5 THE ROBOT

[This section includes all modifications through Team Update 14]

5.1 OVERVIEW

This section of the 2004 FIRST Robotics Competition Manual provides rules and requirements for the design and construction of the Robot.

This section also includes tips and guidelines for design and construction of some aspects of the Robot.

5.1.1 Other Important Documents

In addition to this section, there are other documents you should review before proceeding with the robot design process:

- *The Arena* and *The Game* sections of this manual
- *Shipping Deadlines* listed in the *Robot Transportation* section of this manual
- Instruction manuals for the *Robot Controller*, *Spike Relay modules*, and *Victor 884 Speed Controllers* which are provided by their manufacturer, Innovation First, Inc., and are available at: http://www.innovationfirst.com/firstrobotics/

  Note: On February 24, 2004 updates to the default user code and an upgrade to the firmware inside the Robot Controller (FRC_Master_Upgrade_V6) were released. These updates are optional but encouraged. For detailed information please visit http://www.innovationfirst.com/FIRSTrobotics/documentation.htm
- Information about the pneumatic components and ordering process are included in the 2004 FIRST Pneumatic Manual available at http://www.usfirst.org/

5.1.2 What is a FIRST Robot?

A FIRST robot is a remotely operated vehicle designed and built by a FIRST student Robotic Competition team to perform specific tasks when competing in "The Game." It is electrically powered by an on-board 12v battery, and utilizes various electrical, mechanical, and pneumatic systems in its operation. These systems employ sensors and feedback, and are controlled by a programmable on-board Robot Controller that communicates with the team's human operators via a two-way wireless modem. The robot may be operated in either an autonomous mode or under the direct control of its human operators via the wireless link.

The building of a robot involves the integration of several basic systems such as supporting structure, electrical, pneumatics, controls, etc. This section summarizes the electrical and pneumatic systems that are based on the parts provided in the Kit. Additional information about the Robot Controller, pneumatic devices, sensors, and other devices is also available in their respective manuals and specification sheets.

The minimum configuration that constitutes a FIRST Robot is 1) a structure; 2) a provided 12V battery, breaker, and fuses; 3) a provided Robot Controller and associated radio modem, 4) all four provided Team Color LEDs .

5.1.3 Safety

There are specific rules and limitations that apply to the design and construction of your robot. Most have been established to ensure that every FIRST robot has been designed in a safe manner. Please ensure that you are familiar with each of these safety rules before proceeding with robot design.

5.1.4 Getting Started

Before proceeding with your robot's actual design, there are several matters that teams should assess. The following are a few important points offered to help teams get started:

1. Evaluate The Game's physical challenges and identify those the robot will have to overcome.
   - Will it have to climb structures, pick and place items, push / pull goals, possess a low profile, extend its height, lift items, hang, etc.?
   - What are the game's implications regarding the robot's center of gravity?

- Are there unique field surface characteristics that you should consider when determining robot driving mechanism tread design?
- Are there any particular offensive / defensive capabilities the robot needs?

2. Review all items provided in the Kit of Parts and gain an understanding of their basic features. Note that there are also suppliers' data sheets for many of the components in the Kit.

3. Read all of The Robot section of this manual, and pay particular attention to the rules.

4. Look through the manuals provided for the Control System and pneumatic components.

5. Look over the specifications and technical notes provided for the various Kit components.

Note: Pay particular attention to the torque/speed/current draw characteristics of the Kit's motors. Poor motor performance or failure may occur if employed transmission gear/sprocket ratios are not properly chosen to allow motors to operate within their preferred torque/speed/current ranges.

6. Note all safety requirements relating to the robot's design.

- The locations and ratings of circuit breakers where indicated in the wiring diagrams
- Any mandatory wire size requirements
- Stored energy guidelines

5.2 ROBOT DESIGN AND CONSTRUCTION RULES

There are specific rules and limitations governing the design and construction of your robot. When reading the rules, use technical common sense (engineering thinking) rather than lawyer interpretation, and try to understand the reasoning behind a rule. **Any noncompliance with a robot design or construction rule must be rectified before a robot will be allowed to compete.**

5.2.1 Safety Rules

<R01> Energy used by FIRST Robotics Competition robots, i.e., stored at the start of a match, may come solely from:

- Electrical energy derived from the onboard 12V and 7.2V batteries
- Storage achieved by deformation of robot part
- Compressed air stored in the pneumatic system, but only supplied by the compressor included in the kit, and stored at a maximum pressure of 120 PSI only in the two Clippard Instruments tanks provided in the Kit
- A change in the altitude of the device's center of gravity

Teams must be very careful when incorporating springs or other items to store energy on their robot by means of part or material deformation**.** A robot may be rejected at inspection if, in the judgment of the inspector, such items are unsafe.

5.2.2 Robot Size Requirements

<R02> The ***maximum allowed size of the robot*** is 30 inches (76.20cm) wide by 36 inches (91.44cm) long by 60 inches (152.40cm) high.

<R03> The starting configuration of a robot immediately prior to being enabled by the Arena Controller at the beginning of a match is the basis upon which a robot will be inspected for compliance with the maximum allowed size. This configuration of the robot must fit within a FIRST Sizing Box that has the following inside surface dimensions: A flat, level rectangular base 30 inches x 36 inches, and a height of 60 inches. Other than resting on the floor of the Inspection Box, no part of the robot may touch the sides or top of the box during size inspection. The robot must be self-supporting while in the Sizing Box.

<R04> If a robot has been designed such that it may have more than one possible starting configuration, the largest possible configuration must be the one used during size inspection.

<R05> Once a match begins, robots may extend beyond the starting size under their own power. Any restraints (elastics bands, springs, etc.) that are used to maintain starting size must remain attached to the robot for the duration of the match.

5.2.3 NEW - Robot Weight Requirements

<R06> The maximum allowed weight **of all** robot configuration components combined is 130.0 pounds (58.97 kg). At the time of weigh in, the basic robot platform and any additional items that might be used in different configurations of the robot must be weighed together**.** Weight limit includes (one) 12V battery, control system, decorations, bumpers, and any other attached parts.

Example: A team has decided to design its robot such that, before any given match, it may quickly change the configuration of the robot based on perceived strengths or weaknesses of an opponent team's robot. The team accomplished this by constructing its robot as a basic drive train platform plus two versions of a ball gripper, each gripper being a quick attach / detach device such that either one or the other gripper may be part of the robot at the beginning of a match. Their robot's platform weighs 120 lb, version A of the gripper weighs 6 lb, and version B weighs 8 lb. Although only one version will be on the robot during a match, both must be on the weight scale along with the robot platform during weigh in. This would result in a ***rejection*** *of the robot because its total weight comes to 134 lb.*

5.2.4 Robot Visibility Requirements

<R07> *Robots must display their team number, sponsor and school names, and/or logos*. The judges, referees, and announcers must be able to easily identify robots by Team Number. Teams must display their Team Number in four locations at approximately 90-degree intervals around the side of the robot. ***The numerals must be at least 4 inches high, at least in 3/4 inch stroke width and in a contrasting color from its background***. *Team Numbers must be clearly visible from a distance of not less than 100 feet.*

<R08> Robots must use all four Team Color LEDs provided in the kit to display their alliance color (red or blue). Previous years rotating lights are not allowed. All four Team Color LEDs must be mounted on the robot such that their displayed color is visible over the entire 360 degree circle around the robot from a distance of at least 100 feet. Instructions for connecting the lights are provided in the Innovation First controller manual. The Robot Controller directly powers and controls the Team Color LEDs. The user has no control over the Team Color LEDs and no programming is required.

5.2.5 Design and Build Rules

<R09> Teams must fabricate and/or assemble all custom parts and assembled mechanisms on the robot by the 2004 team after the start of the Kick-off. Mechanisms from previous year's robots may not be used, however, individual off-the-shelf components from previous year's robots may be re-used to save the cost of re-purchase of these parts IF they meet ALL of the 2004 Additional Parts and Materials Rules.

- If you do use previous years' components, their costs must be included in the 2004 cost accounting, and applied to the overall cost limit.
- You may not use previous years' motors in addition to those provided in the 2004 Kit. You may use previous years' motors as direct replacements for those provided, however they must be the same identical motor as in the 2004 Kit. [Note that 2002 and 2003 Fisher-Price motors are not the same as those in the 2004 kit, and, therefore, **CANNOT** be used.]
- You may not use previous years Robot Controllers or Victor 883 Speed Controllers.
- ***During the six week period following Kickoff***: You may fabricate spare parts for replacement purposes of items on your robot as long as they are exact replacements for parts on the robot you shipped to the event. They must be brought to the event in a completely disassembled state as individual components (no bolt-on assemblies).
- ***At Events***: Teams are allowed to repair, modify or upgrade their competition robots while participating in a FRC event. They may do so only during the period starting with the opening of the Pit area on Thursday and ending at 4:00PM on Saturday. Work may be done on-site in the Pit or at any facility made available to all teams at the event, e.g., in a team's repair trailer or a local team's shop offered to all teams to use.

<R10> Teams are expected to design and build robots to withstand vigorous interaction with other robots. See The Game section of the manual.

<R11> Mechanisms or components that present an obvious risk of entanglement are not allowed.

<R12> No devices are permitted on the robot that will jam, or interfere with any sensors on competing robots. Teams shall not employ IR sources that could interfere with the IR beacons that are part of the 2004 playing field. FIRST will be monitoring the IR environment at all events with scanning devices to detect any attempted interference.

<R13> Robot wheels, tracks, and other parts intended to provide traction on the playing field ("traction devices") may be purchased or fabricated. In no case, will traction devices that damage the carpet or other playing surfaces be permitted. Traction devices may not have surface features such as metal, sandpaper, or hard plastic studs, cleats, or other attachments. Anchors, i.e. devices that are deployed/used to keep one's robot in one place and prevent if from being moved by another robot, cannot use metal in contact with the carpet or other playing surfaces to "stay put." Gaining traction by using adhesives or Velcro-like fastener material is not allowed.

<R14> Electrical tape may only be used as an electrical insulator. Velcro tape or double-sided sticky foam may be used for attaching components to the robot. Adhesive-backed cable mounts may be used. Small amounts of reflective tape may be used for counting wheel revolutions. Adhesive backed labels may be used for labeling purposes. No other adhesive backed tapes are allowed.

<R15> Lubricants may be used only to reduce friction within the robot. Lubricants shall not be allowed to contaminate the playing field surfaces, balls, or other robots.

<R16> Raw materials may be machined or fabricated into custom parts.

<R17> In order to help reduce the impact forces that the robot will experience during collisions with other robots, teams may add external "bumpers" to the robot. If used, bumpers must satisfy the following constraints:

- Bumpers may extend <u>outside</u> the normal robot starting dimensions (in the horizontal plane) up to 4." per side
- Bumpers <u>must</u> be located in a region from 2" to 8" above the playing field surface.
- Bumpers must not cause the weight of the robot to exceed the weight limit.
- Bumpers must be removable in order to allow the robot starting size to be easily measured during robot inspection.
- Bumpers must remain attached to the robot for the duration of the match.
- Bumpers and any bumper mounts that extend beyond the robot starting size *may not contain "hard" materials* such as metal, wood, or hard plastics. The definition of "hard" is one of common sense, i.e., if you can punch it and not hurt your bare hand, it is ok.
- Adhesive-backed tape may not be used to fasten bumpers.

5.2.6 Electrical System Requirements

<R18> The only legal main source of electrical energy on the robot is one of the two 12v DC non-spillable lead acid battery provided in the Kit of Parts, or a spare of the same part number. The 7.2v "backup" battery is considered an integral part of the Robot Controller, and may not be used for any other purpose. The **<u>only</u>** 12V batteries that can be used on your robot during **<u>competition</u>** (Friday and Saturday) this year are Exide models EX18-12 or ES18-12. (Additional ES19-12 units can be purchased through your local Exide supplier. The EX18-12 is not available through retail outlets.) You may use other <u>equivalent</u> batteries during Thursday practice rounds.

<R19> The 12v Battery may only be charged by a 6 Ampere rated battery charger between matches. When recharging Kit batteries, you may use the charger provided by FIRST or one with equivalent charging current.

<R20> The 12v battery must be wired directly to a quick connect / disconnect connector (provided in the kit) that in turn feeds power to the Main Power Disconnect Switch and Circuit Breaker Assembly.

- The breaker will automatically "trip" to the open state if a current in excess of its 120A rating passes through it for several seconds. It remains tripped until manually reset.
- The main disconnect switch is manually operated, and is used to totally shut down the robot's 12v electrical system. Then, the Robot Controller must be reset to shut down the 7.2v backup system.
- You must install the 120A circuit breaker in series with the positive terminal of the 12v battery such that all battery output flows through the breaker before being distributed to any electrical

component on the robot. The breaker must be readily accessible for inspection and testing at each FIRST Robotics Competition event.

<R21> Power from the main breaker must be fed to the Maxi-style breaker panel, and either or both of the two current distribution blocks that provide power to individual branch circuits on the robot, each protected by an automatically resetting circuit breaker.

<R22> All electrical devices must be isolated from the Robot Frame; the robot structure may not be used to carry electrical current. The negative (return) wiring must be electrically isolated (floating) from the robot's frame. (This isolated ground arrangement is necessary due to polarity reversals that occur under certain operating conditions such as during motor direction reversals.)

<R23> The Robot Controller must manage all electrical operation of the robot.

5.2.7 Control System Rules

<R24> The control system is provided to allow wireless control of the robots. The Operator Interface, Robot Controller, Servos, Speed Controllers, Relay Modules, Radio Modems, Batteries, Battery Charger, AC Adapter, 9-pin cables, Maxi-style power distribution block, ATC breaker panels, circuit breakers, and fuses may not be tampered with, modified or adjusted in any way, (Tampering includes drilling, cutting, machining, gluing, rewiring, etc.) with the following exceptions:

- The dip switches on the Operator Interface may be set as appropriate.
- The user programmable code in the Robot Controller may be customized.
- The Speed Controllers may be calibrated as described in owner's manuals.

<R25> You must design your Robot to be operated by the wireless, programmable Innovation First 2004 Robot Control System.

<R26> Teams are responsible for any software bugs introduced into the Robot Controller's control program when using a custom program or for any unwanted or unanticipated robot behavior when using additional electronics.

<R27> The Robot Controller must be positioned within the robot so that its indicator lights may be seen during inspection and during operation in a match. This will greatly facilitate analysis in case of problems.

<R28> All circuit breakers must be accessible for inspection at each FIRST Robotics Competition event.

<R29> The terminals on the 12v battery must be insulated with electrical tape to reduce the risk of short circuits.

<R30> The team number settings on the Operator Interface must be set to the team number assigned to the team by FIRST, then the Robot Controller must be tethered to the Operator Interface to transfer the Team Number setting to the Robot Controller. This only needs to be done once after setting the Operator Interface.

<R31> A Relay Module must receive its power from a 20A circuit breaker, and may power no more than one motor or the compressor.

<R32> The Robot Controller, Relay Modules, 12Vdc LEDs, additional electronics, and muffin fans may be connected directly to 20A circuit breaker outputs. The Speed Controllers for the Globe motors, Fisher-Price motors, and the Van Door motor may be connected to 30A or 20A circuit breaker outputs. **Only the Speed Controllers for the Drill motors and CIM motors may be connected to the 40A Maxi Breaker Block outputs.**

<R33> The Drill motors, Fisher-Price motors, Globe motors, CIM motors, and Van Door motors may only be powered by the Speed Controllers. Do not connect these motors to the Relay Modules**.**

<R34> No more than one drill motor, CIM motor, Fisher-Price motor, Globe motor or Van Door motor may be powered by each Speed Controller

<R35> The Seat motor, Window motors, and 12Vdc LEDs may be powered by the Speed Controllers or the Relay Modules. Optionally, one Speed Controller may power two window motors.

<R36> The air compressor must be powered by a Spike Relay connected to a 20A breaker on the ATC breaker panel.

<R37> Do not connect 12Vdc power, Relay Module outputs, Speed Controller outputs, or PWM outputs to the analog or digital I/O on the Robot Controller.

<R38> You must connect all outputs from the sensors and additional electronics circuits used on the robot directly to the analog or digital I/O on the Robot Controller. ***Sensors may not be wired in series with their loads to directly control those loads***. The loads must be controlled by PWM signals sent by the Robot Controller to relays or speed controllers. It is acceptable to wire switches used as sensors in series or parallel with each other.

<R39> The 7.2V Robot Control backup battery must be connected to the controller as described in the controller's manual. The 7.2v battery must be charged to at least 7.0v before entering a match. Besides the EDU battery, any 7.2V NiCad battery pack can be used.

<R40> A remote reset and remote programming switch may be wired to the Robot Controller's RESET/PROG header. Any switch may be used. See the Robot Controller manual for wiring information.

5.2.7.1 Wiring Requirements

<R41> The wire supplied in the Kit is to be used to conduct electricity. The chassis of the robot is ***not*** be used to conduct electricity. You may use additional wire as long as it meets the gauge and insulation color requirements.

<R42> Electrical devices may only be wired as indicated in this section. For your convenience, reference the **2004 Robot Power Distribution Diagram.**

<R43> All wires distributing power with a constant polarity (i.e., except for Relay Module outputs, Speed Controller outputs or sensor output) must be color-coded as follows:

- Use Red or White wire for +12 Vdc and +5 Vdc connections.
- Use Black wire for Common (-) connections.

<R44> *You must use **6 AWG wire*** to connect the 12v battery to the quick disconnect connector, then to the 120A main circuit breaker/disconnect switch and then to all circuit breaker panels.

<R45> *You must use **10 AWG** or larger* diameter wire for connections from the Circuit breaker Panel or Block to the Speed Controllers if they are used with the Drill, CIM, Fisher-Price, Globe or Van Door motors.

<R46> *You must use **16 AWG** or larger* diameter wire for connections from the Circuit breaker Panel to the Speed Controllers if they are used with the seat motor or window motors

<R47> *You must use **16 AWG** or larger* diameter wire for connections from the Circuit breaker Panel to the Robot Controller, large muffin fans or Relay Modules

<R48> *You must use **24 AWG** or larger* diameter wire for connecting sensors (switches, potentiometers, pressure sensor, optical sensors, current sensor analog outputs) to Robot Controller inputs, for extending the PWM cables, for the small muffin fans, or for wiring LEDs. It is acceptable to use ribbon cable smaller than 24 AWG to connect to the 9 pin ports on the robot controller; color coding is not necessary.

5.2.8 Custom Circuit Rules

<R49> Additional electronics must be wired to their ATC breaker using a ***16 AWG** or larger* diameter wire.

<R50> The use of additional electronics is intended to allow teams to construct custom circuits for their robots. The custom circuits may be used to indirectly affect the robot outputs, by providing enhanced sensor feedback to the Robot Controller to allow it to more effectively decide how to control the robot. The custom circuits must draw power from a 20A circuit breaker. Smaller value fuses may be incorporated into the custom circuits for additional protection. All outputs from the custom circuits must be connected to the analog inputs, digital I/O, TTL Serial Port, or Program Port on the Robot Controller.

<R51> Inputs to custom circuits may be connected to the following sources:

- Circuit breaker outputs
- Speed Controller or Relay module outputs
- PWM or Relay outputs on Robot Controller
- Switches, Potentiometers, the outputs from Current Sensors, Optical Sensors, Motors, and other additional electronics allowed

<R52> Custom Circuits may **not:**

- Interfere with the operation of other robots

- Directly affect any output devices on the robot, such as by providing power directly to a motor, supplying a PWM signal to a speed controller or supplying a control signal to a relay module. (Custom high impedance voltage monitoring or low impedance current monitoring circuitry connected to the robot's electrical system are acceptable, because the effect on the robot outputs should be inconsequential.)
- Be used for wireless communication, such as sending or receiving a signal to and/or from the alliance station
- Connect to the radio or tether ports on the Robot Controller

5.2.9 Pneumatic System Requirements

The pneumatic system uses compressed air from a 12V DC powered compressor that discharges into two air storage tanks. The compressor may be mounted on the robot, or if teams prefer, they may leave it off their robot, and pre-charge and store compressed air in the storage tanks prior to bringing their robot onto the playing field. Tank pressure is automatically limited to 125 psi by means of a pressure relief valve and compressor controls provided in the Kit. The output of the storage tanks is fed to a pressure regulator that limits the downstream "line working air" to a maximum pressure of 60 psi. Instructions for configuring and using the pneumatics, and a list of additional available pneumatic components are provided in the FIRST Pneumatic Manual 2004.

<R53> Pneumatic components supplied in the Kit (pump, regulators, pressure switches, cylinders, valves, fittings, tubing, etc.) may not be modified except as follows:

- The tubing may be cut.
- The wiring for the valves and pressure switch may be modified as necessary to interface with the rest of the control system.
- Mounting and connecting pneumatics components using the pre-existing threads, mounting brackets, etc., is not considered a modification of the components. Removing the pin from the rear of an air cylinder is allowed as long as the cylinder itself is not modified.
- Do not, for example, file, machine, or abrasively remove any part of an air cylinder. Consider pneumatic components sacred. They must remain in "out of the shipping box" condition.

<R54> You may only use the Thomas Industries compressor and Clippard Instruments air storage tanks provided in the Kit to compress and store air on the robot. Please refer to the Pneumatics Manual for information about using pneumatics on your robot. **Teams are not allowed to remove or adjust the 125 psi set relief valve attached to the compressor.** The Nason Co. pressure switch must be connected to the output end of one of the Clippard tanks to sense the tank's pressure. The two wires from the pressure switch must be connected directly to a digital input and ground terminals on the Robot Controller, and the controller must be programmed to sense the state of the switch to operate the relay that powers the compressor.

- The pressure vent valve must be connected to a Clippard tank such that, when manually operated, it will vent to the atmosphere to relieve any stored pressure. The valve must be placed on the robot so that it is visible and accessible.
- "Working" air pressure on the robot must be no greater than 60psi. All working air must come from the Norgen adjustable pressure regulator, and all other pneumatic components must be downstream from this regulator. A pressure gauge must be placed adjacent to the pressure regulator and display the downstream pressure.
- There is no limit to the number of solenoid valves, air cylinders, and connecting fittings you may use on your robot. They must, however, be "off the shelf" pneumatic devices rated by their manufacturers for pressure of at least 125psi. Besides the "free" pneumatic components listed on the Pneumatic Components Order form, you may use additional 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.
- You may use a previous year's Kit pneumatic cylinders and solenoid valves in addition to those items in the 2004 Kit, but you must account for their costs as explained in the Cost Limits and Accounting section.

- You may use the TI pressure transducer provided in the Kit to measure the air pressure at any point in the pneumatic system. It provides an analog output voltage that may be used as an input to the Robot Controller or custom electronics.
- A device that creates a vacuum is not considered to be a pneumatic device, and is allowed. This includes, but is not limited to, venturi-type vacuum generators and off-the-shelf vacuum devices (as long a they are powered by one of the Kit motors).

5.2.10 Non-Functional Decoration Rules

Teams may add "Non-functional" decorations to robots under the following conditions:

<R55> Decorations must not cause the robot weight or size to exceed requirements.

<R56> Decorations must not affect the outcome of the match.

<R57> Any decorations that involve broadcasting a signal to/from the robot, such as remote cameras, must be cleared with FIRST Engineering prior to use. Teams may **not** use *900 MHz camera systems.*

<R58> Decorations may draw power from the 12v electrical system as long as they are powered via a dedicated 20A or 30A circuit breaker and do not affect the operation of other control system components.

<R59> Decorations must be on your robot at the time of final inspection.

<R60> Decorations must be in the spirit of "Gracious Professionalism."

5.3 ROBOT MATERIAL USAGE RULES

<R61> A FIRST robot may be built using only

- Items provided in the FIRST supplied Kit of Parts (or their exact replacement part)
- Allowed Additional Parts and Materials as defined in this section in quantities consistent with the Cost Accounting requirements

5.3.1 FIRST Provided Kit of Parts

FIRST provides each team a Kit of Parts. Only the exact parts provided in the Kit (or their exact replacement) are considered as Kit Parts. Some Kit Parts may legally be used in additional quantities. Additional quantities of these parts are considered to be Additional Parts and not Kit Parts.

The official list of Kit Parts and quantities appears in a separate section of this manual titled *The Kit.*

5.3.1.1 NEW - Kit Contents vary by Team Age

The FIRST 2004 Kit of Parts consists of two large plastic containers of robot parts and construction materials, a structural metals box, and a box containing documentation and software. (**Air compressor and battery charger not included.)**

Kit contents vary by team age. Teams that were new in 2003, and new 2004 teams are being provided with an additional "Year One and Two Team Box." The "Year One and Two Team Box" contains an air compressor, three vibration isolators for the compressor, and a battery charger. All teams that participated in FRC 2003 are to reuse their compressors and battery chargers that FIRST provided in the 2003 Kit of Parts. The reason for this policy change is to limit Kit costs.

5.3.1.2 NEW - Kit Inventory

FIRST has an extremely limited supply of replacement parts

Teams will have until **January 16, 2004** to inventory their entire kit of parts and determine if any parts are missing or broken and fax or mail their checklist back to FIRST. The 2004 Kit of Parts checklist is located in Section 6 of this manual.

- Missing items must be clearly marked on the checklist. – Please fax the checklist to 603-666-0043 attn: FRC parts. *Put your team number on EVERY PAGE*
- Broken items must be returned with the checklist in order to be replaced. FIRST will not provide replacements for broken parts due to any modifications. Please send them to: FRC Parts, FIRST, 200 Bedford Street, Manchester, NH 03101
- Unless otherwise specified, replacement parts shipped from FIRST will ship via 2nd day within one business day of receipt of the broken part. Teams may opt for overnight shipment at their expense

by requesting it and providing their shipping company preference and account number (UPS or FedEx, ONLY.*)*.

5.3.1.3 NEW - Obtaining Replacement or Spare Kit of Parts

We will have a VERY LIMITED listing of parts available at events posted via the web no later than January 16, 2004.

Please note – If your robot uses any other parts, and there is a reasonable possibility it may become damaged or broken during a competition event, then it is STRONGLY RECOMMENDED that you obtain and bring appropriate spare parts to events.

FIRST Loan policy for Control System Components:

Teams are responsible for all Innovation First products required at events. If, at any event, a team needs to borrow any part of the Control System, the team must provide a Credit Card number to ensure proper return of the items after the completion of the event.

- If the part is not returned at the end of the event, FIRST retains the right to bill the provided credit card number for the borrowed items.
- All "loan" items are available on a first-come, first-served basis.

Innovation First Products:

Do not contact FIRST for repair or replacement of these Control System items as they are covered by a product warranty from Innovation First. Please visit the Innovation First web site for product support or to obtain a Return Merchandise Authorization Number (RMA#) to return Control System components for replacement.

Contact Innovation First at: 903-454-1978 or at www.innovationfirst.com/firstrobotics/

5.3.1.4 Kit of Parts Rules

<R62> The motors in the kit may **not** be modified except as follows:

- It is acceptable to modify the mounting brackets and/or other structural parts of the motors (output shaft, housing, etc.) as long as the electrical system is not modified and the integral mechanical system of the moving parts (bearings, bushings, worm gear output stages, etc.) is not changed or removed.
- The gearboxes for the Fisher-Price, Drill, and Globe motors are not considered "integral" and may be separated from the motors. FIRST will not provide replacement for parts that fail due to modification.
- Caution advised regarding the ½" drill motors: You should not replace the blue wires, however, you may shorten them such that there is a minimum of 1.5 inches still attached to the motor and solder heavier gauge wire to their cut ends. Do not attempt to unsolder the blue wires from the brush housings. The plastic brush support housing will distort if exposed to soldering temperatures and the alignment of the brushes will be affected, which can permanently degrade motor performance.

<R63> Teams may replace lost or damaged Kit components only with identical components of the same material, dimensions, and treatment.

<R64> Materials in the Kit may not be changed chemically with the following exceptions:

- Rope ends may be singed to prevent loose ends or to bind them together
- Metal may be heat treated
- Metal may be plated or anodized

<R65> You may not use the plastic Kit containers, part packaging, and any documentation in the Kit container as a component to build the robot or robot control system.

5.3.2 Additional Parts and Materials Rules

Besides items directly supplied in the 2004 Kit, teams are allowed to use Additional Parts and Materials in the construction of their robots.

<R66> The use of an Additional Part or Material shall not violate any design rule.

<R67> Additional Parts shall not be made from hazardous materials or be unsafe.

<R68> Additional Parts must be generally available from suppliers such that any other FIRST team, if it so desires, may also obtain them at the same price. (A specific device **fabricated by a team** from non-2004 Kit materials does not have to be available to others, however, the materials it is made from must be available to other teams.)

<R69> The sum of all Additional Parts and Materials must be compliant with the Cost Accounting Rules with which teams must comply.

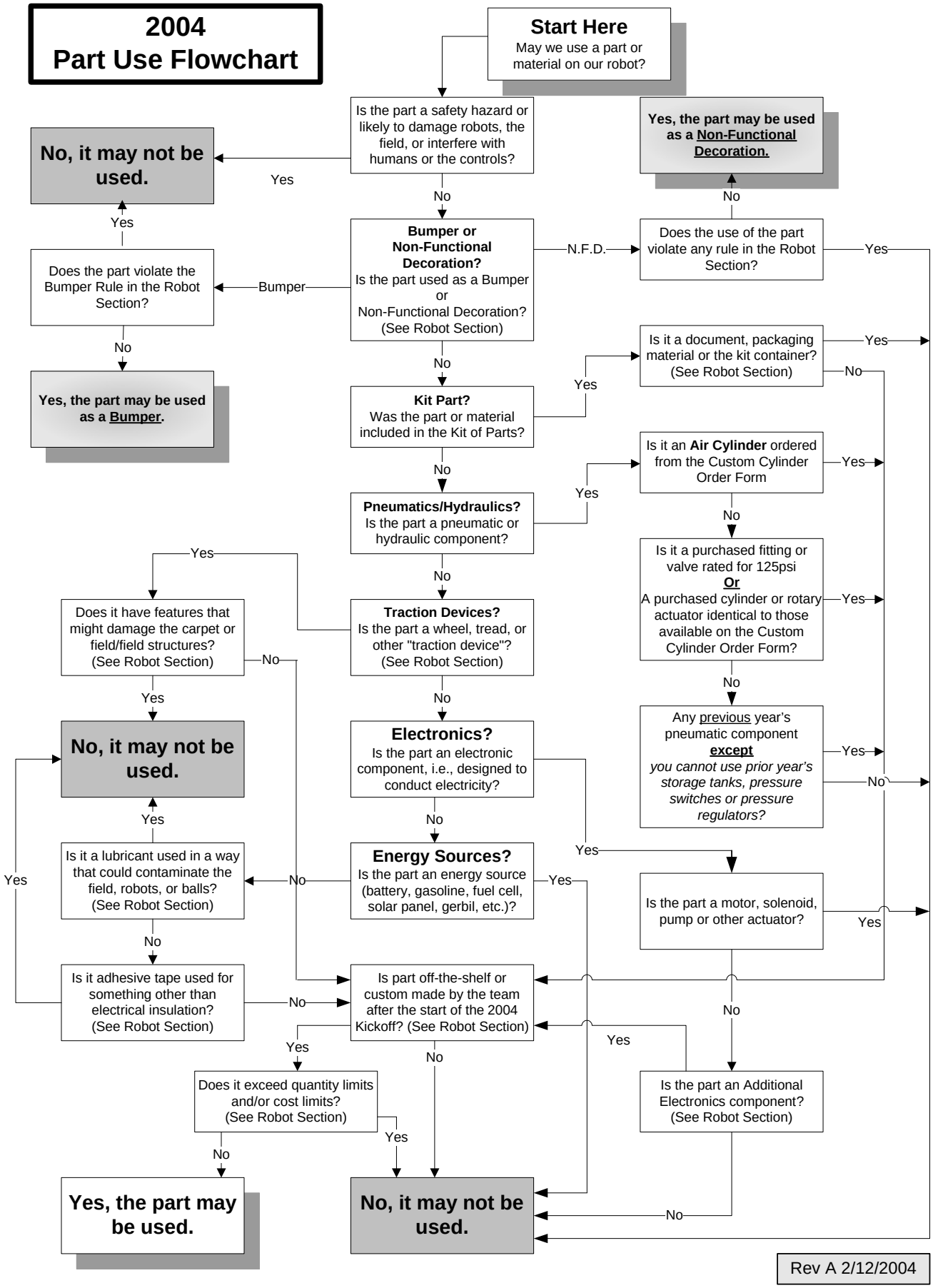
<R70> Specific items NOT allowed include:

- Batteries different from or in addition to those provided in the Kit.
- Circuit breakers different from those provided in the Kit Note: the Snap Action brand circuit breakers provided have unique "trip" characteristics. No substitute brands are permitted.
- Electric motors different from or in addition to those in the Kit.
- Any air compressor, pressure relief valves, or air storage tanks other than those provided in the Kit.
- Hydraulic fluids or hydraulic components.
- Materials classified as hazardous by their MSD Sheets. (Teams should provide MSD Sheets for any materials they use that might be considered questionable during robot inspection.)

<R71> Additional electronic components for use on the robot must be currently available from or equivalent to those available from Newark InOne (http://www.newarkinone.com), Future Active (http://www.future-active.com), Radio Shack (http://www.radioshack.com) or Digi-Key Corporation (http://www.digikey.com). Additional electronic components include any object that conducts electricity other than IFI relays and voltage controllers, wires, connectors and solder. The total catalogue value of additional electronic components must not exceed $300.00 USD. This cost is counted as part of the $3,500 limit. No single electronic component shall have a catalog value of over $100.00 USD.

<R72> Refer to the Part Use Flowchart to help determine the legality of a part.

2004 Part Use Flowchart



5.3.2.1 Cost Limits and Accounting

<R73> The costs of all non-2004 Kit parts and materials used in the construction of a robot must be recorded (in US dollars) by the team, and a list of all such items and their costs made available during robot inspection**. An Additional Part or Material is defined as an allowed additional quantity of any part provided in the 2004 Kit, or any item that was not included in the 2004 Kit's inventory list.**

<R74> All costs are to be determined as explained in the *Cost Determination* section.

<R75> The total cost of all non-Kit items may not exceed $3,500.00 USD. No individual item may exceed $400.00. Non-functional decorations are exempt from this rule. The total cost of components purchased in bulk may exceed $ 400 USD as long as the cost an individual component does not exceed $400. Items such as fasteners, adhesives, lubricants, etc. are also exempt from the cost calculation, unless any one component exceeds $1.00.

<R76> The costs of "spare" parts are excluded from this rule. A spare part is defined as a part that a team has obtained as a direct replacement for a failed or defective Robot part (Kit part or non-kit part)

<R77> The costs of additional non-spare robot control system components obtained from Innovation First Inc. are included in the above $3500 limit. The cost of additional speed controllers and spike relays are excluded from the $3500 limit.

<R78> A list of all purchased materials, including costs, used in the construction of the robot shall be made available if requested by FIRST during the robot inspection process. At each competition event, teams should be prepared to present a complete materials list/spreadsheet that details the source and cost of each additional component of the robot, if requested.

5.3.2.2 Cost Determination

The "cost" of each additional item is counted as follows:

- The purchase price of a non-custom built item offered for sale by a vendor to a general customer base.
- The total cost (materials + labor) of an item you pay someone else to make; Example: A team orders a custom bracket fabricated by a vendor to the team's specification. The vendor's material cost and normally charged labor rate apply.
- The fair market value of an item obtained at a discount or as a donation; Fair market value is that price at which the item would be normally offered by the supplier to any party. Also considered to be "fair market value" are the discounted prices offered to all teams by those suppliers who have established them for FIRST. Example: The special price discounts MSC Industrial Supply Co., Newark InOne, and Terminal Supply Co. are offering to all FIRST teams.
- The cost of raw material obtained by a team + the cost of non-team labor expended to have the material processed further. Team member processing labor is not included. Example: A team purchases steel bar stock for $10.00 and has it machined by a local machine shop that donates its 2 hours of expended labor. The team must include the estimated normal cost of the labor as if it were paid to the machine shop, and add it to the $10.00. Exception Examples: If the team members themselves did the actual machining, there would be no associated labor cost. If the machine shop were part of the team, its labor cost would not apply.
- The cost of items purchased in bulk or large quantities may be prorated on the basis of their actual use on the robot. Example: A team purchases a 4' x 4' sheet of aluminum, but only uses 30 square inches of it on their robot. The cost that the team would have to report would be 30 divided by 2304 times the actual cost of the whole sheet.
- Shipping costs of Non-Kit items are not counted.
- Parts that teams had to buy to replace kit parts not received need not be accounted for, i.e., should not be charged against the $3,500 robot limit.

5.4 ROBOT INSPECTION

FIRST will post a copy of the Offical Inspection Sheet approximately the first week of February. Use this sheet as a guide to pre-inspect your robot before it ships.

Note that robot inpectors will be looking for sharp corners that could pop the game balls. Please try to mitigate all sharp corners.

<R79> On Thursday, at each event, all robots must pass inspection for compliance with the rules herein before being allowed to compete in Qualification Rounds on Friday. At the time of inspection, teams must present a list of all Non-Kit items and costs used in the construction of their robot. **Noncompliance with any robot design or construction rule may result in disqualification of the machine at a FIRST competition event. At the discretion of the lead Inspector,** the robot may be allowed to participate in practice rounds before passing inspection.

<R80> If a team makes a modification to improve performance or reliability, the team may ask FIRST officials to reinspect. If you suspect that another team's robot is in violation of the robot rules, please approach FIRST officials and we will review the robot in question. This is an area where "Gracious Professionalism" is very important.

<R81> At the time of robot inspection, you must present ***all*** mechanisms that you will use on the robot during the entire competition event. It is acceptable, however, for a robot to play matches with a **subset** of the mechanisms that were present during inspection. Only mechanisms that were present during the inspection may be added, removed or reconfigured between matches. If subsets of mechanisms are changed between matches, the robot must still meet all inspection criteria. Robots must satisfy all rules and requirements at all times.

<R82> During inspection, teams must be able to demonstrate the operation of any robot mechanism intended to interact with the Pull-up Bar on the center structure on the field, and show that its tip velocity complies with the 10 feet/ second velocity maximum limit requirement. One way that this may be accomplished is by recording the tips motion with a camcorder with a known frame rate (to provide delta time) against a measuring tape background reference (to provide delta distance).

<R83> If a robot is rejected because of excess "tip velocity" or a safety concern related to the team's method of storing energy, the concerned mechanisms must be disabled or removed from the robot before it may compete in a match. The team bears the burden of proof that such a rejection is not valid. Teams should be prepared to provide justifiable test data or calculations during inspection to support their design.

5.5 OPERATOR INTERFACE REQUIREMENTS

<R84> The team number settings on the Operator Interface must be set to the team number assigned to the team by FIRST.

<R85> The Operator Interface Console designed by your team must fit on the 42" wide by 9" deep shelf in the Alliance Station and The Radio Modem connected to the Operator Interface must be able to reach the mounting bracket on the operator stations. Be sure to leave at least 48" of slack in the 9-pin cable.

<R86> Teams are permitted to connect a portable computing device (Laptop computer, PDAs, etc.) to the RS232 Output of the Dashboard Port of the Operator Interface for the purpose of displaying feedback from the robot while competing in Competition matches. Portable computing devices *may not* be connected to inputs on the Operator Interface. Please note that ***AC power will not be available at the playing field so these devices will have to run on internal batteries.***

<R87> Teams may not use Innovation First Operator Interfaces from previous years' competitions.

5.6 GUIDELINES FOR WIRING THE ROBOT

WARNING! *Please read this and 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.*

5.6.1 Power Distribution Circuits

The 120A main circuit breaker/disconnect switch functions *both* as the Main power on/off switch for the robot *AND* as a safety current overload protection device.

Shut off robot 12v power manually by pushing the RED BUTTON on the breaker. Turn power back on by pushing the RESET lever back into position.

You **must** wire the 120A circuit breaker/disconnect switch supplied in the Kit of Parts in series with the *positive (+) terminal* on the 12v battery such that all power from the 12v battery flows through the 120A breaker. Do not connect anything other than the 120A main circuit breaker/disconnect switch directly to the 12v battery's positive (+) terminal.

The circuit breaker current ratings indicated for specific circuits are the *maximum* allowed, and the AWG wire sizes are the *minimum* allowed. The Maxi style circuit breaker panel will only hold the 40A Maxi auto re-settable circuit breakers. The 20A and 30A auto re-settable circuit breakers must be used in the two provided 12 position circuit breaker panels.

Table 5.1 Robot Circuits

Circuit	Power Source/Device
Main 12V Battery Circuit	Electric power from the 12v battery passes through a 120A main circuit breaker/disconnect switch to the circuit breaker/fuse panels.
Backup 7.2v Battery Circuit	Connects to the Robot Controller directly. Used as a backup to the Robot Controller only if 12v is not available. Also powers any servos connected to the PWM outputs.
Robot Controller, Relay Modules, Fans, LED, Optical Sensor, Custom circuits	Power is distributed from the circuit breaker/fuse panels via 20A auto-resetting breakers to these devices.
Speed Controller Circuit	Power is distributed from the circuit breaker/fuse panels via single 20, 30 or 40A auto-resetting circuit breakers to the Speed Controllers (see Table 5.2)
All other electrical devices circuits	Sensors, motors, air valves, and the air compressor receive power from either the Robot Controller, Relay Modules, or Speed Controllers as described below.

WARNING! *Be very careful to avoid short circuits!* The 12Vdc SLA batteries 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.

It is *unlikely* that the 120 main circuit breaker/disconnect switch will trip to "off" as a result of the large impact forces sometimes experienced by robots in competition matches.

FIRST ***recommends protecting the top of the breaker and the mechanical trip release. Power from the 120A breaker must be distributed to all loads via the three circuit breaker/fuse panels included in the kit.***

Note: Two of the circuit breaker/fuse panels each contain 12 protected (via the 20A or 30A Snap-Action circuit breakers) outputs connected to one input. On each panel, there is also a 12 position, un-fused terminal block that is isolated from the fused portion of the panel. This un-fused block is intended to act as a Common (-) terminal. Do not connect any 12Vdc (+) terminals of the circuit breaker/fuse panel to the Common (-) terminal. A third (Maxi-style) circuit breaker panel is provided that contains 4 positions to accommodate the larger size 40A Snap Action breakers that protect the Bosch drill and CIM motors.

The FIRST Robot Power Distribution Diagram shows more relay modules and speed controllers than are included in the Kit of Parts in order to show how additional devices may be connected on your robot. You may obtain additional relay modules and speed controllers by purchasing them from Innovation First.

Except as noted herein, each Ground (GND or Common (-) wire from a speed controller, relay, or Robot Controller must go directly from that item to one of the 12 Common (-) terminal tabs on the circuit breaker/ fuse blocks.

Exception: The Ground (GND or Common -) wires from low current items such as relays controlling solenoid pneumatic valves, custom circuits, sensors, LEDs, and fans may be connected as a group to one common wire that leads back to a Common (-) terminal tab on an ATC panel, or directly to the ground stud.

CAUTION! Check wiring periodically!

Be sure to check the wiring on a periodic basis to prevent failures that could harm the control system or cause a robot to stop dead in the middle of a match. Crimp-on connectors that are improperly crimped may work at first, but can fail easily due to the operating vibration of a robot. Also, be sure to avoid tension on the wires when components are installed on the robot, and never remove a connector by pulling on the wire. Loose connections can result in poor performance, intermittent failures, and/or short circuits.

- FIRST recommends that all wiring be laid out in a logical, orderly manner and be managed by the use of plastic quick ties, shrink-wrap tubing or plastic helical wire wrap. The wiring scheme should be easy to trace and interpret during technical inspection.
- It is advisable for a team to create a robot-specific wiring diagram for reference. This would greatly facilitate solving any electrical problems.
- It is also advisable to label wires and devices to facilitate tracing and reconnecting wiring.

5.6.2 Wire Size

At any given current level, the smaller the gauge of a wire, the greater the voltage drop and power loss in the wire due to its inherent resistance. FIRST has specified minimum allowed wire sizes based on guidelines used in the automotive industry. The wires and cables included in the Kit are intended for specific uses. Table 5.2 shows the minimum wire sizes allowed for hookup of the various control system devices. Note that you may use larger wire sizes than indicated in the table or shown on the 2004 Robot Power Distribution Diagram.

Table 5.2: Minimum Wire Size and Protection by Device Type

Device	Wire Type	Circuit Breaker
Power distribution from 12v battery through 120A Main Circuit Breaker/Disconnect Switch to fuse panels	6 AWG/red & black	120A
Drill motors, CIM motors; Speed Controllers used with Drill motors and CIM motors.	10 AWG/red & black	40 A
Fisher-Price motors, Van Door motors, Globe motors; Speed Controllers used with Fisher-Price Van Door, or Globe motors	10 AWG/red & black	30A
Robot Controller power, Relay Modules, seat motor, window motors, compressor, solenoids, large muffin fan; Speed Controllers used with window motors	16 AWG/2 conductor	20A (Relay Modules also have integral 20A fuses.)
All switches, PWM cables, optical sensors, potentiometers, pressure sensor, LEDs, small muffin fans, custom circuits	24 AWG/2 or 3 wire conductor	Requirements vary

It is acceptable to shorten or lengthen Control System cables containing 3 or fewer wires as needed as long as the following conditions are met:

- The connection is insulated.
- The proper wire type is used. (As specified above)

This means, for example, that you may use 24 AWG wire to lengthen a PWM/Relay cable.

Other devices that may be connected directly to the fuse panel (Robot Controller, Fans, etc.) must be connected via a 20A circuit breaker. The same breaker may power all these devices. The 12 Vdc panel mounted LEDs provided in the Kit are intended to be used on the robot as indicator lamps and may be used on Speed Controller or Relay Modules outputs alone, or in parallel with any other devices. You may also power the LEDs directly from an auto-resetting breaker.

5.6.3 Relay Modules

For information about the Relay Modules, refer to the *Spike Users Manual* available on Innovation First's website.

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

Under certain circumstances, it is acceptable to power more than one device from a single Relay Module. A single Relay Module may power no more than one motor or the air compressor. A single Relay Module may be used to power valves and/or fans in conjunction with a single window motor. Each Relay Module must receive power via a 20A circuit breaker. It is acceptable to distribute power from a single 20A circuit breaker to multiple Relay Modules.

The Spike Relay modules have a 20A fuse installed onboard. This fuse may be replaced with a 20A circuit breaker only on the Relay Module that is used to control the air compressor. This Relay Module must still be fed from a 20A circuit breaker on the ATC the breaker panel.

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

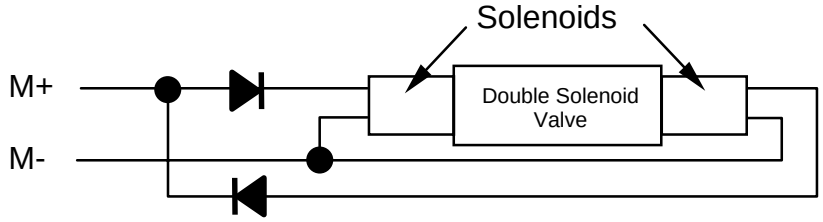


Figure 5.1 Use of Diodes with Double Solenoid Valve

5.6.4 Speed Controllers

For information about the Speed Controllers, refer to the document ***Victor /884 Users Manual*** on the Innovation First website. Each Speed Controller must receive power via a dedicated 20A, 30A or 40A circuit breaker.

Warning!

The Speed Controllers will be damaged if reverse polarity is applied to the power inputs. Please be careful when wiring the Speed Controllers.

5.6.5 Muffin Fans

12Vdc muffin fans are included in the Kit. FIRST recommends installing these fans to direct cooling air over the components that run the hottest (high use motors). You may provide constant power to the fans directly via a 20A circuit breaker or use a Relay Module to switch power to the fans.

Warning! The muffin fans provided in the kit are not reversible. You can damage them if you apply reverse polarity. Please be careful when wiring the muffin fans.

5.6.6 Sensor Inputs and the Robot Controller

Within the rules described below, and in compliance with the documentation supplied by Innovation First, teams may use sensor devices to create a custom sensor system on the robot. Innovation First provides detailed wiring information for sensor inputs connected to the Robot Controller. As a generic reference, Figure 5.2 illustrates typical wiring configurations for connecting analog sensors, switches and other devices to the **analog** or **digital** terminals on the Robot Controller.

Warning! Do not connect switches to +5v Output Pins) of the Robot Controller. The +5v Output Pins are intended to supply fused 5Vdc power for use by sensors.

Warning! *Do not connect any voltages greater than +5v to the analog inputs on the Robot Controller. It may damage the Robot Controller.*

Specific pin selections should conform to the *Pinout and Software Function Schedules* included in the Innovation First, Inc. ***Robot Controller Reference Guide***.

5.6.7 NEW - Current Sensors

New in the Kit for 2004 are two Allegro Microsystems, Inc. current sensors, part number AC750, and high current rated printed circuit boards on which the sensors must be mounted. The sensors are nominally rated to carry currents of 75Amp, and may be used to monitor the current being drawn by the Bosch and CIM motors. They consist of Hall effect devices that measure the strength of the magnetic field created by current passing through an integral copper bus. Their output is treated as an analog signal that may be connected to any analog input on the Robot Controller. This signal is proportional to the current passing through the bus. When soldering the sensor to the high current circuit board, pay particular attention to the integrity of the solder joints. Because both the sensor and circuit board have a high "thermal mass," they require the use of a heavy-duty soldering iron that can provide sufficient heat to properly flow the solder.

5.6.8 NEW - Infrared Receiver Module

In order to detect the infrared beacon signal that is part of The Game for 2004, a Vishay IR Receiver Module, P/N TSOP4840 has been provided in the Kit. It should be connected to a digital input port on the Robot Controller. It detects the 40KHz signal transmitted by the IR beacon, and allows teams to implement an IR tracking system.

The IR code for the robot and beacon can be found on the Innovationfirst website at:

http://www.innovationfirst.com/FIRSTRobotics/documentation.htm

- Navigate.zip contains the code used on the robot.
- Beacon.zip contains the beacon code used on the field

The Vishay photo-detector drawing has been reposted with a revision id and date on it.

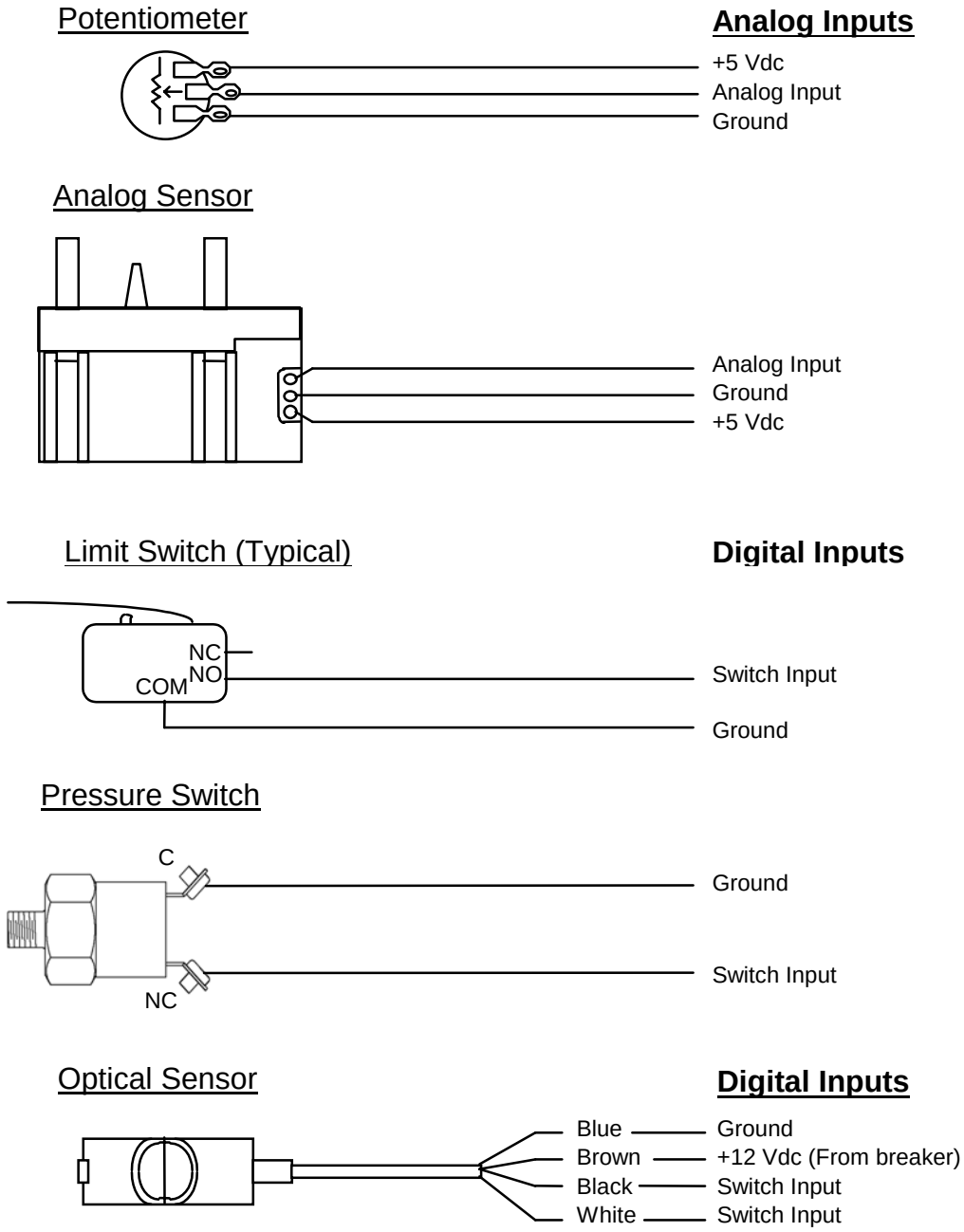


Figure 5.2: Examples of sensor connections to the Robot Controller

5.6.9 Custom Circuits and Additional Electronics

It will be impossible for FIRST to test all custom circuits, so we are relying on all teams to use Gracious Professionalism (and good engineering) when using custom circuits.

Please read the control system documentation from Innovation First for information on the robot controller sensor inputs. Support by FIRST and Innovation First for the additional electronics and custom circuits is limited to the documentation provided in your kit and on the Innovation First website.

5.7 OPERATOR INTERFACE GUIDELINES

5.7.1 Operator Interface Power Distribution

Power may be supplied to the Operator Interface in 3 different ways.

- The A/C Adaptor power supply for the Operator Interface can be plugged into the power jack.

- The Robot Controller will provide power to the Operator Interface when the units are connected together by the tether cable. This disables the radio modems, but is useful in situations where no AC power is available for the power supply.
- During competition matches, a cable that plugs into the Competition port will supply power for the Operator Interface.

Due to the low current used by all the devices that connect to the Operator Interface, 24 AWG or larger wire is sufficient for all Operator Interface wiring.

5.7.2 Operator Interface Sensor Inputs

The exact wiring configuration for the joysticks, switches, potentiometers, LEDs, and analog sensors connected to the Operator Interface is not specified. 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.

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) on the project box, and use the 15-pin molded cable(s) to make the connection(s) to the Operator Interface.

The +12 Vdc 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.

CAUTIONS Connect switches between a Digital I/O Signal and Ground. *Do not use lighted switches with the Operator Interface unless the light 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, Ground, and an analog input. Potentiometers must be connected to +5 Vdc and an analog input. 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 examples and will vary depending on the number of devices connected.

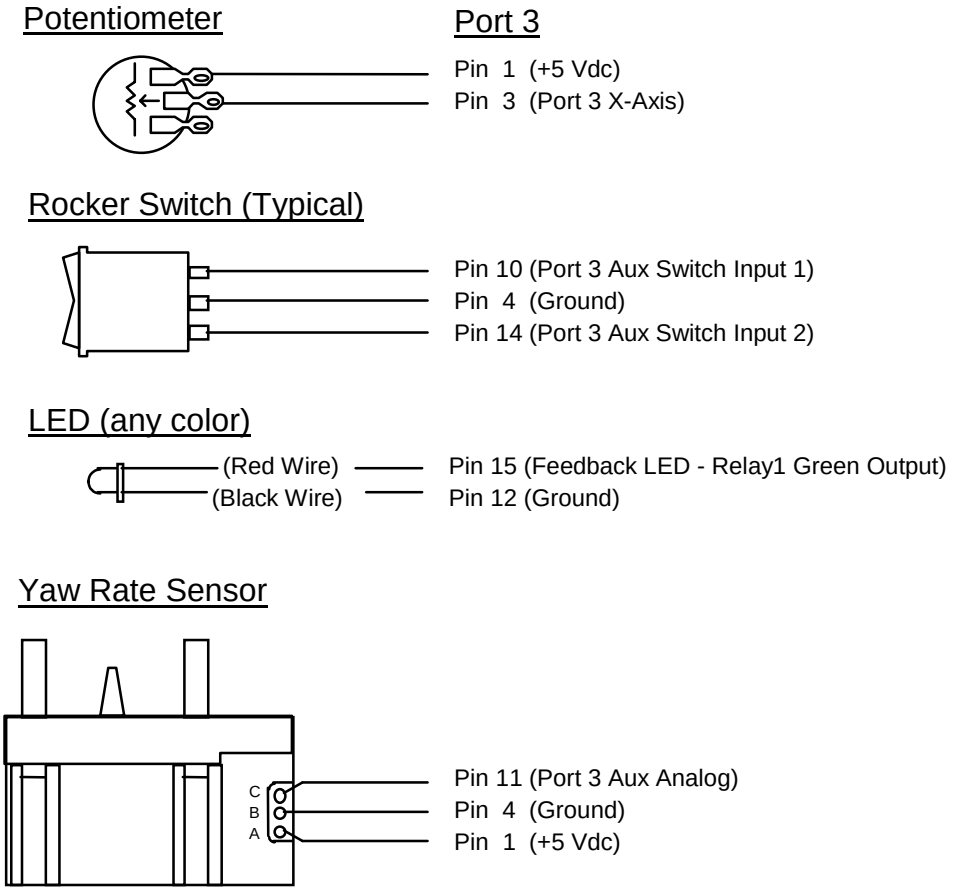


Figure 5.3: Connection Examples for Operator Interface

5.7.3 Dashboard Port

Innovation First offers pre-written software for use in a Dashboard. 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/firstrobotics

5.8 GENERAL TIPS AND GUIDELINES

5.8.1 Motors

Selection of the appropriate motors to perform specific functions such as turning wheels, lifting arms and squeezing claws is an important part of the design process.

The motors supplied with the Kit of Parts have various power and torque/speed capabilities. Some are quite powerful and draw very high current when loaded to their limits. Others have very high-speed capability. Some have integral transmissions that magnify their torque output. Some are equipped with selectable two-speed transmissions. Before choosing a motor for a particular use, be sure you thoroughly understand the characteristics of the motor.

Drill motors have an internal cooling fan that is not effective at low motor speeds. Do not operate the Drill motors at the stall condition because they will quickly overheat and fail.

As a general rule, design your robot transmissions and choose gear ratios so that drive motors will not be operated beyond the current draw level of their maximum output power point. Verify this by monitoring motor current during robot design verification testing.

5.8.2 Motor Mounting

Many of the motors supplied in the Kit were not originally designed to drive robots. The motor shafts on the drill and Globe motors were designed to provide axial torque only, and cannot sustain large *side loads*

imposed on their motor shafts. *Take care to securely fasten these motors and couple them with flexible couplings to the rest of the drive train when they are used for motive power*.

5.8.3 Drive Train Construction

The Drive Train consists of those components that connect the drive motors to the wheels or tracks of the robot. Design your drive train so that the weight of the robot is supported by axles and shafts *and not* by the drive shafts of the motors. Incorporate sufficient gear reduction in your drive train to provide ample drive torque and sufficient robot speed. Use bearings and bushings to provide proper shaft support and minimize friction. Remember, *the more the robot weighs, 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, support the coupled shaft with bearings at two points, and use a flexible coupling to connect the motor to it.*

FIRST recommends using the Kit-provided motor mounts, drive train mounts, shafts, gears, sprockets, chain, couplings, and connections to provide proper speed reduction and power transmission between the motors and the robot traction load.

5.8.4 Use of Two-Speed Drill Motor Transmissions

The Drill motor assembly provided in the Kit consists of the motor, a two-speed planetary gear reduction transmission, and an adjustable clutch.

The motor is a high-speed brush-type motor specifically suited to drive the transmission. Although it is not recommended, you may easily remove the motor from the transmission and use it separately. Thoroughly understand the internal workings of these units.

The two-speed transmission is capable of operating at 0-450 RPM in low speed range and 0-1500 RPM in high-speed range. Incorporated in it are two small spring clips that connect the internal shifter mechanism to the outer gear select sleeve. These clips should be held in place on the transmission using the rubber bands provided in the Kit. (Put the rubber bands in place before mounting the motor/transmission assembly as a unit into your robot's drive train.) If you plan to utilize both speeds (shift the transmission), be sure that the drill motor is stopped before shifting gears. Also, be sure to fully engage and securely hold the gear select sleeve in each speed range setting. If you plan to use only one speed range, fasten the gear select sleeve securely to prevent it from slipping out of gear.

The clutch is adjustable and can be set to disengage under different load conditions or not at all. *If not set properly, the clutch will slip under a lower load than required.* **The drill's clutch housing contains two internal back drive preventer pins that keep the motor shaft from being turned (back driven) by its output shaft. These pins may be removed, allowing the motors to be back-driven by the robot's momentum in an un-powered state. FIRST recommends that you remove these pins. Detailed instructions about doing so are available on our website.**

5.8.5 Motor Electrical Overload Protection

The Drill motors and CIM motors are protected by 40 Amp, Maxi-style auto-resetting circuit breakers. Since the motors are capable of drawing over 100 Amps at stall, operating a motor at high torque for more than a few seconds may trip the auto-resetting circuit breaker. This can result in a stopping of your robot until the circuit breaker cools sufficiently. The breaker will eventually reset, and the motor will resume operation. Sudden acceleration, pushing/pulling, climbing sloped surfaces, turning and rapid change of forward-reverse direction require high motor torque and could overload the circuit breaker.

It is essential to select drive train gear ratios that keep the motor's current within the protection limit of the circuit breaker. Circuit breaker protection is required to prevent burning up the motors, controllers, and wiring system.

5.8.6 Electrical Power Distribution

This section covers *power distribution* and *wiring rules* for the robot, Robot Controller, and Operator Interface system. It gives examples of how to wire parts included in the Kit to the Innovation First Control Systems. **New in 2004 is an additional 7.2V NiCad battery to be connected to the Robot Controller**. **This battery and connecting cable has been provided with the EDU Robot Controller, and must also be used with the 2004 Robot Controller**. **Also new are four Team Color LEDs that replaces the robot's rotating light.** The 7.2V battery provides backup electrical power to the Robot Controller during low voltage

conditions that can occur in the robot's 12V main power circuit. It also is the source of power for any servos connected to the PWM outputs of the Robot Controller. For information about the battery and Team Color LED, please refer to Innovation First's control system documentation on their website at: http://www.innovationfirst.com/firstrobotics/

5.8.7 Batteries and Chargers

Teams are responsible for ensuring that their batteries are sufficiently charged to compete in each match. It is estimated that each battery can store sufficient energy to power a robot for at least 5 matches. It should not be necessary to swap batteries after each match.

5.8.7.1 Charging Your Battery

Teams must charge their batteries at their pit stations at each FIRST Robotics Competition event. For instructions on charging the batteries, please refer to the battery charger documentation. You may use additional battery chargers as long as their charging rate is no greater than the one provided by FIRST.

NOTE: If you have a battery that you know is damaged, please do not put it in the trash. **Immediately replace and properly recycle the damaged battery.**

WARNING! Allow a warm battery to cool before charging. Please do not attempt to cool a battery by immersing it in ice, water, or snow. A battery that has been left out in cold weather must be allowed to reach room temperature before charging. Failure to do so may cause serious damage to the battery and may leak toxic liquid as a result. Be careful to avoid shorting the batteries. Short-circuit current exceeds 200A and can cause fire, serious injury, and leakage of toxic fluids.

5.8.7.2 Battery Recommendations / Cautions

To connect the 12V battery to the rest of the control system, FIRST recommends using the ring terminal contacts and red Anderson Power Products connectors provided in the Kit. This allows for a quick exchange of batteries on the robot.

Although rare, the 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.

When connecting the battery, be very careful to observe the proper polarity in order to prevent damage to control system components.

In addition to the 7.2V Robot Controller backup battery, only one of the 12 Volt Direct Current Sealed Lead/Acid (SLA) batteries supplied by FIRST may be used to power a robot during a match. You may charge the 12V batteries through the normal operation of the battery charger that FIRST provides. Use the Innovation First EDU charger to charge the EDU 's 7.2V battery. Other 7.2V batteries must use the appropriate charger.

5.8.8 "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 occurs when your PC corrupts the serial port timing. USB-serial converters are more susceptible. If this problem continues to re-occur, try downloading your 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.

The above is one of the many FAQs at: http://www.innovationfirst.com/firstrobotics/faq Search criteria: USB

5.8.9 Tips

TIP: An example of an acceptable bumper design is a series of foam rubber tubes held in place by Velcro straps around the perimeter of the robot.

TIP: The 120A circuit breaker is also the power switch for your robot. *Please make it safely and quickly accessible.*

TIP: If using ribbon cable, please take care to protect it from physical abuse (straining, pinching, or sharp bending) or failure of the internal wires is likely.

TIP: Recognizable Team Identification is very important so that judges can give proper credit for exceptional performance and unique design features exhibited during competition matches.