



# Integration of Open-Source Controls and Sensors in a Low-Cost Desktop CNC Mill

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## Introduction

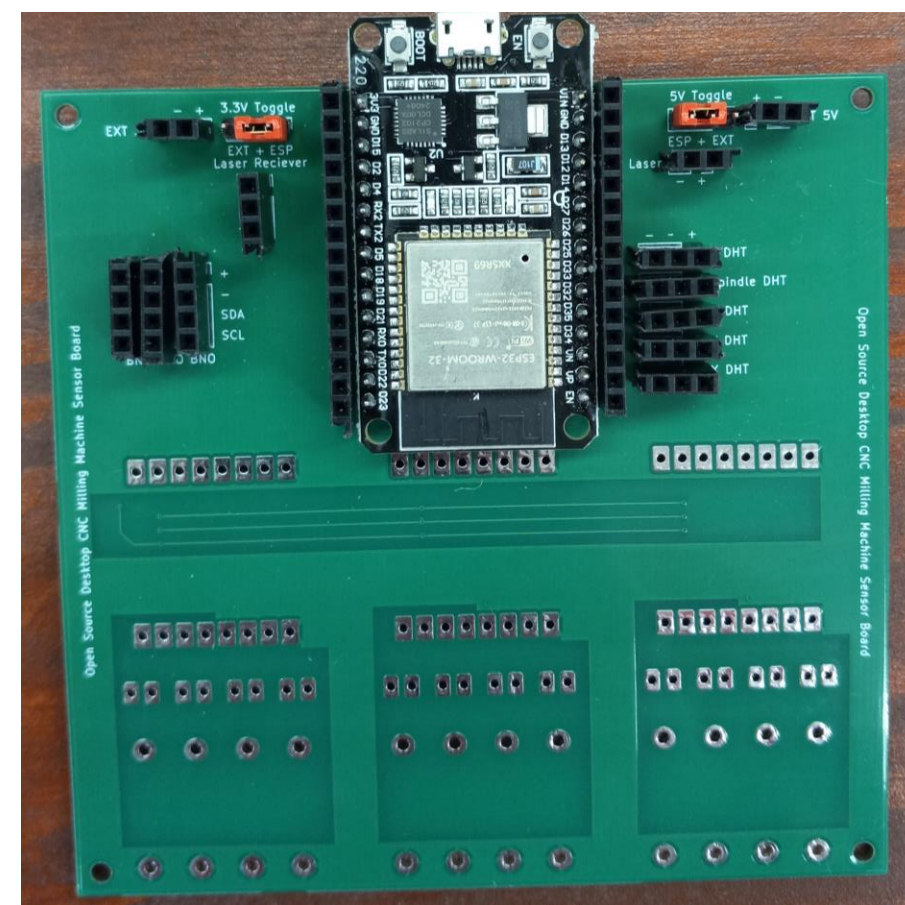
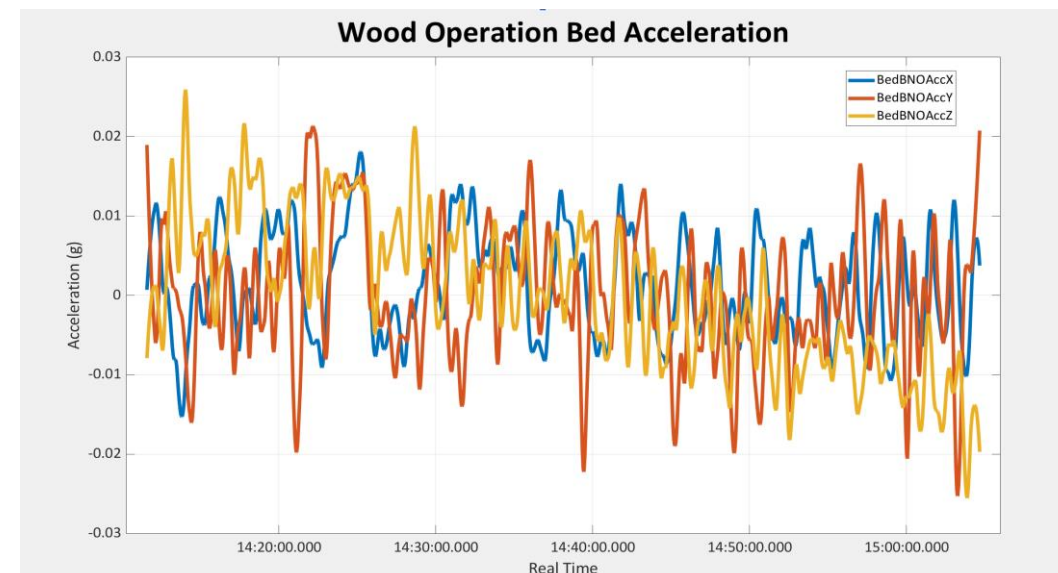
**Objective:** Integrate an improved control architecture and sensor suite into an open-source computer-numerical-control (CNC) mill for students and hobbyists.

**Impact:** An open-source desktop CNC machine for WPI students and hobbyists increases access to CNC machining on campus.

## Requirements

- Customizable open-source software and firmware
- Functionality verification: accelerometers, temperature sensors, tolerance measurements, and dial indicator
- Robust safety systems
- Automatic tool changer, fourth axis, and *Raspberry Pi* computer addons
- Mechanical bed leveling

## Testing and Validation



### Sensors:

- 3 BNO and 2 WitMotion accelerometers
- 4 DHT temperature sensors
- 1 Tachometer
- 1 dial indicator

### Data Collected:

- Orientation and linear acceleration of frame, table, gantry, and bed
- Temperature of x, y, z, and spindle motors

### Validation:

- 0.15% travel error
- Runs softwood, teflon, and 6061 aluminum
- 50 RPM max spindle deviation
- Bed leveled within 0.0045"

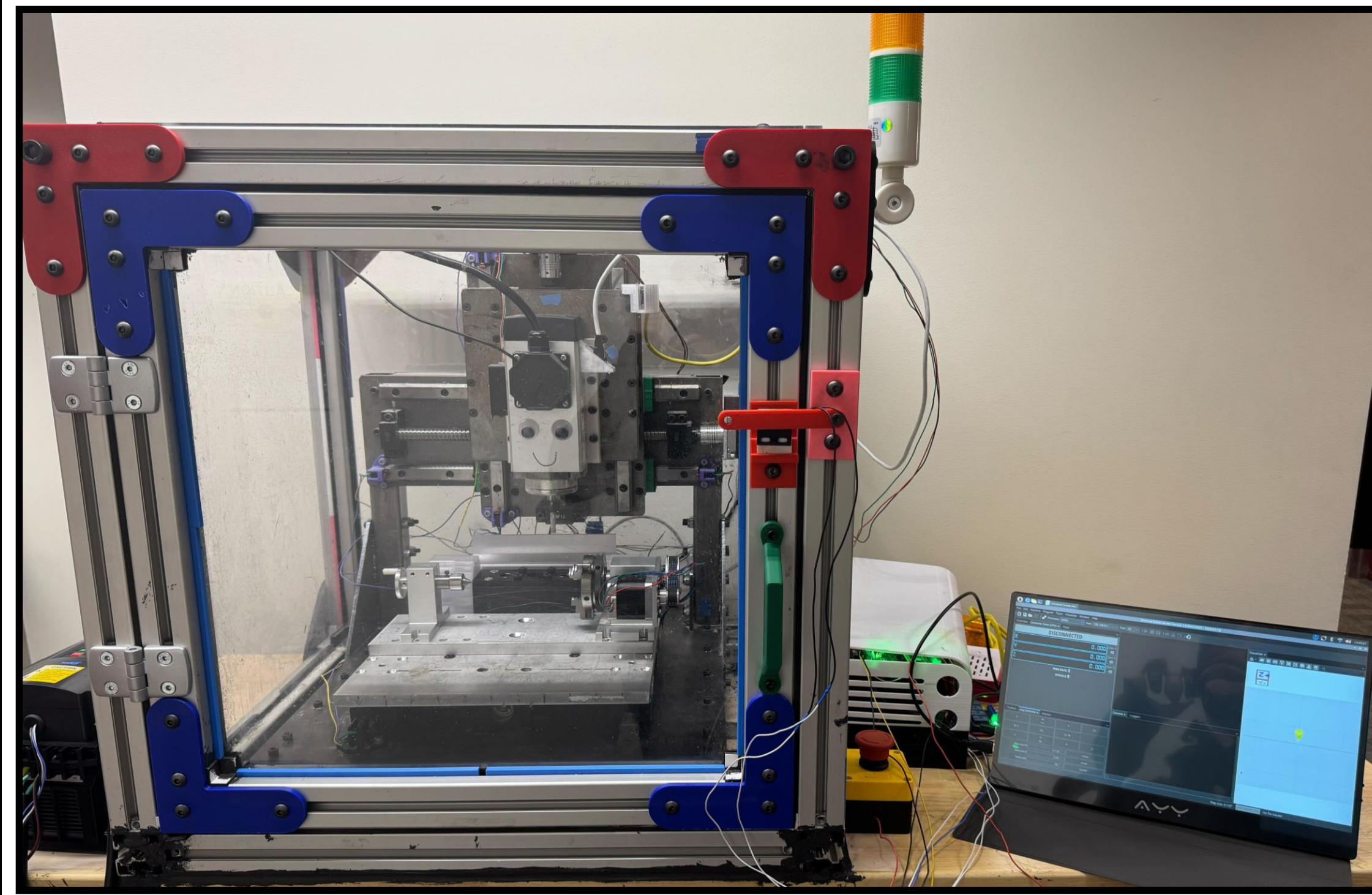
### Mach3:

- 0.006" avg. tolerance error
- 43° C max motor temps
- Max 0.15g on gantry

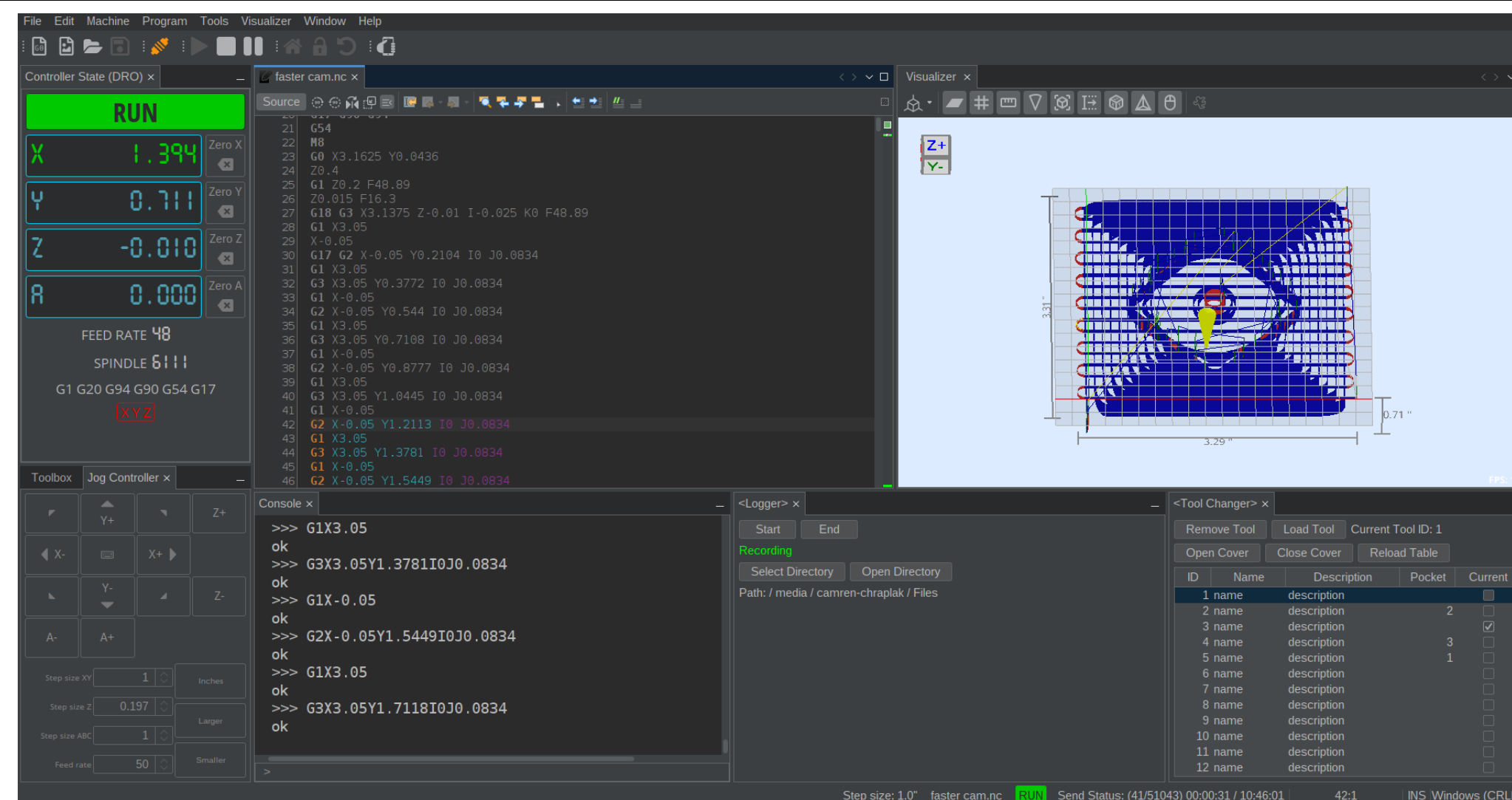
### grblHAL:

- 0.002" avg. Tolerance error
- 42° C max motor temps
- Max 0.15g on gantry

## CNC Machine Design



## Software and Firmware



### UGS Logger Plugin:

- Store G-Code commands
- Store machine position, feed rate, and spindle speed

### UGS Tool Table Plugin:

- Position tools in pockets and spindle
- Actuate servo dust cover
- Command tool changes
- Select tool to exchange

### grblHAL Stack Light Plugin:

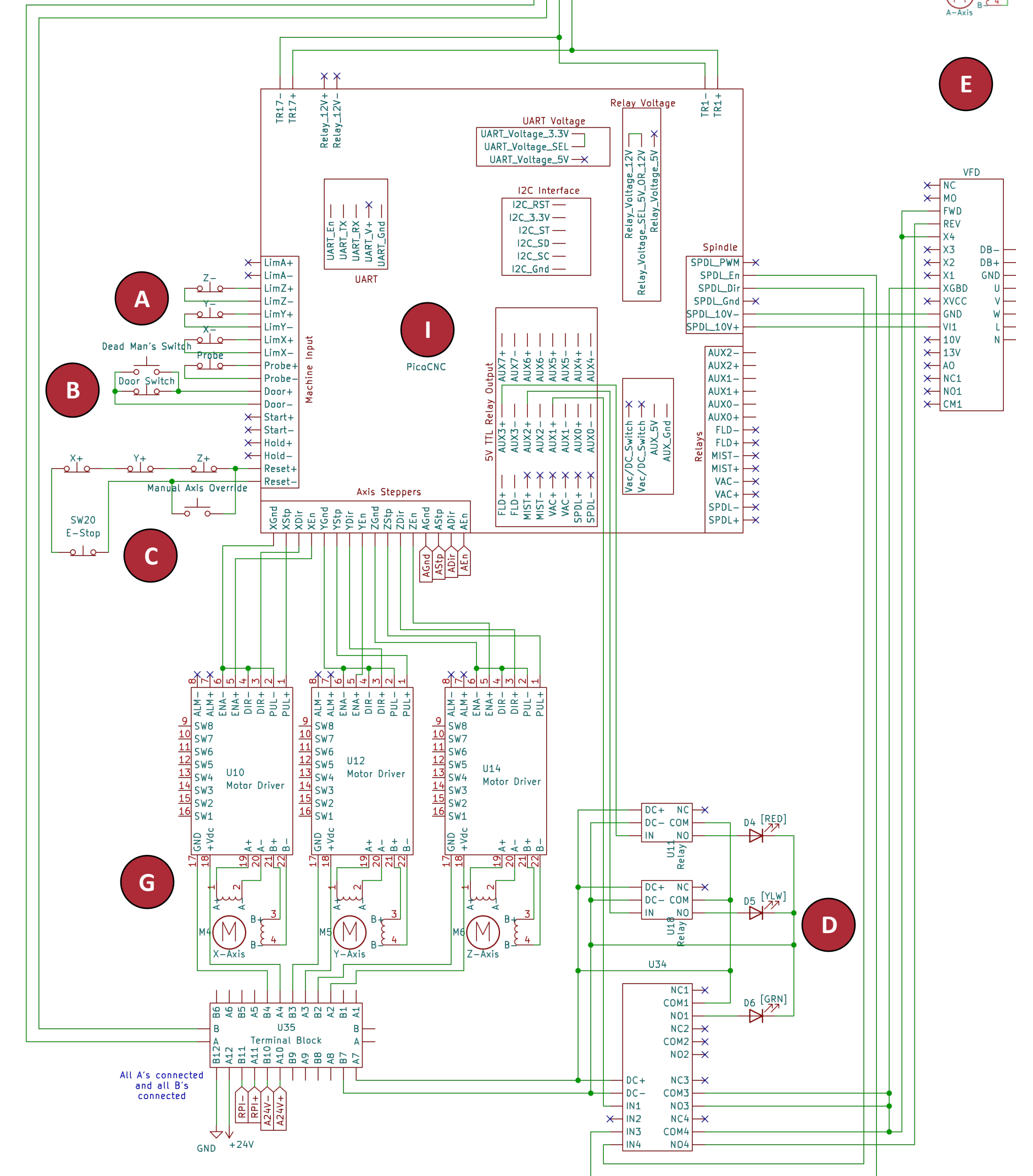
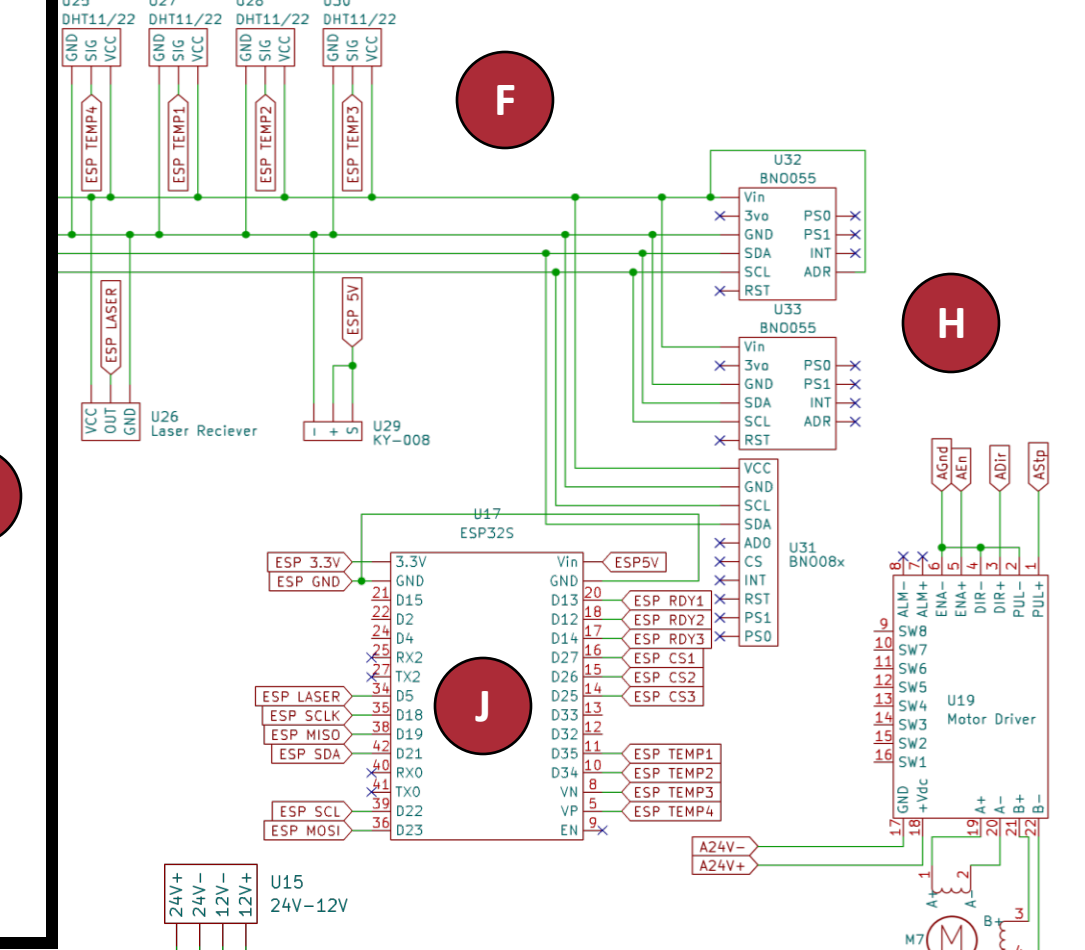
- Control LEDs from machine state

### grblHAL Automatic Tool Change Plugin:

- Replace preset tool change implementation
- Control motion paths for tools
- Integrate with existing architecture
- Check tool changes for issues
- Set custom firmware settings

## Electrical Design

- Limit Switches **A**
- Door Latch **B**
- E-Stop **C**
- Stack Lights **D**
- Spindle Control **E**
- DHT Temperature Sensors **F**
- Axis Motors **G**
- BNO Accelerometer **H**
- PicoCNC **I**
- ESP32 Microcontroller **J**



## Future Recommendations

- Mitigate EMI issues to prevent sensor errors
- Tune motor trajectory curve to reduce acceleration
- Increase assortment of integrated sensors for analysis
- Overhaul wire management system