

# FIRST *GUIDELINES,* *TIPS, & GOOD* *PRACTICES*



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# G FIRST GUIDELINES, TIPS, & GOOD PRACTICES

## G.1 GENERAL

The *FIRST* guidelines are intended to provide some useful thoughts, ideas, and directions as you design and build the robot. It is not an all-inclusive step-by-step list or any substitute for common sense. However, this information is provided consistent with good design practices and standards and, if followed, should yield excellent results for your project.

### G.1.1 CONVENTIONS

Specific methods are used throughout this document to highlight Notes, Cautions, Warnings, key words or phrases to alert the reader to important information designed to help teams in constructing a robot complying with the Rules in a safe and workmanlike manner. Notes, Cautions, and Warnings appear in bordered boxes.

Key words, Phrases, or References appear in bold italics.

Example: ***Always Wear Safety Glasses.***

Operating keys, controls, buttons appear in bold capital letters.

Example: **OFF/ON** switch, **RESET** button, etc.

This section will include some hypertext. Clicking on the Blue Underlined Italic text or graphics will link you to additional information related to the item or subject being discussed.

### G.1.2 SAFETY

Regardless of whether you are an experienced veteran or “first-year rookie” team, a mentor, or a teacher participating in the *FIRST* Robotic Competition program, it is essential that safety is everyone’s foremost concern at all times. *FIRST*, by presenting Industrial Safety awards, continues to celebrate teams that progress beyond the basic practice of safety fundamentals to those who have developed innovative ways to eliminate or protect against hazards,. The winning teams will those that consistently demonstrate excellence in promoting industrial safety throughout the competitions.

Here are some important common sense safety fundamentals that should be followed anytime, whether involved in shop work, hanging around with the robots in the Pits at competitions, or in the vicinity of the competition playing field:

#### G.1.2.1 General Shop Recommendations:

- ***Obey all Safety Regulations*** as posted in the shop area.
- ***Always Wear Safety glasses.*** Eye injuries are the most common hazards in shop environments. Don’t become victims; stay safe wearing your glasses.
- ***Wear proper clothing.***
  - Avoid wearing loose fitting clothing that could get caught up in shop machinery or by sprocket & chain apparatus on the robot.
  - Safety shoes should always be worn. Wearing sandals, open-toed shoes, or sneakers could be asking for trouble.
  - Long hair should be restrained or covered by a cap to avoid any entanglement in machinery or mechanisms.
  - Wearing good work gloves can save unnecessary wear and tear on your hands.
- ***No one should work alone*** in the shop. Use teamwork. In the event of an accident, immediate assistance should be available.
- Untrained personnel should not use machinery.
- Keep hands and fingers away from machinery tools while in operation.
- ***Keep the work area neat*** and organized. Keep the floor clean of metal debris, oil, or greases.
- ***Use the proper tool*** for the job.
- ***Horseplay is not allowed!***

### G.1.2.2 Robot Safety:

#### **Mechanical**

- Use caution when working around the robot. Avoid and eliminate hazards posed by protruding objects and devices, spring-loaded actuators, sharp edges and corners. Where possible, de-burr all holes and sharp edges
- Confirm that all devices restraining mechanically stored energy are either safely secured or fully released before working on the robot.
- Use care whenever lifting and carrying a robot to avoid personal injury such as muscle strains and/or pinched fingers.
- When transporting the robot on carts, rest the robot on blocks and not on the wheels. Use bungee cords or tie downs to restrain the robot on the cart.

#### **Electrical**

- Shut the Power OFF before working on electrical circuits or exchanging components. Open the Main Circuit Breaker with the **RESET** button and/or unplug the battery.
- Remember to always verify the correct polarity when connecting devices. Some components may not be clearly marked. Always confirm the correct polarity from the manufacturer's manuals.
- Following electrical service work be sure to inspect, test as necessary, and clear potential short circuits before applying power.
- Protect electrical circuits and wiring from accidental contact by persons and metallic foreign objects. Cover these areas with clear acrylic plastic panels where necessary.
- Routinely inspect batteries for evidence of electrolyte leakage, cracked, or damaged battery cases, etc. Use caution and avoid contact with the battery chemicals.
- Always use the recommended battery charger to prevent overcharging and potential damage to the battery. Old or defective batteries must be safely discarded as specified for the disposal of hazardous materials.

#### **Pneumatic**

- Respect stored pneumatic energy. Do not aim or direct high-pressure air at co-workers as a joke. Serious injury could be an unintentional result.
- Before servicing pneumatic components, confirm that the Main Vent valve is fully open. Inspect all pressure gauges to verify that NO pressure is present.
- Stay clear of any cylinders and mechanical attachments when the air system is charged, particularly when setting a cylinder in motion.

## **G.2 KIT OF PARTS**

The table below provides an on-line address for Companies providing materials and support for *FIRST* Robotics teams in 2006. Teams may visit these sites for product information. Teams should first visit the *FIRST* and Innovation First websites and download applicable documents and specifications since most are readily available with minimal research.

### G.2.1 TABLE OF RESOURCES & REFERENCES

| <b>Resource/Supplier</b> | <b>Product Type</b>                        | <b>Phone Number</b> | <b>Web Site</b>   |
|--------------------------|--|---------------------|---|
| 7" Ball                  | 7" Foam basketball                         | 800 329-8697        | <a href="http://www.poof-slinky.com/">http://www.poof-slinky.com/</a>   |
| 80/20 Inc.               |  |                     | <a href="http://www.8020.net/">http://www.8020.net/</a>                 |
| American ANKO Co.        | Joysticks                                  | 562 903-7002        | <a href="http://www.avbusa.com/">http://www.avbusa.com/</a>             |
| Allegro Microsystems     | Gear Tooth Sensors                         |                     | <a href="http://www.allegromicro.com/">http://www.allegromicro.com/</a> |
| Analog Devices           | DA Accelerometer/<br>Yaw rate Gyro sensors |                     | <a href="http://analog.com/">http://analog.com/</a>                     |

|                                     |                           |              |   |
|-------------------------------------|---------------------------|--------------|---|
| Anderson Power Products             | Quick disconnect plugs    | 800 786-3445 | <a href="http://andersonpower.com/">http://andersonpower.com/</a>                   |
| AndyMark, Inc.                      | Battery safety plug       | 765 455-1376 | <a href="http://www.andymark.biz">http://www.andymark.biz</a>                       |
| Bimba Manufacturing                 | Pneumatic Cylinders       |              | <a href="http://www.bimba.com/">http://www.bimba.com/</a>                           |
| Bosch-Rexroth                       | Pneumatic Valves          |              | <a href="http://www.boschrexroth.com/">http://www.boschrexroth.com/</a>             |
| CCL Industrial Motor, LTD           | CIM motors                |              | <a href="http://www.cimmotor.com/">http://www.cimmotor.com/</a>                     |
| Clippard Instrument Laboratory, Inc | Volume Tank               |              | <a href="http://www.clippard.com">http://www.clippard.com</a>                       |
| Delphi Connection Systems           | Wire & cable              |              | <a href="http://www.delphi.com/">http://www.delphi.com/</a>                         |
| EPM-Pabst                           | 12V Fans                  |              | <a href="http://www.ebmpapst.us/">http://www.ebmpapst.us/</a>                       |
| Exide Technologies                  | 12V Battery               |              | <a href="http://www.exidetechologies.com/">http://www.exidetechologies.com/</a>     |
| Festo                               | Single solenoid valves    |              | <a href="http://www.festo.com">http://www.festo.com</a>                             |
| Fisher-Price                        | Motor/Gearbox Assy        |              | <a href="http://www.fisher-price.com/">http://www.fisher-price.com/</a>             |
| Flexcon Corporation                 | Totes                     |              | <a href="http://www.flexconcontainer.com">http://www.flexconcontainer.com.</a>      |
| FPEF                                | Pneumatic                 |              | <a href="http://www.fpef.org">http://www.fpef.org</a>                               |
| Freelin Wade                        | Tubing products           | 888 373-9233 | <a href="http://www.freelinwade.com/">http://www.freelinwade.com/</a>               |
| Globe Motors                        | Globe motor               |              | <a href="http://www.globemotors.com/">http://www.globemotors.com/</a>               |
| HPE Automation                      |                           |              | <a href="http://www.hepco.com">http://www.hepco.com</a>                             |
| IGUS                                | Plastic bearings & guides | 800 521-2747 | <a href="http://www.igus.com/">http://www.igus.com/</a>                             |
| Innovation First, Inc.              | Robot control system      |              | <a href="http://www.innovationfirst.com/">http://www.innovationfirst.com/</a>       |
| intelitek                           |                           | 800 777-6268 | <a href="http://www.intelitek.com">http://www.intelitek.com</a>                     |
| Kent Elastomer                      | Latex tubing              | 800 331-4762 | <a href="http://www.kentelastomer.com/">http://www.kentelastomer.com/</a>           |
| Kerk Motion Products                | Lead screw & nut          |              | <a href="http://www.kerkmotion.com">http://www.kerkmotion.com</a>                   |
| Lord Corporation                    | Vibration Isolaters       |              | <a href="http://www.lordmpd.com">http://www.lordmpd.com</a>                         |
| Mabuchi Motor Co.                   | Mabuchi motor             |              | <a href="http://www.mabuchimotor.co.jp/">http://www.mabuchimotor.co.jp/</a>         |
| Microchip Technology                |                           |              | <a href="http://www.microchip.com">http://www.microchip.com</a>                     |
| Midtronics                          | Battery Charger           | 800 776-1995 | <a href="http://www.midtronics.com/">http://www.midtronics.com/</a>                 |
| Monnier Corp.                       |                           | 810 794-4935 | <a href="http://www.monnier.com/">http://www.monnier.com/</a>                       |
| MSC Industrial Supply               |                           |              | <a href="http://www.mscdirect.com">http://www.mscdirect.com</a>                     |
| Nason Company                       |                           |              | <a href="http://www.nasonptc.com/">http://www.nasonptc.com/</a>                     |
| National Instruments                |                           |              | <a href="http://www.ni.com/">http://www.ni.com/</a>                                 |
| Norgren                             | Regulators, relief valves |              | <a href="http://www.norgren.com/">http://www.norgren.com/</a>                       |
| Nypro                               |                           |              | <a href="http://www.nypro.com/">http://www.nypro.com/</a>                           |
| Oznum                               | Cold cathode lights       | 800 245-8131 | <a href="http://www.oznum.com/">http://www.oznum.com/</a>                           |
| Parker Hannifin, Inc.               | Air cylinders             |              | <a href="http://www.parker.com/">http://www.parker.com/</a>                         |
| Plastic Supply                      | Target lens               |              | <a href="http://www.plasticsupply.com/">http://www.plasticsupply.com/</a>           |
| Rockwell Automation                 | Photoelectric Sensors     |              | <a href="http://www.rockwellautomation.com/">http://www.rockwellautomation.com/</a> |
| Sager Electronics                   | Micro Switches            |              | <a href="http://www.sager.com">http://www.sager.com</a>                             |
| Skyway                              | 8" wheels                 |              | <a href="http://www.skywaywheels.com">http://www.skywaywheels.com</a>               |
| SMC Pneumatics, Inc.                | Pneumatic fittings        |              | <a href="http://www.smcusa.com">http://www.smcusa.com</a>                           |
| T & L Publications                  | Nuts & Volts magazine     |              | <a href="http://www.nutsvolts.com">http://www.nutsvolts.com</a>                     |
| Terminal Supply Company             | Fuse panels & terminals   | 800 989-9632 | <a href="http://www.terminalsupplyco.com">http://www.terminalsupplyco.com</a>       |
| The Timkin Co.                      | Ball Bearings             |              | <a href="http://timken.com/">http://timken.com/</a>                                 |
| Thomas Industries                   | Air compressor            |              | <a href="http://www.thomasind.com/">http://www.thomasind.com/</a>                   |
| Wika Instruments                    | Pressure gauges           |              | <a href="http://www.wika.com/">http://www.wika.com/</a>                             |

## G.3 ROBOT MECHANICAL

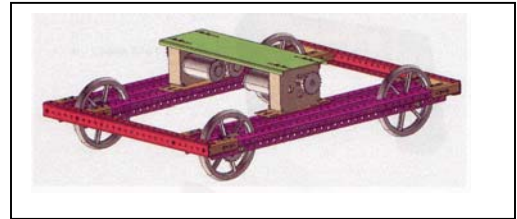
### G.3.1 GENERAL

This year it is likely that teams will continue to design and build robots in a variety of robust forms to perform the games strategic functions. Many robots will be speedy and highly maneuverable. Other designs may focus on strength and control. Most will be very capable of withstanding vigorous interaction with other robots.

The end product for each team customarily will be the result of brainstorming and building to a unique game strategy and plan. Along the way, there are a few general design rules to keep in mind.

- A **Remember; Thy Robot Weight Limit-** All of the elements of the robot such as the drive system, frame, battery & electrical system, pneumatics, and other mechanisms share a portion of the overall total weight. The weight limit for any robot is 120 pounds (less the battery and ½ of the Anderson Power connector assembly).

Set up a “weight” budget for each element or segment (such as 25% drive train, electrical 15%, etc). Then stay within the budget throughout the build cycle. At the end of the project you just might have some room to add a bit more weight to enhance a robot system or two as needed rather than urgently performing a “panicky” weight reduction project.



- B **Keep it Simple** – The more complicated the robot design, the more likely something will go wrong. Focus on strengthening the weakest points of your design for best reliability.
- C **Change is good** – A sign of progress is that as you go along building the robot, you will find modifications and adjustments are necessary. It might mean relocating transmissions, moving electrical components, or reinforcing a structure. Then it may include adding materials to repair or enhance a mechanism. Always keep in mind to control your weight budget and implement any changes accordingly.

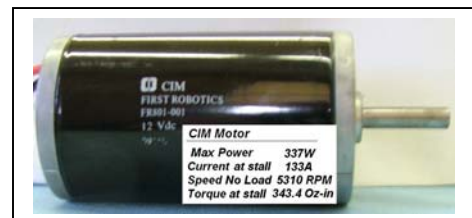
### G.3.2 THE CHASSIS - NEW IDEAS

The [Chassis & Drive Train Instructions](#) provides step by step instructions to assemble the Chassis kit and for mounting the Drive Train. There are several ways these parts could be configured to form a chassis. One example is shown above. Additional concepts for assembling frames are found in [Drive Train Improvements](#), “The next step...” The design decision will be defined by the team’s game strategy and the functions the robot needs to perform.

Once the chassis frame is assembled the motor and transmission assemblies can be mounted to the chassis and the drive wheels added.

### G.3.3 DC MOTORS

Selecting the appropriate motor to perform specific functions such as turning a wheel, lifting arms and squeezing claws is an important part of the design process. The motors supplied in the KOP are the only motors that may be used in the 2006 competitions and are listed in the table below:



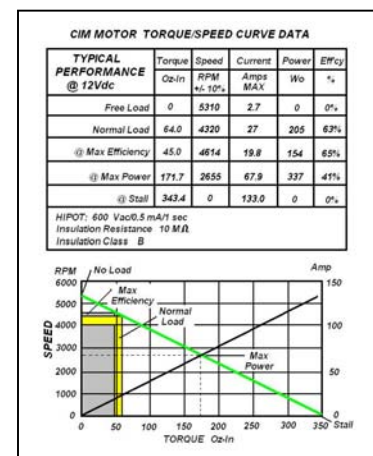
Although some choices are obvious, before you begin to make motor selections, you should have determined two pieces of information. First, know what type of robot you intend to build. Must it be fast and maneuverable, or methodical and precise? Factors, such as moments of inertia, friction characteristics of the load, and power needs, are relevant. Perusing the different motor properties such as RPM, torque, speed, power, and weight will help you to focus on those most important factors to facilitate your design. In the table, the motors are arranged by their peak power ranging from most powerful down to weakest.

| Motor Type           | Description                                | Notes     | Peak Power                 | Gear Ratio | Operation At Stall        |                | Operation No Load                    |                       |
|----------------------|--|-----------|----------------------------|------------|---------------------------|----------------|--------------------------------------|-----------------------|
|                      |  |           |                            |            | Torque                    | Current (Amps) | Speed (RPM)                          | Current (Amps)        |
| <b>CIM FR801-001</b> | Keyed output shaft, ccw                    | 12Vdc     | 337 W                      |            | 343.4oz-in                | 133            | 5310                                 | 2.7                   |
| <b>CIM FR801-005</b> | 16 Tooth Pulley                            | 12V dc    | 270 W                      |            | 570 oz-in                 | 96             | 2700                                 | 1                     |
| <b>Fisher-Price</b>  | Motor Portion of 9003                      | 12Vdc     | 389.5W                     |            | 403.5mNm                  | 63.72          | 16320                                | 1.198                 |
| <b>Fisher-Price</b>  | Motor Portion of 9012                      | 12Vdc     | 387.5W                     |            | 417.7mNm                  | 63.53          | 15636                                | 1.060                 |
| <b>Fisher-Price</b>  | 9003 or 9012 motor w/gearbox, Power Wheels | See Above | See above, subtract losses | 124: 1     | Multiply above times 124. | See above      | Divide above by 124, subtract losses | See above, add losses |
| <b>Bosch</b>         | Van Door, ccw Rot.                         | 10.5Vdc   | 59 W                       |            | 30 N-m                    | 52             | 75                                   | 3.1                   |
| <b>Globe</b>         | 4WD/2WD transfer mtr.                      | 10Vdc     | 55 W                       | 117: 1     | 150 In-lb                 | 21.6           | 81 +/-7                              | 0.82max               |
| <b>Nippon-Denso</b>  | Window Lift, RH                            | 12Vdc     | 22W                        |            | 10.6 N-m                  | 18.6           | 84                                   | 1.8                   |
| <b>Nippon-Denso</b>  | Window Lift LH                             | 12Vdc     | 22 W                       |            | 10.6 N-m                  | 21             | 84                                   | 1.8                   |
| <b>Mabuchi</b>       | W/spur gear CCW rotation                   | 12Vdc     | 16.8W                      |            | 60.8mNm                   | 5.2            | 4700                                 | 0.22                  |

Each motor shown in the table above has a unique set of speed/torque characteristics that can be adapted to perform work by the robot. Some are quite powerful and draw high currents when loaded to their limits. Others have very high-speed capability. Some have integral transmissions that magnify their torque output. The table provides the peak power rating, torque and current at “stall”, and the “no load” speed and current for the kit motors typically based on the voltage input of 12Vdc (or as shown in the Notes column).

The Kit motor specifications normally provide torque/speed characteristics in tabular and/or graphical forms. The torque/speed curves for most motors are depicted as linear from their max to min ranges and these curves can provide a good deal of information about the motor.

In the graphic shown here, a torque curve (black) of the CIM motor rises from the “0” torque reading along the “X” axis to about 343.4 Oz-in at “stall”. The motor “speed” curve (green) on the “Y” axis reaches a maximum RPM of 5310 in a No Load state and motor current is only about 2.7 Amps. However, since torque and speed are inversely proportional, as torque increases, the speed drops to “0” or the “stall” condition. At the same time current is peaking near 133 amps.



The point where the two curves intersect is the point of Maximum power; where speed, peak power, and torque for this motor are optimized. For any motor this becomes the truest measure of a motors power by taking into account the torque, speed, characteristics of the motor.

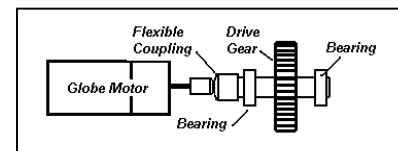


The yellow box shows a normal load range (determined by the manufacturer) for this motor with a torque output up to 64 oz-inches, a current of about 27 amps, and a speed up to 4350 RPMs. Teams will ultimately determine their own normal operating range, based on their robot requirements. Perhaps a trade-off of slightly higher current and a little less speed for more torque will be important in the design or vice versa.

As you can see here, considering the Max Power point, a reasonable CIM motor operating range would be around 1000 to 3000 RPM at its output shaft. Obviously this is too fast to connect directly to the wheels. Besides, the available torque at those speeds is pretty small. Typically, some gear reduction with a transmission and sprockets will bring the speed down to around 150 to 250 RPM and increase available torque. The benefits are in gaining starting power, getting the top speed down to something that can be controlled, and increasing the pushing power and maneuverability of the robot.

Just a caution to say that the torque/speed data presented here is based on a single voltage level (12V). In actual operation the motor speed/torque will shift toward the origin as the voltage applied to a motor is reduced because of either your joystick setting or decreasing battery voltage. Lower voltage produces lower speed and torque. Conversely, higher voltage yields higher torque and speed with higher current and more heating of the motors.

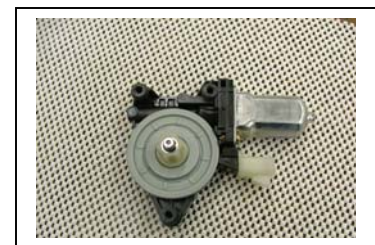
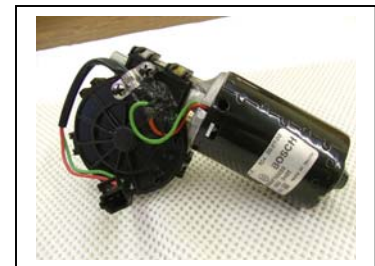
Most of the motors supplied in the Kit were not originally designed to drive robots. For example, the motor shafts on the Globe and Mabuchi motors are designed to provide axial torque only, and cannot withstand any significant *side loads* imposed on their motor shafts. *When using these motors, take care to securely fasten the motors and then couple the shafts via flexible couplings to the rest of the drive train when used for motive power* (as suggested in this graphic).



Selecting appropriate ratios for gear, sprockets, chains, etc. to perform within a motor's power band is the goal. Poor motor performance or premature failure may occur if the employed transmission ratios are not properly chosen or suited to allow motors to operate within their preferred or "normal" torque/speed/current ranges. Using the supplied transmissions and sprockets will help toward making these choices easier for you.

### **Motor Bias**

When looking at the table above, teams should also note that certain motors have a built-in bias toward a preferred direction of rotation. This bias is assumed a result of brush timing. When the motor is operated in the preferred direction, it will produce more torque and turn faster. In the reverse direction of rotation, the same motor will run a bit slower producing less torque. So, suppose for example that a pair of CIM motors were to exhibit timing bias symptoms. Normally, when the robot is steered forward one motor rotates in the clockwise direction while the companion CIM motor is rotating counter-clockwise. With pronounced timing bias, any speed difference between the motors will cause the robot to drive off the intended straight track to one side. Generally CIM motors are fairly well balanced, but should you encounter this symptom you may need to try a different motor pair to achieve a more balanced result.



Also be cautious and consider most torque/speed curves as valid only for the primary direction of rotation. If balanced performance will be critical to your design, torque/speed measurements should be checked in both directions.

Note in the table above that the CIM motors are one example of a motor very capable of drawing in excess of 100 Amps at stall. Operating these motors near the Max power point for more than a few seconds likely will trip the auto-resetting 40 Amp circuit breaker and result in losing drive control of the robot until the circuit breaker cools sufficiently. The breaker will eventually reset, and the motor will resume operation. Its better to limit or avoid this situation and in your design select gear ratios that will keep the motor current operating within the safe range of the current protection offered by the circuit breakers.

### G.3.3.1 Special Notes on Motors

**CIM Motors** - The 2006 Kit of Parts again provides four CIM Motors. This year there are 2 - FR801-001 motors and new to the kit are 2 - FR801-005 Mini-bike motors. The torque/speed data for these motors appears in the Motor table at the start of this section. The kit also includes a pair of Drive transmission gearboxes as supplied last year, which readily accept the mounting of the FR801-001 CIM motors. The FR801-005 CIM motors do not directly fit onto the transmission housing, but teams may want to adapt the motors to use the transmission gearboxes with appropriate hardware. For information and details on adapting these motors, contact AndyMark at <http://www.andymark.biz/>

**Nippon Denso Motors** – This year the Kit includes a pair of Denso Window motors. One is a left hand version and the other a right hand version of the motor. These motor/gearbox assemblies have an automotive quick-connect Packard connector (P/N 12129487). The Packard mating connector Part Number is 12129486 and is not provided in the kit. An investigation for a source of supply for these connectors is underway

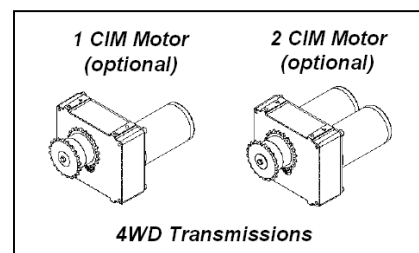
While having a genuine mating connector is ideal, an alternate connection method is to use a pair of 14-16 ga. female insulated Slip-on (Quick Disconnect) terminals such as Terminal Supply part BB-8185 or Stakon's RB14-110F terminals. These terminals fit posts 110 x .032 in. and will make a firm and reliable connection for the motor.

**Fisher-Price Motors** – Please note that two flavors of the Fisher-Price motors are listed on the Motor Type table. The 2006 Kit of Parts contains a pair of FP Motor gearboxes using one of these motors labeled either 9003 or 9012. The motors are identical except the 9012 motor has a thermal protection circuit built-in. Teams can compare the motor specifications to see the very slight difference in the characteristics. However, the Motor gearboxes are supplied as identical pairs in the kits.

### G.3.4 DRIVE TRAIN

The Mechanical Drive Train consists of those components that connect the drive motors to the wheels or tracks of the robot. The KOP again contains a pair of the versatile 2005 drive train transmissions to provide drive interface capability for the robot. *FIRST* recommends using these transmissions, gears, sprockets, chain, couplings, and connections, not only for convenience, but to take advantage of the engineering solution for proper speed reduction and power transmission between the CIM motors and the robot drive loads afforded by the kit. Listed below are some general considerations and helpful ideas as you plan and build up a robot drive system from scratch.

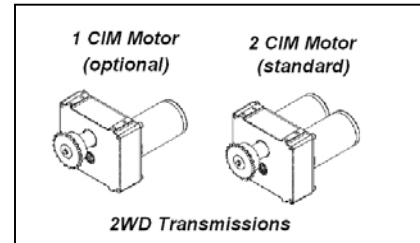
- If designing an axle-based drive train, assure that the weight of the robot is fully supported by the axles and shafts of the transmission *and not* by the drive shafts of the motors. Use bearings and bushings on the axles and shafts to provide proper support and minimize friction. Remember, *the greater the robot weight, the more internal friction the drive train components will experience*. Align mechanical power transmission components accurately.
- *If you couple a motor shaft to another shaft, assure that the coupled shaft is supported with bearings at two points as shown on the previous page. Use a flexible coupling to connect the motor shaft to the shaft.*
- Incorporate sufficient gear reduction in your drive train to provide ample drive torque and sufficient robot speed.





### G.3.4.1 Transmissions

The FRC Transmission kits provide the necessary materials to assemble 2 complete transmission units for the robot. The kits are designed to utilize the CIM motors and with a reduction of 12.75:1 will achieve a speed reduction very near typical drive operating speeds. In addition, these assemblies are very robust when compared to drive system designs from previous years.



The “standard” transmission uses Dual CIM motors on each assembly for 2WD as shown in the figure. Alternately the transmissions can be configured to use just a single CIM motor to drive each unit. Dual motors allow the transmission to deliver double the torque (17.7 N-m) at twice the power to the output shaft, but at the added cost of one CIM motor per transmission.

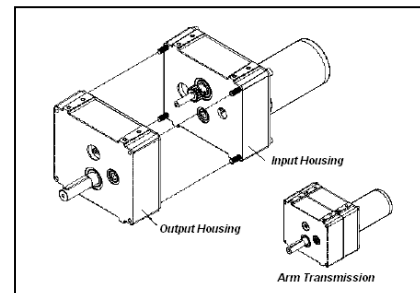
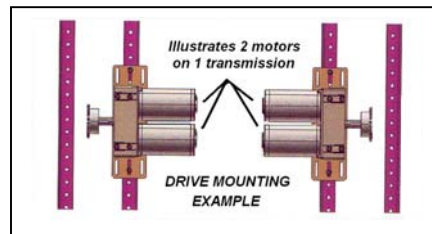
The output shaft is configurable for 4WD by adding a second sprocket. The second sprocket is not supplied in the kit, but can be ordered separately.

| Specification                   | Single Motor | Dual Motor | Arm   |
|---------------------------------|--------------|------------|-------|
| Stall output torque (N-m)       | 25.3         | 50.6       | 291.5 |
| Free output speed (RPM)         | 423          | 423        | 32.5  |
| Stall current (Amps/motor)      | 107          | 107        | 107   |
| Free current (Amps/motor)       | 4            | 4          | 6     |
| 40 amp output torque (N-m)      | 8.9          | 17.7       | 97.9  |
| 40 amp output speed (RPM)       | 275          | 275        | 21.6  |
| Maximum power output (watts)    | 280          | 560        | 247   |
| Power output at 40 amps (watts) | 254          | 509        | 221   |

The transmissions are adaptable to powerfully drive an arm assembly when configured in a cascade arrangement shown here. The cascaded transmission can deliver 5 times more torque than the dual motor version while operating at a fraction of the speed.

Step-by-Step instructions and additional information to assemble any of the three configurations can be found in the *FIRST* Transmission Manual on

<http://www.ifirobotics.com/>.



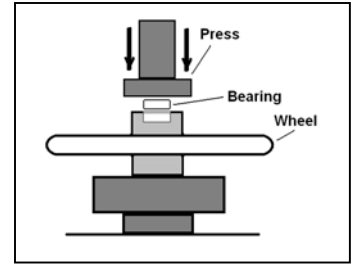
### G.3.4.2 Assembling the Wheels

The *FIRST* KitBot supports a fixed-axle system where the driven sprocket is mounted directly to the wheel and not to an axle. The components required for assembling a driven Skyway wheel are presented in a visual assembly sequence as shown in the photos below. Each wheel requires two bearings (S3KDD) from the IFI Motor Kit. The driven wheels also require two wheel hubs from the Coupler bag in the Blue Tote (as depicted in the left photo) and a drive sprocket with the hub-mating hole pattern pre-drilled in the flange of the sprocket to be bolted through the wheel hubs. This 28-tooth sprocket is already provided in the Drive Train bag in the kit. A starting point will be to install the bearings into the wheel.



- Bearing Insertion

Inserting a pair of bearings into each side of the wheel hub can be a relatively simple operation if an Arbor Press is available in the shop. The wheel hub has a slight recess at the opening of the bearing cup and this recess helps to set the bearing in a true orientation for insertion.



Center the wheel and bearing under the press face.

Apply moderate light pressure on bearing face to start driving the bearing down into its recessed position.

Check that the press surface applies equal force across the entire bearing face and not just on the inner race of the bearing. Also check that the bearing is uniformly being driven into the hub. If the bearing is not properly aligned, the bearing and/or the wheel hub could be damaged.



The bearings also can be inserted by using a softheaded hammer or rubber mallet. Lay an intermediate flat surface such as a small metal plate over the bearing and tamp on the plate to seat the bearing.

After both bearings have been installed, the pair of plastic wheel hubs can be slid over the bearing collars on each side of the wheel such that the slots in the hub capture the wheel spokes as shown in the center photo. Before attaching the hubs and sprocket/s with the #10- 32 hardware, you may need to pre-drill through the 6 holes in the hubs to open the clearance with the spoke skirt. Use a #6, or #7, or 13/64" drill bit and use the sprocket as a drill bit guide.



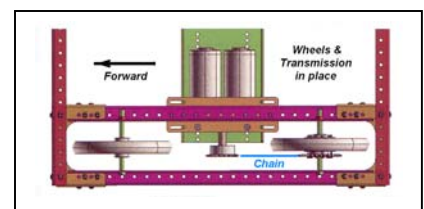
Shown here is the wheel assembly with the sprocket attached. The sprocket is bolted onto the hub assembly using the appropriate hardware 6 each - #10-32 x 1.75" Round or Button head SS machine screws, lock washers, and nuts). The wheels are now ready for mounting onto the chassis frame.

### G.3.4.3 Wheel Placement

A 5" long 3/8" Hex Head Cap bolt provides a cost-effective and satisfactory axle when using the Chassis kit frame. Spacers and washers should be used to take up the free space to hold the wheel in a semi-fixed position on the axle. Essentially, the wheels should be centered in the wheel channel. However, a golden rule for chain and sprockets is given here, as follows:

- When using chain and sprockets in your drive train, be sure that wheel sprocket and the gearbox sprockets are properly aligned with each other. Make sure the sprockets are in the same plane and with the chain attached, make sure the chain angle is not cocked and always leaves the sprocket gearing in a straight path to the other sprocket as the wheel is rotated.

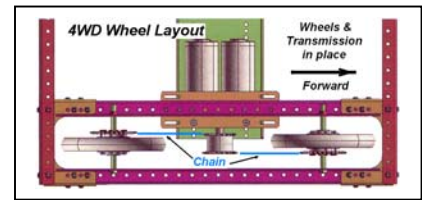
It may be too early to check this situation for real problems. Just keep this alignment requirement in mind and plan ahead for adjustment, if necessary.



In this 2WD wheel mounting setup, the driven wheels are

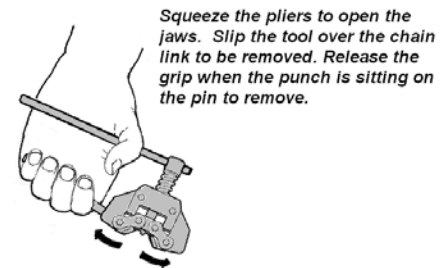
mounted at the rear of the chassis with the free wheels mounted forward. The left-side wheel arrangement opposes the right side in that the sprockets will face outward on the rear wheels. The wheels can be positioned forward or backward from the locations shown in the drawing and that placement will impact the maneuvering and stability of the robot platform. Fortunately there is reasonable adjustment available in the wheel channel to accommodate effective changes learned in evaluations.

In a 4WD system each wheel is equipped with a sprocket. However, the wheels in each channel need be installed so the inner wheel sprocket will mate up with the inner drive sprocket on the transmission shaft and the outer sprocket can mate up with its outer sprocket. For 4WD, the left-side wheel channel arrangement mirrors the right side. For example, here in the picture, the right forward socket is facing the outside. On the left side of this frame the forward sprocket will face the inside. The drive wheel sprockets can then be connected to the individual transmission sprockets via chain if the transmissions are mounted.



No doubt you have discovered that the KOP includes a 10-foot length of ANSI #35 chain and a pair of master links. The #35 chain is selected because the chain can handle a lot of abuse appropriate for robotic needs without being too heavy. Chore #1 will be to determine the length of chain you will need between sprockets. Chore #2 is to break the existing chain at the necessary length with a chain breaker tool. Finally, chore #3 will be to join the chain back together with a master link. The number of chains you will need depends on whether the robot will be a 2WD, 4WD, or perhaps even 6WD.

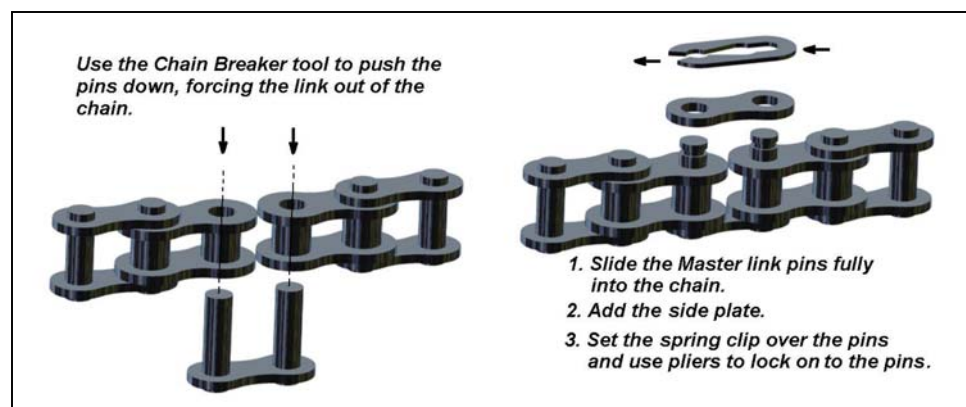
So now you have the frame, with a pair of transmissions mounted on the frame and a set of wheels mounted as shown in the figure above. You will need to join two clean ends of the chain with a master link. So when you size the chain, select a particular link & pin that will produce a “clean link” (end with an open internal hole) and the length should result in the chain being slightly longer. That’s better than ending up with a chain that’s too short.



The tool you’ll need is called a Chain Breaker. This tool is designed to slip over and grip the links on the chain by squeezing the handles as shown.

The tool “punch tip” should be positioned directly over the pin to be removed. When the punch is sitting squarely on the pin, turn the upper handle “cw” to start driving the pin down through the link plate. When the pin is about even with the plate surface, move the tool to the second pin and drive it down into the plate about half way. Finish by driving pin 1 through the link plate and then drive pin 2 through the plate.

Now that the chain is broken to the correct length all that remains is to rejoin the chain on the sprockets with a master link. The master link is a reusable link that uses a side plate



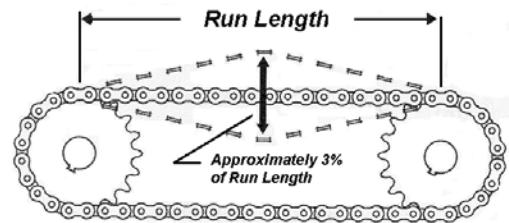
and spring clip to hold the chain together.

1. Wrap the chain onto the sprockets such that the clean links are supported on the sprocket.
2. Slide the master link fully through both pinholes.
3. Add the side plate over the master link pins.

Place the spring clip (as shown) over the pins with open end of the clip touching the second pin. With the pliers, squeeze the end of the clip using the pin as a lever and guide the open end of the clip around the second pin.

Here are a couple of points to check as you connect the chains:

- Check the chain tension. If the chain is too loose or sloppy, it could result in poor response to direction changing and in the worst case, could start jumping teeth on the sprocket, resulting in lost drive. The rule of thumb for slack is about 3% of run length (distance between sprocket centers. Typically +/- 0.5".
- New chains will “stretch” after installation and it is most likely that some slack will need to be removed. However, if the chain is too tight at this point of assembly, remember that when the full weight of the robot structure is applied, the transmission components and the drive train will likely be subjected to extreme friction with a serious reduction in drive efficiency. The ideal chain tension is simply that point where the chain will not slip.
- Whenever two chains drive a pair of wheels or four chains drive four wheels, it is especially important to assure the chain tension is identical for both drives.



**DETERMINING CHAIN SLACK**

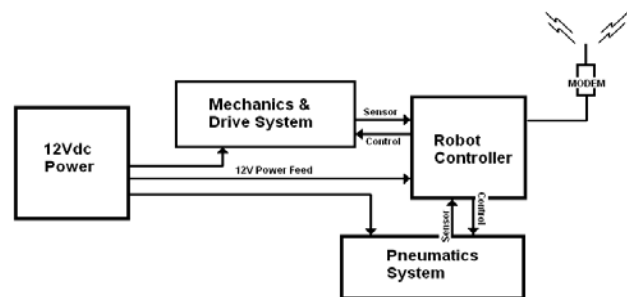
## G.4 ROBOT ELECTRICAL

### WARNING!

*Please read the following sections very carefully. Failure to wire your robot properly could result in personal injury, damage to the control system, or damage to your robot. It could invalidate the control system warranty. FIRST and/or Innovation First will not provide free replacement of components damaged due to misuse or improper wiring. Teams will be required to correct wiring that is not configured according to this section and the control system rules in the Robot Rules section before being allowed to compete.*

In all cases, please refer to the [2006 Robot Power Distribution Diagram](#) for specific guidance to wire the electrical system of the robot.

The Electrical System is the primary source of energy for the robot. The system includes the 12V battery, the electrical devices and the network of wires that distribute the electrical energy to the motors, to the pneumatic actuators, and to the Robot Controller and sensors. The drawing illustrates the basic electrical energy supply relationship between the Main Power



**ROBOT ELECTRICAL BLOCK DIAGRAM**



system, the Mechanics & Drive systems, Pneumatics system, and the Robot Controller.

One can see that getting full electrical energy to each system is critical to the robots performance. So, using wires large enough and connections properly made without restrictions (resistances) is essential to provide the necessary current to do the work. Bottom line: make sure the wire you use is rated to the current that you expect to put through it!

## G.4.1 CONDUCTORS

### G.4.1.1 Wire & Wire Size

A small conductor permits less electron flow than a larger conductor. The choice of using an appropriate conductor size to handle electrical current can be an important decision.

All wires are classified by the American Wire Gauge system, and are assigned “gauge” numbers according to the wire’s cross-sectional area. The table shows standards for the AWG gauge number including: the wire circular size in “mils”, the diameter in inches and millimeters, the wire resistance per 1000 feet, and a maximum rated current for the wire gauge at 12Vdc input.

*Note the higher the AWG number, the smaller the wire size.* For example, a #20 AWG wire has a diameter of 0.0369 inches. A #12 AWG wire has a diameter of 0.0933 inches.

| AWG | Size             |                  | Resistance<br>ohm/1000' | 6 feet<br>Resistance<br>(Ohms) | Voltage<br>Drop<br>(Volts) | Maximum<br>Current<br>Capacity |
|-----|------------------|------------------|-------------------------|--------------------------------|----------------------------|--------------------------------|
|     | Circular<br>mils | Diameter<br>inch |                         |                                |                            |                                |
| 20  | 1,362            | 0.0369           | 10.360                  | 0.0622                         | 6.22                       | 5 A                            |
| 18  | 2,162            | 0.0465           | 6.520                   | 0.0397                         | 3.97                       | 7 A                            |
| 16  | 3,446            | 0.0587           | 4.080                   | 0.0245                         | 2.45                       | 12 A                           |
| 14  | 5,476            | 0.0740           | 2.580                   | 0.0155                         | 1.55                       | 20 A                           |
| 12  | 8,705            | 0.0933           | 1.620                   | 0.0097                         | 0.97                       | 30 A                           |
| 10  | 13,853           | 0.1177           | 1.020                   | 0.0061                         | 0.61                       | 50 A                           |
| 8   | 22,023           | 0.1484           | 0.640                   | 0.0038                         | 0.38                       | 80 A                           |
| 6   | 35,006           | 0.1871           | 0.402                   | 0.0024                         | 0.24                       | 125 A                          |
| 4   | 55,696           | 0.2360           | 0.253                   | 0.0015                         | 0.15                       | 200 A                          |

Calculation shown for 6 feet of wire @ 100 Amps @ 12Vdc  
Max Current rating based on allowable 2.5% voltage drop

Two additional columns show the wire resistance for a 6-foot length of the cable and the voltage drop in that section of cable when a 100A current flow is applied through the wire. The maximum current rating is based on a maximum 2.5% allowable voltage drop.

*FIRST* Robot Rules specify the minimum allowed wires AWG sizes that may be used to supply the robot’s electrical loads in compliance with SAE J1292 wiring standards. Remembering that choosing the wire size (AWG) can be important toward delivery of full power to a load while protecting the wiring integrity, teams can always use larger gauge wiring (smaller AWG number) if so desired.

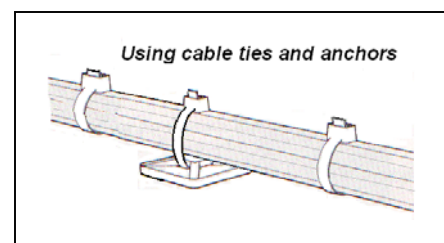
### G.4.1.2 Polarity and Current Paths

In addition to being electrically isolated from each other, all positive and negative wiring must be isolated from the robot’s chassis. Teams must ensure that no electrical devices or custom circuitry on their robot are electrically common with the chassis (no “grounded” housings). **The negative terminal of the battery must not be connected to the robot chassis.** Teams should use the 2006 Robot Power Distribution diagram as a guide when wiring their robot.

### G.4.1.3 Cable Routing & Harnessing

*FIRST* recommends all teams follow good cable routing & harnessing practice and that all wiring be laid out in a logical, orderly manner between circuit devices.

- Wires leaving devices should be grouped and bound together with plastic ties to form wire harnesses. Binding the wire bundles together using plastic tubing or quick ties and chassis anchors provides rugged support for the wires.



- Harnesses should be sorted and separated into “high power” and “PWM/sensor” cable groups and run in different pathways their destinations. This is very important to minimize cross-talk interference between wires and useful as an aid in troubleshooting and servicing the robot. Choosing a safe and protected pathway for the harness adds to the robustness and reliability of the electrical system.
- Wires and groups of wires, passing through chassis holes or around cutouts with sharp edges, must be protected by plastic sleeving, plastic tubing, plastic helical wire wrap, and/or by rubber grommets on chassis edges for protection.

#### G.4.1.4 Wire Terminations

The first rule of termination is to keep in mind that any connected wire terminal or plug may need to be disconnected for service on occasion. So it’s a good idea to leave a slight amount slack in each length of wire to permit detachment from terminals. However, avoid leaving excessive slack. Not only is it messy, but also loose wires can get pinched, grabbed, or torn away by intruding metals. Use good judgment both in routing and terminating wiring.

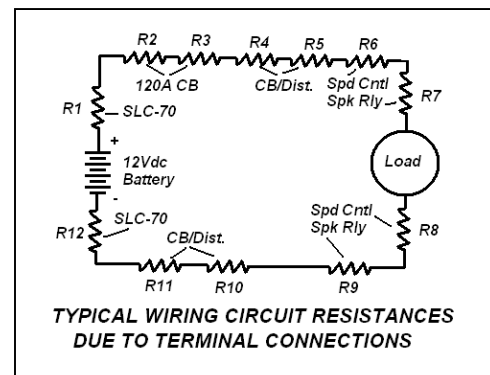
#### NOTE

If you are attaching wires or a harness to a moving part, use sufficient slack and strain relief to prevent damage to wires and connections. Use common sense and plan to protect wiring effectively.

| COLOR  | WIRE SIZE    |
|--------|--------------|
| RED    | 18 TO 22 AWG |
| BLUE   | 14 TO 16 AWG |
| YELLOW | 10 TO 12 AWG |

Quantities of various insulated RBY Ring and Slip-on terminals are provided in the Terminal Bag found in the kit of parts. “R, B, and Y” stands for the basic red, blue and yellow colors found on the insulated terminals and splices. The insulation color (as shown in the table above) identifies the AWG gauges of wire that the terminal lug is designed to accept. It is a bad idea to use a terminal lug that is not designed for the wire.

One key towards getting full power delivered to load circuits in the robot’s construction is in fabricating good terminal connections. This may sound simple, but to maintain electrical integrity, tensile strength and insulation properties, sound-crimping techniques must be used. The drawing shows an example of a typical robot electrical circuit. The “R” components shown are just the resistances added to the circuit from each terminal connection. Ideally, these would be negligible. However, one bad crimp or poor solder job could insert several ohms of resistance into a circuit and equal one big voltage drop and plenty of lost power.



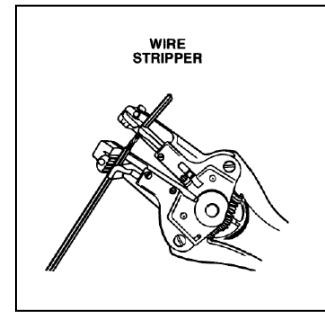
The first thing to consider is that a good crimp relies on the preparation of the wire, the terminal type, and the quality and use of the crimping tool. If any of these items are out of specification, an unacceptable crimp may result.

So, a good tip is: Invest **in a good crimping tool!**

The general rule is to strip the outer insulation from the wire using a wire stripper tool with cutting slots matching the wire gauge size. The insulation should be stripped (approximately ¼”) so that, when fully seated in the terminal lug, the ends of the wire strands just protrude through the barrel.

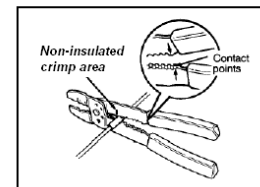
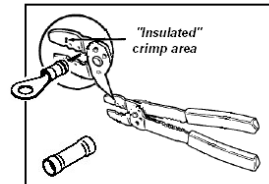


Slide the terminal lug over the wire strands so that all strands are fully into the terminal sleeve and the wire insulation is under the insulating sleeve of the lug and just butting up to the inside sleeve inside the terminal barrel. The wire insulation must be fully seated inside the lug insulation sleeve for proper support. You should now see the tips of the copper strands just protruding through the barrel.



When using the kit crimping tool use the “insulated crimp” area of the tool as shown in the figure. Center the lug barrel on the proper die on the tool approximately at the 1/3-point closest to the stud end of the lug. Apply firm grip pressure. More pressure is usually needed for larger wires. Test the crimp by holding the terminal and tugging on the wire. The lug should not pull off.

- Over-crimping by using excessive pressure distorts the integrity of the wire strands and weakens the binding strength. Eventually the resistance of the joint will increase due to heating and chemical interaction and an unreliable connection may result.
- Careless positioning of the lug and wire in the crimping tool may result in a partial clamp of the wire at the tip, or a clamp on the wire insulation and not the conductors at the end of the barrel. Take your time and get it right. This is very important!



Crimp-on connectors that are improperly crimped may work at first, but can fail easily due to the operating vibration of a robot. Crimps fail if you push the wire so far into the terminal that when the crimp is made, it is only binding on the wire insulation and not on the wire strands. If the crimp is made with insufficient pressure, the wire will pull out easily. The real test is doing an ohmmeter continuity test on the lowest (R x 1) scale. Verify “0” ohms resistance from end to end of the conductor.

There will always be some controversy over practices and procedures. This is surely true when making “solder-less” connections. Solder-less terminal manufacturers consider that the highest levels of reliability are achieved using solder-less terminations. The SAE, (Society of Automotive Engineers) specifications highly recommend that all terminal lugs attached to 10AWG or larger wire should be first be lightly crimped on to the wire and then be soldered. This requires some knowledge and skill about applying solder and making quality solder connections.

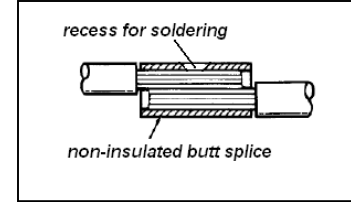
If you choose to follow this recommendation, you will need a soldering gun or iron of at least 45 watts for soldering larger lugs and wires. You should strip the insulation from the wire as before, so that, when fully seated in the terminal, the ends of the wire strands just protrude through the barrel. Then pre-tin the bared wire strands with a melted flow solder, assuring a good clear solder flow (silvery color). Slide the lug onto the wire and crimp the lug lightly with the crimping tool using the appropriate lug size crimp hole.

Then re-apply the tip of the soldering iron onto the junction of the wire protruding at the lug barrel and the lug barrel. Heat this junction, and using a strand of solder, flow melted solder into the junction observing the flow of shiny metal solder. Remove the soldering iron and hold the wire still

to let the junction cool. The junction should remain metallic in appearance and not turn to a chalky white/gray in color.

#### G.4.1.5 Splicing Wires

In the construction of the electrical system wiring it may be necessary at some point to splice wires together to add needed length for a connection. There is an assortment of insulated or non-insulated butt connectors available to make this job easier and more reliable. This drawing shows an example of a non-insulated butt connector being used to join two conductors. This type of splice is normally “crimped and soldered”. The junction should then be wrapped with electrical tape and covered with a length of shrink tubing for protection. Insulated butt splice terminals are frequently just crimped using the procedure described in the Wire Terminations paragraph above.



#### G.4.1.6 Labeling

It is advisable to label wires and devices to facilitate troubleshooting, tracing, and reconnecting wiring. Labeling can be done with heat shrink tubing or white electrical tape and a fine point permanent marker. It is also advisable for a team to create a robot-specific wiring diagram for reference. The diagram and wire labeling greatly facilitates resolving electrical problems. The wiring scheme should be easy to trace and interpret during technical inspection.

#### G.4.1.7 Inspection

Be sure to inspect your robot on a frequent basis following service work or when participating in an FRC event. Detecting and repairing minor damage to harnesses, individual wiring, or connections may prevent a failure that could harm the power or control system or cause a robot to stop dead in the middle of a match.

### G.4.2 12V POWER SYSTEM OVERVIEW

The 12V Power system consists of the **1)** Exide 12Vdc battery, the **2)** 120 Amp Main Circuit Breaker, **3)** Circuit Breaker/Distribution panels, and the **6)** Ground return connection.

#### G.4.2.1 Locating System Components

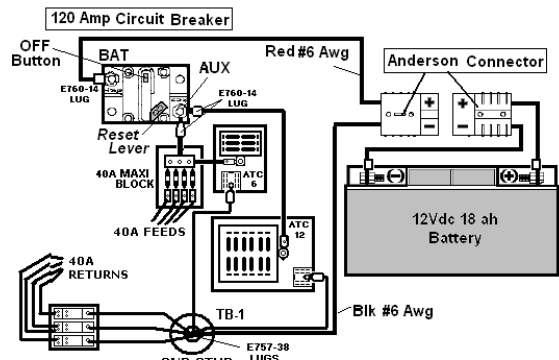
When planning the layout and location of robot hardware and systems, some priority should be given to positioning the 12V Power system components with the following considerations:



The 12Vdc Battery must be:

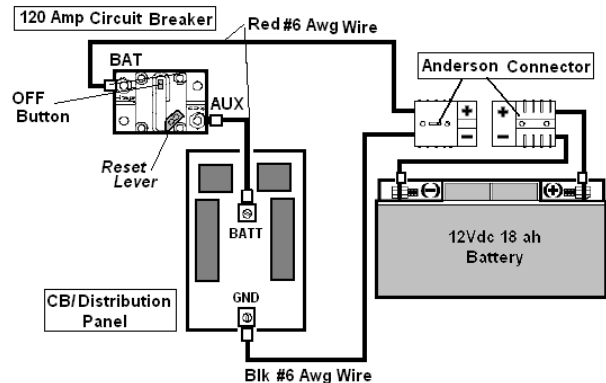
- Accessible for easy replacement and/or recharging and inspection. If, in the heat of competition and with a short time interval between matches you need to swap out batteries, having easy access will be worth its weight in gold.
- Firmly mounted and protected from contact by the robot’s own mechanical hardware or by other robots or field hardware Batteries can be damaged when hammered by another robot.
- Be located as close as possible to the 120A Main Circuit Breaker, and to the Circuit Breaker/Distribution panels to keep wire lead lengths short.

The 120-Amp Circuit Breaker serves as the Main Power ON/OFF switch for the robot and as the Main Safety current overload protection device. The 120-Amp Circuit Breaker ***must be located in an accessible*** and protected area. By Rule, the battery positive terminal must connect directly to the 120-Amp Circuit Breaker via the Anderson Connector. So it is generally a good idea to mount the 120-Amp Circuit Breaker assembly nearby the battery location.



**2006 Main Power Connections**

In many cases, the circuit breaker & distribution panels should be located next to the 120-Amp Circuit Breaker to minimize power wire lengths where possible. Plan ahead to orientate the panels for the best position to accept the incoming wiring from the battery and load sources. It also helps to have accessibility, protection, and convenience to service the panels whenever necessary.



**2005 Main Power Connections**

#### G.4.2.2 12VDC System Assembly

A Starting point might be preparing the Anderson Power Connector to interconnect the battery posts to external circuitry. The Connector is pre-wired with 12" lengths of #6 AWG wire.

*FIRST* supplies a pair of the Red Anderson Power Connector (Misc. Bag) to connect the 12V battery to the rest of the Power Distribution system. The Anderson connector provides a means of quick disconnect and exchange of the battery on the robot whenever necessary. In the Terminal Supply bag SLU-35 Copper lugs are supplied to mate #6 AWG cable to the battery posts and to the Main Circuit Breaker and the Ground connection point.

The (Red) wire on the Input side of the Anderson connector **must** be connected directly to the Positive post of the Exide EX12-18 Battery. Tighten bolt. Finish by fully insulating the post with electrical tape. The Negative (Black) # 6 AWG wire must be connected to the Negative post on the Battery. Tighten the bolt. Finish by fully insulating the post with electrical tape.

Although rare, impact forces that robots sometimes experience during matches have been known to cause the Anderson Power Products connectors to disconnect. *FIRST* recommends utilizing a quick-release fastener, such as a Velcro strip, to hold the power connectors together during a match.

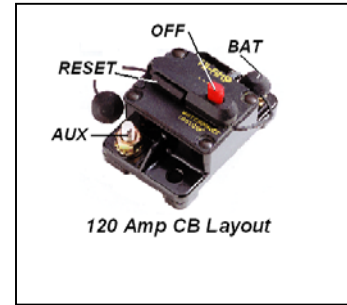
### **WARNING!**

*Make a final re-check that the Red wire is on the (+) post and Black on the (-) post. Improper polarity can damage CONTROL SYSTEM components.*

#### G.4.2.3 120A Circuit Breaker

The 120A main circuit breaker/disconnect switch functions as the Main Power **ON/OFF** switch for the robot and as a Safety current overload protection device.

To power down the robot power manually, push the Red **OFF** button on the breaker. To reset Robot Power to ON, push the **RESET** lever back into position.

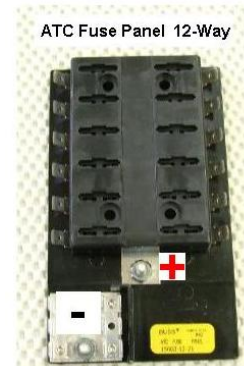


The Positive (Red) wire on the output side of the Anderson connector should have an E760-14 Ring lug crimped/soldered on and then be connected directly to the **BAT** post of the 120A main circuit breaker. Tighten the nut. Finish by fully pushing the rubber-insulating cap back down over the nut. This will assure that all power from the 12v battery now flows directly to the 120A breaker. Do not connect anything other than the 120A main circuit breaker/disconnect switch directly to the 12v battery's positive (+) terminal.

A fully charged 12Vdc battery can deliver current in excess of 200 Amps for a sustained period of time (minutes) in a short circuit situation. This amount of current can make wires turn red hot and melt through their insulation in a fraction of a second, and can result in serious burns or other injuries. Short circuits can also destroy control system components, cause fires, or cause the 12v battery to leak highly corrosive acid or explode. Always make sure that the 120A main circuit breaker/disconnect switch is wired in series with the 12v battery positive (+) terminal.

#### G.4.2.4 The ATC Fuse Panels

The Positive 12Vdc output of the 120 Amp Circuit Breaker typically is fed from the **AUX** terminal to the power distribution panels via a length of # 6 AWG (Red) wire and connected to the + Bolt at the center terminal of the ATC panel. The battery negative connection from the fuse panel connects to the GND Bolt.



The 6 and 12-way ATC panels can hold a population of 30A, and 20A Snap-Action re-settable circuit breakers. The 20 and 30 Amp circuit breakers can be plugged into any available socket running the length of the panel. The Positive load wires are attached to the panel male tabs at the desired circuit breaker using the slip-on terminals provided in the Terminal Bag.

The Negative (Black) # 6 AWG wire on the output side of the Anderson connector must be connected to the GND Stud.

*The battery negative connection must not be connected to chassis ground.*

#### **NOTE:**

*While the terminal is marked "GND" we refer to this connection as "Battery Negative. NOT chassis ground.*

#### G.4.2.5 Maxi Style Fuse Block

The Maxi Style fuse block is used to support the 40 Amp service requirements of the larger drive motors. Up to four 40 Amp circuit breakers can be fitted into the clips on the Maxi fuse block shown here. One end of the Maxi is the +12V feed block (top end in this photo) accepts up to three #6 AWG wires to distribute the +12V.

The load end of the Maxi provides 4 circuit feeds to the Speed Controllers. The Negative wires of each load should be attached to the Power Distribution block, which is then connected to the ground stud.



Shown above is the 2005 *Power distribution* diagram. Teams may choose to purchase the IFI CB/Distribution PCB and use it in place of the fuse panels provided in the 2006 Kit as an option.

Current ratings of the circuit breakers are the *maximum ratings* allowed. The AWG wire sizes to be connected to the different sized breakers are specified by the Rules as the *minimum AWG gauge* allowed.

### G.4.3 MOTOR POWER DISTRIBUTION

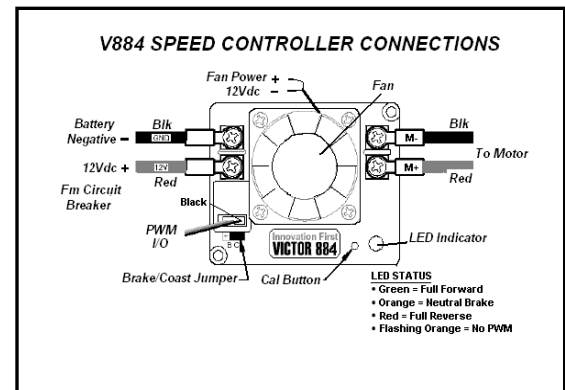
Refer to the 2006 Robot Power Distribution diagram to review the 12Vdc power cabling interconnections between the CB/Distribution panels and the electrical actuators for the various motors.

The sections that follow provide some practical guidelines, recommendations, and cautions regarding these interconnections. You will find the specific wiring, programming, and operating details in the manuals for the various actuators.

#### G.4.3.1 V884 Speed Controllers

The Innovation First Victor 884 Speed Controller is a specialized device primarily intended to control the Main Power, direction, speed, and the braking/coasting actions of the larger (high current) motors associated with lift arm mechanisms and drive systems. Each Speed Controller is rated for 40 Amps and must receive the 12Vdc power input from a dedicated 20A, 30A, or 40A circuit breaker on the CB/Distribution panel (depending on the output load). The wire size (AWG) to be used for each circuit breaker rating is specified in the Rules.

You may notice that the Victors supplied this year do not label the 12Vdc Power I/O terminals. The figure shown here correctly shows the input terminals from the CB/Distribution Panel are located on the same side of the Victor as the PWM connection and per the polarity shown. The motor output connections are located on the right side of the Victor with the polarity correct as shown. On the PWM cable, the Black wire side of the PWM plug is nearest the fan. The fans on Speed Controllers should be wired so the fan is always ON whenever the Victor 884 is ON.



Be sure to connect Speed Controllers controlling high current motors such as the CIM and Fisher-Price motors to the 40A circuit breakers in order to maximize power output and prevent unexpected shutdowns. The Ring-type terminal lugs supplied in the kit, rather than fork lugs, should be used on both the 12V supply-side wires and the load feed wires to assure maximum surface contact and therefore minimum resistance at the screw terminals for maximum power delivery.

Only one large motor (CIM, Van Door, Fisher-Price, Globe or similar motor) should be controlled per Speed Controller. The Speed Controllers may be wired to the 30A circuit breaker outputs when connected to the Globe motors or the Van Door motor. More than one low current small motor (window/ Mabuchi) or actuator may be optionally connected to a single Speed Controller.

Control signals from the RC are communicated to the Victors via PWM cables. Be careful, when handling and using the PWM ribbon cables, to protect the cables from physical abuse (i.e. to the internal wires such as; straining, pinching, or sharp bending), which may cause unexpected failures. Make sure the PWM cable is plugged into the RCs and Victors according to the wire color coding as marked on the device flanges and that the cables are secured to prevent the plugs from becoming unintentionally detached. PWM cables may be grouped into a cable harness and should be routed separately away from the power cabling to the RC unit.

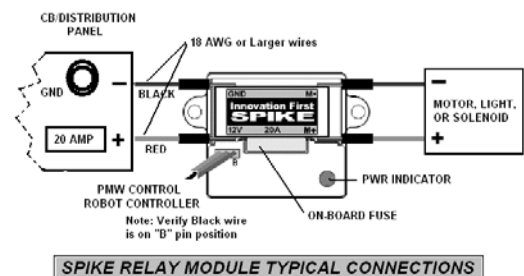
### **WARNING!**

Speed Controllers will be damaged if reverse polarity is applied to their power inputs. Always assure the polarity is correct when wiring the Speed Controllers. Speed Controllers may also be damaged if a short circuit occurs across the load output. So, particularly at installation, verify that a short circuit does not exist before applying any power to the device.

For detailed information about calibrating Speed Controllers or setting the braking/coasting mode for the motor by user switching, refer to the *Victor 884 Users Manual* found on the Innovation First website at: <http://www.innovationfirst.com>.

#### G.4.3.2 Spike Relay Module

The Spike Relay module provided in the KOP is typically used to control the OFF/ON operations of small motors and the forward or reverse direction of the motor output shafts. However, unlike Victors, they do not control the speed of the motor. Spike Relays are also used to operate solenoids or lights. Since Spike Relay modules are rated to 20 Amps, it is recommended that they be used to drive only the smaller motors and actuators such as window motors, seat motors, solenoid valves, air compressor, etc.



Spike Relay Modules must receive their 12Vdc power via one of the 20A circuit breakers on the CB/Distribution panel at their input terminals marked **12V** and **GND**. While the terminal is marked as “GND”, this connection is to “battery negative” and NOT to chassis ground. The wire size (AWG) to be used for the Spike Relay circuit breaker is a minimum of 18 AWG as specified in the Rules.

In some cases it is acceptable to distribute the main power from a single 20A circuit breaker to more than one Spike Relay Module.



A single Spike Relay Module can power no more than one motor. The motor would be connected at the **M+** and **M-** terminals of the Relay module. The truth table (below) shows the M Output signal status for the PWM signal input changes. Note that in the motor “OFF” state, the Brake condition applies and the motor stops in the fixed position. In a simple program application, the Relay Module would supply **+12V** at the **+M** terminal and **GND** at the **M-** terminal for the **ON** state **A**. If so programmed, the module can reverse the situation and supply **GND** at the **+M** terminal and **+12V** at the **M-** terminal for the **ON** state **B**.

The Truth table primarily applies to the control of motors for reversing motor direction. Other devices, such as the Thomas Air Compressor, fans, and lights are intended to only be turned ON/OFF with the spike relay. The compressor motor should never be reversed, but only be connected and operated at the standard M+ and M- polarity input.

| INPUTS |     | OUTPUTS |      | Indicator | Motor Function                      |
|--------|-----|---------|------|-----------|-------------------------------------|
| Fwd    | Rev | M+      | M-   |           |                                     |
| 0      | 0   | +12v    | +12v | Orange    | OFF / Brake Condition (default)     |
| 1      | 0   | +12v    | GND  | Green     | Motor rotates in one direction      |
| 0      | 1   | GND     | +12v | Red       | Motor rotates in opposite direction |
| 1      | 1   | GND     | GND  | Off       | OFF / Brake Condition               |

Under certain circumstances, it is acceptable to power more than one device from a single Spike Relay Module. For instance, a single Relay Module might be used to power a combination of solenoid valves and/or fans in conjunction with a single window motor as long as their function is coincident. The Spike Relay module contains an on-board fuse rated at 20 amps. Still, it makes sense to limit the total load current through each Spike Relay Module, lest you risk failure of a Relay Module.

*Rules prohibit modification of parts and assemblies. Here is one exception:*

When a Spike Relay is controlling the Thomas Air Compressor, that 20A Spike Relay module on-board fuse may be substituted with a 20A circuit breaker. However, this Relay Module must still be fed from one 20A circuit breaker on the CB/Distribution panel.

When the PWM cable is attached to the Relay module, note that the black wire is placed onto the correct pin as noted on the module. The PMW cable must be then routed to the Robot Controller Relay I/O ports and connected per programming requirements.

**WARNING!**

*Attempting to drive a Van Door motor, Globe motors or Fisher-Price motors directly with the Spike Relay Modules could damage the Spike Relay Modules and is, therefore, prohibited.*

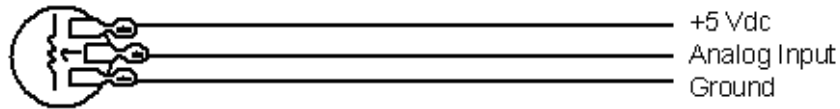
For more information about the Spike Relay Module, interconnections and programming details, refer to the *Spike Relay Users Manual* available on the Innovation First’s website at: <http://www.innovationfirst.com>.

**G.4.4 SENSORS**

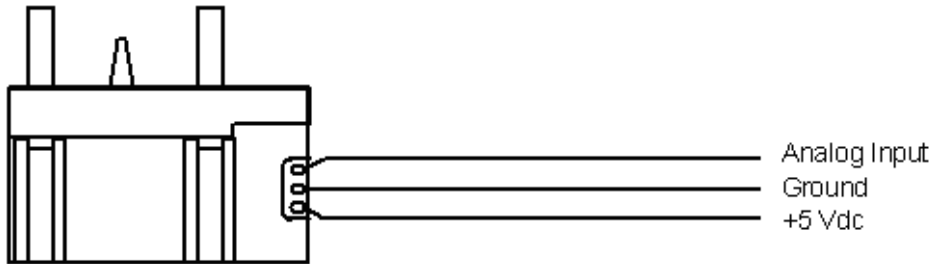
In general, the Robot Controller anticipates receiving inputs from sensors either in the form of contact closures (digital) such as those from a gear tooth sensor, or as 0-5V voltage levels (analog) at its input ports. In the case of analog signals, the Robot Controller supplies 5Vdc at 1 Amp for the analog inputs. As there are 7 input possibilities, each port should be limited to approximately 50ma. The input types, a combination of potentiometers, accelerometers, and gyro (yaw) rate sensors, should present high impedance to the analog input. All potentiometers must be 100KΩ.

## Analog Inputs

### Potentiometer

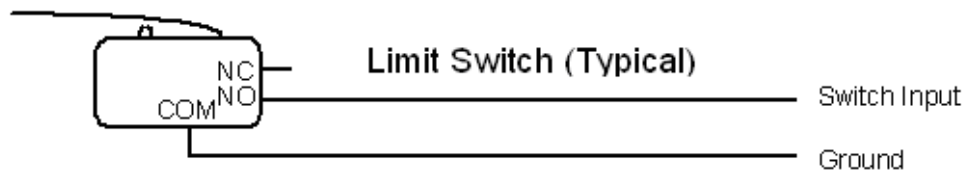


### Analog Sensor

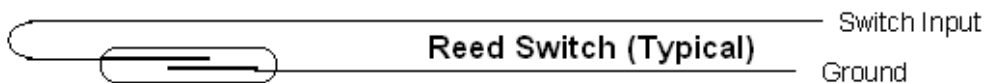


## Digital Inputs

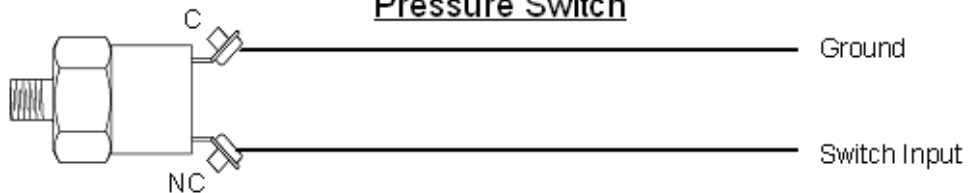
### Limit Switch (Typical)



### Reed Switch (Typical)



### Pressure Switch



The Figure above illustrates typical wiring configurations for connecting various analog sensors, switches and other devices to the **analog** or **digital** input terminals on the Robot Controller. Specific pin selections should conform to the Pin out and Software Function Schedules included in the Innovation First, Inc. 2005 *Robot Controller Reference Guide* at: <http://www.innovationfirst.com>.

### **WARNING!**

Do not connect switches to the +5v Output Pins of the Robot Controller. The +5v Output Pins are intended to supply a fused 5Vdc AUX power for use by analog sensors. Do not connect any other voltage to the analog inputs on the Robot Controller. It may damage the Robot Controller.

This year's Kit of Parts provides an interesting assortment of sensors and software tools to help teams develop a very competitive robot. In particular, the game relies on advanced robot control by vision system sensing and direction control of the robot platform. A good place to start is a discussion of the CMUCam2 and this year's vision system.

#### G.4.4.1 CMUcam2 Vision Sensor

This year's game heavily relies on a robust on-board CMUcam2 Vision Sensor (color-tracking camera) and programming to accomplish specific color tracking tasks during the game.

The CMUcam2 components supplied in the Electronic Kit include the CMUcam2 Lens Module, the Main Control PCB assembly, the TTL PCB, a pair of Hitec HS-322 Servomotors, and a **NEW ITEM**, a Pan/Tilt Bracket kit assembly for camera positioning control. The new hardware allows the camera to efficiently track a target and control the robot to maintain lock to the target. The key to realizing efficient tracking lies in skillful software programming of the control system. Here's where the fun begins.

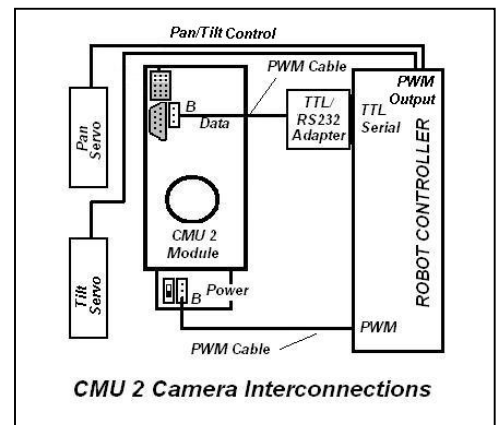


The 2006 kit continues to provide the **MPLAB Integrated Development Environment** software interface for text base programming in the ANSI C programming language and includes the MPLAB C18 compiler. New libraries for the sensors and camera are available to help programmers working in the IDE format.

However, an alternative this year is the development and use of a new GUI (graphical user interface) programming tool by intelitek for the 2006 FRC called “**easyC™ Robotics Design System**”. This GUI programming tool contains all the code for the new sensors in this year's kit and is available for download by 2006 *FIRST* teams following Kickoff.

An additional software from National Instruments, a graphic-based software called **NI LabVIEW 8** for testing, measurement, and control, is also provided in the kit. Sample applications are included with LabVIEW to analyze and calibrate the CMUcam2 Vision sensor, perform motor performance simulation testing, and a virtual instrument to process and display data from the Operator Interface dashboard. These softwares include significant advancements and a great head-start opportunity for teams in getting ready for competitions.

The *FIRST* website offers downloads for Vision system set-up. The [CMUCam2 Setup and Initialization](#) guide provides essential configuration, setup, and operational information to get the basic camera feature going on your robot. This document is also included in the [2006 CMUCam2 Workbook](#) and in a package of documents and programming code for the Vision Sensor 2006 *FIRST* Robotics CMU Cam2 Vision Documents on the *FIRST* website at [http://www.usfirst.org/robotics/doc\\_updt.htm](http://www.usfirst.org/robotics/doc_updt.htm).

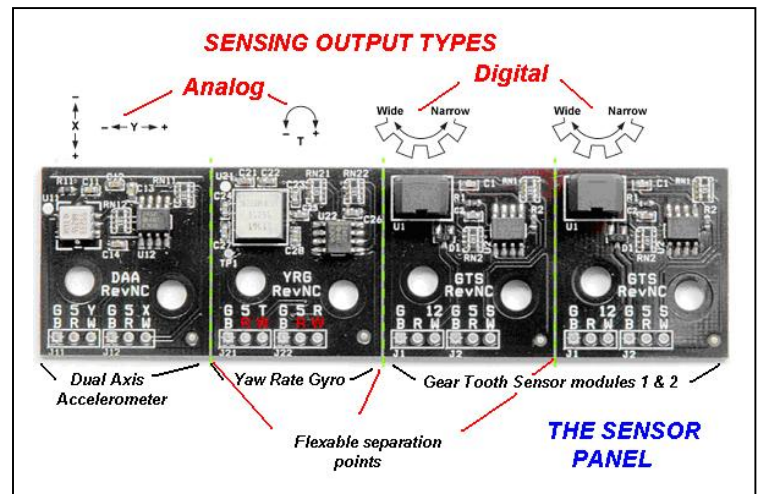


The general camera interconnection diagram (shown here) gives the PWM cable interconnections made from the camera PCB to the Controller. Teams should download the Vision System documents for the detailed assembly, interconnection, and diagram information.

The camera assembly receives DC power from the Robot Controller 7.2V back-up battery via PWM cable interfacing. The Robot Controller receives the CMUcam2 signals via the TTL-232 Converter PCB plugged into the RC TTL Serial port. The RC unit sends control signals to the Pan/Tilt servos as necessary to aim the camera to the target.

#### G.4.4.2 The Sensor Panel

In the kit this year you will receive a Sensor panel containing four new sensor modules for use in the 2006 game. One sensor module is a Dual Axis Accelerometer (DAA) provided by Analog Devices and is described below in section 1.3.4.3. Another item is Yaw (angular) Rate (YRG) sensor also from Analog Devices, and two Gear Tooth (GTS) sensors from Allegro Microsystems pre-packaged onto a PCB interface module for your convenience.



The individual PCB modules are scored and are separated from the panel by gripping the PCBs between your fingers and apply a gentle rocking motion to break apart the PCBs at the serrated edges. The PCBs are mounted using the hardware kit from the kit. Note that plastic washers are used to isolate the PCB from chassis.

Analog values can be with the User Processor's A/D inputs. Use the GET\_Analog\_Value routine found in ifi\_utilities.c. The results will range from 0 (0 volts) to 1023 (5.0 volts).

#### G.4.4.3 Gear Tooth Sensor

The ATS651 Hall-Effect IC is used for detecting and counting magnetic fields from ferrous gear teeth related to a robot's drive operations. An example will be counting teeth on a gear to measure speed and direction traveled. The device output is a PWM digital signal at a nominal 45µs pulse period for forward or clockwise rotation out of the "S" port and 90µs for counter clockwise or reverse rotation at the sense "S" output port. This speed and direction sensor is self-calibrating, adept at handling vibration, and is immune from air gap variations.



As seen in the figure above, two PWM cables are needed to interconnect the module. One cable is used to supply 12Vdc from the sensor distribution circuit breaker. The other PWM cable connects to an available digital input on the Robot controller to deliver the sensed pulse counts from the "S" port and receive +5V from the RC unit. "G" is always the ground connection

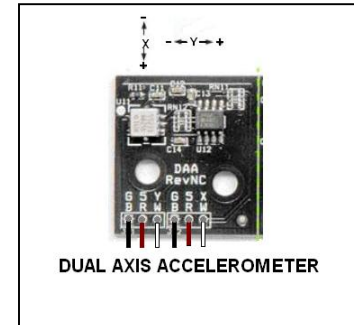
A complete technical data sheet is available for download for the *Gear Tooth Sensor* on the *FIRST* web site Specifications documents.

Just a note here that you should make it a check-off item and a standard practice to periodically inspect and clear the Hall-Effect sensor of any ferrous debris particularly following fabrication and mounting of the sensor assembly, periodically prior to robot testing, and/or before a competition.

Pre-drilled mounting holes for the Gear Tooth sensor module on the transmission covers, and using the GTS hardware supplied in the kit of parts will make installation particularly easy.

#### **G.4.4.3.1 Accelerometer**

Another new and very useful sensor in the kit this year is a rugged Dual Axis Accelerometer provided by Analog Devices (P/N ADXL311). The Accelerometer measures both dynamic motion (vibration) and static motion (gravity) so it's ideal for tilt (or orientation) and motion sensing measurements. The device provides high-resolution measurements along an X and Y oriented axis. The output signals are analog voltages proportional to the sensed level of acceleration both positive and negative at a magnitude up to +/- 2g for each axis.



The Accelerometer is most sensitive to “tilt” when its sensitive axis is parallel to the earth’s surface (or perpendicular to the Earth’s gravity field). For example, in this orientation the output changes nearly 17.5 mg per degree of tilt up to an angle of 45° where the resolution declines to 12.2 mg per degree. The accelerometer module is powered from 5VDC via two PWM cables.

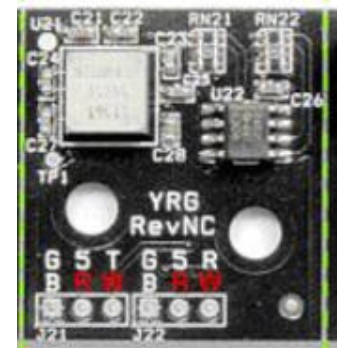
#### **HANDLE WITH CARE!**

Accelerometers are extremely sensitive to rough handling. Simply dropping the module on the floor could generate several thousands g of acceleration, exceed the absolute maximum limits of the device, and possibly destroy the device.

#### **G.4.4.3.2 Yaw Rate Gyro**

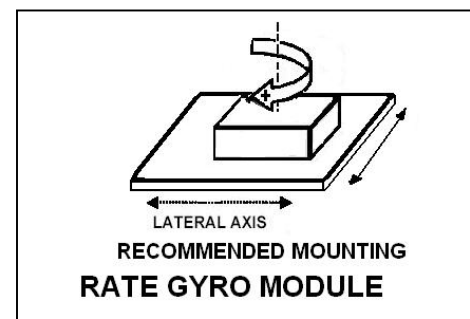
The Yaw Rate Gyro senses angular changes and provides an output voltage proportional to the angular rate change about the top surface axis of the device. The output is useful for guidance, stability and control of the robot platform.

One thing to keep in mind as you are laying things out on the robot and using the Yaw rate Gyro sensor module is that the lowest apparent drift on the gyro will occur when the module is mounted flat in or near the center axis of the robots rotation. The figure below indicates the rate change increase for clockwise rotation.



When mounting the YRG module, use nylon washers to isolate the PCB from the chassis.

Use two PWM cables to connect from the module BRW terminals to the Robot Controller analog inputs. The color code for the cable is shown on the figure above with “black” on the left, “white” on the right, and red in the center. The Yaw Rate gyro receives 5V from the RC and connects to two of the Robot Controllers Analog inputs.





The “T” output is a measure of twist or rotational acceleration. The “T” output will increase with clockwise rotation. “No rotation” at the “T” output produces 2.5Volts. Accelerating cw produces a voltage above the 2.5 V. The “T” output varies at approximately 12.5 millivolts per degree per second.

The “R” output is a measure of relative temperature. The “R” output varies by 8.4 millivolts per degree Kelvin. A temperature of 298K (about 25°C) will give an analog value of 2.5V. A cooler temperature provides lower voltage at “R”

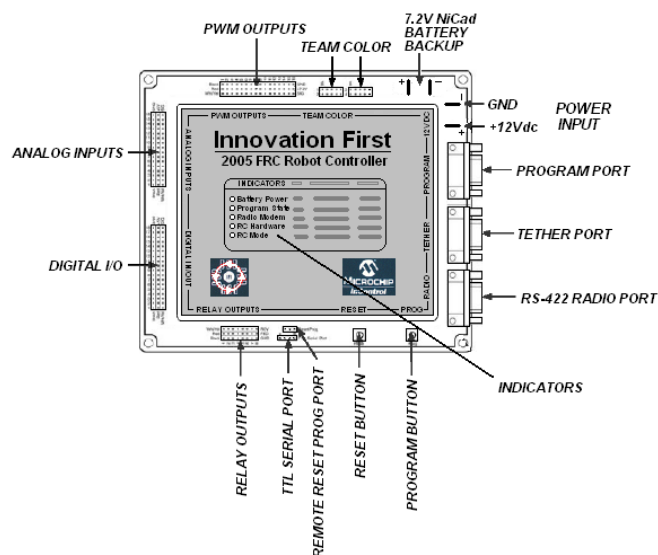
### G.4.4.3 Custom Circuitry

It is not possible for *FIRST* to test all custom circuits other than as specified in the Rules. So, we rely on all teams to use Gracious Professionalism (and good engineering) when building and implementing custom circuits in their design.

Please read the CONTROL SYSTEM documentation from Innovation First for information on the robot controller sensor inputs. Support by *FIRST* and Innovation First for ADDITIONAL ELECTRONICS and custom circuits is limited to the documentation provided in your kit and that found on the Innovation First website.

### G.4.5 THE ROBOT CONTROLLER

The Robot Controller (RC) typically gathers and organizes information from the Operator Interface Unit and from the connected on-board sensors, determines the action or functions the Robot should be performing, and operates the necessary actuators to perform the required work. The Controller also sends essential performance data to the Operator Interface to alert the operators of the robot performance status and issues and to aid operators in deciding tactical operations.



The RC provides a group of 5 LED indicators on its front panel to indicate the status of battery power, program run, radio modem communication, RC Hardware operation, and the current RC Mode (enabled/autonomous/ or disabled).

As you can see, the RC provides a number of interconnection possibilities around the perimeter of the module. It is a high probability that most of these ports and controls will be in use on your robot. The objective of this section is to familiarize the reader with the general interconnections and useful considerations for installing and interconnecting the RC to the actuator devices and sensors on-board the Robot. For specific interconnection details, refer to the *2005 Robot Controller Reference Guide* at: <http://www.innovationfirst.com>.

#### G.4.5.1 Locating the Controller

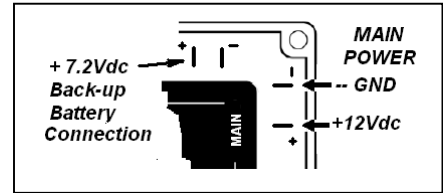
The first thing to remember is that the Rules specifies that the RC must be mounted on the Robot in such a way that the LED indicators on the front panel are clearly visible. In addition, easy access to the Tether connection and to the Reset Button should be provided since frequent use of these



facilities is certain. Frequently the RC is located under a protective acrylic panel. In deciding the location, also consider the routing of the various PWM cables and sensor cables. Keep in mind that these cables should be kept somewhat isolated from the motor & solenoid power cabling and harnessed together to reach the RC via an efficient route. Determining that pathway might be helpful in siting the RC unit.

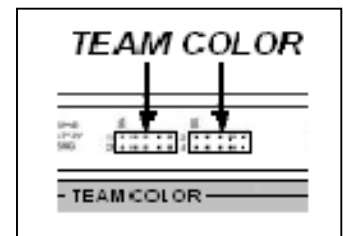
#### G.4.5.2 Power Input Connections

As a reminder, the Robot Controller power wiring must come directly from the CB/Distribution panel via an independent 20 Amp circuit breaker. The wires must be a minimum of 18 AWG and the conventional color-coding of wires must be used for wire pair as stated in Rule 60. Use slip on terminals to complete the interconnections at the location shown in the diagram.



#### G.4.5.3 Robot Team Lights

When the light is mounted on the robot, the PWM cables are to be routed to the RC unit and connected to the Team Color plugs as shown in the figure. Note the location of the “B” stamped on the RC and be sure to plug each cable with the Black wire at the end of the plug nearest the “B”. Be sure to properly secure the PWM cable harness to the robot framework to protect the wires from potential damage or disconnection.



The lights will blink at power on to confirm electrical connections are valid.

#### G.4.5.4 7.2V Back-up Battery

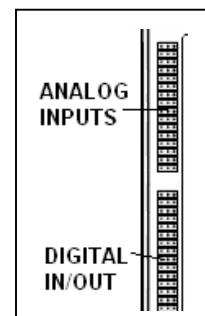
The 7.2V NiCad battery, connecting cable with plug, and a 7.2V charger module are provided in the KOP again this year. The battery must be connected to the RC at the 7.2V NiCad Battery connection (shown on the power input diagram above). The 7.2V battery does provide backup electrical power to the RC during low input voltage conditions that can occur in the robot’s 12V Main power circuit. However, it also is the source of power for the new CMU Vision Sensor as well as servos connected to the PWM outputs of the RC.

The team should plan on buying extra 7.2V NiCad back-up batteries so a fully charged battery will always be available when required for competition. You may use a larger capacity 7.2V Battery in place of the battery provided in the kit. For information about the 7.2V NiCad Battery specifications, please refer to Innovation First’s Control System documentation on their website at:

<http://www.innovationfirst.com>.

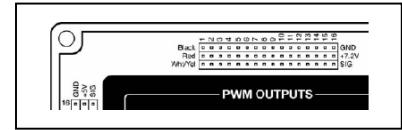
#### G.4.5.5 Digital and Analog Inputs

The Controller provides 16 Digital and 7 Analog Input ports for connecting to various sensors. Digital inputs are provided by switch open/closures. The analog input ports are used to receive inputs from analog sensors and potentiometers of a voltage that ranges from 0 to 5V relative to some position or event of the Robots’ mechanisms. User software code programmed to the RC will set the intended output action for all sensor inputs.



#### G.4.5.6 PWM Output Ports

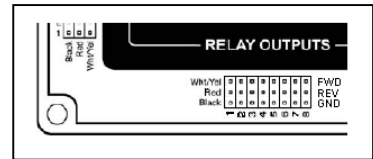
On the Output side, the Controller is fitted with 16 PWM outputs ports used primarily to control Victor 884 Speed Controllers. The PWM signals are derived from joystick operations at the Operator Interface unit (OI). The variable Pulse Width Modulation signals activate the Victor to turn drive motors OFF/ON, enable forward or reverse modes, and operate motors at variable speeds.



The PWM ports supply 7.2V to the CMU2 Vision sensor, miscellaneous servos and to the Victor devices.

#### G.4.5.7 Relay Outputs

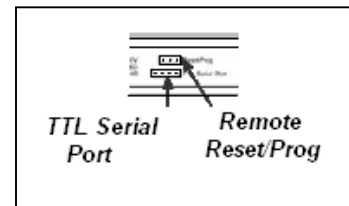
The Relay outputs are also used to control Spike Relay modules, which operate various small motors in OFF/ON and forward/reverse modes. Spike Relay modules also operate the Air Compressor and pneumatic solenoids.



The Relay output connection block is the termination point for the PWM cables from the Spike relays. The RC User or Custom program will set the Spike relay operations as determined by operator control of joysticks or switching inputs, or as is determined by on-board robot sensor inputs to the RC processor.

#### G.4.5.8 TTL Serial Port

The Serial port enables the receipt of RS-232 serial data into the RC unit. This port is used to input the RS-232 data from the CMU camera via the TTL to RS232 Converter interface PCB assembly. This connection is described in the “Start Here” Vision Sensor Guide which is part of the CMUcam2 Zip file at <http://www.InnovationFirst.com>.



#### G.4.5.9 Reset/Prog

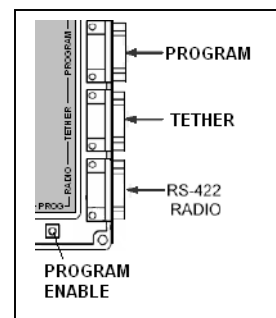
This connection can be used in place of the on-board buttons to input a switch closure for performing a remote RC Reset or to enable the RC to accept programming downloads from a PC.

#### G.4.5.10 Reset Button

The Reset button should be pressed at each power-on to perform a complete hardware reset of the RC and restart the RC processors. A Reset also causes the external radio to go into a channel “search” mode.

#### G.4.5.11 Program Button

The PROG button is intended to stop the User program from executing and to await a download from a PC. The button is necessary when programming via some PC Serial ports. When activated, a solid yellow light appears at the “program state” LED.



#### G.4.5.12 Radio Modem

This connection accepts the plug of the 6 foot DB9 cable which interconnects the external RS-422 Radio to the RC unit. Generally the radio is the last item mounted on the robot. It should be mounted in the vertical position securely. Excess interconnecting DB9 cable should be coiled and secured in

an isolated area of the robot frame away from other cabling to prevent pick-up of cross-talk interference. It is strongly suggested to use only the supplied cable to maintain shield and signal integrity.

#### G.4.5.13 Tether

This plug allows the Operator Interface (OI) to be plugged directly into the RC for communication and control testing. When Tether is used, power for the OI is supplied from the RC 12Vdc supply. Radio modem communication is not required nor enabled in the tether mode.

It is strongly suggested to NOT leave a pigtail on the Tether connector during competition as picked up interference could change robot operation.

#### G.4.5.14 Program

The Program Port is primarily used to enter new user code into the RC unit. Initially the RC contains a default program, which is sufficient to provide basic robot operations. This code can be replaced with a custom program created by the team following Innovation First guidelines. The Program port may also be used as the second serial input port for the RC to monitor the CB/Distribution panel operation, or to support custom circuitry.

It is strongly suggested to NOT leave a pigtail on the Program connector during competition as picked up interference could change robot operation.

#### G.4.5.15 “Stuck” Robot Controllers

Some teams have seen the following symptoms, which appear as if their Full-size Robot Controller is "stuck" following a USER program download.

Cause: The problem appears to occur when a PC corrupts the serial port timing. USB-serial converters are more susceptible. If this problem continues to re-occur, try downloading the User code from another PC.

Identifying Problem: The "Battery Power" LED blinks green, the "Program State" LED is solid yellow, and all others are dark. Resetting the RC does not clear it. Code will download, but it will not run. Your RC will not link to an OI.

Solution: Follow the procedure below with power applied to reset the RC unit from this “stuck” state:

1. Press and hold the **RESET** and **PROG** buttons at the same time.
2. Release **RESET**; continue to hold **PROG** until the "Battery Power" light becomes a solid green.
3. Release **PROG**.
4. Hit **RESET**.

You should be operational again and able to link with an OI. You may now download new User code if required.

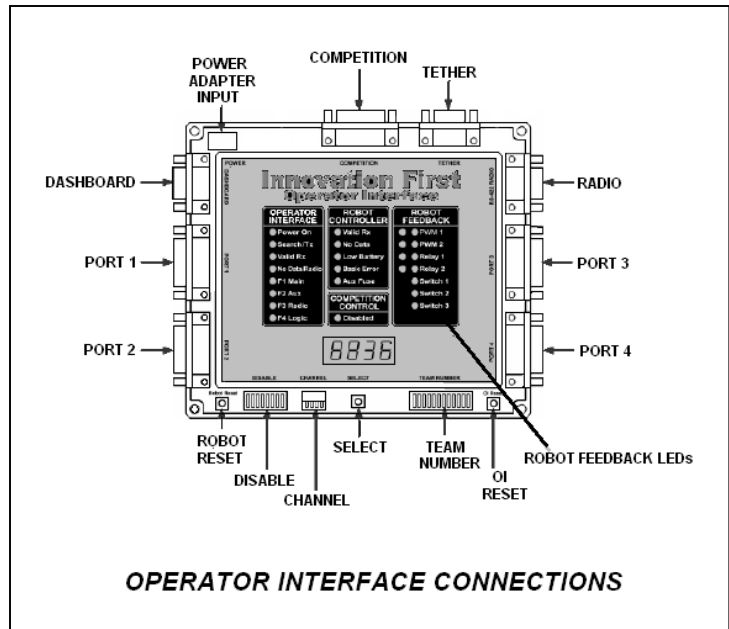
### G.4.6 OPERATOR INTERFACE

The Operator Interface is intended to communicate via two-way radio modem to a remote Robot Controller. The input from joysticks, buttons, custom control boxes, or any other input device at the Operator interface is communicated to the robot to control its operation. Feedback from the robot is relayed to the OI and monitored at the operator station.

The exact wiring configuration for the joysticks, switches, potentiometers, LEDs, and analog sensors connected to the Operator Interface is not specified here, but can be found in the *FR 2005 Operator Interface Reference Guide* at: <http://www.innovationfirst.com>

Teams may wire these devices, within the rules as described below and according to the documentation supplied by Innovation First, in order to create a custom interface for the robot operators. Note that sensor load limits may apply when several devices are to be connected to the OI unit.

Although not a requirement, it is suggested that teams use a project box as a housing for the switches, potentiometers, LEDs, and sensors. When using a project box, wire all components to the 15-pin male connector(s), mount the connector(s) onto the project box, and use the 15-pin molded cable(s) to make the connection(s) to the Operator Interface.



The LEDs may be connected between +5Vdc and Ground or between an LED output and Ground to serve as a visual indicator to the robot operators. This can be helpful during a competition match when a robot operator may not have a good view of the Operator Interface.

### CAUTION

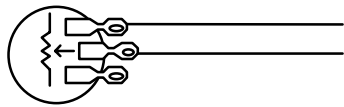
Connect switches between a Digital I/O Signal and Ground. Do not use lighted switches with the Operator Interface unless the switch light circuit is disabled.

### WARNING!

*Do not connect switches to the +5Vdc fused Aux Pin (Pin 1) of the Input Ports of the Operator Interface. It may damage the switches. Pin 1 is intended to supply fused 5Vdc power for use by analog sensors and Potentiometers.*

Any analog sensor must be connected to +5 Vdc Aux, Ground, and an analog input. Potentiometers must be connected to +5 Vdc Aux and an analog input. All potentiometers should be 100KΩ. Due to the special nature of the analog inputs on the Operator Interface, connecting potentiometers to Ground is optional but *not required*. See the Innovation First documentation for more information. Figure 5.3 shows an example of the proper way to connect a switch, potentiometer, LED, and yaw rate sensor to the **Operator Interface**. Port and Pin designations shown in Figure 5.3 are merely examples and will vary depending on the number of devices connected.

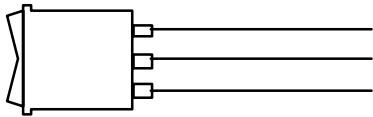
### Potentiometer



### Port 3

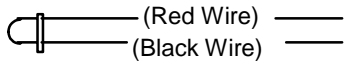
Pin 1 (+5 Vdc)  
Pin 3 (Port 3 X-Axis)

### Rocker Switch (Typical)



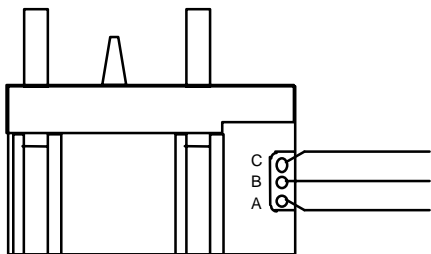
Pin 10 (Port 3 Aux Switch Input 1)  
Pin 4 (Ground)  
Pin 14 (Port 3 Aux Switch Input 2)

### LED (any color)



Pin 15 (Feedback LED - Relay1 Green Output)  
Pin 12 (Ground)

### Yaw Rate Sensor



Pin 11 (Port 3 Aux Analog)  
Pin 4 (Ground)  
Pin 1 (+5 Vdc)

**Figure 5.3: Connection Examples for Operator Interface**

#### G.4.6.1 General Hookup & Powering

There are three ways that the Operator Interface unit may be powered up. They are:

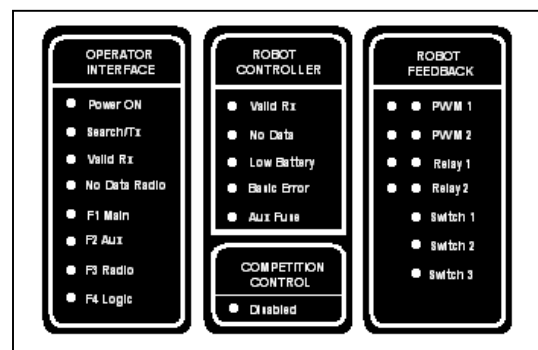
- Using the supplied AC Adapter.
- By a Tether connection directly to the Robot Controller
- Via the Competition port

The AC Adapter provides the correct output voltage and current to operate the Operator Interface unit from the 115Vac 60Hz power available. When tethered, the robot battery will provide the system power. When competing in the practice, qualification, or elimination rounds of a competition, the Competition port provides the control power.

Other connections to the OI typically include a pair of joysticks.

#### G.4.6.2 LEDs & Displays

The Operator Interface features a highly visible indication system for system integrity and to alert the operator of system malfunction. Typically, the operator views the Power ON and “Valid Rx” LED indicators between the robot and the OI. In the event of a failure such as the loss of communication data, a low battery level, detected data errors, or a blown fuse, steady or blinking LED lights will warn the operator.



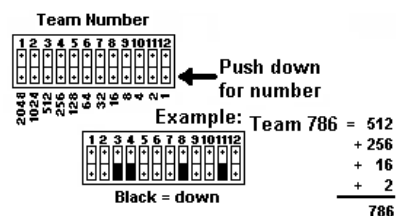
The Competition Control Disable LED indicates one of three states will exist when illuminated: Disabled, Autonomous, and Enabled. If the LED is ON solid it indicates that the robot controller PWM and relay outputs are in the “disabled” mode and the robot is “dead” This occurs at the start of a match or when the robot has been disabled by an E-stop in a match for protection. When the LED is blinking, it is indicating that “Autonomous” mode is active, and the robot is under the control of the Autonomous programming. If the LED is “OFF”, then the robot is in the “Enabled” mode and is under driver control.

#### G.4.6.3 Team Number

The team number is a most important entry made directly on the Operator Interface. The Team Number DIP switch is used to set the binary value of the team number by closing selected switches along the 12- position switch assembly.

|                |      |
|----------------|------|
| Team Number    | 0000 |
| Channel Number | c40  |
| Robot Voltage  | 12.3 |
| User Mode      | u000 |

Step 1 is to press the **SELECT** button to sequence the readouts to display the row of “0000” (4-digit readouts intended for the team number). When “0000” is displayed, enter the team number by pressing down the highest binary- numbered switch less than the team number. Calculate the difference and close the switch less than the difference value. Continue until you have the correct team number displayed on the readouts.



Attach the tether cable to the RC unit to download the new team number information to the robot. The RC unit will store the number to EEROM memory.

#### G.4.6.4 Dashboard Port

The Dashboard Port may be used to provide output information from the Operator Interface to a PC. The data may be the data sent from the robot or the data sent from the OI out to the robot. Innovation First offers a Windows™ compatible Dashboard Viewer software program for use in viewing the data by a PC. The data type is selected by moving a jumper on the OI between OI and RC.

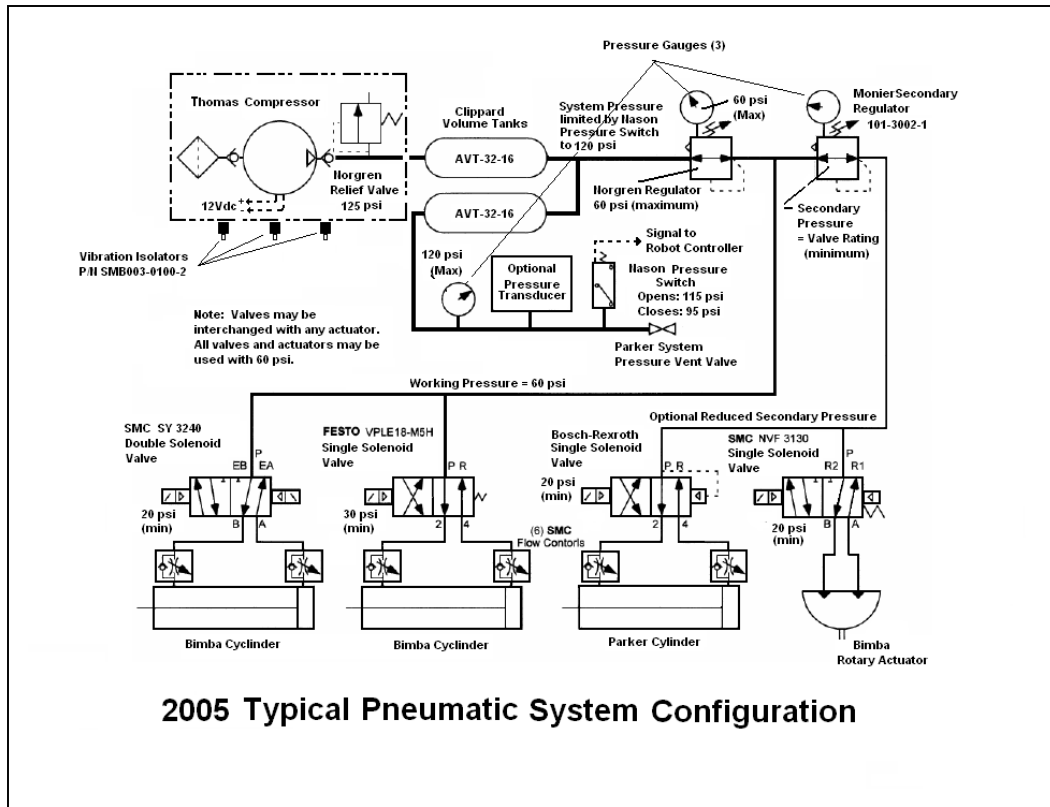
Teams assume all risk associated with use of this program and/or data collected from the Dashboard port. For more information, consult the Innovation First website at: <http://www.innovationfirst.com>

## G.5 ROBOT PNEUMATICS

This pneumatics section is intended to give introductory information on how a pneumatics system could be useful in operating various mechanisms on your robot. The *FIRST* Pneumatic Manual, available at <http://www.usfirst.org/> provides general information about installing pneumatic components. The manual also includes information about the ordering process for additional air cylinders and actuators.



The figure below shows a diagram of a typical Pneumatics System that may be configured from pneumatic components supplied in the *FIRST KOP*. This system converts electrical energy into highly pressurized air (pneumatic energy) via a compressor, which is stored in Air Volume tanks.



Whenever the robot controller programming requires air energy, it is delivered via the high-pressure tubing to a selected solenoid-controlled valve to operate a cylinder to perform work for the robot.

### G.5.1 COMPONENT DEFINITIONS

**Thomas Compressor** - The Compressor operates from the 12Vdc battery and, when turned ON/OFF by the controller signals, will charge the Clippard Air volume tanks to 120psi.

**Norgren Relief valve** - Limits the Compressor output to 125psi.

**Vibration Isolators** - are provided in the kit to shock-mount the Compressor, which, during air charging, will vibrate significantly.

**Clippard Tanks** – Two tanks are provided in the KOP and may be used to store and provide a steady volume of 120psi compressed air to downstream regulators and actuators.

**Nason Pressure Switch** - Monitors the stored air pressure. The Pressure switch sends signals to the controller to start and stop the compressor to maintain the pressure.

**Wika Pressure Gauges** – Located on each regulator and on the High-pressure line, pressure gauges are required to be installed in your pneumatic system to display the 60psi (working) and the 120psi (storage) pressures. The third gauge showing the secondary regulator “psi” value is not required, but recommended.

**Optional Pressure Transducer** – Sensor outputs voltage proportional to air pressure to report air pressure status to custom circuitry.

**Parker Vent Valve** – The Vent valve is a **required safety component** used to bleed all air pressure from the air storage tanks whenever the system is not in use.

**Norgren Regulator Valve** – The Norgren Regulator valve **is a required component** that must be mounted in line directly after the storage tanks and is adjustable to limit the “working” air pressure of the system to a maximum of 60psi.

**Monier Secondary Regulator** – The secondary regulator is located after the Norgen 60psi Regulator connection and allows for a lower pressure pneumatic leg if needed.

**Solenoid Valves** – The solenoid valves electrically control the position of mechanical valves to steer air into the cylinders and drive or retract the cylinders in the desired direction. In the KOP four valves are “single” solenoid operated. When these solenoids are not energized, the solenoid is spring actuated to set the valve rod to retract the cylinder. When the solenoid is operated, the valve rod will be electromagnetically driven to change the airflow port direction. The air will then drive the cylinder into its extended position until the solenoid is de-energized. Then spring pressure resets the valve rod to vent the air and retract the cylinder.

In the figure above, all solenoids are shown in the de-energized state. The arrows indicate the direction of airflow from the P (pressure) line to R (return). When energized, the arrows are shifted to the right and the airflow will now be supplied in reverse direction to the cylinder. Two SMC “12V Double” solenoids are provided. A “Double” solenoid has a pilot solenoid coil on each end of the spool assembly. By pulsing one coil and/or the other, you can control the air direction and, as a result, the amount of extension or retraction of the cylinder at will. When power is removed, the cylinder remains in a fixed position until the manual overrides are activated to release air pressures.

**BEST BET:** *On a double solenoid, energize only one solenoid at a time!*

**Air Cylinders & Actuators** - The Pneumatic System drawing shows linear air cylinders and a rotary actuator that could be used. To help in getting started, a Parker 1.5” x 8” cylinder is supplied in the KOP. You can order up to three more (cylinder/rotary actuator) devices supplied free using the order form in the *FIRST Pneumatic Manual*. Besides free components, you may use additional solenoid valves and air cylinders or rotary actuators. However, they must be identical to those listed on the Pneumatic Components Order form, and obtained from a Bimba or Parker Hannifan distributor.

**NOTE:**

Bimba Magnetic Reed switches cannot be used with a Parker cylinder since it is not magnetic.

**Flow Control Valves** - Above each end of the linear air cylinders, is the Graphic symbol for a Flow Control valve. These adjustable valves (mounted on or as close to the cylinder as practical) permit free airflow from a solenoid valve to a cylinder, but control the exhaust airflow rate from the cylinder, thus slowing its mechanical action in returning to the relaxed state.

## G.5.2 PNEUMATIC ELECTRICAL DISTRIBUTION

The figure below shows a simple electrical connection diagram of the power, sense, and PWM control wiring of the pneumatic actuator components. In reality, more pneumatic components may be used in your system, but they will essentially conform to the connections as depicted below and according to the electrical distribution drawing included at the end of this section.

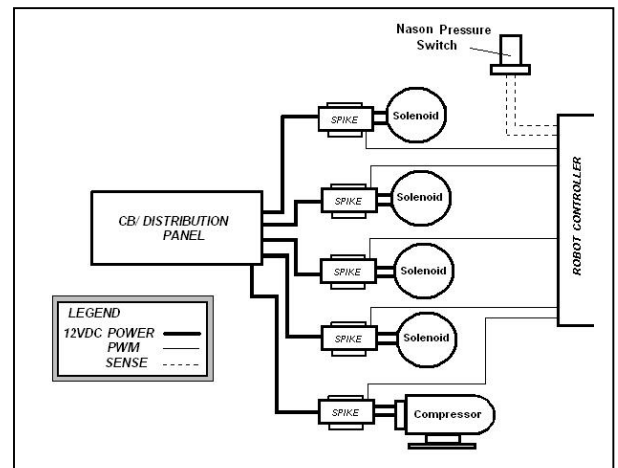
### G.5.2.1 Tips on Assembly

1. **Air Compressor** - Be sure the Air Compressor receives 12Vdc power from its own Spike Relay. We recommend the Spike Relay be operated from a 20-amp Snap-Action circuit breaker.
2. **Nason Pressure switch** - The Nason Pressure switch must be wired via a PWM type cable directly back to the Robot Controller digital input port. The Robot Controller, when programmed, controls the ON/OFF switching of the Compressor Spike Relay.  
Do not wire the Pressure Switch in series with the compressor power lines. Even if the Relay could be operated this way, the switch cannot handle the starting current of the Compressor.

3. **Teflon Tape & Fittings**- all threads on male fittings require Teflon tape to seal properly. Start by wrapping the tape around the fitting leaving the first two threads bare and in the direction of the threads. This is because the fittings are tapered, and should the tape become loose at assembly, it will not block the valve opening.

4. **Tubing** – One thing will become apparent. Tubing that is too short will likely make an unreliable connection. Allow for flexible bends in the tubing as necessary.

Cut tubing with clean perpendicular cuts. Slide tubing fully into the Quick Connect fittings. Press down on the Release Ring to remove the tubing if necessary.



5. **Cylinder** – Assure the load on the cylinder is connected before operating the device.
6. **Leaks** – Once the pneumatic connections and electrical interconnections have been made, the system should be tested for charging air to the pressure values assigned by the Rules for the primary and secondary legs of the system. Close the Norgren Relief valve. Run the Thomas compressor to the 120-psi pressure. At 125 psi the compressor should shut down. The Regulators should then be adjusted as necessary to the 120 psi and 60 psi values permitted. The system pressure should remain intact until a solenoid has been activated. If the pressure is deteriorating without any solenoid operations, the system must be checked for leaks and the faulty coupling repaired, usually by fixing the Teflon tape seal. Open the Norgren relief valve and confirm the system pressure decays to 0 psi before disconnecting any couplings to effect repairs.

When the system pressure test is completed, release any stored air pressure by opening the Norgren relief valve, observing the system pressure decays to 0 psi.

### G.5.2.2 Double Solenoid Wiring Tip

One way to use only *one* Spike Relay Module and avoid running separate power return leads to achieve control of both solenoids on a double solenoid valve is shown below. You can use two diodes (max: 1A, 50V; peak rev.) to steer power to one solenoid at a time. Figure 5.1 shows the schematic for this arrangement.

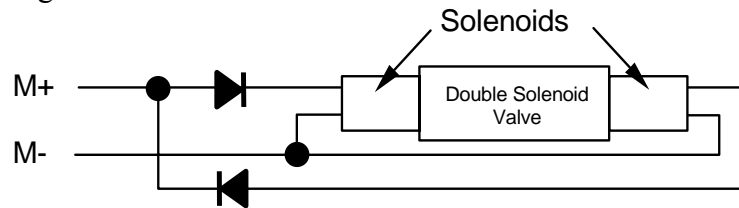


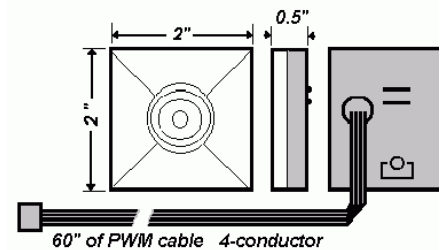
Figure 1.1 Use of Diodes with Double Solenoid Valve

## G.6 THE FINAL TOUCH

### G.6.1 TEAM LIGHT

This year each team will receive 1 Hi-Intensity LED Team Color light cluster. The team will be responsible to install the light prior to robot inspection onto their robot. To help plan and reserve space, this drawing shows the dimensions for this light cluster.

The LED light is supplied with a four-wire PWM type cable at a length of approximately 5 feet. The light needs to be mounted forward on the robot such that the light can readily be seen by field personnel in the Robot's starting position.



Hi-Intensity LED Clusters

There is no direct method of attachment on the module so the best means to do this will be at the discretion of the team. Usually some industrial-grade adhesive backed Velcro is used for this purpose. The PWM cables are hard-wired at the lights and plug into the Team Light jacks on the RC. The excess PWM cabling needs to be secured into a harness and anchored to the chassis.

The LED provides status indication to the field and will blink the Red/Blue colors alternately when the robot is powered up. This will verify the operation. When the OI is connected, the lights will blink twice slowly at the default color when enabled. The light status cannot be controlled by the Operator Interface.

### G.6.2 ONE LAST LOOK

This paragraph is intended to have the team focus on the Game Rules that apply to the anticipated interactive contact in the competitions and to take a last look at their robot. The rules are very specific on the type of strategies that will not be allowed.

One area to check and address now is if your robot has by its design loose cables, hoses, cordage, netting or fabric, etc. that can be entangled or could entangle with other robots in a competition. Robots, so designed, become subject to disqualification in a match and will require repairs before continuing in the competition.

Also recall that arms or mechanisms that protrude from the robot such as forklifts, lifting arms, grapplers, etc. must not pose as a hazard for team members or event staff in that they can impale or puncture personnel or field equipment. No Wedge-type front ends allowed, and "nothing" taller than 60 inches other than the alliance flag.