

THE 2001 FIRST ROBOTICS COMPETITION MANUAL

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1. THE ROBOT

The Robot section of the 2001 FIRST Robotics Competition Manual provides information about the parts provided in the Kit of Parts at the Kickoff Workshop and information on additional parts that can be used to build the robot. It covers power distribution on the robot, gives some wiring examples, and lists the rules covering robot construction.

NOTE: Documentation for the robot control system is provided by the manufacturer, Innovation First, and can be found on their web site at www.innovationfirst.com/firstrobotics/.

Before embarking on the robot design process, it is important to understand that there are certain constraints on the robots that you must observe in order to compete. The reasons for the constraints are many and varied and include making sure that FIRST Robotics Competition events are safe, that all teams have access to the same materials, that teams follow certain good design practices in order to improve reliability and make problem solving and repair easier, or just to provide a design challenge.

1.1 Before You Start Building A Robot

The complete and detailed list of rules governing robot design and construction is included in Appendix A. Listed below are some important concepts from these rules:

1.1.1 Materials

The materials that you are allowed to use to build the robot are limited. There are three sources of materials:

Sources of Robot Materials	Location
1. Parts found in the Kit of Parts	Appendix B, Inventory list
2. Parts from SMALL PARTS, INC.	SMALL PARTS, INC. Catalog Appendix D, Ordering information
3. Parts from Additional Hardware List	Appendix C

IMPORTANT: To keep the competition on a ‘level playing field’, any material used in the robot **must come** from the above sources and no other. *You may not use materials which are not from the above sources.* The amount of materials from these sources may be limited by cost or quantity of material.

1.1.2 Rules Overview

It is very important to become familiar with the rules in Appendix A and read through the allowed materials lists in the appendices. Keep in mind the rules of game play listed in the Game section of the manual and the shipping deadlines listed in the appropriate Regional or National Championship sections. By taking the time to read through the rules carefully, you will save time in the long run. You can waste major blocks of time because of the lack of knowledge about a certain rule at the onset of the design process. Pay special attention to the items listed below.

- The size of the robot when it starts a match is limited. Once a match starts, the robot may expand.
- The weight of the robot is limited.
- Certain uses of allowed materials are disallowed, primarily for safety reasons.
- All robots must pass inspection before being allowed to compete at each event.
- Once a robot starts competing at an event, you may not make certain types of changes to the robot until after the event is over.

1.1.3 Scheduling Overview

Plan your overall schedule to include simulated competition test runs. Give your robot operators as much practice as possible. If you have not built some sort of prototype (motors and wheels mounted on a board running around the floor, pick up mechanisms, etc.) by the end of the 3rd week, you are seriously behind schedule. If in doubt, consult this manual and the team updates. If these do not answer the questions, contact FIRST by e-mail or telephone. It is far better to find out 2 weeks or

even 2 days before you ship your robot that something you wanted to do is against the rules than to find out at the event and have to scramble to re-engineer your robot.

1.1.4 Team Updates

As you progress in the design and build stage, assign several team members to carefully read all team updates which FIRST will periodically issue on the FIRST web site. In addition to rules updates, corrections, and other important information, team updates contain answers to all questions asked by other teams. This helps to ensure that all teams have the same understanding of the rules. Assign several people to read, understand, and interpret the rules and updates for your team.

1.2 Robot Construction Tips

1.2.1 Drill Motors & Drive Assemblies

The drill motors and drive assemblies snap together for convenient handling during assembly of a drill. This motor-drive assembly sub-assembly cannot support normal (side) loads by itself. The gearshift lever on the drive assembly and the gears actuated by it cannot withstand large gear-shifting forces, especially while operating. FIRST recommends using the plastic drill shell to support the motor, drive assembly, and shift mechanism, providing ample speed reduction between the drill and its load.

The drill components were designed for drilling holes and driving screws, not for propelling a heavy robot. Please remember this when designing and operating your robot. Align mechanical power transmission components accurately. If you couple the spindle to another shaft, support the shaft with two bearings and use a suitable flexible coupling. If you mount a gear, pulley, or sprocket to the drive assembly spindle, use the largest pitch diameter possible to minimize side loads resulting from transmitting torque. Note the trade off between side loads and available gear ratio. A small pulley on the spindle allows a good gear ratio, but results in excessive side loads. Seriously consider the possible need for two stages of speed reduction between the drill and its load. If the drill shows signs of overloading, such as clutch disengagement, improve your design. When you get out on the playing field, failures will be far more likely than they were during practice. Refer to Appendix H for Motor Specifications. Refer to Appendix D for a specially coupling designed to attach directly to the threaded output shaft of the gearbox.

If you plan to utilize both speeds of the gearbox, be sure that the drill motor is stopped before changing gears. Also, be sure to fully engage and hold the gear select level in each gear setting. Otherwise, damage to the gearbox is likely. If you plan to utilize a single speed, FIRST recommends using a secondary fastening method, such as pinning the gear select lever, to prevent the gearbox from slipping out of gear.

Many teams have discovered the hard way that the relatively gentle driving a robot did during prototyping and driver practice was not an accurate representation of what goes on during a match, and suddenly their robot keeps stopping out on the field. Often, this is because the 30 Amp auto-resetting circuit-breakers protecting the speed controllers and drill motors are starting to trip. Please keep the following in mind when designing your robot drive system:

- Motor current is proportional to torque output, and the drill motors have a stall current of over 100 Amps. Power to the motors is provided through a 30 Amp auto-resetting circuit breaker. Therefore, operating a drill motor at a high torque for more than a few seconds at a time will trip the circuit breaker, causing the robot to stop moving for a few seconds while the breaker cools off. Once the breaker has tripped, it is more sensitive (hot) for a while and thus you are likely to experience additional motor cutout. Please consider this when determining gear ratios for the robot.

- Sudden acceleration, pushing/pulling, climbing sloped surfaces, slamming the robot into reverse when moving forward, and vice versa all require high torque and can lead to tripping breakers if gear ratios are not appropriate.
- Most robots steer like a tank, requiring the wheels or treads to skid sideways in order to allow the robot to turn. This requires far more torque from each drive motor than when the motors are working in cooperation to move the robot forward or backward, and can lead to tripping breakers if gear ratios are not appropriate. Many teams opt to use low friction wheels or two-wheel drive plus caster wheels in order to allow gear ratios that support higher speeds without requiring high torque to turn.
- Some teams have discovered that using “break” mode on the speed controllers will cause the breakers to trip more often. For more information about break mode, refer to the Victor 883 documentation from Innovation First.
- Some teams have discovered that their robot’s drive system works perfectly when the robot is being tested on a bench but will flex and bind up when under load. Friction in the drive system increases the load on the motors and can lead to tripping the circuit breakers.
- A good rule of thumb when designing your drive system gear ratio: A robot that is so fast that it is difficult to steer has too high a gear ratio and is likely to experience breaker problems when competing.
- Sometimes what appears to be a breaker problem is really something else. Loose drive chains and belts, transmissions which disengage, shaft couplings that slip, and faulty electrical connections are just as detrimental as a tripping breaker and can lead to intermittent or total failure during a match.

1.2.2 Globe Motor with Drive Assembly

The drive assembly on the Globe Motor provides a 117 to 1 planetary gear redirection. *The output shaft of the drive assembly is not intended to support side loads.* It is required that your robot design incorporate a safe yield to prevent damage to the drive assembly from side loads. Refer to Appendix H for Motor Specifications.

NOTE: *The output shaft of the drive assembly is not designed to support side loads. If the output shaft is not properly supported, it will damage the drive assembly.*

1.2.3 Seat, Window, and Van Door Motors

The seat, window, and van door motors contain one worm gear reduction stage and, in the case of the seat motor, a positive temperature coefficient (PTC) thermistor for overload protection. As the seat motor becomes warm from use, the resistance of the PTC device increases, thereby reducing the motor current and output torque. Operation at or near stall continuously will reduce the output torque to near zero until the motor has been allowed to cool. All motors, even those without a PTC device, will lose output power as they heat up.

To prevent overheating, take care to couple the output shaft in a manner that does not impose large side loads, use an appropriate gear ratio, and minimize the internal friction of the mechanism driven. Refer to Appendix H for Motor Specifications.

1.2.4 Mechanical Power Transmission

One of the most common problems teams have experienced in past competitions is mechanical power transmission failure. Typical torques at the final stage of your propulsion power transmission assembly are large enough to cause serious problems for most conventional means of fixing gears, pulleys, or sprockets to shafts.

Set screws almost always fail. Pins offer better torque transmission, but can cost you valuable time if one breaks. Be careful not to use a pin so large that it occupies so much of the original shaft cross-section that the shaft breaks. Consider carefully the use of good clamping-type couplings, even though they may be expensive.

1.3 FIRST Policy on Repair and Replacement of Kit Parts during build and design.

FIRST has developed the following policies on the repair and replacement of various kit parts.

If you experience a failure in any of the items mentioned below, please review the appropriate documentation to ensure that the components are correctly configured. If this does not resolve the problem, you will be instructed to follow the steps outlined below. Please note the differences in procedure based on the component that is determined to be inoperative.

FIRST has a limited quantity of replacement parts available. If, during examination of components, a failure is determined to be due to misuse or incorrect wiring, in general only one additional unit will be supplied, or the original unit will be repaired only once. *FIRST reserves the right to refuse to provide replacements to teams that break the same part over and over.*

- Before sending back the item, *you must photocopy and fill out the problem report found in Appendix F.* Mail this report in with the item.
- Unless otherwise specified, replacement parts shipped from FIRST will ship via 2nd day air within one business day of receipt of the non-functional part. Teams may opt for overnight shipment at their expense by requesting same and providing their package shipping provider and account number.
- FIRST does not provide “spare” parts to teams. When possible, FIRST will provide teams with information on who to contact to obtain spare kit parts. However, due to the nature of how the Kit of Parts is assembled, there may be some kit parts for which spares are simply not available. Teams wishing to obtain extra parts for use in robot development or to have on hand as backup should utilize regular retail channels or consult the supplier contact information in *Appendix G*. If contact information for a part supplier is not listed in the supplier contact information, it is because they are not prepared to supply parts directly to teams.

NOTE: *Please do not contact parts suppliers if they are not listed in the supplier contact information.*

FIRST Policy on Replacement of Kit Parts at event sites.

Due to the continued growth of the FIRST Robotics Competition, we have had to change some of our policies on the replacement of various kit parts at event sites. Please read the following carefully. Many kit parts will no longer be available at any of the event sites. This is due to the continued increase in the number of teams as well as the difficulty in obtaining extras.

The following items will no longer be available at event sites:

Two Bolt Self Aligning Flange
Channel for Tape Drive
Crimping Tool
HDPE Block
LDPE Rod

The Entire Rod Container
The Entire Hardware bag
L & R Window Lift Brackets
Window Lift Triangular Mount

Batteries will be on limited supply for FINAL matches, and will be provided “On Stage” only. No extra batteries will be available at any other time during any Regional event and the National Championship.

No more than 2 of each type of motor will be given to any team at any Regional event and the National Championship. Example: Team XXX - Thursday morning needs 1 Van Door motor , 2 Fisher-Price and 2 Drill motors. They will not be eligible for any more Fisher-Price or Drill motors for the remainder of the event.

Please remember to use "Gracious Professionalism" when requiring new motors. FIRST does not have enough motors to provide for all teams at every event.

Loaner Control Systems at Regional events and the National Championship.

FIRST No longer provides replacements for electronic components at events. 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, such as Radio Modems, RC, OI, Wall Adapter, Spike Relay Module or Victor 883 Speed Controllers, a Credit Card number must be provided 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, Innovation First retains the right to bill the credit card number provided for the items borrowed.

These "loaner" items are on first-come first-served basis.

1.3.1 Innovation First Products

The following kit parts are Innovation First products:

- Operator Interface
- Robot Controller
- Radio Modems
- AC Adapter for Operator Interface
- Speed Controllers (Victor 883)
- Relay Modules (Spike)
- PWM/relay cables
- 9-pin cables
- 15-pin cables

Do not contact FIRST for repair or replacement of these items. These units are covered by a product warranty. Please visit the Innovation First web site at www.innovationfirst.com/firstrobotics/ for product support and/or to obtain an RMA #.

1.3.2 Motors and Drive Assemblies

NOTE: *If you modify the drive assembly, and a failure occurs, FIRST will not provide a replacement.*

There are a limited number of replacement motors and drive assemblies available. If you have a burned out motor or non-functional drive assembly, please do the following:

1. Fill out a photocopy of the problem report form in *Appendix F*. Ship the non-functional motor/drive assembly to FIRST. Teams are responsible for the shipping cost.
2. Seriously consider the fact that if a brand new motor or drive assembly failed with the current robot design, a replacement may also fail during a competition event. Carefully evaluate the shock loading of the drive assembly, the interim and overall gear ratios, and the driving techniques used.

FIRST will ship a replacement motor to the team via 2nd day UPS shipment within 1 business day of receipt. *If you want your shipment sent overnight, remember to provide your shipping provider (UPS, FED EX, etc.) and account number.*

1.3.3 All Other Kit Parts

1. Fill out a photocopy of the problem report form in Appendix F. Ship the non-functional part to FIRST. Teams are responsible for the shipping cost.
2. FIRST will ship a replacement to the team via 2nd day UPS shipment within 1 business day of receipt. *If you want your shipment sent overnight, remember to provide your shipping provider (UPS, FED EX, etc.) and account number.*

2. ROBOT ELECTRICAL SYSTEMS

This section covers power distribution and wiring rules for the robot and operator controls and gives examples of how to wire parts included in the kit to the Innovation First control systems. Please note that Innovation First provides control system documentation. Please use their web site: www.innovationfirst.com/firstrobotics/.

WARNING

Please read this and the following sections 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 miswiring. Teams will be required to correct wiring that is not configured according to this section and the control system rules in Appendix A before being allowed to compete.

2.1 Wiring the Robot

2.1.1 Power Distribution

Item / Location	Power Source
Battery	Electric power from a 12 Vdc sealed-lead-acid (SLA) battery passes through a 60A main circuit breaker to fuse panels.
Robot Controller, Relay Modules, Fans, LEDs, Optical Sensors	Power is distributed from the fuse panels via 20A auto-resetting breakers.
Speed Controllers	Power is distributed from the fuse panels via 30A auto-resetting circuit breakers.
All other electrical devices	Sensors, motors, the rotating light, valves, and the pump receive power from either the Robot Controller, Relay Modules, or Speed Controllers as described below.

For safety reasons, the 60A circuit breaker supplied in the kit must be wired in series with the +12 Vdc output terminal on the battery. Insulate both battery terminals with electrical tape.

CAUTION:

Do not connect anything other than the 60A main circuit breaker directly to the +12 Vdc battery output.

WARNING:

Be very careful to avoid short circuits:

The 12 Vdc SLA battery can deliver current in excess of 200 Amps for a sustained period of time (minutes). This level of power can make wires turn red hot and melt through the insulation in a fraction of a second, which can result in serious burns, scars, and/or other injuries. Short circuits can also destroy control system components, cause a fire, and/or cause the battery to leak highly corrosive acid or explode. Always make sure the breaker is in series with the battery output. Please be careful!

Although unlikely, it is possible that the large impact forces sometimes experienced by robots in competition matches could cause the lever on the main circuit breaker to switch to the off position. FIRST recommends using a quick-release fastening mechanism to hold the switch in place during matches. Holding the switch in the on position will not prevent the breaker from tripping in the event of an electrical overload.

Power from the battery must be distributed via the fuse panels included in the kit. Note that each fuse panel contains 6 or 12 fused (via the 20 or 30A circuit breakers) outputs connected to one input, and 12 non-fused outputs connected to a second input. The fused and non-fused sides are not connected, so that the panel can be used to distribute both 12 Vdc and Ground.

Figure 2.1 shows an example schematic for power distribution. For clarity, only the +12 Vdc distribution is shown. The non-fused portion of the fuse panel is used to distribute Ground.

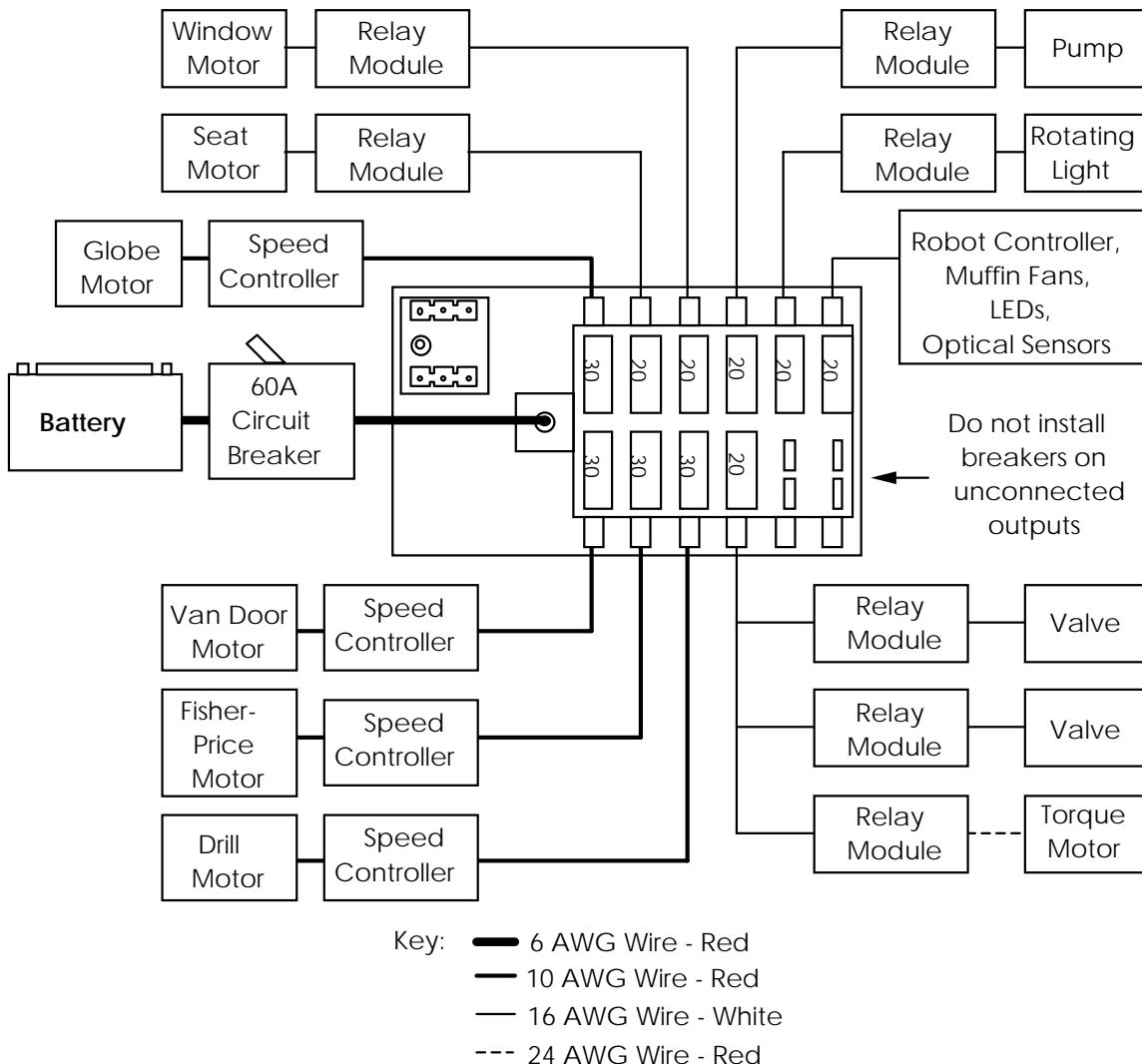


Figure 2.1: +12 Vdc power distribution

Note: Figure 2.1 shows seven relay modules in order to show how devices may be connected on your robot. Only four relay modules are provided in the kit. Additional relay modules may be obtained by purchasing them from Innovation First.

CAUTION:

Check wiring periodically.

Be sure to check the wiring on a periodic basis to prevent failures which 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 normal 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. Improper or abused connections can result in poor performance, intermittent failures, and/or short circuits.

In order to minimize mistakes and facilitate diagnosis of any problems, all wires distributing power with a constant polarity (i.e. not an output from a Relay Module, Speed Controller, or Sensor) must be color coded as follows:

- Use Red or White wire for +12 Vdc and +5 Vdc.
- Use Black wire for Ground.

The wires and cables included in the Kit are intended for specific uses. Table 2.1 shows the minimum wire sizes allowed for hookup of the various control system devices.

Table 2.1: Minimum Wire Size by Device Type

Device	Wire Type
Power distribution from battery to fuse panels	6 AWG, red & black
Drill motors, Fisher-Price motors, van door motors, Speed Controllers used with drill, van door, or Fisher-Price motors	10 AWG, red & black
Robot Controller power, Relay Modules, seat motors, window motors, Globe motors, pump, valves, large muffin fan, Speed Controllers (if used with seat, window, or Globe motors)	16 AWG, 2 conductor
All switches, PWM cables, optical sensors, potentiometers, yaw rate sensor, LEDs, small muffin fans, torque motor	24 AWG, 2 or 3 conductor

It is acceptable to shorten or lengthen control system cables containing 3 or less 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, or use 16 AWG wire to lengthen a connector for a seat motor.

Due to their high current requirements, the drill motors, Fisher-Price motors, Globe motors, and van door motors may only be powered by the Speed Controllers. The torque, seat, and window motors may be powered by Speed Controllers or Relay Modules. Use only Relay Modules to drive the rotating light, pump, and valves.

CAUTION

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. No more than one seat or window motor may be powered by a single Relay Module. A Relay Module may be used to power the torque motor, valves, and/or fans in conjunction with a single seat motor, window motor, pump, or rotating light. See section 2.1.3 for details on how to control more than one device with a single Relay Module.

Each Speed Controller must receive power via a dedicated 30A circuit breaker. 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 if no more than one of the following devices is powered via the 20A breaker: pump, rotating light, window motor, or seat motor. Other devices which may be connected directly to the fuse panel (Robot Controller, Fans, etc.) must be connected via a 20A circuit breaker. These devices may all be powered by the same breaker.

No devices other than the 60A main circuit breaker may be connected directly to the +12Vdc battery output. No devices other than the 20A and 30A circuit breakers in the fuse panels may be connected directly to the output of the 60A main circuit breaker.

The 12 Vdc panel mounted LEDs 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.

2.1.2 Rotating Light

A Relay Module must be used to power the rotating light provided in the kit. The light must turn on when the robot is enabled and turn off when the robot is disabled. The control system will provide this functionality automatically when a Relay Module is connected to relay output 8 on the Robot Controller and the default program is running. Wire the light such that the black power lead is connected to M- and the red power lead is connected to M+ on the Relay Module.

2.1.3 Relay Modules

There are two types of Relay Modules in use in the 2001 FIRST Robotics Competition. Both provide identical power handling capacity, but there is an important difference. *The different types of Relay Modules can be identified by the red or blue color of the “Spike” label.*

The “red” Relay Modules connect the M+ and M- outputs to +12 Vdc when in the off state. The “blue” Relay Modules connect the M+ and M- outputs to Ground when in the off state. On both types, M+ is connected to +12 Vdc and M- is connected to Ground when the Relay Module is in “Forward” mode, and vice versa for “Reverse” mode. Normally, the Relay Modules are connected across both leads of a DC motor, which means that both types provide equivalent bi-directional motor control. However, it may be desirable to utilize the M+ and M- outputs to independently control simple on-off devices or motors which only need to run in a single direction, in order to reduce the number of Relay Modules needed. If independent control of two devices is to be used, the wiring must be based on the type of Relay Module.

Figure 2.2 shows how to achieve independent control of two devices from a single Relay Module:

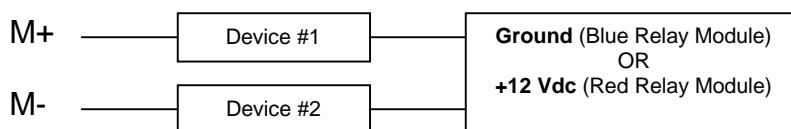


Figure 2.2: Controlling two devices with one Relay Module

Section 2.1.1 details what combinations of devices may be simultaneously powered by a Relay Module.

To achieve control of both solenoids on the double solenoid valve, use only one Relay Module, and avoid running separate power return leads, use the two diodes provided in the kit to route power to one solenoid at a time. Figure 2.3 shows the schematic for this arrangement.

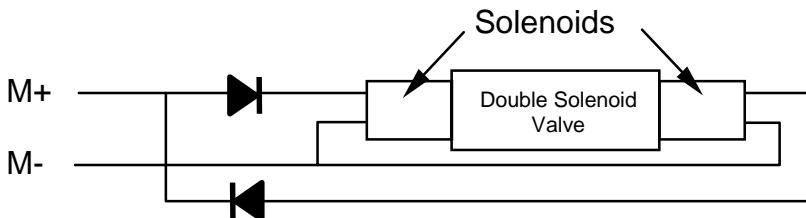


Figure 2.3: Use of Diodes with Double Solenoid Valve

Caution

The red Relay Modules will be damaged if reverse polarity is applied to the power inputs. Please be careful when wiring the relay modules.

For more information about the Relay Modules, refer to the documentation from Innovation First.

2.1.4 Speed Controllers

Caution

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

For information about the Speed Controllers, refer to the documentation from Innovation First.

2.1.5 Muffin Fans

Several 12V muffin fans are included in the Kit primarily for added protection against motor overheating. FIRST recommends installing these fans to direct cooling air over the components that run the hottest. You may provide constant power to the fans via a 20A circuit breaker or use a Relay Modules to switch power to the fans.

CAUTION

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.

2.1.6 Sensor Inputs on the Robot Controller

The exact wiring configuration for sensors connected to the Robot Controller 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 sensor system on the robot.

- Connect switches between Ground and the switch input pin of your choice.
- Connect potentiometers with +5 Vdc at one end and Ground at the other end. Connect the wiper to the analog input pin of your choice.

CAUTION

Do not connect switches to +5Vdc, it may damage the switches.

To connect the Yaw Rate Sensor to the Robot Controller, connect +5 Vdc (only use pin 1 - +5Vdc Aux. on the Analog Input port for power to this sensor) to the +5 Vdc input on the sensor, connect Ground to Ground, and connect the sensor output to the analog input pin of your choice. Output characteristics of the Yaw Rate Sensor are described in the manufacturers' specification sheets included in Appendix H.

CAUTION

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

Figure 2.4 shows an example of the proper way to connect a limit switch, potentiometer, yaw rate sensor, optical sensor, and pressure sensor to the Robot Controller.

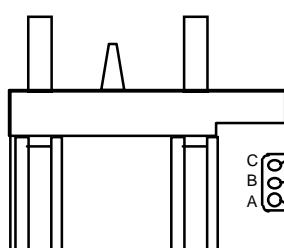
Potentiometer



Analog Inputs

- Pin 14 (+5 Vdc)
- Pin 2 (Analog Input 1)
- Pin 15 (Ground)

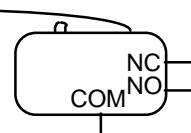
Yaw Rate Sensor



Analog Inputs

- Pin 16 (Analog Input 2)
- Pin 4 (Ground)
- Pin 1 (+5 Vdc)

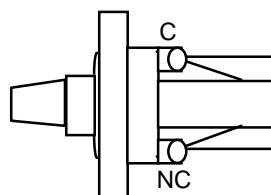
Limit Switch



Digital Inputs

- Pin 1 (Switch Input 1)
- Pin 14 (Ground)

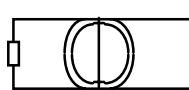
Pressure Switch



Digital Inputs

- Pin 6 (Ground)
- Pin 2 (Switch Input 2)

Optical Sensor



Digital Inputs

- Blue — Pin 3 (Ground)
- Brown — +12 Vdc (From breaker)
- Black — Pin 15 (Switch Input 3)
- White — Pin 16 (Switch Input 4)

Figure 2.4: Connection Examples for Robot Controller

2.2 Wiring the Operator Controls

2.2.1 Power Distribution

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

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

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

2.2.2 Sensor Inputs on the Operator Interface

The exact wiring configuration for the joysticks, switches, potentiometers, LEDs, and yaw rate sensor 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, teams may use the black project box as a housing for the switches, potentiometers, LEDs, and yaw rate sensor. When using the 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.

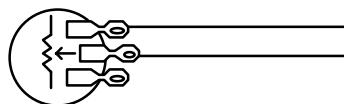
The +12 Vdc LEDs may be connected between +5Vdc and Ground or between an LED output and Ground to serve as a visual indicator to the robot operators. This can be helpful during a competition match when a robot operator may not have a good view of the Operator Interface. Connect switches between a switch input and Ground. *Do not use lighted switches with the Operator Interface unless the light is disabled.*

NOTE: Do not connect switches to +5Vdc.

The yaw rate 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 2.5 shows an example of the proper way to connect a switch, potentiometer, LED, and yaw rate sensor to the Operator Interface.

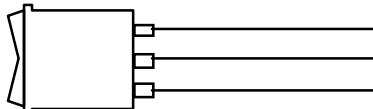
Potentiometer



Port 3

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

Rocker Switch



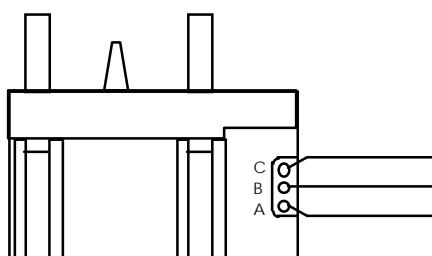
Pin 10 (Port 3 Aux Switch Input 1)
Pin 4 (Ground)
Pin 14 (Port 3 Aux Switch Input 2)

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 2.5: Connection Examples for Operator Interface

2.2.3 Dashboard Port

Teams are permitted to connect a portable computing device (Laptop computer, Palm Pilot, etc.) to the RS232 output of the Dashboard Port for the purpose of displaying feedback from the robot while competing in FIRST Robotics Competition matches. *Please note that AC power will not be available at the playing fields, so these devices will have to run on internal batteries.*

Innovation First offers pre-written software for such a purpose on their web site. 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 web site at www.innovationfirst.com/firstrobotics/.

2.3 Batteries and Chargers

Teams are responsible for managing the power consumption of their robot and for ensuring that their batteries are sufficiently charged to compete in each two-minute match. This means that 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 included in the Kit.

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 will cause serious damage to the battery, which 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 materials.

NOTE: If you have a battery that you know is damaged, please do not put it in the trash. Return the damaged battery to FIRST so that it can be recycled properly.

It is estimated that each battery can store sufficient energy to power a robot for at least 5 two-minute matches. Thus, it should not be necessary to swap batteries after each match.

Please adhere to the following:

- To connect the battery to the rest of the control system, FIRST recommends using ring terminal contacts and the red Anderson Power Products connectors. This allows for easy connection and disconnection of batteries in the robot.
- Although rare, the impact forces that robots sometimes experience during matches has 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.
- During any FIRST Robotics Competition event, the robots may only be powered by a single 12 Vdc SLA battery supplied by FIRST. You may charge these batteries through the normal operation of the battery charger that FIRST provides.

APPENDIX A: ROBOT RULES

The rules governing robot construction are divided into three sections. See below for an explanation of the labeling.

<u>Prefix</u>	<u>Rules Designation</u>
M	Machine Design & Operation
C	Control System
K	Kit Materials Usage and Limitations

M Machine Design & Operation Rules

M1. Energy used by FIRST Robotics Competition robots must come solely from:

- Electrical energy derived from the onboard battery.
- Storage achieved by deformation of springs or latex tubing.
- Compressed air stored in the pneumatic system, but only by the Pump included in the kit with a maximum pressure of 120 PSI.
- A change in the altitude of the device's center of gravity.

M2. Robots must:

- Sit, unconstrained, inside a 36"x30" rectangular footprint .
- Be no more than 60" high at the start of a match.
- Weigh not more than 130.0 pounds. (Weight limit includes battery and control system)

Size ≤ 36" long dimension x 30" short dimension x 60" high; Weight ≤ 130.0 pounds

TIP: *Keep in mind that these are maximum dimensions. It is recommended that you design your robot for slightly smaller dimensions and weights in order to allow a degree of tolerance for oversized/overweight mechanisms and differences in measurement between the team and the official inspection. Many teams have discovered the hard way that reducing size and/or weight while preserving functionality is no easy task after the robot has been constructed. Also, many shippers such as UPS will not ship packages as large as a full robot. Many teams have found it helpful to make ease of disassembly and reassembly one of their design goals.*

- M3. All robots will be inspected, weighed, and measured during the practice day at each FIRST Robotics Competition event. The robot must pass inspection before competing in any competition matches. Robots may be re-inspected at anytime during an event at the discretion of FIRST. If modifications to your robot are necessary to comply with the Robot Rules, you must complete them before the robot will be allowed to compete in further competition matches. If a team wishes to have their robot re-inspected to ensure rules compliance, they may ask FIRST officials to do so. 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.
- M4. Teams are expected to design and build robots to withstand vigorous interaction with other robots.

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- M5. Until the controls are enabled at the beginning of each match, robots must remain unconstrained within the 36"x30"x60" starting size. Once a match begins, robots may extend beyond that limit under their own power.
- M6. Robots must be designed to operate by reacting against the surface of the playing field, the innermost face of the 4x4 field border, the bridge, the horizontal rail dividing the field, the goals, the balls, the other robots, and the air. Robots should not be designed to react off of the top face of the 4x4 field border or other parts of the field border. If your robot inadvertently drives on the top of the 4x4 field border, you will not be penalized unless the playing field is damaged.
- M7. Robots must display their team company and school names and/or logos. The judges, referees, and announcers must be able to easily identify them by name. In addition, teams must display their number on at least two opposite sides (180 degrees apart) of the robot. Numbers should be at least 5 inches high and clearly visible from a distance of not less than 50 feet.
- M8. Robots must use the rotating light provided in the kit to display starting position color (red, blue, yellow, or green). The light must be mounted on the robot such that the color is visible in at least 4 locations 90 degrees apart around the sides of the robot from a distance of at least 50 feet. The light should be mounted to allow easy changeover of the colored lens before matches. *See Section 2.1.2 for wiring information.*
- M9. Teams may add “Non-functional” decorations to robots under the following conditions:
- Decorations must not cause the robot weight or size to exceed initial requirements.
 - Decorations must not affect the outcome of the match.
 - Any decorations which involve broadcasting a signal to/from the robot, such as remote cameras, must be cleared with FIRST prior to use.
 - Decorations may draw power from the control 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.
 - Non-functional decorations do not count against the cost limit on parts from **SMALL PARTS, INC.** or the quantity limits on Additional Hardware List items.
 - Decals, paint, bumper stickers, etc. are considered non-functional decorations.
- M10. You must design your Robot to be operated by the wireless, programmable control system.
- M11. Gaining traction by using adhesives or by damaging the surface of the playing field or the balls is not allowed. Using Velcro to adhere to the carpet has the potential to damage the carpet and is therefore prohibited.
- M12. During robot inspection, you must present *all* mechanisms that will be used on the robot at the event. It is acceptable, however, for a robot to play matches with a subset of the mechanisms that were present during inspection. Mechanisms that were present during the inspection may be added, removed, or reconfigured between matches. Also, you may reprogram the control system between matches.
- M13. No substitute robots are permitted; however, “functionally identical” replacement parts are allowed. “Functionally identical” implies it is a part that is of the same geometry, materials, etc. and not an improved design.

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- M14. Only items listed under the PNEUMATICS section of the Kit list may be used to store, generate, or transmit compressed air or vacuum, with the following exceptions:
- Suction cups may be fabricated from legal Kit parts, as defined in rule K1 below.
 - Tubing may be compressed in order to block the flow of air.
 - Tubing may not be compressed in order to generate compressed air or vacuum.
- Not Allowed: Custom-made pneumatic components (fittings, air cylinders, pumps, valves, etc). You may not use materials from SMALL PARTS INC (tubing, fittings, etc.) for pneumatics.*
- M15. Pneumatic components supplied in the Kit (pump, regulators, cylinders, valves, fittings, tubing, etc.) may not be modified except as follows:
- 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.
 - The pressure switch may be calibrated by the normal operation of the adjustment screw.
 - Mounting and connecting pneumatics components using the pre-existing threads, mounting brackets, etc. is not considered a modification of the components.
- M16. All mechanisms on the robot should be fabricated/assembled by the 2001 team after the start of the Kick-off Workshop. Mechanisms may not be reused from previous year's robots.
- M17. Referees may disallow mechanisms which present a risk of entanglement.
- M18. 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 Torque motors are not considered "integral" and may be separated from the motors. FIRST will not provide replacement for parts that fail due to modification.

C Control System Rules

- C1. 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, Power Supply, 9 pin cables, circuit breakers, fuses, and joysticks may not be tampered with, modified, or adjusted in any way, with the following exceptions:
- The dip switches on the Operator Interface and Robot Controller may be set as appropriate.
 - The program select jumper on the Robot Controller 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.
- Tampering includes drilling, cutting, machining, gluing, rewiring, etc. All items listed in Rule C1 must be mounted without alteration*
- C2. The Radio Modem connected to the Operator Interface must be able to reach the mounting bracket on the operator stations. Be sure to leave sufficient slack in the 9 pin cable.
- C3. The black project box is intended to serve as a mounting point for the rocker switches, push button switches, and potentiometers used by the robot operators. You may also use it to enclose the associated wiring. You may modify the project box in any manner to accommodate your needs.

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- C4. The wire supplied in the Kit may be used to conduct electricity. The chassis of the robot may not be used to conduct electricity. You may use additional wire as long as it meets the gauge and insulation color requirements as described in Section 2.
- C5. Electrical devices may only be wired as described in Section 2 and/or the Robot Rules.
- C6. You must use six gauge wire to connect the battery to the 60A main circuit breaker and fuse panels.
- C7. You must use ten gauge or larger diameter wire for connections to and from the Speed Controllers if they are used with the drill, Fisher-Price, or van door motors.
- C8. You must use sixteen gauge or larger diameter wire to connect Globe, seat, or window lift motors to the Speed Controllers, from the Fuse Panels to the Robot Controller, for the large muffin fan, and for any connections to and from the Relay Modules. The only exceptions are that 24 AWG wire may be used to connect the Torque motor, small muffin fans, and any LEDs to the outputs of a Relay Module.
- C9. You must use twenty-four gauge or larger diameter wire for connecting sensors (switches, potentiometers, yaw rate sensor) to inputs, for extending the PWM cables, for the small muffin fans, or for wiring the LEDs.
- C10. No more than one window motor or seat motor may be powered by a Relay Module. Section 2.1.1 details acceptable Relay Module output configurations.
- C11. Only the Robot Controller, Relay Modules, 12 Vdc LEDs, and muffin fans may be connected directly to the fused battery outputs.
- C12. The drill motors, Fisher-Price motors, Globe motors, and van door motors may only be powered by the Speed Controllers. Do not connect the drill motors, Fisher-Price motors, Globe motors, or van door motors to the Relay Modules.
- C13. No more than one drill motor, Fisher-Price motor, Globe motor, or van door motor may be powered by each Speed Controller.
- C14. The seat motors, window lift motors, and 12 Vdc LEDs may be powered by the Speed Controllers or the Relay Modules. A maximum of two of these types of motors may be powered by each Speed Controller.
- C15. One 30A circuit breaker (provided in the Kit) must be installed in series with each Speed Controller on the +12 Vdc input. All circuit breakers must be accessible for inspection at each FIRST Robotics Competition event.
- C16. You must install the 60A circuit breaker in series with the positive terminal of the battery, such that all battery output flows through this fuse before being distributed to any electrical component on the robot. The breaker must be accessible for inspection at each FIRST Robotics Competition event.
- C17. Do not connect 12 Vdc power, Relay Module outputs, Speed Controller outputs, or PWM outputs to the analog or switch inputs on the Robot Controller.

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- C18. You must connect all sensors used on the robot directly to the analog or switch inputs on the Robot Controller. Sensors may not be wired in series with the motors. It is acceptable to wire switches in series or parallel with each other
- C19. If the control system is damaged due to improper wiring or misuse, Innovation First will charge for repair or replacement of the affected items.
- C20. During each competition match, your robot may contain only one of the two batteries provided by FIRST.
- C21. When recharging Kit batteries, you may only use the charger provided by FIRST.
- C22. All wires distributing power with a constant polarity (i.e. not a Relay Module, Speed Controller, 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 Ground connections.
- C23. Teams are responsible for any software bugs introduced into the Robot Controller's control program when using a custom program.
- C24. The Robot Controller must be positioned within the robot so that its LED's may be seen during operation in a match. This will greatly facilitate analysis in case of problems and will be beneficial to you and field personnel during the FIRST Robotics Competition.
- C25. Position the 12 Vdc battery within your robot so that it is accessible and may be easily changed out between matches. The terminals on the battery must be insulated with electrical tape to reduce the risk of short circuits.
- C26. The rotating light provided in the kit must be powered by a Relay Module such that it turns on when the robot is enabled, and turns off when the robot is disabled. Section 2.1.2 details how to do this.
- C27. The team number settings on the Robot Controller and Operator Interface must be set to the team number assigned to the team by FIRST.

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K Kit Materials Usage & Limitations

K1. Each robot must be constructed exclusively from materials provided in the Kit of Parts ("the Kit") supplied by FIRST, with the following additions and exceptions:

- Material available from outside sources, as explained below.
- The Kit containers, part packaging, and any documentation in the Kit container may not be used to build the device.
- Adhesive tape may not be used except as an electrical insulator.
- Lubricants may be used to reduce friction within the robot.

Outside Sources - SMALL PARTS, INC. Catalog

- Each team receives a SPARK (SMALL PARTS Addition to the Robotics Kit) certificate which provides a grant to each team as follows:
 - The first \$200 in purchases – FREE.
 - The next \$1000 in purchases – at a 50% Discount.
 - Beyond \$1200 in purchases – Stated Catalog or Bulletin price.
- See Appendix D for more details on SPI Ordering Information
- Up to \$1200 worth of drive components, materials and parts purchased from **SMALL PARTS, INC.** (SPI) may appear in your final robot. You may go beyond this dollar limitation for prototyping or to purchase spare parts from SPI, but only \$1200 may appear in your final robot. *Items which appear in the Additional Hardware List do not count against the \$1200 SPI limit.* When your robot is inspected at a competition, you will be asked to verify that you have not used more than \$1200 worth of materials from SPI on your robot. Be prepared to show documentation to support this requirement, e.g. a bill of materials and purchase prices.
- If you use only a portion of what you buy from **SMALL PARTS, INC.** you may prorate the dollar amount used to the smallest quantity listed for purchase in the catalog.

Example: If you buy 5' of rod which could have been purchased by the foot, but end up using only 6", you may calculate the amount used as the purchase price for one foot (the minimum amount that you could have purchased in order to build your robot). If the price per foot is higher for a one foot rod than for a five foot rod, you must use the higher per foot price.

Outside Sources - Additional Hardware List

- *Materials on the Additional Hardware List may be obtained from any supplier and are not limited by cost, but may be limited by quantity.* A specific list of materials and maximum quantities/dimensions is provided in Appendix C.
- If an item on the Additional Hardware List is available from **SMALL PARTS, INC.** (SPI), then it may be purchased from SPI without being counted against the \$1200 limit on SPI parts used on the robot. However, any amount of the item purchased from SPI beyond the quantity limit in the Additional Hardware List will count against the \$1200 limit on SPI parts used on the robot.

K2. Many of the materials in the Kit are raw materials. They are intended to be used for manufacturing structural or mechanical parts for your robot.

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- K3. Items listed in the Additional Hardware List must be "commercially available," strictly *off-the-shelf* only. No custom or special orders. Items that are normally purchased in a custom size, such as an off-the-shelf belt cut to length for the customer, are not considered custom or special orders.
- K4. For safety reasons, you may not fabricate your own springs. However, it is acceptable to elastically deform and relax materials not designated as springs as long as the rate at which the energy is released does not exceed the rate at which the energy was stored. This is intended to allow reasonable use of the elastic properties of materials without creating unsafe conditions caused by sudden release of stored energy in materials not designed to act as springs. Materials which are designated as springs include:
- All items listed in the Springs section of the Kit List.
 - Springs from **SMALL PARTS, INC.**
 - Latex tubing.
- Pneumatic actuators may not be modified or plugged in any way for use as a spring.
- K5. A limited number of replacement parts will be made available by FIRST upon justified request.
- K6. Teams may replace lost or damaged Kit materials only with identical components of the same material, dimensions and treatment.
- K7. 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
 - Resin and hardener may be mixed to produce epoxy.
 - Metal may be heat treated
 - Metal may be anodized to improve appearance
- The melting and recasting of materials, such as a block of aluminum, is allowed as long as the basic alloy or chemical composition is not changed. Note, however, that other rules restrict which parts may and may not be modified. For example, the motors and pneumatic cylinders in the kit may not be melted and recast.
- K8. The mailing tube provided in the Kit is considered packaging material and may not be used on the robot.
- K9. Although SPI can special order parts in sizes other than those listed in the catalog, special ordered parts may not be used on the robot unless the catalog specifically mentions, on the same page as a given type of parts, that sizes other than those listed are available. One of the reasons for using the SPI catalog is to ensure all teams have equal access to parts. This helps to create a "level playing field" for all teams. Allowing a team to use a part that other teams did not know was available would be unfair.
- K10. The robot may not contain more than one of the batteries provided in the kit during a match.

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APPENDIX B: KIT OF PARTS

2001 FIRST Robotics Competition Kit Parts

Bearings

Part Name/Description	Dimensions	Location	Qty /Kit	Product Supplier
Pillow Block	1/2"	Green Container - Bearing Bag	2	The Torrington Company
Radial Ball Bearing With Spherical O.D.	1/2" I.D., Self Locking Collar	Green Container - Bearing Bag	4	The Torrington Company
Roller Clutch	3/8" I.D.	Green Container - Bearing Bag	2	The Torrington Company
Single Row Radial Flanged Ball Bearing	1/4" I.D.	Red Container - Miscellaneous Bag	4	The Torrington Company
Single Row Radial Flanged Ball Bearing	3/8" I.D.	Green Container - Bearing Bag	4	The Torrington Company
Two Bolt Self Aligning Flange	Fits 1/2" Bearing	Green Container - Bearing Bag	8	The Torrington Company

Control System

Part Name/Description	Dimensions	Location	Qty /Kit	Product Supplier
1 Conductor Wire	10', #6 AWG, Black	Red Container - Loose	1	Delphi Packard Electric Systems
1 Conductor Wire	10', #6 AWG, Red	Red Container - Loose	1	Delphi Packard Electric Systems
1 Conductor Wire	35', #10 AWG, Black	Red Container - Loose	1	BICC General
1 Conductor Wire	35', #10 AWG, Red	Red Container - Loose	1	BICC General
15 Pin Molded Cable	DB15 pin M-F, 6 feet	Green Container - Loose	2	Innovation First
15 Pin Solder Cup Connector	DB15 Female	Green Container - Electronics Bag	2	AMP Foundation
2 Conductor Jacketed Wire	30', #24 AWG	Red Container - Loose	1	BICC General
2 Conductor Jacketed Wire	35', #16 AWG	Red Container - Loose	1	BICC General
25 Pin Solder Cup Connector	DB25 Male	Green Container - Electronics Bag	2	AMP Foundation
3 Conductor Shielded Wire	30', #24 AWG	Red Container - Loose	1	BICC General
9 Pin Cable	DB9 Male to Female, 6', Shielded	Green Container - Loose	4	Innovation First
Anderson Power Products Catalog	Catalog	Green Container - Loose	1	Anderson Power Products
Battery	12 volt	Green Container - Loose	2	Exide
Battery Charger	Sealed Lead Acid Battery, 4 amp	Red Container - Loose	1	Xenotronix
Circuit Breaker	20 amp, 12 volt, Auto-Resetting	Green Container - Electronics Bag	6	Snap-Action, Inc.

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Circuit Breaker	30 amp,12 volt, Auto-Resetting	Green Container - Electronics Bag	6	Snap-Action, Inc.
Circuit Breaker	60 Amps, Ratings: 1-63A set at 77°F	Green Container - Electronics Bag	1	SquareD
Connector for Seat Motor	2 pin, 16 AWG x 12" cable	Red Container - Loose	2	Delphi Packard Electric Systems
Connector for Window Motor	2 pin, 16 AWG x 12" cable	Red Container - Loose	2	Delphi Packard Electric Systems
Connector for Yaw Rate Sensor	3 pin, 24 AWG x 12" cable	Red Container - Loose	1	Delphi Packard Electric Systems
Diode	Max:1 Amp, 50V (peak rev.)	Green Container - Electronics Bag	2	Brevan
Flightstick Joystick	7" Cable with Male DB15	Green Container - Loose	2	CH Products
Fuse Panel	ATC, 12 fuseable, 12 unfused	Green Container - Electronics Bag	1	Bussmann
Fuse Panel	ATC, 6 fuseable,6 unfused	Green Container - Electronics Bag	1	Bussmann
Heat Shrink Tubing	1/2"Ø x 6", Black, 2:1 Shrink Ratio	Red Container - Miscellaneous Bag	1	Brevan
Heat Shrink Tubing	1/4"Ø x 6", Black, 2:1 Shrink Ratio	Red Container - Miscellaneous Bag	1	Brevan
Heat Shrink Tubing	1/8"Ø x 6", Black, 2:1 Shrink Ratio	Red Container - Miscellaneous Bag	1	Brevan
Heat Shrink Tubing	3/16"Ø x 6", Black, 2:1 Shrink Ratio	Red Container - Miscellaneous Bag	1	Brevan
Heat Shrink Tubing	3/4"Ø x 6", Black, 2:1 Shrink Ratio	Red Container - Miscellaneous Bag	1	Brevan
Heat Shrink Tubing	3/8"Ø x 6", Black, 2:1 Shrink Ratio	Red Container - Miscellaneous Bag	1	Brevan
Knob for Potentiometer	1" Hexagon, Fits 1/4" Shaft	Green Container - Electronics Bag	2	Radio Shack
LED, Panel Mount	Amber, 12V	Red Container - Miscellaneous Bag	2	Chicago Miniature Lamp, Inc.
LED, Panel Mount	Green, 12V	Red Container - Miscellaneous Bag	4	Chicago Miniature Lamp, Inc.
LED, Panel Mount	Red, 12V	Red Container - Miscellaneous Bag	1	Chicago Miniature Lamp, Inc.
Limit Switch		Green Container - Electronics Bag	10	Honeywell - Microswitch Division
Momentary Rocker Switch		Green Container - Electronics Bag	4	Honeywell - Microswitch Division
Muffin Fan	12 Vdc	Green Container - Loose	1	EBM Industries
Muffin Fan (Tiny)	12 Vdc	Green Container - Electronics Bag	4	EBM Industries

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Operator Interface		Red Container - Loose	1	Innovation First
Plastic Shield for 25 Pin Connector	fits DB25 Connector	Green Container - Electronics Bag	2	AMP Foundation
Potentiometer	100 k Ohms, linear taper	Red Container - Miscellaneous Bag	2	Radio Shack
Potentiometer	100KΩ, Linear	Green Container - Electronics Bag	2	Bourns, Inc.
Power Supply for Operator Interface	9 Vdc	Red Container - Loose	1	Innovation First
Project Box	Black	Red Container - Loose	1	Serpac
PWM/Relay Cable	Hitec/JR-style, 36" Long	Red Container - Miscellaneous Bag	8	Innovation First
PWM/Relay Y Cable	Hitec/JR-style, 24" Long	Red Container - Miscellaneous Bag	2	Innovation First
Quick-Disconnect Power Connector (with 1' leads)	#6 AWG Red/Black Wire	Green Container - Loose	2	Anderson Power Products
Radio Modem for Operator Interface	RS-422, 9 pin F, metal antenna	Red Container - Loose	1	Innovation First
Radio Modem for Robot Controller	RS-422, 9 pin F, rubber antenna	Red Container - Loose	1	Innovation First
Reed Switch	Normally Open, Magnet Activated	Green Container - Electronics Bag	4	CP Clare
Relay Module (Spike)	12V, 20A Max	Red Container - Loose	4	Innovation First
Revolving Light	w/ red amber,green,blue lenses	Green Container - Loose	1	North American Signal
Ring Connector	# 10-12 Awg, #6 lug	Green Container - Electronics Bag	20	Thomas & Betts Corp.
Ring Connector	# 14-16 Awg, #6 lug	Green Container - Electronics Bag	10	Thomas & Betts Corp.
Ring Connector	# 22-26 Awg, #6 lug	Green Container - Electronics Bag	7	Thomas & Betts Corp.
Ring Connector	# 6 Awg	Green Container - Electronics Bag	10	Thomas & Betts Corp.
Robot Controller		Red Container - Loose	1	Innovation First
Rocker Switch Cover	Blue	Red Container - Miscellaneous Bag	1	Honeywell - Microswitch Division
Rocker Switch Cover	Green	Red Container - Miscellaneous Bag	1	Honeywell - Microswitch Division
Rocker Switch Cover	Red	Red Container - Miscellaneous Bag	1	Honeywell - Microswitch Division
Rocker Switch Cover	Yellow	Red Container - Miscellaneous Bag	1	Honeywell - Microswitch Division

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Servo	42 oz. in. Peak, 0.19 s/60°	Green Container - Electronics Bag	2	Hitec RCD, Inc.
Spade Connector	Female, 12-10 AWG, Yellow	Red Container - Miscellaneous Bag	5	Thomas & Betts Corp.
Spade Connector	Female, 16-14 AWG, Blue	Green Container - Electronics Bag	7	Thomas & Betts Corp.
Spade Connector	Female, 22-18 AWG, Red	Green Container - Electronics Bag	9	Thomas & Betts Corp.
Spade Connector	Male, 12-10 AWG, Yellow	Red Container - Miscellaneous Bag	5	Thomas & Betts Corp.
Spade Connector	Male, 16-14 AWG, Blue	Green Container - Electronics Bag	8	Thomas & Betts Corp.
Spade Connector	Male, 22-18 AWG, Red	Green Container - Electronics Bag	10	Thomas & Betts Corp.
Speed Controller (Victor 883)		Red Container - Loose	4	Innovation First
Wire Nut	Wire Nut for Wire Sizes #18-10 AWG	Green Container - Electronics Bag	10	Thomas & Betts Corp.
World-Beam Diffuse Sensor		Green Container - Electronics Bag	2	Banner Engineering Corporation
Yaw Rate Sensor		Red Container - Loose	1	BEI Systron Donner

Documentation

Part Name/Description	Dimensions	Location	Qty /Kit	Product Supplier
BASIC Stamp Programming Disk	CD-ROM	Red Container - Loose	1	Parallax, Inc.
BASIC Stamp Programming Manual		Red Container - Loose	1	Parallax, Inc.
Kee Klamp Pipe Fitting Catalog		Red Container - Loose	1	Kee Industrial Products
Small Parts Catalog		Red Container - Loose	2	Small Parts, Inc.

Fasteners

Part Name/Description	Dimensions	Location	Qty /Kit	Product Supplier
5 Minute Epoxy Gel	Resealable 1 oz. Dual Syringe	Red Container - Miscellaneous Bag	1	Kaman Industrial Technologies
Cable Tie	7" x 0.09"	Green Container - Electronics Bag	12	Thomas & Betts Corp.
Cable Tie Mounting Base	Self-Adhesive, #8 Holes	Green Container - Electronics Bag	10	Thomas & Betts Corp.
Drill Housing Screws	#4 x 3/4, Pan Head - Phillips	Red Container - Miscellaneous Bag	16	Fastenal Company
Drill Motor / Gearbox Screw	M4 x 6mm, Button Head 19	Red Container - Miscellaneous Bag	4	Fastenal Company
Helical Plastic Wire Wrap	1/2" Ø x 24"	Green Container - Hardware Bag	1	Tyton Hellermann

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Helical Plastic Wire Wrap	1/4" Ø x 24"	Green Container - Hardware Bag	1	Tyton Hellermann
Polyethylene grommet	3/16" x 24"	Green Container - Hardware Bag	1	Tyton Hellermann
Polyethylene grommet	3/8" x 24"	Green Container - Hardware Bag	1	Tyton Hellermann
Torque Motor Anti-Rotation Bracket		Red Container - Miscellaneous Bag	1	Belimo Aircontrols, Inc.
Velcro 1" Hook & Loop Tape	36" Length, Adhesive Backing	Green Container - Velcro Bag	1	Velcro USA, Inc.
Velcro 1" One Wrap Tape	24" Lengths, Black	Green Container - Velcro Bag	1	Velcro USA, Inc.
Velcro 18" One Wrap grip tie	1"x18" grip tie	Green Container - Velcro Bag	2	Velcro USA, Inc.
Velcro 5/8" One Wrap Tape	24" Lengths, Black	Green Container - Velcro Bag	1	Velcro USA, Inc.
Velcro 8" One Wrap grip tie	1"x8" grip tie	Green Container - Velcro Bag	10	Velcro USA, Inc.
Velcro Grip Ties	8" x 1.75"	Green Container - Velcro Bag	2	Tyton Hellermann
Velcro Sticky Back Coins	5/8" Ø x 36" (48 sets)	Green Container - Velcro Bag	1	Velcro USA, Inc.

Field Components

Part Name/Description	Dimensions	Location	Qty /Kit	Product Supplier
Big Colored Ball	34" Ø ball	Red Container - Loose	1	Sport Fun
Small Black Ball	13" Ø black ball, w/ plastic plug	Red Container - Loose	1	Sport Fun

Misc Hardware

Part Name/Description	Dimensions	Location	Qty /Kit	Product Supplier
Channel For Tape Drive	28" Long	Red Container - Loose	4	Delphi Interior and Lighting Systems
Double Magnet Cabinet Catch		Green Container - Hardware Bag	1	Stanley Hardware
Drill Housing Cover		Green Container - Drill Bag	2	S-B Power Tool Company
Flange Nut for Seat Positioning Unit	M6 x 1.0 Pitch	Red Container - Seat Positioning	8	Delphi Automotive (Lear)
Flat Washers	1/4" I.D., 7/8" O.D.	Green Container - Hardware Bag	4	Fastenal Company
Flexible Shaft Coupling	Black	Red Container - Seat Positioning	2	DEKA
Gate Latch	Steel/Zinc Plated	Red Container - Hardware Bag	1	Stanley Hardware
Hex Head Bolt for Seat Positioning Unit	M6 x 1.0 Pitch x 30mm	Red Container - Seat Positioning	4	Lear Corporation

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Hex Nuts	1/4" I.D., 20 Pitch Coarse Thread	Green Container - Hardware Bag	8	Fastenal Company
Horiz. Act. (L) for Seat Positioning Unit, Left Hand	Black	Red Container - Seat Positioning	1	Lear Corporation
Horiz. Act. (R) for Seat Positioning Unit, Right Hand	Black	Red Container - Seat Positioning	1	Lear Corporation
Lower Channel for Seat Positioning Unit	2.25" x 17" Channel	Red Container - Loose	1	Lear Corporation
Magnet	1/4-20 Plastic Thread	Green Container - Hardware Bag	2	Honeywell - Microswitch Division
Pivot	5/16" Ø	Green Container - Hardware Bag	2	Stanley Hardware
Screen Door Holder	Zinc-Plated	Green Container - Hardware Bag	1	Stanley Hardware
Upper Channel for Seat Positioning Unit	1.3125" x 9.875" Channel with Gear	Red Container - Seat Positioning	2	Lear Corporation
Window Lift Bracket, Left Hand	Color Natural	Green Container - Window Lift	1	Delphi Interior and Lighting Systems
Window Lift Bracket, Right Hand	Color Natural	Green Container - Window Lift	1	Delphi Interior and Lighting Systems
Window Lift Gear	Use with Window Tape, Window Lift Mechanism	Green Container - Window Lift	2	Delphi Interior and Lighting Systems
Window Lift Guide Drive	Use with Guide, Channel, Window Tape	Green Container - Window Lift	8	Delphi Interior and Lighting Systems
Window Lift Guide, Left Hand	Attach to Triangular Mount, Window Lift	Green Container - Window Lift	1	Delphi Interior and Lighting Systems
Window Lift Guide, Right Hand	Attach to Triangular Mount, Window Lift	Green Container - Window Lift	1	Delphi Interior and Lighting Systems
Window Lift Mechanism Tape	16' Length	Green Container - Window Lift	1	Dymetrol Company, Inc.
Window Lift Triangular Mount	White, Window Lift Mechanism	Green Container - Window Lift	2	St. Clair Plastics Company

Motors & Pumps

Part Name/Description	Dimensions	Location	Qty /Kit	Product Supplier
Drill Drive Assembly	225 in-lb max, 3/8-24 UNF outer, M5 X 0.8	Green Container - Drill Bag	2	S-B Power Tool Company
Drill Housing Kit w/ Shift Lever	T-Handle Style Grip, Left/Right	Green Container - Drill Bag	2	S-B Power Tool Company
Drill Motor	12 Vdc	Green Container - Drill Bag	2	S-B Power Tool Company
Fisher-Price 10 Web Jeep Driver	Black	Green Container - Loose	2	Fisher-Price, Inc.
Fisher-Price Axle	7/16" Ø x 26"	Green Container - Loose	1	Fisher-Price, Inc.
Fisher-Price Motor/Gearbox	12 Vdc motor	Green Container - Loose	2	Fisher-Price, Inc.

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Globe Motor with Drive Assembly	12Vdc	Green Container - Loose	2	Globe Motors
Seat Motor	12 Vdc	Red Container - Loose	2	Delphi Automotive
Torque Motor		Red Container - Loose	1	Belimo Aircontrols, Inc.
Van Door Motor - Bosch	12 Vdc, 75 RPM	Red Container - Loose	2	Bosch Automotive
Window Motor, Left Hand	12 Vdc, 12 Tooth Pinion, 16 pitch stub	Red Container - Loose	1	Delphi Automotive (Valeo)
Window Motor, Right Hand	12 Vdc, 12 Tooth Pinion, 16 pitch stub	Red Container - Loose	1	Delphi Automotive (Valeo)

Other

Part Name/Description	Dimensions	Location	Qty /Kit	Product Supplier
Carpet Sample	12" x 12", 20 oz., Closed Loop	Green Container - Loose	1	FIRST
Co-Polymer Gutter Guard	6" x 24"	Red Container - Loose	1	Home Depot

Rods & Shafts

Part Name/Description	Dimensions	Location	Qty /Kit	Product Supplier
Aluminum Rod	1/2" Ø x 24"	Red Container - Tube	2	Cohen Steel Supply Inc.
Delrin (Acetal) Rod	1/4" Ø x 20"	Red Container - Tube	1	Plastic Supply
Drill Rod	1/2" Ø x 18"	Red Container - Tube	2	Cohen Steel Supply Inc.
Drill Rod	1/4" Ø x 18"	Red Container - Tube	2	Cohen Steel Supply Inc.
Drill Rod	3/8" Ø x 18"	Red Container - Tube	2	Cohen Steel Supply Inc.
Drill Rod	5/16" Ø x 18"	Red Container - Tube	2	Cohen Steel Supply Inc.
Flexible Motor Shaft	13.5" Long, Fits Seat Motor	Red Container - Seat Positioning	2	Grand Rapids Controls
LDPE Rod	1" Ø x 24"	Red Container - Loose	1	Plastic Supply Inc.
Lead Screw	3.5" Long	Red Container - Miscellaneous Bag	1	Kerk Motion Products, Inc.
Lead Screw	8" Long	Red Container - Miscellaneous Bag	1	Kerk Motion Products, Inc.
Lead Screw Nut	Nut	Red Container - Miscellaneous Bag	2	Kerk Motion Products, Inc.
Threaded Rod	1/4" Ø x 20", 20 Pitch Coarse Thread	Red Container - Tube	1	Fastenal

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Sheets & Boards

Part Name/Description	Dimensions	Location	Qty /Kit	Product Supplier
HDPE Block	1" x 2" x 6"	Red Container - Loose	1	Plastic Supply

Springs

Part Name/Description	Dimensions	Location	Qty /Kit	Product Supplier
Compression Spring	0.600" O.D. x 2.25 " Long	Green Container - Hardware Bag	2	Associated Spring Raymond
Constant Force Spring, Extra Small	0.34" I.D.	Green Container - Hardware Bag	2	Associated Spring Raymond
Constant Force Spring, Large	1.02" I.D.	Green Container - Hardware Bag	2	Associated Spring Raymond
Constant Force Spring, Medium	0.59" I.D.	Green Container - Hardware Bag	2	Associated Spring Raymond
Constant Force Spring, Small	0.51" I.D.	Green Container - Hardware Bag	2	Associated Spring Raymond
Extension Spring	0.650" O.D. x 2.000" Long	Green Container - Hardware Bag	2	Associated Spring Raymond
Latex Tubing	1/4" I.D., 3/8" O.D., 5'	Red Container - Loose	1	McMaster-Carr
Snugger	Spring With Plastic Guide	Green Container - Hardware Bag	2	Stanley Hardware
Torsion Spring, Left Hand	180 Degrees, 0.404" Dia , 0.048" Wire Diameter	Green Container - Hardware Bag	2	Associated Spring Raymond
Torsion Spring, Right Hand	180 Degrees, 0.404" Dia , 0.048" Wire Diameter	Green Container - Hardware Bag	2	Associated Spring Raymond

Sprockets & Pulleys

Part Name/Description	Dimensions	Location	Qty /Kit	Product Supplier
Pulley With Fixed Eye	1" Ø, For 5/16" Rope	Green Container - Hardware Bag	3	Stanley Hardware

Tool

Part Name/Description	Dimensions	Location	Qty /Kit	Product Supplier
Crimping Tool for Spade/Ring Connectors	Orange/Black Color	Green Container - Loose	1	Thomas & Betts Corp.

Wheels

Part Name/Description	Dimensions	Location	Qty /Kit	Product Supplier
Caster, W/ 1/2-13x1 1/2 stem	300 Pounds, swivel	Green Container - Loose	2	Fastenal
Wheelchair Wheel	6" Ø, 5/16" I.D. Bearings, 1-1/2" Wide	Red Container - Loose	2	Skyway Recreation Products
Wheelchair Wheel	8" Ø, 5/16" I.D. Bearings, 1-1/2" Wide	Red Container - Loose	2	Skyway Recreation Products

APPENDIX C: ADDITIONAL HARDWARE LIST**Control System**

Andersen Power Products Powerpole Modular Connectors	Any amount/size
CH Products Fightstick Joystick	Up to 2
CH Products Flightstick Joystick	Up to 2
DB15 female solder cup connector	up to 4
DB15 female solder cup connector	Up to 8
DB15 female solder cup connector	Up to 8
DB15 M-F Cable	6' Length, Up to 2
DB15 male solder cup connector	Up to 4
Electrical Tape	Any amount when used as an insulator
Heat Shrink Tubing	Any amount, Any Ø
Heat Shrink Tubing	Any amount, Any Ø
Hood for 15 pin connector	Thermoplastic, Up to 12
Insulated Crimp-on Connectors	Spade, Butt, Ring & Bullet, Any amount/size
Permanent Magnet	Any amount
Potentiometer	Any amount, 100 k Ohms, linear taper
PWM/Relay Cable	Hitec/JR-style, 36" Long
PWM/Relay Y Cable	JR-style, Any Amount

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Relay Module (Spike)	Any amount - when used per rules
Speed Controller (Victor 883)	Any amount - when used with motor
Terminal Blocks	Any amount, off-the-shelf, Proper gauge/current rating
Wire	Proper gauge, color & insulated
Wire Nuts	Any amount

Fasteners

Fasteners, Washers, Nuts, Adhesives	Any amount/size
Hose Clamps	Any Ø, Any amount
Joining Plates for Extrusions	Any amount, Any size
Pipe Endcaps	Any amount - if used to cap pipes
Pipe fittings (tees, reducers, elbows, angles)	Any amount - to join sections of pipe
Pipe flanges	Any amount - if used to attach pipes
Rubber Band, Large	3-1/2" x 1/4" wide, Up to 5
Rubber Band, Small	3-1/2" x 1/8" wide, Up to 5

Pulleys

Timing Pulleys	Up to 6
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Rods & Shafts

Copper Water Pipe	Any length, 1/2" Ø
Electrical Conduit Pipe (EMT)	Any length, 1/2" - 3/4" Ø

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Flexible Conduit (ENT)	Any length, 1/2" Ø PVC
Pins - linkage or hinge	Any amount
Schedule 40 PVC Pipe	Any length, 1/2" - 1 1/2" Ø
Shaft Couplings	any amount, any size
Wooden Closet Rod	Any length, up to 1 1/4" Ø

Rope, Belts, & Chain

Nylon Braided Rope	Any length, up to 5/16" Ø
Steel Cable	Any length, up to 1/8"Ø
Timing Belt	Up to 20', single or double sided

Sheets & Boards

1/2" Plywood	1 sheet 4'x8'
1/4" Plywood	1 sheet 4'x8'
Aluminum Plate	Any length, Up to 1/4" thick
HDPE Block	1 Piece 1" x 12" x 12"
Pine Board	Any length, 3/4" x 3-1/2"
Poly carbonate Sheet	Any amount, Up to 3/8" thick
Steel Plate	Any amount, Up to 1/4" thick

Structural

Aluminum Angle	Any length, Up to 2"x2"x 1/4" thick
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Extruded Aluminum	Any length, Up to 2"x3" cross-section
Extruded Fiberglass	Any length, Up to 3"x3" cross-section
Fiberglass	Any amount, Up to 1/8" thick
Resin + Hardener	As needed for fiberglass
Steel Angle	Any length, Up to 2"x2"x 1/4" thick

Wheels

Caster, Swivel	Any amount, part #31CD30X8812MM
Skyway Wheelchair Wheel	5"-8" Ø, Up to 6 non-pneumatic
Skyway Wheelchair Wheel	8" Ø, Up to 2