Advanced Robot Electrical Design

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2007 *FIRST* Robotics Conference

Outline

- Getting the most from your design.
- Real world design example.
- Minimize the losses.
- What happens with a motor under varying conditions.
- Working with a design and layout.
- Techniques and layout.
- Tools
- Questions

How to get the most from your robot electrical system.

- There are a variety of problems you may encounter in robot electrical that affect the performance of your robot. All lead to increased resistance…
  – Resistance in your design.
  – Resistance in your assembly.
  – Resistance in failed parts, crimps, hardware, etc.

Real World Example

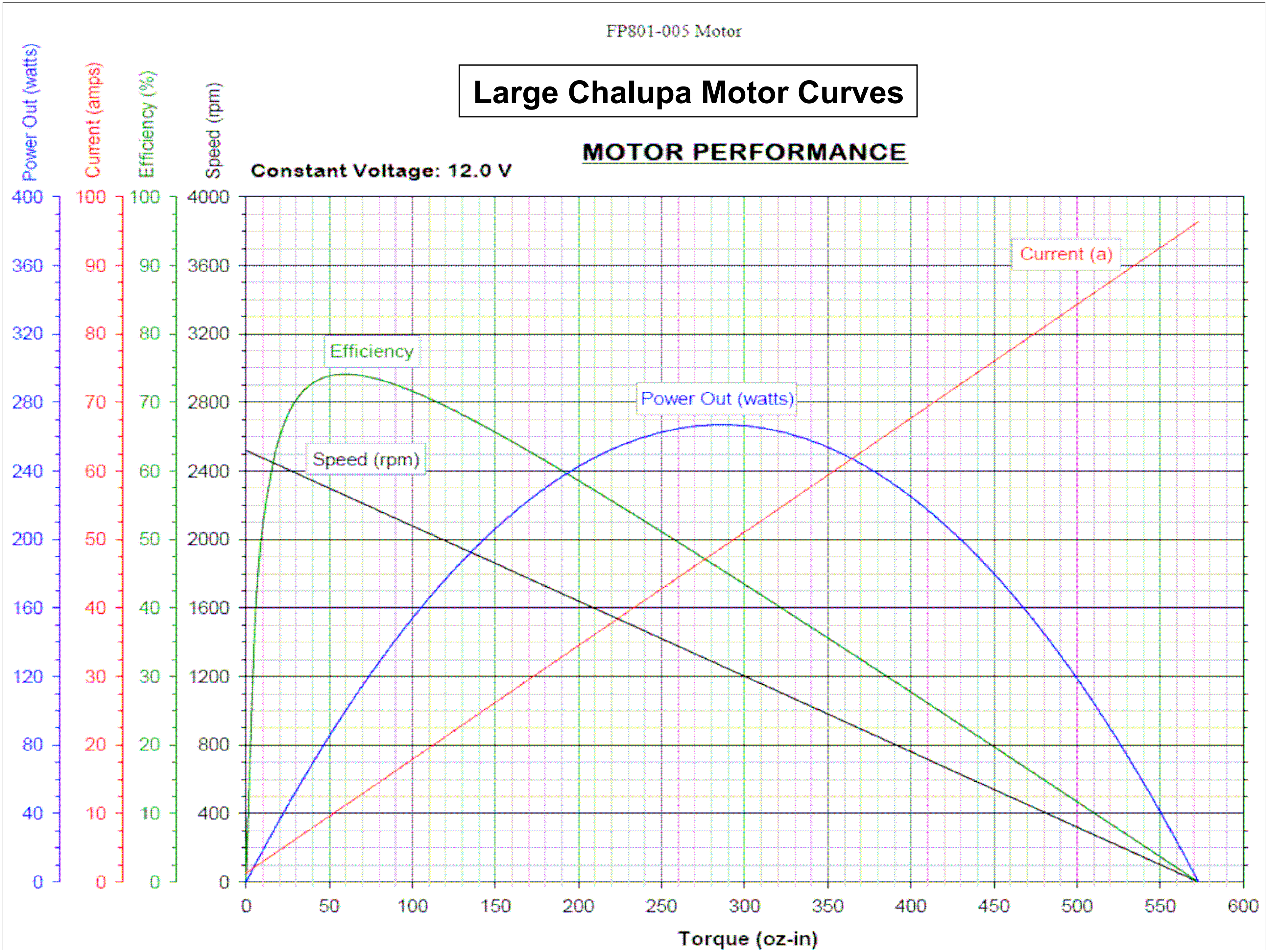
- Function of the robot systems in a real world example.
  - What actually will take place on your robot.
  - Perhaps what is taking place on your robot today.

Typical 2007 Robot Design

- Four motor drive, two large and two small Chalupas into AndyMark Transmissions.
- Multiple motors for arms and/or ramps.
- Pneumatics on robot.
- Sensors and camera.
- Custom Circuit.

Working on the arm motor.

- Lets take a large Chalupa motor with the following specifications:
- Stall Current = 96 amps
- Peak Power Output = 280 watts
- Choose operating point of 1600 RPM@225 oz-in., 40 amps, 160 watts out.
- If input= 12v@40amps, then
- R_{motor} =12/40=.3 ohms


FP801-005 Motor
Large Chalupa Motor Curves
MOTOR PERFORMANCE
Constant Voltage: 12.0 V
Power Out (watts)
Current (amps)
Efficiency (%)
Speed (rpm)
Efficiency
Power Out (watts)
Current (a)
Speed (rpm)
Torque (oz-in)
0
50
100
150
200
250
300
350
400
450
500
550
600
0
400
800
1200
1600
2000
2400
2800
3200
3600
4000
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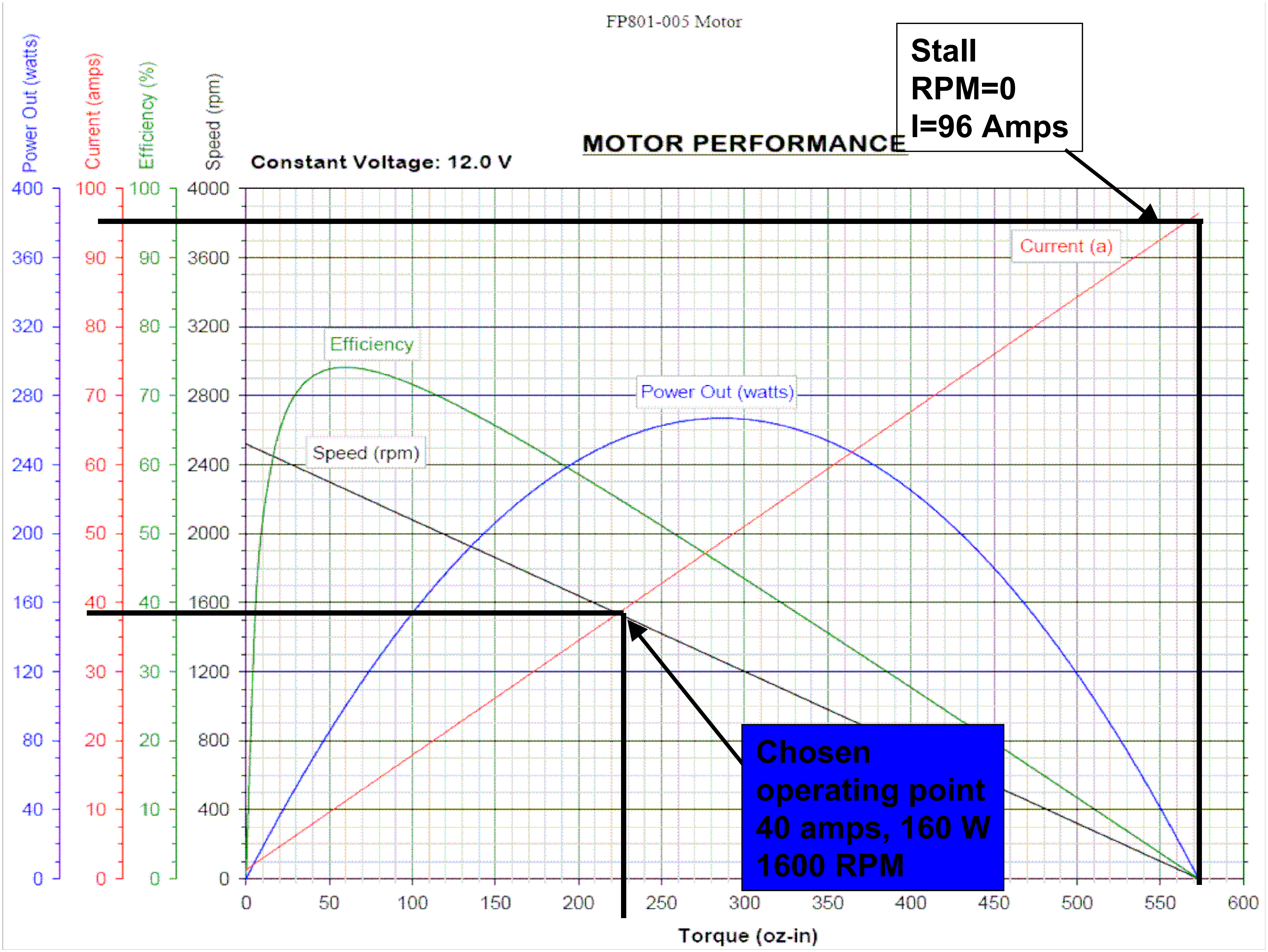
160
200
240
280
320
360
400



FP801-005 Motor
MOTOR PERFORMANCE
Constant Voltage: 12.0 V
Stall
RPM=0
I=96 Amps
Power Out (watts)
Current (amps)
Efficiency (%)
Speed (rpm)
Efficiency
Power Out (watts)
Speed (rpm)
Current (a)
Chosen operating point
40 amps, 160 W
1600 RPM
Torque (oz-in)

If there is resistance in series with a circuit, the current will decrease in direct proportion to the resistance. A decrease in current will provide less power from the motor.

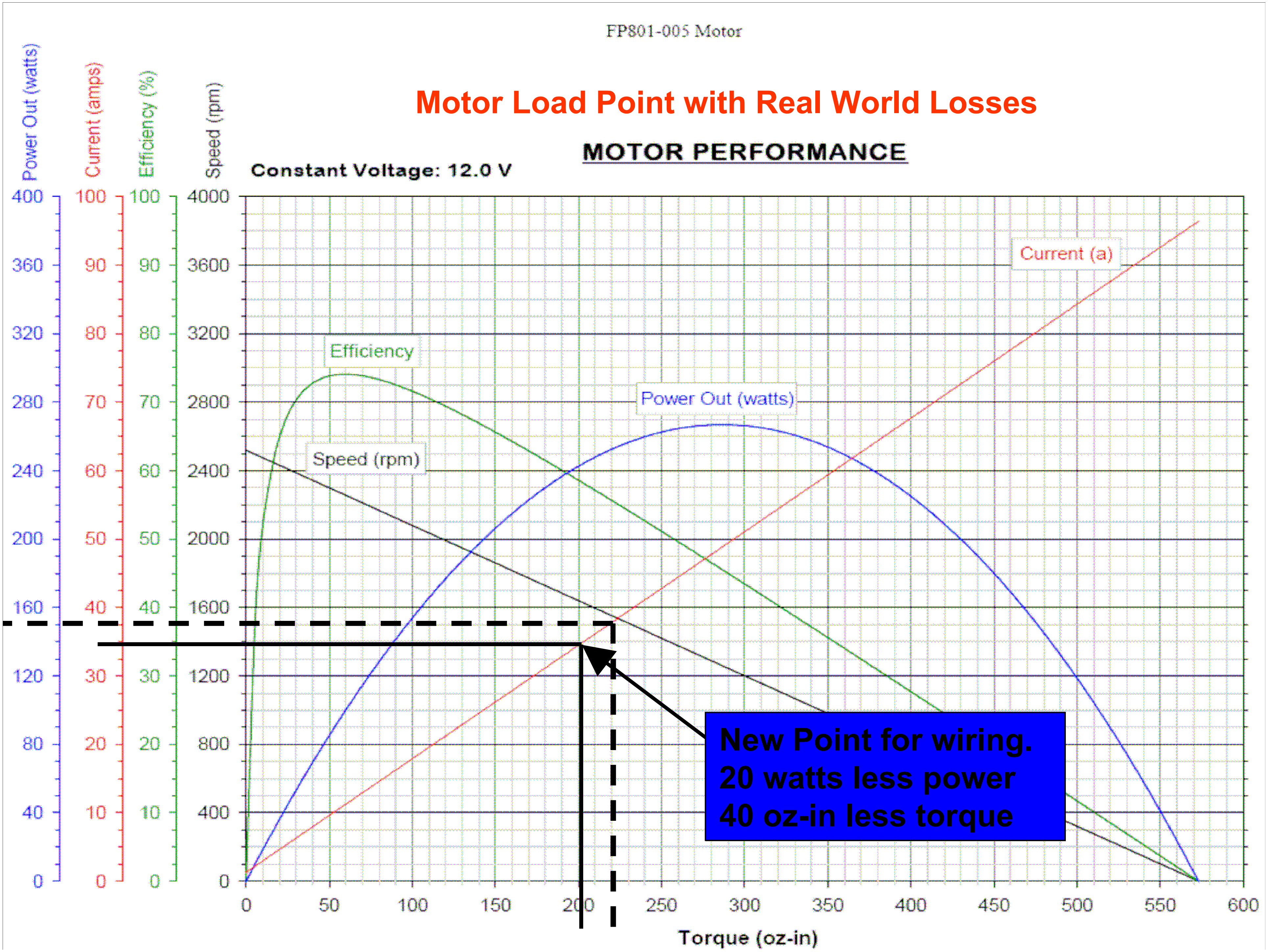
Ohm's Law

$R_{(motor)}$ =V/I=12V/40A=0.3 Ohms

Calculating for 4' of #10, 2' of #6, 0.011 ohms for the battery internal resistance and .002 ohms for breakers and terminals.

.3+.008+.0028+.011+.002=0.3238 ohms

$I_{(motor)}$ =V/R=12V/.3238 Ohms=37 Amps


FP801-005 Motor
Motor Load Point with Real World Losses
MOTOR PERFORMANCE
Constant Voltage: 12.0 V
Power Out (watts)
Current (amps)
Efficiency (%)
Speed (rpm)
Efficiency
Power Out (watts)
Current (a)
Speed (rpm)
Torque (oz-in)
New Point for wiring.
20 watts less power
40 oz-in less torque

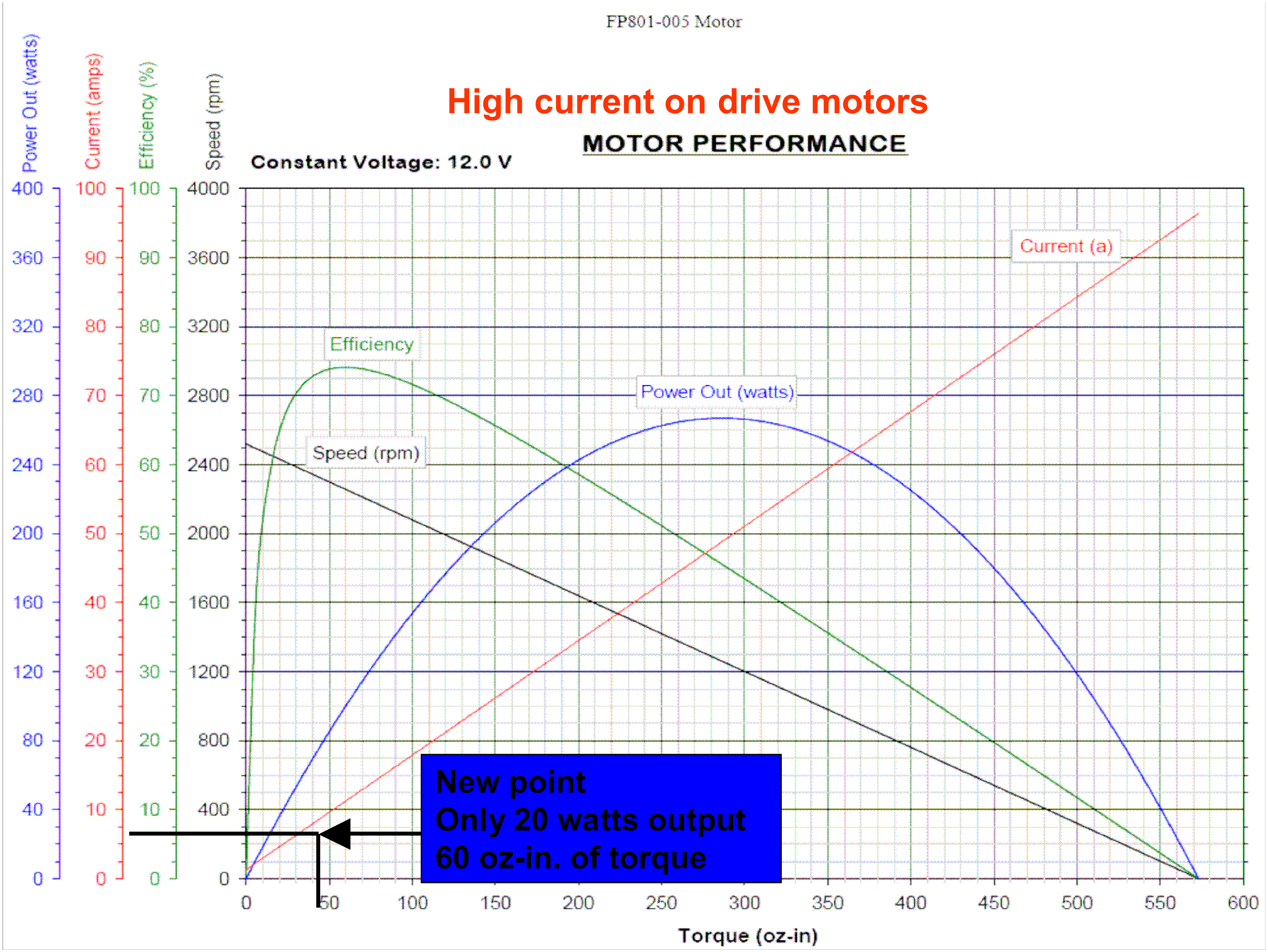
If this is an average system and four small Chalupa drive motors are near stall,

$I_{(stall)}$ =100 amps x 4 motors=400 amps.

The battery is capable of delivering more than 600 amps when fully charged. So for this example 400 amps flows through 4' of #6, a few connectors and the fuse panel, then the voltage loss in this robot is:

V=I*R=400*0.0238ohms=9.52 volts.

That leaves only 2.5 volts available for all other systems including the RC. In terms of motor current, I=V/R=2.5/.3238 ohms=7.7 Amps (if the RC were still in control).


FP801-005 Motor
High current on drive motors
MOTOR PERFORMANCE
Constant Voltage: 12.0 V
Power Out (watts)
Current (amps)
Efficiency (%)
Speed (rpm)
Efficiency
Speed (rpm)
Power Out (watts)
Current (a)
New point
Only 20 watts output
60 oz-in. of torque
Torque (oz-in)

Each intermittent load on a motor reduces the available current and therefore reduces power and RPM temporarily.

- This is why many robots with arms are not able to raise a tube as designed, other motors are causing losses in the system.
- It is also why a team that raises the arm when not moving may not achieve the same movement while driving.

What is a stalled motor and why is it bad?

– A stalled motor is one that is **not moving**.
  - Robot is pushing a non-moving robot.
  - Robot has run into an obstacle, goal or wall.
  - Robot is attempting to climb an obstacle.
  - Compressor when starting.

Stalled motors draw excessive current.
  - 133 amps/small Chalupa
  - 96 amps/large Chalupa
  - 63 amps/FP
  - 25 amps Compressor

How to minimize the losses.

- Begin with a good design.
- Layout components to minimize wire losses (length).
- Effectively mount parts and make wire runs balanced for drive motors to help drive straight.
- Use good techniques in making connections and terminating electrical devices.
- Solder terminals when you doubt the effectiveness of the crimp.
- Insulate exposed electrical terminations.

To Begin Design and Layout of Robot Electrical System, know your robot system.

- It is essential to know the list of requirements for the system before you begin.
- It is essential to have an grasp on the location of mechanical parts and needed clearance.
- Must work with mechanical designer to place major components in a central location, i.e. battery, main breaker, fuse panels.

- ***You must know how many motors will be used.***
  - How many and what type of motors for drive and where located.
  - How many motors for actuators, are they required to be speed controlled or operated by relay.
  - How many motors for steering.
  - How many servo motors.
  - Where will all these be located on the robot?

– ***You must know if you will be using sensors.***

- Light Sensors
- Gear Tooth Sensor
- Accelerometer
- Current Sense
- Custom Sensor
- Camera

– ***Do the sensors need power?***

- What sensors need 5 volts, what need 12 volts?
- Will the power be provided by a Custom Circuit, RC or Breaker?

– ***If you will be using a custom circuit…***

- Will it need sensors?
- What kind?
- What will be the interconnect requirements?
- How will it connect to the RC?
- What power does it require?
- What will happen when the power droops?
- Does it allow software changes?
- Does it need an enclosure, special connectors or custom cable assembly?

- ***You must know if you will be using pneumatics.***
  - On board compressor (25 amps starting/ 10 amps run current)
  - Off Robot Compressor (no current)
  - How many valves?
  - Norgren pressure switch?
  - Other pressure Transducer?
- ***What Breaker Panel will you need/use?***
  - Will you be using more than one ATA panel?
  - Will you need to use the Maxi Block(s)?
  - What are the advantages of one or the other?

– ***You must know what electrical hardware you will be using.***
  - How many Victors and how many Spikes will be needed?
  - Will you be using the SLU or crimp connectors for the mains wiring?
  - How do I attach cable to the battery terminals?
  - Do I need to use insulated or non insulated terminals?
  - Do we need to solder?

- **Know the installation failure modes of all devices.**
  - How should it react when powered?
  - Does it have indicators and what do they mean?
- **Know the correct handling of all devices.**
  - What component is best for terminations?
  - What are the mechanical stresses due to mounting and termination?
  - What happens if you drop the device?
  - What is the correct wiring polarity?
  - How should it be electrically protected?
  - Is there a common mistake when installing?

Now, Let's Begin With a Plan!

- Make a table of controlled components needed
- Add control components (Victor or Spike)
- Obtain the control inputs and outputs from the software team
- What Breakers are needed
- Will sensors be associated with the motors?
- Other data, color coding

Color code everything, make a list of functions. Electrical and software will need this list.

Motor Functions - 2007

Motor	Control	Feedback	Speed Controller	Relay	PWM Output	Braking (A-B)	Current Rating	Comp Output	Connection
Chiaphua	PWM	Distance/Velocity encoder, Current	Blue		1	No	40A	Flipped	PowerLoc
Chiaphua	PWM		Green		2	No	40A	Flipped	PowerLoc
Chiaphua	PWM	Distance/Velocity encoder, Current	Orange		3	No	40A	Normal	PowerLoc
Chiaphua	PWM		Red		4	No	40A	Normal	PowerLoc
Globe	PWM	Digital Pot - 270 Deg	Yellow		5	No	30A	Normal	PowerLoc
Globe	PWM	Digital Pot - 270 Deg	Grey		6	No	30A	Normal	PowerLoc
Fisher Price	PWM	Digital Pot - 300 Deg	Purple		7	No	30A	Normal	PowerLoc
Window	PWM	Digital Pot - 270 Deg	Brown		8	No	20A	Normal	PowerLoc
Window	PWM	Digital Pot - 180 Deg	Black		9	No	20A	Normal	PowerLoc
	PWM		White		10	No			
	PWM		Green/Brown		11	No			
	PWM		Black/Brown		12	No			
			Relay		Relay Output				
Air Piston #1	In/Out	1-way Valve On-Off		Blue/Black	1		20A		
Air Piston #2	In/Out	1-way Valve On-Off		Blue/White	1				
Air Piston #3	In/Out	1-way Valve On-Off		Green/Black	2		20A		
				Green/White	2				
Air Piston #4	In/Out	1-way Valve On-Off		Orange/Black	3		20A		
				Orange/White	3				
servo or cylinder				Red/Black	4		20A		
servo or cylinder				Yellow/Black	5		20A		
				Grey/Black	7		20A		
				Red/Green	6		20A		
				Purple/Yellow			20A		
			Digital Inputs	Port			Analog Inputs	Port	
			Pump	1			Front Crab Pot	1	
				2			Rear Crab Pot	2	
				3			Shoulder Pot	3	
				4			Forearm Pot	4	
				5			Rotation Pot	5	
				6				6	

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Color code everything, make a list of functions. Electrical and software will need this list.

Motor Functions - 2007

Motor	Control	Feedback	Speed Controller	Relay	PWM Output	Braking (A-B)	Current Rating	Comp Output	Connection
Chiaphua	PWM	Distance/Velocity encoder, Current	Blue		1	No	40A	Flipped	PowerLoc
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Chiaphua	PWM	Distance/Velocity encoder, Current	Orange		3	No	40A	Normal	PowerLoc
Chiaphua	PWM		Red		4	No	40A	Normal	PowerLoc
Globe	PWM	Digital Pot - 270 Deg	Yellow		5	No	30A	Normal	PowerLoc
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Window	PWM	Digital Pot - 180 Deg	Black		9	No	20A	Normal	PowerLoc
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	PWM		Green/Brown		11	No			
	PWM		Black/Brown		12	No			
			Relay		Relay Output				
Air Piston #1	In/Out	1-way Valve On-Off		Blue/Black	1		20A		
Air Piston #2	In/Out	1-way Valve On-Off		Blue/White	1				
Air Piston #3	In/Out	1-way Valve On-Off		Green/Black	2		20A		
				Green/White	2				
Air Piston #4	In/Out	1-way Valve On-Off		Orange/Black	3		20A		
				Orange/White	3				
servo or cylinder				Red/Black	4		20A		
servo or cylinder				Yellow/Black	5		20A		
				Grey/Black	7		20A		
				Red/Green	6		20A		
				Purple/Yellow			20A		

Motor List

Digital Inputs	Port
Pump	1
	2
	3
	4
	5
	6

Analog Inputs	Port
Front Crab Pot	1
Rear Crab Pot	2
Shoulder Pot	3
Forearm Pot	4
Rotation Pot	5
	6

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Motor Functions - 2007

Motor	Control	Feedback	Speed Controller	Relay	PWM Output	Braking (A-B)	Current Rating	Comp Output	Connection
Chiaphua	PWM	Distance/Velocity encoder, Current reading	Blue		1	No	40A	Flipped	PowerLoc
Chiaphua	PWM		Green		2	No	40A	Flipped	PowerLoc
Chiaphua	PWM	Distance/Velocity encoder, Current reading	Orange		3	No	40A	Normal	PowerLoc
Chiaphua	PWM		Red		4	No	40A	Normal	PowerLoc
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	PWM		Black/Brown		12	No			
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Air Piston #1	In/Out	1-way Valve On-Off		Blue/Black	1		20A		
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Air Piston #3	In/Out	1-way Valve On-Off		Green/Black	2		20A		
				Green/White	2				
Air Piston #4	In/Out	1-way Valve On-Off		Orange/Black	3		20A		
				Orange/White	3				
servo or cylinder				Red/Black	4		20A		
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Digital Inputs	Port
Pump	1
	2
	3
	4
	5
	6

Analog Inputs	Port
Front Crab Pot	1
Rear Crab Pot	2
Shoulder Pot	3
Forearm Pot	4
Rotation Pot	5
	6

PWM & Brake

Current and Polarity

- ***You must know the mechanical layout of the robot.***
  - Work with the mechanical designer to position electrical parts. Keep in mind shortest wire runs, protection of electronic components and try to balance out the distribution of loads equally.
  - Establish mounting areas for:
    - Main battery, low and near the center of robot.
    - Main circuit breaker, accessible but not vulnerable.
    - Location of the Terminal Blocks to minimize wire length and allow easy connection of 40 amp returns.
    - Location of circuit breaker panels to minimize wire from terminal block
    - Location of Speed Controllers and Spikes
    - Wire runs and tie down points
    - Sensors
    - Custom Circuit Board
    - Special needs, i.e. moving assemblies, removable modules, optional motors, multiple configurations.

Be prepared to change with mechanical design changes.

Robot design is constantly changing throughout the build season and at events.

- **Mount the battery to satisfy the following conditions:**
  - Mount so that heat generated within the device can escape.
  - Mount near center of robot for better balance.
  - Mount so that it will not move when the robot is struck.
  - Mount so that it will not contact metal parts when installed or removed.
  - Insulate all exposed metal, <u>both terminals, please</u>.

•Select main breaker mounting position so that the following criteria is satisfied:

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

- **Select Breaker Panel mounting to satisfy the following criteria:**
  - Near main breaker to minimize wire run.
  - In a visible spot on the robot so you can see that all breakers are installed and wiring is correct gauge.
  - Mount away from high temperature components, i.e. away from drive motors. Heat will affect the trip point on circuit breakers.
  - Do not mount upside down. Breakers will loosen and fall out.

Select Location for Terminal Blocks

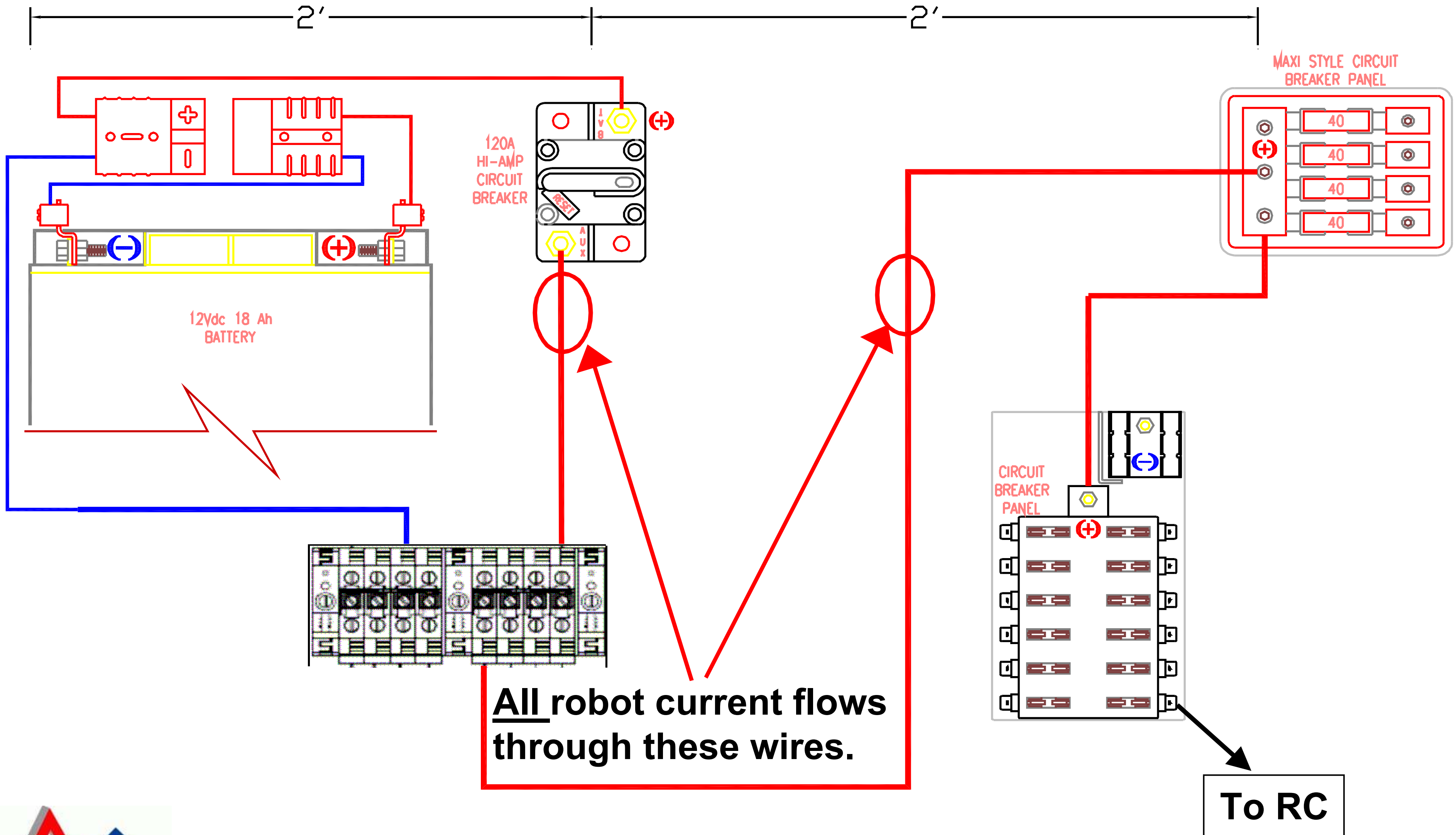
- The terminal blocks should be close to the main circuit breaker and battery negative wire.
- Blocks should be close to the Maxi-block fuse holders.
- Blocks should be centrally located within the robot for balanced wire runs to drive motors.
- Blocks may be mounted in any position but need access to screws for securing wires.

- **Mount the speed controllers to satisfy the following:**
  - Do not confine or cover the controller.
  - Mount so that it is easy to replace.
  - Mount so that it is between the breaker panel and the motor in a nearly direct line.
  - Mount so you can check hardware, check PWM cable, have access to brake jumper and see the indicator.
  - Mount so you can <u>calibrate!</u>

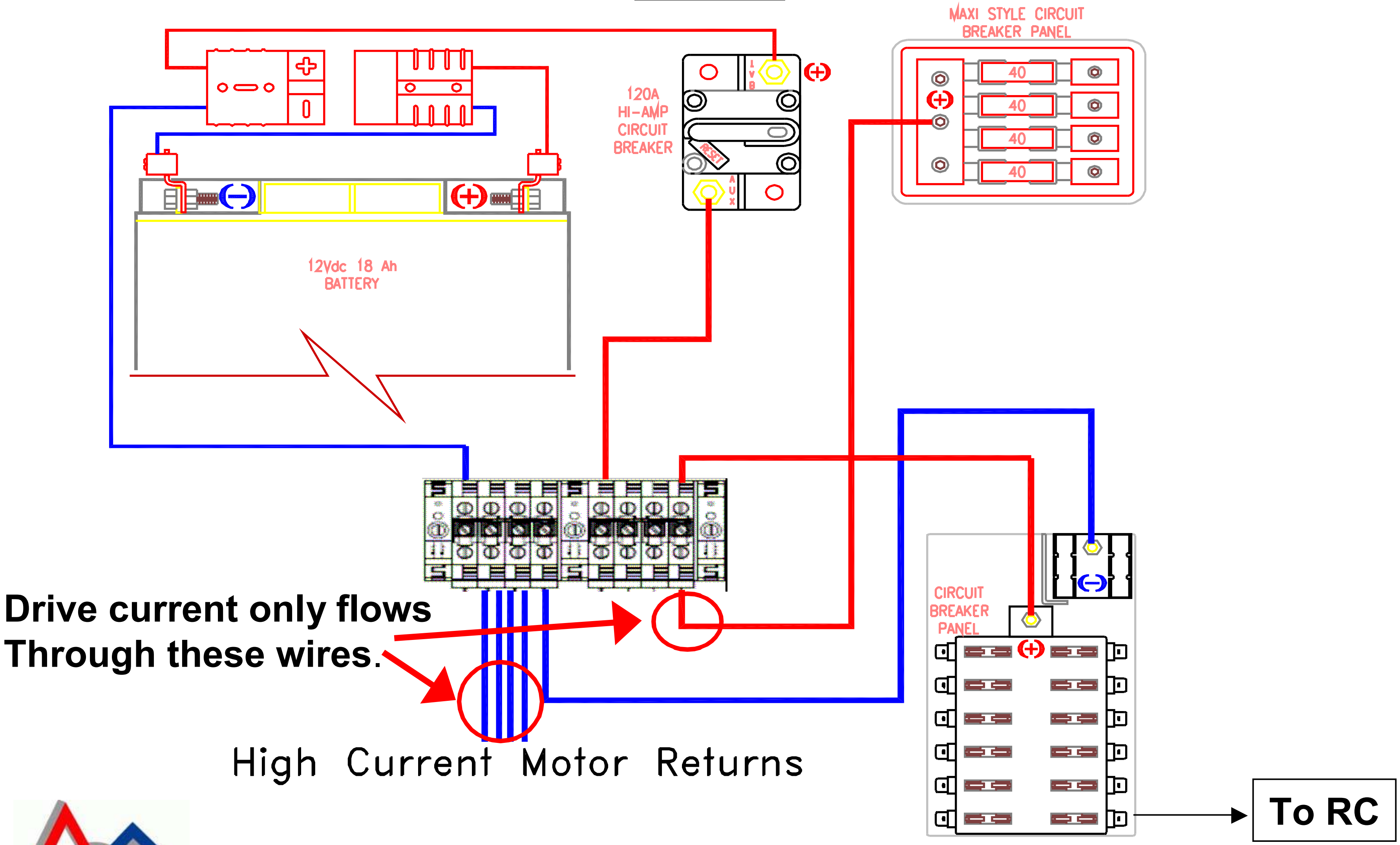
Primary Electrical Wiring

- Consists of #6 wiring, 50 amp Anderson connector, Main breaker, terminal blocks and wiring to breaker panel(s).
  - Carries **all** robot current.
  - The same current that flows through the red wire flows through the black wire.
  - The main breaker is a temperature sensitive device.
  - #6 wire is about .0005 ohm/ft. At 200 amps, at least 0.4 volt drop across the supplied wire, more if the Anderson connector is damaged.

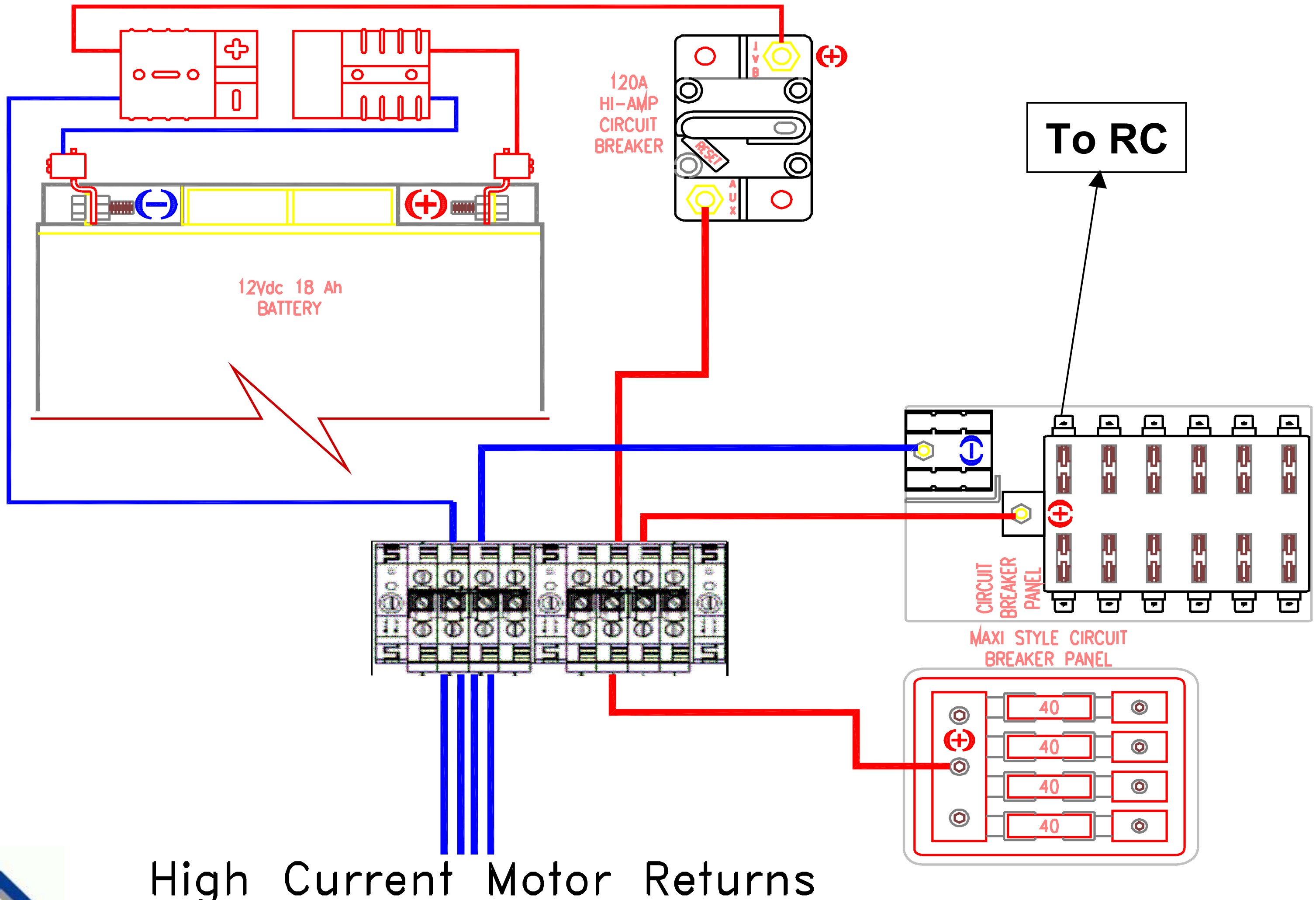
Bad #6 AWG Wiring Long wire runs, shared currents with high current loads.
Voltage to RC estimated to be about 9 volts during pushing, much less during stall.



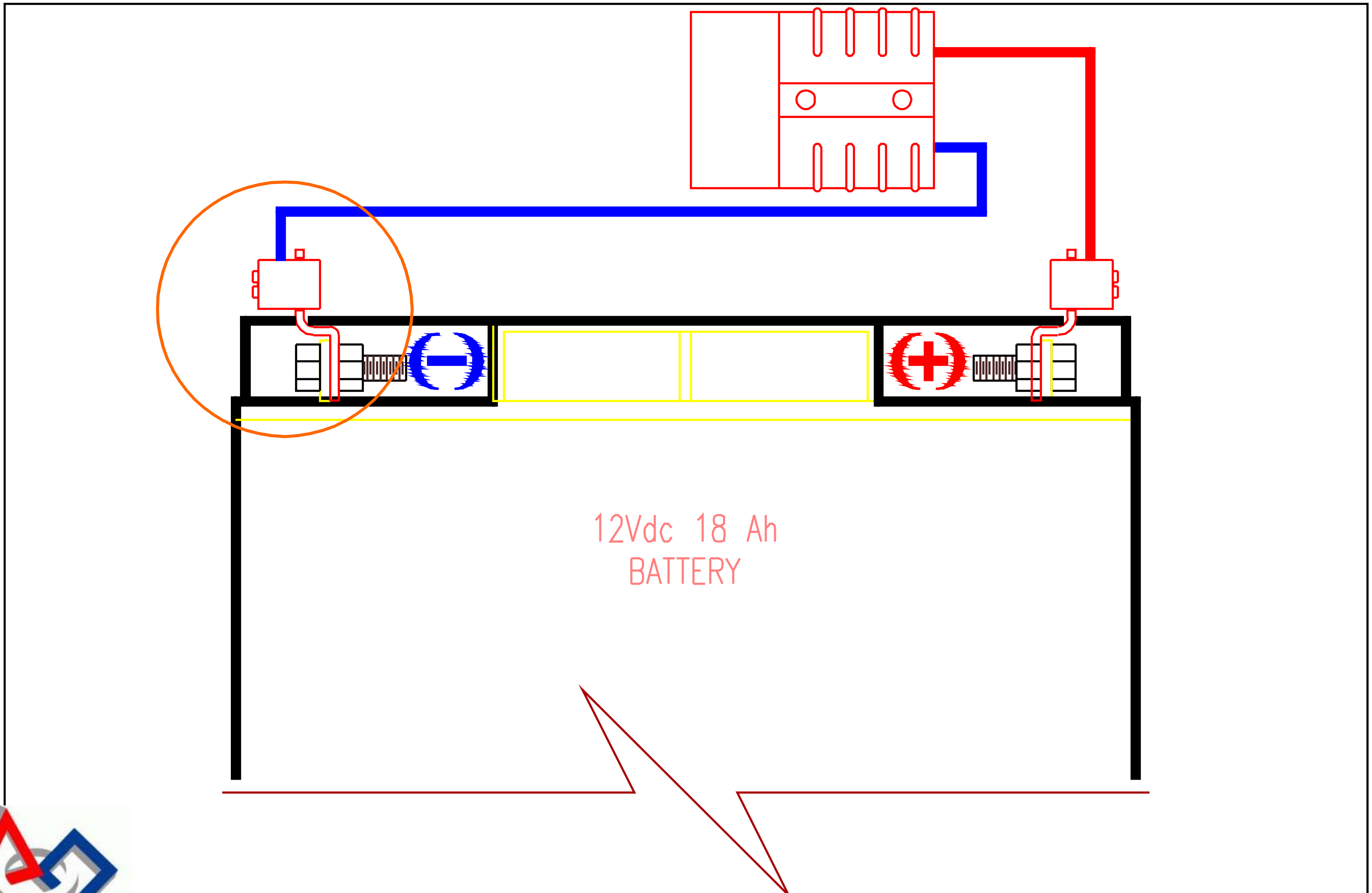
<u>Better #6 AWG wiring</u> **Current sharing is reduced, wire runs are shorter. Jumper still taking a lot of current. RC fed at sensitive position on block.**
Voltage to RC estimated to be max <u>9.6 volts</u> during pushing, less during stall.



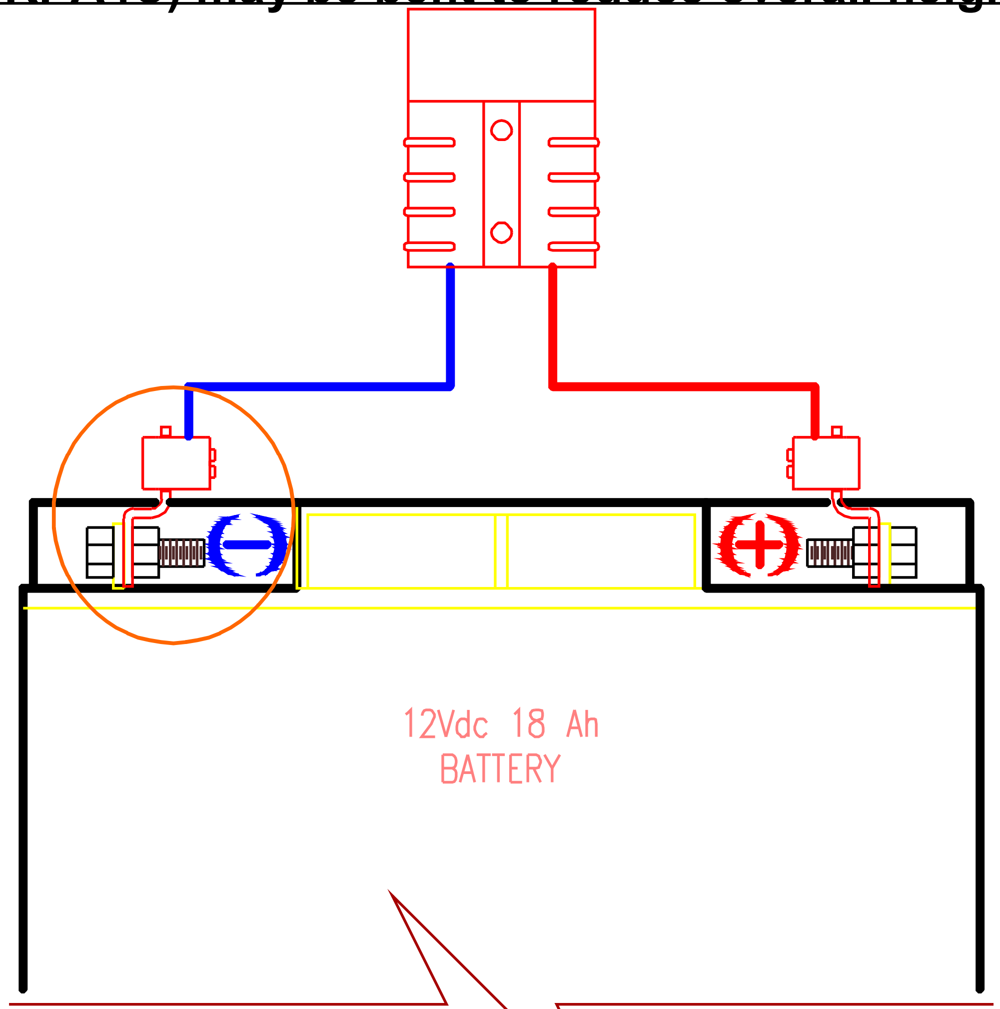
Best #6 AWG wiring Current sharing is reduced, wire runs are shorter. Jumper carries less current, reduction in single point failure. RC fed from minimum loss terminal on small breaker panel. Voltage to RC estimated to be at least 9.8 volts during pushing, less during stall.



Many team batteries are wired this way.
Terminals close to battery edge run the risk of abrasive breakdown of insulation.
Unequal wire length makes connection difficult and mating questionable.



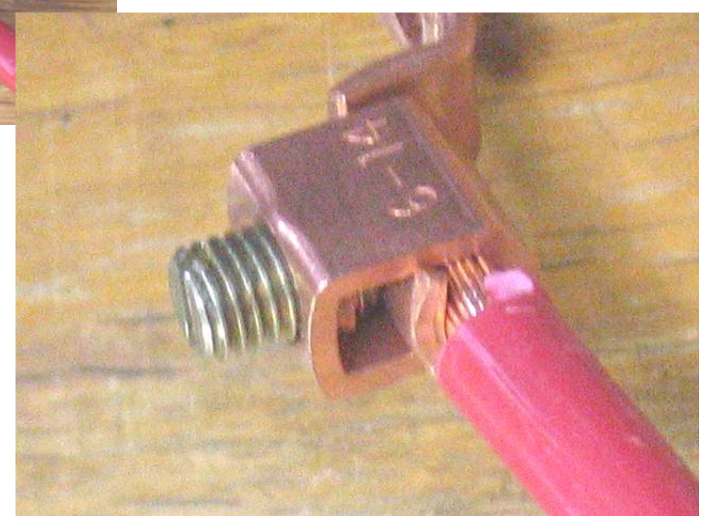
Best battery wiring. Terminals are turned to inside and are mounted on inside of terminal, allowing battery case to shield them from abrasion.
Wire length is equal to allow ease of connection. If battery or mount moves during match, secure Anderson connector with ty-wrap to prevent opening.
Terminals (SLA or KPA4C) may be bent to reduce overall height above battery case.



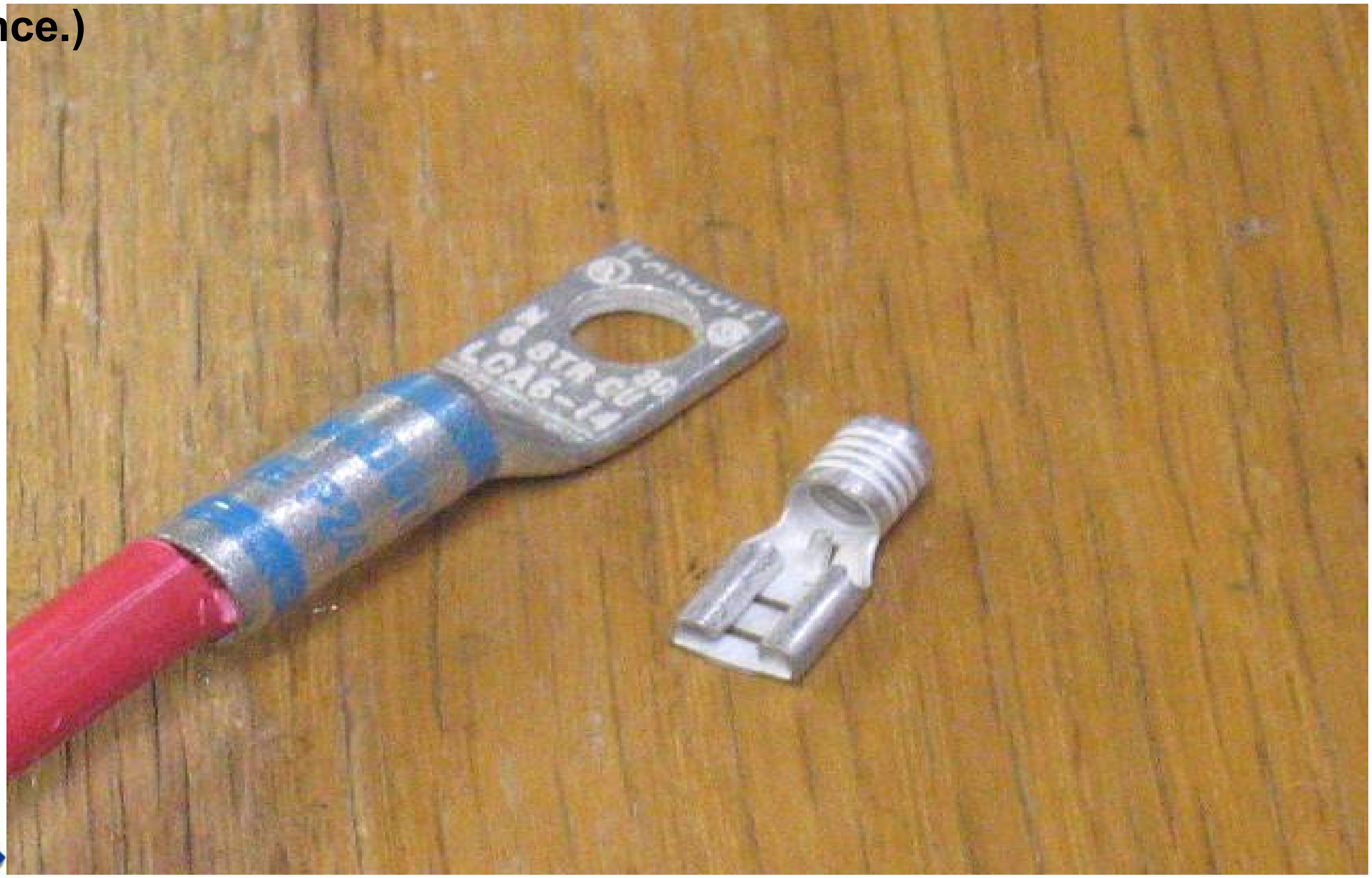
Note battery terminals turned to inside, away from chassis supports. Terminals are well insulated and wires are held out of the way. Battery is securely mounted and cannot move.

Note: Wire is stripped back the length of the terminal, about ¾”. Insert wire between the shell and the terminal.
<u>Do not insert wire under screw!</u>
The screw pushes on the copper not the wire. When terminated properly, the wire should take on the shape of the shell and cannot be moved. You can solder but insert solder from the terminal side, not the wire side. Stop when solder flows to the insulation. This will keep the wire flexible.

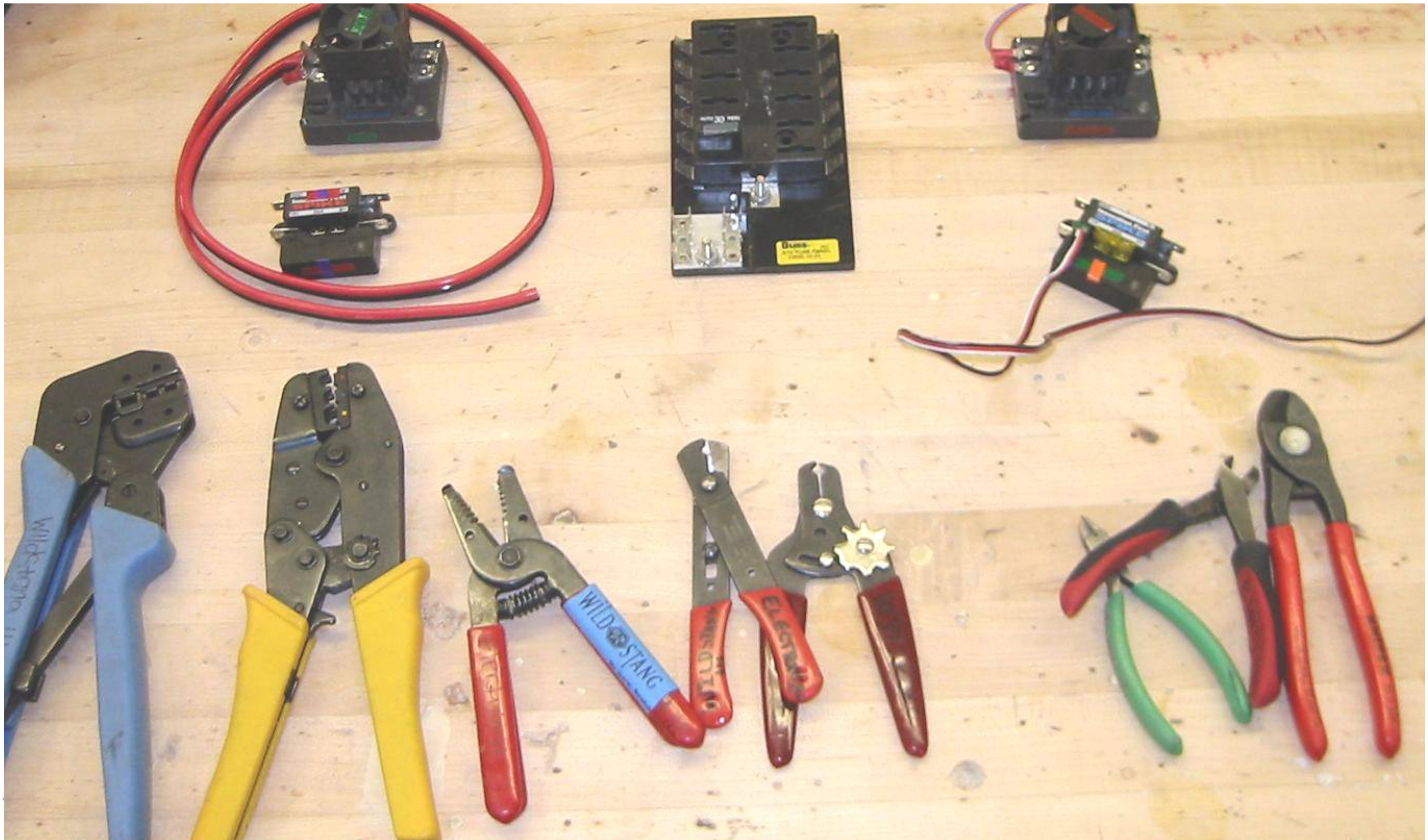
For SLA or KPA4C Connector Termination Soldering is Recommended! Insulation is a must!



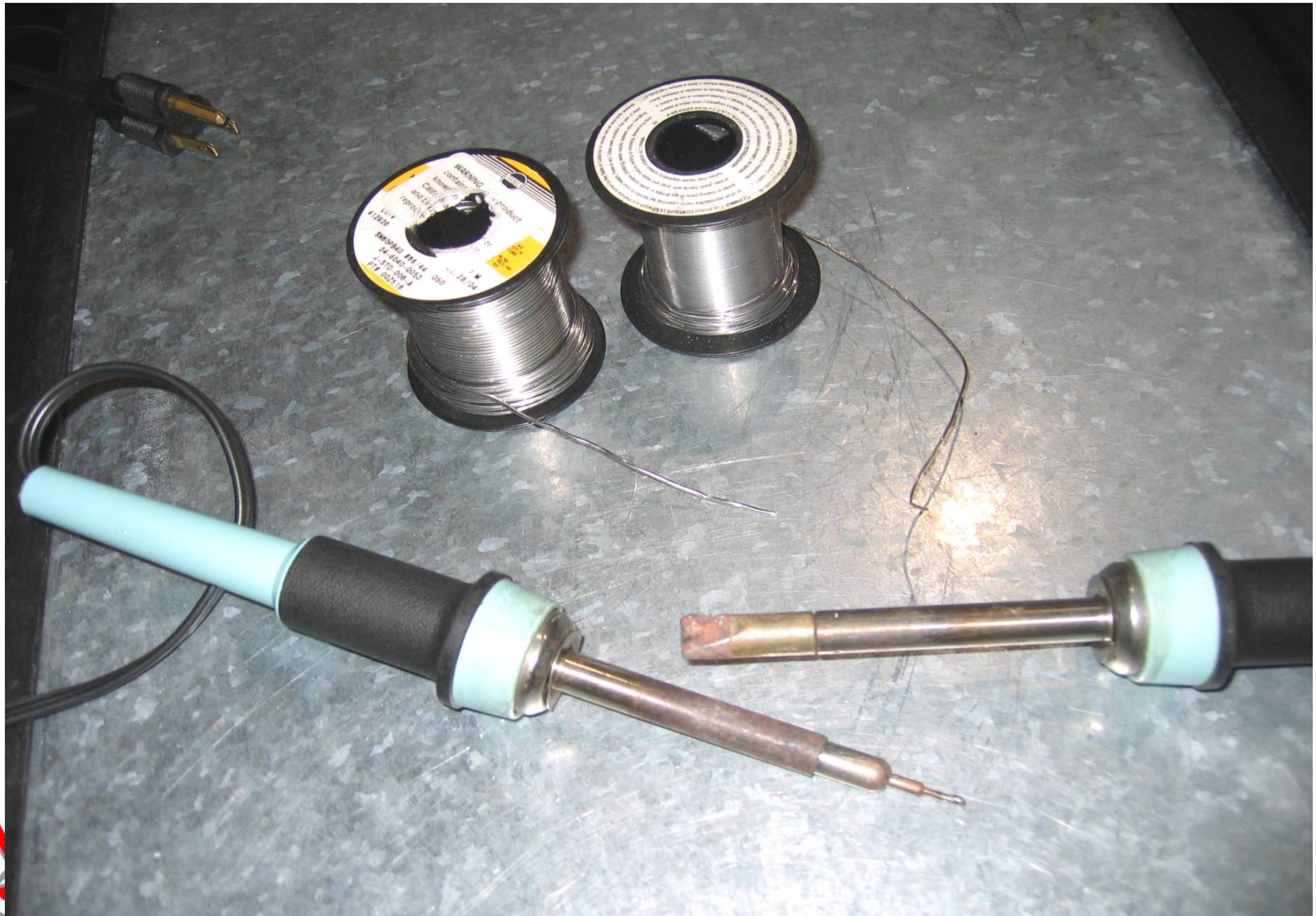
Crimp terminals are also allowed. They are easily crimped with the corners of a vise if the correct crimper is not available. Solder these the same way as SLA or KPA4C connectors. There is a solder hole in the terminal side of the connector. Again only add enough solder to prevent it from flowing under the insulation. Pulling the wire should not give any movement. Insulate with electrical tape or heat shrink (A #10 push on shown for reference.)



Various hand tools: Ratchet style crimpers on left, then small wire strippers and cutters, followed by a cutter meant for #6 only.

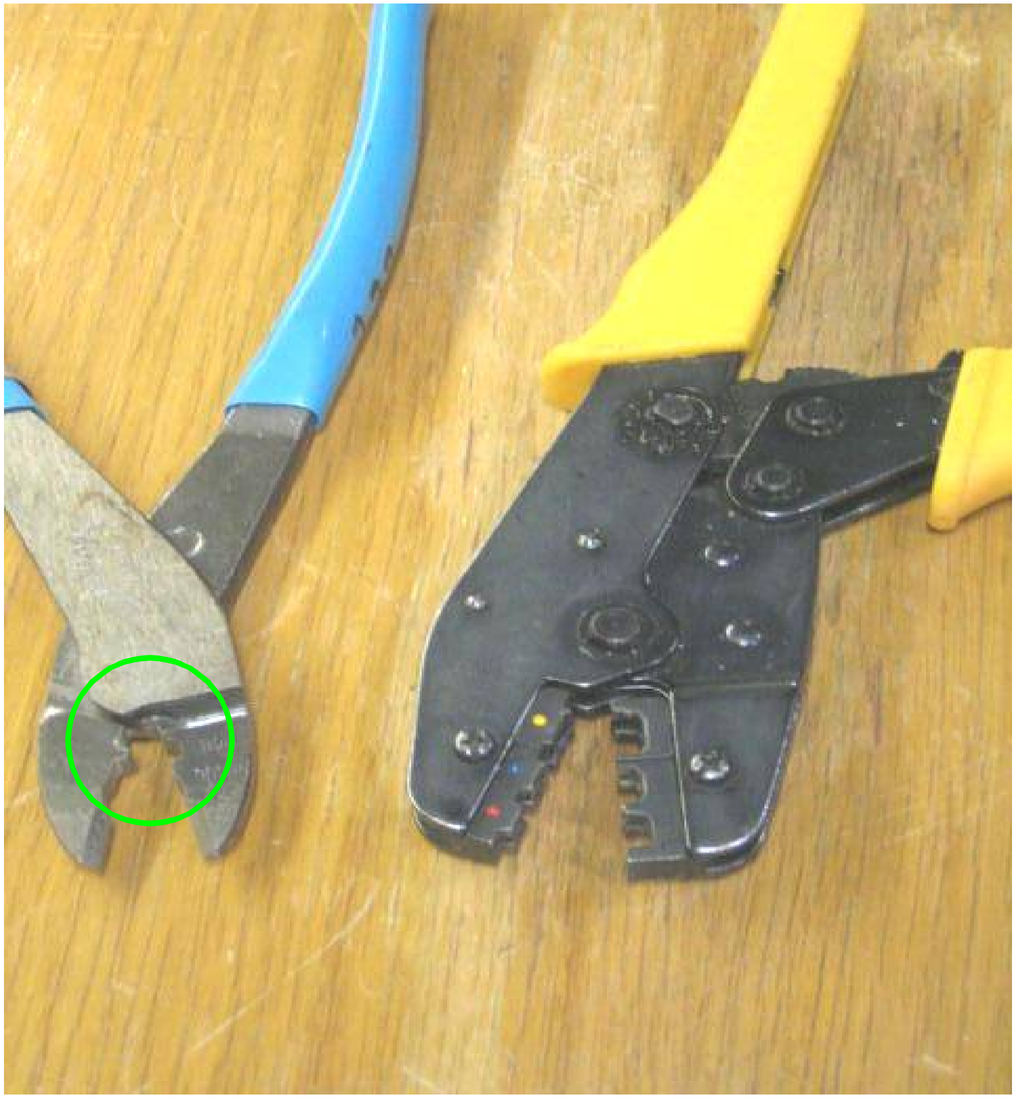


The iron on the left is a 25 watt screw in element with small screwdriver tip. Iron on the right is 45 watt with large screwdriver tip. This is suitable for SLA or KPA4C connectors. .031 and .045 solders are shown.



Automatic stripper designed for 18 -10 AWG. This is the easiest tool to use for students. It can be used with one hand and can be set to remove a uniform length of insulation. Available at Radio Shack, MCM and Digikey.

Automatic stripper shown with common T type stripper for 16-24 AWG.



Thomas and Betts crimper on left can be used for both insulated and non-insulated terminals. Ratchet crimper on right will not release the jaws until the correct force has been applied.

The T&B crimper should be used on non-insulated terminals by orienting the slit in the terminal against the concave side of the jaw. When correctly terminated, the slit should remain closed and the wire can not move within the terminal.

- Fluke 77 VOM
- Useful for measuring all electrical on robot.
- Measures voltage & resistance.
- Use for troubleshooting.
- Fluke 410 Current Clamp
- Useful for measuring currents up to several hundred amps.
- May give inaccurate readings when measuring output of Victor at less than full power but is still useful.

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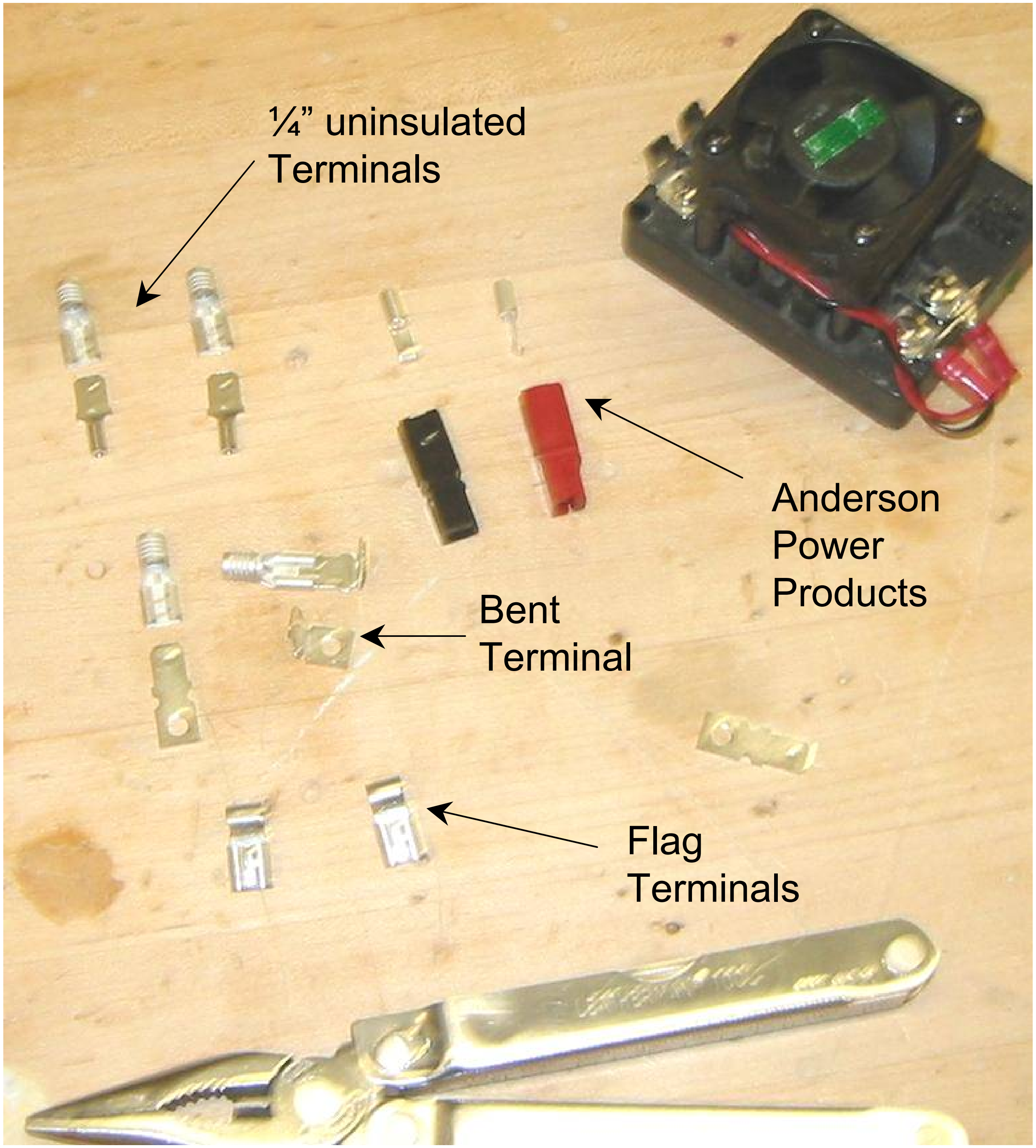
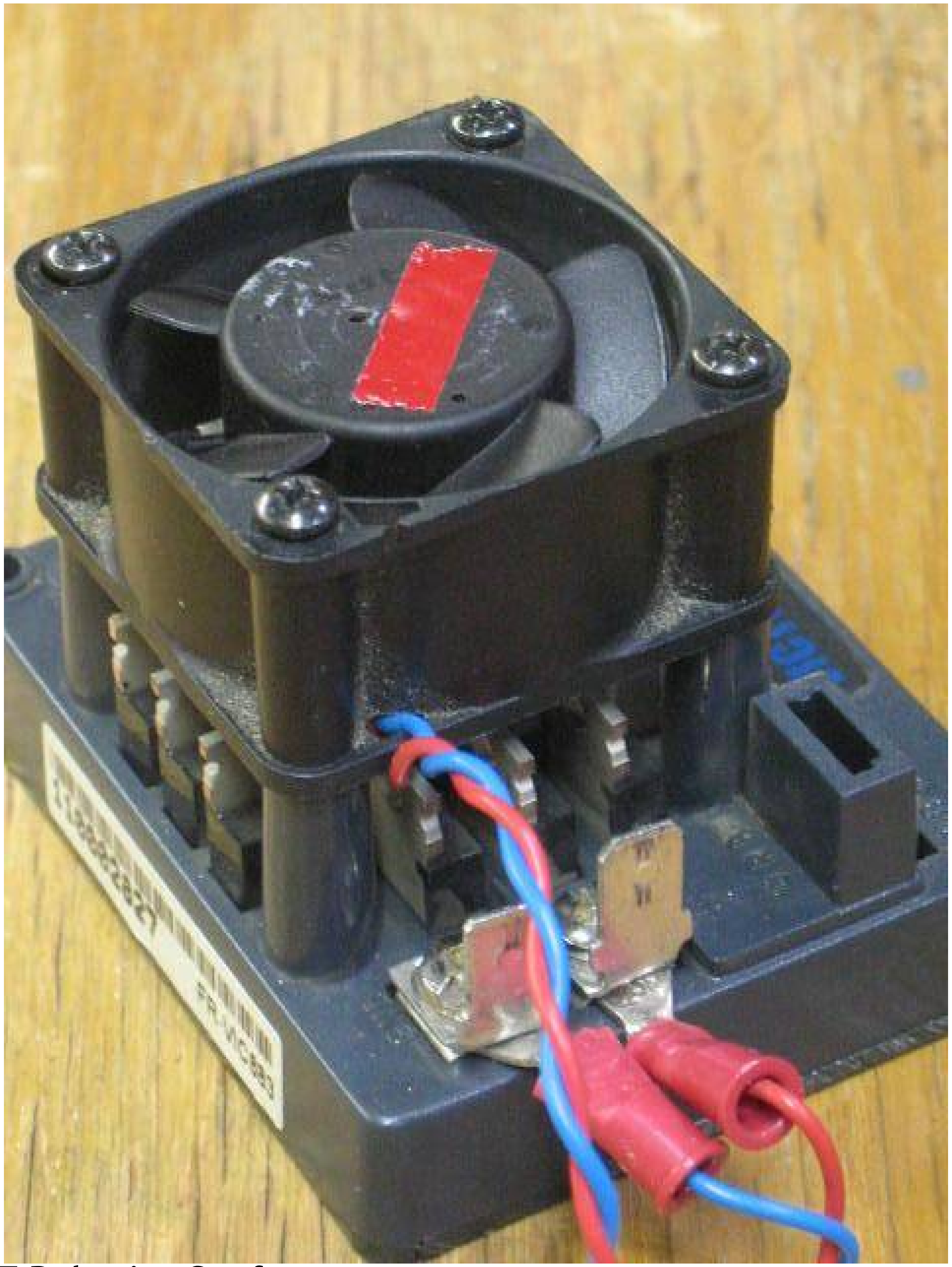
3M Color Wheel contains a few yards of each of the EIA colors (resistor code). Useful for marking all electrical wiring and components. (power wires, Victors, breakers, Spikes, motors, and PWM wiring)

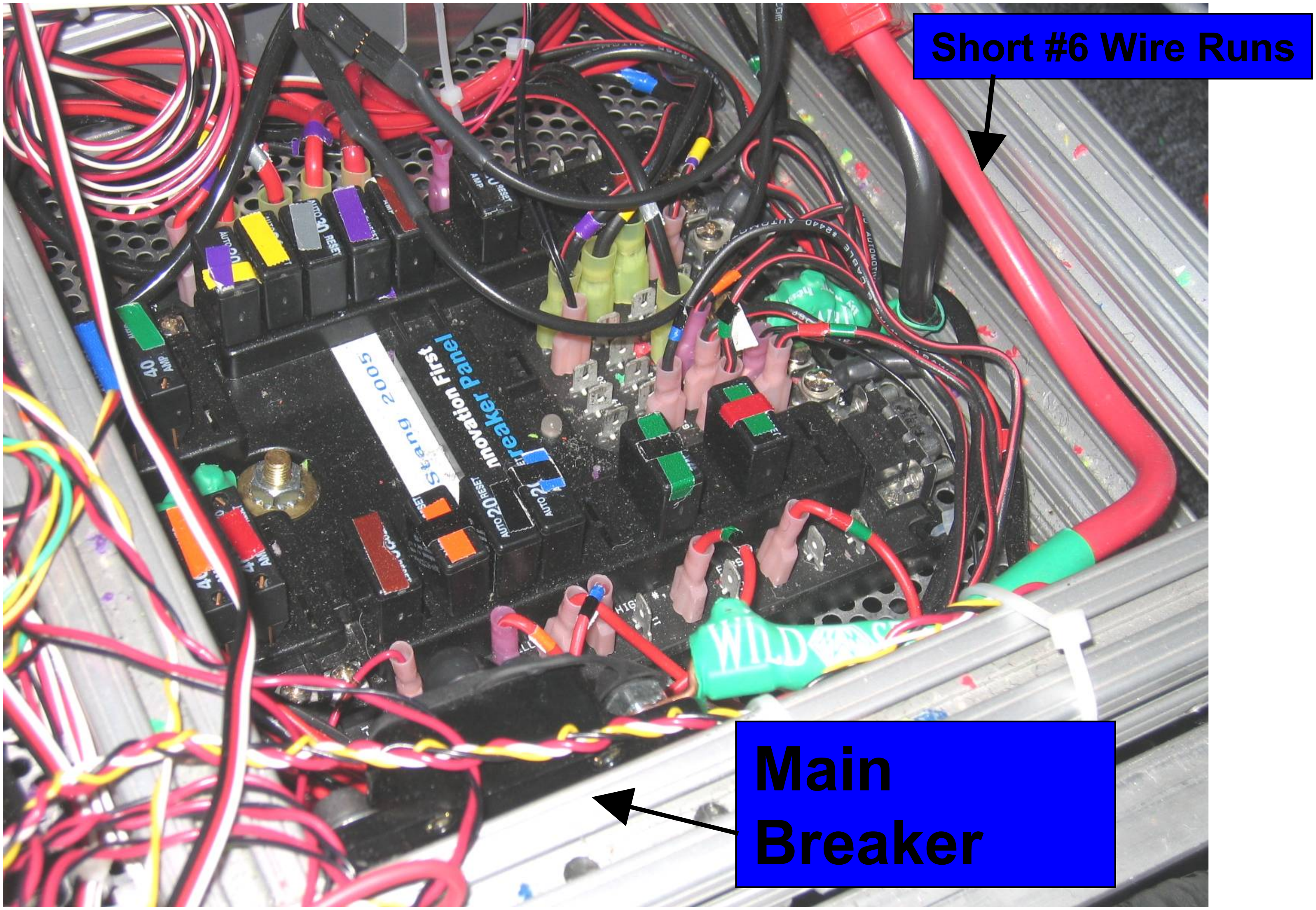

¼" uninsulated
Terminals
Anderson
Power
Products
Bent
Terminal
Flag
Terminals

A simple method of adding bent screw terminals to a Victor. This method allows rapid removal in case of failure and ease of use when trouble shooting wiring.
It eliminates the need for tools when replacing a device. There will be no danger of lost hardware.
Resistance is negligible.
<u>Note color coding on fan.</u>
Use TyWraps to mount and there will be no hardware to loosen or fall into other electronics.



Stranded, flexible “zip cord” is available in sizes from 18 – 10 AWG.
Source MCM or Newark in rolls of 50’ or 100’

Prototype wiring showing color codes on wires and breakers. Standard insulated terminals are used on prototype but non insulated terminals, crimped and soldered, are used on the competition robot. Color codes are the same between both robots. Note short #6 AWG wiring.



Common Mistakes

- Long wire runs.
  - Adds resistance and lowers available current to motors.
  - Difficult to troubleshoot.
  - Needs wire management.
  - Worse case when using smaller than optimal wire gauge (#12 or #14).

Common Mistakes

- **Components mounted where convenient not where practical for lowest loss or replacement.**
  - Adds to wire length.
  - Requires longer control PWM wiring.
  - May put components out of sight.

- **High currents shared in same wire.**
  - Currents add together reducing available voltage.
  - Currents shared by same terminals.
  - Add to wire and breaker heating.

Common Mistakes

- **Bad crimp-on solderless connectors.** (either bad crimp or loose/spread contacts.)
  - Raises effective resistance of circuit.
  - Causes localized heating at connector.
  - Heat causes higher resistance of contact, domino effect leads to failure.
- **Low values for breakers.**
  - Using a 30 amp breaker instead of a 40 amp does not limit the current on CIM and FP motors.
  - Early tripping of breaker.
  - Breaker overheats and trips at less than specified current.

Common Mistakes

- Using smaller wire gauge to save weight.
  - Smaller gauge limits available current.
  - Chalupas and FP motors run better with #10 or larger.
  - Robot wire gauge rules do not follow National Electrical Code. Ampacity is increased because the heating time is short and wire is in open air.
  - Crimp on connectors (on #12 or #14) are under sized for actual current. This causes voltage drops and high heat. At breaker panel(s) this will result in breaker heating.
  - Small wire does not fit the Maxi block insert points.

Common Mistakes

- **Using the supplied alligator clips on the battery charger to connect to the Anderson Connector.**
  - This causes scratching of the Anderson contact surface. The scratches create high spots which reduce the contact area and therefore increase the resistance of the contact. This causes extreme heating during high current peaks. Early connector failure is almost always the result.
  - The high heat in turn is conducted through the wire into the main breaker which lowers the point at which it trips.
  - No way to effectively insulate the supplied clips.

Common Mistakes

- Loose connections.
  - Loose hardware on battery, main breaker or breaker panels causes heating and voltage loss.
  - When using the maxi blocks, improper termination of the #6 wire reduces the effective connection to that of a #10 or even a #14 wire.
  - Loose connections on Victors cause intermittent operation. Stutter drive motion of a robot is generally a result of loose hardware.

Common Fixes

- Keep wire runs short, especially those that share currents (#6 primary wiring).
- Mount components in practical locations for short wire runs and easy access.
- Be sure of crimp on connectors by using a ratchet style crimper and/or solder all crimp connections.
- Use 40 amp breakers for Chalupas (large and small) and FP when used for drive.

Common Fixes

- Use #10 wire for high current loads. The weight saving of #12 does not justify the loss (almost double that of #10)
- Add a 50 amp Anderson Connector to your battery chargers. It prevents scratching and reverse polarity. The charger may only supply 6 amps but the battery more than 500. This will weld wires in the event of a short.
- Use lockwashers between the battery terminals and the wire terminals to prevent terminals from twisting and causing loose hardware.

Common Fixes

- When using the Maxi block, terminate the #6 by stripping back ¾ to 1” of insulation and folding the wire back on itself. This causes the wire to be the diameter of a #2 wire which is the largest wire designed for that block.
- Solder KPA4C connectors after you have tightened the clamp screw so they don’t loosen up. These connectors are meant for a non vibrational environment. Heat terminal then apply solder to the end of the wire and inside terminal. Do not allow solder to wick under the insulation. This reduces the flexibility of the wire.

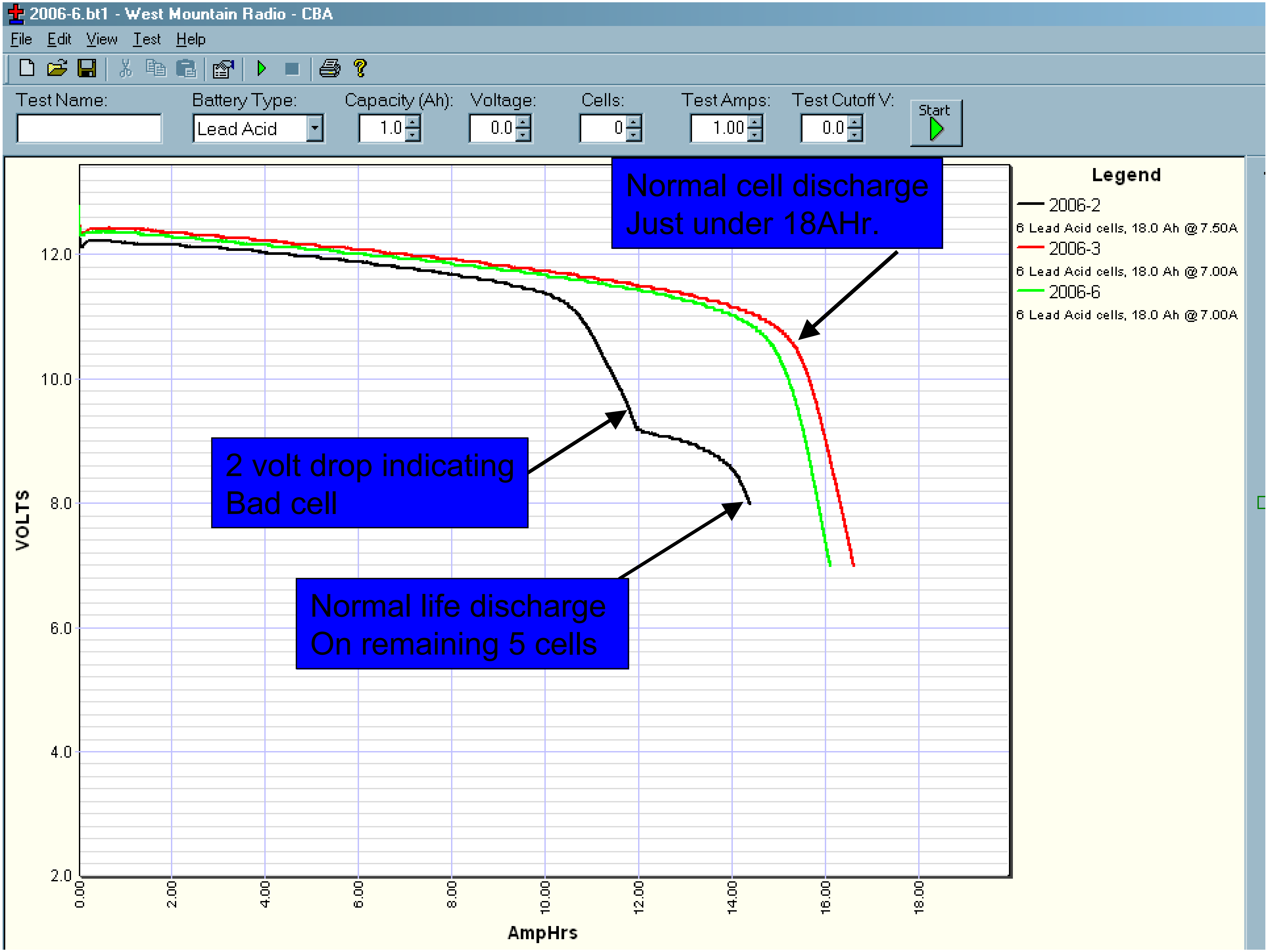
Some Rules of Thumb

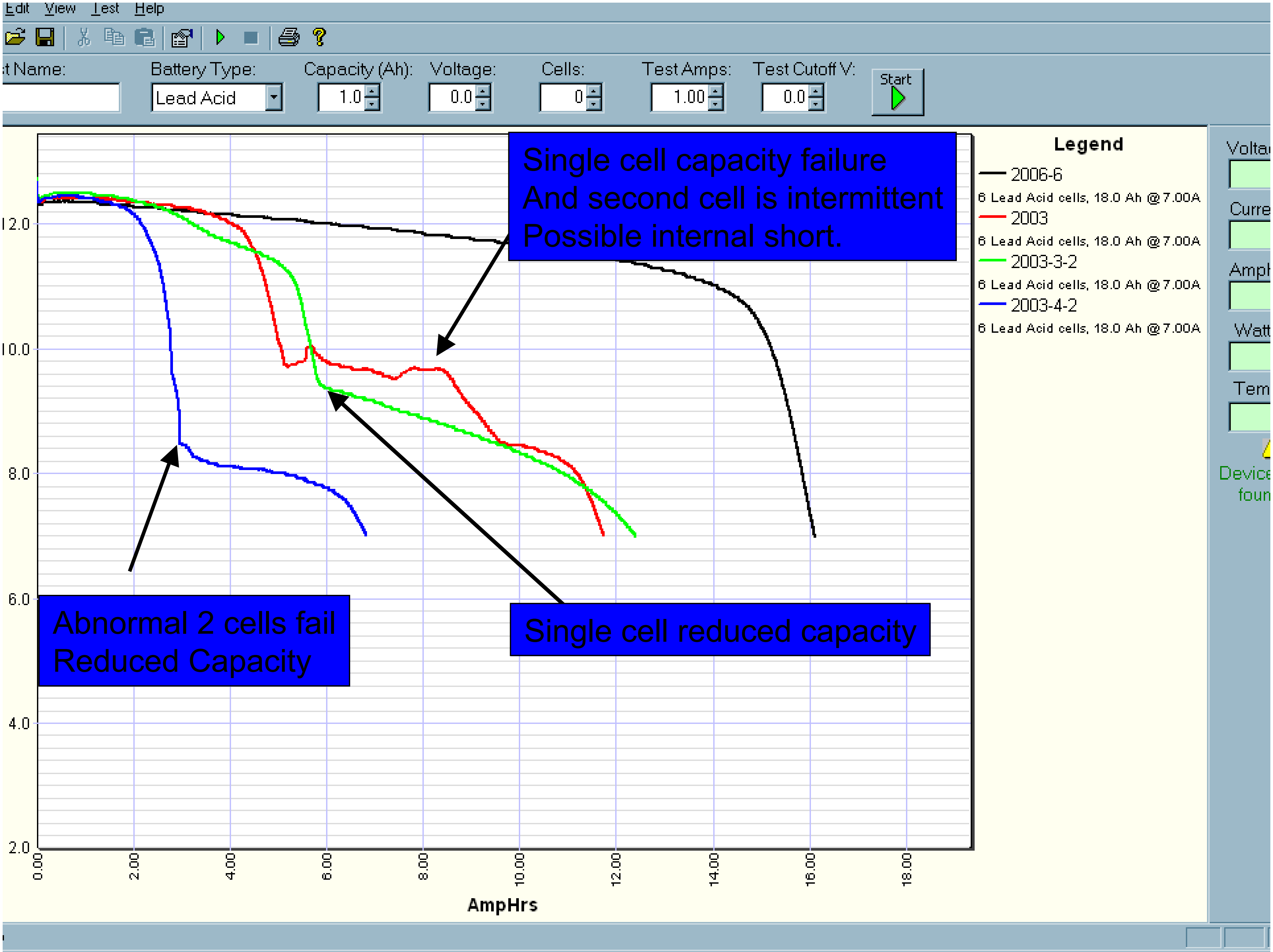
- **Wire Foot(WF)**
  - Equivalent to loss in 1 foot of #10 wire.
  - At stall current of the three large motors, about 100 amps, this is equivalent to 0.1 volt/wirefoot(WF).
  - 1 ft. of #6 wire =0.5 WF
  - 1 ft. of #10 wire=1 WF
  - 1 ft. of # 12 = 2 WF
  - Battery Internal Resistance=11 WF
  - Victor Series Resistance=6 WF
  - Bad crimps=1-3 WF each
  - Remember, there are two wires in every circuit, positive and negative.

Some More Rules of Thumb

- Murphy's Law
  - Anything that can go wrong will…at the worst possible time.
  - Robot postulate…It will go wrong in the last match of the finals on Einstein.
  - My favorite is Murphy's Law of selective gravitation. A dropped tool will fall where it will do the most damage.

When you have checked everything else…
Check the battery!

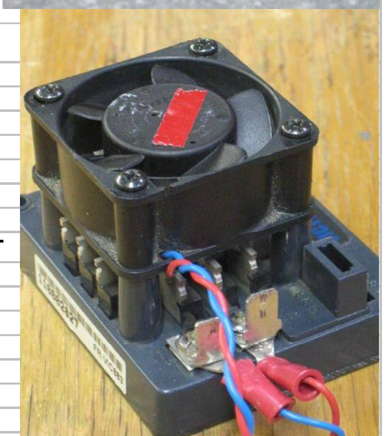

2006-6.bt1 - West Mountain Radio - CBA
File Edit View Test Help
Test Name:
Battery Type:
Lead Acid
Capacity (Ah):
1.0
Voltage:
0.0
Cells:
0
Test Amps:
1.00
Test Cutoff V:
0.0
Start
Normal cell discharge
Just under 18AHr.
2 volt drop indicating
Bad cell
Normal life discharge
On remaining 5 cells
Legend
2006-2
6 Lead Acid cells, 18.0 Ah @ 7.50A
2006-3
6 Lead Acid cells, 18.0 Ah @ 7.00A
2006-6
6 Lead Acid cells, 18.0 Ah @ 7.00A
VOLTS
12.0
10.0
8.0
6.0
4.0
2.0
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
AmpHrs


Edit View Test Help
t Name:
Battery Type:
Lead Acid
Capacity (Ah):
1.0
Voltage:
0.0
Cells:
0
Test Amps:
1.00
Test Cutoff V:
0.0
Start
Single cell capacity failure
And second cell is intermittent
Possible internal short.
Abnormal 2 cells fail
Reduced Capacity
Single cell reduced capacity
Legend
2006-6
6 Lead Acid cells, 18.0 Ah @ 7.00A
2003
6 Lead Acid cells, 18.0 Ah @ 7.00A
2003-3-2
6 Lead Acid cells, 18.0 Ah @ 7.00A
2003-4-2
6 Lead Acid cells, 18.0 Ah @ 7.00A
12.0
10.0
8.0
6.0
4.0
2.0
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
AmpHrs

This is a list of tools, wire, terminals and other parts you have seen pictured in this presentation.
Included is also a Wire Foot reference to help you analyze what might be taking place on your robot.
Copies are available, please take one.
Pictured is a closeup of Victor with push on tabs and color ID tape as well as tools and wire.

MCM Electronics		
Description	Part #	Price
18 GA zip cord/100'	24-1870	$11.97
14 GA zip cord/100'	24-1900	$24.88
12 GA zip cord/100'	24-1915	$31.45
10 GA zip cord/100'	24-1930	$46.47
Solder	21-1845	$14.44
WP30 Soldering Iron	96-429	$47.95
Iron Tip, Large Flat	96-1565	$5.76
Iron Tip, Conical	96-320	$5.76
80 Watt Soldering Iron	21-4345	$8.23
Large Wire Cutters	96-1309	$24.17
General Purpose Cutter	96-235	$20.93
Flush cutters	96-1188	$17.21
T Stripper	28-2700	$15.50
Auto Stripper 10-22AWG	22-3045	$29.95
T&B Style Crimper	22-1780	$10.95
Ratchet Crimper	22-770	$25.95
Needle Nose Pliers	96-1330	$22.75
Retracting Utility Knife	22-825	$3.99
Color Wheel Tape Marker	108-035	$24.95
TERMINALS		
Non insulated Female,12-10	108-275	2.99/25
Non insulated Female,14-16	108-270	3.89/50
Full Insulated Female, 12-10	108-290	7.49/25
Full Insulated Female, 14-16	108-285	10.75/50
1-800-543-4330	www.,mcminone.com	
fax:1-800-765-6960		

WIRE FOOT EQUIVALENTS 1WF@100AMPS=0.1VOLT	
Device	WF
#10 Wire per foot	1
#6 Wire per foot	0.5
#12 Wire per foot	~2
Victor	6-8
Spike	<1
Crimp (good)	1
Crimp (poor)	1-3
Crimp (soldered)	<<1
Battery	11
Circuit Breaker	<1
Rockwell Terminal Block (tight)	<1
Rockwell Terminal Block (loose)	5-20
50 amp disconnect	<1
50 amp disconnect (scratched)	>10



Thanks for coming out early this morning!

- Questions?