X-Car Electrical Maintenance Tool

Group 7

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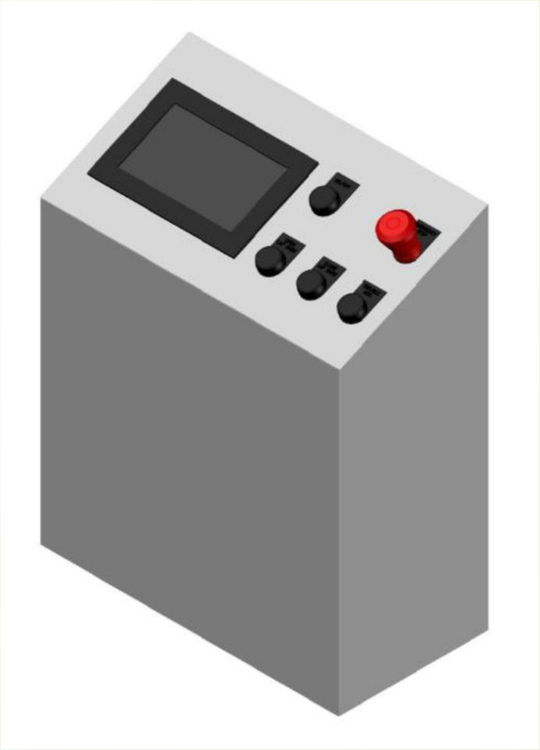


Background

- The ride vehicle has circuitry onboard that act as a device under test (DUT) to the Ride Control System (RCS) at HRRR.
- When any of these DUT systems fail to respond, the RCS will stop the dispatch system for a fail-safe condition.
- The RCS interfaces with the ride vehicle

  through use of a bus bar and collector

  shoe combination.

Background (cont'd)

- Each ride vehicle has 8 separate current collector shoes which have their own purpose.
- Current collector shoe function:
  - 1- RFID Channel 1
  - 2- Ground
  - 3- RFID Channel 2
  - 4- Open Lap Bars
  - 5- Lap Bar Status
  - 6- Vehicle Present
  - 7- Signal Power
  - 8- Close Lap Bars

Hollywood Rip Ride Rockit Universal Orlando

RIDE VEHICLE DISPATCHED FROM STATION

Motivation

- At Universal Orlando in the Technical Services department, our top goals are safety and reliability.
- Improve guest satisfaction by reducing downtimes.
- The X-Car Electrical Maintenance (XEM) troubleshooting tool was developed to eliminate troubleshooting bottlenecks.
- Current bottlenecks include a lack of high power output to operate lap bars, difficulty measuring weak connections, and testing the feedback signals from ride vehicles.

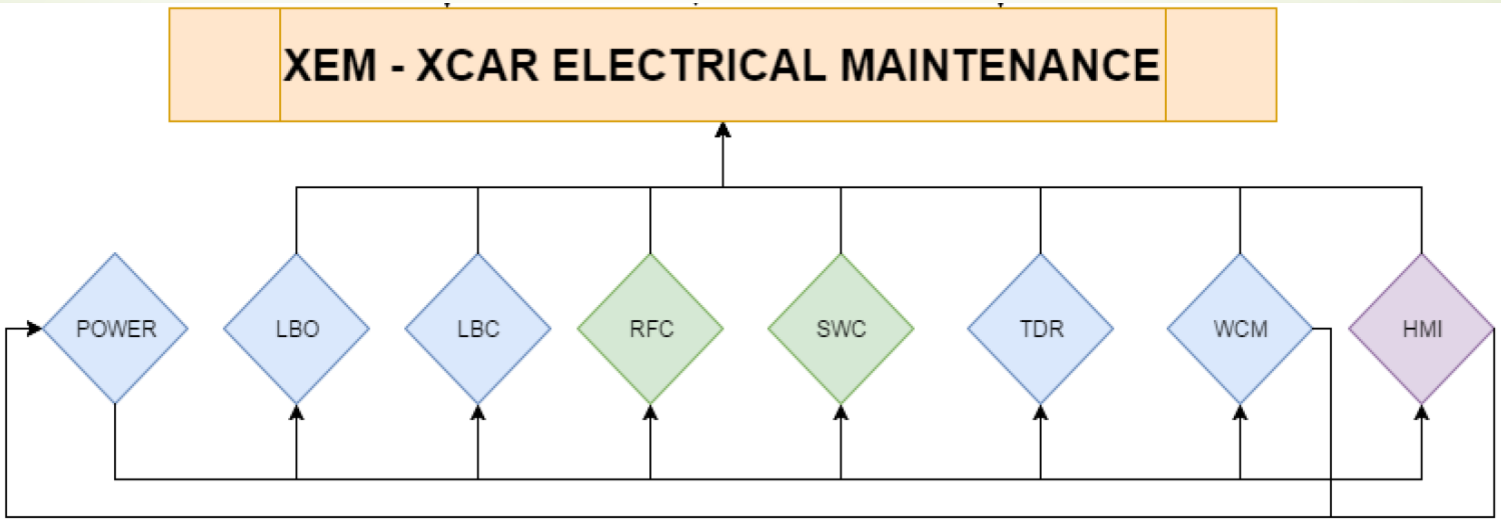
Goals and Objectives

- The XEM will simulate the RCS in the offline maintenance position allowing end users to troubleshoot more efficiently.
- The XEM has a few different connectors which allow for troubleshooting different parts of the ride vehicle onboard circuitry.
  - There is the Bus Bar Connector, the X21 Connector, and coaxial cable.
- The XEM will measure resistances, voltages, and currents being used by the ride vehicle DUT.
- The XEM will detect loose, broken, or damaged connections.
- The XEM will use the same logic in the RCS to test the ride vehicle.

Specifications

- The XEM will be powered by a 120V/20A socket.
- The XEM will provide 1.2kW of DC power at 24V.
- The XEM will detect resistances in the tenth of an ohm range.
- The XEM will detect voltages in the tenth of a Volt range.
- The XEM will detect voltages up to 28V.
- The XEM will detect currents up to 50A.
- The XEM will monitor 6 different control/signal lines on the ride vehicle.
- The XEM will operate the lap bar mechanism on the ride vehicle.
- The XEM will provide fault monitoring of the hardware and messaging.
- The XEM lap bar operation can be controlled remotely.

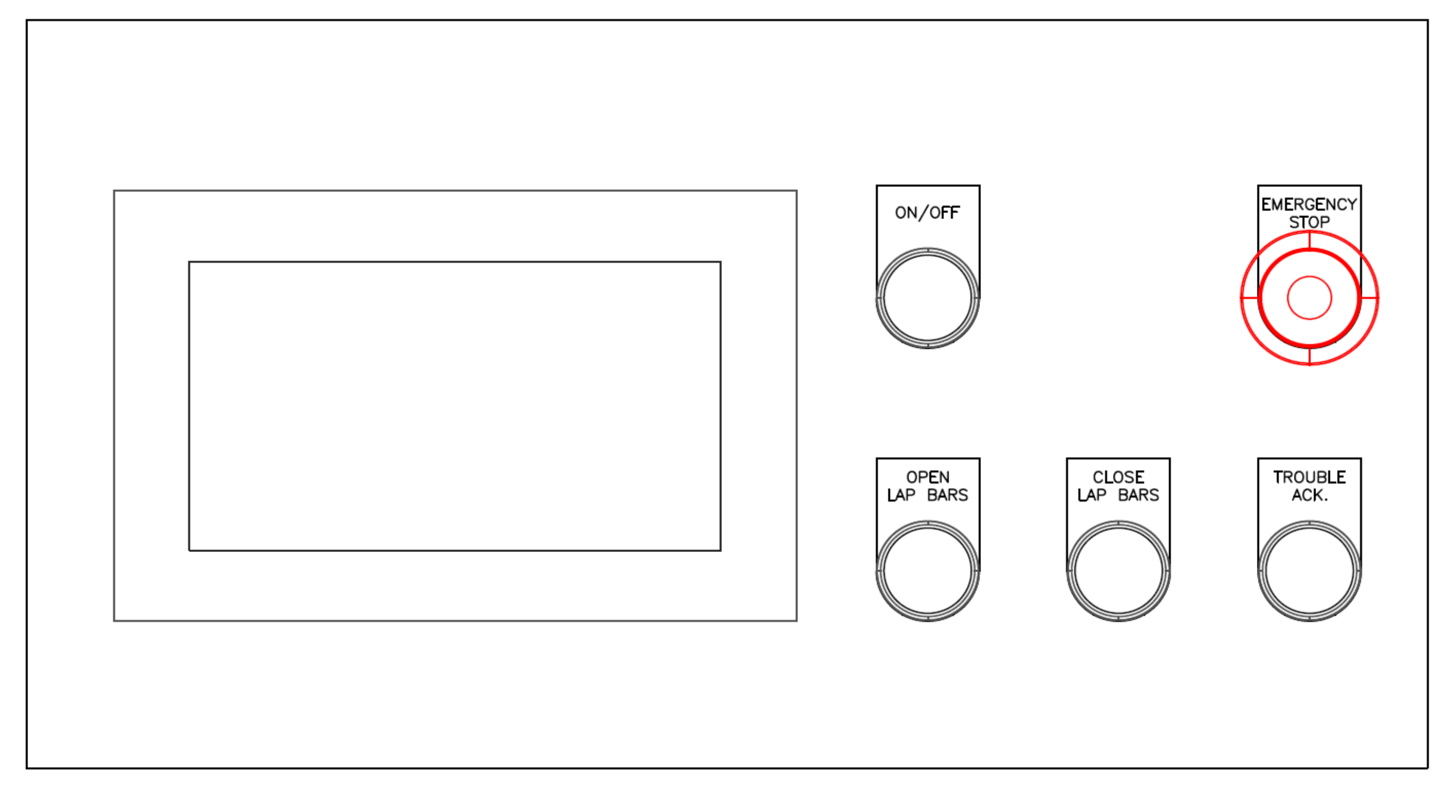
Overall System



Definitions

LBO - Lap Bar Open Circuit
LBC - Lap Bar Close Circuit
RFC - RFID Check Circuit
SWC - Sector Wiring Check Circuit
TDR - Time Domain Reflectometry Circuit
WCM - Wireless Control Module Circuit
HMI - Human Machine Interface Circuit

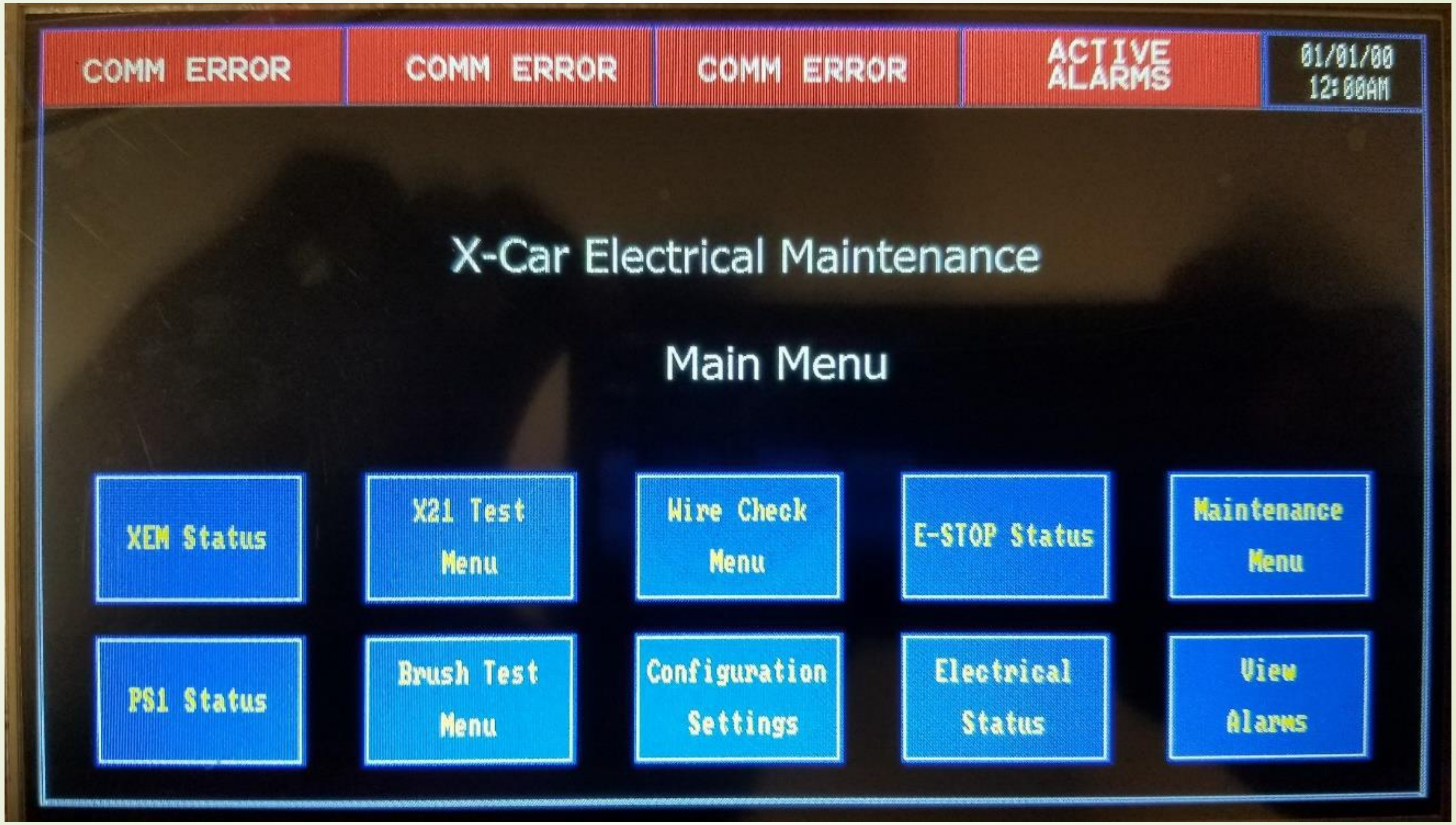
Human Machine Interface (HMI)



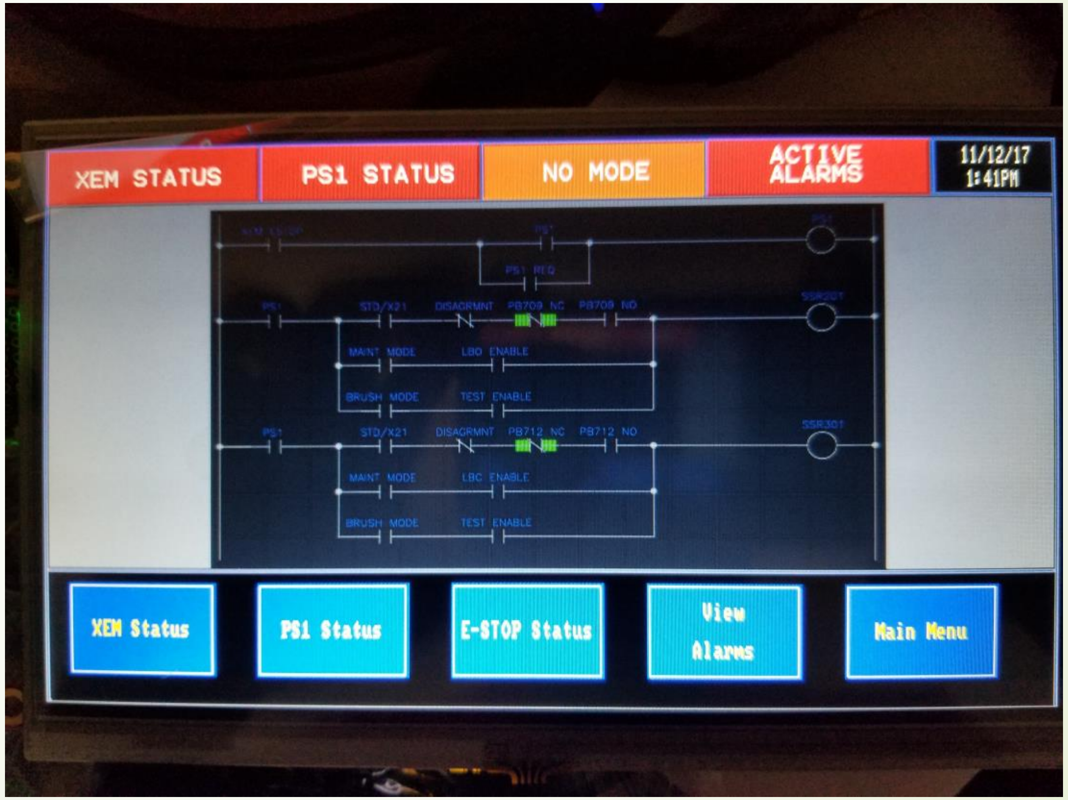
Human Machine Interface (HMI)

- Provides interface for end user control
- Has hardware buttons for inputs to the XEM circuitry
- Test modes and configuration settings are modified using the HMI
- Alarms and other informational messages are displayed through the HMI
- Safety circuit is tied in to the HMI through hardware push button and software push buttons

Human Machine Interface (HMI)



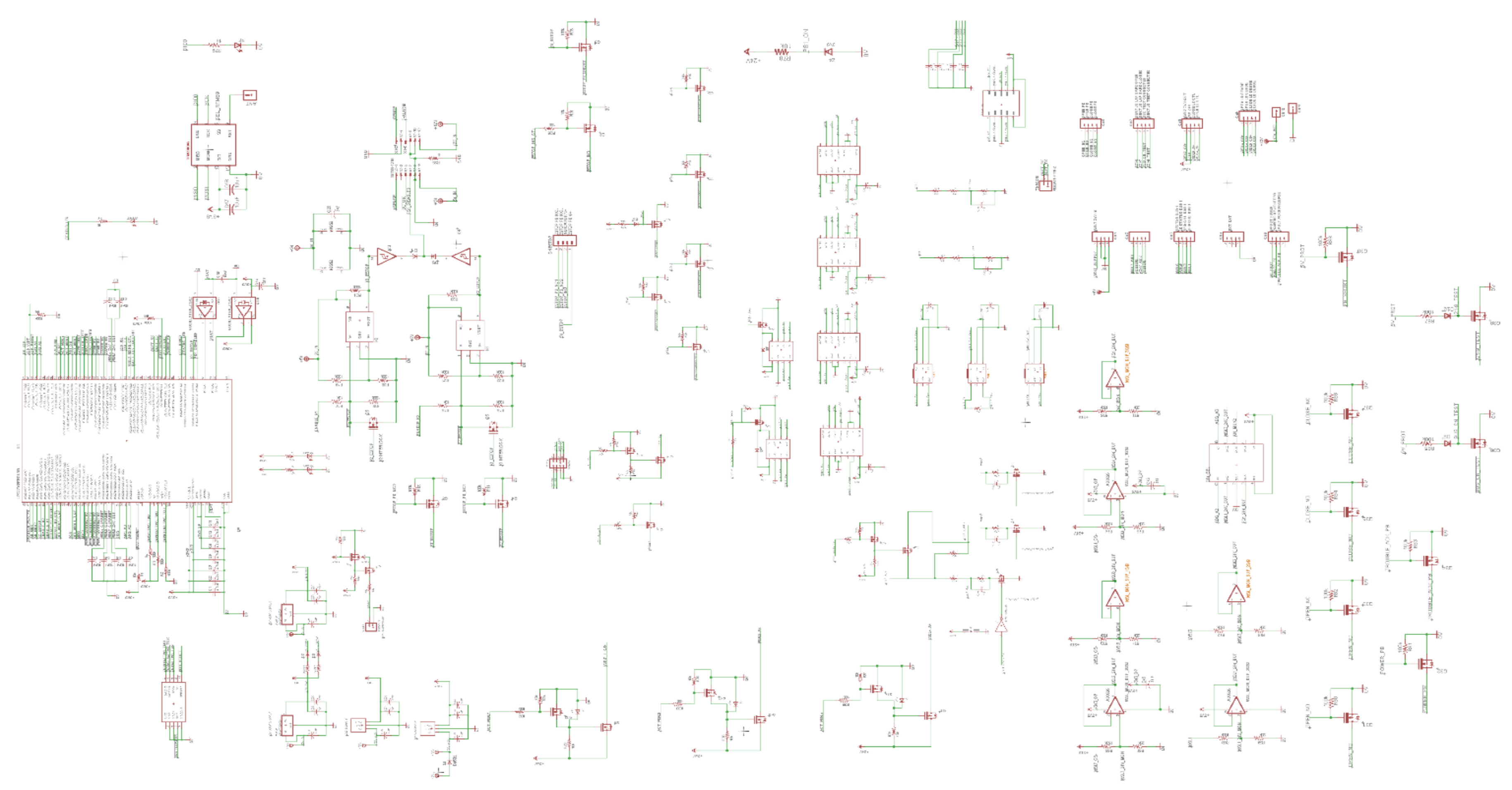
Human Machine Interface (HMI)



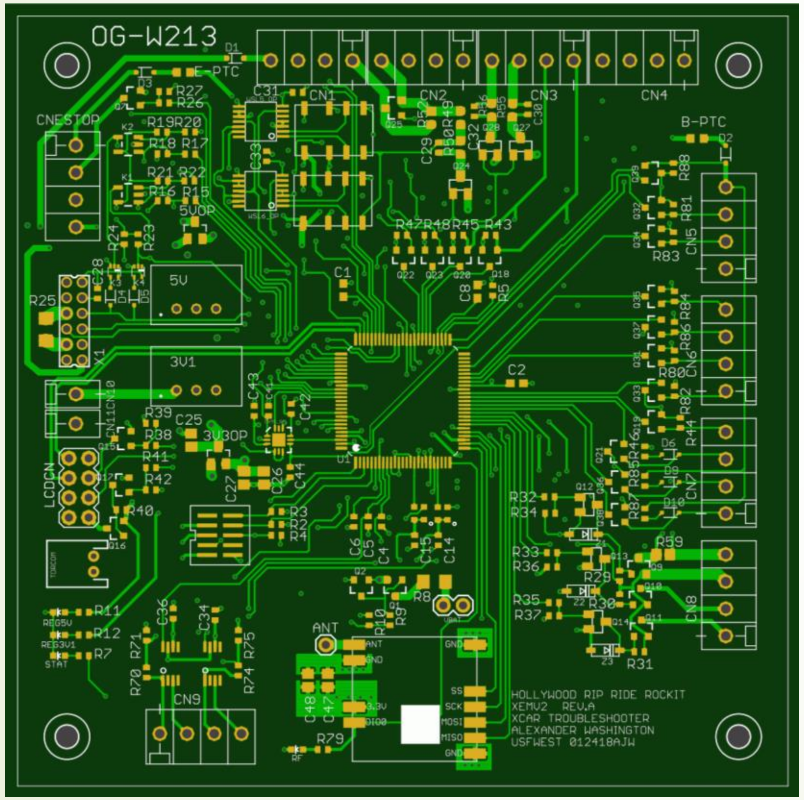
Overall Main Circuit Board

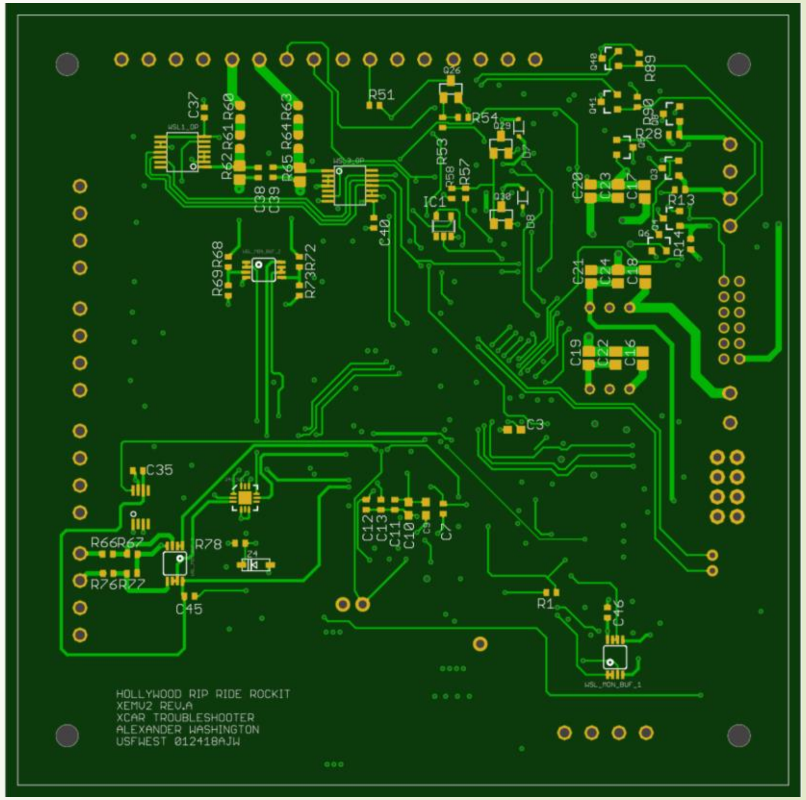
- Main controller with inputs and outputs for control onboard.
- Simulates the RCS logic.
- Provides safety functions.
- 1.6mm thick FR4 PCB.
- 4 Layer board
    - Upper – Signals and Components
    - Upper Middle – Power
    - Lower Middle – Ground
    - Lower – Signals and Components
- Schematic split in to several sections for clarity: MCU, Low Voltage Supply, E-STOP Circuit, 24V Controlled Outputs, LCD Connections, Test Connections (Digital), Test Connections (Analog), Monitored (Analog), Monitored (Digital), Terminal Block Connections, Wireless, and Input Buffers.

Overall Main PCB Circuit

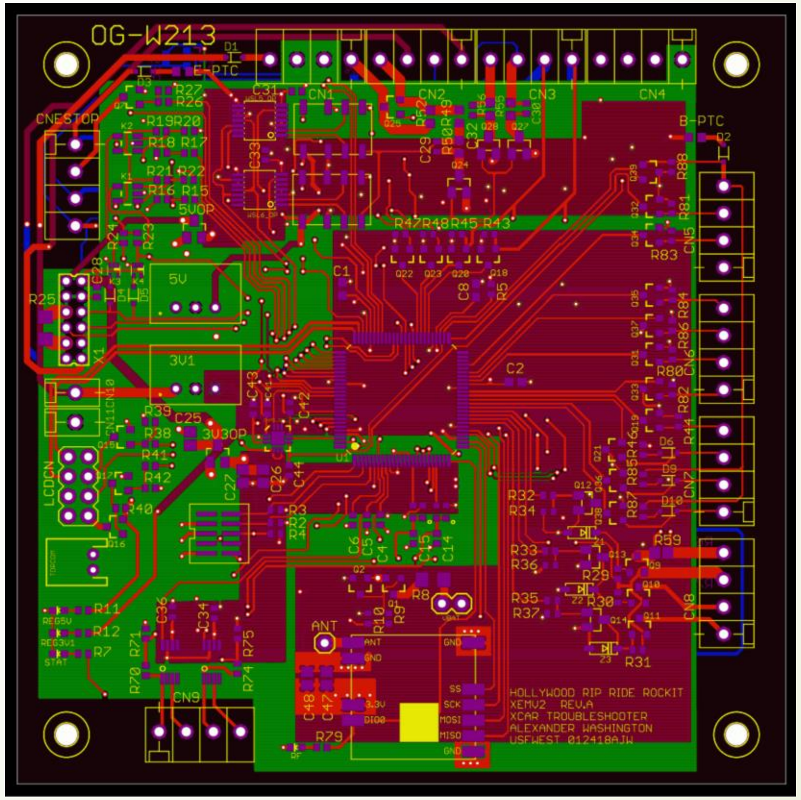


Overall Main Circuit Board





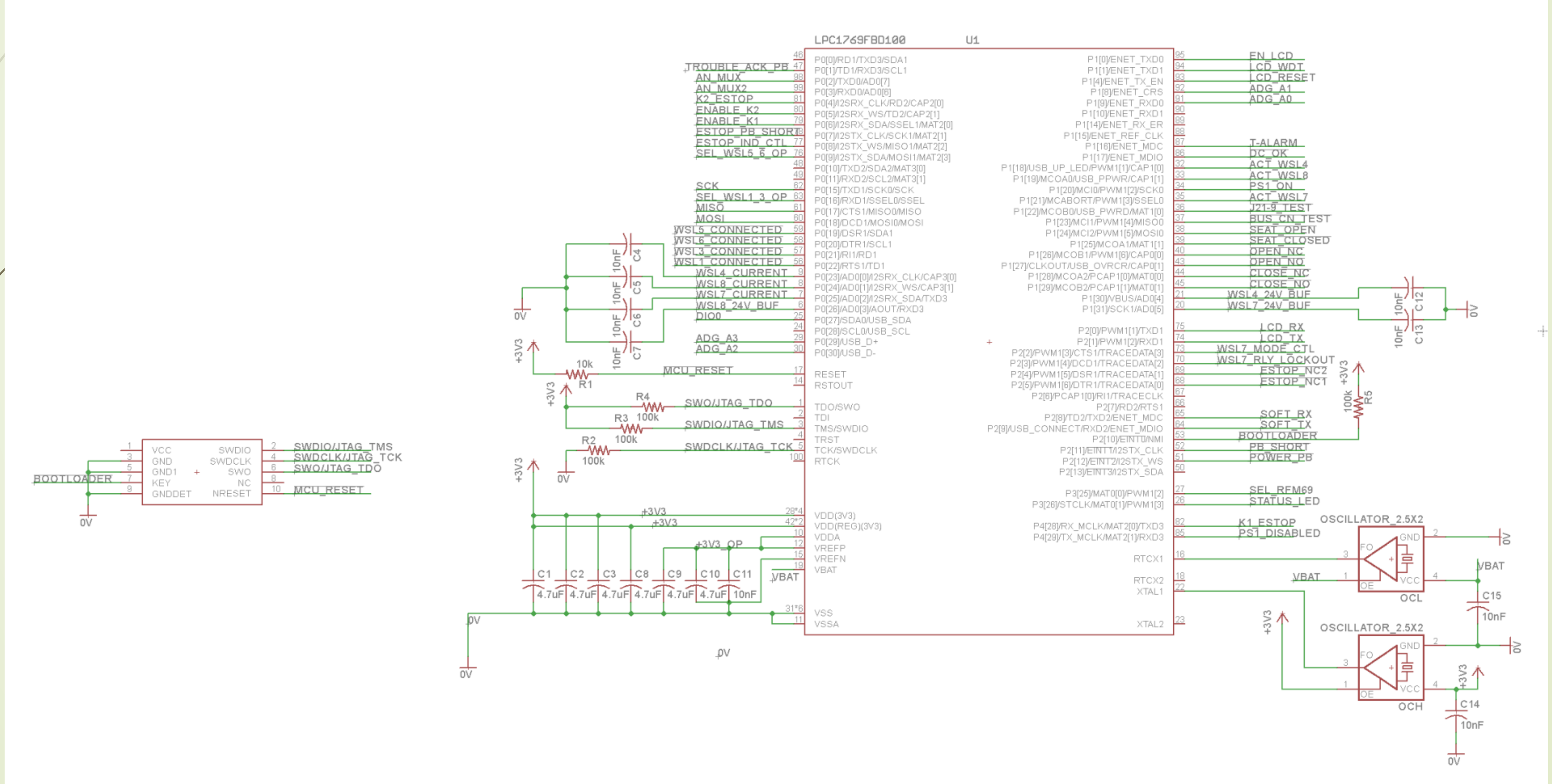
Overall Main Circuit Board



Microcontroller

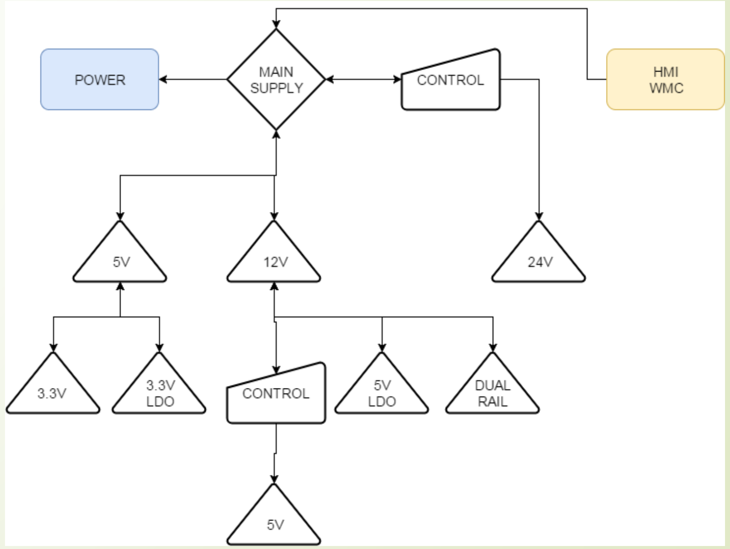
- XEM uses NXP's LPC1769 microcontroller vs ATMEL ATMega2560
- ARM architecture vs AVR
- 100 Pin LFQP package
- 120MHz clock frequency
- Operates at 3.3V
- Handles 5V inputs

Microcontroller Circuit

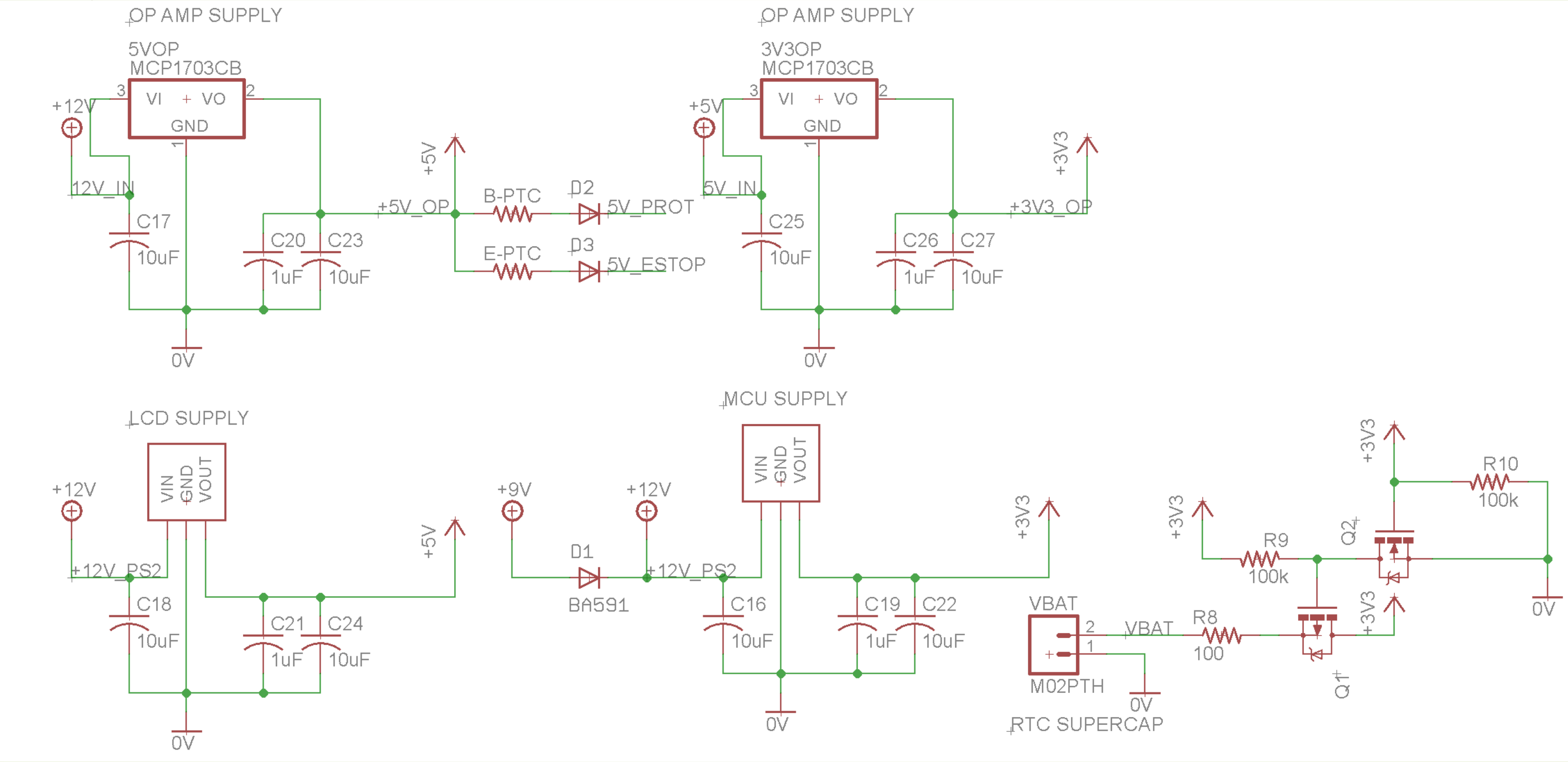


Power Supply

- The XEM has an intricate power supply system.
- The power supply system involves a high power 24V system, a low power 24V supply, a moderate 12V supply, a low power 5V supply, and low power 3.3V supply.

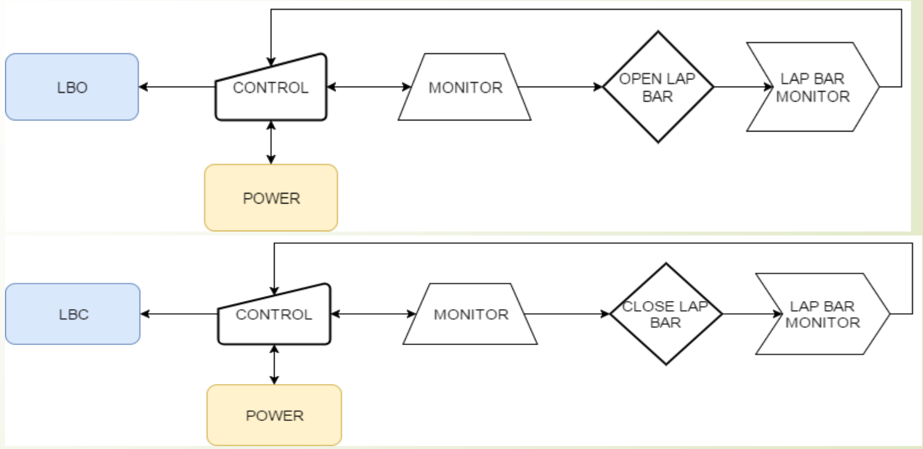


Low Power Supply Circuits

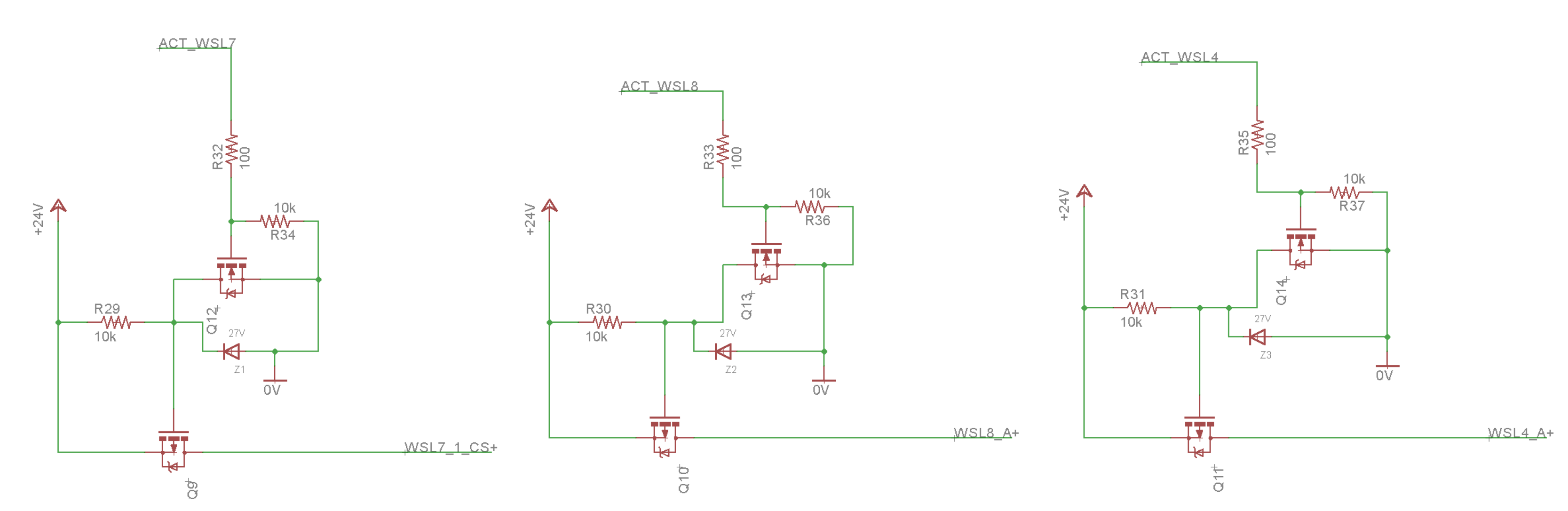


Lap Bar Control

- There are separate controls for opening the lap bar and closing the lap bar.
- The open lap bar circuit uses the most power in the system.
- Solid state relays were used for reliability and ease of control.



Lap Bar Control Circuit

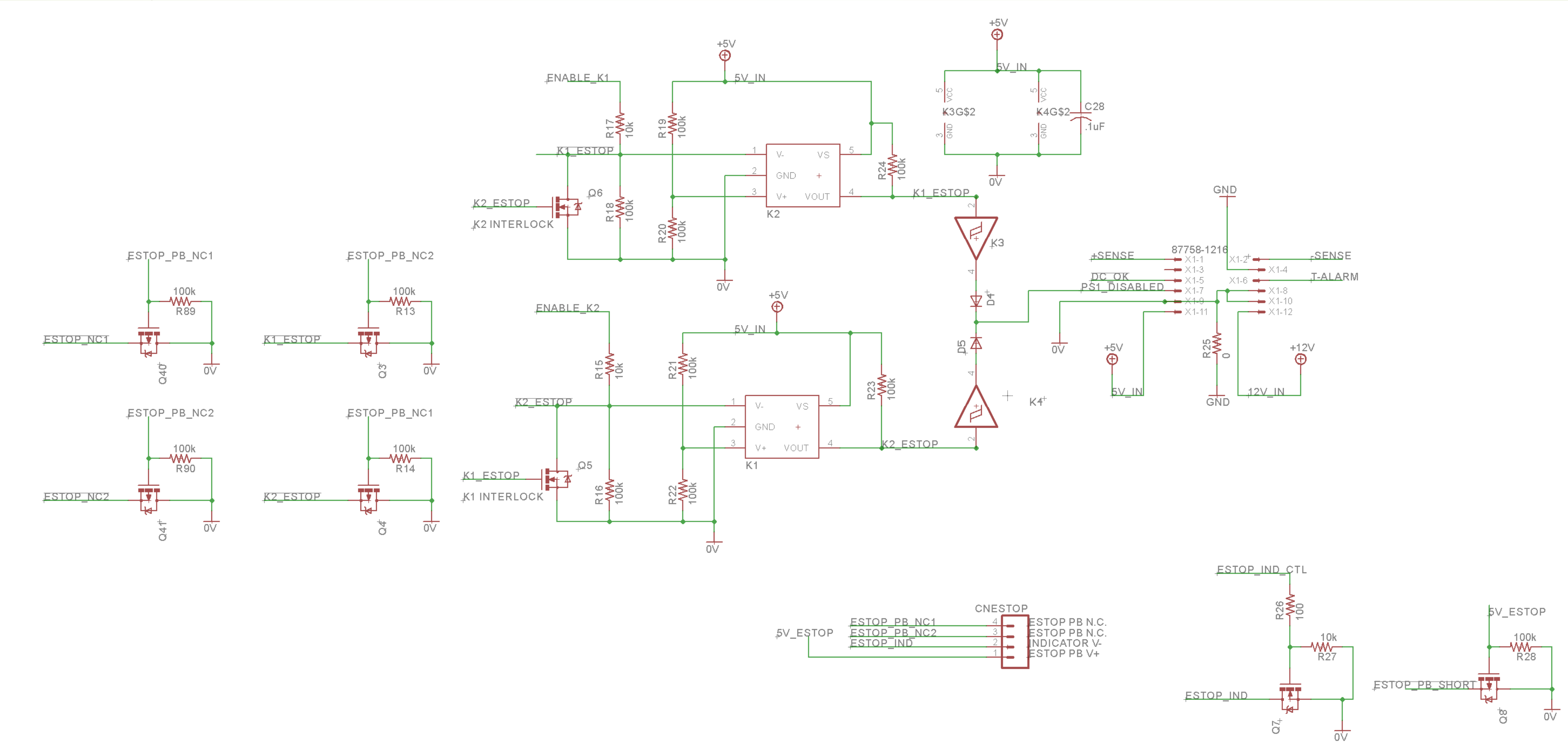


Safety Circuit

- There is hardware and software limitations to ensure the XEM is always in a controlled and safe state
- The software monitors for hardware failures and unsafe electrical states.
- The HMI also includes a hardware emergency stop button which can also prevent any failure or unsafe electrical state.
- The emergency stop circuit stops the high power outputs and 24V outputs.
- There are circuit breakers and fuses external to the circuit board that also protect the hardware.

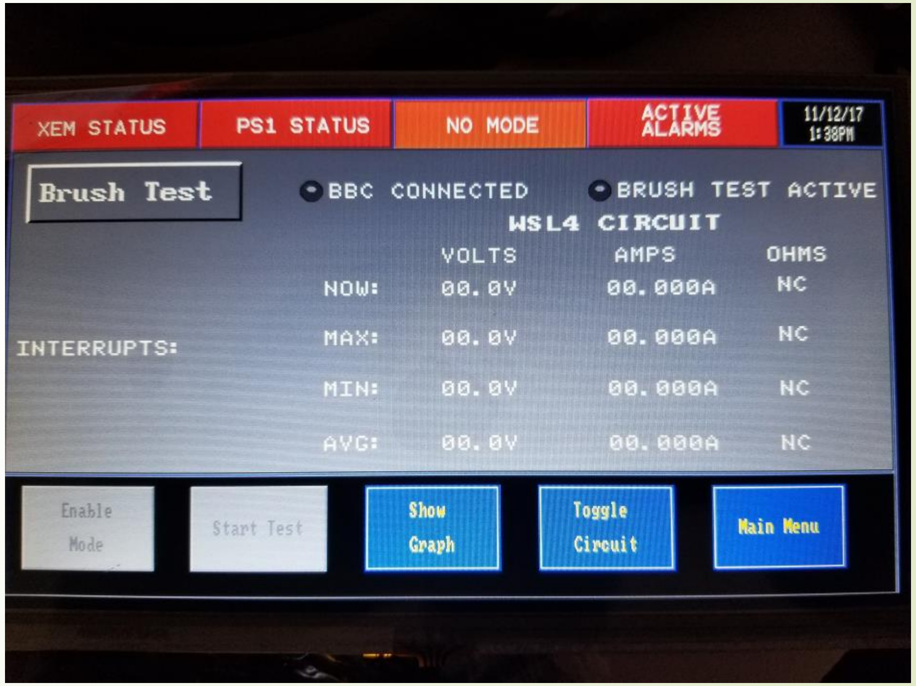
ENABLE K1 ON	ENABLE K2 ON	ESTOP PB NC1	ESTOP PB NC2	PS1 ON
0	x	x	x	0
x	0	x	x	0
x	x	0	x	0
x	x	x	0	0

User/Equipment Safety Circuit

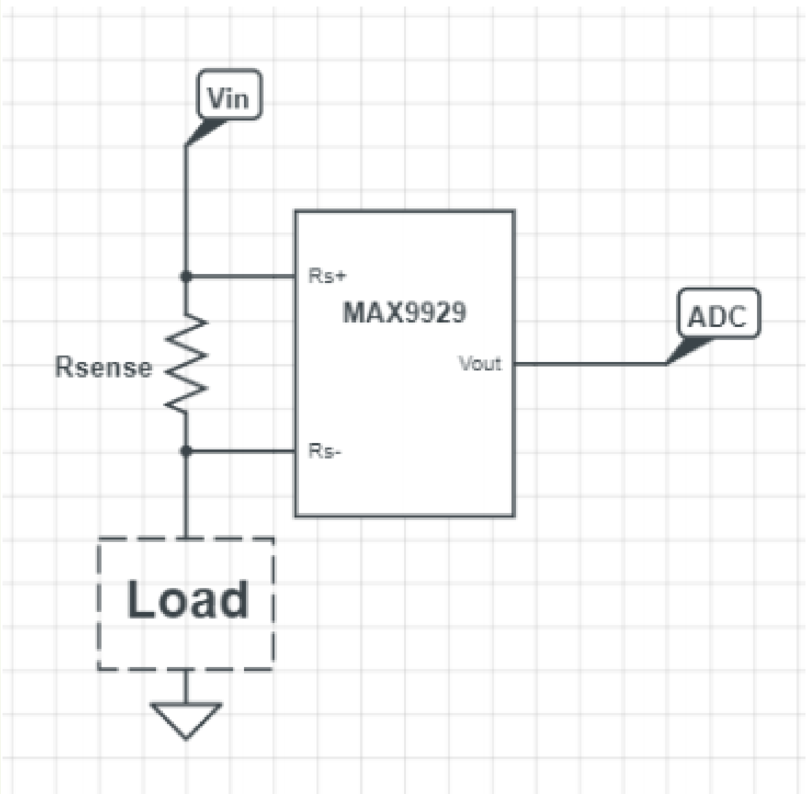


Monitoring Circuits

- The monitoring circuits include digital inputs and analog inputs.
- Most of these circuits help determine the device under test parameters (current, voltage, resistance).
- Other parts of the circuit monitor feedback of outputs and push buttons.

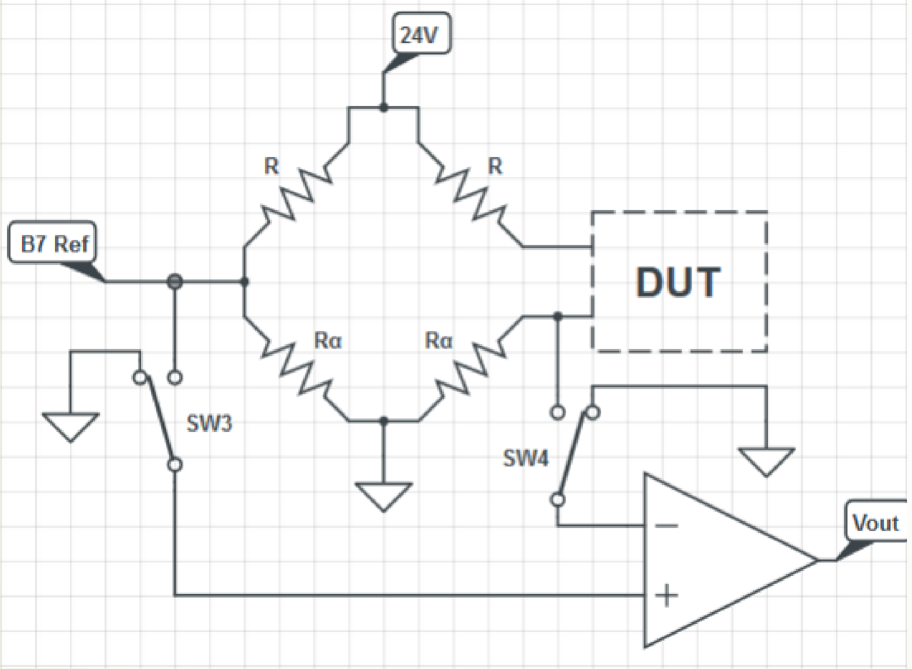


MAX9929 Current Measurement



- Current Sense Amplifier
- High side, between source and load
- Internal comparator, output voltage
- R sense determines the output voltage
- Polarity across R sense is maintained

Wheatstone Bridge Resistance



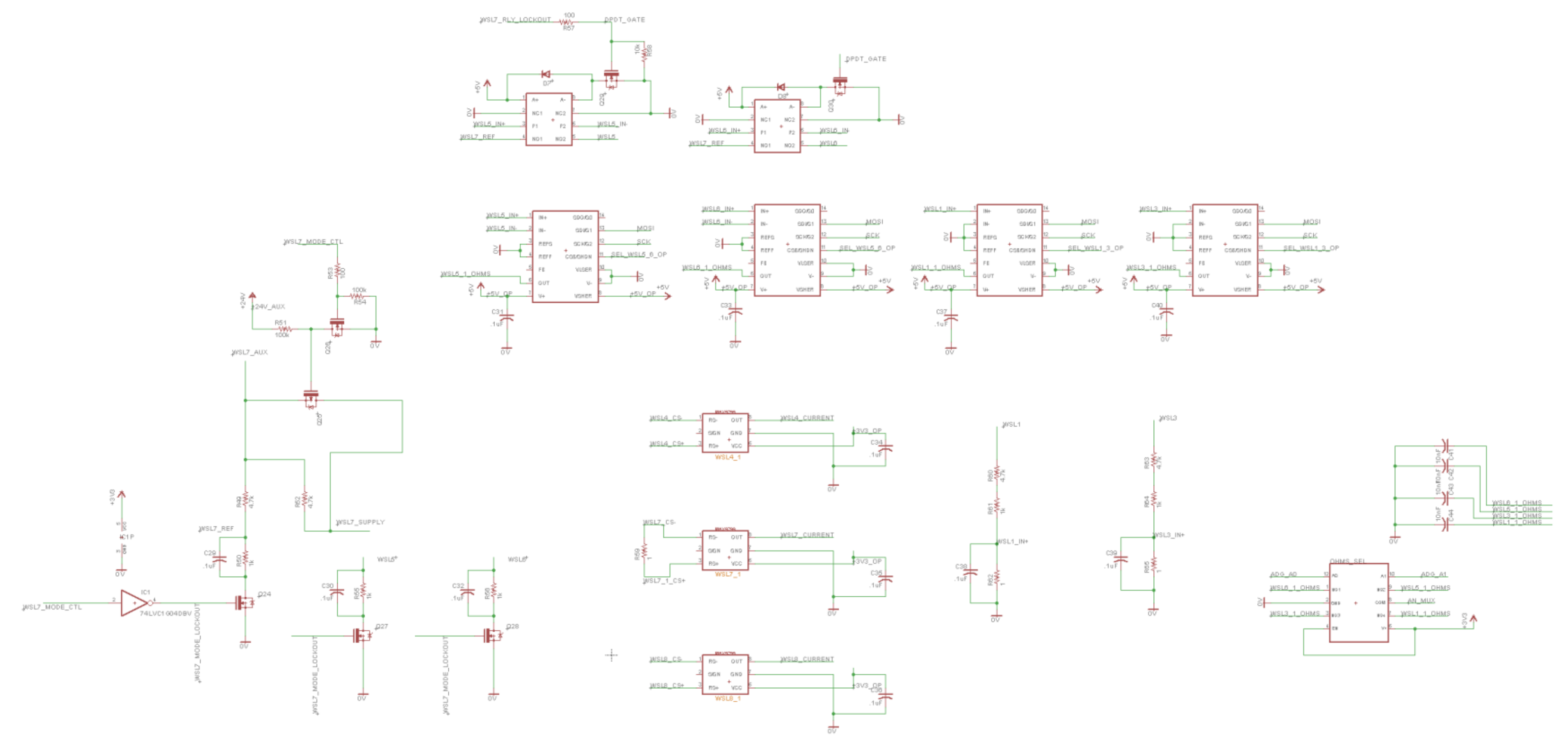
- Wheatstone Bridge setup
- DUT added on the right side
- Causes the resistance to differ on the two sides
- Differential voltage measured and output to the ADC
- Low offset voltage needed

Sense Resistor

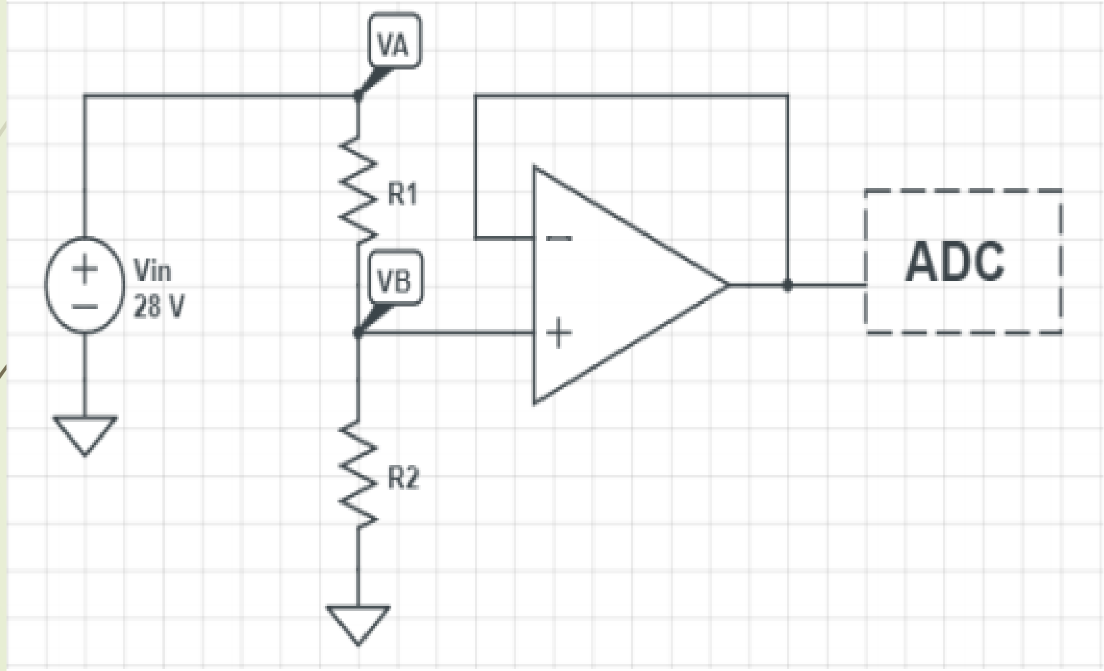
	Ω				
Parameter	**100**	**2500**	**5700**	**8000**	**10000**
mV	237.624	9.596	4.21	3	2.4
Gain sense	47524.75	1919.232	841.958	599.925	479.952
mV/mΩ	0.238	0.01	0.004	0.003	0.002
mV/mΩ gain	47.524	1.919	0.842	0.6	0.48
Steps/mΩ	58.973	2.382	1.045	0.744	0.596
mA	237.62	9.6	4.21	3	2.4
mW sense	56.47	0.09	0.02	0.01	0.01
mW resistor	5646.51	230.22	101.02	71.98	57.59
Error mΩ	0.21	5.21	11.877	16.669	20.835

- Higher resistance allows for more accurate measurement given a lower current
- High current through the sense resistor dissipates more power and is inefficient
- A tradeoff is made to determine the best choice

Monitoring Circuits

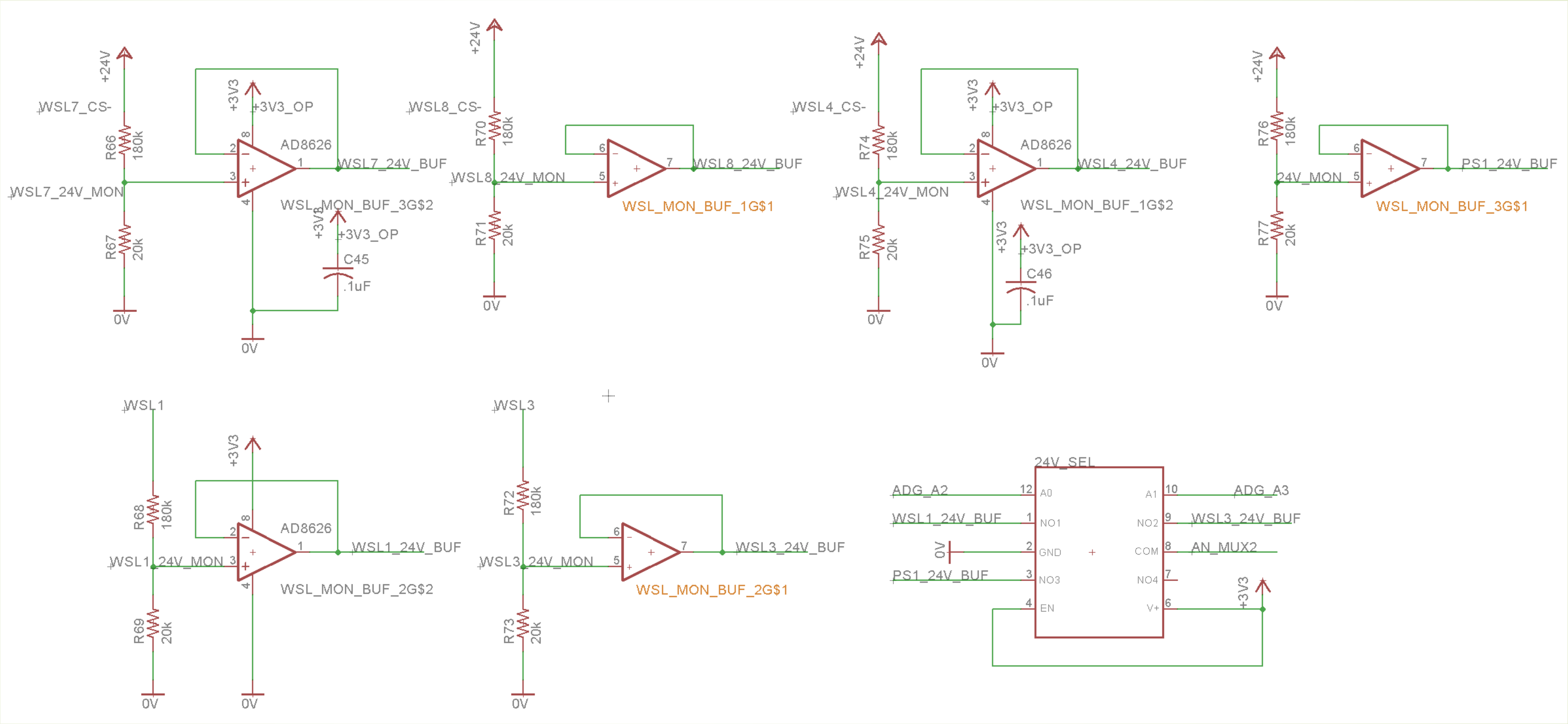


Voltage Measurement



- Uses the ADC of the LPC1769
- Voltage divider driven, uses 20k and 180k resistors to divide the voltage by 10
- Buffer using AD8626 to source the ADC sampling current.

Monitoring Circuits



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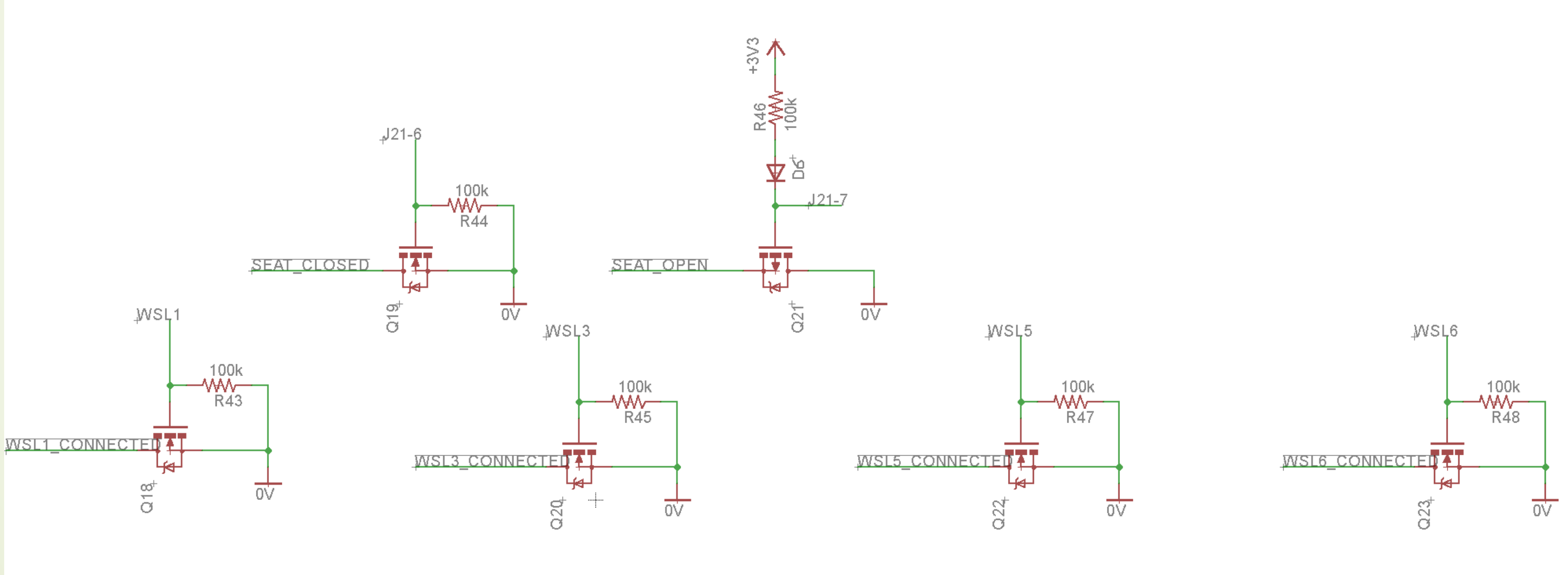

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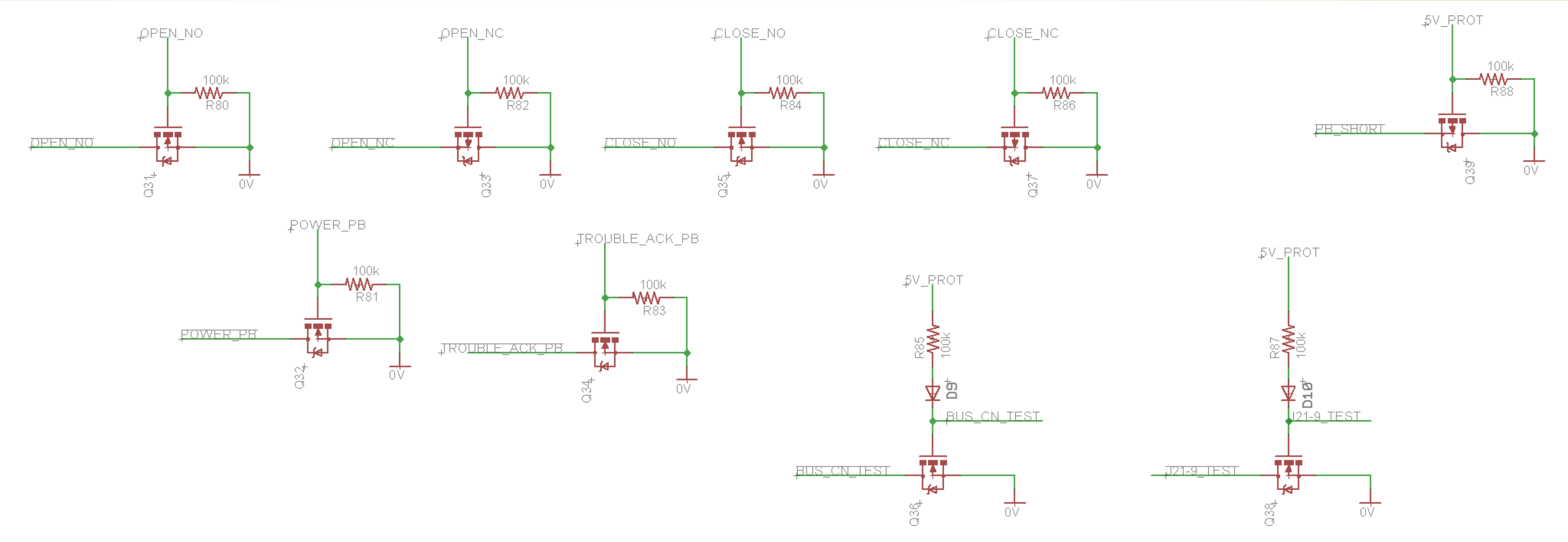


Wireless Control Module

- Utilizes an ATMega328P and RFM69HCW
- Simple input output application
- Typically disabled, until enabled by the XEM
- Three different signals
  - Open LapBar
  - Close LapBar
  - E-Stop
- The functions of each are the same as if executed by the main system

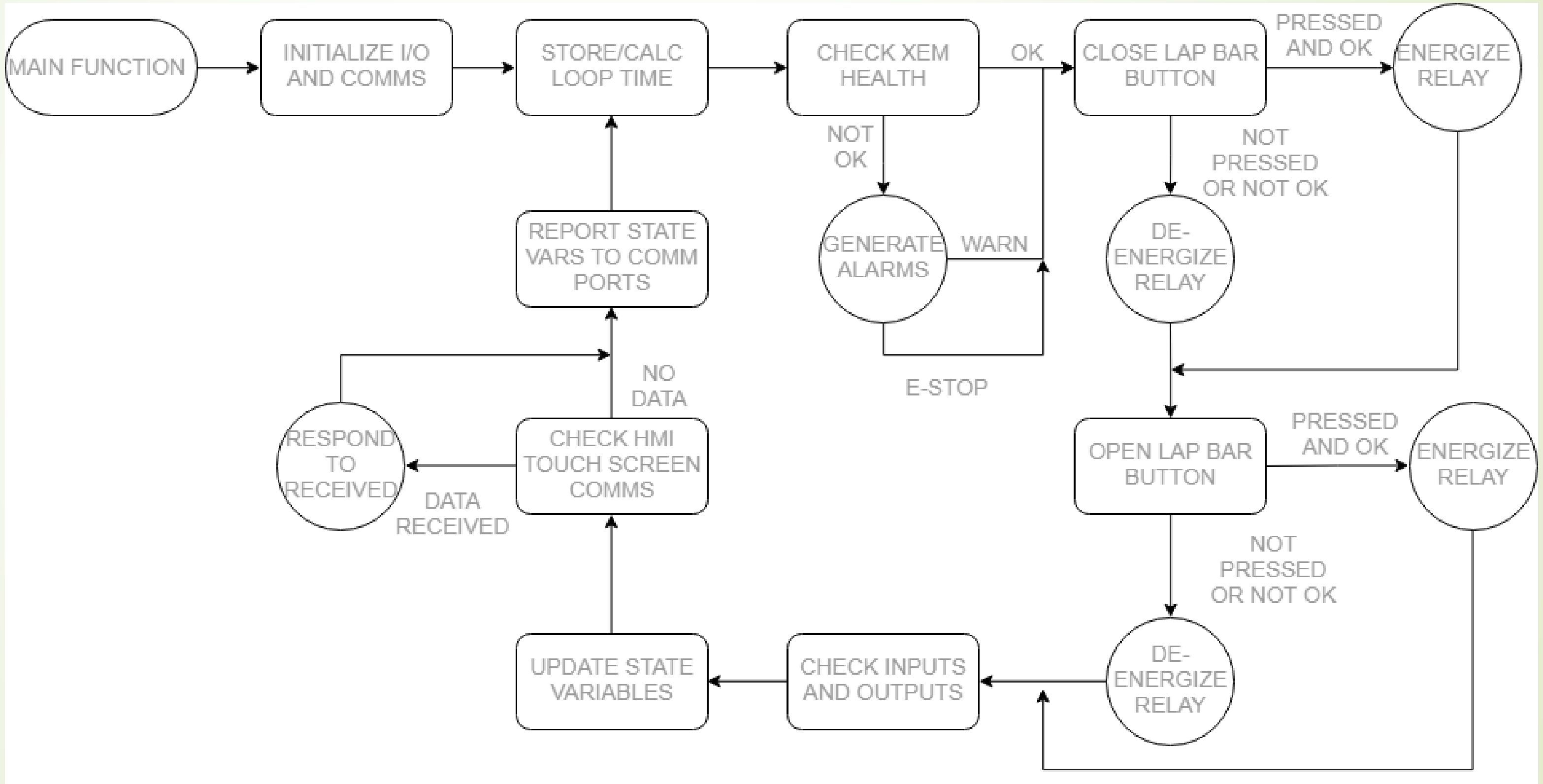
RFM69HCW

- Wireless transceiver, operating in the unlicensed ISM (Industry, Science, and Medicine) band.
- Operates on the 915MHz frequency
- Capable of transmitting up to 100mW and up to 300kbs, configurable
- Simple monopole wire antenna can transmit signals through an office building, or over 500 meters in open air
- Transmits data packets up to 66 bytes long
- Features AES encryption (Advanced Encryption Standard)

Software Design

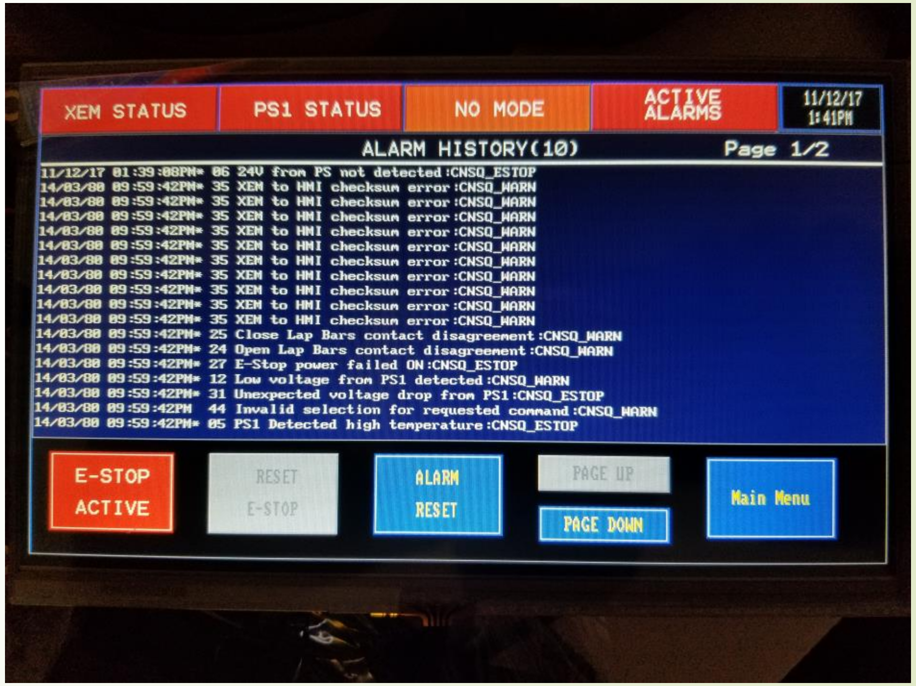
- Four software programs needed to be written
- The XEM and TDR have NXP LPC microcontrollers and are written in C using LPCXpresso's version of Eclipse IDE
- XEM's software was written to be similar to PLC ladder logic (easy to follow, minimal loops, outputs and states are actively written)
- The WCM is written with Arduino software (Similar to C++)
- The HMI is written using proprietary language by 4D Systems, it is similar to C

Software Design – Flow Chart



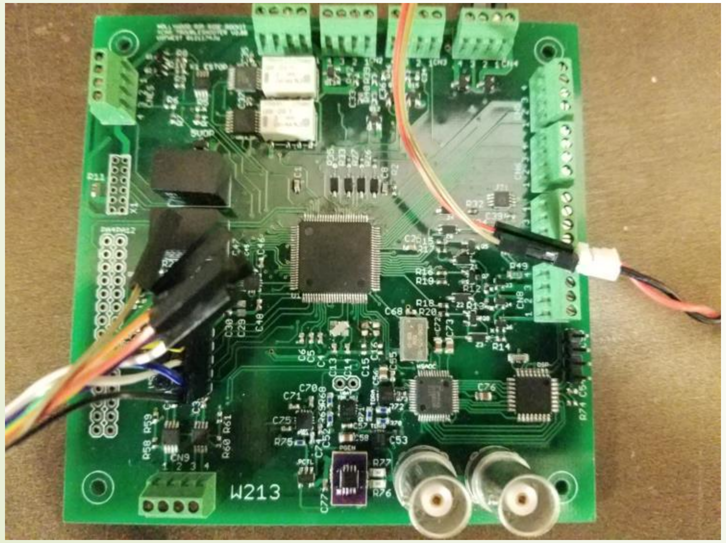
Software Design – Alarm Management

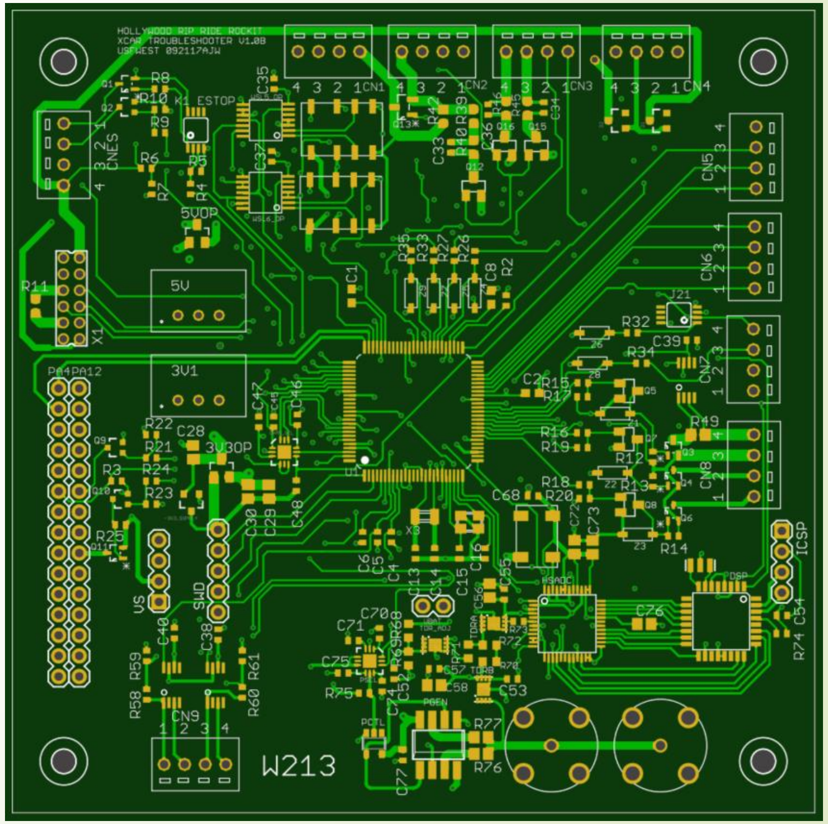
- Alarms are generated on the Main XEM program
- Alarms can be either warnings which disable a function or emergency stops which halts all operations
- Alarms are displayed on the HMI
- Severe alarms must be remedied before the XEM outputs can be used again



Design Failures & Improvements

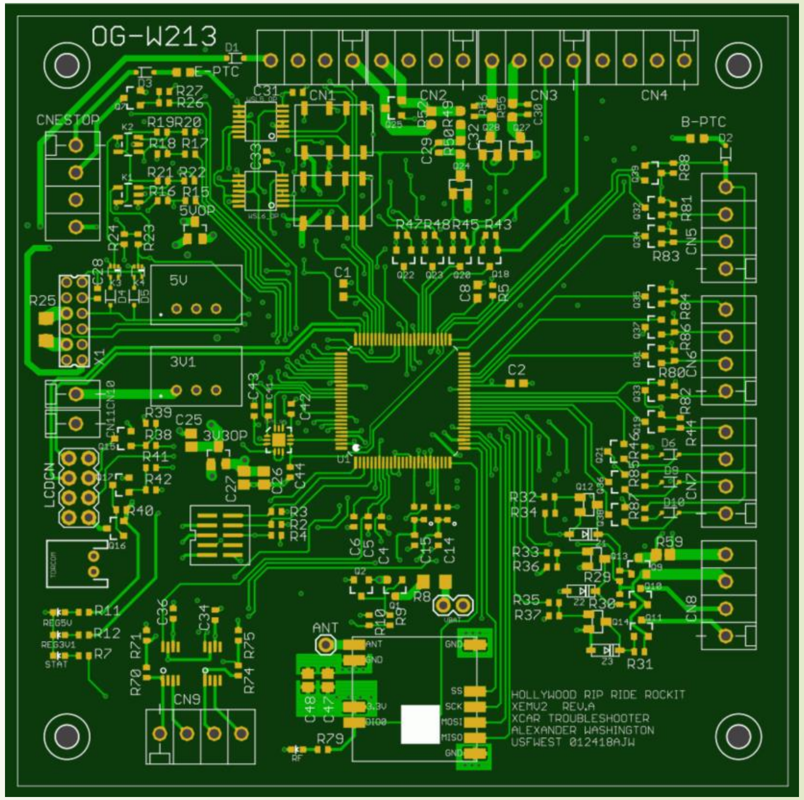
- Weak Programming Port Design
- Small Terminals
- Incorrect Footprints
- Poor TDR performance





Design Failures & Improvements

- Improved Programming Port Design
- Larger Terminal Blocks
- Corrected Footprints
- Added wireless control
- Improved TDR performance over five times the speed
- Improved power and grounding
- Added more signal isolation/protection
- Added more robust fail-safe hardware
- Added status LEDs



Budgeting & Sponsorship

- The budget was estimated and split in to 5 sections
- The XEM Chassis is the enclosure housing the XEM MAIN PCB and XEM TDR PCB
- The XEM REMOTE PCB is contained in the XEM REMOTE CHASSIS
- Sponsorship was provided by Universal Orlando

PART	COST
XEM MAIN PCB	$800.00
XEM CHASSIS	$2,500.00
XEM TDR PCB	$800.00
XEM REMOTE PCB	$200.00
XEM REMOTE CHASSIS	$300.00
TOTAL SPONSORSHIP:	$4,600.00

Progress and Milestones

SD2 Spring 2018				
	Week 1	Week 2	week3	week4
January	Break	Starts: order/make all parts	Review and get parts	Build prototype
February	Test prototype, assess	Acquire more parts, fix, review, and change	Build main project (extension of prototype)	Build main project and test
March	Build main project and test	Test, assess Acquire more parts, fix, review, and change	Build main project and test	Build main project and test *final*
April	Test, assess Acquire more parts, fix, review, and change	Test, assess fix, review, and change, (MUST work)	Test, assess fix, review, and change (MUST work)	End, final presentation

XEM Tool – Questions?