# VFD Motor Controller

Mackenzie Miller
Andrew Nguyen
Aidan Rader
Ryan Regan

# EXECUTION AND VALIDATION PLAN

REVISION – 1
28 April 2025

# Execution Plan

| Exexcution Plan 8/20/2024-12/5/2024 | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 8/20 | 8/27 | 9/3 | 9/10 | 9/17 | 9/24 | 10/1 | 10/8 | 10/15 | 10/22 | 10/29 | 11/5 | 11/12 | 11/19 | 11/26 | 12/3 | Date |
| CONOPS Report | | | | | | | | | | | | | | | | | 9/15 |
| FSR, ICD, Milestones, & Validation Plan | | | | | | | | | | | | | Not Started | | | | 9/26 |
| Firmware: GUI Development/Testing | | | | | | | | | | | | | In Progress | | | | 9/24 |
| **Project Introduction Presentation** | | | | | | | | | | | | | Completed | | | | 9/30 |
| Optoelectronics: Subsystem Introduction Project | | | | | | | | | | | | | Behind Schedule | | | | 10/7 |
| Microcontroller: Subsystem Introduction Project | | | | | | | | | | | | | | | | | 10/7 |
| Parts Order 1 | | | | | | | | | | | | | | | | | 10/8 |
| Power: Subsystem Introduction Project | | | | | | | | | | | | | | | | | 10/14 |
| Firmware: Subsystem Introduction Project | | | | | | | | | | | | | | | | | 10/15 |
| Firmware: Develop Outline | | | | | | | | | | | | | | | | | 10/15 |
| **Project Update Presentation** | | | | | | | | | | | | | | | | | 10/21 |
| Firmware: Add Debug Print Statements to Outline | | | | | | | | | | | | | | | | | 10/22 |
| Firmware: Write to Demo Each Component Needed | | | | | | | | | | | | | | | | | 10/22 |
| Firmware: Single-Phase Potentiometer Duty Cycle Control | | | | | | | | | | | | | | | | | 10/29 |
| Optoelectronics: Schematic Layout | | | | | | | | | | | | | | | | | 10/29 |
| Power: DC Link Schematic Layout | | | | | | | | | | | | | | | | | 11/2 |
| Power: Rectifier Schematic Layout | | | | | | | | | | | | | | | | | 11/3 |
| Power: Power Control Schematic Layout | | | | | | | | | | | | | | | | | 11/4 |
| Microcontroller: Schematic Layout | | | | | | | | | | | | | | | | | 11/4 |
| Optoelectronics: PCB Layout | | | | | | | | | | | | | | | | | 11/5 |
| Microcontroller: PCB Layout | | | | | | | | | | | | | | | | | 11/5 |
| Power: PCB Layout | | | | | | | | | | | | | | | | | 11/5 |
| Optoelectronics: Order PCB | | | | | | | | | | | | | | | | | 11/5 |
| Microcontroller: Order PCB | | | | | | | | | | | | | | | | | 11/5 |
| Power: Order PCB | | | | | | | | | | | | | | | | | 11/5 |
| Parts Order 2 | | | | | | | | | | | | | | | | | 11/12 |
| Optoelectronics: PCB Assembly | | | | | | | | | | | | | | | | | 11/18 |
| Microcontroller: PCB Assembly | | | | | | | | | | | | | | | | | 11/18 |
| Power: PCB Assembly | | | | | | | | | | | | | | | | | 11/18 |
| Firmware: Convert PWM signal to three-phase | | | | | | | | | | | | | | | | | 11/18 |
| **Final Presentation** | | | | | | | | | | | | | | | | | 11/18 |
| Optoelectronics: Validation/Debugging | | | | | | | | | | | | | | | | | 11/26 |
| Microcontroller: Validation/Debugging | | | | | | | | | | | | | | | | | 11/26 |
| Power: Validation/Debugging | | | | | | | | | | | | | | | | | 11/26 |
| Firmware: Validation/Debugging | | | | | | | | | | | | | | | | | 11/26 |
| Project Subsystem Demonstration | | | | | | | | | | | | | | | | | 11/26 |
| Final Report | | | | | | | | | | | | | | | | | 12/5 |

*Figure 1: Execution Plan Fall 2024*

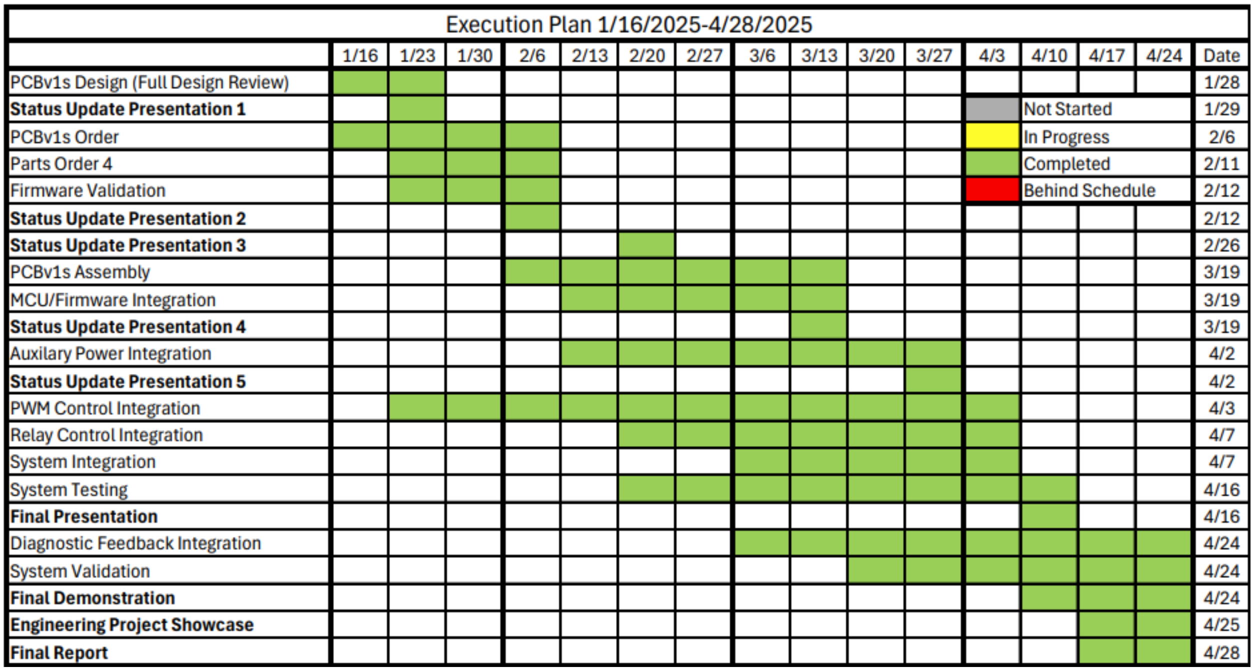

*Figure 2: Execution Plan Spring 2025*

# Validation Plan

| Paragraph # | Test Name | Success Criteria | Methodology | Status | Responsible Engineer(s) |
|---|---|---|---|---|---|
| 3.2.3.11 | 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 |
| 3.2.3.12 | 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 |
| 3.2.3.13 | 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 |
| 3.2.3.14 | Low Voltage Auxiliary Power | System shall convert 15 $V_{DC}$ to isolated 15 $V_{DC}$ , 3.3 $V_{DC}$, | Apply 15 $V_{DC}$ input using a DC power supply. Verify 15 $V_{DC}$ , 3.3 $V_{DC}$, and 5 | Tested | Mackenzie, Drew, Aidan |

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| | | and isolated 5 $V_{DC}$. | $V_{DC}$ outputs using an oscilloscope. | | |
| 3.2.3.15 | 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 |
| 3.2.3.16 | 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 |
| 3.2.3.17 | 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 |
| 3.2.3.18 | 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 |
| 3.2.3.19 | 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 |
| 3.2.3.20 | Firmware Relay Signal Generation | Dev board shall toggle the relay signal to 3.3 | (On the dev board) Apply 3.3 $V_{DC}$ supply voltage and 3.3 $V_{DC}$ button signal using | Tested | Ryan |

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| | | $V_{DC}$ with the button signal. | a DC power supply. Verify 3.3 $V_{DC}$ output using an oscilloscope. | | |
| 3.2.3.21 | 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 |
| 3.2.3.22 | 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 |
| 3.2.3.23 | 10 VAC to 12 VDC 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 |
| 3.2.3.24 | 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 |
| 3.2.3.25 | Power Control | Power control shall invert three high and three low 5 $V_{DC}$ PWM | Apply 40 $V_{DC}$ bus voltage and 15 $V_{DC}$ supply voltage using a DC power supply. Apply three high | Tested | Aidan |

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| | | signals into three modified sine waves. | 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. | | |
| 3.2.3.26 | 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 |
| 3.2.3.27 | 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 |
| 3.2.3.28 | 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 |

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| 3.2.3.29 | Firmware PWM Signal Generation | Dev board shall generate three high and three low 3.3 $V_{DC}$ PWM signals with the knob signal. | (On dev board) 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 | Ryan |
| 3.2.3.30 | Firmware Knob Signal Generation | Rotating dev board potentiometer changes frequency to speed up and slow down motor. | (On dev board) Oscilloscope each signal output, spin knob and ensure the motor speed varies as expected. | Tested | Ryan |
| 3.2.3.31 | 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 |
| 3.2.3.32 | 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 | Untested | All |

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| | | | after a knob turn using a video. | | |
| 3.2.3.33 | 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 MCU and use multimeter at the motor LED via. | Tested | Drew, Ryan |
| 3.2.3.34 | 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 MCU, then press relay toggle button and ensure the motor LED toggles. | Tested | Drew, Ryan |
| 3.2.3.35 | System 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 MCU and use multimeter at the system LED via. | Tested | Drew, Ryan |
| 3.2.3.36 | System 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 MCU and ensure the system LED turns on. | Tested | Drew, Ryan |
| 3.2.3.37 | Firmware Motor On/Off LED Signal Generation | Firmware shall toggle the dev board's on/off LED signal to 3.3 $V_{DC}$ with the button signal. | Directly inject 15V to dev board and use multimeter at the motor LED via. | Tested | Ryan |

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| 3.2.3.38 | Firmware Motor On/Off LED | Firmware shall toggle the dev board's on/off LED between on and off states with the motor on/off signal. | Directly inject 15V to dev board, then press relay toggle button and ensure the motor LED toggles. | Tested | Ryan |
| 3.2.3.39 | Firmware System LED Signal Generation | Firmware shall toggle the dev board's on/off LED signal to 3.3 $V_{DC}$ when the board receives power. | Directly inject 15V to dev board and use multimeter at the system LED via. | Tested | Ryan |
| 3.2.3.40 | Firmware System LED | Firmware shall toggle the dev board's on/off LED when the board is connected to power with the circuit on/off signal | Directly inject 15V to dev board and ensure the system LED turns on. | Tested | Ryan |
| 3.2.3.41 | 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 |
| 3.2.3.42 | Diagnostic Feedback Signal Isolation | Diagnostic feedback circuit shall transport the voltage, current, and temperature signals from | Apply 15 VDC supply voltage, isolated 15 VDC supply voltage, and three 15 VDC feedback signals using a DC power supply. Verify three | Untested | Mackenzie |

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| | | across the isolation barrier to the MCU. | 15 VDC outputs using an oscilloscope. | | |
| 3.2.3.43 | 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 |
| 3.2.3.44 | 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 |