Innovation First, Inc.
Full-Size Robot Controller
Reference Guide
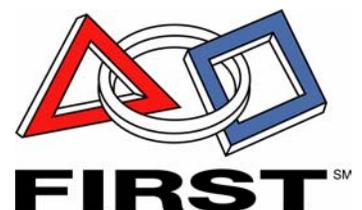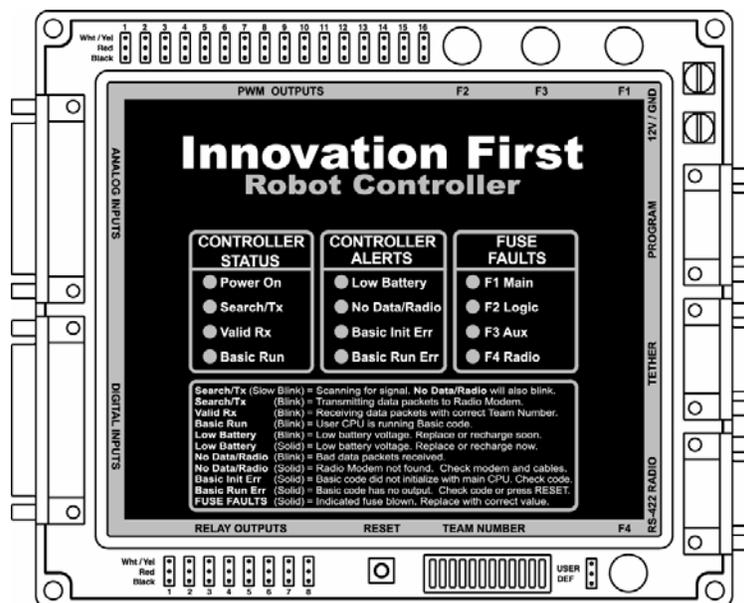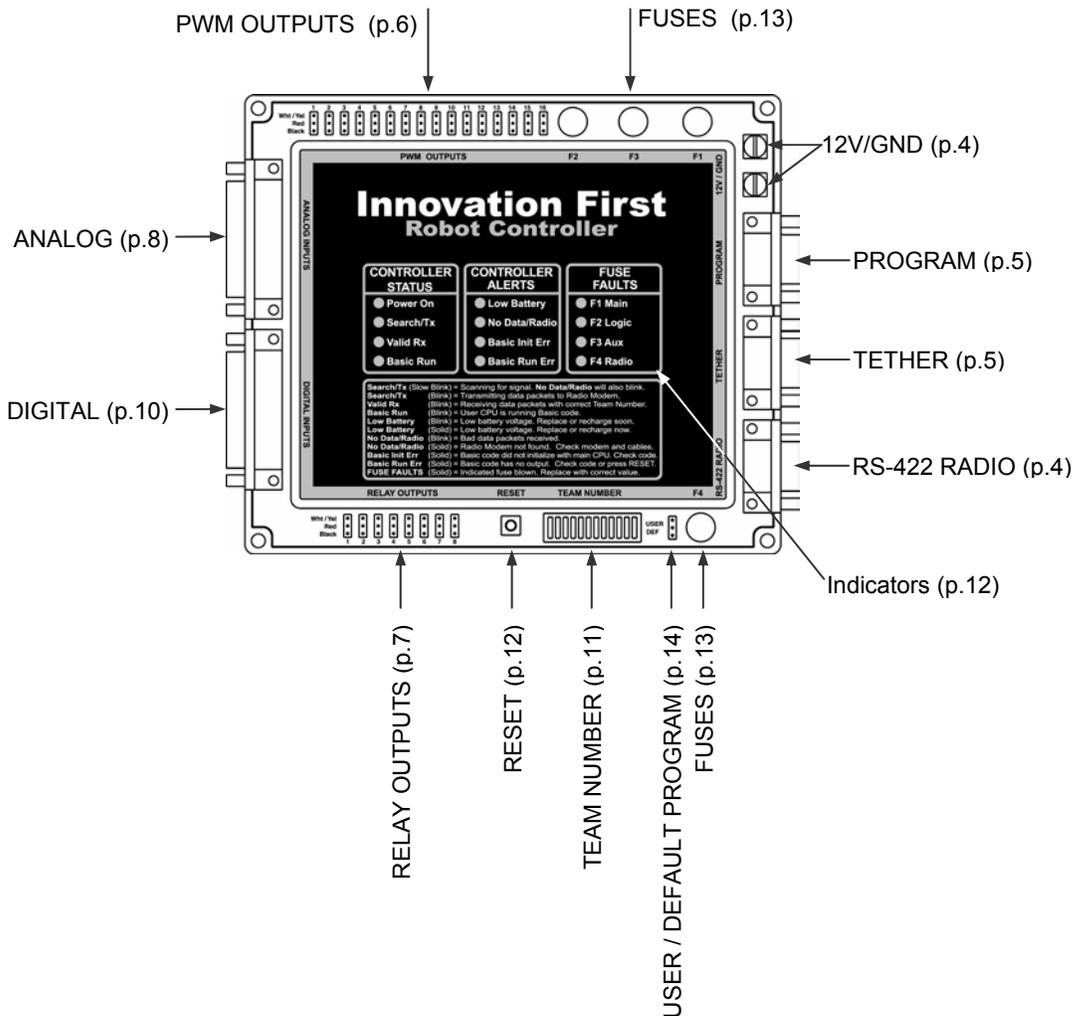
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1. Robot Controller Basics

The Robot Controller (RC) receives information from the Operator Interface, gathers additional information from sensors on-board the robot, determines how the robot should function, and instructs the robot to perform the functions. The Robot Controller also sends data back to the Operator Interface, giving the human operator(s) feedback of critical information.

There are 2 types on Robot Controllers, the Full-Size Robot Controller and the EDU Robot Controller. The Full-Size Robot Controller is a large unit with an external Radio Modem. The EDU Robot Controller has fewer inputs and outputs and has an integrated internal Radio modem.

The Full-Size Robot Controllers gather on-board sensor data via the ANALOG and DIGITAL inputs. There are 16 digital inputs and 7 analog inputs on the Full-Size Robot Controller. Switches of various types may be connected to the digital inputs. Sensors that provide a 0-5V output, such as potentiometers and gyros (yaw rate sensors) may be connected to the analog inputs.

The Robot Controller takes the collected data from both the Operator Interface and the on-board sensors and then forwards it to the PBASIC program processor. The program takes the data, 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. The Robot Controller comes with a default and user program that will handle most robot control needs. If more sophisticated control of the robot is desired, then the default or user program can quickly be modified to provide the required functions from the robot.

The PBASIC source code is available at www.innovationfirst.com.
Programming tools and manuals are available at www.parallaxinc.com.

The Full-Size Robot Controller has 16 PWM outputs and 8 RELAY outputs. The PWM outputs are used to drive Victor 883 speed controllers and servos. The most common use of these outputs is to control a variable speed motor. The PWM outputs will also control most industry standard servos. The Relay outputs are used to drive Spike bi-directional relay modules. The most common use of these outputs, when connected to a Spike, is to drive small motors in Full Forward, Full Reverse or Off. The Relay outputs, in conjunction with a Spike, can also be use to turn On or Off solenoids, pumps, and lights.

Both Robot Controllers have a new Autonomous Mode. When in autonomous mode, the Operator Interface is not needed. The RC will run as normal in Autonomous Mode, except there is no user input, only onboard sensors. The use of Autonomous Mode requires that custom software be written to command the robot. Autonomous Mode can be turned ON by 1) turning the RC OFF-remove power, 2) setting the team number to Zero, and 3) turning the RC back ON -apply power.

Reference Documents (available at www.innovationfirst.com)
    Size, weight, and mounting info
    Frequently asked questions
    FIRST Control System Quick Start Guide
    2003 Default Code listing
    2003 User Code listing

2. Input Power

The +12V and GND connectors on the Robot Controller are intended to accept power from a +12V battery. The current draw for the Robot Controller is typically between 0.75A to 1.5A. The maximum voltage allowable is +15.0V. Exceeding the +15.0V limit may damage internal voltage regulators and will void the warranty. The minimum required voltage is +8.0V.

Use circle or u-shaped crimp lugs to connect +12V and GND wires to the Robot Controller. Use a minimum of 16GA wire to minimize voltage drop to the Robot Controller. Fuses prior to the Robot Controller are not required. Always follow FIRST Competition rules when building for FIRST competitions.
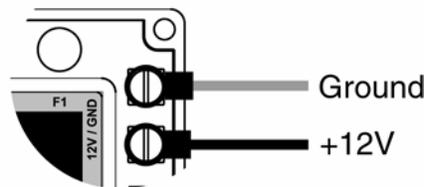
When wiring to the Robot Controller, ensure that the +12V and GND lugs do not short at the Robot Controller. Connect GND to the corner connector and +12V to the inside connector. The Robot Controller is internally protected from reverse polarity.

3. RS-422 Radio

The RS-422 Radio port is intended to connect to the Innovation First RS-422 Robot Controller Radio modem only. This port uses RS-422, instead of RS-232, to minimize noise interference in the communication link. Caution: Do not connect any other equipment to this port.

There are two different radios provided with the system. Be sure to connect the Robot Controller to the radio that has a black antenna and is marked "Robot Controller." Use a DB9 Male-Female Pin-to-Pin cable (maximum length 6 ft.) to connect the Robot Controller to the RS-422 Radio modem.

4. Tether

The TETHER port is intended to connect the Robot Controller to the Operator Interface. Tether is used to communicate to an Operator Interface over a "hard" wire connection instead of using a wireless radio link. The TETHER port passes the same data as the radios, allowing full functionality without the use of radios. A tether connection can be made with or without Radio Modems connected. The system will always use tether if it is available. . When a tether connection is made, you will see the status indicators on the Radio Modems switch to Standby. Both the Operator Interface and the Robot Controller will automatically detect a tether connection and switch to tether without requiring power OFF or a reset.

A tether connection also provides power to the Operator Interface from the Robot Controllers +12V battery. Tether power provides a means to power the Operator Interface when 115V 60Hz power is not available. Tether power is useful before or after competition rounds to check your system or collapse your robot.

Caution: This port is not intended to interface with a computer.

Use a DB9 Male-Female Pin-to-Pin cable (maximum length 6 ft.) to connect the Robot Controller to the Operator Interface.

5. Program

The PROGRAM port is used to change the program on the Robot Controller. This port is intended to connect to a PC's serial port.

Use a DB9 Male-Female Pin-to-Pin cable (maximum length 6 ft.) to connect the PROGRAM port on the Robot Controller to PC serial port.

6. PWM Outputs

The PWM outputs are used to drive Victor 883 speed controllers and servos on the Full-Size Robot Controller. The most common use of these outputs is to control a variable speed motor from a joystick axis connected to the Operator Interface. The PWM outputs will control most industry standard servos on the Full-Size Robot Controller. Each of the PWM outputs generates a unique Pulse Width Modulated (PWM) signal corresponding to a specific output of the PBASIC program. Custom PBASIC software can be used to control the PWM outputs as desired.

Use a PWM/Relay extension cable to connect an appropriate device to one of the PWM output ports. Be sure to connect the cable so the black wire is on the indicated side. A Y-cable can be used on any PWM output to drive two like devices at the same time.
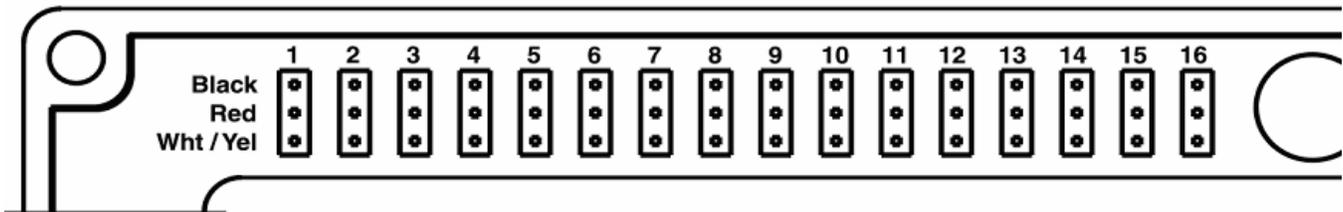
Warning: The PWM outputs are only to be used with Victor 883 Speed Controllers or servos. The use of other speed controllers may damage the unit and will void the warranty.

Table 7.5a below shows which of the PWM outputs are controlled by joysticks on the Operator Interface. This table is only valid for Default code. These functions and variable names may be changed for user programs.

Table 7.5a: PWM Output Map (Default Code Only)

PWM Output	PBASIC Variable	Output Controlled by
PWM1	p1_y	Port 1 joystick Y-axis
PWM2	p2_y	Port 2 joystick Y-axis
PWM3	p3_y	Port 3 joystick Y-axis
PWM4	p4_y	Port 4 joystick Y-axis
PWM5	p1_x	Port 1 joystick X-axis
PWM6	p2_x	Port 2 joystick X-axis
PWM7	p3_x	Port 3 joystick X-axis
PWM8	p4_x	Port 4 joystick X-axis
PWM9	p1_wheel	Port 1 joystick Wheel
PWM10	p2_wheel	Port 2 joystick Wheel
PWM11	p3_wheel	Port 3 joystick Wheel
PWM12	p4_wheel	Port 4 joystick Wheel
PWM13	Fixed at 127	No input assigned
PWM14	Fixed at 127	No input assigned
PWM15	Fixed at 127	No input assigned
PWM16	Fixed at 127	No input assigned

Note: Twelve Robot Controller digital inputs are configured by the default code to act as limit switches for PWMs 3, 4, 9-12. Refer to Section 9 on page 10 for more details.

The User Code PWM outputs differ slightly from the Default Code. The only differences are the PWM outputs 13 – 16. Table 7.5b below shows how the User Code differs from the Default Code.

Table 7.5b: PWM Output Map (User Code Differences Only)

PWM Output	PBASIC Variable	Output Controlled by
PWM13	drive_R	Port 1 joystick Y & X –axis mixed
PWM14	drive_R	Port 1 joystick Y & X –axis mixed
PWM15	drive_L	Port 1 joystick Y & X –axis mixed
PWM16	drive_L	Port 1 joystick Y & X –axis mixed

7. Relay Outputs

The Relay outputs are used to drive Spike bi-directional relay modules on the Full-Size Robot Controller. The most common use of these outputs on the Full-Size RC, when connected to a Spike, is to drive small motors in Full Forward, Full Reverse or Off. The Relay outputs, in conjunction with a Spike, can also be use to turn On or Off solenoids, pumps, and lights from a joystick button on the Operator Interface. Each of the eight ports generates two binary signals corresponding to a specific output of the PBASIC program. Custom PBASIC software can be used to control the Relay outputs as desired.

Refer to the Spike Users Manual (available at www.innovationfirst.com) for detailed instructions on wiring to motors, solenoids, pumps, and lights.

Use a PWM/Relay extension cable to connect a Spike to one of the Relay outputs. Be sure to connect the cable so the black wire is on the indicated side. Each Relay output can be used with a Y-cable to drive two Spikes from the same output.
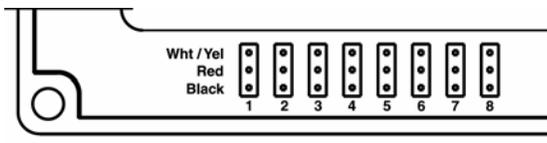

Table 7.6 below shows which of the Relay outputs are controlled by joysticks connected to the Operator Interface. This table is only valid for Default and User code. These functions and variable names may be changed for user programs. Refer to the 2000 User Default and User code available at www.innovationfirst.com.

### Table 7.6: Relay Output Map (Default and User Code Only)

Relay	Operator Interface Connector	Operator Interface Control Switch	Pin	PBASIC Variable
Relay 1 Forward	OI Port 1	Joystick Trigger Switch	2	p1_sw_trig
Relay 1 Reverse	OI Port 1	Joystick Thumb Switch	7	p1_sw_top
Relay 2 Forward	OI Port 2	Joystick Trigger Switch	2	p2_sw_trig
Relay 2 Reverse	OI Port 2	Joystick Thumb Switch	7	p2_sw_top
Relay 3 Forward	OI Port 3	Joystick Trigger Switch	2	p3_sw_trig
Relay 3 Reverse	OI Port 3	Joystick Thumb Switch	7	p3_sw_top
Relay 4 Forward	OI Port 4	Joystick Trigger Switch	2	p4_sw_trig
Relay 4 Reverse	OI Port 4	Joystick Thumb Switch	7	p4_sw_top
Relay 5		Unused by default and user code		
Relay 6		Unused by default and user code		
Relay 7		Unused by default and user code		
Relay 8		Always Forward		

Note: Four Robot Controller digital inputs are configured by the default code to act as limit switches for Relay 1 and Relay 2. Refer to Section 9 on page 10 for more details.

8. Analog Inputs

The analog inputs on the Robot Controller can be used to measure various conditions on the robot and trigger automatic responses by the control program. There are 7 analog inputs available on the ANALOG INPUT port on the Full-Size Robot Controller. Potentiometers and gyro (yaw rate) sensors may be connected to the analog inputs.

Potentiometers should be wired per the diagram below when connecting to the Analog Inputs. Always use 100kΩ potentiometers.

+5V Aux

Analog Input   100k Ω

Ground
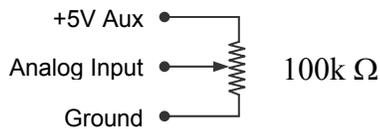
For wiring yaw rate sensors, refer to the sensor manufacturer's data sheet.

Table 7.7: Analog Input Pinout and Software Function

Pin	Function	PBASIC Variable
2	Analog 1	sensor1
16	Analog 2	sensor2
5	Analog 3	sensor3
19	Analog 4	sensor4
8	Analog 5	sensor5
22	Analog 6	sensor6
11	Analog 7	sensor7
3	+5V for Potentiometers (50mA max)	
6	+5V for Potentiometers (50mA max)	
9	+5V for Potentiometers (50mA max)	
12	+5V for Potentiometers (50mA max)	
14	+5V for Potentiometers (50mA max)	
17	+5V for Potentiometers (50mA max)	
20	+5V for Potentiometers (50mA max)	
23	+5V for Potentiometers (50mA max)	
4	Ground	
7	Ground	
10	Ground	
13	Ground	
15	Ground	
18	Ground	
21	Ground	
24	Ground	
1	+5V Aux (Fuse F3) for Gyro power only	
25	Unused	

9. Digital Inputs

The digital inputs on the Robot Controller can be used to monitor various conditions on the robot and trigger automatic responses by the PBASIC control program. There are 16 digital inputs available on the DIGITAL INPUT port on the Full-Size Robot Controller. Various switches may be connected to the digital inputs.

Wire switches between the desired digital input signal pin and any ground pin. Digital inputs are "looking" only for ground signals to become "active". Do not connect positive voltage to any switch or digital input pin, only ground. Switches may be wired individually, in parallel or in series.

Table 7.8: Digital Input Pinout and Software Function

| Pin	Function	PBASIC Variable	PBASIC Default Code Function
1	Switch 1	rc_sw1	Relay 1 won't go Forward if rc_sw1 is ON
2	Switch 2	rc_sw2	Relay 1 won't go Reverse if rc_sw2 is ON
15	Switch 3	rc_sw3	Relay 2 won't go Forward if rc_sw3 is ON
16	Switch 4	rc_sw4	Relay 2 won't go Reverse if rc_sw4 is ON
4	Switch 5	rc_sw5	PWM 3 won't go Forward if rc_sw5 is ON
5	Switch 6	rc_sw6	PWM 3 won't go Reverse if rc_sw6 is ON
18	Switch 7	rc_sw7	PWM 4 won't go Forward if rc_sw7 is ON
19	Switch 8	rc_sw8	PWM 4 won't go Reverse if rc_sw8 is ON
7	Switch 9	rc_sw9	PWM 9 won't go Forward if rc_sw9 is ON
8	Switch 10	rc_sw10	PWM 9 won't go Reverse if rc_sw10 is ON
21	Switch 11	rc_sw11	PWM 10 won't go Forward if rc_sw11 is ON
22	Switch 12	rc_sw12	PWM 10 won't go Reverse if rc_sw12 is ON
10	Switch 13	rc_sw13	PWM 11 won't go Forward if rc_sw13 is ON
11	Switch 14	rc_sw14	PWM 11 won't go Reverse if rc_sw14 is ON
24	Switch 15	rc_sw15	PWM 12 won't go Forward if rc_sw15 is ON
25	Switch 16	rc_sw16	PWM 12 won't go Reverse if rc_sw16 is ON
3	Ground		
6	Ground		
9	Ground		
12	Ground		
13	Ground		
14	Ground		
17	Ground		
20	Ground		
23	Ground		

10. Setting the Team Number

A quick method of setting the Team Number without using binary is described in the Full-Size Control System Quick Start Guide.

Setting the Team Number on the Robot Controller is best accomplished by first setting the Team Number on the Operator Interface, then copying the switch setting to the Robot Controllers TEAM NUMBER dipswitch.

Setting the Team Number on the Robot Controller requires changing the TEAM NUMBER dip switch settings. The Team Number is set by changing the switches to match the binary equivalent of your Team Number.

The diagram below shows the location of the Most Significant Bit (MSB) and the Least Significant Bit (LSB).
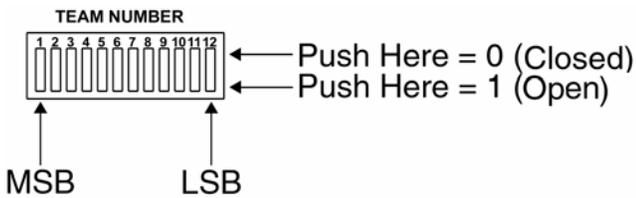
The following diagram is an example of setting the Team Number to **34**. The black areas on the Team Number Switch indicate which half of the switch is in the down position.
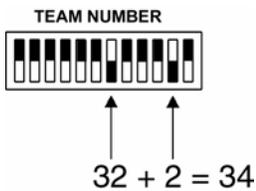
11. Robot Controller Indicators

The Robot Controller has the following LED indicators.

Table 8.2: Robot Controller LEDs

Power ON	(Solid)	Input power is ON from +12V/GND.
Search/TX	Blink	Transmitting data packets to Radio Modem.
Valid RX	Blink	Receiving data packets with correct Team Number and Channel Number.
Basic Run	Blink	User CPU is running PBASIC code. The PBASIC code has stopped executing if the light is ON Solid or OFF. (This may be disabled in custom PBASIC programs)
Low Battery	Blink	Low battery voltage detected. Replace or recharge battery soon. Low Battery will remain blinking if the voltage ever drops below 9.0V. The Low Battery Blink threshold is user definable in the PBASIC code.
Low Battery	Solid	Low battery voltage detected. Replace or recharge battery now. Low Battery will remain solid if the voltage ever drops below 8.0V.
No Data/Radio	Blink	No data packets received or bad data packets received.
No Data/Radio	Solid	Radio Modem not found. Check modem and cables.
Basic Init Err	Solid	PBASIC code did not initialize properly with main CPU. Check code. Re-download the "default" code to help verify a coding problem.
Basic Run Err	Solid	PBASIC code has no output. Check code or press RESET. You can also try re-downloading the "default" code to help verify a coding problem.
F1 Main	Solid	Fuse F1 blown. Replace with correct value (see Section 13 on page 1).
F2 Logic	Solid	Fuse F2 blown. Replace with correct value (see Section 13 on page 1).
F3 Aux	Solid	Fuse F3 blown. Replace with correct value (see Section 13 on page 1).
F4 Radio	Solid	Fuse F4 blown. Replace with correct value (see Section 13 on page 1).

12. Reset

The RESET button performs a complete hardware reset of the Robot Controller, including the Master, Slave, and BS2SX PBASIC processors. Resetting also re-initializes the external radio to "Search" or channel scan mode. Power cycling the Robot Controller and pressing the RESET button both have the same result.

The following are the most common uses for the RESET button:
- Pressing RESET restarts the BS2SX processor in case of a PBASIC programming error.
- Pressing RESET after the CHANNEL dipswitch on the Operator Interface is changed will initiate a radio channel scan.

Note: The ROBOT RESET button on the Operator Interface does not perform the same function as the RESET on the Robot Controller. ROBOT RESET on the Operator Interface only resets the BS2SX and not the entire Robot Controller.

When in doubt, pressing RESET won't hurt.

13. Fuses

The four fuses on the Robot Controller are intended to protect the circuitry from a short circuit. In the unlikely event that a fuse blows, a LED on the front panel will indicate the fuse that failed. The most likely cause of a blown fuse is improper wiring. Prior to replacing the fuse, check your wiring for shorts or incorrect pin connections

Be sure to replace the fuse only with a slow blow TR-5 style fuse of the appropriate value. Replacement fuses are available at the Innovation First website or from electronics vendors. If the replacement fuses continue to blow and you have thoroughly checked you wiring, contact Innovation First for further assistance.

Fuse	Protects	Value	Valid Range		Type
F1	Main	4.0 Amps	4.0 – 5.0	Amps	Slow Blow
F2	Logic	0.5 Amps	.50 - .75	Amps	Slow Blow
F3	Aux	1.25 Amps	1.0 – 1.5	Amps	Slow Blow
F4	Radio	0.5 Amps	.50 - .75	Amps	Slow Blow

14. Programming the Robot Controller

The Robot Controller is supplied with a "Default" and User program in order to help get the robot up and running quickly. The functionality of the default and User control program is described below. If more sophisticated control of the robot is desired, then a custom program   can be quickly created by modifying the default program. In order to facilitate the creation of a custom program, source code for the default program is provided. The default program, " Full-Size Default Program RevNC.bsx" is available at www.InnovationFirst.com.

Program Language
All programs running on the Robot Controller 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. With the exception of the source code for the default program, the programming utility and manuals can be obtained via the Internet from Parallax, Inc. at www.parallaxinc.com.

Program Jumper
The Robot Controller has 2 memory chips and can therefore hold 2 different PBASIC programs.   The "Program Jumper" controls which memory location is written over when a new BPASIC program is downloaded to the Robot Controller.   The two-memory locations are "DEF" and "USER". Reprogramming over "USER" program will not erase the default "DEF" control program. Thus, the Robot Controller can be easily changed back to using the default program by moving the program jumper in the event of problems with the user program.

The Program Jumper on the Robot Controller also is used to select which control program (default or user) is running. The diagram shows the Robot Controller jumper switch settings. Install a jumper across the upper two pins to run default program. Install a jumper across the lower two pins to run user program. After changing the jumper, press RESET on the Robot Controller.
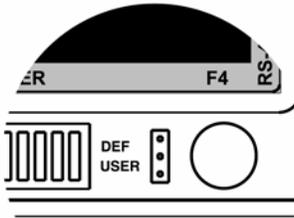
The Robot Controller programming steps are as follows:
1. Power ON the Robot Controller.
2. Connect a DB9 Male-Female Pin-to-Pin cable (maximum length 6 ft.) to connect the PROGRAM port on the Robot Controller to PC serial port.
3. Set the Program Jumper to USER or DEF (whichever code you wish to write over).
4. Run Parallax, Inc. BASIC Stamp Version 1.091 beta or higher.
5. Load the desired program into the BASIC Stamp Editor.
6. Press CTRL-R to download the program.
7. Press RESET on the Robot Controller if needed.

Successful Programming: Basic Run Indicator
After programming the Robot Controller, after the Robot Controller is communicating with an Operator Interface, and after pressing RESET on the Robot Controller if needed, you should see the BASIC RUN LED flashing. This BASIC RUN LED indicates that the new program is running. The PBASIC program controls this light. You may not see the BASIC RUN LED flashing if you have changed the default code that controls this LED.

Programming Problem: Basic Run Error Indicator
If after programming and resetting the Robot Controller, the BASIC RUN ERR LED is ON, then the basic code has no output. This means that the code is not running properly. Check for errors in the code. The BASIC RUN ERR light is controlled by the Output microprocessor.

Programming Problem: Basic Init Error Indicator
If after programming and resetting the Robot Controller, the BASIC INIT ERR LED is ON, then the basic code did not properly initialize the data packet structure with the master microprocessor. Check the initialization part of the code for errors. A common mistake is having a different number of variables in the SERIN command, as compared to the requested data setup in the "Set the Initialization constants you want to read" section of the code. The BASIC INIT ERR light is controlled by the Master microprocessor.