinBreeze Dispensing Machine (2023)



Custom Controllers

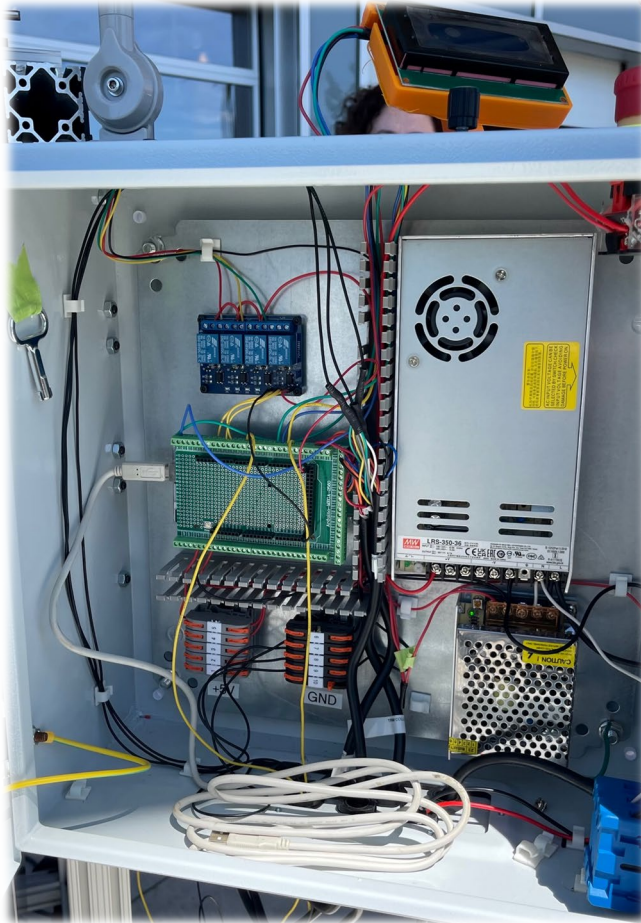


Cider bottling machine (2023)

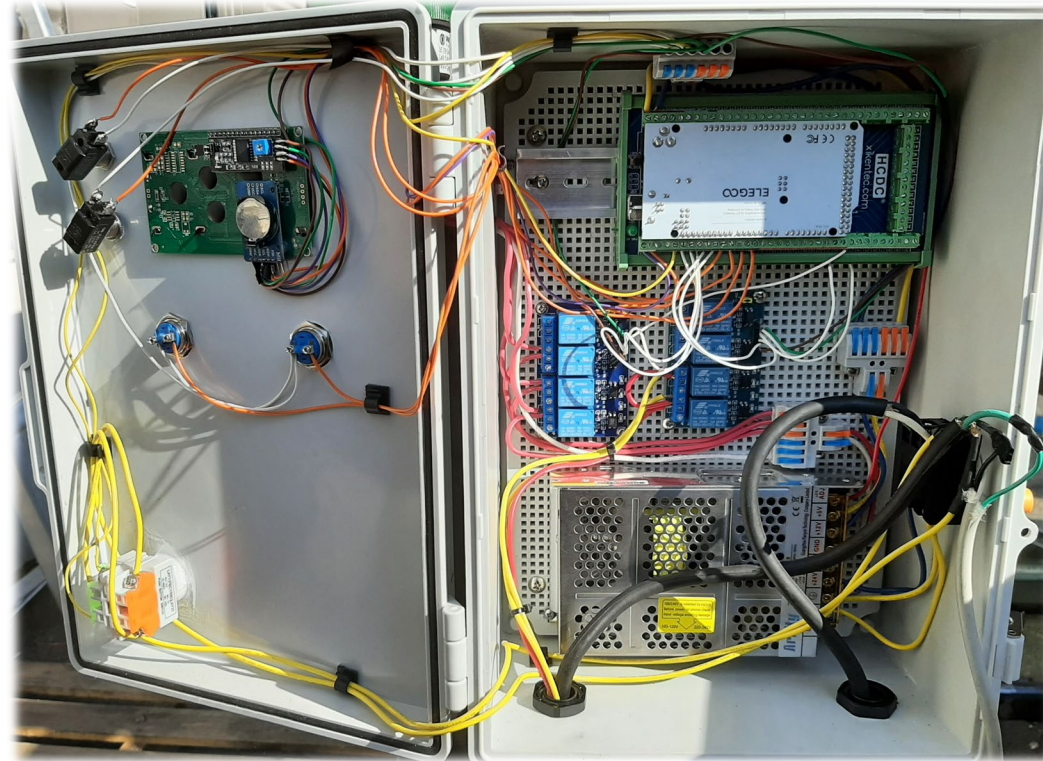


**Shawnigan Waterworks filter cleaning
machine (2022)**

Custom Controllers



**Beeswax fabric cutting machine
(2023)**



Automated Composting Machine (2024)



THANK YOU!

