Dwight Look College of ENGINEERING TEXAS A&M UNIVERSITY

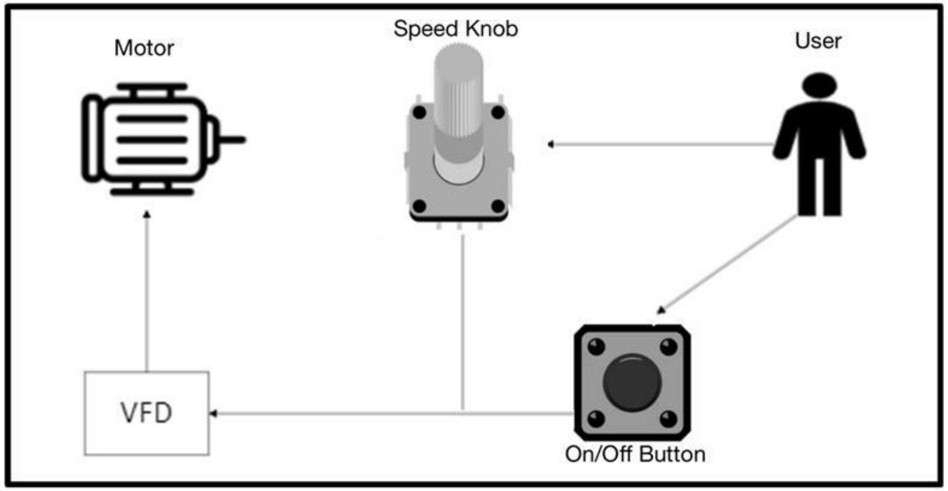
ECEN 404 Final Presentation
Team 70: VFD Motor Controller

Mackenzie Miller
Andrew Nguyen
Aidan Rader
Ryan Regan
TA: Ali Alenezi
Sponsor: John Lusher

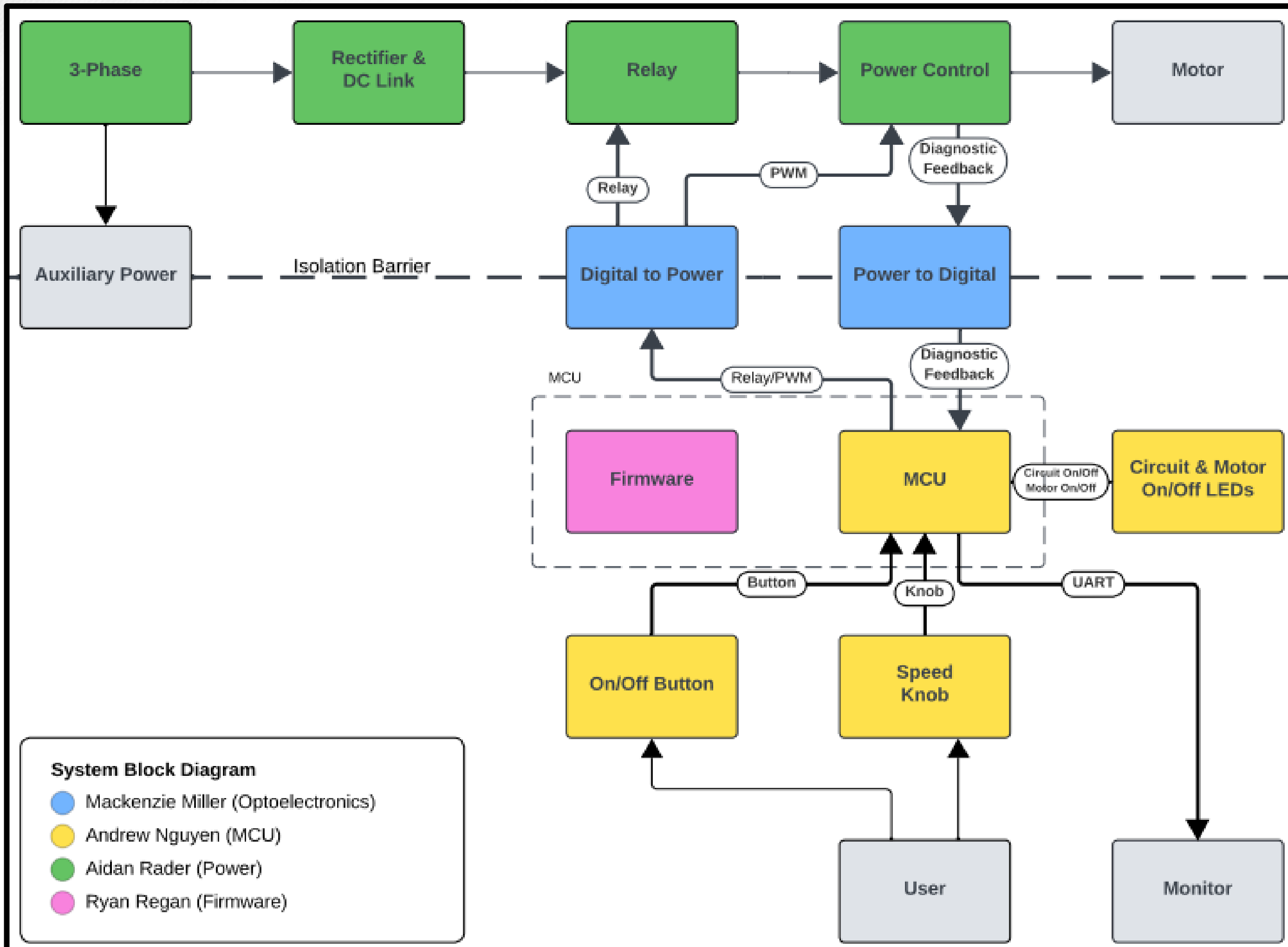
Project Overview

- Problem: Traditional motor control systems cannot adjust to varying load demands, resulting in poor energy efficiency, excessive heat generation, and premature component failure

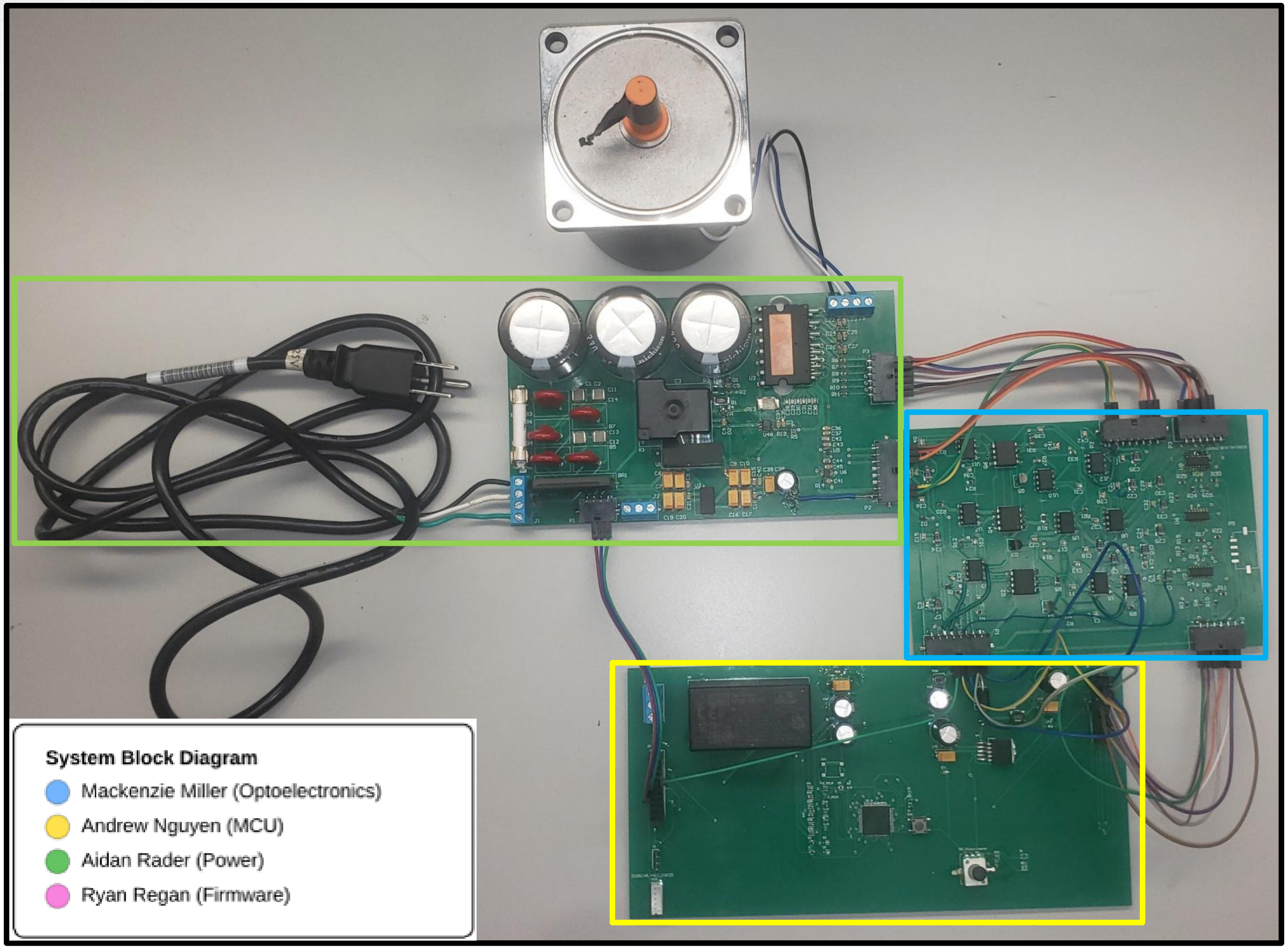
- Solution: Develop a Variable Frequency Drive (VFD) motor control system to adjust frequency and voltage to load demands



Project Overview – Block Diagram



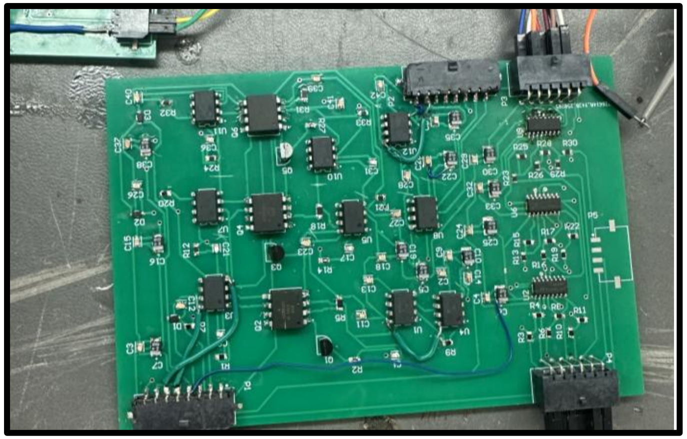
Integrated System Diagram



Engineering Design Accomplishments

Mackenzie Miller

- Completed digital isolation PCB design
- Tested and validated digital isolation circuit – 3.3V in, 5V out
    - 6 PWM signals – 3 phases H and L
- Tested and validated relay signal isolation
- PWM output responds to potentiometer
- Completed analog isolation PCB design
    - Voltage, temperature, and current
- Tested analog isolation 1:1 ratio
- Have yet to fully test feedback



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Engineering Design Accomplishments

Mackenzie Miller

PWM input	PWM output
1H – 3.3V	5V
1L – 3.3V	5V
2H – 3.3V	5V
2L – 3.3V	5V
3H– 3.3V	5V
3L – 3.3V	5V

Challenges/Solutions

Mackenzie Miller

Challenges:

- Lack of knowledge/experience
  - Altium
  - PCB design
  - Proper testing
- Trace Errors
  - Vcc and GND switched on opamps – resulted in voltage drop
  - 3.3V not connected to digital isolators
- Getting all components to work at the same time

Solutions:

- Trial and error, asking questions, learned as time went on
- Rerouted and ordered new board/cut traces and blue
  - Fixed some unrouted capacitors
  - Rearranged connectors for convenience
  - Manually switched Vcc and GND with blue wire
- Replaced parts as needed, once trace errors were fixed, this problem lessened

Engineering Design Accomplishments

Andrew Nguyen

- Designed and tested 3.3V buck converter
- Designed and tested AC/DC converter
- Verified that the MCU received 3.3V to all the necessary pins
- Successfully flashed firmware onto PCB using Pickit5
- MCU sends relay signal
- Button turns motor on and off
- MCU sends correct PWM signals
- Potentiometer functions properly

PWM output after flashing code

Engineering Design Accomplishments

Andrew Nguyen

Load [mA]	V_{out} [V]
0	3.2993
30	3.2952
50	3.2824
72	3.2812
95	3.2601
122	3.2512
153	3.2243

Buck Converter Load Regulation Test

V_{in} [V]	V_{out} [V]
16.0	3.3003
15.5	3.2997
15.0	3.2997
14.5	3.2995

Buck Converter Line Regulation Test

V_{in} [VAC]	V_{out} [VDC]
118 (wall)	15

AC/DC Converter Test

Challenges/Solutions

Andrew Nguyen

Challenges:

- Lack of PCB design knowledge
- Flashing the firmware onto the MCU
- Making sure the MCU received 3.3V to all the proper pins

Solutions:

- Researched, worked with team and others, lots of trial and error, asked questions
- Ensured the AVDD pin received 3.3V by rerouting board (originally blue wired) and switched to a new Pickit5 since the Pickit4 was faulty
- Rerouted PCB, adjusted trace widths accordingly for ground and the AC/DC converter and buck converter outputs, changed resistors and capacitors

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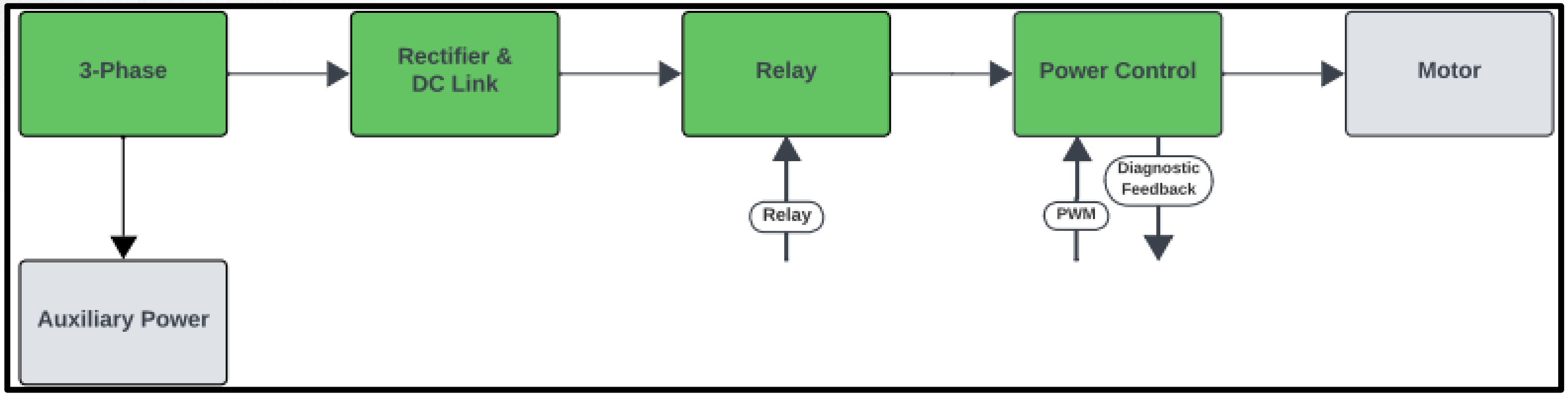
Engineering Design Accomplishments

Aidan Rader



15 V_{DC} to Isolated 15 V_{DC} Converter

V_{in} [V]	$V_{in,pp}$ [mV]	V_{out} [V]	$V_{out,pp}$ [mV]
9.1	200	15.1	400
15.1	500	15.0	400
20.9	500	14.9	400
27.0	500	15.3	500
33.0	578	14.9	264
35.8	503	14.9	264

3.3 V_{DC} to Isolated 5 V_{DC} Converter

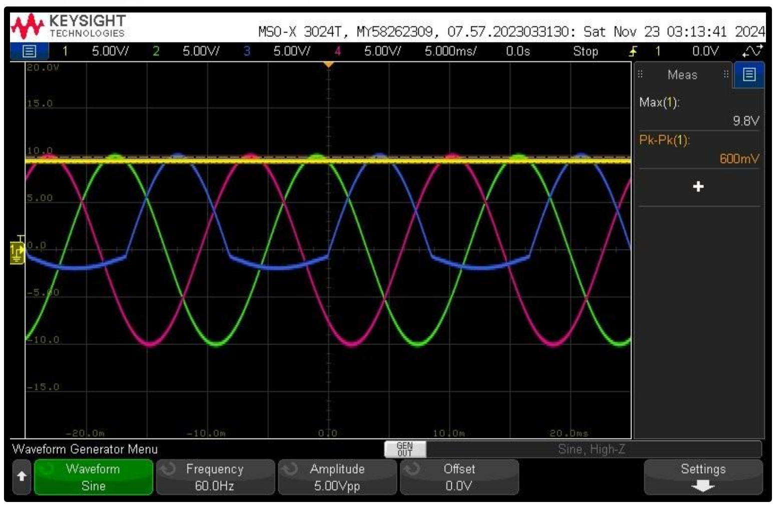
V_{in} [V]	$V_{in,pp}$ [mV]	V_{out} [V]	$V_{out,pp}$ [mV]
2.8	500	4.9	500
3.2	500	4.8	500
3.3	500	5.3	500
3.6	500	5.7	500

Engineering Design Accomplishments

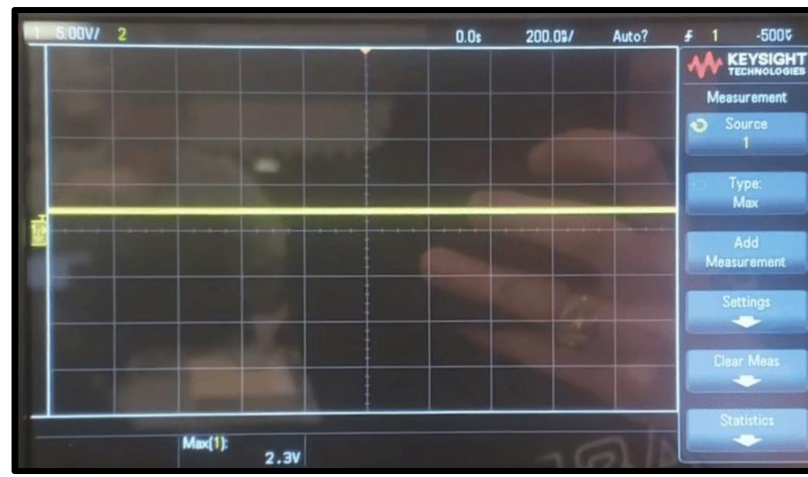
Aidan Rader

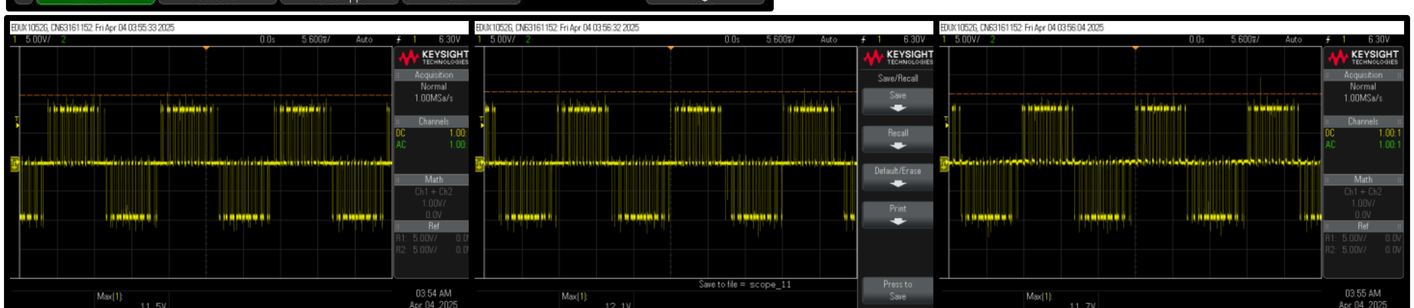
- Diagnostic feedback: voltage, current, temperature, in progress

Rectifier & DC Link



Relay





Power Control

Challenges/Solutions

Aidan Rader

Challenges:

- Lack of knowledge over power electronics
- Lack of knowledge on electronic load testing
- Missing and incorrectly routed traces on original board
- High voltage testing fried rectifier and traces

Solutions:

- Conducted research and registered in ECEN 438 (Power Electronics)
- Conducting research and postponing test
- Designed new board and blue-wired remaining trace errors
- Replaced rectifier and blue-wired traces, worked on high voltage testing with Professor, and pushed high voltage testing to the end of the project

Engineering Design Accomplishments

Ryan Regan

- Wrote a C language program in MPLAB X IDE to instruct a dsPIC33CK256MP508 microcontroller as part of a Variable Frequency Drive
  - Three phase PWM signals
    - Oscillating duty cycles
    - Sine wave table
    - Potentiometer
    - Timing
  - Relay start/stop button
  - (In progress) Diagnostic feedback signals

- Learned how to solder and desolder to increase team efficiency

Challenges/Solutions

Ryan Regan

Challenges:

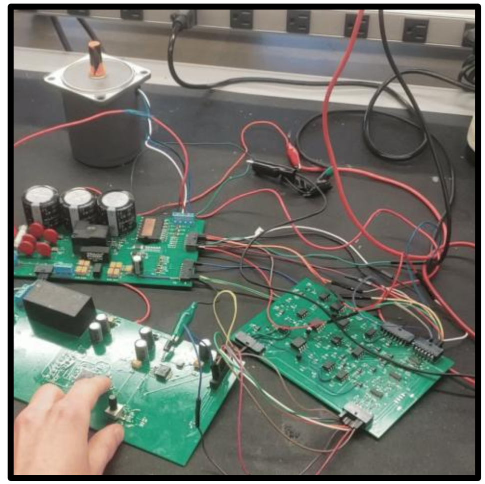
- Lack of experience working with MPLAB X IDE and C code
- Several varying issues with code
  - Frequency range too low
- Issues with integrations
  - Flashing firmware onto Microcontroller PCB
  - Sending PWM signals through Optoelectronics PCB

Solutions:

- Read through user's manual for development board and microcontroller, and watched instructional videos on people programming similar controllers with MPLAB X IDE
- Debugged and learned more about MPLAB's Code Configurator
  - Put PWM function under a timer interrupt so the print statements would not affect frequency
- Helped teammates with finding problematic components between integrations
- Learned how to solder and desolder to increase efficiency

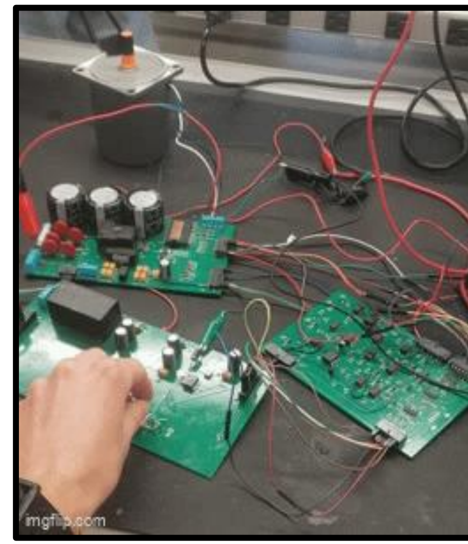
Integrated System Results

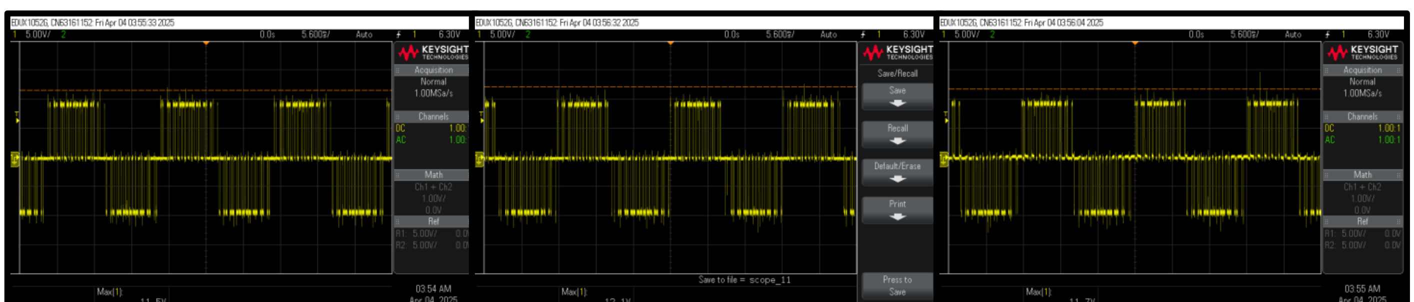
- Motor On/Off LED
- Circuit On/Off LED
- Diagnostic Feedback



On/Off Button

Speed Knob





PWM Signals

Conclusions

System Design Changes:
- Removed tachometer
- Added computer/monitor for UART console in diagnostic feedback

Current Status:
- Integration and low voltage testing complete except for diagnostic feedback:
  - diagnostic feedback to be completed by 4/22
- Validation ongoing:
  - to be completed by 4/24
- High voltage testing incomplete:
  - to be completed on 4/24

Conclusions

Paragraph #	Test Name	Success Criteria	Methodology	Status	Responsible Engineer(s)
FSR 1	15 V_{DC} to Isolated 15 V_{DC} Conversion	Power converters shall convert 15 V_{DC} to isolated 15 V_{DC}.	Apply 15 V_{DC} input using a DC power supply. Verify 15 V_{DC} output using an oscilloscope.	Tested	Aidan
FSR 1	15 V_{DC} to 3.3 V_{DC} Conversion	Power converters shall convert 15 V_{DC} to 3.3 V_{DC}.	Apply 15 V_{DC} input using a DC power supply. Verify 3.3 V_{DC} output using an oscilloscope.	Tested	Drew
FSR 1	3.3 V_{DC} to Isolated 5 V_{DC} Conversion	Power converters shall convert 3.3 V_{DC} to isolated 5 V_{DC}.	Apply 3.3 V_{DC} input using a DC power supply. Verify 5 V_{DC} output using an oscilloscope.	Tested	Aidan
FSR 1	Low Voltage Auxiliary Power	System shall convert 15 V_{DC} to isolated 15 V_{DC} , 3.3 V_{DC}, and isolated 5 V_{DC}.	Apply 15 V_{DC} input using a DC power supply. Verify 15 V_{DC} , 3.3 V_{DC}, and 5 V_{DC} outputs using an oscilloscope.	Tested	Mackenzie, Drew, Aidan
FSR 1	120 V_{AC} to 15 V_{DC} Conversion	Power converters shall convert 120 V_{AC} to isolated 15 V_{DC}.	Apply 120 V_{AC} input using a 120 V_{AC} outlet. Verify 15 V_{DC} output using an oscilloscope.	Tested	Drew
FSR 1	120 V_{AC} Auxiliary Power	System shall convert 120 V_{AC} to 15 V_{DC}, isolated 15 V_{DC} , 3.3 V_{DC}, and isolated 5 V_{DC}.	Apply 120 V_{AC} input using a 120 V_{AC} outlet. Verify 15 V_{DC}, 15 V_{DC} , 3.3 V_{DC}, and 5 V_{DC} outputs using an oscilloscope.	Tested	Mackenzie, Drew, Aidan
FSR 1	208 V_{AC} to 15 V_{DC} Conversion	Power converters shall convert 208 V_{AC} to isolated 15 V_{DC}.	Apply 208 V_{AC} input using a 208 V_{AC} outlet. Verify 15 V_{DC} output using an oscilloscope.	Untested	Drew
FSR 1	208 V_{AC} Auxiliary Power	System shall convert 208 V_{AC} to 15 V_{DC}, isolated 15 V_{DC} , 3.3 V_{DC}, and isolated 5 V_{DC}.	Apply 208 V_{AC} input using a 208 V_{AC} outlet. Verify 15 V_{DC}, 15 V_{DC} , 3.3 V_{DC}, and 5 V_{DC} outputs using an oscilloscope.	Untested	Mackenzie, Drew, Aidan
FSR 2	Relay	Relay shall toggle the motor with the relay signal.	Apply 15 V_{DC} coil voltage, 10 V_{DC} contact voltage, and 5 V_{DC} relay signal using a DC power supply. Verify 10 V_{DC} output using an oscilloscope.	Tested	Aidan
FSR 2	Relay Signal Isolation	Digital to power shall convert the relay signal from 3.3 V_{DC} to 5 V_{DC}.	Apply 5 V_{DC} supply voltage, 3.3 V_{DC} supply voltage, and 3.3 V_{DC} relay signal using a DC power supply. Verify 5 V_{DC} output using an oscilloscope.	Tested	Mackenzie
FSR 2	Relay Signal Generation	MCU shall toggle the relay signal to 3.3 V_{DC} with the button signal.	Apply 3.3 V_{DC} supply voltage and 3.3 V_{DC} button signal using a DC power supply. Verify 3.3 V_{DC} output using an oscilloscope.	Tested	Drew, Ryan
FSR 2	Button Signal Generation	Button shall toggle the button signal to 3.3 V_{DC} with a button press.	Apply 3.3 V_{DC} supply voltage using a DC power supply and initiate a button press. Verify 3.3 V_{DC} output using an oscilloscope.	Tested	Drew
FSR 2	On/Off Button	System shall toggle the motor between on and off state with a button press.	Apply 15 V_{DC} coil voltage, 10 V_{DC} contact voltage, 5 V_{DC} supply voltage, and 3.3 V_{DC} supply voltage using a DC power supply. Initiate one button press and later a second button press. Verify the motor rotates after the first button press and stops after the second button press using a video.	Tested	All

Conclusions

Paragraph #	Test Name	Success Criteria	Methodology	Status	Responsible Engineer(s)
FSR 3	120 V_{AC} to 112 V_{DC} Rectification	Rectifier shall convert 120 V_{AC} to 112 V_{DC}.	Apply 120 V_{AC} input using a 120 V_{AC} outlet. Verify 112 V_{DC} output using an oscilloscope.	Tested	Aidan
FSR 3	208 V_{AC} to 296 V_{DC} Rectification	Rectifier shall convert 208 V_{AC} to 296 V_{DC}.	Apply 208 V_{AC} input using a 208 V_{AC} outlet. Verify 296 V_{DC} output using an oscilloscope.	Untested	Aidan
FSR 4	Power Control	Power control shall invert three high and three low 5 V_{DC} PWM signals into three modified sine waves.	Apply 40 V_{DC} bus voltage and 15 V_{DC} supply voltage using a DC power supply. Apply three high and three low 5 V_{DC} PWM signals at 120° phase shifts using a function generator. Verify three modified sine waves at 120° phase shifts using an oscilloscope.	Tested	Aidan
FSR 4	PWM Signal Isolation	Digital to power shall convert three high and three low PWM signals from 3.3 V_{DC} to 5 V_{DC}.	Apply isolated 5 V_{DC} supply voltage and 3.3 V_{DC} supply voltage using a DC power supply. Apply three high and three low 3.3 V_{DC} PWM signals at 120° phase shifts using a function generator. Verify three high and three low 5 V_{DC} PWM signals at 120° phase shifts using an oscilloscope.	Tested	Mackenzie
FSR 4	PWM Signal Generation	MCU shall generate three high and three low 3.3 V_{DC} PWM signals with the knob signal.	Apply 3.3 V_{DC} supply voltage and 3.3 V_{DC} speed knob signal using a DC power supply. Verify three high and three low 3.3 V_{DC} PWM signals at 120° phase shifts using an oscilloscope.	Tested	Drew, Ryan
FSR 4	Knob Signal Generation	Rotating potentiometer changes frequency to speed up and slow down motor.	Oscilloscope each signal output, spin knob and ensure the motor speed varies as expected.	Tested	Drew, Ryan
FSR 4	Low Voltage PWM Control	System shall change the motor speed with the knob signal.	Apply 40 V_{DC} bus voltage, 15 V_{DC} supply voltage, isolated 5 V_{DC} supply voltage and 3.3 V_{DC} supply voltage using a DC power supply. Verify the motor rotates at a different speed after a knob turn using a video.	Tested	All
FSR 4	112 V_{DC} PWM Control	System shall change the motor speed with the knob signal.	Apply 112 V_{DC} bus voltage, 15 V_{DC} supply voltage, isolated 5 V_{DC} supply voltage and 3.3 V_{DC} supply voltage using a DC power supply. Verify the motor rotates at a different speed after a knob turn using a video.	Untested	All
FSR 4	296 V_{DC} PWM Control	System shall change the motor speed with the knob signal.	Apply 296 V_{DC} bus voltage, 15 V_{DC} supply voltage, isolated 5 V_{DC} supply voltage and 3.3 V_{DC} supply voltage using a DC power supply. Verify the motor rotates at a different speed after a knob turn using a video.	Untested	All

Conclusions

Paragraph #	Test Name	Success Criteria	Methodology	Status	Responsible Engineer(s)
FSR 5	Motor On/Off Signal Generation	MCU shall toggle the motor on/off LED signal to 3.3 V_{DC} with the button signal.	Directly inject 15V to board and use multimeter at the VDD pins on MCU.	Tested	Drew, Ryan
FSR 5	Motor On/Off LED	System shall toggle the motor on/off LED between on and off states with the motor on/off signal.	Directly inject 15V to board, then press relay toggle button and ensure the second LED toggles.	Tested	Drew, Ryan
FSR 6	Circuit On/Off Signal Generation	MCU shall toggle the circuit on/off LED signal to 3.3 V_{DC} when the board receives power.	Directly inject 15V to board and use multimeter at the VDD pins on MCU.	Tested	Drew, Ryan
FSR 6	Circuit On/Off LED	System shall toggle the circuit on/off LED when the board is connected to power with the circuit on/off signal	Directly inject 15V to board and ensure the first LED turns on.	Tested	Drew, Ryan
FSR 7	Computer Display	MCU will display diagnostic feedback information to the UART console on a computer running MPLAB X IDE.	Connect system to MPLAB X IDE using a laptop and USB-UART cable. Verify diagnostic print statements are being output to UART console.	Untested	Drew, Ryan
FSR 7	Diagnostic Feedback Signal Isolation	Diagnostic feedback circuit shall convert the voltage, current, and temperature feedback signals from 60 VDC to 20 VDC.	Apply 15 VDC supply voltage, isolated 15 VDC supply voltage, and three 60 VDC feedback signals using a DC power supply. Verify three 15 VDC outputs using an oscilloscope.	Untested	Mackenzie
FSR 7	Diagnostic Feedback Signal Generation	Power Control shall generate 60 V_{DC} voltage, current, and temperature feedback signals.	Apply 40 V_{DC} bus voltage and 15 V_{DC} supply voltage using a DC power supply. Apply three high and three low 5 V_{DC} PWM signals at 120° phase shifts using a function generator. Verify three 60 V_{DC} outputs using an oscilloscope.	Untested	Aidan
FSR 7	Diagnostic Feedback	System shall send the voltage, current, and temperature signals to the computer display.	Each feedback signal will be verified through the UART console output.	Untested	All

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Thank you