THE 1999 FIRST ROBOTICS COMPETITION MANUAL

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1. THE ROBOT

1.1 Introduction

The Robot section of the 1999 FIRST Robotics Competition Manual provides information about the parts provided in the Kit of Parts at the Kickoff Workshop, information on additional parts that can be used to build the robot, documents the robot control system, and lists the rules covering robot construction. In short, this section should provide most of the information you will need to build a robot for the 1999 FIRST Robotics Competition.

1.2 Before You Start Building A Robot

Before embarking on the robot design process, it is important to understand that there are certain constraints on the robots which must be observed 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, and that certain good design practices are followed in order to improve reliability and make problem solving and repair easier.

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

- The materials that may be used to build the robot are limited. There are four sources of materials that may be used; the Kit of Parts, parts from Small Parts, Inc., the Additional Hardware List, and Unlimited Quantity Items. Materials which are not from these sources may not be used. The amount of materials from these sources may be limited by cost or quantity of material. See Appendix B for an inventory list of the Kit of Parts, and Appendix C for the Additional Hardware List. Appendix D contains ordering information for Small Parts, Inc. Rule K1 in Appendix A lists Unlimited Quantity Items.

- 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, certain types of changes to the robot may not be made until after the event is over.

Thus, it is very important to become very familiar with the rules in Appendix A and read through the allowed materials lists in the following appendices. Additional rules you should keep in mind are rules of gameplay, listed in the Game section of the manual, and the shipping deadlines listed in the Administrative Details section. By taking the time to read through the rules carefully, you will save time in the long run. Major blocks of time can be wasted rebuilding, due to the lack of knowledge about a certain rule at the onset of the design process.

Plan your overall schedule to include simulated competition test runs and 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, picking up mechanisms, etc.) by the end of the 3rd week, you are way behind schedule. If in doubt, consult this manual and team updates. If these do not answer the questions, call FIRST. 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.

As you progress in the design and build stage, be sure to carefully read all team updates which will be periodically issued 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, which helps to insure that all teams have the same understanding of the rules.

1.3 FIRST Policy on Repair and Replacement of Kit Parts

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 call FIRST to insure that all 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.

- If, during examination of components, a failure is determined to be due to misuse or miswiring, in general only one additional unit will be supplied, or the original unit will be repaired only once.

- Before sending back the item, please fill out the problem report found in Appendix F. This report is to be mailed in with the item.

1.3.1 Transmitter or Receiver

1)   Ship the unit to FIRST. Teams are responsible for this shipping cost.

2)   Upon receipt of the unit, it will be examined to determine whether it can be repaired or must be replaced.

3)   FIRST will ship the repaired or replacement unit to the team via 2nd day UPS shipment within 1 business day of receipt.

1.3.2 Speed Controllers

Tekin Speed Controllers

Tekin speed controllers have a 90 day warranty. Teams have the option of contacting Tekin for repair/replacement of defective units. Tekin estimates an approximate 3 day turnaround time from receipt of units to shipment of repaired/replacement units.

FIRST is able to provide these replacement speed controllers through a special arrangement with Tekin, and has only a limited number of speed controllers available. This policy is intended to provide teams with failed units a timely method of obtaining replacements. Teams wishing to obtain spare speed controllers must go through regular retail channels.

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If you do experience a failure, you should seriously consider the fact that if one speed controller failed with the current robot design, a replacement may also fail during the Competition. Carefully evaluate the abrupt startup and reversing loads on the motor, the interim and overall gear ratios, and the driving techniques used.

1.   Ship the non-functional unit to FIRST. Teams are responsible for this shipping cost.

2.   FIRST will ship a replacement speed controller to the team via 2nd day UPS shipment within 1 business day of receipt.

Innovation First Speed Controllers

Teams should contact Innovation FIRST for replacement of failed Innovation FIRST speed controllers.

1.3.3 RNets

1.   Ship both RNets to FIRST.

2.   FIRST will ship a pair of replacement RNets via 2nd day UPS shipment within 1 business day of receipt.

1.3.4 Servos & Servo Cables

These units will be shipped via 2nd day UPS air. As with speed controllers, FIRST has a limited number of servos available. Teams wishing to purchase spare servos may purchase equivalent models through regular retail channels.

1.   Ship the non-functional unit to FIRST. Teams are responsible for this shipping cost.

2.   FIRST will ship a replacement to the team via 2nd day UPS shipment within 1 business day of receipt.

1.3.5 Joysticks

Flightstick joysticks are available in most computer stores.

Replacement Flightstick joysticks can be supplied by FIRST, but limited quantities are available.

1.   Ship the non-functional unit to FIRST. Teams are responsible for this shipping cost.

2.   FIRST will ship a replacement to the team via 2nd day UPS shipment within 1 business day of receipt.

1.3.6 Drill Motors and Drive Assemblies

There are a limited number of replacement motors and drive assemblies available.

If you have a burned out motor:

1.   Ship the non-functional motor to FIRST.

2.   FIRST will ship a replacement motor to the team via 2nd day UPS shipment within 1 business day of receipt.

If you have a non-functional drive assembly:

1. Ship the drive assembly to FIRST.

2. Seriously consider the fact that if a brand new drive assembly failed with the current robot design, a replacement may also fail during The Competition. Carefully evaluate the shock loading of the drive assembly, the interim and overall gear ratios, and the driving techniques used.

3. FIRST will ship a replacement drive assembly to the team via 2nd day UPS shipment within 1 business day of receipt.

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

Alternately, teams may purchase a new Bosch 12 volt cordless drill from S-B Power Tool Company. The drill parts supplied in the Kits are from Bosch model 3315K 12V cordless drill.

1.3.7 Seat, Window, Globe Motors with Drive Assembly and Van Door Motors

1. Ship the non-functional motor to FIRST.

2. FIRST will ship a replacement motor to the team via 2nd day UPS shipment within 1 business day of receipt.

As with other components, FIRST has a limited number of replacement motors available.

1.3.8 Batteries and Battery Chargers

1. Ship the non-functional battery or charger to FIRST.

2. FIRST will ship a replacement battery or charger to the team via 2nd day UPS shipment within 1 business day of receipt.

As with other components, FIRST has a limited number of replacement batteries and chargers available. Teams wishing to purchase these items may purchase equivalent models through CSB Battery of America Corp. for batteries and Xenotronix for battery chargers, respectively.

1.3.9 Contact Information for Suppliers

Teams wishing to obtain additional parts direct from FIRST suppliers consult contact information in Appendix A of the Administrative Details Section.

2. CONTROL SYSTEM MANUAL

2.1 Introduction & General Description

WARNING

> **Please read the following section carefully.** **Failure to configure your control system properly could result in personal injury, damage to the control system, or damage to your robot. FIRST will not provide free replacement of control system components damaged due to misuse or miswiring. Furthermore, teams will be required to correct control systems that are not configured according to this section and the control system rules in Appendix A before being allowed to compete.**

In this section you will find:

- Descriptions of the control system components

- Configuration options

- Wiring diagrams

- Hook-up instructions

If, after reading this section, you have problems configuring the control system, please contact FIRST's Engineering Department for assistance. We will be happy to answer any questions you may have. See the Administrative Details section of the manual for information on how to contact FIRST.

Before proceeding with a discussion of the individual components that make up the control system, it is helpful to understand the overall function of the control system.

The heart of the control system is comprised of two main units: the Transmitter and the Receiver. Basically, the Transmitter takes input from the robot operators and passes it along to the Receiver. The Receiver takes this information, gathers additional information from sensors on-board the robot, determines how the robot should function, and has the robot perform the functions.

More specifically, the Transmitter reads the joystick, switch, and potentiometer inputs controlled by the robot operators and relays this information to the Receiver via the RNet radio modems or tether cable. The Receiver takes this information, verifies that it has been received correctly, and then forwards it to the control program. The control program takes the data from the Transmitter, reads the sensor inputs on-board the robot, determines what to do with the outputs to make the robot behave as desired, and sets the PWM and relay outputs to the appropriate states. Figure 2.1 shows a block diagram illustrating this concept.

Robot Operators

Transmitter
1. Read Inputs
2. Send Data to RNet
3. Repeat

Joysticks

Switches
&
Potentiometers

RNet

Receiver
1. Read RNet
2. Verify Data
3. Pass OK Data to
   Control Program
4. Repeat

RNet

Output Devices

Drill Motors,
Fisher-Price
Motors,
Van Door Motors,
Seat Motor,
Window Motors,
Globe Motors

Speed
Controllers

Control Program
1. Get Data
2. Read Sensors
3. Determine
   Actions
4. Set Outputs
5. Repeat

On-board Sensors

Switches,
Yaw Rate Sensors,
Optical Sensor,
& Potentiometers

Servos

PWM
Outputs

Seat Motor,
Window Motors,
Globe Motors,
Pump, Valves

Relay
Outputs

Figure 2.1: Control System Function Block Diagram

Below you will find the details necessary to hook up the control system and ensure that it operates properly.

2.2   Control System Components

The Kit contains a variety of <u>input</u> <u>devices</u>:

• three-axis proportional joysticks with trigger and thumb switches

• momentary rocker switches

• latching pushbutton switches

• limit switches

• reed switches

• pressure switch

• potentiometers

• optical sensor

• solid-state yaw rate (turning rate) sensors

The joysticks and potentiometers may be used with the Transmitter to provide up to 8 channels of proportional input.

The rocker switches and pushbutton switches may be used with the Transmitter to provide up to 16 switch inputs. In addition, there are two switch inputs on each joystick, which share input channels with some of the rocker switch inputs. If desired, the joystick switches can be disabled by setting some DIP switches inside the Transmitter.

The limit switches, reed switches, and pressure switches are intended for use as feedback sensors on the robot, but may also be used for switch inputs on the Transmitter. The Receiver can handle up to 16 switch inputs.

The potentiometers and yaw rate sensors may be used with the Receiver to provide up to 4 channels of proportional input on-board the robot.

The optical sensor has two outputs which can be connected to the switch inputs on the Receiver.

There are also a variety of <u>output</u> <u>devices</u>:

- servos
- reversing speed controllers
- cordless drill motors
- seat motor
- window motors
- air pump
- pneumatic valves
- van door motors
- additional motors
- LEDs (5 & 12 Vdc)

The servos provide proportional position control, while the speed controllers provide proportional velocity control for the motors. Both the servos and speed controllers are controlled by the PWM outputs on the Receiver.

Due to their high current requirements, the drill motors, Fisher-Price motors, and van door motors may be driven only by the Innovation FIRST speed controllers. If proportional control of the seat , window, or Globe motors is desired, they may be driven by the Tekin or Innovation FIRST speed controllers.

The seat and window motors may also be driven by the relay outputs for simple non-proportional forward/off/reverse control.

Speed controllers may only power one motor per controller with the exception of the seat and window motors. Either brand of speed controller may be used to power up to two total seat and/or window motors. No other combinations are allowed.

CAUTION

Attempting to drive the drill motors, van door motors, or Fisher-Price motors directly with the Receiver relay outputs could damage the control system and is therefore prohibited.

The 5 Vdc panel mounted LED is the only output device for use with the Transmitter. It may be powered by the +5 Vdc output on the Transmitter's Auxiliary Input Port.

The 12 Vdc panel mounted LEDs are intended to be used on the robot for indicator lamps and may be used on speed controller or relay outputs alone or in parallel with a motor.

All other output devices may be driven only by the relay outputs on the Receiver. No more than one motor may be powered by a single relay output.

2.3 Power Distribution

The Transmitter is powered by the 7.5 Vdc regulated power supply. In turn, the transmitting RNet receives power from the Transmitter.

CAUTION

Use the 7.5 volt power supply included with the Kit to power the Transmitter. Use of an alternate power supply could damage the Transmitter and/or RNet and is therefore prohibited.

On the Robot, power distribution is more complex. Electrical power from a 12 Vdc sealed-lead-acid (SLA) battery is distributed, via a fuse, directly to the Receiver, speed controllers, muffin fan, and optical sensor. All other electrical devices may receive power only from the Receiver and/or speed controllers as described below.

WARNING

Be very careful to avoid short circuits! The 12 Vdc SLA battery can deliver current well in excess of 100 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 and could cause the battery to leak highly corrosive acid or even explode. Always make sure the fuse is in series with the battery output. Please be careful!

For safety reasons, the battery fuse supplied in the kit must be wired in series with the +12 Vdc output terminal on the battery.

Although not required, it is recommended that power from the battery be distributed via the junction blocks. Note that each junction block contains 6 fused (via the 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 one junction block can serve to distribute both 12 Vdc and Ground. Also, if desired, the terminal strip may be cut and rearranged into more units with less channels for distribution of power in multiple locations on the robot.

CAUTION

Be sure to check wires in the terminal strip 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. With time, wires in terminal strips can become loose as the soft copper wire strands creep under the pressure of the screw. Also, the normal operating vibration of a robot can loosen wires.

Figure 2.2 shows a schematic for +12 Vdc power distribution using the junction block.

Battery

Battery Fuse

Optical Sensor

Junction Block +12 Vdc

30 30 30
30 30 30

Muffin Fan

Seat Motor — Rebel Speed Controller

Window Motor — Rebel Speed Controller

Globe Motor — Rebel Speed Controller

Relay Power	Logic Power

Receiver

Relay Outputs

Victor 883 Speed Controller — Van Door Motor

Victor 883 Speed Controller — Drill Motor

Victor 883 Speed Controller

Seat Motor

Globe Motor

Window Motor

Pump

Valve

Fisher-Price Motor

Key:
- 6 AWG Wire - Red
- 10 AWG Wire - Red
- 16 AWG Wire - White
- 24 AWG Wire - Red

Figure 2.2: +12 Vdc power distribution

Note that Figure 2.2 shows only the +12 Vdc side of the power distribution. The Ground side is identical except for the absence of the circuit breakers, battery fuse, and optical sensor. The optical sensor is connected to Ground via the sensor port on the Receiver.

CAUTION

> **Do not connect the pump, valves, switches, or any motors directly to the battery. Do not connect battery power directly to the relay outputs as this may damage the Receiver.**

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 or speed controller) must be color coded as follows:

- Use Red 6 AWG, or Black 6 AWG (with red electrical tape) for +12 Vdc.

- **To avoid confusion add red electrical tape to the Black 6 AWG wire if used to distribute 12 Vdc.**

- Use Red 10 AWG or White 16 AWG wire for +12 Vdc.

- Use Black 10 AWG or Black 16 AWG wire for Ground.

The wires and cables included in the Kits 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 junction blocks	6 AWG, red & black
Drill motors, van door motors, speed controllers used with drill, van door, or Fisher-Price motors, Receiver (relay power input)	10 AWG, red & black
Receiver (logic power, relay outputs), seat motors, window motors, speed controllers used with seat, window, or Globe motors, pump, valves, fan	16 AWG, 2 conductor
All switches, PWM cables, yaw rate sensors, potentiometers, optical sensors, LEDs	24 AWG, 2 or 3 conductor

Control system cables containing 4 wires or less may be shortened or lengthened as needed as long as the following conditions are met:

- Proper insulation and electrical connectors must be used.

- Proper wire type, as specified above, must be used.

2.4 Transmitter

The Transmitter reads the joystick, switch, and potentiometer inputs controlled by the robot operators. It relays this information to the Receiver via the RNet radio modems or tether cable. This allows the robot operators to tell the robot what to do, such as turn left or extend an arm.

The connection diagram for the Transmitter is shown in Figure 2.3.

BNC Bulkhead
Connector
(part of Ground
Plane Assembly)

Antenna

Ground Plane
Assembly

BNC Coax Cable

RNet

Right Angle
BNC Connector

9-15 pin
Cable

Joystick

Status LED

Data Out

Joystick 1

+7.5 Vdc

Joystick 2

Aux Input
Port

TRANSMITTER

25 pin
Molded Cable

Switches &
Potentiometers

+7.5 Vdc
Power
Supply
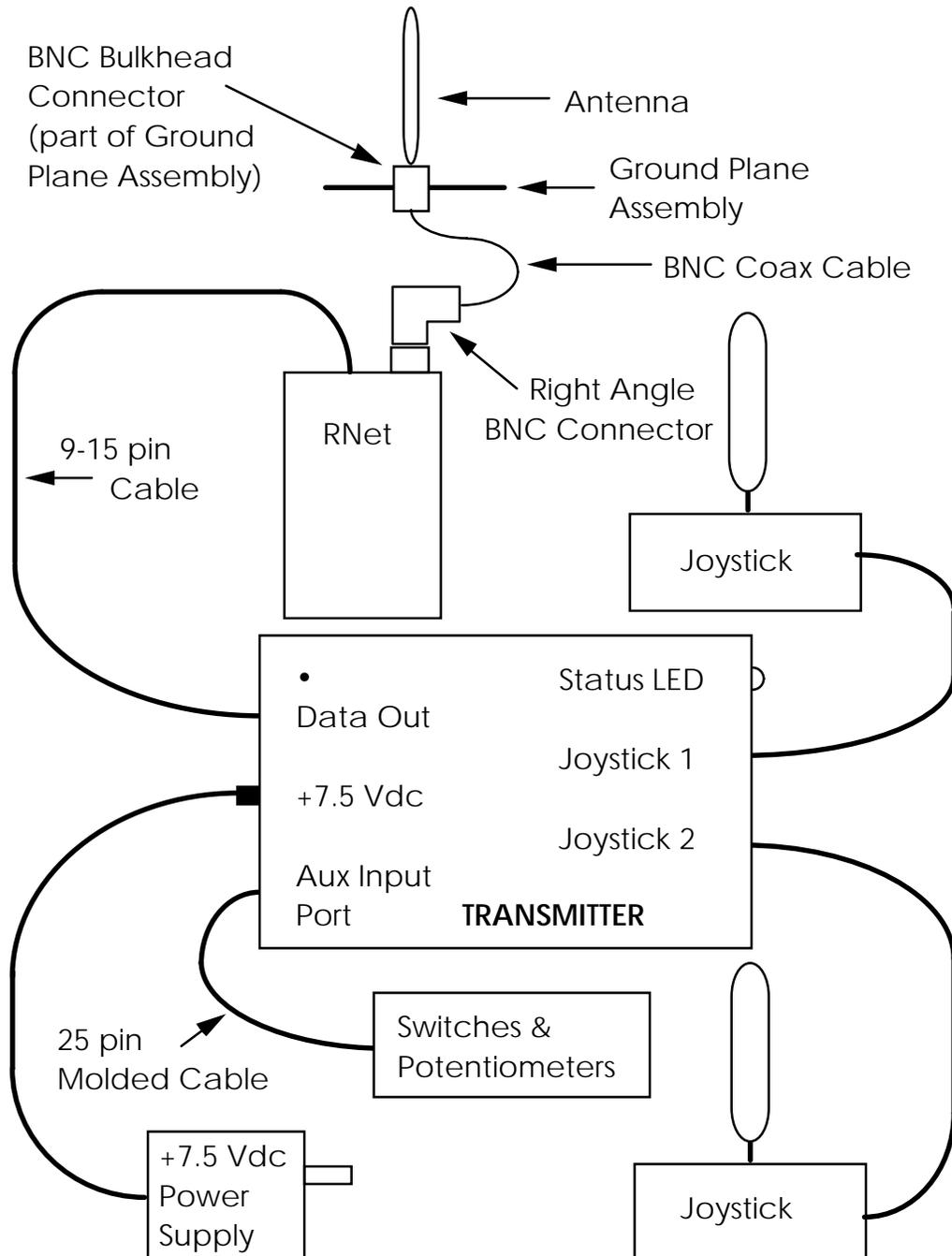
Joystick

Figure 2.3: Connection Diagram for Transmitter

NOTE

There are also two types of Transmitters being used in the 1999 Competition. They are functionally identical, but the position of the connectors for Joystick 1 and Joystick 2 are reversed between the two types of units.

To connect the Transmitter to the transmitting RNet, attach the 9 pin end of a 9-15 pin cable to the Data Out port on the Transmitter and the 15 pin end of the cable to the RNet. Next, attach the right angle BNC connector to the BNC connector on the RNet. Attach one end of a BNC coax cable to the right angle BNC connector, and the other end of the cable to the BNC bulkhead connector on the ground plane assembly. Finally, connect the antenna to the other side of the BNC bulkhead connector.

NOTE

Two different types of RNets are being used in the 1999 Competition. If you receive a set of RNets with 9 pin connectors, you must use 9-9 pin cables instead of 9-15 pin cables to connect the RNets to the Transmitter and Receiver. The 9 pin RNets are functionally equivalent to the 15 pin RNets. Only 15 pin RNets will be used at Competition events, however, so please be sure to choose an RNet mounting location on your robot that is close enough to the Receiver to allow it to connect with a 9-15 pin cable.

CAUTION

The antenna should not be connected directly to the transmitting RNet. Doing so will generate unwanted interference and may prevent the control system from working properly. Always use the right angle BNC connector, BNC cable and ground plane assembly to separate the antenna from the transmitting RNet.

For best reception of data, make sure that the ground plane is level with the floor and the antenna is pointing up.

In order to connect the rocker switches, potentiometers, and 5 Vdc LED to the Auxiliary Input Port on the Transmitter, they must be wired to the 25 pin male soldercup connector. Although not a requirement, teams may use the black project box as a housing for the rocker switches, potentiometers, LED, and 25 pin connector. The 25 pin molded cable must then be used to make the connection from the 25 pin connector to the auxiliary input port on the Transmitter.

The exact wiring configuration for the switches, potentiometers, and LED connected to the Transmitter is not specified. Teams may wire these devices, within the rules as described below, in order to create a custom interface for the robot operators. Table 2.2 shows the pin assignments for the auxiliary input port.

Table 2.2: Transmitter Auxiliary Input Port Pin Assignments

Pin	Description	Pin	Description
1	+5Vdc	14	+5Vdc
2	Transmitter Switch Input 6	15	Transmitter Switch Input 5
3	Transmitter Switch Input 2 (shared with Joystick 1 top button)	16	Transmitter Switch Input 1 (shared with Joystick 1 trigger button)
4	Transmitter Potentiometer Input 1	17	Transmitter Switch Input 8
5	Transmitter Switch Input 7	18	Transmitter Switch Input 4 (shared with Joystick 2 top button)
6	Transmitter Switch Input 3 (shared with Joystick 2 trigger button)	19	Transmitter Potentiometer Input 2
7	Ground	20	Ground
8	Ground	21	Transmitter Switch Input 16
9	Transmitter Switch Input 15	22	Transmitter Switch Input 14
10	Transmitter Switch Input 13	23	Transmitter Switch Input 12
11	Transmitter Switch Input 11	24	Transmitter Switch Input 10
12	Transmitter Switch Input 9	25	+5Vdc
13	+5Vdc		

Switch inputs should be closed to Ground or left open to achieve a 1 (on) or 0 (off) state, respectively, in the data going to the Receiver. Further information about how the Transmitter inputs are used by the Receiver is included in Section 2.5.

NOTE

Do not connect switches to +5Vdc.

The potentiometer inputs on the Transmitter read current, not voltage. To connect a potentiometer to the auxiliary input port, connect one of the outer potentiometer leads to +5Vdc and the middle lead (wiper) to the potentiometer input pin of your choice.

CAUTION

Do not connect potentiometers to Ground on the Transmitter. This may damage the Transmitter.

The +5 Vdc LED may be connected between +5Vdc (red wire) and Ground (black wire) and is intended to serve as a visual indicator to the robot operators that the Transmitter is turned on. This can be helpful during a Competition match when power to the Transmitter is controlled by FIRST. The project box makes an ideal mounting point for the LED.

Figure 2.4 shows an example of the proper way to connect a rocker switch, pushbutton switch, potentiometer, and LED to the auxiliary input port.
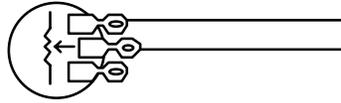
Potentiometer

Aux Input Port

Pin 1 (+5 Vdc)
Pin 4 (Transmitter Potentiometer Input 1)

Rocker Switch
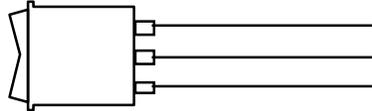
Pin 16 (Transmitter Switch Input 1)
Pin 7   (Ground)
Pin 3   (Transmitter Switch Input 2)

Pushbutton Switch   (back end view)
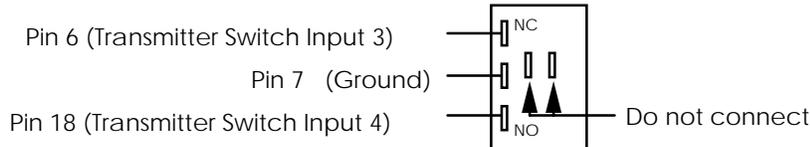
Pin 6 (Transmitter Switch Input 3) —— NC
Pin 7   (Ground) ——
Pin 18 (Transmitter Switch Input 4) —— NO —— Do not connect

LED
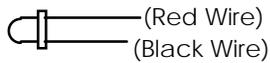
(Red Wire) —— Pin 1 (+5 Vdc)
(Black Wire) —— Pin 7 (Ground)

Figure 2.4: Connection Examples for Auxiliary Input Port

The switch inputs on the joysticks are wired in parallel with some of the switch inputs on the auxiliary input port, as indicated in Table 2.2. If desired, the switch inputs on the joysticks may be selectively disabled by changing the settings of DIP switches inside the Transmitter. To change the DIP switches, the Transmitter must be opened by removing the four screws on the bottom cover. Table 2.3 details the Transmitter DIP switch settings.

CAUTION

Before opening the Transmitter, the power supply must be disconnected. While the Transmitter is open, be careful to avoid static discharges to the circuit board or connectors. Also, do not allow any foreign particles, especially metal fragments, to get inside the enclosure or onto the circuit board. It is best to open the unit in a clean environment away your robot work area. Never operate the Transmitter with the cover off. Failure to observe these precautions could result in damage to the equipment.

Table 2.3: Transmitter DIP Switch Settings

Button	DIP Switch
Joystick 1 - Top	3
Joystick 1 - Trigger	4
Joystick 2 - Top	7
Joystick 2 - Trigger	8

Figure 2.5 shows the location of the DIP switches inside the Transmitter. To access the DIP switches, the cover of the Transmitter must be removed. To remove the cover, unscrew the four Phillips head screws on the underside of the Transmitter. The 9 Vdc power supply must be disconnected prior to removing the cover.

NOTE

There are two different designs of the Transmitter board being used in the 1999 Competition. They are functionally identical, but the DIP Switch locations are different, as indicated in Figure 2.5.
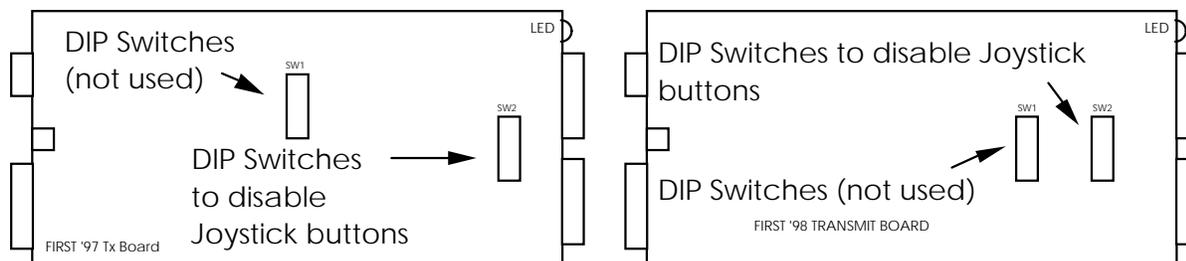
Figure 2.5: Location of DIP Switches Inside Transmitter

2.4.1 Fuse

There is one replaceable fuse in the Transmitter that is designed to protect it from damage. If you discover a blown fuse, carefully check the wiring of the entire electrical system and correct any faults that are discovered. Remember that fuses do not blow themselves. Replace fuses only with fuses of the same rating. If a replacement fuse blows, it means there is still a problem. Do not bypass the fuse -- fix the problem.

Teams are encouraged to replace blown fuses themselves rather than sending the Transmitter back to the FIRST for repair. Full fuse specifications are provided below. For convenience, part numbers for ordering the fuses from Digi-Key are also provided. Contact information for Digi-Key is included in the Vendor Contact List in Appendix A of the Administrative Details section of the manual. Other electronic part supply companies are likely to carry these fuses too.

Table 2.5: Transmitter Fuse Specifications

Fuse	Description	Manufacturer	Mfg. Part #	Digi-Key Part#
F1	*1998 Transmitter* 1.25 A TR5 Sub-Mini Slo-Blo	Wickmann	19374-050-K	WK4050BK-ND
F1	*1997 Transmitter* 2.00 A Slo-Acting Glass Fuse	Littlefuse	218002 (Bulk)	F978-ND

Fuse F1 limits the current coming into the Transmitter. If F1 is blown, the Transmitter will not function at all. If F1 blows, there may be a loose piece of metal inside the Transmitter enclosure, causing the short circuit.

2.5 Receiver

The Receiver takes data from the Transmitter, verifies that it has been received correctly, and then forwards it to the control program. The control program takes the data from the Transmitter, reads the on-board sensor inputs, makes decisions based on all the inputs, and sets the PWM and relay outputs.

The connection diagram for the Receiver is shown in Figure 2.6.
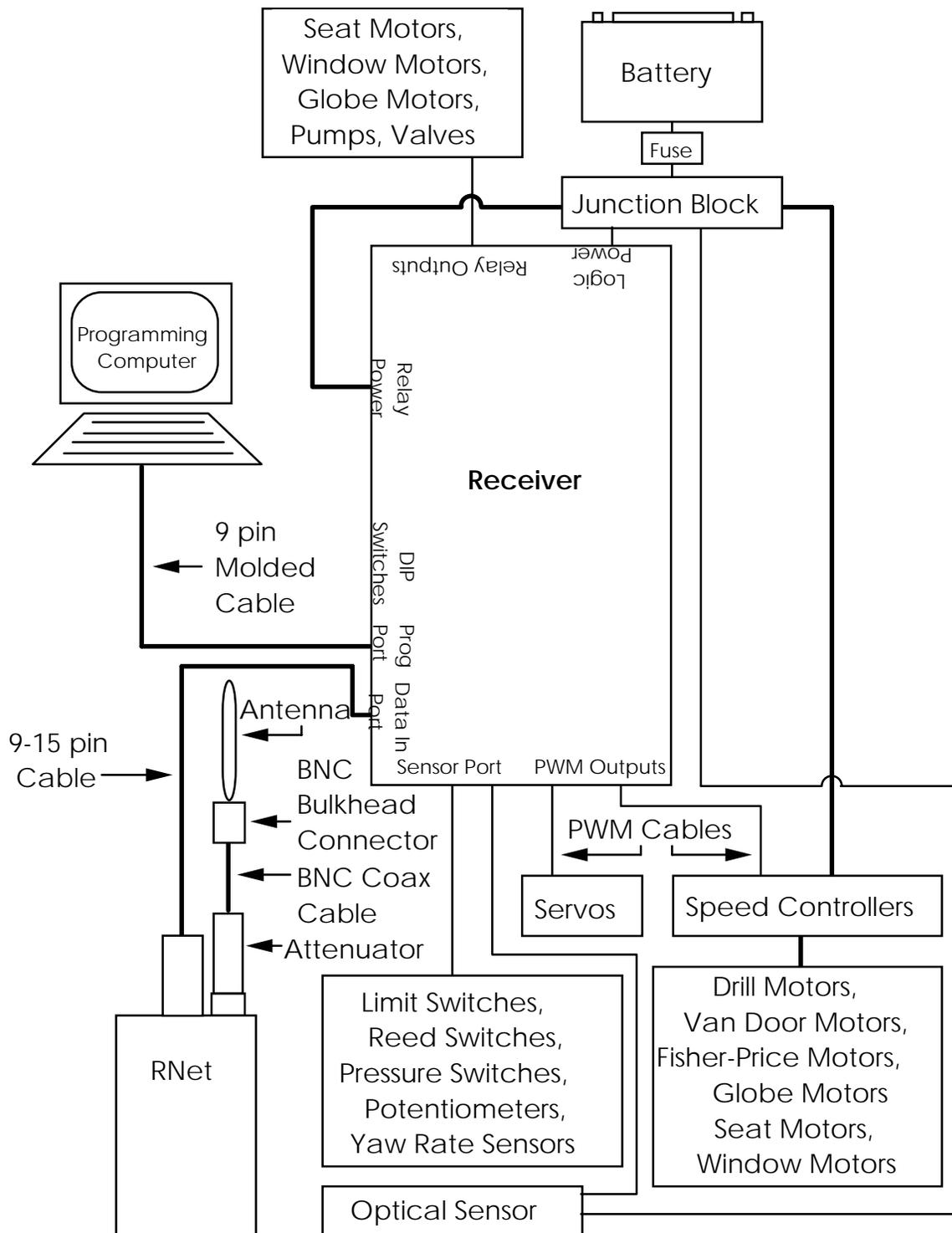
Figure 2.6: Connection Diagram for Receiver

2.5.1 Sensor Inputs

The sensor inputs on the Receiver can be used to measure various conditions on the robot and trigger automatic responses by the control program.

There are 16 switch inputs and 4 analog inputs available. The limit switches, reed switches, air pressure switches, and optical sensor may be connected to the switch

inputs. The potentiometers and yaw rate sensors may be connected to the analog inputs.

The exact wiring configuration for sensors connected to the Receiver is not specified. Teams may wire these devices, within the rules as described below, in order to create a custom sensor system on the robot. Table 2.4 shows the pin assignments for the sensor port.

Please exercise caution when wiring the control system. Teams will be required to pay for replacement or repair of devices damaged due to improper wiring.

CAUTION

Do not connect power or any other signals to the switches or switch inputs. Also, be careful to observe the polarity of the power inputs when wiring the control system. Damage to the switches, Receiver, and/or other components may occur if components are wired incorrectly.

Table 2.4: Receiver Sensor Port Pin Assignments

Pin	Description	Pin	Description
1	Receiver Switch Input 1	14	Receiver Switch Input 2
2	Receiver Switch Input 3	15	Receiver Switch Input 4
3	Receiver Switch Input 5	16	Receiver Switch Input 6
4	Receiver Switch Input 7	17	Receiver Switch Input 8
5	Receiver Switch Input 9	18	Receiver Switch Input 10
6	Receiver Switch Input 11	19	Receiver Switch Input 12
7	Receiver Switch Input 13	20	Receiver Switch Input 14
8	Receiver Switch Input 15	21	Receiver Switch Input 16
9	Ground	22	Receiver Analog Input 3
10	Ground	23	Receiver Analog Input 4
11	Ground	24	Receiver Analog Input 1
12	Ground	25	Receiver Analog Input 2
13	+5Vdc		

In order to connect the switches, potentiometers, and optical sensor to the Receiver, they must be wired to the 25 pin male soldercup connector. The 25 pin connector must then be attached to the sensor port on the Receiver. It is recommended that the plastic hood be used to protect the connections on the 25 pin connector. +12 Vdc power for the optical sensor must be supplied from the junction block.

Switch inputs should be closed to Ground or left open to achieve a 1 (on) or 0 (off) state, respectively, within the control program.

CAUTION

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

The analog input ports on the Receiver read a voltage between 0 to +5Vdc. They are
different than the potentiometer inputs on the Transmitter. To connect a
potentiometer to the sensor port, connect one of the outer potentiometer leads to
+5Vdc, the other outer lead to Ground, and the middle lead (wiper) to the analog
input pin of your choice.

To connect an optical sensor to the sensor port, the 4 pin connector on the end of the
sensor cable must be removed. Connect the red wire to +12 Vdc on the junction
block, the black wire to Ground on the sensor port, and the white and green wires to
the sensor port switch input pins of your choice.

To connect a yaw rate sensor to the sensor port, connect +5 Vdc to the +5 Vdc input
on the sensor, connect Ground to Ground, and connect the sensor output to the
sensor port analog input pin of your choice.

Output characteristics of the optical sensor and yaw rate sensors 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 sensor port. It may damage the
Receiver.**

Figure 2.7 shows an example of the proper way to connect a limit switch,
potentiometer, yaw rate sensor, and optical sensor to the sensor port.
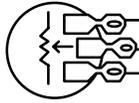
Potentiometer   Sensor Port

Pin 13 (+5 Vdc)
Pin 24 (Receiver Analog Input 1)
Pin 9 (Ground)

Limit Switch

NC
NO
COM
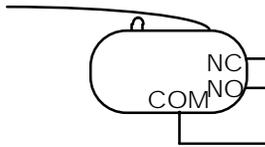
Pin 1 (Receiver Switch Input 1)

Pin 9 (Ground)

Optical Sensor
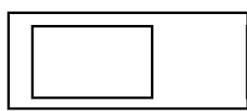
Red (Power) ——— Terminal Strip (+12 Vdc)
Black (Ground)——— Pin 9 (Ground)
White (Output) ——— Pin 14• (Receiver Switch Input 2)
Green (Diag Output)— Pin 2 (Receiver Switch Input 3)

Yaw Rate Sensor

C
B
A
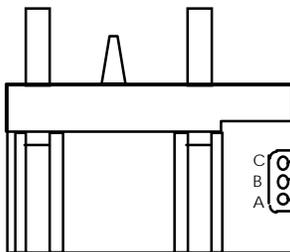
Pin 13 (+5 Vdc)
Pin 25 (Receiver Analog Input 2)
Pin 9 (Ground)

Figure 2.7: Connection Examples for Sensor Port

2.5.2 RNets and Tether Adapter

The Receiver gets data from the Transmitter either via the RNet radio modems or a direct connection via the tether adapter.

To operate the robot via wireless control, attach the 9 pin end of a 9-15 pin cable to the Data In port on the Receiver and the other end of the cable to the receiving RNet. Next, attach the Attenuator to the BNC connector on the RNet. Attach one end of a BNC coax cable to the Attenuator, and the other end of the cable to the BNC bulkhead connector. Finally, connect the antenna to the other side of the BNC bulkhead connector.

CAUTION

The antenna should not be connected directly to the receiving RNet. Always use the BNC cable to separate the antenna from the RNet.

Fabricate a small bracket to mount the BNC bulkhead connector to the robot. Be sure to mount the antenna on the robot so that it is pointing up. Avoid placing the antenna behind large metal objects that could shield it from receiving the radio

waves from the transmitting RNet. Also, try to avoid placing the antenna or receiving RNet near motors, motor wires, or other sources of electrical noise.

To operate the robot with the tether adapter, disconnect the 9-15 pin cables from the Transmitter and Receiver, replace them with 9 pin molded cables, and join the two 9 pin cables with the tether adapter.

At the beginning of each Competition event, FIRST will collect all RNets from teams to prevent accidental transmission of data that could interfere with robots on the playing fields. Robots may only be operated via the tether adapter in the pit area. Prior to each match, teams will be assigned a set of RNets based on playing field starting position. Thus, it is important that robots be designed for easy changeover of RNets.

Tip: Locate the RNet so it can be easily removed. The hook and loop fastener on the RNet provides an easy means of attachment to the robot. However, FIRST recommends a secondary means of attachment because the RNets have broken loose in the past due to the serious impacts and vibrations the robots undergo during The Competition.

Caution

In past years of the FIRST Robotics Competition, teams have occasionally encountered wiring problems on their robots which have rendered their receiving RNet permanently non-functional. Please take extreme caution to prevent the +12 or +5 Vdc power on the robot from coming into contact with the metal housings of the RNet, BNC cable, BNC bulkhead connector, or the antenna. This can happen via wires coming loose and contacting the RNet, accidentally energizing the robot chassis to which the BNC bulkhead connector is mounted, or other similar problems. Although not a requirement of the rules, FIRST urges teams to mount the BNC bulkhead connector in an electrically non-conductive material (wood, polycarbonate, etc.) on the robot in order to help reduce the potential for damage if a wiring fault occurs on the robot.

2.5.3 PWM Outputs

The PWM outputs are, by default, controlled directly by the joystick and potentiometer inputs on the Transmitter. Table 2.7 in section 2.6.2 shows which inputs control which PWM outputs when the Receiver is in it's default state. To change the control of the PWM outputs, a custom control program must be written. See section 6.2 for information on writing a custom control program.

The PWM outputs are designed to drive the servos and to provide a control signal to the speed controllers. The speed controllers and servos may be connected directly to the PWM outputs, or may be connected via the 36" servo extension cables and/or 24" servo Y cables. When plugging a PWM cable onto the output connectors, be sure to observe the orientation indicated on the Receiver's label.

Tip: It can be difficult to align PWM cables vertically with the PWM output connector when looking at the Receiver from above (through the clear cover). This can result in the connector

being placed onto only two of the three pins, which will cause that PWM device not to work (until the situation is corrected). For greater accuracy when connecting PWM cables, be sure to view the Receiver from the side with the PWM outputs.

Some of the PWM cables in the Kits have Hitec/JR style connectors while others have Futaba J-style connectors. The Hitec/JR style cables have yellow, red, and black wires, while the Futaba style cables have white, red, and black wires. These cables are equivalent. However, in order to use the Futaba style connectors, you may need to shave off the external tab to obtain a proper fit. See the Figure 2.8 below for details.
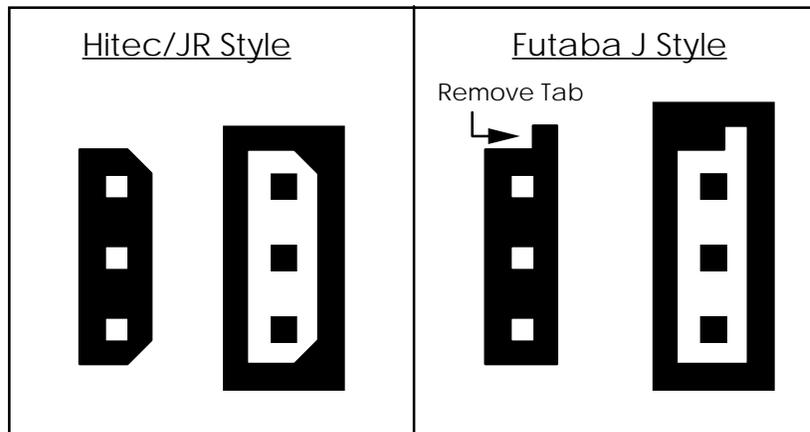
Figure 2.8: Hitec and Futaba-Style PWM Connectors

2.5.4 Relay Outputs

The relay outputs are, by default, controlled directly by the switch inputs on both the Transmitter and Receiver. Table 2.7 in section 2.6.2 shows which inputs control which relay outputs when the Receiver is in it's default state. To change the control of the relay outputs, a custom control program must be written. See section 6.2 for information on writing a custom control program.

The relay outputs are designed to provide forward and reverse control of the seat motors, window motors, pump, and valves. These outputs may be connected directly to the motor/pump/valve with the appropriate wire, as described in Section 2.3.

CAUTION

Do not connect power from the battery into the relay outputs. Doing so will damage the Receiver.

The relay outputs work by switching the pairs of output pins (F & R) to Ground or +12 Vdc. When both pins are at Ground or both are at +12 Vdc, the output is "off." When pin F is at +12 Vdc, and pin R is at Ground, the output is "forward." When pin F is at Ground and pin R is at +12 Vdc, the output is "reverse."

Power and Ground for the relay outputs are routed from the Relay Power connector. If +12 Vdc and Ground are not connected to the Relay Power connector, output devices connected to the relay outputs will not function.

Tip: To achieve control of both solenoids on the double solenoid valve and use only one relay channel, use the two diodes provided in the Kit to route power to one solenoid at a time. Figure 2.9 shows the schematic for this arrangement.
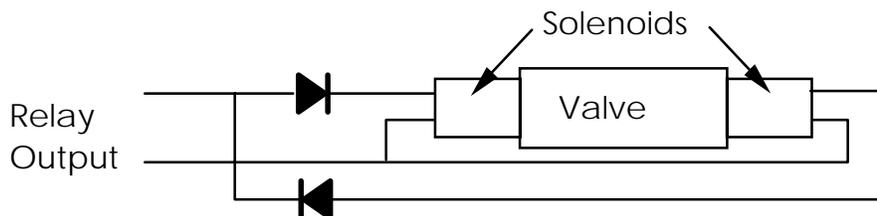
Figure 2.9: Use of Diodes with Double Solenoid Valve

2.5.5 Status LEDs

The Receiver has a number of status LEDs that are useful in debugging problems that may arise. Below is a description of the function of these LEDs.

D5-8 and D13-16 are bi-color (green or red) LEDs that indicate the status of the relay outputs. The mapping of LED to output channel should be obvious. For each channel, the LED will turn green if the forward pin is high and the reverse pin is low, or red if the reverse pin is high and the forward pin is low. If both pins are low or high the LED will be dark. The LED will also fail to light if power and ground are not connected to the Relay Power connector, or if there are blown fuses on that relay channel.

D17-20 are yellow LEDs that indicate whether power is available at various sections of the board. If any of these LEDs fail to light up when +12 Vdc power is applied to the Logic Power input on the Receiver, there is a problem and you should contact FIRST. D17 indicates 12 Vdc is connected to the Logic Power input at the proper polarity. D18 indicates +12 Vdc is past the 3.15A input fuse (F17) and is available for the relay coils (but not relay outputs), 12->7.5 Vdc converter (RNet power) and 12->5 Vdc converters (logic, PWM & sensor port power). D19 indicates +5 Vdc is coming out of the Power Trends 12->5 Vdc converter. D20 indicates +5 Vdc is past the 3.15A fuse (F22) and is available for the PWM outputs and sensor port.

D25 is a bi-color LED that indicates the status of data reception. D25 should blink green each time an uncorrupted packet of data is received from the Transmitter. D25 will blink red if corrupted data is received, and will stay off when data is not being received. When running the default control program, D26 will blink green each time data is passed to the control program. The function of D26 can be changed when running a user control program.

D31-33 are red LEDs that will light if the Receiver detects various problems with the control system. D31 will light if the delay between receiving packets of uncorrupted data is too long. D32 will light if there is a problem sending data to the control program. D33 will light if too much of the data being received is corrupted. If either D31 or D33 light, it is an indication that there is a problem somewhere in the data transmission or reception hardware (RNets, antennas, data cables, 9-15 adapters, and/or tether adapters). If D32 lights, it could be due to a user control program that has crashed or is taking too long to respond, incorrect DIP switch settings on the

Receiver, or a problem with the Receiver circuit board. Loading a user control program into the Receiver while it is receiving data will also cause D32 to light, but this should not be interpreted as an error. If any of these problems are detected, corrective action should be taken. Otherwise, the robot may fail to operate properly during a Competition.

2.5.6 Fuses

There are a number of replaceable fuses in the Receiver that are designed to protect it from damage. If you discover a blown fuse, carefully check the wiring of the entire electrical system and correct any faults that are discovered. Remember that fuses do not blow themselves. Replace fuses only with fuses of the same rating. If a replacement fuse blows, it means there is still a problem. Do not bypass the fuse -- fix the problem.

Teams are encouraged to replace blown fuses themselves rather than sending the Receiver back to the FIRST for repair. Full fuse specifications are provided below. For convenience, part numbers for ordering the fuses from Digi-Key are also provided. Contact information for Digi-Key is included in the Vendor Contact List in Appendix A of the Administrative Details section of the manual. Other electronic part supply companies are likely to carry these fuses too.

Table 2.5: Receiver Fuse Specifications

Fuse	Description	Manufacturer	Mfg. Part #	Digi-Key Part#
F1-16	20A ATM Mini Auto	Bassmann	ATM-20	283-2330-ND
F17-18	3.15A TR5 Sub-Mini	Wickmann	19373-124-K	WK3024BK-ND
F19-26	1.25A TR5 Sub-Mini	Wickmann	19373-050-K	WK3050BK-ND
F27	1.25A TR5 Sub-Mini Slo-Blo	Wickmann	19374-050-K	WK4050BK-ND

Fuses F1-16 protect the relay outputs from excessive current draw. Each relay output pin is fused. If either fuse of a relay output channel is blown, the channel will not work. It is best to replace these fuses in pairs, because even if only one blows, the other fuse for the same relay output is often weakened.

F17 limits the current coming into the logic power connector in the event of a short circuit somewhere on the board. If F17 is blown, the Receiver board will not function at all. If F17 blows, there may be a loose piece of metal causing a short circuit somewhere inside the Receiver enclosure.

F18 limits the current supply to the +5 Vdc pins on the PWM outputs and sensor port. Servos, potentiometers, and the yaw rate sensors will not function if this fuse is blown.

F19-26 protects each ground pin on the PWM output connector. Servos and Innovation FIRST speed controllers will not function and Tekin speed controllers may function erratically if connected to a PWM output with a blown ground fuse.

F27 protects the ground connection on the Data In port. If this fuse is blown, the Receiver will be unable to receive data from the Transmitter. If this fuse blows, it is

probably because +12 Vdc has been shorted to the metal case of the RNet, which is connected to ground. Some teams have also experienced failure of fuse F27 in the Receiver after connecting or disconnecting the tether adapter or RNets while power was still applied to the Receiver. **Please disconnect power to the Receiver before connecting or disconnecting cables to/from it.**

2.5.7 Input/Output Control

The inputs on the Transmitter and Receiver are used by the control program running on the Receiver to set the outputs, regardless of whether or not you decide to reprogram the Receiver. This behavior is described in Section 2.6.2.

2.6 Programming the Receiver

2.6.1 Control Programs

The Receiver is supplied with a default control program in order to help get the robot up and running quickly. The functionality of the default control program is described below. If more sophisticated control of the robot is desired, then a custom program, known as the user control program, must be written. In order to facilitate the creation of a user control program, source code for the default control program is provided.

Adding a user control program will not erase the default control program, so the Receiver can be quickly and easily changed back to use the default program in the event of problems with the user control program.

DIP switches on the side of the Receiver are used to select which control program (default or user) is running, and to reset the Receiver in the event of a problem. Table 2.6 shows the Receiver DIP switch settings.

Table 2.6: Receiver DIP Switch Settings

DIP Switch	Setting
1	Default control program
2	User control program
3	Reset
4	Not Used

Notes:

To select an option, place the appropriate switch in the down position.

Only one program (default or user) can run on the Receiver at once. If neither or both programs are selected, the Receiver will not function properly.

The Receiver is designed to prevent the default control program from being overwritten.

To program the Receiver, a 9 pin cable must be connected from the serial port of a PC to the Programming Port on the Receiver, the DIP switches must be set for the user control program and power must be connected to the Logic Power input. The programming software is included on the disk labeled "BASIC Stamp" from

Parallax, Inc. The programming utility STAMP2.EXE is located in the \STAMP2 subdirectory. The source code for the default control program, RXSLAVE.BS2, is on the disk labeled "Control Program Source Code" from FIRST, and is included in printed form in Appendix G. Complete documentation for the STAMP2 program and the PBASIC programming language is provided in the manual entitled "BASIC Stamp Manual" from Parallax, Inc. With the exception of the source code for the default control program, the programming utility and manual can also be obtained via the Internet from Parallax, Inc. at www.parallaxinc.com or ftp.parallaxinc.com. FIRST will make the default control program available to teams via the FIRST web site at www.usfirst.org.

Tip: The documentation files on www.parallaxinc.com are in Adobe's Portable Document Format (PDF). Programs to view these files are available over the Internet for free from Adobe at www.adobe.com.

2.6.2 Input/Output Map

Table 2.7 shows the mapping of Transmitter and Receiver inputs to Receiver outputs when the default control program is running. It also repeats the input pin information and shows what variables in the default control program are used to store the various input values.

Table 2.7: Input to Output Mapping of Default Control Program

Input TX = Transmitter RX = Receiver	Input Pin	Control Program Variable	Receiver Output
TX Joystick 1 - X Axis	-	x1	PWM1
TX Joystick 1 - Y Axis	-	y1	PWM2
TX Joystick 2 - X Axis	-	x2	PWM3
TX Joystick 2 - Y Axis	-	y2	PWM4
TX Potentiometer 1	4	tx_pot1	PWM5
TX Joystick 1 - Thumbwheel	-	wheel1	PWM6
TX Potentiometer 2	19	tx_pot2	PWM7
TX Joystick 2 - Thumbwheel	-	wheel2	PWM8
TX Switch 1	16	sw1_fwd	Relay Output 1 (F)
RX Switch 1 forces off	1	rx_sw1	
TX Switch 2	3	sw1_rev	Relay Output 1 (R)
RX Switch 2 forces off	14	rx_sw2	
TX Switch 3	6	sw2_fwd	Relay Output 2 (F)
RX Switch 3 forces off	2	rx_sw3	
TX Switch 4	18	sw2_rev	Relay Output 2 (R)
RX Switch 4 forces off	15	rx_sw4	
TX Switch 5	15	sw3_fwd	Relay Output 3 (F)
RX Switch 5 forces off	3	rx_sw5	
TX Switch 6	2	sw3_rev	Relay Output 3 (R)
RX Switch 6 forces off	16	rx_sw6	
TX Switch 7	5	sw4_fwd	Relay Output 4 (F)
RX Switch 7 forces off	4	rx_sw7	
TX Switch 8	17	sw4_rev	Relay Output 4 (R)
RX Switch 8 forces off	17	rx_sw8	
TX Switch 9	12	sw5_fwd	Relay Output 5 (F)
RX Switch 9	5	rx_sw9	
TX Switch 10	24	sw5_rev	Relay Output 5 (R)
RX Switch 10	18	rx_sw10	
TX Switch 11	11	sw6_fwd	Relay Output 6 (F)
RX Switch 11	6	rx_sw11	
TX Switch 12	23	sw6_rev	Relay Output 6 (R)

RX Switch 12	19	rx_sw12	
TX Switch 13	10	sw7_fwd	Relay Output 7 (F)
RX Switch 13	7	rx_sw13	
TX Switch 14	22	sw7_rev	Relay Output 7 (R)
RX Switch 14	20	rx_sw14	
TX Switch 15	9	sw8_fwd	Relay Output 8 (F)
RX Switch 15	8	rx_sw15	
TX Switch 16	21	sw8_rev	Relay Output 8 (R)
RX Switch 16	21	rx_sw16	
RX Analog Input 1	24	sensor1	Ignored
RX Analog Input 2	25	sensor2	Ignored
RX Analog Input 3	22	sensor3	Ignored
RX Analog Input 4	23	sensor4	Ignored

In general, with the default control program PWM outputs correspond to joystick and potentiometer inputs on the Transmitter, and relay outputs are turned on (+12 Vdc) if the corresponding switch inputs are connected to ground (1), or relay outputs are turned off (Ground) if the corresponding switch inputs are disconnected (0). However, in the case of Receiver switch inputs 1-8, this behavior is reversed and these switch inputs take precedence over Transmitter switch inputs 1-8 in order to act as directional stop overrides.

2.6.3 Programming Language

All control programs running on the Receiver must be written in PBASIC, a dialect of the BASIC programming language. This language was selected because it is fairly easy to learn, use, and debug in a short period of time. However, as with all programming languages, it is possible to create a program that does not behave as expected. If a user control program is used, the team assumes full responsibility for insuring that the code works as expected.

NOTE

It must be clearly understood that teams are responsible for any software bugs introduced into the control program when using a user control program. If a software bug negatively impacts the performance of a robot during a Competition match, it will not be grounds for a rematch or even a pause in the match.

See Appendix G for a copy of the default control program source code. This code is provided both as an example of how to write a program in PBASIC, and to provide a head start in writing a user control program. It is recommended that the RXSLAVE.BS2 file be copied, and that the copy be used to write any user control software. This way, the original file will always be available as a backup.

2.6.4 User Program Examples

Below are two simple examples of how the default control program can be modified to provide custom functionality.

Example #1 - Coordinated Mode

Many teams wish to drive their robots with only 1 Joystick, leaving the other joystick for the other robot operator to operate various mechanisms. The most convenient scheme for single joystick driving control is to have the Y-axis control speed, while the X-axis controls the yaw (turning rate). This can be accomplished with a simple modification to the default control program. Source code to do this is provided below:

```
' This example allows Joystick 1 to easily steer a robot with tank-style steering
by
' commanding speed with the Y axis and commanding turning rate with the X axis.
' The left side drive motor should be controlled by PWM1, and the right side drive
' motor should be controlled by PWM2.

Serout SSC, SSCBAUD, [SSC_CMD, PWM1, (((2000 + y1 - x1 + 127) Min 2000 Max 2254) -
2000)]
Serout SSC, SSCBAUD, [SSC_CMD, PWM2, (((2000 + y1 + x1 - 127) Min 2000 Max 2254) -
2000)]
'   Serout SSC, SSCBAUD, [SSC_CMD, PWM1, x1]  ' This line must be commented out
'   Serout SSC, SSCBAUD, [SSC_CMD, PWM2, y1]  ' This line must be commented out
```

> *Tip: PBASIC stores numeric values as positive integers. Byte variables have a value range of 0-255. Word variables have a value range of 0-65535. When performing a calculation that would ordinarily result in a negative number, it will instead wrap around to a very high number, because it knows of nothing less than 0. The example code above shows one possible way to get around this limitation by adding 2000, doing a MIN 2000, and then subtracting 2000 at the end.*

Figure 2.10 below shows the resultant outputs from PWM1 and PWM2.
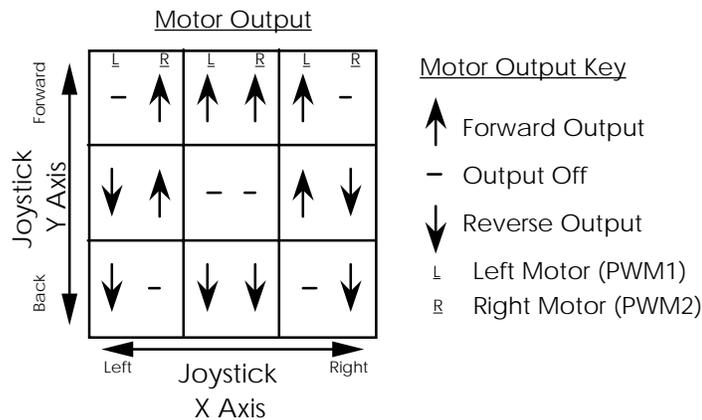
Figure 2.10: Coordinated Mode Motor Output vs. Joystick Position

> *Tip: The x and y-axis values for each joystick will reach maximum when the joystick handle is leaning toward the upper-left corner. The thumbwheels reach maximum when rotated fully forward.*

Example #2 - Coordinated Mode with Joystick Sensitivity Scaling

After experimenting with "coordinated mode", some teams may wish to change the sensitivity of the joysticks. There are two basic strategies:

1.   The easy method: Don't change the sensitivity, just limit the maximum output values. This can be done by a simple adjustment to the Min and Max part of the line. Raise the Min above 2000 to slow down the maximum reverse speed, and lower the Max from 2254 to slow down the maximum forward speed. For example:

```
(((2000 + y1 - x1 + 127) Min 2050 Max 2204) - 2000)
```

2.   The harder but smoother method: Scale the output value down. Take the whole (((...))) part, multiply by a fraction, and add a constant to keep it centered. For example:

```
        ((  ((((2000+y1-x1+127) Min 2000 Max 2254) -2000) * 84/100) + 20 Max
254)
```

> *Tip: When scaling a PWM output, remember that the neutral point (off) is approximately 127. Therefore, you will need to add a constant to the scaled value to keep it centered. Also, remember that PBASIC math is integer-based, so always multiply before you divide to minimize rounding errors.*

Please note that both strategies require the speed controllers to be calibrated <u>prior</u> to modifying the joystick sensitivity. Otherwise, the speed controllers will scale the motor outputs back to maximum reverse and maximum forward and the scaling will appear to have no effect.

2.6.5 Programming the PWM Outputs

The PWM output signals are generated by a chip called the Serial Servo Controller (SSC). Commands in the control program tell the SSC what values to output. For example:

```
  Serout SSC, SSCBAUD, [SSC_CMD, PWM1, x1] ' Update PWM outputs
```

This command sets PWM1 to match the position of the X axis on Joystick 1.

The range of PWM output values which may be sent to Serial Servo Controller is 0-254. 255 is reserved as the Command Prefix (SSC_CMD). The Transmitter will never give a joystick axis, joystick wheel, or potentiometer input reading higher than 254, so it is safe to pass those values straight to the SSC.

When sending a calculated value to the SSC, it is wise to use the Min and Max operators to limit the calculation to appropriate values. The example code in Section 2.6.4 shows this.

> *Tip: The SSC only accepts data for one output at a time. Thus, it takes 8 SSC commands to update all 8 PWM outputs. To speed up the control program, comment out (put a single-quote at the beginning of the line) commands corresponding to unused PWM outputs.*

The SSC, and thus the PWM outputs, is only enabled when uncorrupted data is being received from the Transmitter. This allows the robots to be shutdown remotely. However, whenever the SSC is disabled, it is reset. The default mode for the SSC after a reset is to set all PWM outputs to 127. Thus, it is important to update the PWM values quickly after receiving data.

2.6.6 Programming the Relay Outputs

In the control program, the variable "relays" contains 16 bits that are used to set the state of the relay outputs. Each bit corresponds to a relay output pin. The aliases rly1_fwd, rly1_rev, rly2_fwd, etc. show which bit corresponds to which output pin, and can be used to easily address individual pins. A bit equal to 1 corresponds to an output pin at + 12 Vdc, while a bit equal to 0 corresponds to an output pin at GND.

The variable "tx_sw" contains 16 bits that correspond to the state of the switch inputs on the Transmitter's Auxiliary Input Port and Joystick Ports. Each bit corresponds to a switch input. The aliases sw1_fwd, sw1_rev, sw2_fwd, etc., in conjunction with Table 2.7, show which bit corresponds to which input pin. A bit equal to 1

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corresponds to a closed (grounded) switch input, while a bit equal to 0 corresponds to an open (unconnected) switch input.

Each time the control loop runs, "relays" is initialized to the state of the switch inputs on the Transmitter by the lines:

```
' Set relays to match TX switches
relays = tx_sw
```

This allows the robot operators to control the relay outputs by pressing switches on the joysticks and rocker switches on the project box.

The variable "rx_sw" contains 16 bits that correspond to the state of the switch inputs on the Receiver's Sensor Port. Each bit corresponds to an input pin. The aliases rx_sw1, rx_sw2, rx_sw3, etc., in conjunction with Table 2.7, show which bit corresponds to which switch input pin. A bit equal to 1 corresponds to a closed switch input, while a bit equal to 0 corresponds to an open switch input.

Each time the control loop runs, "rx_sw" is updated by the following lines:

```
' Read Switch Inputs into rx_sw
Gosub ReadSwitches
```

After "relays" is initialized, but before the relay outputs are actually updated, the data in "rx_sw" is used to modify the behavior of the relay outputs in the following lines:

```
' Use 1st 8 RX switches (rx_sw1-8) as STOP switches for Relays 1-4
relays.lowbyte = relays.lowbyte &~ rx_sw.lowbyte

' Use 2nd 8 RX switches (rx_sw9-16) as GO switches for Relays 5-8
relays.highbyte = relays.highbyte | rx_sw.highbyte
```

In the first equation, "relays.lowbyte" addresses the first 8 bits of "relays", which correspond to the forward and reverse pins for the first 4 relays, while "rx_sw.lowbyte" contains the state of the first 8 Receiver switch inputs. A logical (bit for bit) AND NOT (&~) operation is performed and the results are stored back in "relays.lowbyte". This means that bits in "relays.lowbyte" that are off (0) are left off, and bits that are on (1) are left on unless the corresponding bit in "rx_sw.lowbyte" is also on. This translates to leaving off relays off, and on relays on unless a corresponding Receiver switch input is closed. Thus, the first 8 switch inputs on the Sensor Port can be used as safety overrides to force relays 1-4 off.

In the second equation, "relays.highbyte" addresses the last 8 bits of "relays", which correspond to the forward and reverse pins for the last 4 relays, while "rx_sw.highbyte" contains the state of the last 8 Receiver switch inputs. A logical OR (|) operation is performed and the results are stored back in "relays.highbyte". This means that a bit in relays.highbyte will end up on if it starts on or if the corresponding bit in rx_sw.highbyte is on. Otherwise, it will stay off. Thus, the last 8 switch inputs on the Sensor Port can be used to force relays 5-8 on.

Once the values for the relay states have been computed, the outputs are updated by writing the data contained in "relays" to a set of shift registers that actually control the relays. This is done in the following line just before the end of the loop:

```
' Set Relay Outputs
Gosub SetRelays
```

The relay outputs on the Receiver are only enabled when data is being received from the Transmitter. This allows the robots to be shutdown remotely. If data reception is interrupted and then restored, the relays will resume their prior state automatically.

2.6.7 Receiver CPUs

The Receiver has two CPUs, the Master CPU and the User CPU. Both are Basic Stamp 2 CPUs. The Master CPU reads and validates the data from the Transmitter, passes uncorrupted data to the User CPU, and keeps the outputs from shutting down as long as uncorrupted data is being received. It also controls LEDs D25, and D31-33. The User CPU runs the control program and controls LED D26. See section 2.5.5 for a description of the LED behavior.

When power is first applied to the Receiver, or the battery voltage gets too low and there is a brownout on the robot, or the Reset DIP switch is toggled, the CPUs are reset. When this happens, all RAM variables are erased, and the control program restarts at the beginning.

If the control program takes a long time executing instructions within the loop, it will start to miss data coming in from the Master CPU. This is ok, but will result in an increased response time for robot operator and sensor inputs. If the control program takes a really long time (more than 0.10 seconds in the loop) or crashes, the Master CPU will consider this an error and perform the following sequence of actions:

- Disable Relay and PWM outputs

- Turn LED D32 On

- Resume waiting for data from Transmitter and attempting to communicate with control program

Relay and PWM outputs will not be re-enabled until communication with the control program has been reestablished.

2.7 Output Devices

2.7.1 Innovation First Speed Controllers

The manufacturer's specifications and Owners Manual for the Innovation FIRST Victor 883 speed controllers are included in Appendix H.

Each speed controller comes with an integrated 12 Vdc cooling fan. Ring terminals should be installed on the leads of this cooling fan, and the red lead connected to +12 Vdc and black lead connected to Ground at the power input terminals for the speed controller. The fan is not reversible.

For the protection of the speed controllers, one 30A circuit breaker must be installed in series with each Victor 883 speed controller that powers a drill, Fisher-Price, or van door motor. The circuit breaker may be installed on either the input or output side of the speed controller. Do not disable the circuit breaker by connecting its terminals together. Insulate the terminals of this circuit breaker separately so inspectors at the Competition can verify correct installation. If a circuit breaker trips during use, you should use a higher gear reduction ratio to reduce current draw. The circuit breakers usually reset in one to three seconds.

Tip: An easy way to put a circuit breaker in series with an Innovation FIRST speed controllers is to install the circuit breaker in a junction block and draw +12 Vdc from the protected output tab. This method should be fine for most teams and is recommended by FIRST for simplicity and reliability. However, robots pushing the performance barrier can obtain a slightly higher continuous output current from the speed controller by placing the circuit breaker on the output side in series with the motor.

2.7.2 Tekin Speed Controllers

All teams are required to make the following modifications to the Tekin speed controllers:

- Disconnect the red (middle) lead of the 3-wire PWM cable coming out of each Tekin speed controller. This can be done by carefully pulling the pin out of the connector or by physically cutting the red wire. Insulate the pin or ends of the wire with electrical tape or shrink wrap tubing

- Turn on the Battery Eliminator Circuit (BEC) on each Tekin speed controller. This is done by setting the switch coming out of each speed controller to the on position. The on position is indicated by the small tab molded onto the side of the red plastic switch housing.

CAUTION

Failure to make the above modifications to the speed controllers could lead to faulty operation of the Receiver, loss of control of the robot, and/or damage to the control system.

Refer to the Tekin REBEL Owner's Manual for instructions on connecting the speed controllers to the battery and motors.

CAUTION

Each Tekin speed controller comes with a package of capacitors that are intended for use on motors driven by the speed controller. FIRST does not recommend installing the capacitors, because a number of teams in past competitions have experienced short circuits associated with the capacitors that have lead to rapid and permanent failure of the speed controllers and other control system components.

Tekin speed controllers run hotter in reverse than in forward, and actually run hottest at low speeds. If a speed controller shuts off due to overheating during use, you may need to use a higher gear reduction ratio, or you may be running the speed controller continuously in reverse. The speed controller usually takes 30 seconds or more to reset from a thermal shutdown.

2.7.3 Speed Controller Calibration and Troubleshooting - both types

To help insure ease of control, the joysticks and speed controllers should be calibrated. Calibration ensures that the speed controllers will achieve maximum output in forward and reverse when the joystick is at the ends of travel, no output when the joystick is centered, and a proportional output when the joystick is not in the center or at either extreme. Also, with the Tekin speed controllers the reverse delay (braking delay when switching from forward to reverse) can be set, or reverse can be disabled entirely.

Calibration is especially important when using the "Coordinated Mode" steering as mentioned in section 2.6.4. In this mode, the formulas used expect joystick 1 to be centered properly so that x1=127 and y1=127 when the joystick handle is physically centered.

Both the joysticks and speed controllers can be calibrated, and only by coordinating the calibration of both can proper results be obtained.

The Innovation FIRST speed controllers are pre-calibrated with a set of default values that should work well with the FIRST control system, including a neutral point setting corresponding to a PWM value of 127. If these values are not adequate, the speed controllers can be recalibrated by following the instructions in the Victor 883 Owner's Manual. FIRST recommends that all joysticks be calibrated to match the Innovation FIRST speed controller default calibration.

The two small knobs (trimmers) on located on top of each joystick are used to trim (adjust) the X and Y outputs of the joystick. With the control system running, each joystick handle centered, and speed controllers attached to the appropriate PWM outputs, the joystick trimmers should be adjusted until motor output stops. Once the joysticks are calibrated, FIRST recommends placing tape over the trimmers to prevent accidental changes in calibration.

Once the joysticks have been calibrated, FIRST recommends calibrating the Tekin speed controllers to match the joysticks. Also, the reverse delay should be set in all Tekin speed controllers. Instructions for calibrating the Tekin speed controllers and setting the reverse delay are included in the Tekin REBEL Owner's Manuals.

If a speed controller suddenly stops working in forward or reverse, or otherwise behaves unexpectedly, it may be due to one of the following reasons:

- Improper calibration of the joystick and/or speed controller.

- Loose joystick inputs or wiring problems on the Transmitter's auxiliary input port.

- Tekin speed controllers have a reverse disable feature which may be inadvertently activated when attempting to calibrate the speed controller and/or set the reverse delay. The reverse disable feature can be turned off by resetting the reverse delay.

- If connected to a PWM output with a blown ground fuse, Tekin speed controllers may behave erratically and Innovation FIRST speed controllers will not work at all. See section 2.5.6 for information on Receiver fuses.

- Tekin speed controllers have a power switch that, if set improperly, turns them off.

- The PWM cable may be improperly attached to the Receiver, damaged, or disconnected.

- Power to the speed control may be disconnected.

- Tekin speed controllers can undergo a protective shutdown, usually lasting about 30 seconds to 1 minute, if they overheat.

- If problems are experienced while running a user control program, verify that the PWM output values are correct and/or try running the default control program.

- Faulty speed controller electronics.

2.7.4 Muffin Fan

A 12V muffin fan has been included in the Kit primarily for added protection against overheating of the Tekin speed controllers and/or motors. It is recommended that this fan be installed to direct cooling air over the power components that run the hottest. You may provide power to the fan from the 12V power distribution junction blocks directly. Note that the fan is not reversible.

2.7.5 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, and 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 tradeoff 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.

2.7.6 Globe Motor with Drive Assembly

The drive assembly provides a 117 to 1 planetary gear redirection from Globe Motor. 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 damage to the drive assembly will occur.

2.7.7 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 loose 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.

2.7.8 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.

2.8 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 Competition event.

For instructions on charging the batteries, please refer to the battery charger documentation included in the Kit.

WARNING

A warm battery should be allowed 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 100A and can cause fire, serious injury, and leakage of toxic materials.

If you have a battery that you know to be 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 SLA 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.

Due to the short delay between matches upon reaching the elimination match on the final day of each Competition event, FIRST will provide a freshly charged battery to each remaining competitor at each level of finals. For example, a team making it all the way to the finals would receive a freshly charged battery at the start of the quarter-finals, a second freshly charged battery at the start of the semi-finals, and a third freshly charged battery at the start of the finals.

To connect the battery to the rest of the control system, FIRST recommends using ring terminal contacts.

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

See Section 2.3 for information on acceptable wiring of the battery.

During any Competition event, the robots may only be powered by a single 12 Vdc SLA battery supplied by FIRST. These batteries may only be charged through the normal operation of the battery charger provided by FIRST.

APPENDIX A: ROBOT RULES

M   Machine Design & Operation Rules

M1.   The energy used by the robots in the Competition must come solely from:

1. Electrical energy derived from the onboard battery

2. Storage achieved by deformation of springs or the latex tubing

3. Compressed air (or vacuum) stored in the volume chamber (the volume chamber may be charged prior to the start of a match, but only by the pump furnished in the Kit)

4. A change in the altitude of the device's center of gravity.

M2.   Robots must sit, unconstrained, inside a 36x30" rectangular footprint and be no more than 48" high at the start of a match. The weight of the robot, including battery and control system, may not exceed 130.0 pounds.

Size ≤ 36" long dimension x 30" short dimension x 48" high; Weight ≤ 130.0 pounds

Tip: Keep in mind that these are maximum dimensions. It is recommended that robots be designed 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 Competition event. The robot must pass inspection before competing in any competition matches. Teams may be re-inspected anytime during an event at FIRST's discretion. If modifications to your robot are necessary to comply with the Robot Rules, they must be completed before the robot will be allowed to compete in further competition matches. If a team wishes to have their robot re-inspected to insure rules compliance, they may ask FIRST officials to do so. If Team A suspects Team B of a violation, Team A may approach FIRST officials and ask them to take another look at the Team B's robot. This is an area where "Gracious Professionalism" is very important.

M4.   **Teams are expected to design and build robots to withstand vigorous amounts of interaction with other robots.**

M5.   Until the controls are enabled at the beginning of each match, robots and any appendages, or extensions must remain unconstrained within the 36"x30"x48" 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 4x6 field border, the puck, the floppies, the other robots, and the air. Robots should not be designed to react off of the top face of the 4x6 field border or other parts of the field border. If

your robot inadvertently drives on the top of the 4x6 field border, you won't 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, team numbers must be displayed 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. "Non-functional" decorations may be added to machines under the following conditions:

- Decorations must not cause the weight or initial size requirements for the robot to be exceeded.

- Decorations must not affect the outcome of the match. For example, flashing lights are OK as long as they do not blind opponents.

- 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 (batteries or relay outputs) as long as they do not affect the operation of other control system components.

- Non-functional decorations do not count against the $425 limit or Additional Hardware List.

- Decals are considered non-functional decorations.

M9. Robots must be designed to be operated by the wireless programmable control system.

M10. Gaining traction by using adhesives or by damaging the surface of the playing field or the floppies is not allowed. Using Velcro to adhere to the carpet has the potential to damage the carpet and is therefore prohibited.

M11. During robot inspection, all mechanisms that will be used on the robot at the event must be present on the robot. However, it is acceptable for a robot to play matches with a subset of the mechanisms that were present during inspection. Mechanisms may only be added, removed, or reconfigured between matches. Also, the control system may be reprogrammed between matches.

M12. No substitute robots are permitted; however, functionally identical replacement parts are allowed.

M13. <u>Only</u> 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.

- Pneumatic fittings from Small Parts, Inc. may be used.

- 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.

Custom-made pneumatic fittings, air cylinders, pumps, air accumulators, and so forth are not allowed, even if they are created from components included in the Kits. Also, valves, syringes, tubing, and so forth from SPI or outside sources may not be used for pneumatics.

M14. Pneumatic components supplied in the Kit (pump, cylinders, valves, fittings, tubing, etc.) may not be modified except as follows:

- Tubing may be cut.

- The wiring for the pump, valves and pressure switches 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.

M15. All mechanisms on the robot should be fabricated/assembled by the 1999 team and not be reused from previous year's robots.

M16. Mechanisms which present a risk of entanglement may be disallowed by the referees.

C C̲ontrol System Rules

C1. The control system is provided to allow wireless control of the robots. The Transmitter, Receiver, servos, speed controllers, RNets, antennas, batteries, battery chargers, power supply, data cables, tether adapter, circuit breakers, fuse, and joysticks may not be tampered with, modified, adjusted or marked in any way, with the following exceptions:

- The dip switches on the Transmitter and Receiver may be set for custom operation.

- The user programmable code in the Receiver may be customized.

- The speed controllers may be calibrated as described in owner's manuals.

- The red 24 AWG wire on the PWM cable of the Tekin Rebel speed controllers must be cut and both resulting cut wire ends insulated. This must be done to assure trouble free operation.

- It is acceptable to remove material from the edge of the connector housing on the 9-9 pin cables and 9-15 pin cables in order to make a non-interference fit next to the BNC connections on the RNets.

Tampering includes drilling, cutting, machining, gluing, rewiring, etc. All items listed in Rule C1 must be mounted without alteration. Do not write on or otherwise mark control system components.

C2.   Do not attach tape, stick-on hook & loop fasteners, glue, or other adhesives to control system components. FIRST re-uses many of these components, and these items can be difficult to remove. Instead, use clamps, straps, or existing holes for mounting. The only exceptions to this rule are:

- Tape may be used to secure the position of the trimmers on the Joysticks in order to prevent accidental changes in calibration.

- Stick-on hook & loop fasteners may be used to attach the speed controllers and RNets to the robot.

For mounting control system components, use mechanical fasteners, such as cable ties, straps, or brackets. Do not use tape, stick-on hook & loop fasteners, glue, or other adhesives.

C2.   Position the RNet on the robot so that it is easily accessible and can be swapped in and out. During competition matches, when setup time is limited, the 9-15 pin cables will be used to connect the Receiver to the RNet on the robot.

C3.   The black project box is intended to serve as a mounting point for the rocker switches, pushbutton switches, and potentiometers used by the robot operators, and to enclose the associated wiring. You may modify the project box in any manner to accommodate your needs.

C4.   **The wire supplied in the Kit may be used to conduct electricity. Additional wire may be used 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.   Six gauge wire must be used to connect the battery to the junction blocks (or equivalent). Ten gauge wire must be used for connections from the junction blocks (or equivalent) to Innovation FIRST speed controllers, from Innovation FIRST speed controllers to the drill, Fisher-Price, or van door motors, and from the junction blocks (or equivalent) to the Receiver. Sixteen gauge wire

may be used to connect Globe, seat, or window lift motors to either type of speed controller.

C7. Sixteen gauge jacketed cable must be used for any device connected to a relay output.

C8. Twenty-four gauge wire may only be used for connecting sensors (limit switches, reed switches, rocker switches, pushbutton switches, air pressure switches, potentiometers, yaw rate sensors, optical sensor) to inputs, for extending the PWM cables, or for wiring the LEDs.

C9. **Relay outputs may not power more than one device per output.** The double-solenoid valve is considered one device, because the diodes may be used to route power to only one solenoid at a time. Also, the 12 Vdc LEDs may be wired in parallel with other output devices connected to the relay outputs.

C10. **Only the Receiver, speed controllers, optical sensor, 12 Vdc LEDs, and muffin fan may be connected directly to the fused battery outputs.**

C11. The drill motors. Fisher-Price motors, and van door motors may be powered only by the speed controllers.

   Do not connect the drill motors, Fisher-Price motors, or van door motors to the relay outputs.

C12. No more than one drill motor, Fisher-Price motor, or van door motor may be powered by each speed controller.

C13. The seat motor, Globe motors, window lift motors, and 12 Vdc LEDs may be powered by the speed controllers or the relay outputs. 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 Innovation FIRST speed controller, either on the +12 Vdc input or motor output side, if the speed controller is connected to a drill, Fisher-Price, or van door motor. The circuit breaker must be accessible for inspection at each Competition event.

C16. The battery fuse (provided in the Kit) must be installed in series with the positive terminal of the battery, such that all battery output flows through this fuse before being distributed to the Receiver, speed controllers, fan, +12 Vdc LEDs, or optical sensor. This fuse must be accessible for inspection at each Competition event.

C17. Only the 7.5 Vdc power supply included with the Kit may be used to power the Transmitter. Use of an alternate power supply could damage the Transmitter or RNet and is therefore prohibited.

C18. Do not connect 12 Vdc power or ground wires to the relay outputs. Doing so will cause a short circuit and may damage the Receiver.

C19. Do not connect 12 Vdc power, relay, speed controller, or PWM outputs to the sensor port on the Receiver. Power for all sensors, except the optical sensor, is available from the sensor port.

C20. All sensors used on the robot must be connected directly to the sensor port on the Receiver, and may not be wired in series with the motors, pumps, or valves.

C21. RNets may not be used in the Pit Area at any Competition event. A tether must be used for bench testing.

C22. If the control system is damaged due to improper wiring or misuse, FIRST will charge for repair or replacement of the affected items.

C23. During the competition your robot may only be operated with a battery provided by FIRST.

C24. When recharging Kit batteries, you may only use the charger provided by FIRST.

C26. All wires distributing power with a constant polarity (i.e. not a relay or speed controller output) must be color coded as follows:

- Use Red 6 AWG wire (or Black 6 AWG wire wrapped with red electrical tape) for +12 Vdc from the battery.

- Use Red 10 AWG, Red 24 AWG, or White or Red 16 AWG wire for +12 Vdc.

- Use Black 10 AWG, Black 24 AWG, or Black 16 AWG wire for Ground.

C27. **Teams are responsible for any software bugs introduced into the Receiver's control program when using a custom program. If a software bug negatively impacts the performance of a robot during a competition match, it will not be grounds for a rematch or even a pause in the match.**

C28. Position the Receiver within your 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 Competition.

C29. Position the 12 Vdc battery within your robot so that it is accessible and may be easily changed out between matches.

THE 1999 FIRST ROBOTICS COMPETITION MANUAL

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.
- Material satisfying the unlimited quantity criteria, 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 not be used except to reduce friction within your own robot.

Outside Sources - Small Parts, Inc. Catalog

- Each team receives a SPARK (Small Parts Addition to Robotics Kits) certificate representing an account with a $425 credit balance. This account will be debited for the actual purchases you make, meaning you get up to $425 worth of parts for free. You may go beyond this dollar limitation for prototyping or to purchase spare parts, but your team is responsible for paying the balance on the account. See Appendix D for more details on accounting and ordering.

- Up to $425 worth of materials purchased from Small Parts, Inc. (SPI) may appear on your final robot. Items which appear below in the unlimited quantity category do not count against the $425 limit when used as described. When your robot is inspected at a competition, you will be asked to verify that you have not used more than $425 worth of materials on your robot. Be prepared to show documentation to support this requirement, e.g. a bill of materials and purchase prices.

- It has been brought to our attention that the actual prices of components purchased from Small Parts, Inc. may not match the prices printed in the catalog. Please use the catalog prices when calculating the cost of robot components from SPI for compliance with the $425 limit.

- If you use only a portion of what you buy from Small Parts, you may prorate the dollar amount used to the smallest quantity listed for purchase in the catalog. For 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.

Outside Sources - Additional Hardware List

- Materials on the Additional Hardware List may be obtained from any supplier, are not limited by cost, but are 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 $425 limit on SPI parts used on the robot. However, any amount of the item purchased from SPI above and beyond the quantity allowed in the Additional Hardware List will count against the $425 limit on SPI parts used on the robot.

Unlimited Quantity Items

The following items may be used in unlimited quantity subject to the following criteria:

- Fasteners, washers, nuts and adhesives -- if used <u>only for joining and fastening purposes</u>. These items are not to be used to fabricate a structure or device that is not the item's normal function (with the exception of the next stated criteria).

- Pins in a linkage or hinge.

- Crimp-on spade connectors, butt connectors, ring connectors, and bullet connectors -- if used to conduct electricity, used with the proper gauge wire, crimped properly, and fully insulated, such as the spade connectors provided in the Kit.

- Wire – if used to conduct electricity, of the proper gauge, proper color, and fully insulated.

- Wire Nuts -- if used conduct electricity, used with the proper gauge wire and fully insulated.

- Adhesive tape -- if used as an electrical insulator.

- Lubricants -- if used to reduce friction within your own device.

- Teflon tape -- if used around the threads of pneumatic fittings to prevent leaks.

- Shrink wrap tubing of any diameter -- if used for electrical insulation.

- Pipe fittings (tees, reducers, elbows, and angles) -- if used to join sections of pipe

- Endcaps -- if used to cap pipe.

- Pipe flanges -- if used on the ends of pipe.

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.

K3. There is no restriction on the total quantity of sprockets/pulleys/gears and chain/belt that can appear on your robot. However, there is a restriction on the amount which can be obtained from outside sources other than SPI. Any quantity above the amount listed on the Additional Hardware List must therefore be purchased from SPI, or manufactured from raw materials available from either the Kit, the Additional Hardware List, or SPI.

K4.   As denoted in the Additional Hardware List, each team may purchase from an outside source sprockets, gears and/or pulleys and additional chain and/or belt, with the following conditions:

- On your final robot, you may use no more than a combined total of 6 purchased sprockets, gears, and/or pulleys from outside sources other than SPI.

- On your final robot, you may use no more than a combined total of 12' of chain and/or belt from outside sources other than SPI. There are no restrictions regarding pitch or width of chain and/or belt. However, you may not purchase a wide belt, slice it lengthwise, and use more than a 12' length in the final robot.

- These components must be "commercially available," strictly *off-the-shelf* only. No custom or special orders. Within the SPI catalog there are custom lengths of a specific cross section item available for standard parts with special orders. These items may be ordered and are considered *off-the-shelf.*

- A double-sprocket or double-pulley assembly counts as two sprockets or pulleys, respectively.

K5.   The dimensions for sheets and boards listed in the Additional Hardware List represent the maximum length and maximum width which may be purchased, not the total area. The thickness represents a fixed quantity, not a maximum.

K6.   The dimensions for rods and shafts listed in the Additional Hardware List represent the maximum length that may be purchased for a given diameter of rod/shaft.

K7.   You may purchase only ½" plywood **or** 7/16" chipboard listed in the Additional Hardware List.

K8.   If any item listed as an Unlimited Quantity Item is used for a purpose other than its specified use, it must either:

- Be purchased from SPI against the $425 limit

- Be manufactured from raw materials available in the Kit or the Additional Hardware List or SPI.

K10. 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 the 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, and compression, tension, torsion, constant force, Latex tubing, and washer springs available from Small Parts, Inc. You may not modify a pneumatic actuator in any way to use it as a spring.

K11.   A limited number of replacement parts will be made available by FIRST upon justified request. Otherwise, lost or damaged Kit materials may be replaced only with identical components of the same material, dimensions and treatment.

K12.   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 in order to improve surface hardness

- 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.

K13.   The mailing tube provided in the Kit are considered packaging material and may not be used during any Competition event.

K14.   The control system is the property of FIRST and certain components must be returned at the conclusion of the Competition. **The control system is not for sale.** Teams wishing to borrow the control system for a limited amount of time after the Competition may do so by following the procedures outlined in Section 2: The Robot. For teams that wish to operate their robots after this period, FIRST can provide basic instructions on how to refit the robots to use off-the-shelf remote control systems.

K15.   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 insure all teams have equal access to parts. Allowing a team to use a part others did not know was available would be unfair.

APPENDIX B: KIT OF PARTS

1999 FIRST Competition Kit Parts

Bearings

Part Name/Description	Dimensions	Location	Qty /Kit	Product Supplier
2 Bolt Self Aligning Flange	Fits 1/2" Bearing	Gray Container - Bearing Bag	8	The Torrington Company
Pillow Block	1/2"	Gray Container - Bearing Bag	2	The Torrington Company
Radial Ball Bearing With Spherical O.D.	1/2" I.D., Self Locking Collar	Gray Container - Bearing Bag	4	The Torrington Company
Roller Clutch	3/8" I.D.	Gray Container - Bearing Bag	2	The Torrington Company
Single Row Radial Flanged Ball Bearing	1/4" I.D.	Gray Container - Bearing Bag	4	The Torrington Company
Single Row Radial Flanged Ball Bearing	3/8" I.D.	Gray Container - Bearing Bag	4	The Torrington Company
Window Motor Bushing	5/16" I.D. x 1/2" Long	Gray Container - Window Lift	2	Stock Drive Products

Control System

Part Name/Description	Dimensions	Location	Qty /Kit	Product Supplier
1 Conductor Wire	10', #6 AWG, Black	Gray Container - Loose	1	General Cable Company Inc.
1 Conductor Wire	10', #6 AWG, Red	Gray Container - Loose	1	General Cable Company Inc.
1 Conductor Wire	35', #10 AWG, Black	Gray Container - Loose	1	General Cable Company Inc.
1 Conductor Wire	35', #10 AWG, Red	Gray Container - Loose	1	General Cable Company Inc.
15 pin solder cup connector	DB15 female (up to 4)	Additional Hardware List	1	team
2 Conductor Jacketed Wire	30', #24 AWG	Gray Container - Loose	1	General Cable Company Inc.
2 Conductor Jacketed Wire	35', #16 AWG	Gray Container - Loose	1	General Cable Company Inc.
2 Pin Logic Power Connector	Black, European Style Header	Green Container -	1	Thomas & Betts Corp.
25 Pin Cable	DB25 Male to Female, 6', Shielded	Green Container -	1	Brevan Electronics
25 Pin Male D-Sub Solder Cup Connector	25 Pin Male D-Sub Solder Cup	Green Container -	2	AMP Incorporated
3 Conductor Shielded Wire	30', #24 AWG	Gray Container - Loose	1	General Cable Company Inc.
8 Pin Relay Output Connector	Black, 8 Position European Style Header	Green Container -	2	Thomas & Betts Corp.
9 - 15 Pin Cable	3' Long, DB9 Female to HDB 15 Male	Green Container -	2	Brevan Electronics
9 Pin Cable	DB9 Male to Female, 6', Shielded	Green Container -	3	Brevan Electronics

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Antenna, Helical UHF	3" Long	Green Container -	2	Motorola
Attenuator		Green Container -	1	Mini-Circuit
Battery Charger	Sealed Lead Acid Battery, 4 amp	Green Container -	1	Xenotronix or Associated Power Products
Battery Fuse	60 A, Maxi-Fuse	Green Container -	1	Bussmann
Battery Fuse Holder	Maxi-Fuse, 6 AWG leads	Green Container -	1	Bussmann
Battery, Sealed Lead Acid	12 Vdc, 17 Amp Hours	Green Container -	1	CSB Battery of America Corp
BNC Bulkhead Connector	BNC Male to Male, insulated	Green Container -	1	Brevan Electronics
BNC Coax Cable	6 ' BNC Female to Female	Green Container -	2	Brevan Electronics
BNC Right Angle Connector	BNC Male to Female	Green Container -	1	Brevan Electronics
Circuit Breaker For Motors	30 amp,12 volt, Auto-Resetting	Green Container -	12	Snap-Action, Inc.
Diode	1 Amp, Maximum	Green Container -	2	Digi-Key Corporation
Flightstick Joystick	7" Cable with Male DB15	Green Container -	2	CH Products
Fuse Panel	ATC Blade-Type (6 fuseable circuits, 12	Green Container -	2	Bussmann
Ground Plane Assembly	12" x 12" with BNC Bulkhead Connector	Gray Container - Loose	1	FIRST
Heat Shrink Tubing	1/4"Ø x 3", Black, 2:1 Shrink Ratio RNF100	Green Container -	1	Raychem Corporation
Heat Shrink Tubing	1/8"Ø x 4", Black, 2:1 Shrink Ratio RNF100	Green Container -	1	Raychem Corporation
Heat Shrink Tubing	3/4"Ø x 3", Black, 2:1 Shrink Ratio	Green Container -	1	Raychem Corporation
Heat Shrink Tubing	3/8"Ø x 5", Black, 2:1 Shrink Ratio RNF100.	Green Container -	1	Raychem Corporation
Knob for Potentiometer	1" Hexagon, Fits 1/4" Shaft	Green Container -	2	Radio Shack
Latching Pushbutton Switch		Green Container -	2	Honeywell - Microswitch Division
LED, Panel Mount	Amber, 5V	Green Container -	1	Chicago Miniature Lamp, Inc.
LED, Panel Mount	Green, 12V	Green Container -	4	Chicago Miniature Lamp, Inc.
LED, Panel Mount	Red, 12V	Green Container -	4	Chicago Miniature Lamp, Inc.

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Limit Switch		Green Container -	10	Honeywell - Microswitch Division
Momentary Rocker Switch		Green Container -	8	Honeywell - Microswitch Division
Muffin Fan	12 Vdc	Green Container -	1	EBM Industries
Optical Sensor	Miniature DC Sensor	Green Container -	2	Honeywell - Microswitch Division
Potentiometer	100KΩ, Linear	Green Container -	6	Bourns, Inc.
Power Supply	7.5 Vdc, 1.0 Amp max	Green Container -	1	Golden Pacific Electronics, Inc.
Project Box	Black	Green Container -	1	Serpac
Pushbutton Switch Cover	Red	Green Container -	2	Honeywell - Microswitch Division
Quick-Disconnect Power Connector	#10 AWG red/black wire w/connector	Gray Container - Loose	1	Anderson Power Products
Quick-Disconnect Power Connector	#6 AWG Red/Black Wire w/ connector	Gray Container - Loose	2	Anderson Power Products
Receiver	2.25" x 5.75" x 8.75"	Green Container -	1	FIRST
Reed Switch	Normally Open, Magnet Activated	Green Container -	4	CP Clare
Ring Connector	# 6 Awg	Green Container -	7	
RNet 9600sslm, Programmable	High Density DB15 Female	Kick Off Check Out	2	Motorola
Rocker Switch Cover	Blue	Green Container -	1	Honeywell - Microswitch Division
Rocker Switch Cover	Green	Green Container -	1	Honeywell - Microswitch Division
Rocker Switch Cover	Red	Green Container -	1	Honeywell - Microswitch Division
Rocker Switch Cover	Split Red/Green	Green Container -	4	Honeywell - Microswitch Division
Rocker Switch Cover	Yellow	Green Container -	1	Honeywell - Microswitch Division
Servo	Hitec/JR-style Connector, 42 oz. in.	Green Container -	2	Hitec RCD, Inc.
Servo Extension Cable	Hitec/JR-style, 36" Long	Green Container -	4	Hitec RCD, Inc.
Servo Y Cable	Hitec/JR-style, 24" Long	Green Container -	2	Hitec RCD, Inc.
Spade Connector	Female, 12-10 AWG, Yellow	Green Container -	10	Thomas & Betts Corp.

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Spade Connector	Female, 16-14 AWG, Blue	Green Container -	10	Thomas & Betts Corp.
Spade Connector	Female, 22-18 AWG, Red	Green Container -	10	Thomas & Betts Corp.
Spade Connector	Male, 12-10 AWG, Yellow	Green Container -	10	Thomas & Betts Corp.
Spade Connector	Male, 16-14 AWG, Blue	Green Container -	10	Thomas & Betts Corp.
Spade Connector	Male, 22-18 AWG, Red	Green Container -	10	Thomas & Betts Corp.
Speed Controller		Green Container -	2	Innovation FIRST
Speed Controller	7.2 - 12 Vdc, Reversing	Green Container -	2	Tekin Electronics, Inc.
Terminal Strip	Tubular, Double Screw Terminal Strip (7 slots)	Green Container -	1	Thomas & Betts Corp.
Tether Adaptor	Black DB9 Female-Female	Green Container -	1	Brevan Electronics
Thermo-Plastic Shield for 25 Pin Connector	fits DB25 Connector	Green Container -	1	AMP Incorporated
Transmitter	1.75" x 5.50" 7.50"	Green Container -	1	FIRST
Window Lift Mechanism Washer	Fits over Flanged Bushing	Gray Container - Window Lift	2	Fastenal Company
Wire Nut	Wire Nut for Wire Sizes #18-10 AWG	Green Container -	10	Thomas & Betts Corp.
Wiring Harness For Receiver Relay Power Connector	1', #10 AWG, Red and Black	Gray Container - Loose	1	Nova Biomedical/Amp Inc.
Wiring Harness For Seat Motor	5', #16 AWG	Gray Container - Loose	1	Nova Biomedical/Pioneer Packard
Wiring Harness For Window Motor	5', #16 AWG	Gray Container - Loose	2	Nova Biomedical/Pioneer Packard
Yaw Rate Sensor		Gray Container - Loose	2	BEI Systron Donner

Documentation

Part Name/Description	Dimensions	Location	Qty /Kit	Product Supplier
BASIC Stamp Programming Disk	3.5" HD Floppy	Green Container -	1	Parallax, Inc.
BASIC Stamp Programming Manual		Green Container -	1	Parallax, Inc.
Control Program Source Code	3.5" HD Floppy	Green Container -	1	FIRST
Kee Industrial Caster Catalog		Gray Container - Loose	1	Kee Industrial Products
Kee Klamp Pipe Fitting Catalog		Gray Container - Loose	1	Kee Industrial Products

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Operation & Maintenance Manual for the Pneumatic Pump	For the Pneumatic Pump	Green Container -	1	Gast Manufacturing, Inc.
Pneumatic Training Manual CD		Green Container -	1	SMC Pneumatics, Inc.

Fasteners

Part Name/Description	Dimensions	Location	Qty /Kit	Product Supplier
5 Minute Epoxy Gel	Resealable 1 oz. Dual Syringe	Gray Container - Hardware Bag	1	Kaman Industrial Technologies
Cable Tie	11" x 0.14"	Green Container -	10	Thomas & Betts Corp.
Cable Tie	8" x 0.09"	Green Container -	10	Thomas & Betts Corp.
Cable Tie Mounting Base	Self-Adhesive, Holes For #8 Screws	Green Container -	10	Thomas & Betts Corp.
Drill Housing Screws	#4 x 3/4, Pan Head - Phillips	Green Container - Drill	10	Fastenal Company
Drill Motor Mounting Flange Fastening Screws	Button 19, M4 x 5mm	Green Container -	4	Fastenal Company
Helical Plastic Wire Wrap	1/4" Ø x 24"	Gray Container - Hardware Bag	1	Tyton Hellermann
Velcro 1" Hook & Loop Tape (W/ Adhesive backing)	18" Lengths	Green Container -	1	Velcro USA, Inc.
Velcro 1" One WrapTape	18" Lengths, Red	Green Container -	1	Velcro USA, Inc.
Velcro 5/8" One WrapTape	black	Green Container -	1	Velcro USA, Inc.
Velcro Sticky Back Coins	5/8" Ø, 15 Sets Per Pack	Green Container -	15	Velcro USA, Inc.

Motors & Pumps

Part Name/Description	Dimensions	Location	Qty /Kit	Product Supplier
Capacitor, Drive Motor Noise Suppression	0.1 µF, 50 V Ceramic Molded Radial	Green Container -	4	KEMET Electronics Corporation
Drill Drive Assembly	225 in. lbs Maximum Torque	Green Container - Drill	2	S-B Power Tool Company
Drill Housing Assembly	T-Handle Style Grip, Left/Right with Shift	Green Container -	2	S-B Power Tool
Drill Motor	12 Vdc	Green Container - Drill	2	S-B Power Tool
Fisher-Price 10 Web Jeep Driver		Gray Container - Loose	2	Fisher-Price, Inc.
Fisher-Price Axle		Gray Container - Loose	1	Fisher-Price, Inc.
Fisher-Price Motor/Gearbox	12 Vdc, w/ foot pedal & shifter	Gray Container - Loose	2	Fisher-Price, Inc.
Globe Motor with Drive Assembly	12Vdc	Gray Container - Loose	2	Globe Motors

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Seat Motor	12 Vdc	Gray Container - Loose	1	ITT Automotive
Van Door Motor - Bosch	12 Vdc, 75 RPM	Gray Container - Loose	1	Delphi Interior and Lighting Systems
Van Door Motor - Tiagene	12 Vdc, 75 RPM	Gray Container - Loose	1	Delphi Interior and Lighting Systems
Window Motor, Left Hand	12 Vdc, 12 Tooth Pinion, 16 pitch stub	Gray Container - Window Lift	1	ITT Automotive
Window Motor, Right Hand	12 Vdc, 12 Tooth Pinion, 16 pitch stub	Gray Container - Window Lift	1	ITT Automotive

Other

Part Name/Description	Dimensions	Location	Qty /Kit	Product Supplier
Carpet Sample	12" x 12", 20 oz., Closed Loop	Gray Container - Loose	1	FIRST
Co-Polymer Gutter Guard	6" x 24"	Gray Container - Loose	1	Home Depot
Folding Table Leg Brace, Left Hand	Heavy Duty Leg Brace	Gray Container - Loose	1	Stanley Hardware
Folding Table Leg Brace, Right Hand	Heavy Duty Leg Brace	Gray Container - Loose	1	Stanley Hardware

Pneumatics

Part Name/Description	Dimensions	Location	Qty /Kit	Product Supplier
Air Cylinder	12" stroke w/ clevis & nose mounts	Green Container -	1	SMC Pneumatics, Inc.
Air Cylinder	5" stroke w/ clevis & nose mounts	Green Container -	2	SMC Pneumatics, Inc.
Air Filter for the Pneumatic Pump	For the Pneumatic Pump	Green Container -	1	Gast Manufacturing, Inc.
Air Pump	Diaphragm Pump, 1/8HP, 12VDC, 30psi,	Green Container -	1	Gast Manufacturing, Inc.
Check Valve	1/8" Ø Barbs 75 max. psi, black	Green Container -	2	Air Logic
Direct Valve	12 Vdc	Green Container -	1	SMC Pneumatics, Inc.
Double Solenoid Valve	12 Vdc	Green Container -	1	SMC Pneumatics, Inc.
Fitting	Straight fitting for valves	Green Container -	9	SMC Pneumatics, Inc.
One Touch Fitting	Straight fittings for cylinders	Green Container -	6	SMC Pneumatics, Inc.
One Touch Fitting	Straight fittings for pressure switch	Green Container -	1	SMC Pneumatics, Inc.
One Touch Fitting	Straight fittings for Valves	Green Container -	3	SMC Pneumatics, Inc.
Pressure Switch	12 Vdc, Hysteresis	Green Container -	1	SMC Pneumatics, Inc.

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Single Solenoid Valve	12 Vdc	Green Container -	2	SMC Pneumatics, Inc.
Volume Chamber		Green Container -	1	SMC Pneumatics, Inc.

Rods & Shafts

Part Name/Description	Dimensions	Location	Qty /Kit	Product Supplier
Aluminum Rod	1/2" Ø x 24"	Gray Container - Tube	2	Cohen Steel Supply Inc.
Brazing Rod	1/16" Ø x 18"	Gray Container - Tube	1	FIRST
Brazing Rod	1/8" Ø x 18"	Gray Container - Tube	1	FIRST
Delrin (Acetal) Rod	1/4" Ø x 20"	Gray Container - Tube	1	Plastic Supply
Drill Rod	1/2" Ø x 18"	Gray Container - Tube	2	Cohen Steel Supply Inc.
Drill Rod	1/4" Ø x 18"	Gray Container - Tube	2	Cohen Steel Supply Inc.
Drill Rod	3/8" Ø x 18"	Gray Container - Tube	2	Cohen Steel Supply Inc.
Drill Rod	5/16" Ø x 18"	Gray Container - Tube	2	Cohen Steel Supply Inc.
Flexible Motor Shaft	13.5" Long, Fits Seat Motor	Gray Container - Loose	2	Grand Rapids Controls
LDPE Rod	1" Ø x 24"	Gray Container - Tube	1	Plastic Supply Inc.
Lead Screw	18.75" Long	Gray Container - Loose	1	Kerk Motion Products, Inc.
Threaded Rod	1/4" Ø x 18", 20 Pitch Coarse Thread, Alloy	Gray Container - Tube	1	FIRST

Sheets & Boards

Part Name/Description	Dimensions	Location	Qty /Kit	Product Supplier
Aluminum Sheet	1/16" x 12" x 12"	Gray Container - Loose	1	Cohen Steel Supply Inc.
Rubber Sheet, Red	1/16" x 6" x 18"	Gray Container - Loose	1	FIRST

Small Parts

Part Name/Description	Dimensions	Location	Qty /Kit	Product Supplier
Caster, Swivel	165 Pounds, 10mm bolt hole	Green Container -	2	Kee Industrial Products
Channel For Tape Drive	28" Long	Gray Container - Loose	4	Delphi Interior and Lighting Systems
Double Magnet Cabinet Catch		Gray Container - Hardware Bag	1	Stanley Hardware
Drill Housing Cover	T-Handle Style Grip, Left/Right with Shift	Green Container - Drill	2	S-B Power Tool

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Flange Nut for Seat Positioning Unit	M6 x 1.0 Pitch	Gray Container - Seat	8	Lear Corporation
Flat Washers	1/4" I.D., 7/8" O.D.	Gray Container - Hardware Bag	4	Fastenal Company
Flexible Shaft Coupling	Black	Gray Container - Hardware Bag	2	DEKA
Folding Table Brace	9-1/2" Brass plated	Gray Container - Hardware Bag	1	Stanley Hardware
Gate Latch	Steel/Zinc Plated	Gray Container - Hardware Bag	1	Stanley Hardware
Hex Head Bolt for Seat Positioning Unit	M6 x 1.0 Pitch x 30mm	Gray Container - Seat	4	Lear Corporation
Hex Nuts	1/4" I.D., 20 Pitch Coarse Thread	Gray Container - Hardware Bag	8	Fastenal Company
Horiz. Act. for Seat Positioning Unit, Left Hand	Natural Color	Gray Container - Seat	1	Lear Corporation
Horiz. Act. for Seat Positioning Unit, Right Hand	Black and Natural Color	Gray Container - Seat	1	Lear Corporation
Lower Channel for Seat Positioning Unit	2.25" x 17" Channel	Gray Container - Loose	2	Lear Corporation
Magnet	1/4-20 Plastic Thread	Gray Container - Hardware Bag	4	Honeywell - Microswitch Division
Pivot	5/16" Ø	Gray Container - Hardware Bag	2	Stanley Hardware
Roller Guide	7/8" Ø x 1/4" Wheel	Gray Container - Hardware Bag	2	Stanley Hardware
Screen Door Catch	Zinc-Plated	Gray Container - Hardware Bag	1	Stanley Hardware
Trantorque Coupling	3/8" I.D., 3/4" O.D.	Green Container -	2	Small Parts, Inc.
Upper Channel for Seat Positioning Unit	1.3125" x 9.875" Channel with Gear	Gray Container - Seat	2	Lear Corporation
Wheelchair Wheel	6" Ø, 5/16" I.D. Bearings, 1-1/2" Wide	Gray Container - Loose	2	Skyway Recreation Products
Wheelchair Wheel	8" Ø, 5/16" I.D. Bearings, 1-1/2" Wide	Gray Container - Loose	2	Skyway Recreation Products
Window Lift Bracket, Left Hand	Color Natural	Gray Container - Window Lift	1	Delphi Interior and Lighting Systems
Window Lift Bracket, Right Hand	Color Natural	Gray Container - Window Lift	1	Delphi Interior and Lighting Systems
Window Lift Gear	Use with Window Tape, Window Lift Mechanism	Gray Container - Window Lift	2	Delphi Interior and Lighting Systems
Window Lift Guide Drive	Use with Guide, Channel, Window Tape	Gray Container - Window Lift	8	Delphi Interior and Lighting Systems
Window Lift Guide, Left Hand	Attach to Triangular Mount, Window Lift	Gray Container - Window Lift	1	Delphi Interior and Lighting Systems

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Window Lift Guide, Right Hand	Attach to Triangular Mount, Window Lift	Gray Container - Window Lift	1	Delphi Interior and Lighting Systems
Window Lift Mechanism Tape	16' Length	Gray Container - Window Lift	1	Dymetrol Company, Inc.
Window Lift Triangular Mount	White, Window Lift Mechanism	Gray Container - Window Lift	2	St. Clair Plastics Company

Springs

Part Name/Description	Dimensions	Location	Qty /Kit	Product Supplier
Compression Spring	0.600" O.D. x 3.5 " Long x 0.059" Wire Diameter	Gray Container - Hardware Bag	2	Associated Spring Raymond
Constant Force Spring, Large	2.26" I.D.	Gray Container - Hardware Bag	2	Associated Spring Raymond
Constant Force Spring, Medium	0.85" I.D.	Gray Container - Hardware Bag	2	Associated Spring Raymond
Constant Force Spring, Small	0.34" I.D.	Gray Container - Hardware Bag	2	Associated Spring Raymond
Extension Spring	0.500" O.D. x 2.500" Long x 0.049" Wire	Gray Container - Hardware Bag	2	Associated Spring Raymond
Latex Tubing	1/4" I.D., 3/8" O.D., 5'	Green Container -	1	Gulf South Medical Supply
Snugger	Spring With Plastic Guide	Gray Container - Hardware Bag	2	Stanley Hardware
Spring Loaded Hinge	4" x 4", 30 in/lb Maximum	Gray Container - Hardware Bag	2	Stanley Hardware
Torsion Spring, Left Hand	210 Degrees, 0.500" Dia, 0.072" Wire	Gray Container - Hardware Bag	1	Associated Spring Raymond
Torsion Spring, Right Hand	210 Degrees, 0.500" Dia, 0.072" Wire	Gray Container - Hardware Bag	1	Associated Spring Raymond

Sprockets & Pulleys

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

APPENDIX C: ADDITIONAL HARDWARE LIST

Control System

15 pin solder cup connector	DB15 female (up to 4)
15 pin solder cup connector	DB15 male (up to 2)
Flightstick Joystick	Up to 2
Heat Shrink Tubing	Any Amount, Any Ø
Hood for 15 pin connector	Thermo-plastic (up to 6)
Innovation FIRST Speed Controller	Victor 883 (up to 6)
Servo Extension Cable	Hitec/JR-style, Up to 6
Servo Y Cable	Hitec/JR-style, Up to 2
Tekin Speed Controller	Rebel (up to 4)

Fasteners

Hose Clamp	Up to 10 of Any Size
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

Other

Fiberglass Matting	1 Sheet 4' x 8' Up to 1/8" Thick
Resin + Hardner	As Needed for Fiberglass Matting

Rods & Shafts

Blue Conduit	
Copper Water Pipe	1 Length 1/2" Ø x 10'
Electrical Conduit Pipe (EMT)	1 Length 1" Ø x 10'
Electrical Conduit Pipe (EMT)	1 Length 1/2" Ø x 10'
Electrical Conduit Pipe (EMT)	1 Length 3/4" Ø x 10'
Flexible Conduit (ENT)	1 Length 1/2" Ø x 10', PVC
PVC Pipe	1 Length 1" ID x 10', Schedule 40
PVC Pipe	1 Length 1-1/2" ID x 10', Sch 40
PVC Pipe	1 Length 1-1/4" ID x 10', Sch 40
PVC Pipe	1 Length 1/2" ID x 10', Sch 40
PVC Pipe	1 Length 3/4" ID x 10', Sch 40
Shaft Couplings	Any Size, Up to 4
Wooden Closet Rod	1 Rod 1 1/4" Ø x 6'

Rope, Belts, & Chain

Chain/Belt	Up to 12' Total, Any Combo
Nylon Braided Rope	1 Length 5/16" Ø x 20'

Sheets & Boards

1/2" Plywood OR 7/16" Chipboard	1 Sheet 4' x 4'
1/4" Plywood	1 Sheet 4' x 4'

Aluminum Plate	1 Piece 1/4" x 2' x 2'
Aluminum Plate	1 Plate 1/32" x 4' x 4'
HDPE Block	1 Piece 1" x 12'" x 12"
Pine Board	1 Board 3/4" x 3-1/2" x 10'
Polycarbonate Sheet	1 Sheet 1/16" x 4' x 4'
Polycarbonate Sheet	1 Sheet 1/4" x 4' x 4'
Polycarbonate Sheet	1 Sheet 3/8" x 2' x 4'
Steel Plate	1 Piece 1/4" x 2' x 2'

Small Parts

Caster, Swivel	165 Pounds, 10mm bolt hole
Skyway Wheelchair Wheel	6" Ø, Up to 2
Skyway Wheelchair Wheel	8" Ø, Up to 2

Sprockets & Pulleys

Sprockets, Gears and Pulleys	Up to 6 Total, Any Size/Combo

APPENDIX D: SMALL PARTS, INC. ORDERING INFORMATION

SMALL PARTS INC.

ORDERING GUIDELINES

FIRST – Robotics Competition 1999

Toll-Free Fax: **877-573-9273**
Web Site: **www.smallparts.com/first**
E-mail: **first@smallparts.com**
Tel: **305-825-7961**

SMALL PARTS, INC. is your team's major source for the additional material and parts needed to design, prototype and build your final robot. (See SPARK Certificate on facing page and see *Outside Sources, Rule K1 - Page 44, The Robot Section* of this manual.)

To order parts please follow these guidelines:

REGISTERING

Prior to placing your initial order with **SPI** you must register your team. Once registered, your team may order at any time during the competition.

By Fax: Fill out the Registration Form (next page) and send it **Toll-Free** to **877-573-9273**
By Internet: Go to **www.smallparts.com/first** and follow the instructions.

ORDERING (*Your team must register before ordering.*)

We encourage teams to place their orders via Fax or the Internet. This allows us to enter your order directly from a hard copy and immediately contact you if any problems are found. Please make sure you fill out all sections of the Order Form. Any section not completely filled out may delay the processing and shipping of your order.

It is not necessary to specify to **SPI**, at the time you order, which materials you will be using in your final robot. All purchases by your team will be placed in your team's account. Your **SPARK** credit will be deducted from your account and reflected on your invoice.

SHIPPING

All orders will be shipped within 24 hours ARO (after receipt of order). We will make every effort to ship orders placed before noon (your time zone) that same day. Our standard method of shipping for the competition will be via UPS with 2-Day guaranteed delivery, unless you request an alternate method. 2-Day is guaranteed delivery on the second business day after pickup from **SMALL PARTS INC.** *Please plan accordingly*. Placing orders late in the week may require additional charges to assure delivery by the weekend.

Shipping charges apply to all orders and will appear on your invoice.

Shipping charges will be applied as follows:

        Shipping weights under 20 lbs . . . . $6.00 shipping charge.
        Shipping weights in excess of 20 lbs . . . . Current UPS rate.
        Overnight Shipping . . . . Current UPS rate.
        Saturday Delivery . . . . Overnight shipping charge + $10.00.
        FedEx or Other Carrier . . . . Actual charges per your direction.

BACK ORDERS

SPI has increased its product stocking levels for the competition. However, sometimes the demand exceeds our on-hand quantity. Should a part be temporarily out-of-stock, **SMALL PARTS INC.** will make every effort to supply your item in a timely manner.

RETURNS

Returns must be made within 30 days of receipt. For full credit, products must be returned in their original unopened individual packages. Please call Customer Service at **305-557-7955** to obtain an RMA number. Be sure to have your packing slip(s) available when you call, since you must provide the packing slip number(s) for the material to be returned. Returns may be subject to a 15% restocking fee.

HOLIDAY SCHEDULE

SPI will be closed for the following National Holidays:
        Monday, January 18, 1999 . . . . Martin Luther King Day
        Monday, February 15, 1999 . . . . Presidents' Day

SMALL PARTS INC.

Toll-Free Fax: 877-573-9273

Tel: **305-825-7961**
E-mail: **first@smallparts.com**
Web Site: **www.smallparts.com/first**

REGISTRATION FORM

FIRST – Robotics Competition 1999

Team No.: _____ Date: _____

Team Name:_____

Corporate Sponsor: _____

Contact Person: *(Individual responsible for team purchasing records.)*

Name: _____ Title: _____

Address: _____

City: _____ State: _____ Zip: _____

Phone: (_____) _____ Fax: (_____) _____ E-mail: _____

24-hour emergency phone number for problem resolution: _____

Other team members who can order:

Name: _____ Affiliation: _____

Name: _____ Affiliation: _____

Name: _____ Affiliation: _____

Name: _____ Affiliation: _____

Name: _____ Affiliation: _____

Billing Information: *(For charges outside the SPARK credit)*

Name:_____ Title: _____

Address:_____

City: _____ State: _____ Zip: _____

Phone: (_____) _____ Fax: (_____) _____ E-mail: _____

Use Purchase Order No.: _____

CREDIT CARD INFORMATION ☐ AMEX ☐ VISA ☐ MASTERCARD   Expiration Date: _____

Card No.: _____ Cardholder Name: _____

Billing Address: _____

City: _____ State: _____ Zip: _____

## Send packages to:*

Name: _____ Title: _____

Address: _____

City: _____ State: _____ Zip: _____

Phone: (_____) _____ Fax: (_____) _____ E-mail: _____

FEDEX Account No. (if applicable): _____

* All packages are shipped to this address unless an alternative is given with the order.

FAX ORDER FORM

SMALL PARTS INC.

Toll-Free Fax: 877-573-9273

Tel: **305-825-7961**
Web Site: **www.smallparts.com/first**
E-mail: **first@smallparts.com**

FIRST – Robotics Competition 1999

Team No. _____

Team Name _____

Corporate Sponsor _____

Date:_____ Ref. No.: _____

Your Name: _____

E-mail: _____

Phone: _____ Fax: _____

PAYMENT METHOD

☐ From Allotment *(If this order exceeds allotment, please bill as indicated)*

☐ Blanket P.O. No. _____   ☐ Credit Card

SHIPPING METHOD

UPS   ☐ 2-Day   ☐ RED Label   ☐ Saturday Delivery (RED Only)

FEDEX Account No. _____
       ☐ Priority   ☐ Standard   ☐ Saturday Delivery

CREDIT CARD INFORMATION

☐ AMEX   ☐ VISA   ☐ MASTERCARD   Expiration Date: _____

Card No.: _____

Cardholder Name: _____

Billing Address: _____

_____

City: _____ State: _____ ZIP: _____

USE THIS ALTERNATE SHIPPING ADDRESS

Attention: _____

Address: _____

_____

City: _____ State: _____ ZIP: _____

Phone: _____ Fax: _____

USE THIS ALTERNATE BILLING ADDRESS

Attention: _____

Address: _____

_____

City: _____ State: _____ ZIP: _____

Phone: _____ Fax: _____

ITEM	QTY.	PART No.	DESCRIPTION	UNIT PRICE	TOTAL
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					

TOTAL [_____]

APPENDIX E: KEE KLAMP ORDERING INFORMATION

PURCHASE ORDER FORM – FIRST Competitors – SPECIAL PRICING
Kee Industrial Products, Inc
100 Stradtman Street, Buffalo, NY 14206 - Fax: (716) 896-5696
Kee Klamp® Pipe Fittings / Flexello Casters

Team #		Corporate Sponsor:						
Phone:		Fax:			Ship To Address:			
PAYMENT METHOD:				City:		State		Zip
Master Card / Visa #:		Exp. Date		Attn:				
Card Holder Name:				Phone :				
Signature:				SHIPPING METHOD:				
PLEASE FAX COMPLETED FORM TO (716) 896-5696				RPS/UPS Ground		UPS Next Day		Two Day

Any questions, please call (800) 851-5181

Description		NET
All Flexello Casters required for the Robot		**$14.16**
Bill of Materials:	Note: Two (2) of these casters were supplied in the kit:	
Flexello Casters		
311B-HR	3" Caster w/bolt hole & Hard Rubber Wheel	2	7.08

Description		NET
Flexello Casters & Kee Klamp Fittings required for the Puck		**$103.10**
Bill of Materials:		
Flexello Casters & Kee Klamp Fittings		
311-HR	3" Casters w/ Hard Rubber Wheel	10	7.08
60-7	Kee Klamp Extra Heavy Flange	2	15.24
77-7	Kee Klamp Plastic Plug	2	.91

Description		NET
Kee Klamp Driver Station **All Kee Klamp Fittings Required for one Driver Station**		**$51.36**
Bill of Materials	Note: Please specify Quantity (up to 4 Driver Stations per playing field)	
Kee Klamp Fitting		
KK 61-7	Kee Klamp Flange	3	5.62
KK 26-7	Kee Klamp Two Socket Cross \	1	6.86
KK 19-7	Kee Klamp Adjustable Side Outlet Tee	2	13.82

Description		NET
Kee Klamp Border **All Kee Klamp Fittings Required for the complete Border**		**$311.64**
Bill of Materials		
Kee Klamp Fitting		
KK 61-7	Kee Klamp Flange	24	5.62
KK 77-7	Kee Klamp Plastic Plug	12	.91
KK 19-7	Kee Klamp Adjustable Side Outlet Tee	12	13.82

Effective: January 1, 1999   Terms: Only Master Card/Visa Accepted   F.O.B. Buffalo, NY Warehouse
SPECIAL PRICING FOR U.S. FIRST COMPETITION ONLY, ALL ORDERS MUST BE TAGGED OR IDENTIFIED AS: "FIRST COMPETITION"

APPENDIX F: PROBLEM REPORT FORM

PROBLEM REPORT PROCEDURE

On occasion, your team may experience difficulty with a part or a system supplied by FIRST. If you do, please follow these procedures:

1. **Try to solve the problem yourself.**

(Refer to the Robot section of the manual referring to the Policy on Repair and Replacement of Kit Parts.)

2. **Call our engineers.**

(They may be able to give advice and save you shipping costs, time, and money.)

3. **Fill out the Problem Report Form completely:**

- Team Number

- Reported Defect (Explain the problem fully)

- Name

- Date Sent

- Phone Number (Where we can reach you during the day)

- Special Attention (Any special handling, timing, etc.)

4. **Carefully package the item(s) and enclose the filled out Problem Report Form.**

5. **Label the package and it send to:**

    FIRST

    Technical Repair Department

    200 Bedford Street

    Manchester, NH 03101

We have a two-day turnaround policy on repairs. We try very hard to send back the item(s) two days (or less) after we receive it.

PROBLEM REPORT FORM

Team Number: _____

Program: FIRST Robotics Competition

Reported Defect(s) (You may use a separate sheet to explain):

_____

_____

_____

_____

_____

Name: _____

Date: _____

Phone Number: _____

Special Attention:

_____

_____

APPENDIX G: DEFAULT CONTROL PROGRAM

```
'
' PROGRAM: RXSLAVE.BS2
' Program run by User Programmable CPU in 1999 FIRST Receiver Board
' Written by: Eric Rasmussen
' Date: 12/11/97
'
' Declare variables
'
x1         VAR byte
y1         VAR byte
x2         VAR byte
y2         VAR byte
tx_pot1    VAR byte
wheel1     VAR byte
tx_pot2    VAR byte
wheel2     VAR byte
tx_sw      VAR word
rx_sw      VAR word
sensor1    VAR byte
sensor2    VAR byte
sensor3    VAR byte
sensor4    VAR byte
relays     VAR word
delta_t    VAR byte ' Time delay (units = 20 ms) between loop iterations
' delta_t = 1 means no missing/bad data (1st packet)
' delta_t > 1 means data is missing/bad, but it could be due to a slow
' User Control Program loop speed which will cause Master CPU to miss data
' (delta_t=2 or 3 is common).


'
' Define Aliases (variables which are sub-divisions of those defined above)
'                (aliases don't require any additional RAM)
'
sw1_fwd   VAR tx_sw.bit0      ' Aliases for each TX switch input
sw1_rev   VAR tx_sw.bit1
sw2_fwd   VAR tx_sw.bit2
sw2_rev   VAR tx_sw.bit3
sw3_fwd   VAR tx_sw.bit4
sw3_rev   VAR tx_sw.bit5
sw4_fwd   VAR tx_sw.bit6
sw4_rev   VAR tx_sw.bit7
sw5_fwd   VAR tx_sw.bit8
sw5_rev   VAR tx_sw.bit9
sw6_fwd   VAR tx_sw.bit10
sw6_rev   VAR tx_sw.bit11
sw7_fwd   VAR tx_sw.bit12
sw7_rev   VAR tx_sw.bit13
sw8_fwd   VAR tx_sw.bit14
sw8_rev   VAR tx_sw.bit15
rx_sw1    VAR rx_sw.bit0      ' Aliases for each RX switch input
rx_sw2    VAR rx_sw.bit1
rx_sw3    VAR rx_sw.bit2
rx_sw4    VAR rx_sw.bit3
rx_sw5    VAR rx_sw.bit4
rx_sw6    VAR rx_sw.bit5
rx_sw7    VAR rx_sw.bit6
rx_sw8    VAR rx_sw.bit7
rx_sw9    VAR rx_sw.bit8
rx_sw10   VAR rx_sw.bit9
rx_sw11   VAR rx_sw.bit10
rx_sw12   VAR rx_sw.bit11
rx_sw13   VAR rx_sw.bit12
rx_sw14   VAR rx_sw.bit13
rx_sw15   VAR rx_sw.bit14
rx_sw16   VAR rx_sw.bit15
```

```
rly1_fwd  VAR relays.bit0      ' Aliases for each relay output
rly1_rev  VAR relays.bit1
rly2_fwd  VAR relays.bit2
rly2_rev  VAR relays.bit3
rly3_fwd  VAR relays.bit4
rly3_rev  VAR relays.bit5
rly4_fwd  VAR relays.bit6
rly4_rev  VAR relays.bit7
rly5_fwd  VAR relays.bit8
rly5_rev  VAR relays.bit9
rly6_fwd  VAR relays.bit10
rly6_rev  VAR relays.bit11
rly7_fwd  VAR relays.bit12
rly7_rev  VAR relays.bit13
rly8_fwd  VAR relays.bit14
rly8_rev  VAR relays.bit15
'
' Define Constants
'
MASTERCPU CON 0        ' Pin used to communicate with Master CPU
FPIN      CON 1        ' Pin used to for flow control with Master CPU
RLYDATA   CON 5        ' Shift Register Data Pin for Relay Outputs
RLYCLOCK  CON 6        ' Shift Register Clock Pin for Relay Outputs
RLYLATCH  CON 7        ' Shift Register Latch Pin for Relay Outputs
SWDATA    CON 8        ' Shift Register Data Pin for Switch Inputs
SWCLOCK   CON 9        ' Shift Register Clock Pin for Switch Inputs
SWLATCH   CON 10       ' Shift Register Latch Pin for Switch Inputs
SSC       CON 11       ' Pin used to communicate with Serial Servo Controller
ADC_SO    CON 12       ' Analog to Digital Converter (ADC) data output pin
ADC_SCLK  CON 13       ' ADC Clock Pin
ADC_CS0   CON 14       ' Pin to initialize/reset ADC
ADC_SI    CON 15       ' Pin used to send data to ADC
GOODLED   CON 3        ' Pin used to turn status LED green
ERRLED    CON 4        ' Pin used to turn status LED red
SSCBAUD   CON $0020    ' Baud rate for communications with SSC
BS2BAUD   CON $4020    ' Baud rate for communications with BS2 (Master CPU)
PWM1      CON 8        ' Define SSC addresses for PWM outputs
PWM2      CON 9
PWM3      CON 10
PWM4      CON 11
PWM5      CON 12
PWM6      CON 13
PWM7      CON 14
PWM8      CON 15
SSC_CMD   CON 255      ' Command Prefix for SSC
'
' Initialize Hardware and Variables on Power Up or Reset
'
' All pins default to low (ground) & input (floating) on powerup or reset.
' PWM outputs are automatically set to 127 on powerup or reset by the SSC
'
Output SSC            ' Prevent floating before data is sent (low)
Output FPIN
Output RLYDATA
Output RLYCLOCK
Output RLYLATCH
Output SWDATA
Output SWCLOCK
Output SWLATCH
Output GOODLED
Output ERRLED
Output ADC_SI
Output ADC_SCLK
High SWLATCH          ' These should be normally high
High ADC_CS0
relays = 0            ' Make sure relays all start off
Gosub SetRelays
```

```
'
' Main Program
'
Loop:

  ' **********************************************************************
  ' STEP 1: COLLECT DATA FROM TRANSMITTER AND ON-BOARD SENSORS
  ' **********************************************************************

  ' Get Transmitter data from Master CPU
  Serin MASTERCPU\FPIN, BS2BAUD, [Wait(255,255), x1, y1, x2, y2,
tx_sw.lowbyte, tx_pot1, wheel1, tx_sw.highbyte, tx_pot2, delta_t, wheel2]

  ' Read Receiver Switch Inputs into rx_sw
  Gosub ReadSwitches

  ' Read Receiver Analog Sensor Inputs into sensor1-4
  Gosub ReadSensors

  ' **********************************************************************
  ' STEP 2: CALCULATE ACTIONS BASED ON INPUT DATA
  ' **********************************************************************

  ' Set relays to match TX switch inputs
  relays = tx_sw

  ' Use 1st 8 RX switches (rx_sw1-8) as STOP switches for Relays 1-4
  relays.lowbyte = relays.lowbyte &~ rx_sw.lowbyte

  ' Use 2nd 8 RX switches (rx_sw9-16) as GO switches for Relays 5-8
  relays.highbyte = relays.highbyte | rx_sw.highbyte

  ' **********************************************************************
  ' STEP 3: PERFORM ACTIONS
  ' **********************************************************************

  ' Update PWM Outputs
  High GOODLED ' Turn LED Green to show loop is running
  Serout SSC, SSCBAUD, [SSC_CMD, PWM1, x1] ' Update PWM outputs
  Serout SSC, SSCBAUD, [SSC_CMD, PWM2, y1]
  Serout SSC, SSCBAUD, [SSC_CMD, PWM3, x2]
  Serout SSC, SSCBAUD, [SSC_CMD, PWM4, y2]
  Serout SSC, SSCBAUD, [SSC_CMD, PWM5, tx_pot1]
  Serout SSC, SSCBAUD, [SSC_CMD, PWM6, wheel1]
  Serout SSC, SSCBAUD, [SSC_CMD, PWM7, tx_pot2]
  Serout SSC, SSCBAUD, [SSC_CMD, PWM8, wheel2]
  Low GOODLED  ' Turn LED off

  ' Update Relay Outputs
  Gosub SetRelays

  ' **********************************************************************
  ' STEP 4: RETURN TO BEGINNING AND WAIT FOR MORE DATA
  ' **********************************************************************

  Goto Loop ' Start over at Loop:

End ' It should never actually get here!
'
' Subroutines
'
ReadSwitches: ' Reads receiver switch inputs into variable rx_sw
  Pulsout SWLATCH, 1
  Low SWLATCH
  Pulsout SWCLOCK, 1
  High SWLATCH
  Shiftin SWDATA, SWCLOCK, LSBPRE, [rx_sw\16] ' Read in the data
  rx_sw = rx_sw ^ 65535 ' Invert bits so that a closed switch is true (1)
Return
```

```
ReadSensors: ' Read receiver sensor inputs into variables sensor1-4
  ' Read Channel 1 (Comment out next 4 lines if not using sensor1)
  Low ADC_CS0                               ' Initialize ADC
  Shiftout ADC_SI, ADC_SCLK, msbfirst, [12\4]  ' Select Channel 1
  Shiftin ADC_SO, ADC_SCLK, msbpost, [sensor1] ' Read Channel 1
  High ADC_CS0                              ' Reset ADC
  ' Read Channel 2 (Comment out next 4 lines if not using sensor2)
  Low ADC_CS0                               ' Initialize ADC
  Shiftout ADC_SI, ADC_SCLK, msbfirst, [14\4]  ' Select Channel 2
  Shiftin ADC_SO, ADC_SCLK, msbpost, [sensor2] ' Read Channel 2
  High ADC_CS0                              ' Reset ADC
  ' Read Channel 3 (Comment out next 4 lines if not using sensor3)
  Low ADC_CS0                               ' Initialize ADC
  Shiftout ADC_SI, ADC_SCLK, msbfirst, [13\4]  ' Select Channel 3
  Shiftin ADC_SO, ADC_SCLK, msbpost, [sensor3] ' Read Channel 3
  High ADC_CS0                              ' Reset ADC
  ' Read Channel 4 (Comment out next 4 lines if not using sensor4)
  Low ADC_CS0                               ' Initialize ADC
  Shiftout ADC_SI, ADC_SCLK, msbfirst, [15\4]  ' Select Channel 4
  Shiftin ADC_SO, ADC_SCLK, msbpost, [sensor4] ' Read Channel 4
  High ADC_CS0                              ' Reset ADC
Return

SetRelays: ' Use data in variable "relays" to control actual relays
  Shiftout RLYDATA, RLYCLOCK, LSBFIRST,[relays\16]
  Pulsout RLYLATCH, 1
Return
```

APPENDIX H: MANUFACTURER PART SPECIFICATIONS

The following pages are manufacturers' specifications for parts provided in the Official Kit of Parts.

Additional booklets are in the Kit.

Be sure to read these spec sheets in order to properly allocate and use components.

Specification sheets in this section are in the order listed below for the following suppliers:

Supplier	**Kit Part**
Air Logic	Check Valves
AMP Incorporated	Connector Housing
Associated Spring Raymond	Springs
BEI Systron Donner Intertial Division	Yaw Rate Sensor
Bourns, Inc.	Potentiometer
CP Clare	Reed Switch
CSB Battery of America, Inc.	Battery
Delphi Interior and Lightning Systems	Van Door Motors
Gast Manufacturing Corporation	Air Compressor
Globe Motor	Motor and Drive Assembly
Honeywell - Microswitch Division	Optical Sensor
Innovation FIRST	Speed Controller
ITT Automotive	Seat Motor and Window Lift Motor
S-B Power Tool Company	Drill Motors
Skyway Recreation Products	Wheel Chair Wheels
Snap-Action, Inc.	Circuit Breakers
The Torrington Company	Ball Bearings