Electrical Handbook

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REVISION HISTORY

DATE	DESCRIPTION OF CHANGE
V160401	RJV, revised with 2015-2016 Lessons learned
V151223	RJV, revised detail design process, add ICD document
V151107	RJV, updated information flow, TOC, web based schematic programs, design process
V150406	RJV, updated design process
V150302	Original

1 INTRODUCTION

1.1 Purpose

The purpose of this handbook is to provide electrical best practices in design, fabrication, testing, and troubleshooting. The handbook also provides index to electrical documentation, electrical training, electrical tips and reference material.

1.2 Scope

The scope of this document is to provide a best practice handbook for the electrical sub-team.

1.3 Audience

The audience for this document is the CougarTech Robotics technical team.

1.4 References

Information in this handbook and in the training were leveraged from the experience of FIRST Teams and general electrical theory.

First 2007 Guidelines,Tips, & Good Practices

2005CON Electrical Design Team111

2006CON Electrical Design Team2018,Team71

2009 Advanced robot electrical design and technique team111

Team358 electrical workshop 2010

Introductory Circuit Analysis Robert L. Boylestad : Chapter 4 – Ohm's Law, Power and Energy

CPO Science Foundations of Physics unit7 chapter 19

Electrical Systems 101 Team 2377

Electronics Workshop Team604

Mentor workshop - Electrical sub-system Team358

FIRST Wiring the FRC 2015 Control System

Electronic Best Practices Team2641

RoboJackets: Session5: Robot Electronics

Team995 - Electric Team Certification

Team 358 Hauppauge High School Electrical Workshop 2010

Team148 2015 Control System Beta 10-18-14

1.5 Definitions

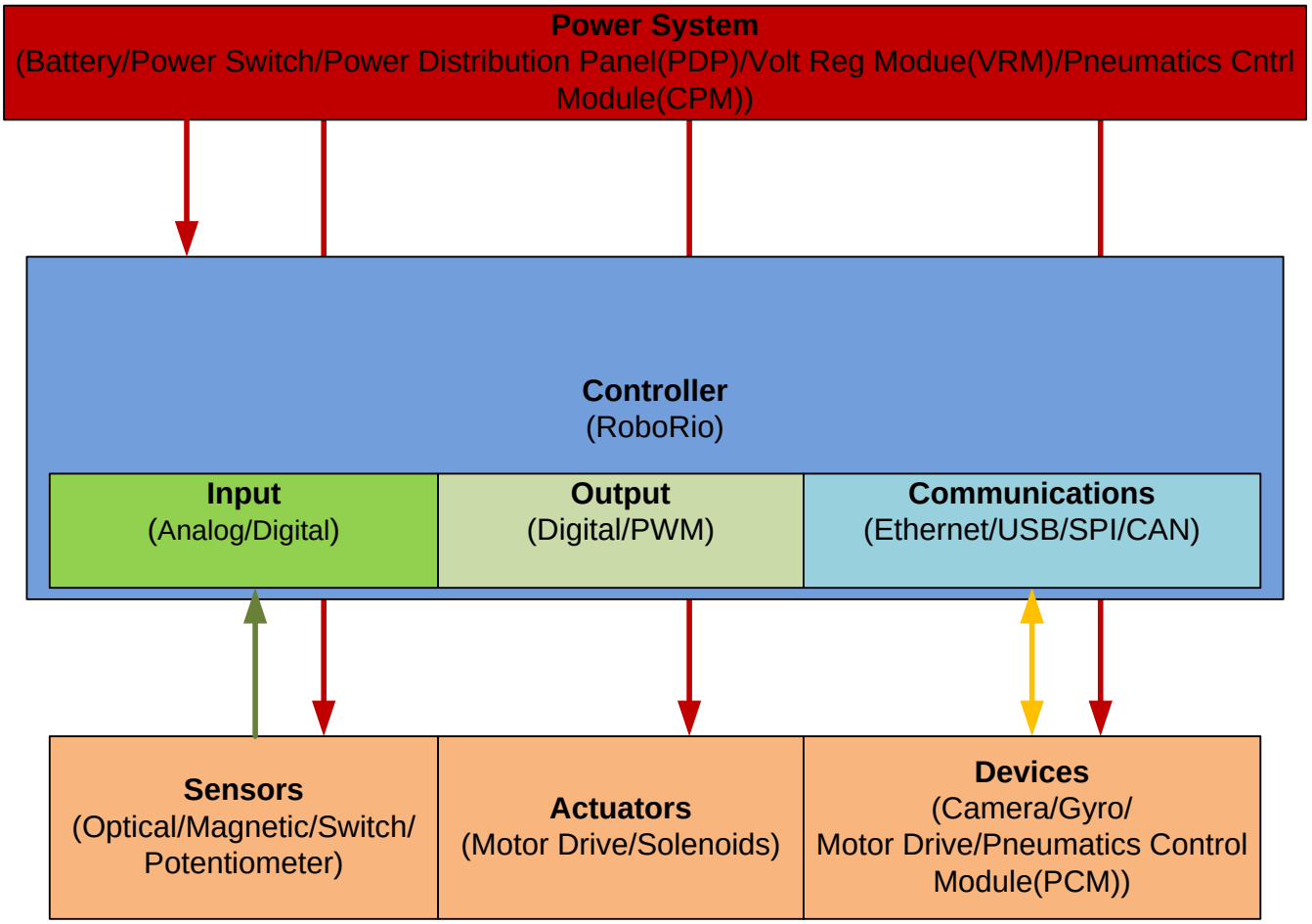
BOM	Bill Of Materials
CAN	Controller Area Network
CID	Control Interface Document
ESC	Electronic Speed Control
PCM	Pneumatics Control Module
PDP	Power Distribution Panel
PPD	Pulse Position Modulation
PWM	Pulse Width Modulation
SPI	Serial Peripheral Interface
USB	Universal Serial Bus
VRM	Voltage Regulator Module

2 OVERVIEW

2.1 Description

FIRST constrains the design of the electrical system by specifying the electrical components that FIRST teams can use. This puts all teams on the same level of control. This handbook provides a best practice reference for the electrical design process and use of electrical components.

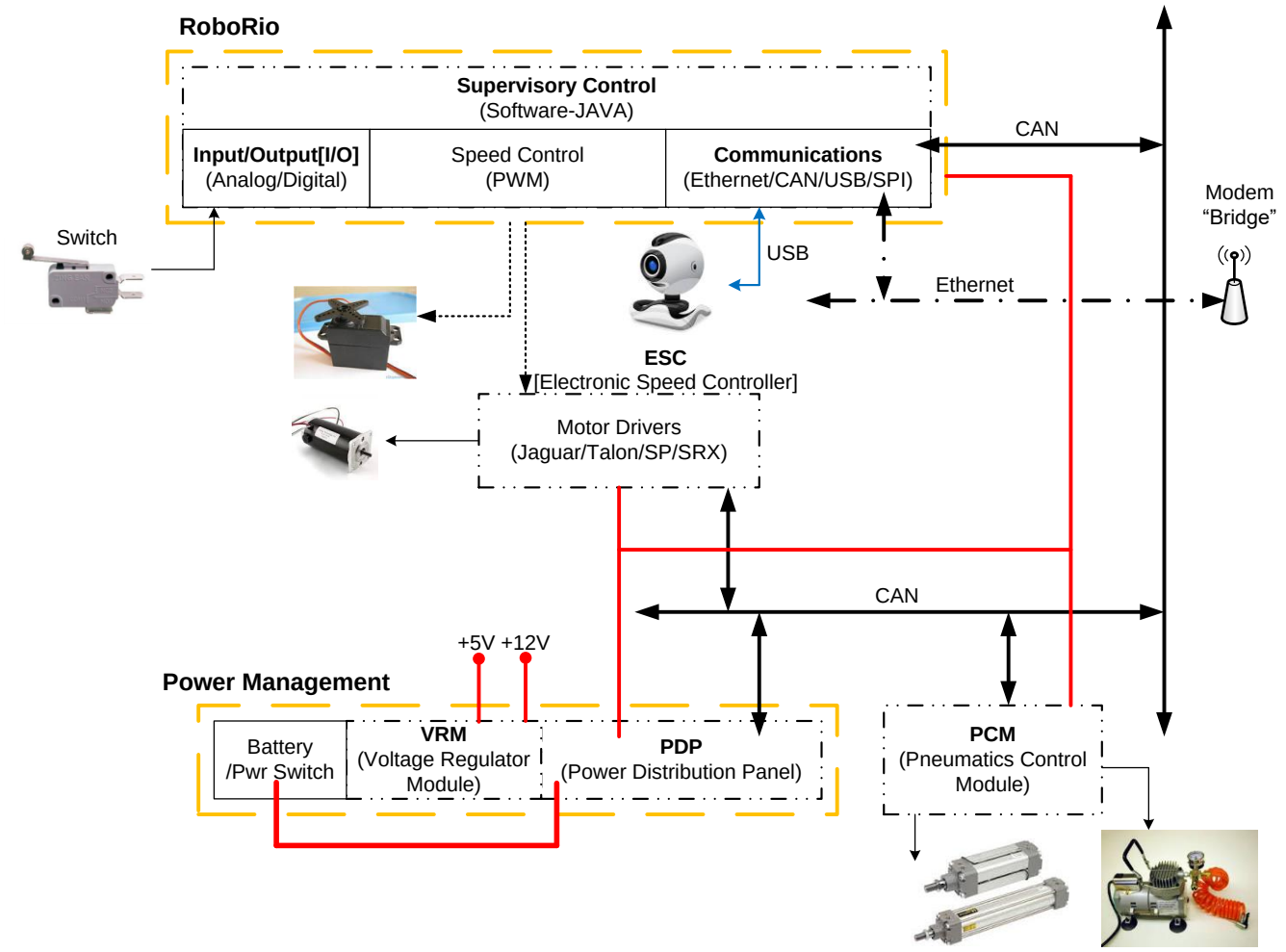
2.2 Electrical Modules



There are three electrical module levels to the robot:

1) Power System: Battery, Power switch, power distribution, and voltage regulation
2) Controller: RoboRio
3) I/O: sensors, actuators and devices

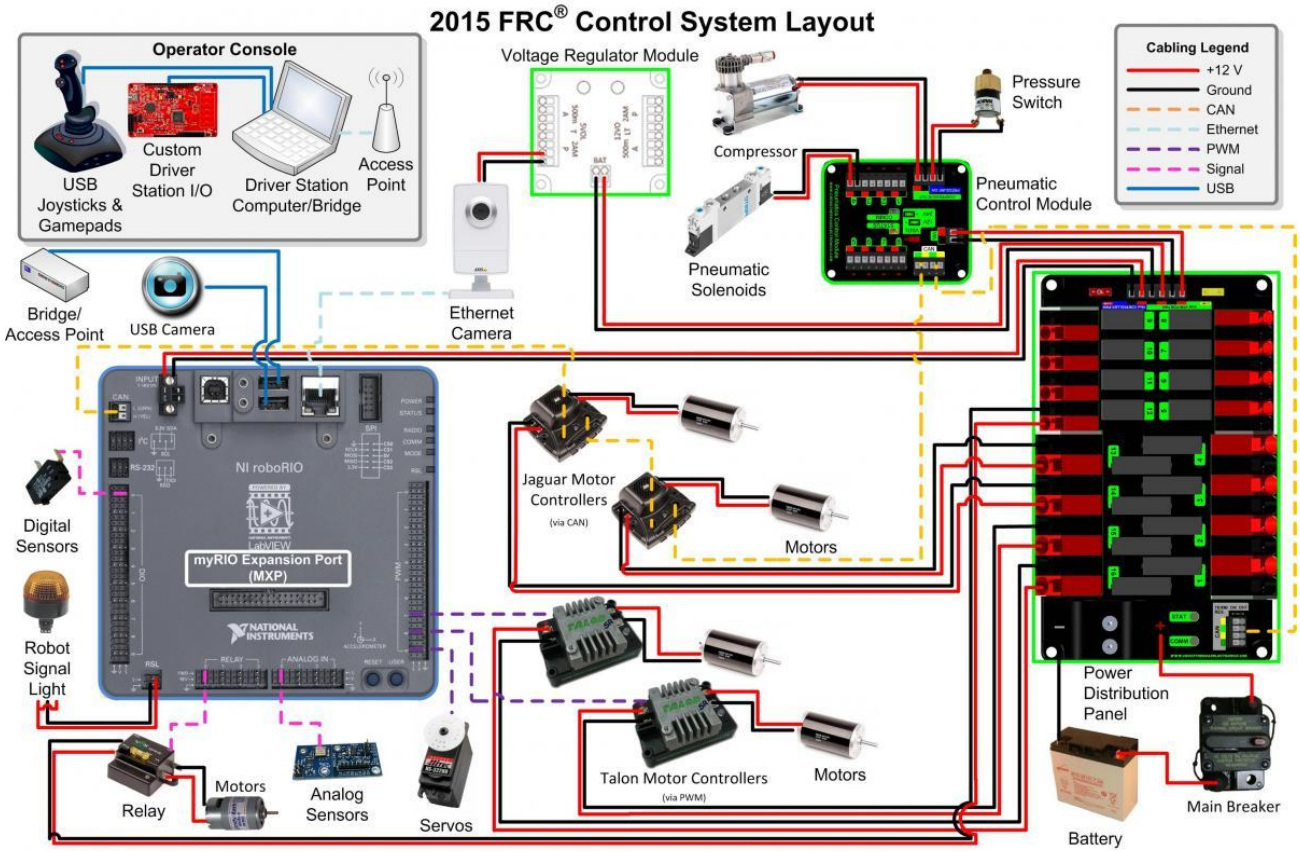
2.3 Electrical System Block Diagram



There are three main sections in the design of the robot electrical System;

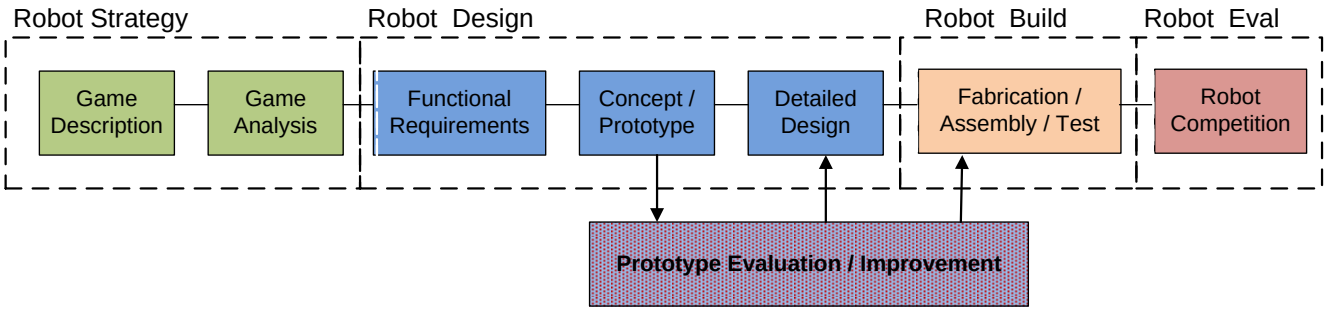
1. Power Management: This includes the Battery/Main Robot power switch, Power Distribution Panel(PDP) and the Voltage Regular Module(VRM)
2. Pneumatics Control: This includes the Pneumatics Control Module(PCM)
3. Robot Controller: This includes the RoboRio and RF Modem(Bridge)

2.4 FIRST Electrical Schematic



3 ROBOT ELECTRICAL DETAILED DESIGN

3.1 Overall Robot Design Process Steps



3.2 Robot Strategy

3.2.1 Team Development of Game Strategy

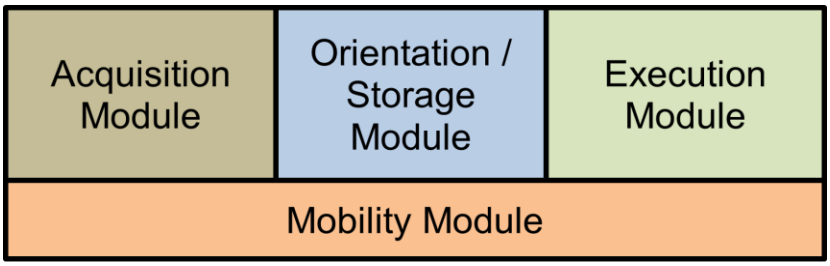
After the kickoff video and READING the game manual, the team will develop the following:

1. A game strategy that includes how the robot will move on the playing field and what actions the robot has to do to play the game.
2. The team will also define the constraints of the robot from the Game Manual.

3.3 Robot Design

3.3.1 Technical Team Robot Module Requirements

The technical team(Mechanical/Electrical/Software) will group the robot actions developed by the team with respect to the basic robot module model shown below. The robot constraints listed by the team will also be grouped with respect to the robot model.



3.3.2 Technical Team Robot Concept Development

During the robot concept development the electrical team is responsible for developing the sensor input and actuator output list for the robot mechanism concepts.

3.3.2.1 Control Interface Document(CID)

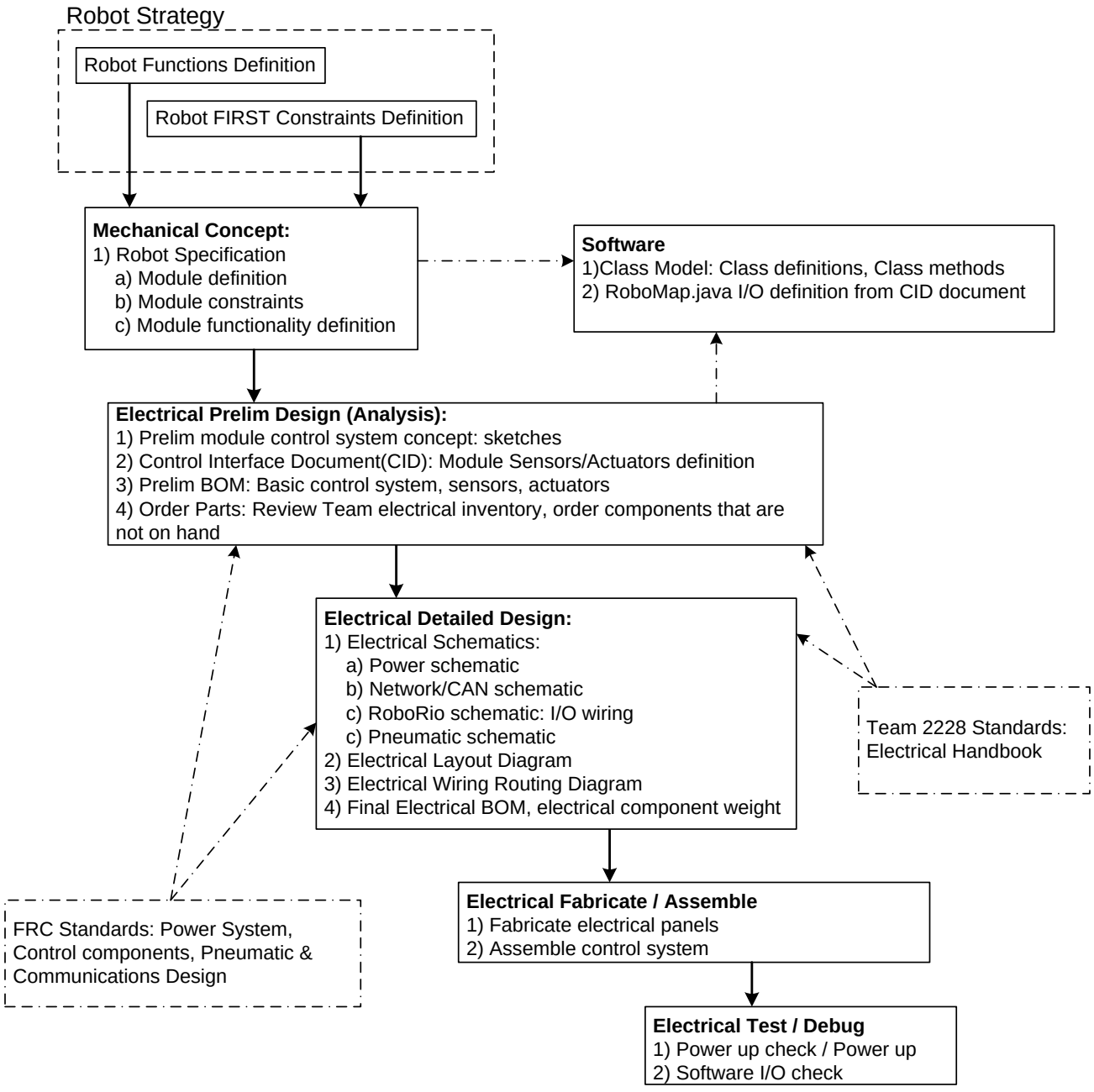
The control devices are documented in the Control Interface Document(CID). The CID is typically an Excel table that has the following columns:

1) Item Number
2) Module Name: (e.g. lift)
3) I/O device name (e.g. lift Motor)
4) I/O device type: (e.g. switch, motor, solenoid, encoder, ultrasonic, optical switch)
5) Device ID: (e.g. M1, SW3, ENC1, US1, SOL1)
6) Controller ID: (e.g. PWM0, K3,
7) Cable ID: From Tag - To Tag: (e.g. PWM1 - M3)

The software team is responsible for understanding how the robot will function.

3.4 Design Information Cascade

The general flow of a robot design has a cascade effect on when technical disciplines engage in the design and fabrication process. The cascade effect is shown in the following diagram.



3.5 Electrical Robot Build Schedule

3.5.1 Week 1:

1. Support concept and prototype development

2. Develop first cut of CID document: Robot mechanical modules, control components(sensors, motors, etc)
3. Develop first cut electrical layout
4. Develop power schematic and start the electrical BOM

3.5.2 Week 2:

1. Develop electrical architecture – matching I/O to control components
2. Develop electrical layout
3. Develop first cut electrical I/O schematics and update electrical BOM
4. Order parts needed

3.5.3 Week 3:

1. Complete schematics and BOM
2. Complete panel layout
3. Kit control system parts
4. Test functionality of parts where possible
5. Image RoboRio, update firmware on motor controllers, set CAN addresses
6. Update CID document with firmware version, CAN addresses
7. Complete pre assembly checklist

3.5.4 Week 4:

1. Build electrical control panels.

3.5.5 Week 5:

1. Install electrical panels
2. Wire sensors and motors
3. Complete assembly check list
4. Complete power up check list

3.5.6 Week 6:

1. Support robot during driver testing and robot evaluation

3.6 Concept and Preliminary Design

During the Concept and Preliminary Design process The following items should be considered:

1. The electrical system should be considered early in the design. It should not be an afterthought that there will be the correct space for the electrical system.
2. The electrical sub-team needs to work with the mechanical and software sub-teams to understand the robot functions and control concepts to develop the electrical system.
3. By the end of the concept and preliminary design phase of the robot design, a preliminary layout, electrical schematic, and BOM should be developed. New parts should be ordered.

3.7 Detailed Electrical Design

3.7.1 Electrical Design Documentation

In designing the electrical system the following documentation should be developed:

1) Electrical schematics should be developed.
2) Electrical layout drawings. This would include electrical panel layout, cable/cable tag layout between I/O devices and control modules(noting control module ID's)
3) Electrical "Control Interface Document" (CID)

a. The CID document is typically a spread sheet that names all the sensors and motors by module with names agreed on by the team.
b. The CID should be formatted as a table for sorting purposes
c. Device naming convention: **Module-Module function-electrical device name** (e.g. Shooter-Elevator-Motor; [software will have a corresponding name e.g. shooterElevatorMotor)
d. Example of a CID document:

MODULE	DEVICE NAME (Directory Style: Module-Function-DeviceClass)	DEVICE CLASS	DEVICE ID	CAN ID	DEVICE NAME	GEAR STYLE	GEAR RATI	ENCODER STYLE	ENCODER CNTS/RI	RoboRio CONNECTION	PDP CONNECTIO	PDP FUSE VALUI	REMARKS2
Controls	Cntrl-RoboRio	Controls	CNTRL1		RoboRio						RoboRio	10A	
Controls	PwrDist(PDP)	Controls	PDP	00	PDP								
Controls	VltReg(VRM)	Controls	VRM		VRM						VRM	20A	
Controls	Communication Bridge	Controls	BRDG		BRIDGE								Pwr from VRM
Controls	Battery	Battery	BAT		BAT								
Controls	Power Switch	Switch	PWRSW		PWR SWITCH								
Controls	Drive Team Camera	Camera	CAM1		USB Camera								Pwr from VRM
Drive Train	DrvTrn-Left motor1	Motor	DTLM1		CIM								
Drive Train	DrvTrn-Left MC1	Motor Controller	DTLMC1	01	Talon SRX						Channel 0	40A	Ch0-3, 12-15: 40A
Drive Train	DrvTrn-Left motor2	Motor	DTLM2		CIM								
Drive Train	DrvTrn-Left-MC2	Motor Controller	DTLMC2	02	Talon SRX						Channel 1	40A	
Drive Train	DrvTrn-Left-Encoder	Encoder	DTLENC		CIMCoder			Mag Encoder	20				
Drive Train	DrvTrn-Lft-Gear box	Gear Box	DTLGB			Spur	11:1						
Drive Train	DrvTrn-Rgt-motor1	Motor	DTRM1		CIM								
Drive Train	DrvTrn-Rgt-MC1	Motor Controller	DTRMC2	03	Talon SRX						Channel 2	40A	
Drive Train	DrvTrn-Rgt-Motor2	Motor	DTRM2		CIM								
Drive Train	DrvTrn-Rgt-MC2	Motor Controller	DTRMC2	04	Talon SRX						Channel 3	40A	
Drive Train	DrvTrn-Rgt-Gear box	Gear Box	DTRGB			Spur	11:1						
Drive Train	DrvTrn-Rgt-Encoder	Encoder	DTRENC		CIMCoder			Mag Encoder	20				
Gatherer	Gatherer-Spinner-Motor	Motor-Gear	GTSPM		RS-550	Planetary	16:1						
Gatherer	Gatherer-Spinner-MC	Motor Controller	GTSPMC		Talon SP						Channel 4	30A	
Gatherer	Gatherer-Lifter-Motor	Motor-Gear-Enc	GTLFTENC		RS-550	Planetary	17:1	CTR Mag Enc	1024				
Gatherer	Gatherer-Lifter-MC	Motor Controller	GTLFTMC	05	Talon SRX						Channel 5	30A	
Gatherer	Gatherer-Lifter-Dwn Lim	Switch	GTLFTDWNLS		Limit Switch								
Shooter	shooter-Left Wheel-Motor	Motor-Gear-Enc	SHLWHLM		RS-550	Planetary	5.4:1	CTR Mag Enc	1024				
Shooter	Shooter-Left Wheel-MC	Motor Controller	SHLWHLMC	06	Talon SRX						Channel 8	30A	
Shooter	Shooter-Right-Wheel	Motor-Gear-Enc	SHRWHLM		RS-550	Planetary	5.4:1	CTR Mag Enc	1024				
Shooter	Shooter-Right Wheel-MC	Motor Controller	SHRWHLMC	07	Talon SRX						Channel 9	30A	
Shooter	Shooter-Elevator-Motor	Motor-Gear-Enc	SHELVM		RS-550	Planetary	171:1	CTR Mag Enc	1024				
Shooter	Shooter-Elevator-MC	Motor Controller	SHELVMC	08	Talon SRX						Channel 10	30A	
Shooter	Shooter-Elv Dwn-Lim Switch	Switch	SHELVDWNLS		Limit Switch								
Shooter	Shooter-Bld Present-Sensor	Sensor	SHBLDSEN		PhotoElectric					Digital0			
Shooter	Shooter-Bld Advance-Servo	Motor	SHBLDADVM		Servo					PWM0			

4) Team BOM (Bill of materials) is an spread sheet which includes the following items:
   a. Quantity
   b. Component name
   c. Component description
   d. Component part number
   e. Supplier
   f. Supplier part number
   g. Web address of supplier
   h. Weight
   i. Cost.
5) Robot BOM – BOM for robot competition which includes the following items:
   a. Item: supplier part number
   b. Description: description of electrical component
   c. Material: (Not used)
   d. Source: Name of supplier

e. Quantity: how many
f. Measure: “Piece”
g. Unit Price: in dollars

Note: A core BOM that has the basic control components should be available before build season.

3.7.2 Schematic Diagrams

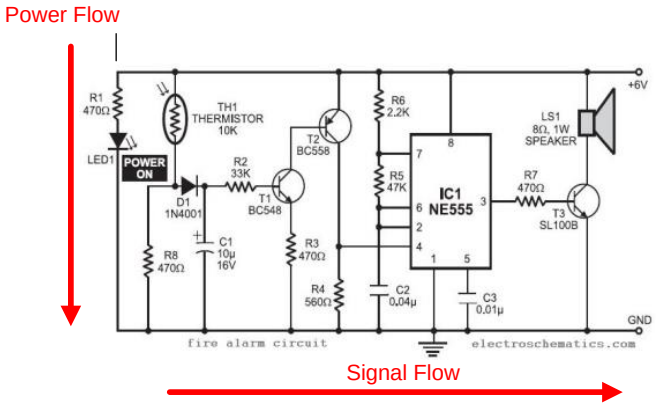
A schematic diagram is a documentation on how the electrical system is wired. There are three types of schematics:

1) Wiring - A diagram showing how electrical sub-system components are wired. Electrical sub-system components are typically shown as boxes.
2) Electronic - A wiring diagram of electronic components on a printed circuit board. There are a variety of symbols depicting electronic components.
3) Electrical Layout and cable routing - A diagram showing the physical placement of electrical sub-system components and how wiring will be routed. This can be done in CAD to check for mechanical inferences.

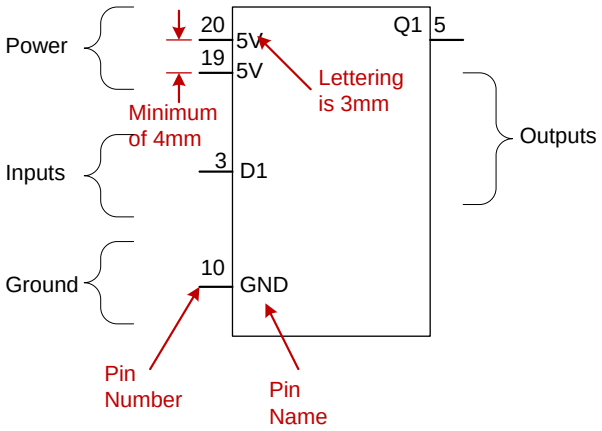
3.7.2.1 Schematic Drawing Conventions

The following is an example of an example of a circuit diagram:

Electrical Schematic Layout



Electrical Symbol Layout

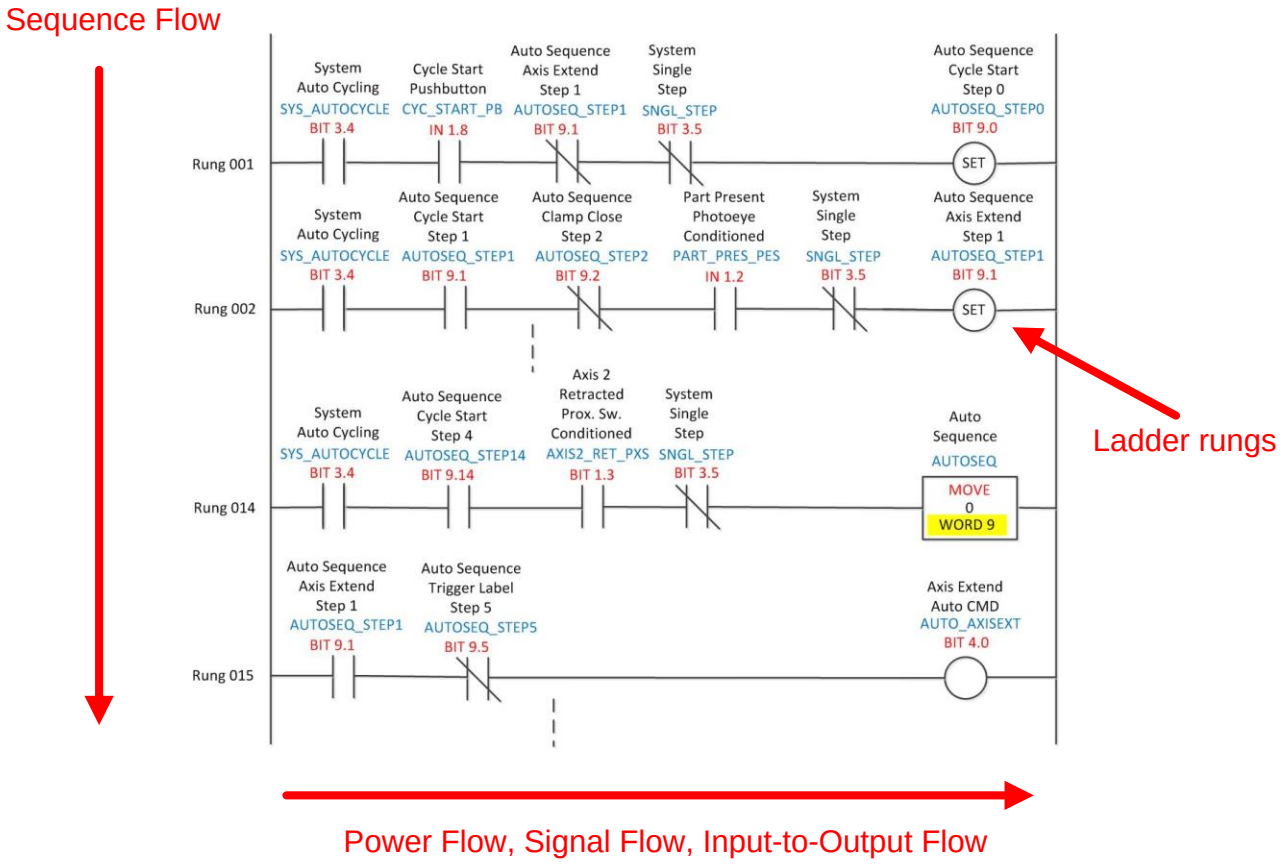


Drawing Paper Size (in)

ISO	ANSI	Width	Length	
A4	A	8.5	11	
A3	B	11	17	Use for all electrical Dwgs
A2	C	17	22	
A1	D	22	32	

The following is an example of an electrical ladder diagram. This circuit layout is typically used for relay circuits and for I/O interface diagrams:

Electrical Ladder Diagram Layout

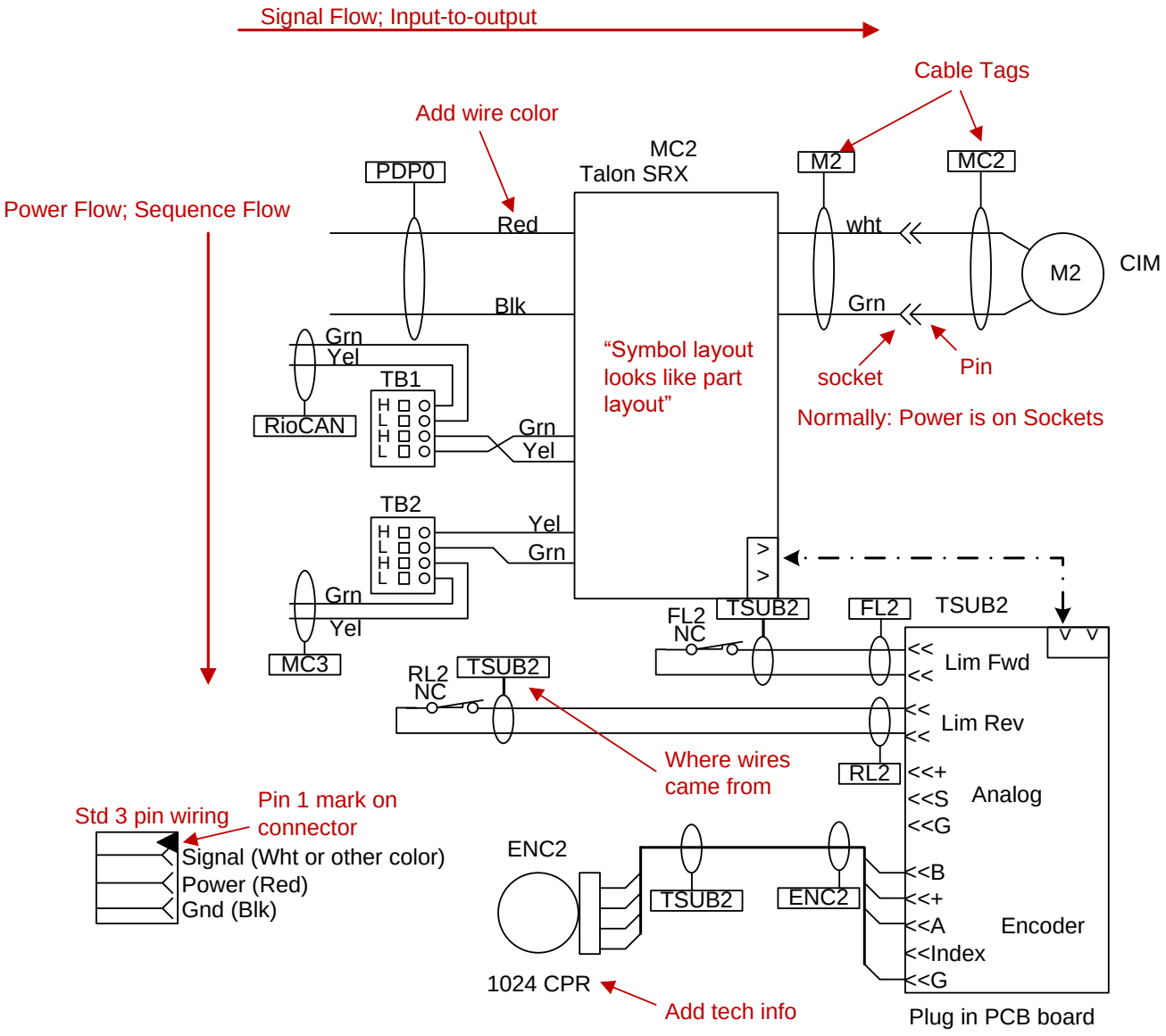


Typical circuit diagram conventions are as follows:

1) Logic flow should be from left to right
2) Inputs to sub-system components should be shown on the left side of the box
3) Output of sub-system components should be shown on the left side of the box
4) Power should be shown on the top of the box or top of the left side and common or ground should be shown on the bottom of the box or the bottom of the left side.
5) **Controller nomenclature:** PDP, RoboRio, PCM, VRM
6) **Controller I/O nomenclature:** PWM(0-9), Relay(0-3), DIO(0-9), AI(0-1); PDP(0-15); PCM(0-7)
7) **I/O Device nomenclature**: Relay[Spike](K), Solenoid(SOL), Encoder(ENC), Ultrasonic sensor(US), limit switch(SW), optical sensor(PE), motors[DC/Servo](M), Resistors(R), Camera(CAM)
8) **Cable Labeling** is as following: tag wire ties should be attached at each end of a cable. The tag should be labeled noting what device the wires came from.

3.7.2.2 I/O Schematic Diagram Example

Typical motor controller schematic layout and wiring with a Talon SRX motor controller:



3.7.2.3 Electrical Schematic Program

TinyCAD will be used as the electrical schematic / wiring layout drawing CAD package. TinyCAD is on the school computers.

Set the options up to measure in mm and the paper size should be A3. When printed on 8.5x11 paper the diagram is still readable.

To make a new symbol:

1. Click on the Open the Libraries button
2. Select Team2228 library and then select edit library
3. Right click on library and select new symbol

The text in symbols are 3mm high. Thus the minimum distance for pins should be 4mm.

3.7.2.4 Robot Schematics – Robot Wiring Sequence

There should be Five Electrical Schematic diagrams for a robot.

1. Electrical Panel Layout with ID tags noted
2. Electrical Wiring Layout showing all I/O devices and cable tags
3. Power Wiring Diagram – this schematic details how power is wired on the robot.
4. Input / Output wiring diagram – this schematic details how all the robot electrical input – output devices are wired
5. Communications Wiring Diagram – this schematic details how to wire all communications connections (e.g Ethernet, CAN, USB, SPI, SP).

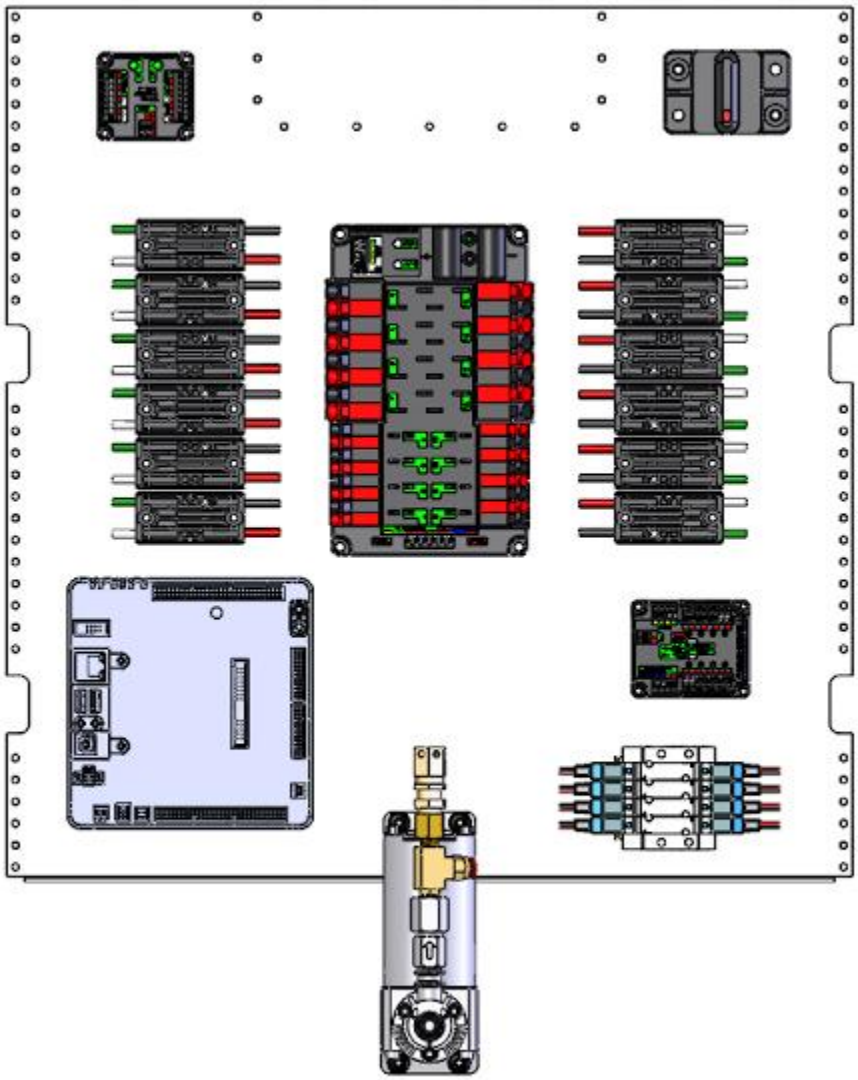
To reduce wiring errors, the robot should be wired in the same sequence noted (e.g. Power, I/O, Communications).

3.8 Electrical Layout Best Practice

The following items should be considered in the layout of the electrical system:

3.8.1 Typical Layout

This is a typical layout(From Team148). The important items to note are the layout of the power components(i.e. The power switch, power distribution, and the motor speed controllers). The goal is to mount components in practical locations for short wire runs and easy access.



3.8.2 Battery

1. Secure the battery so it doesn't fall out
2. Main battery, low and near the center of robot or as counter weight for another robot system.

3. Mount so that it will not move when the robot is struck
4. Mount so that it will not contact metal parts when installed or removed
5. Use a removable belt, strap or clamp to fix in place
6. Battery should be mounted securely and is readily removable(During competition, there is often very little time between matches).

3.8.2.1 Care of Batteries

1. Don't drop batteries
2. Don't pick up batteries by terminals or attached wires
3. Store away from heat
4. Periodically top off charge during the offseason
5. Make sure to always have extra batteries charged
6. A fully charged battery should be used in each match

3.8.3 Main Breaker

The following items should be considered in the layout of the electrical system:

1. Position the breaker so it is easy to get at from outside the robot
2. Mount breaker on a flat surface so that the body of the breaker cannot be stressed or cracked.
3. Mount where the breaker will complete the shortest run from battery disconnect to first distribution block.
4. Mount so that mechanical systems cannot move against the terminals and other robots cannot push the reset button

3.8.4 Motor Drivers

1. The design of the electrical panels should be design such that they can be accessed for repair or testing.
2. The motor power leads should be short(close to the PDP)
3. The panels should be assembled with electrical components and fitted on the robot to test for any interferences.
4. The wiring should not be a rats nest. Control wiring(low voltage) should be routed together separate from motor wiring. (This is done to prevent electrical noise from coupling into low level sensor circuits.)
5. All cables should be labeled.
6. The CAN communications wires should be twisted pair wires. (This is done to prevent electrical noise from coupling into low level sensor circuits.)
7. Color code should be consistent throughout the robot

3.8.4.1 General Jaguar Precautions

1. Mount the Jaguar module so that the vents in the top and sides of the unit are not restricted in any way. Maintain a clearance of at least ½ inch between modules.
2. Do not exceed the absolute maximum supply. Doing so causes permanent damage to the module
3. Protect Jaguar from all situations where debris could enter through ventilation slots or connector openings.

3.8.5 Wiring Layout

1. All wiring should be laid out in a logical, orderly manner between circuit devices
2. **KEEP WIRING NEAT:** Wires should be routed and extra length wrapped in a loop and wire tied in two places.
3. Keep wiring out of the way of moving components
4. Use wire ties to tie down wiring.
5. Make sure to label all wiring so that if components need to be replaced
6. Use labeling system to associate wires with functions.
7. Reduce wiring - Make sure to use as little as needed. Inspectors can readily see what you have, and will be able to check things much faster
8. Choose a safe and protected pathway inboard the main robot frame for the harness to ensure the robustness and reliability of the electrical system
9. Whenever possible, harnesses should be sorted and separated into “power” and “Signal” cable groups. Ideally they should be run in different pathways to their destinations. If signal wires have to cross over power wires, the signal wires should be perpendicular to the power wires.

3.9 Robust Electrical Design-

The following items should be considered in the design of a robust electrical design:

1. Metal Filings – are bad, bad, bad for electronics; remove or cover all electronics before any filing, drilling, sawing, etc
2. Liquids – keep these away, don’t tempt fate
3. Allow for airflow (cooling)
4. Vibration – mount electronics so they don't get mechanically shocked, vibrated, shaken to death, crushed, collided, or otherwise mutilated
5. Location of the Terminal Blocks to minimize wire length and allow easy connection of 40 amp returns
6. Control System status lights and buttons visible and accessible
7. Keep ports on robot controller clear
8. Neatness counts – tie-up cable runs
9. Access to all components for test and replacement
10. Reduce resistance in the electrical design. This is accomplished by short power wire runs, good crimps(high current should be soldered)

4 ELECTRICAL CRIMPING-TAPING-WIRING

4.1 Crimping

1. Be sure of crimp on connectors by using a ratchet style crimper. Use the proper terminal size and proper length of stripped area.
2. Solder terminals when you doubt the effectiveness of the crimp
3. Solder critical terminals (like the 6 AWG battery lugs)
4. Insulate exposed electrical terminations

4.2 Taping

1. To make taping easy to remove, the following process should be used:
    a. After you cut a piece of tape, bend over both end of the tape to form two end tabs
    b. Wrap the tape around the components being taped
    c. To remove the tape, pull on the outside tab to separate the tape

4.3 Wiring

1. Use appropriate gauge wire. Inspectors will be checking this closely
2. Leave some slack in wire to allow for swapping of parts
3. Wires leaving devices should be grouped and bound together with plastic ties and chassis anchors to form wire harnesses
4. Consider weight of wire - short wire runs
5. Secure wire so a hit from another robot doesn't stretch, pull or break the wiring from robot devices
6. Run wiring through frame members such that mechanicals don't drill into it
7. Make sure all connections are insulated. Use insulated connectors, electrical tape, or adequate heat shrink for all connections.

4.4 Electrical Assembly

1. Before assembling any electrical subsystem all parts should be gathered into a kit
2. The pre-assembly check list should be completed
3. After assembly the assembly check list should be completed
4. Before power up the power up check list should be completed

5 FRC TYPICAL WIRING RULES

Every year the Robot manual should be reviewed for electrical requirements by FIRST. Also the Inspection sheet should be reviewed(2015 - CTElect-.First 2015-FRC-Inspection-Checklist)

5.1 Wire Color Code

Power:

RED: +12 volts
RED/BROWN: +5

BLACK: +12 Volt Power return line
BLACK/BLUE: +5 Volt Return

CAN wires:

YELLOW, GREEN twisted

Signal wires:

WHITE: Signal line
BLACK/GREEN: Signal return line

5.2 Power Wiring

1. Keep wire runs short, especially those that share currents
2. Use #6 wire or larger for primary loop
3. Crimp and solder heavy ring terminals for screw terminations Consists of #6 wiring, 50 amp Anderson connector, Main breaker, Power Distribution Panel and battery
4. Use lock washers between the battery terminals and the wire terminals to prevent terminals from twisting and causing loose hardware
5. Frame must be electrically isolated from battery(>10k Ohm between either PD battery post and chassis)
6. #10 for high current loads(i.e. main motors)

5.3 Components

1. Spike must have 20 amp fuse installed
2. Only one motor or load may be attached to each Spike, Jaguar Talon SRX
3. (however two pneumatic valves may be driven by a single Spike).
4. Motor/Actuator Power –CIM and FP motors must be fed by speed controllers
5. Motors can only be driven directly by PWM signals from a RoboRIO or by CAN bus
6. Only one wire per weldmuller connection

5.4 Fuses

1. Only 20, 30 and 40 Amp Snap-Action breakers may be installed in the PDP
2. Wire / Fuse conventions:
    a. 40 amp breakers have min #12 AWG
    b. 30 amp breakers have min #14 AWG
    c. 20 amp breakers have min #18 AWG

5.5 Fuse Loads

1. Each speed controller must be

A. Each speed controller branch circuit must be protected by one and only one 20-amp, 30-amp, or 40-amp circuit breaker on the Power Distribution Board. No other electrical load can be connected to the breaker supplying this circuit.

B. Each relay module branch circuit must be protected with one and only one 20-amp circuit breaker on the Power Distribution Board. No other electrical load can be connected to the breaker supplying this circuit.

C. Each Digital Sidecar branch circuit must be protected with one and only one 20-amp circuit breaker on the Power Distribution Board. No other electrical load can be connected to the breaker supplying this circuit.

D. If the compressor is used, the relay module branch circuit supplying the compressor must be protected with a 20-amp circuit breaker. No other electrical load can be connected to the breaker supplying this circuit.

Each power-regulating device (speed controller or relay module) shall control one and only one electrical load (motor, actuator or compressor).

A. Exception: Multiple low-load, pneumatic solenoid valves may be connected to a single relay module. This would allow one relay module to drive multiple pneumatic actions. No other electrical load can be connected to a relay module used in this manner.

6 ELECTRICAL TESTING - DEBUG

STOP-STOP-STOP-STOP-STOP-STOP- STOP-STOP-STOP-STOP-STOP-STOP

6.1 Electrical Testing Levels

There are four levels of electrical testing:

1. Pre-assembly testing; see pre-assembly check list in appendix
2. Assembly testing; see assembly check list in appendix
3. Power up testing; see power up check list in appendix
4. Debugging

6.2 Safety: Power Up Verbal Verification Process:

1. A safety observer shall be assigned.
2. The person on the “Power Switch” Shall proclaims “**Power ON**”
3. Only the safety observer after assessing the situation responses **“All Clear**”

4. The person on the “Power Switch” final response should be “**Power Active**” (This response is a verification of the safety observer.)

6.3 After Power Is Turned On

1. After power is turned on check the status of all troubleshooting LED's
2. With the RoboRio powered up and the driver station powered up, use the I/O test screen to check all I/O

6.4 Working On Electrical Equipment With Power On

1. Shut the Power OFF before working on electrical circuits or exchanging components. Also vent the pneumatic system.
2. Following electrical service work always inspect potential short circuits before applying power

7 TROUBLESHOOTING

7.1 Troubleshooting Process

When troubleshooting the following items should be checked:

1. Is everything plugged in?
2. Is there power?
3. Are all connections secured?
4. Are there any loose or broken wires?
5. Is there any debris shorting something out?
6. What do the troubleshooting lights say?
7. If the system was working, what has changed?

Remember people skills are important, everyone has a suggestion on how to fix the problem or who is to blame. You may have to "fix the customer" before you fix the equipment. Here is where Gracious Professionalism comes into play.

7.2 Device Troubleshooting Lights

See CTElect-FIRST Status LED Troubleshooting. This document covers:

- Robot Signal Light
- RoboRIO
- Power Distribution Panel
- Voltage Regulator Module
- Pneumatics Control Module
- Jaguar speed Controller
- Talon-SPX speed Controller
- Spike Relay

7.3 Jaguar Motor Controller

7.3.1 The LED status is as follows (not all conditions recreated here..)

1. Fast flashing yellow means you're NOT getting a valid signal on the wire. If you've got this, check your code or your wiring.
2. Solid yellow means you're getting a valid signal on the wire and that it is in the neutral range, and should produce 0 V on the output.

3. Fast flashing green means that you are going forward, and should produce between 0 V and 12 V.
4. Solid green means that you're at full forward, and should produce 12 V on the output.
5. Fast flashing red means that you are going reverse, and should produce between 0 V and -12 V.
6. Solid red means that you're at full reverse, and should produce -12 V on the output.
7. Output voltage measured across M+ and M- (white terminal to green).
8. Also, check your limit switch jumpers are both installed

8 ROBOT ELECTRICAL TRAINING

8.1 Elect1 - Electrical Processes and Tools

Topics:

1. How to crimp a terminal
2. How to solder
3. How to splice an inline wire
4. How to solder a component to a printed circuit board
5. How to de-solder a component from a printed circuit board

8.2 Elect1 - Electricity - Magnetics - Wire

Topics:

1. Electricity - Mechanical Analogy
2. Basic components: Battery, Resistance
3. Electrical relationships(E=IR...)
4. Wire Characteristics
5. Magnetics in action(Relay, Solenoid, Motor)

8.3 Elect2 - FRC Control System Components

Topics:

1. 2015-2019 Control System Components
2. Sensor overview

8.4 Elect2 - Electrical Design - Layout - Wiring

Topics:

1. FRC Wiring Architecture
2. Electrical Schematics / BOM
3. Electrical Layout
4. Wiring Control System Components
5. Wire routing
6. Competition Electrical Inspection
7. Fail Safe Wiring
8. Robust electrical design

8.5 Elect2 - Troubleshooting

Topics:

1. Electrical Power up process
2. Component LED status lights
3. Driver Station I/O checkout

4. Electrical Measurements

8.6 Elect2 - Electronics - Drivers - Sensors

Topics:

1. Signals: analog / Digital
2. Transistors - Integrated circuits
3. Drivers: Output Driver, Solenoid driver, motor driver
4. Sensors: Switches, Encoders, Ultrasonic's, Optical, LIDAR, accelerometers, gyro, Vision

8.7 Elect3- Motor Sizing

Topics:

1. Motor equations
2. Motor curves
3. Mechanical advantage: gears
4. Motor sizing

8.8 Elect3- Electrical Magnetics(Solenoid/Motor/Motor Control)

Topics:

1. Magnetics(Magnetics at work: solenoid, motor)
2. Motor control components - architecture
3. Motor operational theory
4. Motor driver theory(PPM, PWM, H-Bridge)
5. Motor Feedback: analog - Digital(encoder)

8.9 Elect3 - Printed Circuit Design(PCB)

Topics:

1. Bread Board Design
2. Schematic Capture
3. PCB CAD tools
4. PCB Etching

8.10 Electrical Cross Training

It is the expectation that the electrical sub-team members have cross training in mechanical and software topics. See Technical Director handbook on training matrix.

9 Appendix A: Electrical Pre-Assembly Checklist

- ☐ Are the Electrical schematics completed?
- ☐ Are signal levels between devices correct?
- ☐ Is the Electrical Bill of Materials completed?
- ☐ Has the electrical system weight been determined?
- ☐ Has the control system kit of parts completed?
- ☐ Has the RoboRio been imaged?
- ☐ Have the Motor controllers configured and firmware updated?
- ☐ Have the motor controllers been configured with CAN bus addresses?
- ☐ Has the CID documented updated with motor controller firmware version?
- ☐ Have motors been evaluated? (i.e. Motor resistance and quick 12volt operational test)
- ☐ Have sensors been tested for operation?
- ☐ Are all components labeled with ID tags with respect to CID?
- ☐ Are component cables labeled with ID tags with respect to CID?

10 Appendix B: Electrical Assembly Test Checklist

10.1 Visual Checks

- ☐ Open the Main Circuit Breaker with the RESET button and/or unplug the battery
- ☐ Check all connections. Check for any wires that may be shorted or frayed wires
- ☐ Check for broken wires
- ☐ Check that there is no debris shorting something out
- ☐ Inspect battery for cracked, or damaged battery cases, or any evidence of electrolyte leakage
- ☐ Check for polarity wiring on all modules, speed controllers (Talon SRX, Jaguar)
- ☐ Check CAN wiring. Is the PDP the last module in the network chain?

10.2 Electrical Tests

- ☐ With a multi-meter measure the resistance on the circuit side of the power switch that there are no shorts.
- ☐ Check CAN resistance: Measure with an ohm meter across the GREEN and YELLOW wire. The meter should be about 60 ohms. (The bus has two 120 ohm terminating resistors, one at each end)
- ☐ With electrical test box test the cabling, function of all sensors, and encoders.
- ☐ Mark off on CID document sensors and motors tested.

11 Appendix C: Power UP Check List

11.1 Before Power is Applied – Visual inspection

- ☐ Open the Main Circuit Breaker with the RESET button and/or unplug the battery
- ☐ Check all connections. Check for any wires that may be shorted.
- ☐ Check for broken wires
- ☐ Check that there is no debris shorting something out
- ☐ Inspect battery for cracked, or damaged battery cases, or any evidence of electrolyte leakage

11.2 Before Power is Applied – Electrical Test

- ☐ With a multi-meter measure the resistance on the circuit side of the power switch that there are no shorts.

11.3 Safety: Power Up Verbal Verification Process:

1. A safety observer shall be assigned.
2. The person on the “Power Switch” Shall proclaims “**Power ON**”
3. Only the safety observer after assessing the situation responses **“All Clear**”
4. The person on the “Power Switch” final response should be “**Power Active**” (This response is a verification of the safety observer.)

11.4 After Power is Applied

- ☐ Check the status of all troubleshooting LED's
  - Robot Signal Light
  - RoboRIO
  - Power Distribution Panel
  - Voltage Regulator Module
  - Pneumatics Control Module
  - Jaguar speed Controller
  - Talon-SPX speed Controller
  - Spike Relay
- ☐ With the RoboRio powered up and the driver station powered up, use the I/O test screen to check all I/O