TALRIK JUNIOR ADVANCED VERSION ROBOT™

TJ-AVR™
ASSEMBLY MANUAL

by
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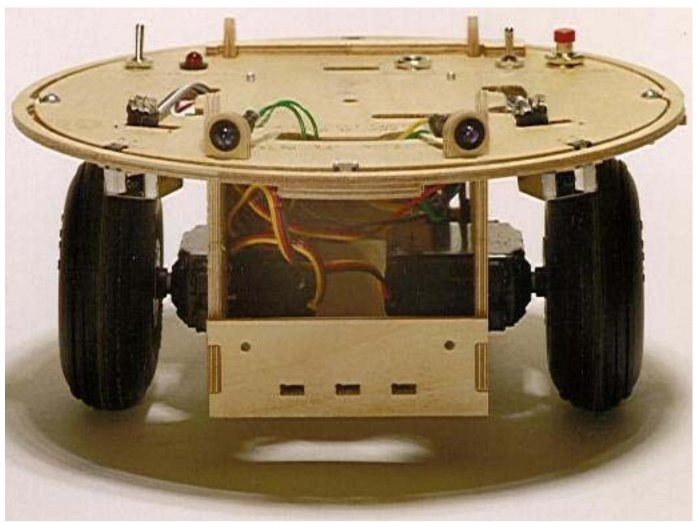
Version 01



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MANIFESTO

Mekatronix™ espouses the view that the personal autonomous agent will usher in a whole new industry, much like the personal computer industry before it, if modeled on the same beginning principles:

- Low cost,
- Wide availability,
- Open architecture,
- An open, enthusiastic, dynamic community of users sharing information.

Our corporate goal is to help create this new, exciting industry!

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1. GUIDE TO THIS MANUAL

If you want to learn a little more detail about the TJ-AVR™ robot features before you start assembly, read Section 6 first. If you want to examine the features of the microcontroller circuitry and printed circuit board layout, read Section 12. Section 17 provides details of servo/motor control. These three sections do not have assembly procedures in them and may be skipped, if desired. I have included them so as to provide orientation and to increase your understanding during the assembly process. Otherwise, perform the assembly process as your read the manual straight through.

2. TOOLS AND MATERIALS YOU SUPPLY

You will need some tools and supplies not included in the kit. These are

1. Phillips-head screwdriver and a Flat-blade screwdriver, jeweler's size
2. Soldering iron
3. Rosin core solder
4. Hot-glue gun
5. Hot glue
6. Wire strippers and cutters
7. Needle nose pliers, small
8. ¼ inch socket wrench, small (optional: to hold #4 nuts while tightening screws)
9. Acrylic glue (Super Glue®)
10. About 2 square inches of thin construction paper (about 1/64 inch thick), color not important, but I prefer black on the black plastic and beige on the wood
11. Hobby paint (optional)

The screwdrivers, pliers, and socket wrench allow you to assemble the robot body. You will use the wire strippers, soldering iron and hot-glue gun to assemble the various connectors and cables. You will use the acrylic glue to attach the bumper guides and bumper switch mounts. Those who have artistic design inclinations will want to apply hobby paint to personalize the robot's appearance.

3. TJ-AVR™ DOCUMENTATION AND DISTRIBUTION SOFTWARE

You can download ADOBE® ".pdf" versions of the TJ-AVR™ Assembly Manual and Users Manual from www.mekatronix.com →Manuals. You must make arrangements with your Mekatronix distributor to download the software distribution folder, which comes bundled with the purchase of your TJ-AVR™. You can also make arrangements to purchase the manuals and the software distribution folder (**Table 1**) placed on a single CD. Purchase of Mekatronix software, separate from a robot purchase, is also possible.

Table 1 TJ-AVR™ Documentation

Qty	Part Number	Description	Function
1	tjavrasm--.pdf	TJ-AVR™ Assembly Manual	Instructions to Assembly TJ-AVR™ robot
1	tjavrum--.pdf	TJ-AVR™ Users Manual	Operational Use of the TJ-AVR™
1	tjavrdist--	TJ-AVR™ Software Distribution	TJ-AVR™ device drivers object, two applications

4. WHAT IS IN YOUR TJ-AVR™ HARDWARE KIT?

The contents of your TJ-AVR™ expert kit appear in **Table 2** and **Table 3** .

Table 2 TJ-AVR™ Kit

Part	Quantity
Assembled & Tested MAVR128™	1
TJ-AVR™ Kit Bag	1
TJ-AVR™ Plastic (Plywood) Body	1
Plywood (Plastic) Bumper Girdle	1
Servos plus Mounting Hardware	2
Wheels plus Servo Horns	2
TJ-AVR™ Distribution Software	1

Table 3 TJ-AVR™ Kit Bag

Component	Quantity
IR Detectors	2
IR LEDs	3
LED Mounts	4
Red LED	1
Green LED	1
Bump Switches	4
Toggle Switches	2
Reset Button	1
Charge Jack	1
½ inch 4-40 machine screws	14
¼ inch 4/40 machine screws	16
# 4 Nuts	10
# 4 Lock Washers	10
Angle brackets	8
64-Wire Ribbon Cable	225mm (9")
Battery Holder (6-AA)	1
9V Battery connector	1
Skid	1
150 Ohm Resistor	2

5. UNPACK THE TJ-AVR™ KIT

Carefully unpack TJ-AVR™ and verify the presence of all the parts. Use **Table 4**, **Table 5**, and **Table 6** to check off items. Extra pieces may or may not be present, but only **QTY** quantities are guaranteed. If the body parts of TJ-AVR™ have been shipped attached to a parts sheet, remove them. Plastic parts break away easily, but wood parts should be cut away from the sheets with a sharp modeler's knife to avoid splintering the parts and defacing the surface layers. Lightly sand the cut edge surfaces of either wood or plastic to smooth and clean them. For the plastic robots, be careful not to sand the top or bottom surfaces.

Table 4 Microcontroller, LEDs, and Connectors

Qty	Part Number	Description	Function
1	MAVR128™	Assembled pcb	Microcomputer controller
2	Resistor 150 ohm	¼ watt	Charge current limiting, wired in parallel.
1	MVLED, Red	Visible LED, Red	Power-on Light
1	MVLED, Green	Visible LED, Green	Charge light
1	FC36	Female connector, 36pins	Cable connectors
1	FC12	Female connector, 12pins	Cable connectors
1	BHS6AA	Battery holder, 6-Pack	Holds 6 AA NiCd Batteries.
1	BSNAP9V	Battery pack snap leads	Connects Battery to MAVR128™
1		9 inches of 40 wire ribbon cable	Cable wiring.

Table 5 TJ-AVR™ Sensors, Switches and Motors

Qty	Part Number	Description	Function
2	MIR58Y40D	Digital IR Detectors, 40KHz, 940nm	Proximity sense. Must convert to Analog[1]
3	MIR27E	IR Emitters, 940nm	IR light projection
4	SWPBMT100	Tactile PB Switch	Bumper switches
1	SWSPST	Toggle switch	On-Off and Servo Power
1	SWSPST	Toggle Switch	Download-Run
1	SWPBR	Push Button Switch	Reset switch
1	MPMJ21	2.1mm ID, 5mm OD DC Panel Mount Jack	D.C. Charger Jack.
2	MS410	Gear Head Motor, 6V, 42oz-in	Wheel actuators
1	W275T	Pair of 2.75" wheels	TJ-AVR's Wheels.

Table 6 TJ-AVR™ Body Parts

Qty	Part Number	Description	Function
4	TJBGUIDE10	Bumper guides	Support Bumper, Moves with bumper
2	TJBMPCLIP10	Bumper Clips	Supports bumper,Fix to TJTOP61 with 4/40 screws
1	TJBUMPER70	Floating Ring Bumper	Bumper
3	TJCDS20	CdS cell Holders	Mounts for CdS cells (expansion kit only)
3	TJIRE20	IR Emitter Holders	Mounts for IR emitters
1	TJKEY30	TKey, Top Plate Clamp	Locks top plate (TJTOP61) onto the frame.
2	TJPLANK40	Cross Planks	Holds two sides of the chassis together.
2	TJPLANK50	Front Plank with three eyelet mounts	Fastens front together. Holes for mounting CdS cells and TJ-AVR™ sensor expansion board
2	TJSIDE50	Side	Sides of robot. Servo mounts.
5	TJSWSPACER04	Bumper Switch Mount	Supports bumper switches.
1	TJTOP65	Top Plate of Robot	Mounts switches, IR, bumper and other features.
1	TJSKID01	Plastic Skid	Back Skid.
14		½ inch 4-40 machine screws	Mount MAVR128™ (4 screws), Mount Bumper clips (2 screws), Mount Servos (8 screws)
16		¼ inch 4/40 machine	Mount four planks (4 screws each, 16 screws total)

[1] Refer to Analog Sensor hack in Section 8. You can also purchase factory-hacked IR detectors.

		screws	
10		# 4 Hex Nuts	Bumper Clips (2 nuts), Servos (8 nuts)
10		# 4 Lock Washers	Bumper Clips (2 lock washers), Servos (8 lock washers)
8		Angle brackets	Two per four planks (8 brackets total)
5	T1-3/4	LED Panel Mounts	Holds IR emitters , Power on LED, Green Charge LED

6. TALRIK JUNIOR ADVANCED VERSION ROBOT™

This manual describes how to assemble the TALRIK JUNIOR ADVANCED VERSION ROBOT™ (TJ-AVR™). The TJ-AVR™ consists of a TALRIK JUNIOR™ chassis controlled by the Mekatronix MAVR128™ microcontroller system. The brains of the Mekatronix MAVR128™ microcontroller system consists of the Atmel's AVR® Atmega128L microcontroller with supporting headers, integrated circuits and discrete components.[1]

The Atmega128L™ microcontroller features

1. 128-Kbyte, self-programming, flash program-memory,
2. 4-Kbyte SRAM,
3. 4-Kbyte EEPROM,
4. 8 channel 10-bit A/D-converter,
5. 8 MIPS throughput at 8 MHz,
6. 3 volt operation, and
7. A JTAG interface for on-chip-debug.

The JTAG feature, while not utilized in Mekatronix robot applications, allows the user to do so. Refer to Atmel Corp < www.atmel.com> for more details about the Atmega128L and the JTAG interface.

6.1 Mechanical Structure

1. TJ-AVR™ body parts may be made from tough, 5-ply, model airplane plywood or from black durable ABS plastic.
2. TJ-AVR™ fits into a right circular cylinder 7 inches in diameter by 3.25 inches high. (Volume approximately 125 cubic inches or 0.072 cubic feet)

6.2 Power Requirements

1. Six AA rechargeable Nickel-Cadmium batteries with at least 600 ma-hr capacity, 5.4-7.2 volts (Sold separately). Mekatronix premium batteries at 800 ma-hr capacity provide more run-time for your robot.

Warning!

Use only NiCd Batteries for TJ-AVR™. Do not use alkaline or other battery types. They will destroy the robot electronics.

2. Recharger, 12 volts D.C. rated at 500ma (Sold separately).

[1] AVR® is a registered trademark of Atmel Corporation.

Recommended.

When not in use for more than a few minutes, plug TJ-AVR™ into the charger unit to keep the batteries fresh. During programming sessions, Mekatronix also advises you to keep TJ-AVR™ connected to the charger so that the robot batteries will always have a full charge during experimental runs.

6.3 Motor and Servo Control

MAVR128™ microcontroller system on the TJ-AVR™ can control up to 16 MS455 servos, either hacked as gearhead D.C. motors or as servos. Two motor control ports are reserved for the wheel motors; two for the pan tilt head on the Argos™ enhancement kit (optional); and three for the shoulder, wrist and gripper servos on the MekArm™ enhancement kit (optional). The Argos™ tilt servo and the MekArm™ shoulder share the same motor port, reducing the total number of reserved motor control ports for the TJ-AVR™ to six. You may use the remaining ten motor ports to control other motors and servos or as general IO pins.

The gearhead DC motor drive for each wheel satisfy the following general specifications:

1. Voltage: 4.5 to 7.2 volts.
2. Current: 100 -120 ma under load, 80 ma no-load.
3. Speed: 1.25 revolutions/sec at 7.2 volts (full battery charge). Speed decreases proportionally as the voltage drops.

The servos satisfy

1. Voltage: 4.5 to 7.2 volts
2. Torque: 45 oz-inch
3. Speed: 60 degrees/0.2seconds

6.4 Robot Controller MAVR128™

The Mekatronix MAVR128™ microcontroller system is self-contained and does not require any external hardware to download and program the flash memory or to control any of the Mekatronix robot line. The MAVR128™ provides the brains and communication for the TJ-AVR™ and supports exceptional versatility for the robot. Control and communication features include the following:

1. Atmega128L microcontroller (see features listed in Section 2),
2. DOWNLOAD/RUN toggle-switch mode option,
3. 115.2Kbaud, 5volt serial communications interface (USART0) with RS-232 protocol,
4. Embedded 115.2Kbaud High-Speed Serial Downloader (HSSDLX128) program,
5. 5volt synchronous, serial peripheral interface (SPI), up to 4 MHz data rate,
6. Two-wire serial bus, up to 400KHz,
7. Second serial communications interface (USART1) with RS-232 protocol,
8. Programmable square wave generator on pin PB4, frequencies from16Hz to 4MHz,
9. 29 channels of multiplexed analog inputs for sensor and signal measurement,
10. 16 motor/servo control ports, and
11. Up to 24 general IO pins. The exact number of IO pins depends upon the use of other Atmega128L and Mekatronix features such as the SPI, Two-Wire, USART1, square wave generator, and other controller functions.

The MAVR128™ functional capabilities far exceed the basic requirements of the entry level TJ-AVR robot kit. Even fully expanded with a sensualized Argos™ pan-tilt head or with a MekArm, complete with Gripper and additional contact and proximity sensors, the MAVR128™ has functionality to spare. For this reason, all of Mekatronix Advanced Version Robots use the same microcontroller, the MAVR128™.

6.5 High-Speed Serial Downloader HSSDLX128

The Mekatronix proprietary software downloader, the HSSDLX128, furnishes full program-load performance in DOWNLOAD MODE. HSSDLX128 downloads Intel ASCII hex-format object code files*, .ihex*, into the Atmega128 flash program memory at 115.2Kbaud. A standard terminal, or personal computer terminal simulator, using X-Modem protocol, sends the *.ihex* object files via an RS-232 port, through the standard Mekatronix MB2325 serial communications board, to the MAVR128™ five-volt serial communication interface. The HSSDLX128 software not only receives the ASCII hex file, but translates it to binary code and programs the code into flash memory.

6.6 Input-Output Expansion Capability

The MAVR128™ circuit board provides TJ-AVR™ with exceptional IO power for a robot its size. These IO features appear in Section 6.4. The SPI and Two-Wire serial bus protocols permit attaching a large number of IO devices to the robot controller. For example, the Two-Wire serial bus addresses up to 128 read/write devices, as long as the bus capacitance remains below 400pf.

6.7 Flash Memory Programs Not Annihilated when Power Turned Off

Often you will want to program your robot, turn it off, and then come back to it later and execute the program. With flash memory, you can do this without using battery power during the off phase and without establishing serial communication to download the program again. This is a great advantage when you wish to set up a demonstration ahead of time.

6.8 Memory Usage

MAVR128™ possesses five types of memory of concern to the programmer,

Table 7 MAVR128™ Memory

Type	Size	Usage	Retention
Flash	128-Kbytes	programs	non-volatile
SRAM	4-Kbytes	data memory	volatile
EEPROM	4-Kbytes	data constants	non-volatile
Register	32 bytes	volatile data	volatile
IO	224 bytes	IO registers	volatile

Each of these memories has a specific function. The flash memory stores program code and constants and does not change during program execution. Flash changes only when downloading a program using the HSSDLX128 loader. SRAM holds program variables and values that change under program control. EEPROM stores non-volatile data constants. You can program EEPROM constants with any program and use those constants across applications, since the HSSDLX128, which downloads applications, is not enabled to write constants to EEPROM.

While programming in the C-language, your programs will not typically address the register memory directly, the compiler does that implicitly. You will often program the IO registers, however, so they and their bit fields have been given specific, predefined C-variable names and can be used as C-variables.

6.9 TJ-AVR™'s Starter Sensor Suite

Every TJ-AVR™ comes with the minimum sensor suite listed in Table 8. These sensors are wired directly to headers on MAVR128™ microcomputer circuit board.

These sensors have the following characteristics:

1. Two Forward-Looking IR Emitters. Signal wavelength equals 940nm.
2. One Backward-Looking IR Emitter. Signal wavelength equals 940nm.
3. Two Forward-Looking analog IR Detectors for 40KHz modulated 940nm IR. These sensors produce analog channel readings from about 88 to 128 out of a possible 256. The number 256 corresponds to five volts.
4. Three Front bumper Momentary Tactile Switches, each switch closure separately identifiable with analog bumper reading.
5. One Back Bumper Momentary Tactile Switch. Also, separately identifiable.

Table 8 TJ-AVR™'s Sensor Suite

Label	Name	Function	Header
IRDLF	Infrared Detector, Left Front	Proximity Sensor	MUX21
IRDRF	Infrared Detector, Right Front	Proximity Sensor	MUX23
FBRSW	Front Bumper Right Switch	Front contact Sense	FRONTBMP Pins 3-4
FBCSW	Front Bumper Center Switch	Front contact Sense	FRONTBMP Pins 5-6
FBLSW	Front Bumper Left Switch	Front contact Sense	FRONTBMP Pins 7-8
RBSW	Rear Bumper Switch	Rear contact Sense	FRONTBMP Pins 9-10

6.10 Enhanced Sensory Capabilities

Many sensors can be added to the basic sensor suite. For example, you can add microphones, photoresistors, sonars, a digital compass, gyroscopes, accelerometers, pressure sensors, force sensors, tactile sensors, GPS sensors, heat sensors, motion sensors, etc. to TJ-AVR™ platform. The numerous sensory possibilities and add-on features are limited only by the input/output capability of the MAVR128™ and your imagination.

6.11 Switches and Charge Jack

Three switches on the robot body permit various controls (Table 9).

Table 9 Robot Control Switches

Switch	Function
Red push button	Reset robot
Toggle	Mode switch to Download or Run Program
Toggle	Power Off-On.

A charge jack allows you to recharge the robot while programming or when not in use.

6.12 Standard LED Indicators

1. POWER-ON: Red LED,
2. BATTERY CHARGING in progress: Green LED.

6.13 Support Software

You can write TJ-AVR™ programs in Atmega128L Assembly Language or C, or any other language whose compiler for the Atmega128 that you can lay your hands onto. Mekatronix recommends and provides, without charge, the freeware *GNU* C-compiler coupled with the *AVR Studio's Integrated Development Environment* (IDE), and the AVRFREAKS© package to utilize the *GNU*© compiler with *AVR Studio*.

Bundled with each TJ-AVR™, Mekatronix supplies the object code for TJ-AVR™ Mekatronix libraries, interrupt control, motor and servo drivers, sensor reading and square wave generation on pin PB4. Supplied Mekatronix header files define robot global variables and constants. Source and object code may be purchased separately for educational applications.

You may also purchase a commercial C-compiler for the MAVR128™. Contact a Mekatronix distributor for more information (Go to www.mekatronix.com and select *How to Buy* in the Menu bar).

6.14 Applications Software

Mekatronix™ distribution software package includes an elementary program, source and object code, that allows TJ-AVR™ to explore its environment and avoid bumping into things, most of the time! If TJ-AVR™ does bump into something, its bumpers so indicate and it moves away, or, in some cases, it gets stuck and needs help!

You can develop your own applications, limited only by your imagination and 128Kbytes of program and 4Kbytes of data memory.

1. Make TJ-AVR™ do figure eights, or any other shape, while at the same time avoiding people and furniture.
2. Program TJ-AVR™ to be an artist who draws on cardboard with a pen attached to his body (pen-holder not included) (Be sure TJ-AVR™ stays on the cardboard!).
3. Design an obstacle course for TJ-AVR™ to learn.
4. Scare TJ-AVR™ by blasting it with your TV remote!
5. Write a program so TJ-AVR™ will be attracted to your TV remote!
6. Control TJ-AVR™'s behavior with your TV remote…an IR controlled vehicle! (A Mekatronix kit sold separately (See http://www.mekatronix.com)
7. Get two or three TJ-AVRs™ and program them to follow each other.
8. Get three TJ-AVRs™ and teach them to flock like goslings as they move around together.

6.15 Serial Communication

To develop your applications requires communications between a Personal Computer and the TJ-AVR™ robot (**Figure 1**). The additional purchase of an MB2325 communications board and a 6-wire RS-232C communications cable will provide the hardware for that capability. Only one MB2325 board and cable is necessary to enable you to sequentially load and download any number of Mekatronix™ robots, since the MB2325 board can remain attached to the PC and not the robot.

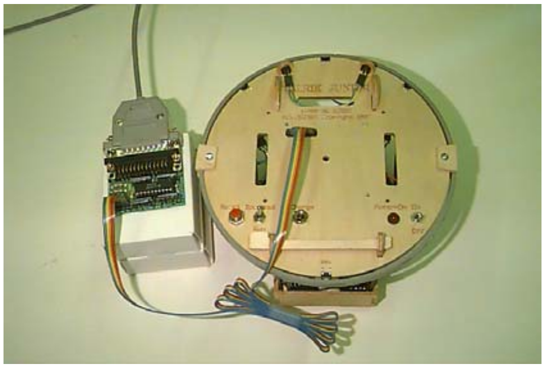

Figure 1. This Photograph shows the gray serial cable from a PC COM port mating with the D-25 connector on the communications board (com-board = MB2325 = the exposed circuit board sitting on the white boxes). The multicolored 6-wire serial cable attaches to the male header on the com-board and into the serial slot on the TJ-AVR™ plate. Note the same color orientation of both **ends of the 6-wire cable for the configuration pictured.**

A 6-pin male header permits the MAVR128™ to serially communicate with other MAVR128™ boards or personal computers via a 6-wire cable (C2325) connected to a bidirectional serial communications board (MB2325). The 6-pin male, serial communications header is mounted underneath the MAVR128™ circuit board. This placement of the header makes it easily accessible through the rounded rectangular opening on the robot top plate

***Caution**: Do not connect a standard RS232-C cable to the 6-wire connector. The voltage specified for RS232-C will destroy the electronics*

7. TJ-AVR™'S MECHANICAL STRUCTURE

A schematic of TJ-AVR™'s structure appears in **Figure 2**. TJ-AVR™'s wheel axis determines

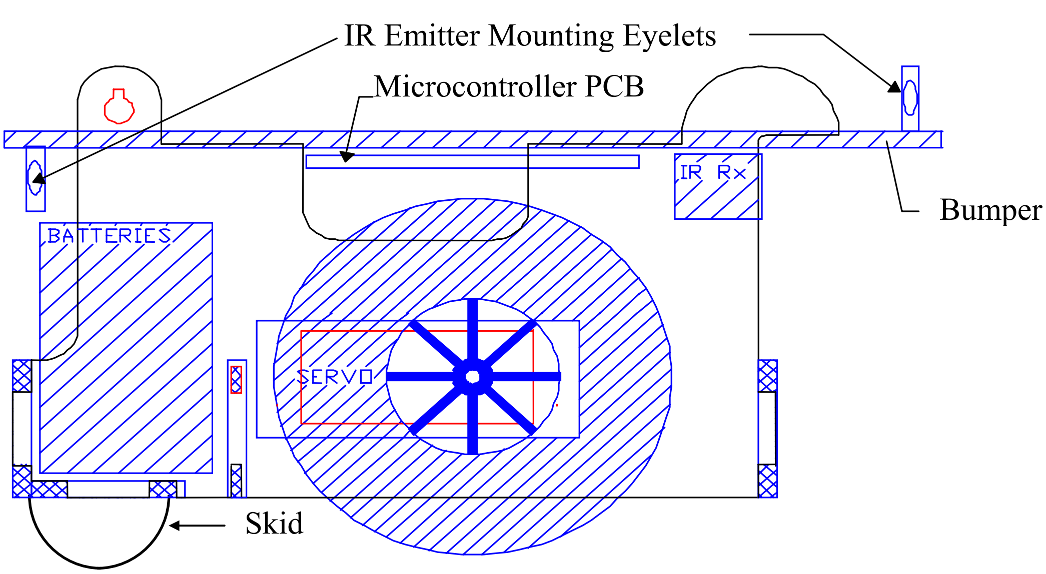

Figure 2 Schematic side view of TALRIK, JR.™

the robot's left-to-right axis. The diameter perpendicular to the wheel axis determines the front-to-back axis. The battery carrying space identifies the rear end of the robot.
Corresponding IR Detectors and emitters, those oriented in roughly the same direction, must be mounted on opposite sides of the top plate. The basic TJ-AVR™ possess two forward looking IR emitters, mounted in the front eyelets on top of the plate, and two forward looking IR detectors mounted underneath the front of the top plate, next to the sides. A third IR emitter mounts in an eyelet underneath the top plate and points back. An optional third IR detector can be mounted above the back IR emitter.

The MAVR128™ printed circuit board (pcb) mounts on the top plate with four ½" 4/40 machine screws. Three hex nuts on each screw serve as spacers between the pcb and the top plate. These nuts keep the six pins of the Serial communications port from projecting above the top of the plate and presenting a puncture hazard to human body parts! The screws themselves screw snugly into the surface of the top plate, flush with the top surface. Because of the small tolerances, the screws securely fasten the pcb to the top plate without nuts on top of the plate.

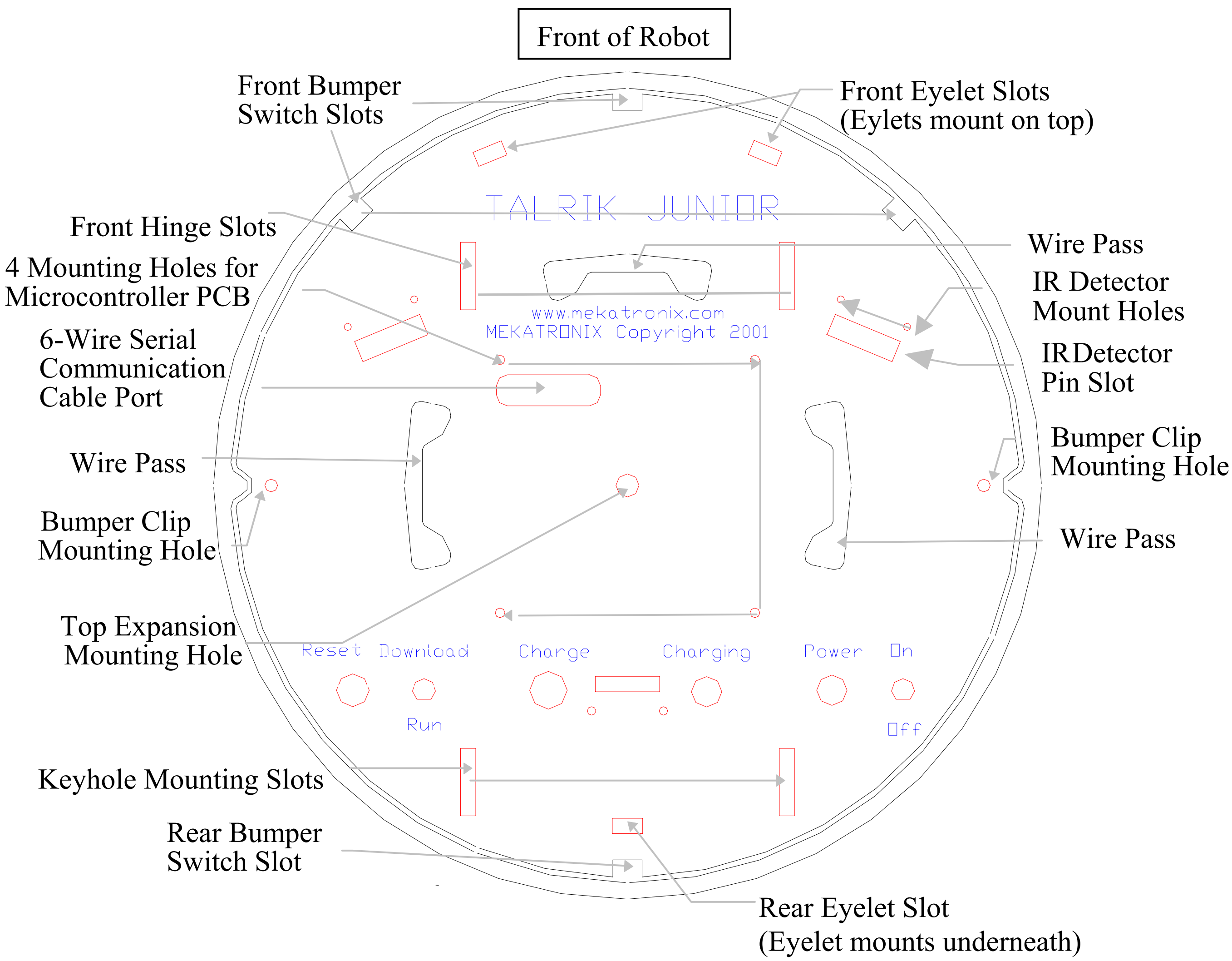

Figure 3. Layout of TJ-AVR™'s Top Plate. The three wire pass cutouts are parts (TJBGUIDE10). Do not throw away!

The circular top plate (**Figure 3**) mounts on the sides similar to a reverse automobile engine hood. The shaped slots on top of the plate are used for wire conduits.

Two front slots on the top plate slip onto the “goose” necks of each side. The circular plate should be perpendicular to the floor for initial insertion of the goose necks. Holding the plate firmly against the vertical ends of the front end of the side pieces, the plate should be slowly rotated 90 degrees toward the rear as you release the pressure holding the plate vertically. Make sure no wires bind or catch between the plate and the two sides as you close the plate down. Two slots in the rear of the plate slide over the tabs with keyed circular holes. A key can be slipped through the tab holes to lock the top plate into place.

TJ-AVR™ possesses three switches mounted on the top plate in the rear (**Figure 3**), 1) *OFF/ON*, 2) *DOWNLOAD /RUN*, and 3) *RESET*. In the *DOWNLOAD* position, the *DOWNLOAD /RUN* switch forces the processor into program download mode upon reset. When the processor is in program download mode you can program code and constant data into the microcontroller’s flash memory. With the switch in *RUN* mode the processor, upon reset, executes the downloaded program.

The recharge plug is located just to the right of the *DOWN-LOAD/RUN* toggle switch. The green charging light indicates when the robot is charging.

In addition to the control switches, three bumper switches mount on the front edge of the plate and one on the back edge (**Figure 3**).

Each side piece (TJSIDE50) supports a servo and wheel assembly. The servos slide into the large rectangular opening in each side’s center. Four small cross planks (one in front with eyelet holes (TJFRONT50), one in back, one underneath in back, and one inserted between the sides, a little more than an inch from the rear end) hold the sides rigidly apart and simultaneously provide a battery case for the 6 AA battery pack located just above the back nylon skid.

7.1 TJ-AVR™’s Body Parts

Figure 4 illustrates the twelve structural components of TJ-AVR™’s body. The list in **Table 10** specifies TJ-AVR™’s body parts, the quantity employed in constructing a TJ-AVR™ frame and the function of each part. The plastic tail-skid is listed as well.

Table 10 TJ-AVR™ Body Parts

Qty	Qty Used	Part Number	Description	Function
5	4	TJBGUIDE10	Bumper guides	Support Bumper, Moves with bumper
2	2	TJBMPCLIP10	Bumper Clips	Supports bumper, Fix to TJTOP61 with 4/40 screws
1	1	TJBUMPER70	Floating Ring Bumper	Bumper
4	0	TJCDS20	TJ-AVR™ CdS cell Holders	Mounts for CdS cells (expansion kit only)
4	3	TJIRE20	TJ-AVR™ IR Emitter Holders	Mounts for IR emitters
1	1	TJKEY30	TJ-AVR™ Key, Top Plate Clamp	Locks top plate (TJTOP61) onto the frame.
3	3	TJPLANK40	TJ-AVR™ Cross Planks	Holds two sides of the chassis together.
2	1	TJPLANK50	Front Plank with three eyelet mounts	Fastens front together. Holes for mounting CdS cells and TJ-AVR™ sensor expansion board
2	2	TJSIDE50	TJ-AVR™ Side	Sides of robot. Servo mounts.
5	4	TJSWSPACER04	Bumper Switch Mount Spacers	Supports bumper switches.
1	1	TJTOP65	TJ-AVR™ Top	Mounts switches, IR, bumper and other features.
1	1	TJSKID01	Plastic Skid	Back Skid.

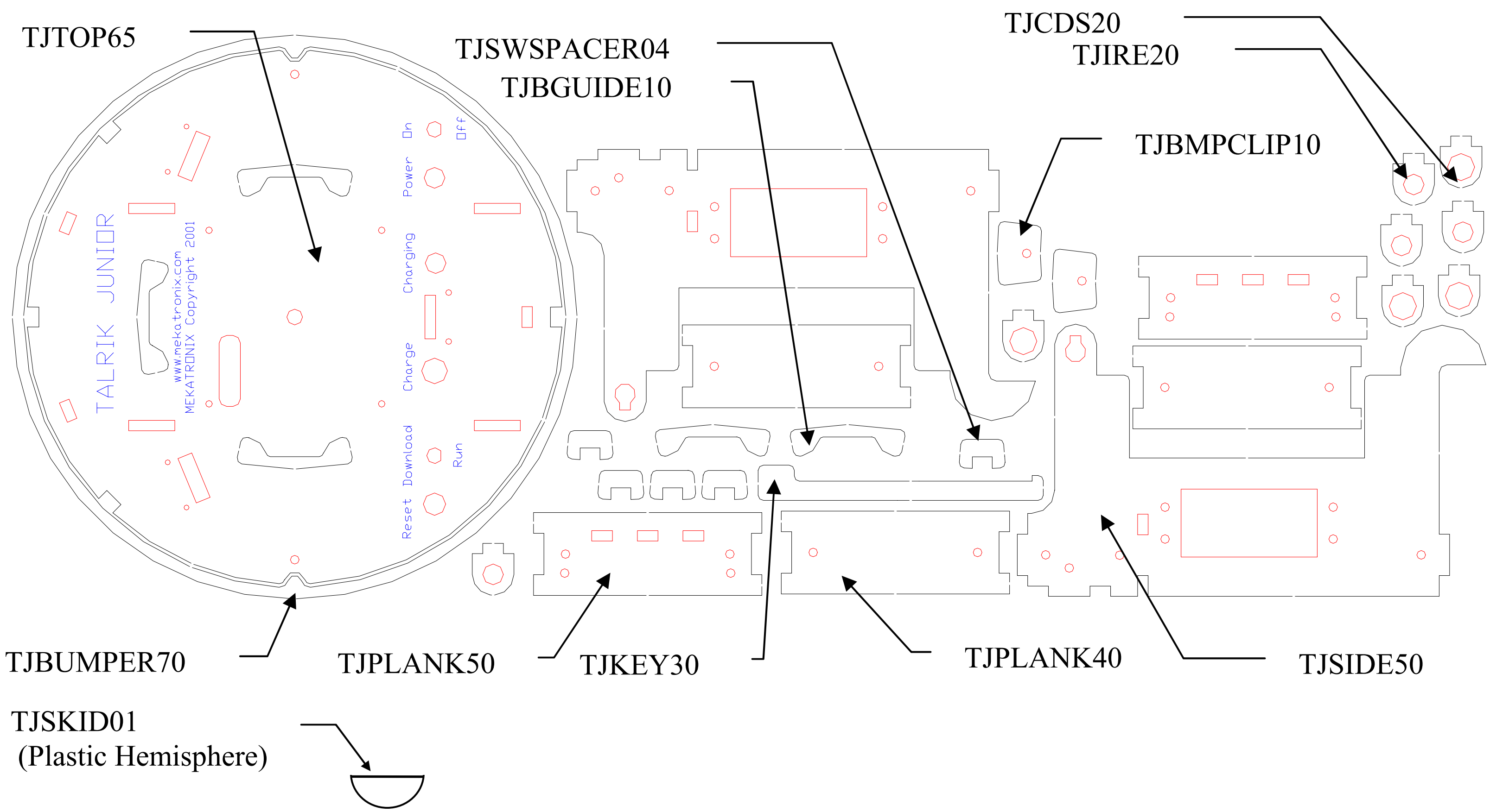

Figure 4 TJ-AVR™'s Body Parts

8. ANALOG HACK OF THE DIGITAL IR DETECTOR

The IR detectors operate as digital devices and must be converted to analog devices for the front detectors IRDLF and IRDRF. This hack applies to the SHARP GPIU58X or the GPIU58Y.These two parts possess identical electrical characteristics. The three leads of the GP1U58X project from the back of the can in line with the viewing lens. Those of the GP1U58Y project perpendicular to the viewing lens, allowing for easy printed circuit board mounting. The unmodified Sharp has only a single digital output pin. This signal is taken from a Schmitt trigger in series with a 40KHz band-pass filter and signal amplifier. An integration element (0.1µf capacitor) is applied before the Schmitt trigger.

Gain access to the Sharp miniature, internal, printed circuit board by carefully bending the lower lid back. Careful! Bending the lid too many times will cause the metal to fatigue and break, thus, eliminating the lower part of the faraday cage protecting the device from electromagnetic interference. Examine the exposed side of the Sharp printed circuit board. Refer to **Figure 5** in the following discussion.

1. Carefully bend back the metal cover of the GP1U58X or GP1U58Y.
2. Cut the trace to the output pin (leftmost inside pin).
3. Solder 30 AWG wire from the top of the 0.1 microfarad capacitor to the output pin.
4. Solder 30 AWG wire from the ground pin to the case with a large blob of solder. Be sure to make a good connection. The output pin will now give the analog response.
5. Close up the can. The hack is complete.

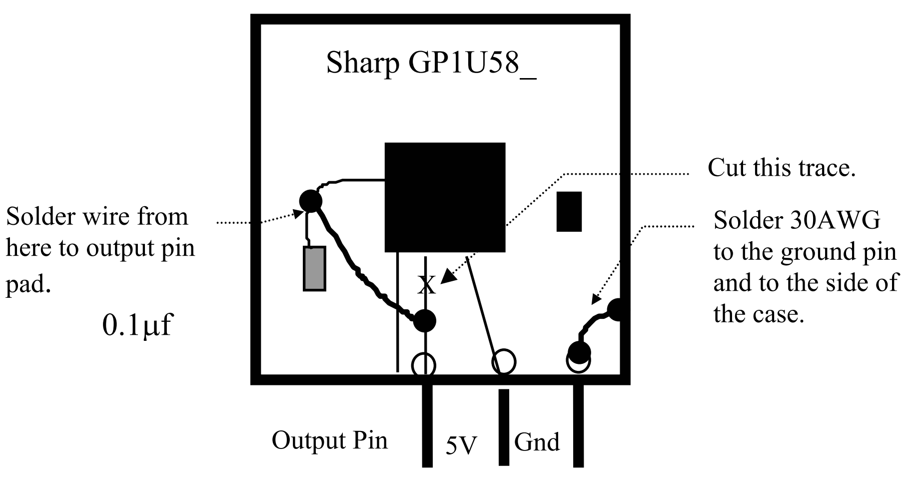

Figure 5. To convert a digital IR sensor to an analog IR sensor, cut the trace to the Output pin, solder the ground (Gnd) pin to the side of the case, and connect the top of the 0.1 µf capacitor to the Output pin.

The analog output voltage will vary from about 1.5 volts to 2.5 volts with a rise time of about 100ms and a fall time of about 50ms. The processor analog-to-digital converter (ADC) will typically provide digital outputs in the range 88 to 130, yielding about 5 bits of precision.

The effective range of the hacked IR sensor depends upon the IR emitter illumination level and degree of beam collimation. With a current of 5ma through uncollimated IR emitters, the effective range varies from about 4 inches to 16 inches, ideal for proximity sensing.

9. HACKING THE SERVOS INTO DC GEARHEAD MOTORS WITH CONTROLLERS

A standard Mekatronix servo, e.g., an MS410 or MS455, can be hacked in the following manner to create a DC gearhead motor. Refer to **Figure 6**. This (almost) ruins the servo as servo, but in its place you have a D.C. geared motor with electronic control!

1. Mount a servo horn on the output shaft and rotate the servo to the center of its range.
2. Avoid rotating the potentiometer shaft from its center position from here on.
3. Remove the 4 back plate screws and carefully remove the gear box cover on top.
4. Remove the output gear.
5. With sharp, miniature diagonal cutters, cut off the plastic stop tab.
6. Take the potentiometer lock-tab out of the output gear (**Figure 7**) so it will not turn the potentiometer shaft.
7. Remount the output gear *without* the shaft-lock tab and reassemble the servo.

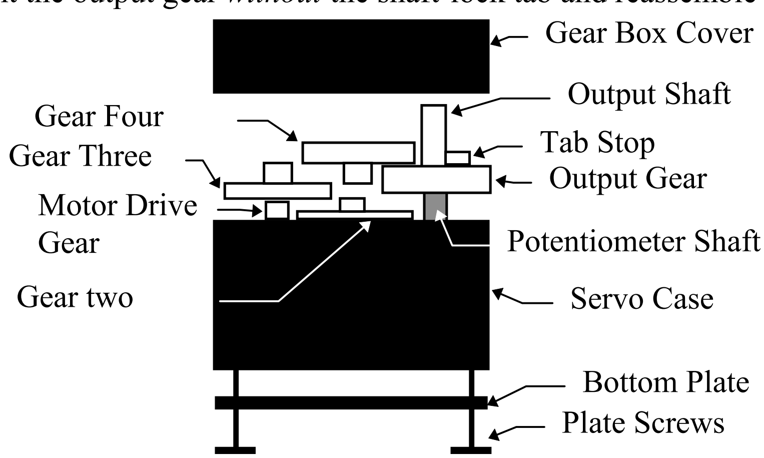

Figure 6. Servo hack: Remove tab stop, remove potentiometer tab inside *Output Gear*, set potentiometer shaft at center setting.

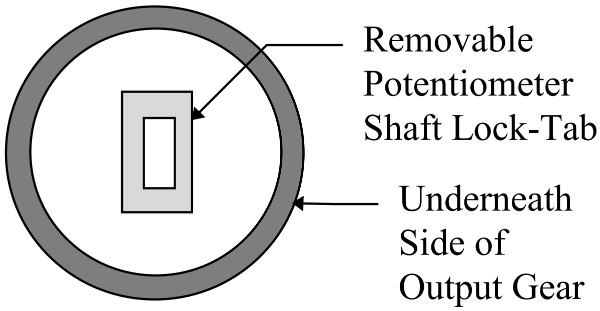

Figure 7. Illustration of the potentiometer shaft lock-tab inside the output gear.

9.1 Variation on the Servo Hack

The gear cover on top of some servos has separate screws from the bottom plate. This permits you to remove only the gear cover. Do not remove the bottom plate screws. Otherwise, the hack described above applies.

Some servos have ball bearings under the output gear and their raceways and often disassemble as you take the output gear off. Usually, the ball bearing grease keeps the bearings together or stuck to some other part of the gearbox. Nonetheless, be careful not to lose the tiny bbs. The outer raceway fits snugly into the underside of the output gear and must be gently removed. Be careful not to damage the raceway. Reassemble the bearing. Be sure to place all the bbs between the raceways. At this point in the procedure, remove the potentiometer shaft-lock tab in the output gear and center the potentiometer shaft as described above. Press the reassembled bearing inside the output gear. Reassemble the gear train and box. Close up the gear box to complete the hack.

10. MOUNT SERVO HORNS ON WHEELS

The servo mounting hardware comes together in a package. In the procedures listed here, be sure you center the servo horns onto the wheels in all cases. Otherwise the wheels will wobble as they turn.

Alternative 1:
Mount the servo horns (**Figure 8**) onto the wheels as shown in **Figure 9**.

1. Center and glue a 1 inch washer on the wheel hub.
2. The top of the horn has a ridge that you can center into the washer. If the ridge has side support ridges, razor blade them off and sand smoothly so that the plastic ridge easily fits inside the center hole of the washer.
3. Insert the horn center screw into the top of the horn.

4. Now center and glue the top of the horn onto the washer. The horn screw is now trapped by the narrow wheel shaft hole and cannot fall out. The horn, hence, the wheel, can still be attached and detached from the servo output shaft by means of a small jeweler's screwdriver inserted through the wheel shaft hole.
5. After glue dries, mount wheel onto servo output drive shaft.

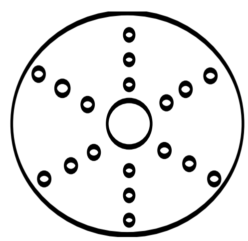

Figure 8 Round servo horn.

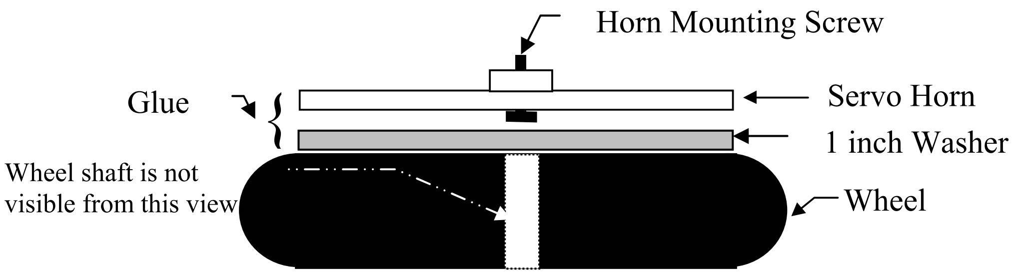

Figure 9 Center the washer and glue to wheel. Insert horn mounting screw into horn. Center and glue top of horn to washer. Do not allow the horn screw to fall out or to become glued. Screw horn onto servo output shaft after glue dries.

***Alternative 2**:*

Mount the servo horns (**Figure 8**) onto the wheels as shown in **Figure 10**. Pilot holes for the screws can be conveniently created by pressing an awl into the wheel plastic at the desired locations, or by drilling holes about 1.5mm in diameter. The holes do not have to be too deep, since the screws self-thread into the plastic. Any of the common horns, a round plastic disc with holes or a plastic two-, three-, four-, or six-pronged horn can be used. Each horn has a center tap for mounting the horn on the output shaft of the servo. Be sure that the horn's center screw is in place before attaching the servo horn onto the wheel frame. You can tighten or loosen the servo horn screw using a small screwdriver whose blade will fit through the hole in the center hub of the wheel.

Note: Be careful to mount the horn flat and parallel to the wheel frame, otherwise the horn will tilt when screwing it down. This will cause the wheel to wobble as it turns.

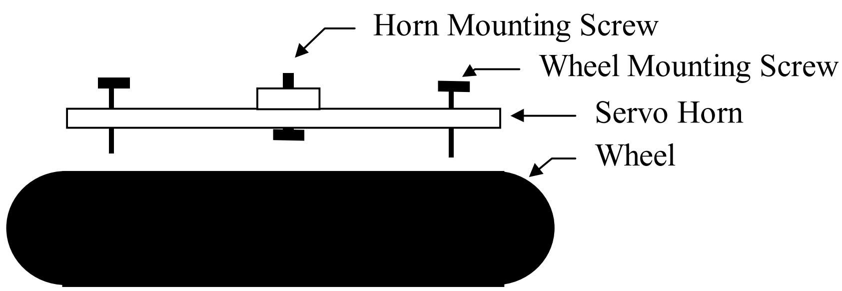

Figure 10 How to mount a servo horn onto a wheel. Be sure the horn mounting screw is placed into the horn before fastening the horn to the wheel with the other two screws.

Alternative 3:

The horn can be bonded to the wheel directly with Zap-A-Gap™ adhesive. Be sure to keep the horn centered on the wheel. This is easiest of the three methods, but less reliable, as there is often not enough contact surface with the horn and it will fall off under use.

11. ASSEMBLE THE TJ-AVR™ BODY

Before assembly you will want to unpack the kit and verify the presence of all the parts. Become familiar with the parts and their usage as you check them off. This will help you in the assembly process. To further assist you, refer to various tables and figures already presented as well as those given here.

11.1 Mount the Hacked Servos onto the Sides

Be sure to hack the wheel motor servos before mounting. Refer to Section 9 for hacking directions. Insert the servos as illustrated in **Figure 11**.

1. Tilt the servo slightly to get the cable grommet on the servo past the rectangular orifice in the side (TJSIDE50).
2. Once the grommet passes through, straighten the servo and slide it up snugly.
3. Pass ½ inch 4/40 machine screws through the top mounting flange holes of the servo and the four holes in the robot side (TJSIDE50).
4. Fasten the four servo mounting screws with a lock washer and nut.

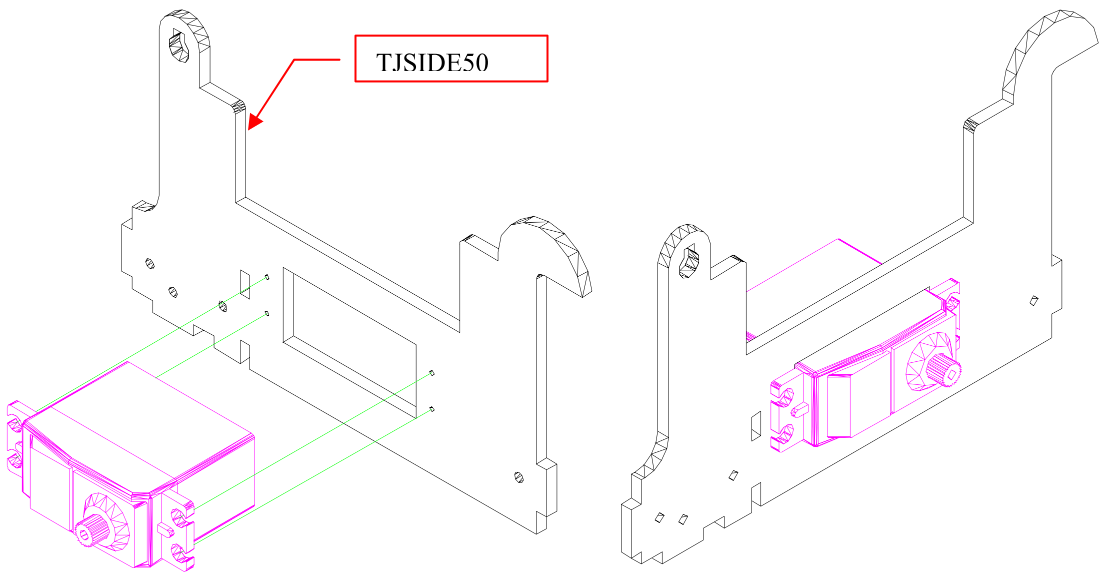

Figure 11. Slip the servos into the sides as shown in a) and b) and then fasten with four ½ inch, 4/40 machine screws. Two screws on the diagonal, however, is sufficient and makes disassembly easier.

11.2 Mechanical Assembly of the TJ-AVR™ Body

Join the four cross pieces to the robot's sides with small right-angle brackets and ¼ inch, 4/40 machine screws, as shown in **Figure 12** .

1. With ¼ inch 4/40 screws tightly attach two right-angle brackets to each of two TJPLANK40 and to each of two TJPLANK50 cross pieces in the orientation shown. The long side of each angle bracket lies on the crosspiece. The screw heads pass through the body piece and screws into the right-angle bracket.
2. Line up the holes on the sides (TJSIDE50) to the interior plank (TJPLANK40).
3. With ¼ inch 4/40 screws loosely attach the interior plank (TJPLANK40) to the sides (TJSIDE50).
4. With ¼ inch 4/40 screws loosely attach the bottom (TJPLANK40), back (TJPLANK50) and front (TJPLANK50) cross pieces to the sides (TJSIDE50).
5. Align the cross pieces as you gradually tighten the screws.
6. Tighten all screw to a snug fit.
7.

The completed chassis assembly is illustrated in **Figure 13**.

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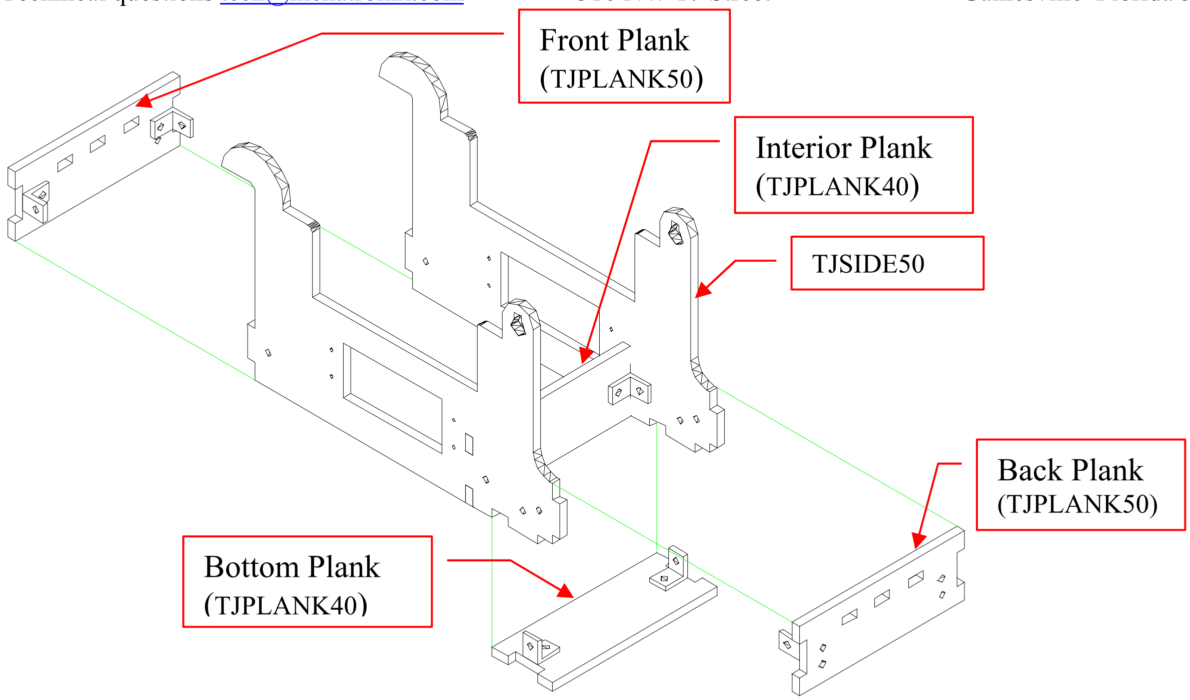

Figure 12. This drawing of theTJ-AVR™ frame assembly shows how to connect the four cross planks to the sides. For clarity, the servos are not shown mounted. The long side of each angle bracket lies on the crosspiece. The short side of the angle bracket connects to the side pieces of the body with ¼ inch 4/40 machine screws. The screw heads show on the outside.

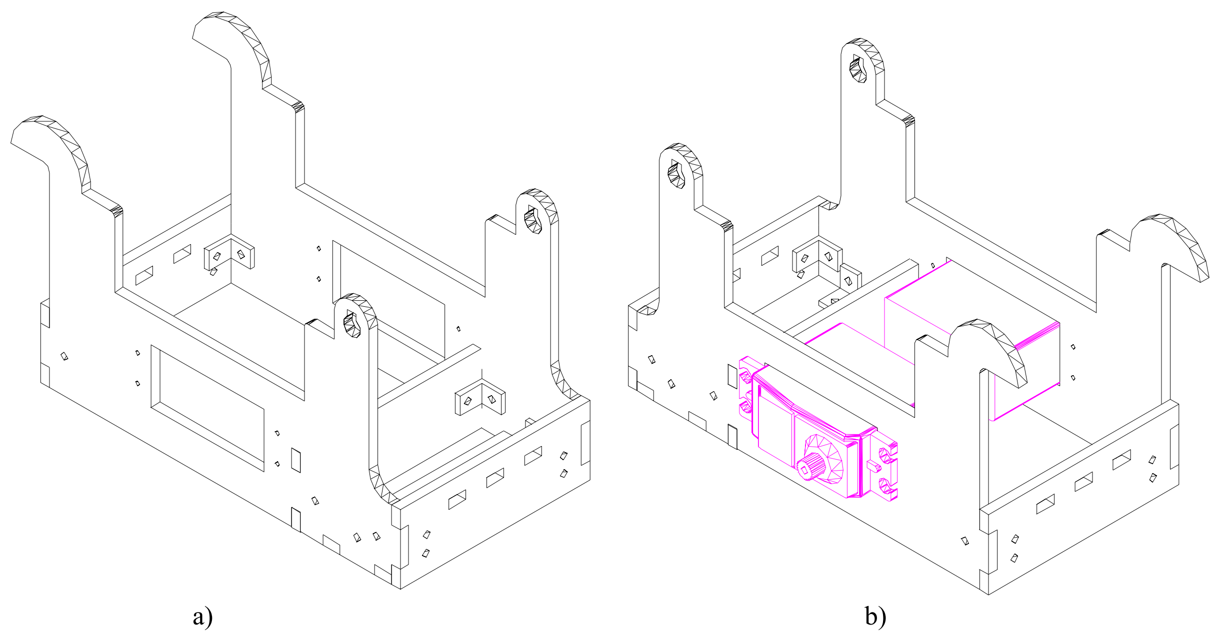

Figure 13. Completed assembly of the TJ-AVR™ robot chassis a), with servos mounted b).

11.3 Finish Surfaces

You should lightly sand TJ-AVR™'s wood structures using very fine grade sandpaper. After sanding, we recommend clear-coating TJ-AVR™ to bring out the natural beauty of the wood. Of course, you can varnish, stain or paint wild color schemes to taste! All finishing should be performed before electronic assembly, as the wires and electronic components prevent effective finishing later. You can silk screen or paint plastic bodies to taste.

11.4 Mount Tailskid

Glue the beige, hemispherical, plastic tailskid to the bottom plank, centered between the two sides and close to the rear edge of the bottom plank.

11.5 Glue Bumper-Switch Mounts and IRE Eyelets onto Top Plate

Refer to **Figure 14** and **Figure 15**.

1. Glue the four switch supports TJSWSPACER04 on the bottom of the top plate TJTOP61. Be sure the TJSWSPACER4 switch slot lines up perfectly with the switch slot on the TJTOP61 plate. The push button bumper switches will slide into the gaps later.
2. Glue the three IR eyelets (TJIRE20) onto the top plate as shown in **Figure 15**. Notice the one in the rear points downward and is mounted on the underside of the plate. Since the eyelets fit loosely, you might want to use hot glue here.

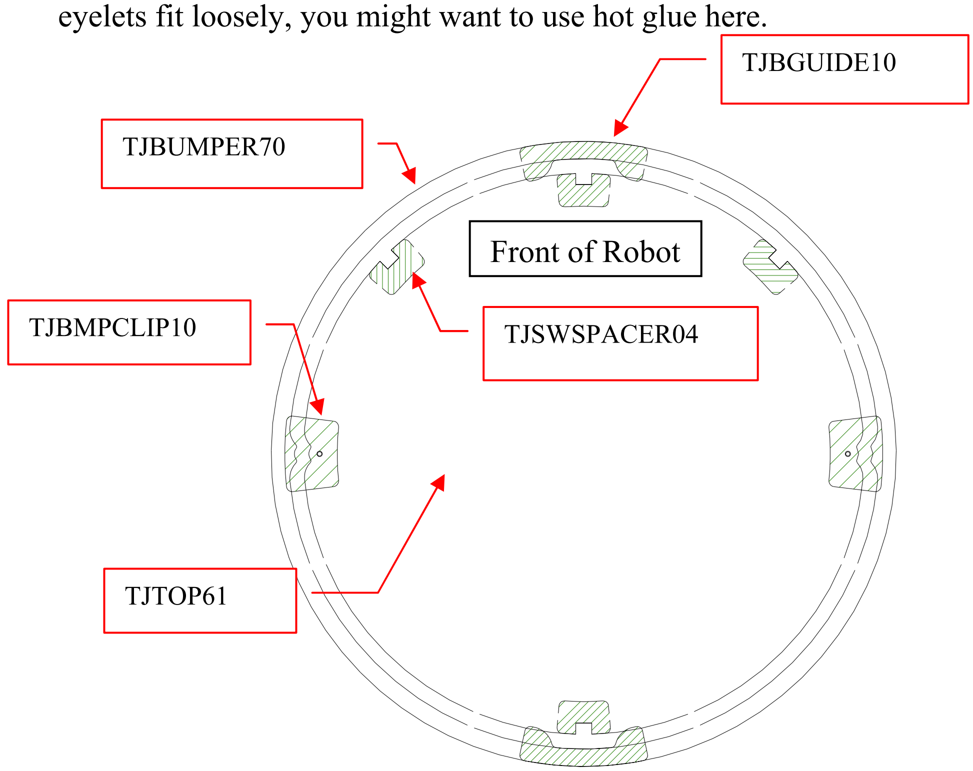

Figure 14. TJ-AVR™'s bumper assembly.

11.6 Assemble the Floating Ring Bumper and Mount

Figure 14 depicts a schematic diagram of TJ-AVR™'s bumper system. Refer to **Figure 15** to visualize the bumper more clearly.

1. Cut four pieces of thin construction paper (1/64 inch) in the bone shape of the TJBGUIDE10. These will serve as shims to keep the floating ring bumper guides from fitting to tightly onto the top plate, thus, allowing the bumper to move freely.
2. Glue one construction paper *bone* onto each of the four TJBGUIDE10s. Trim to fit.
3. Glue the construction paper side of the bumper guides (TJBGUIDE10) to the underneath side of the floating ring bumper (TJBUMPER70), one in front of FBCSW and the other in front of the RBSW.
4. With the plate upside down, place the floating ring bumper around the top plate so that only the guides touch the bottom of the plate.
5. Screw two bumper clips (TJBMPCLIP10) over the bumper with half inch 4/40 screws coming through the top of the plate, which is face down. Clamp the bumper clips with a 4/40 lock washer and nut on the underneath side.
6. The floating bumper is free to move but will not fall off or rotate in place!
7. Flip the robot over and glue the construction side of the bumper guides (TJBGUIDE10), aligned with the ones glued on the bottom side of the bumper, to the top side of the floating ring bumper (TJBUMPER70).

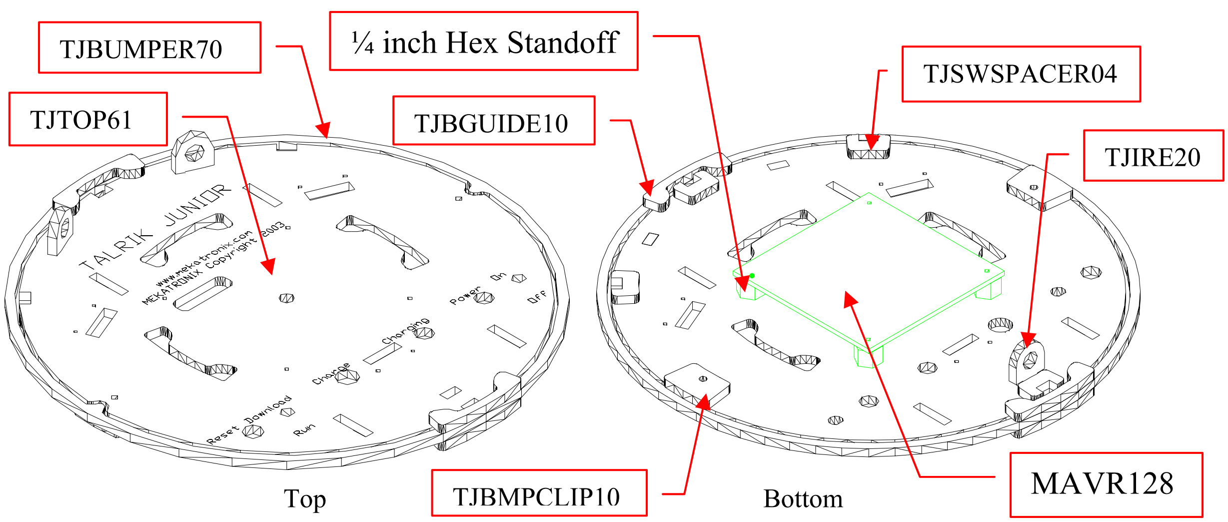

Figure 15. These two figures present the top and bottom view of the robot's top plate with the bumper, switch mounts, printed circuit board, and IR eyelets attached.

11.7 Mount the Microcontroller onto the Top Plate

The MAVR128™ printed circuit board (PCB) mounts underneath the top plate (**Figure 15**). Four mounting holes are provided. The 6-pin serial communications header is mounted on the non-component side of the MAVR128™ PCB. A slot on the top plate provides access to this header.

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Proper mounting of the PCB on the top plate will recess the serial communications header below the top surface of board.

1. Orient the MARV128™ PCB on the bottom of the plate as shown in **Figure 16**.
2. Thread four ½ inch 4/40 machine screws through the top of the PCB and into the four ¼ inch hex standoffs underneath the board. Leave about 1/16 inch space between the PCB and the standoffs.
3. Center the screws, now projecting through the standoffs, onto the holes in the top plate provide for this purpose. Thread them gently into the top plate. This will cinch the PCB, standoffs, and top plate together. DO NOT OVERTIGHTEN or you will strip the threads you are making in the plate.
4. If you strip a hole in the top plate, use a 5/8 inch 4/40 screw with lock washer and nut to secure the PCB. The parts in this step are not provided.

The ¼ inch standoffs between the PCB and the top plate provides spacing to pass wires underneath the PCB and keeps the serial communication header pins from sticking out above the surface of the top plate. This latter feature will prevent injury to fingers or hands when picking up the robot. With this spacing the ends of the mounting screws should extend about 1/16 inch above the top surface of the plate.

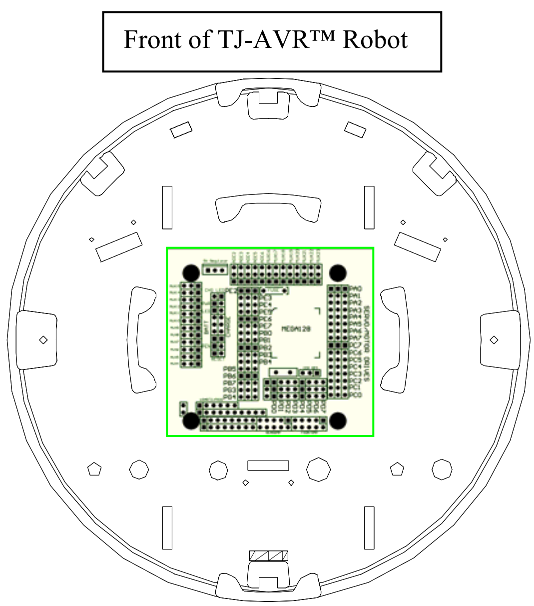

Figure 16. This figure shows the orientation of the microcontroller PCB on the plate's underside.

If you later decide to add an Argos™ pan-tilt head or a MekArm™ manipulator to the robot, you may need to replace the ½ inch 4/40 machine screws with ¾ inch 4/40 machine screws. The screws will then project a greater distance through the top plate making it easier to mount the threaded hex standoffs used to fix the Argos™ or MekArm™ to the top plate.

11.8 Completed Body Assembly or Closing the Hood

The top of the TJ-AVR™ body operates like a car engine hood that opens from the rear. Refer to **Figure 17**. Although you have not yet wired the sensors or motors, you may want to perform a trial run of the following instructions. After wiring the robot, you will then perform this operation again.

1. Hold the back plane of the top plate parallel to the front plane of the robot's front cross member. The rear part of the plate is in the highest vertical position.
2. Align the two front slots of the plate with the goosenecks located in the front of the sides.
3. Slip the goosenecks through the plate slots. Be sure to clear all wiring away from the slots.
4. Plug in the BATT connector and the wheel motor connectors.
5. Slowly tilt the plate back towards the rear of the robot.
6. Insert the key holders on the robot's sides through the rear plate slots provided for this purpose.
7. Be sure all wires are cleared and none are being pinched as you push the top down.
8. Secure the top (now horizontally to the floor) and insert the key (**Figure 18**).
9. Twist the key flat to lock the top plate to the rest of the body.

The top is now mounted and secure. You will have to reverse this procedure to get the top off to access the microcontroller for wiring.

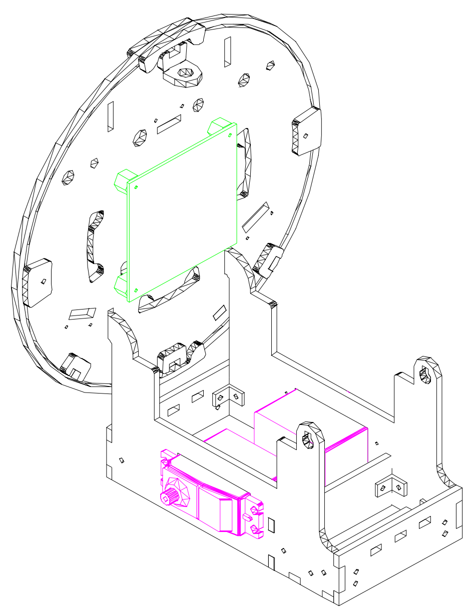

Figure 17. Orientation of top plate for mounting onto the lower body of the robot.

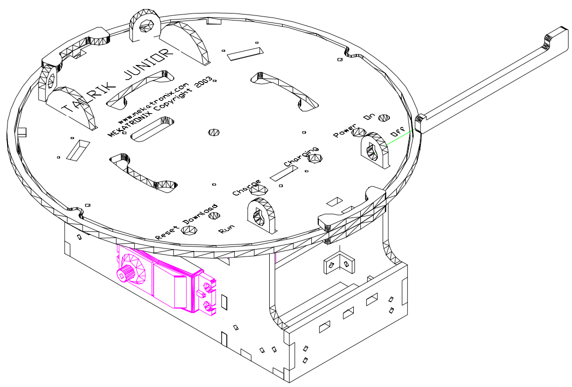

Figure 18. The above drawing illustrates a complete body assembly without wheels, sensors, switches, LEDs, cables or connectors.

12. TJ-AVR™'S MICROCOMPUTER CIRCUIT

The Mekatronix microcomputer circuit, the MAVR128™, which measures about 2.4 inches by 2.4 inches, is a completely functional microcomputer system useful for a wide variety of embedded applications. The MAVR128™ circuit board already comes assembled and tested.

Caution: MAVR128™ possesses static sensitive parts. Static discharge can destroy them. Avoid working on carpet and ground yourself properly before touching any of the electronics.

PICTURE HERE OF MAVR128™

Figure 19 Photograph of the MAVR128™ microcontroller printed circuit board. The large chip at the top is the Atmega128L processor. The column of 3-pin male headers along the right side of the chip make Atmega128L PortA and PortC signals available for motor and servo control outputs. Other headers attach to robot sensor connectors and LED outputs.

The MAVR128™ circuit schematic **Figure 20** illustrates the various resources, integrated circuits, and headers of the microcontroller. The wiring diagram **Figure 21** of indicates how to connect the various motors, sensors, LEDs, and switches of the TJ-AVR™ to the MAVR128™ circuit board.

The Atmega128 microprocessor dominates the schematic **Figure 20**. Integrated circuits (ICs) U1, U2 and U3 are analog multiplexers that expand analog channels ADC0, ADC1 and ADC7, respectively. The only other IC on the printed circuit board (PCB) is the 5volt regulator LT1083.

In the following sections, continually refer to **Figure 20, Figure 21**, and **Figure** 22 to clarify the presentation. A complete summary of cable connections is provided in Section 15.

12.1 General Description of the MAVR128™ Headers and Power Rails

The circuit pin configuration appears in **Figure 22**. The rectangular pads indicate pin one in each case. Thick red lines designate the regulated power buses for the various groups of three pin headers which consist of a signal, power, and ground pin. The thick blue lines indicate ground rails. A special servo-power rail, indicated by the thick pink line on the right side of the circuit board, provides unregulated power to the servos through a direct connection to the battery supply.

The labels in **Figure** 22 next to the three-pin headers help you identify their locations when connecting cables to them. For each header, the pin closest to the Atmega128 (MEGA128) microcontroller chip is the signal pin whose label appears next to the header

Three-pin male header labels in **Figure** 22 correspond to the connector labels in **Figure 20** to help you associate function with the headers. For each header, note that the pin closest to the Atmega128 microcontroller chip is the signal pin and that the middle pin is power and the outer pin is ground.

12.2 Serial Communications Header

The USART0/PROG serial communications interface header connects to the MB2325 communication board via a 6-wire connector and cable. Through this interface your personal computer serially communicates with the robot. Mekatronix also offers a radio link option that substitutes for the 6 wire cable.

The USART0/PROG connectors are electrically keyed so that reversing the 6-wire connection causes no electrical damage. The USART0/PROG does not function, however, when the 6-wire female connector is reversed. In any case, always be sure that the 6-pins of the USART0/PROG header mate exactly with the six-pin female connectors, otherwise there is a possible threat of shorting power to ground.

***Caution**: The connectors are not mechanically keyed. Electrical damage can occur if you displace the connector so that power and ground pins connect.*

12.3 Sensor Headers

Five of the eight analog channels, ADC2:ADC6, connect to 3-pin male headers. The other three multiplexed analog channels, ADC0, ADC1, and ADC7, connect to 3-pin male headers labeled MUX4 to MUX23. The robot uses MUX0 and MUX1 internally for the battery voltage level detection and charge voltage level detection, respectively. MUX2 monitors the REARBMP header inputs and MUX3 monitors the FRONTBMP header inputs. The TJ-AVR™ uses the FRONTBMP header for both the front and rear bump switches. Momentary push-button switches on the robot bumper connect across pairs of pins on FRONTBMP. Closure of a bumper switch develops a voltage divider circuit from Vcc to ground with ADC7 measuring that voltage.

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The resistor ranges have been so chosen that individual closures can be determined by a single analog voltage measurement. The REARBMP header is reserved for the optional MekArm™ attachment. The MekArm™ consists of a 2-Degree-of-Freedom manipulator with gripper that mounts on the top plate of the TJ-AVR™ robot

For a complete description of all TJ_AVR™ sensor headers refer to **Table 11**below.

Table 11. Analog Sensor Headers for TJ-AVR™

Sensor Number	Header	TJ-AVR™ Sensor Name
0	MUX16	LIRA (Argos-Head left IR detector)
1	MUX17	LCDSA (Argos-Head left CDS)
2	MUX18	SONARA (Argos Sonar)
3	MUX19	RCDSA (Argos Head right CDS)
4	MUX20	RIRA (Argos-Head IR detector)
5	MUX21	LEFT_IR (Plate IR detector)
6	MUX22	REAR_IR (Plate IR detector)
7	MUX23	RIGHT_IR (Plate IR detector)
8	MUX8	SENSOR_ARM01(Shoulder)
9	MUX9	SENSOR_ARM02 (Shoulder)
10	MUX10	SENSOR_WRIST01 (Wrist)
11	MUX11	SENSOR_WRIST02 (Wrist)
12	MUX12	SENSOR_GRIP01 (Gripper)
13	MUX13	SENSOR_GRIP02 (Gripper)
14	MUX14	Reserved
15	MUX15	Reserved
16	NA	Reserved
17	NA	Reserved
18	NA	Reserved
19	NA	Reserved
20	NA	Reserved
21	MUX0	BATTERY (Battery Level)
22	MUX1	CHARGE (Charge Voltage)
23	REARBMP (MUX2)	HAND (MekArm Hand, 1-3) Reserved Pins 4, 5
24	FRONTBMP (MUX3)	BUMPER (Front & Rear) RBSW (Rear) Pins 9-10 FBLSW (Front-Left) Pins 7-8 FBCSW (Front-Center) Pins 5-6 FBRSW (Front-Right) Pins 3-4 Reserved Pins 1-2
25	MUX4	Reserved
26	MUX5	LFR (Line Follow Right)
27	MUX6	LFM (Line Follow Middle)
28	MUX7	LFL (Line Follow Left)

12.4 Frequency Modulation Headers for IR Emitters and User Devices

The PB4 rail brings out pin PB4 of the Atmega128 to eight different pins aligned to connect in pairs to the pins just above them in **Figure** 22. These eight pairs constitute the FM (Frequency Modulated) headers, for reasons to become clear. The non-PB4 pins of the FM headers connect to a 330 Ohm resistor SIP. Short green lines in the figure show these connections which are already on the printed circuit board. Since PB4 may be software enabled to produce a square wave with frequencies varying from 16Hz to 4MHz, the PB4 rail may be used to modulate various output devices or sensors with the 330 Ohm resistor SIP serving to limit current to the device connected across the two-pin FM header.

If a particular circuit does not require current limiting, you can ground the appropriate non-PB4 header pin of the FM header pair. This will require a jury-rigged header of your own making since the ground wire and the second wire to your device will share the same pin. For such arrangements you must ensure that PB4 possesses sufficient drive current for your devices. Refer to the Atmega128L Reference Manual for details.

For the TJ-AVR™, each of the three IR LED emitters connects to an individual FM header with a 330 Ohm resistor SIP to limit current through the LEDs.

12.5 Servo Headers

PortA and PortC of the processor, under software control, supply 16 pulse-width-modulated (PWM) control signals, to drive up to a combined total of 16 servos or motors. Three-pin servo cable connectors fit onto these headers without modification. The ground pin of a servo connector slides onto the outside pin of the servo bus. The middle pin of the servo header supplies the servo with power. The servo driver software generates a pulse-width-modulated (PWM) control on the header's signal pin.

TJ-AVR™ uses PC0 to control the left wheel motor and PC1 to control the right wheel motor. The right and left wheel motors are actually servos hacked to behave like geared D.C. motors. The hack allows the robot to take advantage of the control and power drive electronics on the servo itself. Under software control, you can specify which ports drive servos and which drive geared D.C. motors that have been created by hacking servos.

The servos on the MekArm™ manipulator option connect to PA1, PA2 and PA3 while the servos on the Argos™ Pan-Tilt head options connect to PA0, PA1. Typically, this is not a problem since these two options would interfere with each other mechanically if mounted together on the robot.

Regulated voltage Vcc cannot drive the servos and motors. The high current demand of two or more servos or motors changing speed would depress the regulated voltage temporarily and reset the processor. Consequently, the servo-power rail connects directly to the battery supply, which can furnish all the surge current demanded when motors change speed or direction.

12.6 Digital IO Headers and Alternate Functions

Twenty-two, three-pin male headers labeled PD0:PD7, PG3, PG4, PB0:PB3, PB5:PB7, PE2:PE3, and PE5:PE7 allow you to mix any combination of digital inputs or digital outputs (refer to **Figure 22**). Each of these pins have secondary functions as well, including a second asynchronous serial port USART1, a Two-Wire synchronous serial bus interface TWI, a synchronous serial peripheral interface SPI, up to 8 external interrupts, and two input capture pins. For full details of pin functions refer to the Atmega128 Reference Manual.

12.7 Switches and Indicator LEDs

The *DOWNLOAD/RUN* toggle switch connects across the PE4 header and determines the processor mode upon reset. The red push-button reset switch connects across the *RESET* header and the *POWER-ON/OF* toggle switch connects across the *PWR* header. The charge jack connects to the 4-pin *CHARGE* header and the 4-pin battery connector plugs into the *BATT* header. The electrically keyed 4-pin BATT and CHARGE connectors do not cause damage if inadvertently reversed.

***Caution**: The BATT and CHARGE connector is not mechanically keyed, so displacing the connector laterally may connect the power and ground pins, shorting out the battery and causing severe electronic damage and possible battery explosion.*

The red power-on LED and the green charge LED connect across the LED and CHG LED headers, respectively.

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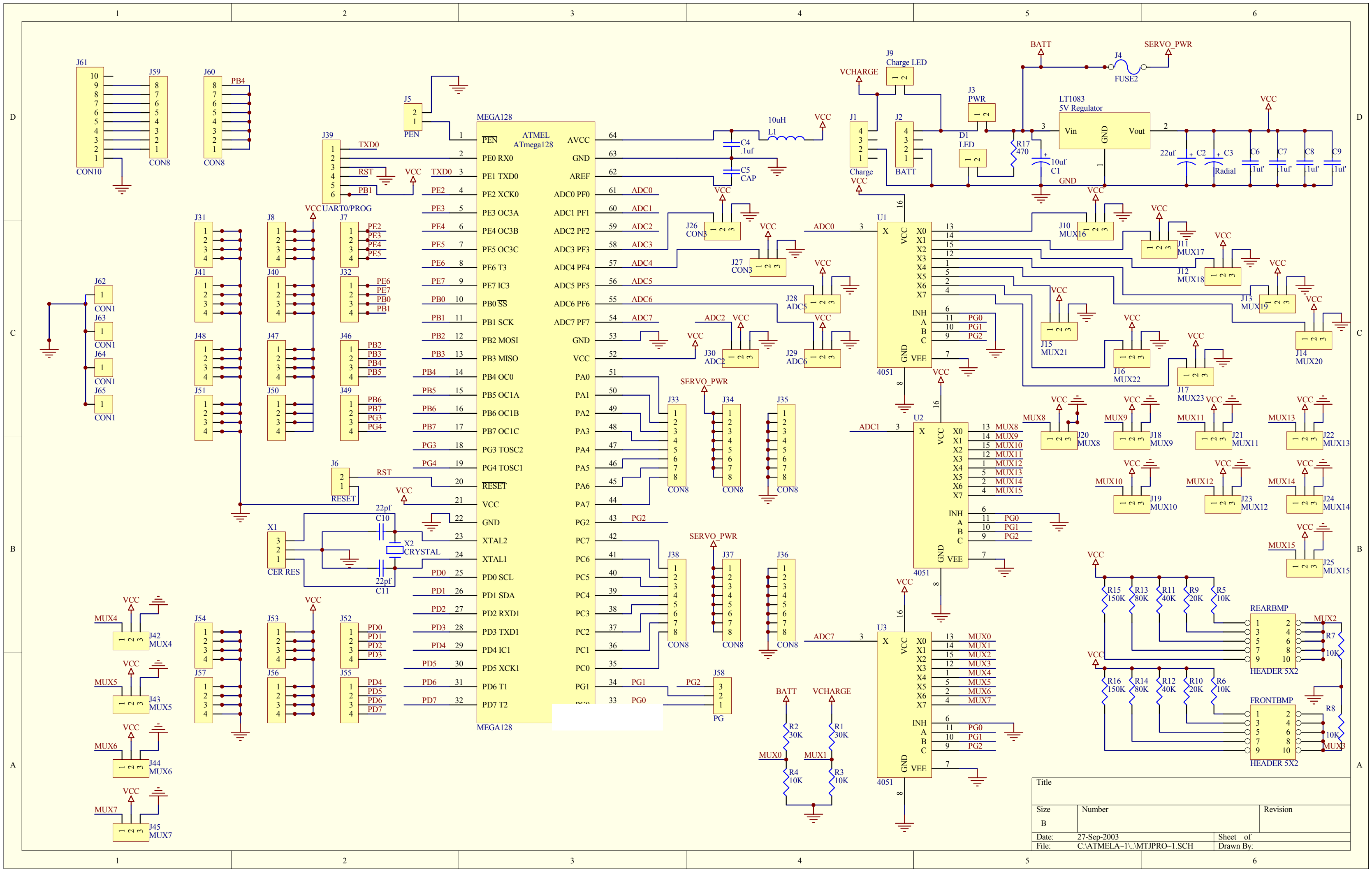

Figure 20. Schematic diagram of the Mekatronix MAVR128™ Robot Controller.

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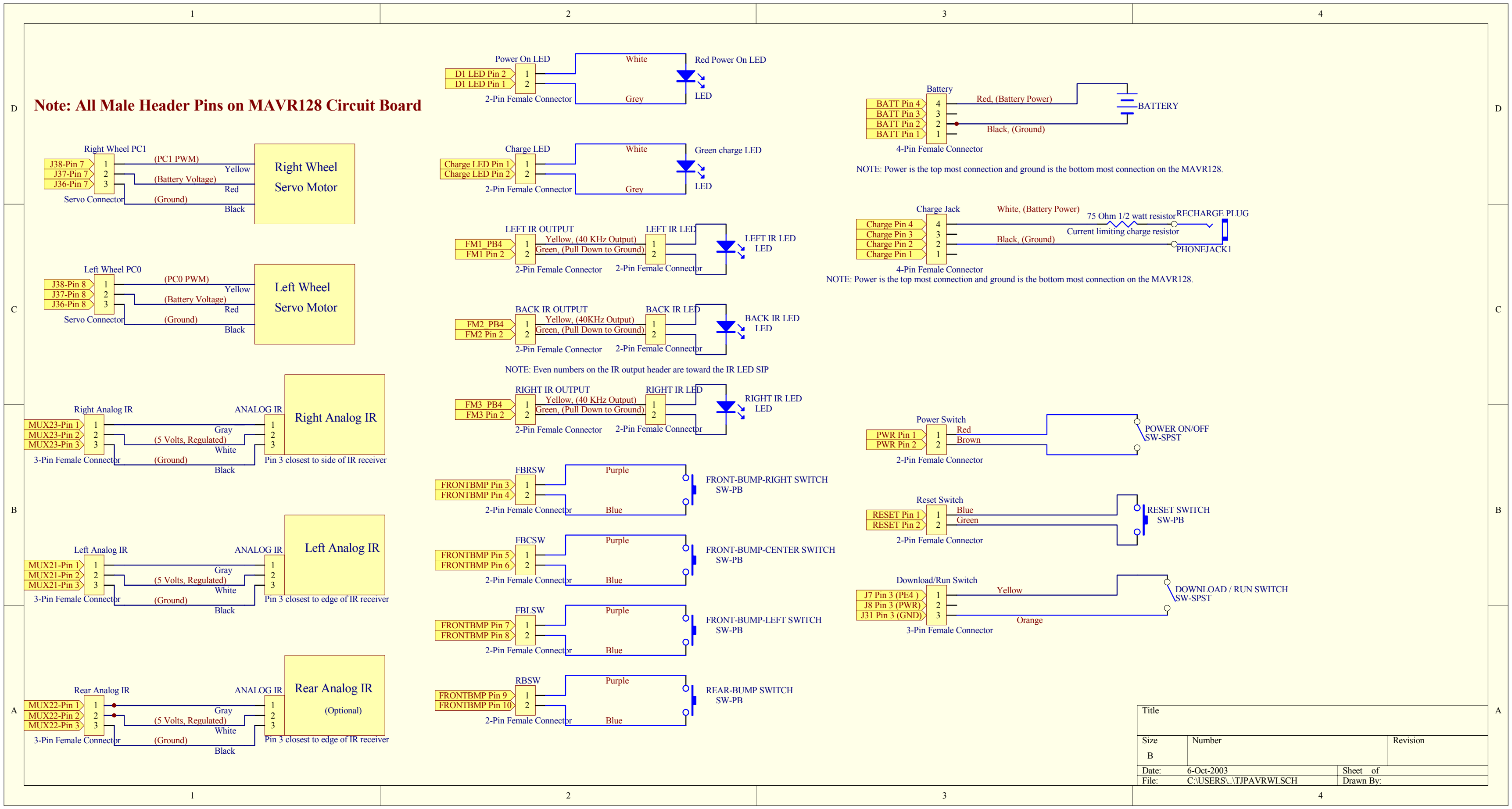

Figure 21. This wiring diagram for the TJ-AVR™ robot illustrates how to connect a battery pack and charge jack, and various sensors, motors, switches and LEDs to the MAVR128™ microcontroller circuit board.

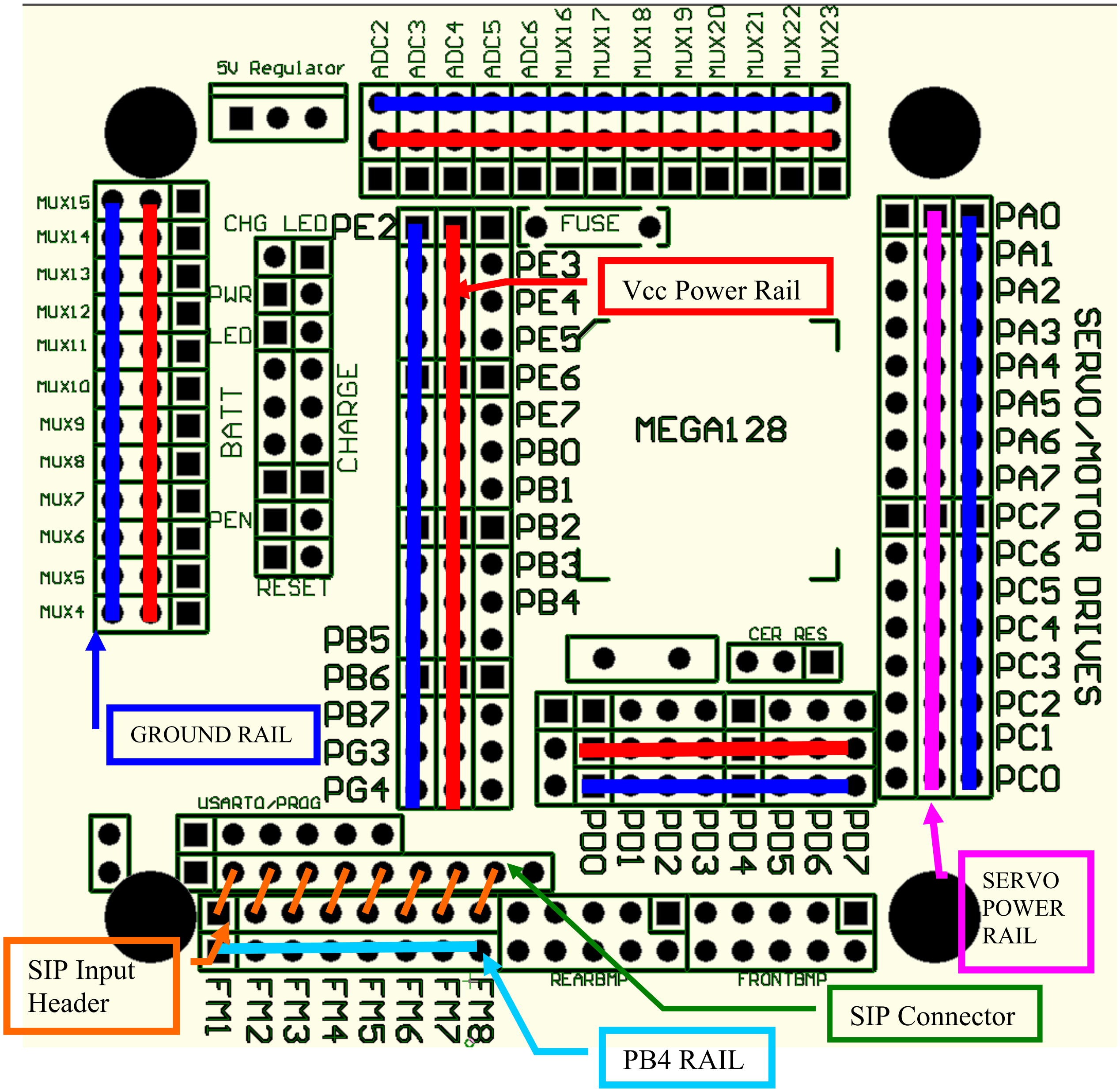

Figure 22. This version of the Mekatronix MAVR128™ Robot Controller PCB layout designates ground rail with blue lines and the regulated Vcc power rails with red lines. The unregulated servo power rail (pink line) attaches directly to the battery pack via a fuse and does not connect to the regulated power rail. The pin labels refer to the pins not connected to a rail. For each of the three-pin headers, you will observe that the pin closest to the Atmega128 (MEGA128) microcontroller chip is the signal pin whose label appears next to the header.

13. TJ-AVR™ CABLE DESCRIPTIONS

All Talrik Junior Advanced Version Robot™ wiring harnesses are constructed from multi-stranded colored ribbon cable. The basic robot requires a total of 15 cables (Refer to Figure 21).

Figure 23 and **Table** 12 illustrate the common cable types used in TJ-AVR™'s construction. The cable type *FnWkFm* refers to a cable with *k* wires. The wires are connected to an *n*-pin female connector at one end and to an *m*-pin female connector at the other end, $k \leq n$ and $k \leq m$. If a designator is missing, the corresponding component is missing. For example, W2F4 is a cable with two wires connected to a 4-pin female connector at one end only, as illustrated in **Figure 23**. **Table 13** lists recommended cable code and lengths. Although you need not stick to the color code, systematic color-coding may help you maintain the robot. The suggested lengths may be longer than needed. You can, of course, cut the cable lengths to suit your requirements.

Figure 23 Illustration of several cable types.

Table 12 Example Cable Types

Cable Type	Description
F2W2F2	Two stranded wires connecting two 2-pin female connectors.
F3W3F3	Three stranded wires connecting two 3-pin female connectors.
F4W2F4	Two stranded wires connecting two 4-pin female connectors. Every other pin is connected.
F6W6F6	Six stranded wires connecting two 6-pin female connectors.

Female connectors can be cut from a multi-pin female connector, either FC36 and FC12 listed in **Table 4**. When making cables, be sure to tin the wire and connector ends before soldering. After soldering, cover the exposed wires with hot glue to provide mechanical strength. For additional strength and esthetics you can place heat shrink tubing (not provided in kit) over the connectors and wires.

Broken wires on connectors can be a source of frustration and error. Unplug the appropriate cable and check for continuity when errors arise relating to the components connected.

Table 13 Recommended Cables Type and Color-Code for the TJ-AVR™ Robot

Cable Name	Cable Type	Color Code
CIRDRF	F3W3F3	(gray, white, black) = (signal, 5 volts, ground) = Pin(1,2,3)
CIRDLF	F3W3F3	(gray, white, black) = (signal, 5 volts, ground) = Pin(1,2,3)
CIRDB[1]	F3W3F3	(gray, white, black) = (signal, 5 volts, ground) = Pin(1,2,3)
CREDLED	F2W2F2	(white, black) = Pin(2,1) (Note reversal of pin numbers)
CGRNLED	F2W2F2	(white, black) = Pin(1,2)
CIRELF	F2W2F2	(yellow, green) = (anode, cathode) = FM1(PB4_RAIL pin 1, SIP Input Header pin 1)
CIREB	F2W2F2	(yellow, green) = (anode, cathode) = FM2(PB4_RAIL pin 2, SIP Input Header pin 2)
CIRERF	F2W2F2	(yellow, green) = (anode, cathode) = FM3(PB4_RAIL pin 3, SIP Input Header pin 3)
CRBSW	W2F2	(blue, violet) = Pin(1,2)[2]
CFBLSW	W2F2	(blue, violet) = Pin(1,2)[2]
CFBCSW	W2F2	(blue, violet) = Pin(1,2) [2]
CFBRSW	W2F2	(blue, violet) = Pin(1,2) [2]
CCHRGE	W2F4	(white, black) =(Soldered to two 150 ohm resistors soldered in parallel to outside charge- jack pin, center charge-jack pin) = Pin (4,2)
CBATT	W2F4	(red, black) = Pin(4,2)
CPWR	W2F2	(red, brown) = Pin(1,2)[2]
CRESET	W2F2	(blue, green) = Pin(1,2)[2]
CDWNRN	W2F3	(yellow, orange) = Pin(1,3)

13.1 MAVR128™ Wiring

The wiring diagram (**Figure 21**) indicates how to connect all the switches, sensors and actuators to the MAVR128™ printed circuit board. The MAVR128™ layout in **Figure 22** indicates all the headers which connect to the IR emitters, detectors, bump sensors and motors on the body of the robot.

Table 14 names the cables, specifies their lengths and what is connected at each end. A photograph (**Figure 33**) illustrates the cable connections to the MAVR128™.

[1] IR detector in back is optional and must be purchased separately from kit.
[2] The switch connectors are bilateral, i.e., it does not matter how you plug them into the header, but I recommend sticking with the pins assigned in the connection table.

Table 14 Wiring Harnesses for the TJ-AVR™ Robot

Cable Name	From:	To MAVR128™: Header_Name(Pins)	Length:
CIRDLF	Left Analog IR Sensor	MUX21(1,2,3)	6 inches / 150 mm
CIRDRF	Right Analog IR Sensor	MUX23(1,2,3)	6 inches / 150 mm
CIRDB[1]	Back Analog IR Sensor	MUX22(1,2,3)	3 inches / 75 mm
CREDLED	Red LED	LED(1,2)	4 inches / 100 mm
CGRNLED	Green LED	CHG LED(1,2)	4 inches / 100 mm
CIRELF	Left Front IR LED	FM1(PB4_RAIL_1,SIP_IN_HEADER_1)	4 inches / 100 mm
CIREB	Back IR LED	FM2(PB4_RAIL_2,SIP_IN_HEADER_2)	6 inches / 150 mm
CIRERF	Right Front IR LED	FM3(PB4_RAIL_3,SIP_IN_HEADER_3)	4 inches / 100 mm
CRBSW	Back bump switch	FRONTBMP(9,10)	7 inches / 180 mm
CFBLSW	Front left bump switch	FRONTBMP(7,8)	4 inches / 100 mm
CFBCSW	Front center bump switch	FRONTBMP(5,6)	4 inches / 100 mm
CFBRSW	Front right bump switch	FRONTBMP(3,4)	4 inches / 100 mm
CCHRGE	Charge Jack	CHARGE(4,2)	4 inches / 100 mm
CBATT	Battery	BATT(4,2)	6 inches / 150 mm
CPWR	Power switch	PWR(1,2)	5 inches / 125 mm
CRESET	Reset switch	RESET(1,2)	3 inches / 75 mm
CDWNRN	Download / Run switch	PB4(1,3)	3 inches / 75 mm

14. CABLE FABRICATION

The figures in this section illustrate the three-step process of fabricating the sixteen standard cables for the TJ-AVR™ robot. The figures also include the optional seventeenth cable, CIRDB.

1. Cut wire to length, strip about ¼ inch of insulation off the ends and tin,
2. Solder the appropriately-sized female connectors where required,
3. Cover soldered connections with hot glue to give mechanical strength and stability.

For step three, use a clamping device covered with a surface that hot glue does not adhere to, for example, a variable crescent-wrench whose jaws are covered with tape. Clamping will insure even distribution of the glue and produce a relative smooth surface.

[1] IR detector in back is optional and must be purchased separately from kit.

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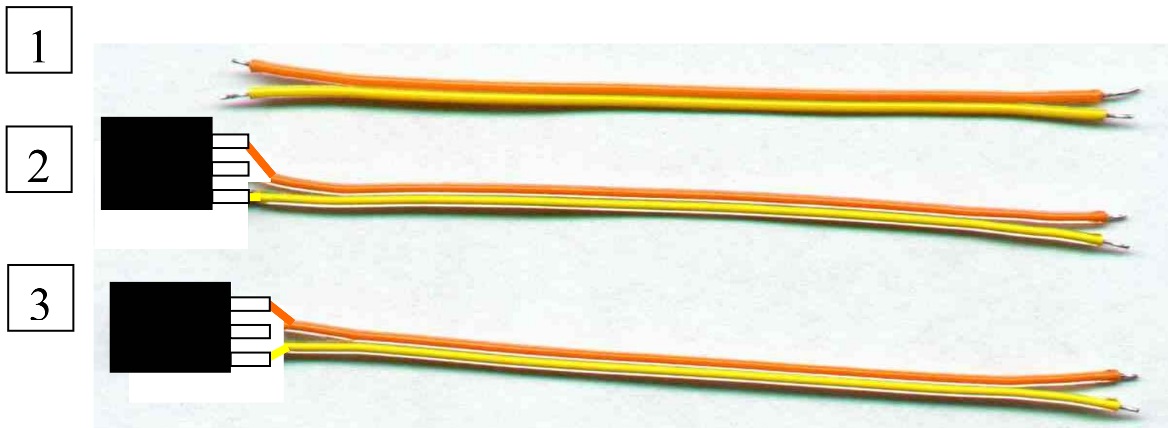

Figure 24. F2W2 DOWNLOAD/RUN CABLE: CDWNRN (3 inches).

For **Figure 24**,

1. CUT WIRE TO LENGTH. STRIP AND TIN LEADS
2. SOLDER 3-PIN CONNECTOR TO LEADS: ORANGE WIRE TO PIN-3 AND YELLOW WIRE TO PIN-1
3. HOT-GLUE CONNECTOR TO FINISH CABLE.

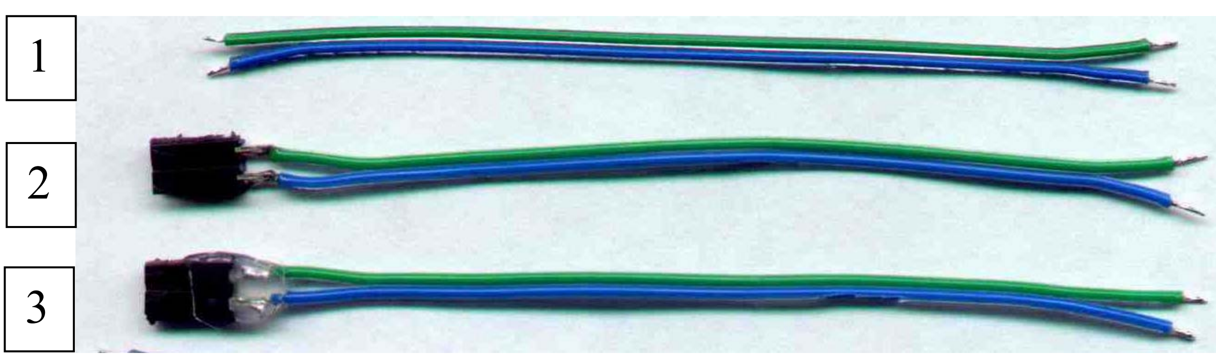

Figure 25. F2W2 RESET SWITCH CABLE: CRESET(3 inches).

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1
2
3

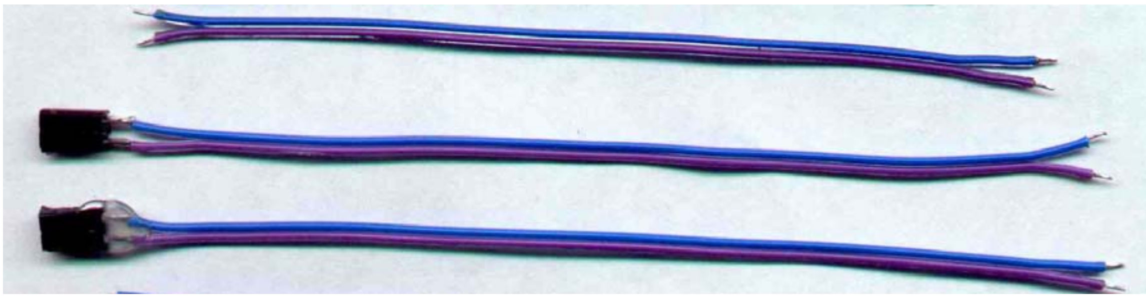

Figure 26 F2W2 BUMPER SWITCH CABLES: CRBSW(7 inches), CFBLSW, CFBCSW, CFBRSW (4 inches each).

1
2
3

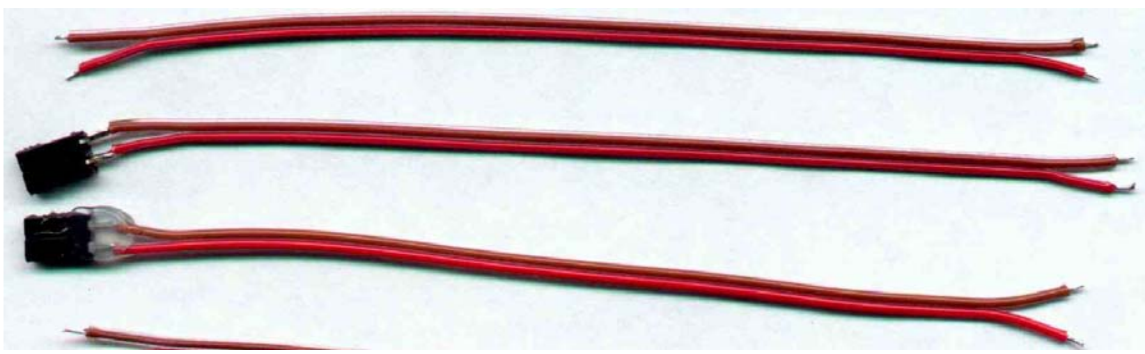

Figure 27. F2W2 POWER ON/OFF SWITCH CABLE: CPWR(5 inches).

For **Figure 25**, **Figure 26**, and **Figure 27** ,

1 CUT WIRE TO LENGTH. STRIP AND TIN LEADS.

2 SOLDER 2-PIN CONNECTOR TO LEADS AT ONE END.

3 HOT-GLUE CONNECTOR TO FINISH CABLE.

1
2
3

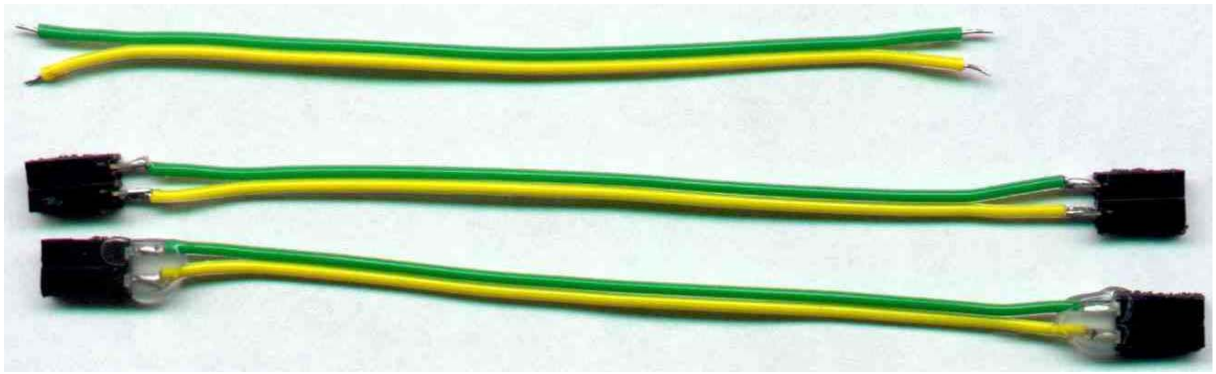

Figure 28. F2W2F2 IR EMITTER CABLES: CIRELF (4 inches), CIREB (6 inches), CIRERF(4 inches).

1
2
3

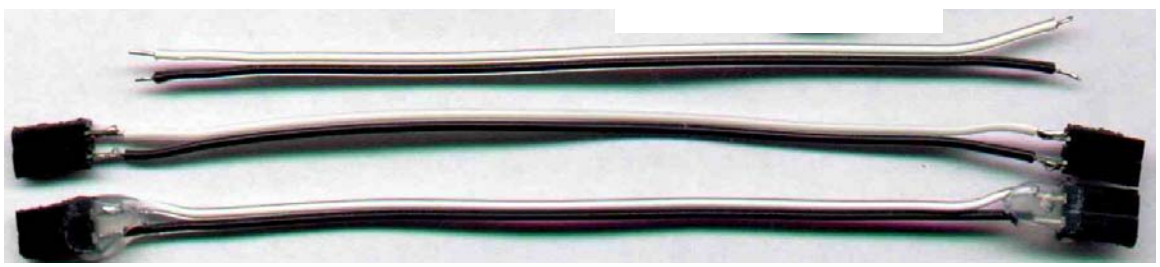

Figure 29. F2W2F2 POWER-ON LED CABLE: CREDLED (4 inches) and F2W2F2 CHARGE LED CABLE: CGRNLED (4 inches)

For **Figure 28** and **Figure 29**,

1 CUT WIRE TO LENGTH. STRIP AND TIN LEADS.

2 SOLDER 2-PIN CONNECTORS TO LEADS AT BOTH ENDS.

3 HOT-GLUE CONNECTORS TO FINISH CABLE.

1

2

3

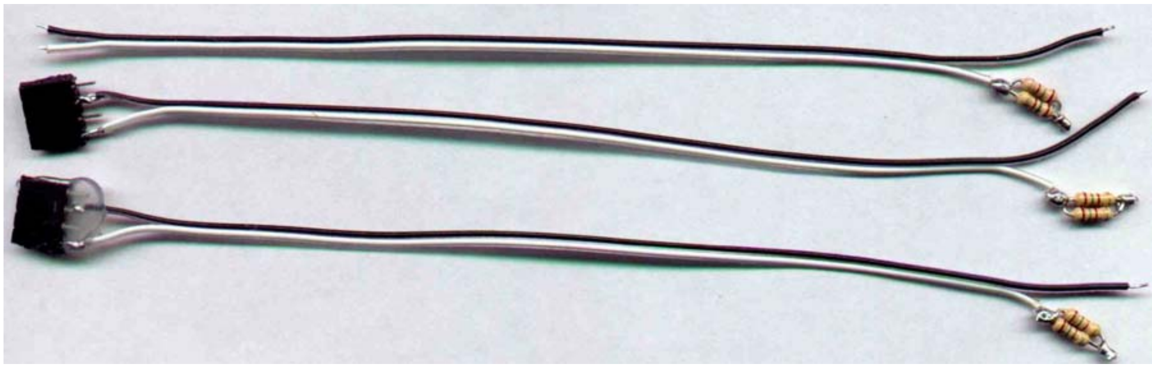

Figure 30. F4W2 CHARGE CABLE: CCHRGE (4 inches)

For **Figure 30**,

1 STRIP AND TIN LEADS.
SOLDER 150 OHM RESISTORS IN PARALLEL.
SOLDER RESISTORS TO WHITE LINE.

2 SOLDER 4-PIN CONNECTOR TO LEADS :
WHITE WIRE TO PIN-4.
BLACK WIRE TO PIN-2.

3 HOT-GLUE CONNECTOR TO FINISH CABLE.

1

2

3

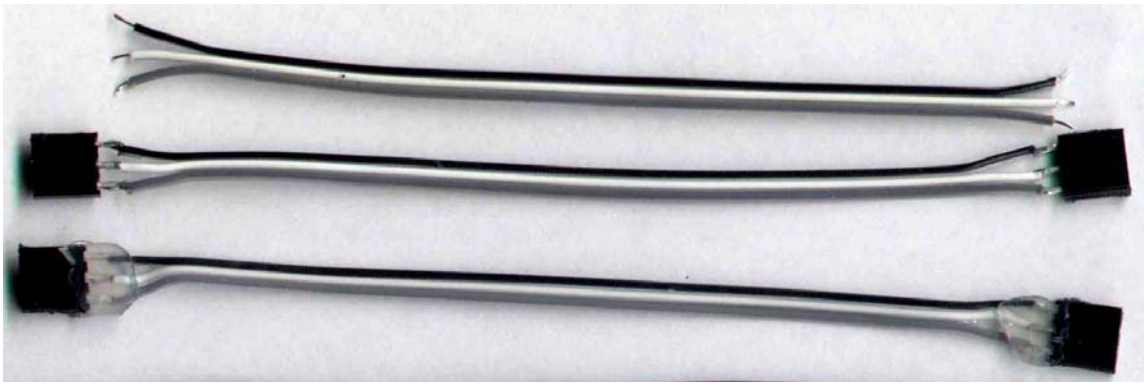

Figure 31. F3W3F3 IR DETECTOR CABLE: CIRDLF (6 inches), CIRDRF(6 inches), CIRDB (optional, 3 inches).

For **Figure 31**,

1 STRIP AND TIN LEADS

2 SOLDER 3-PIN CONNECTORS TO LEADS AT BOTH ENDS. WHITE WIRE TO MIDDLE PIN

3 HOT-GLUE CONNECTORS TO FINISH CABLE.

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1 2 3

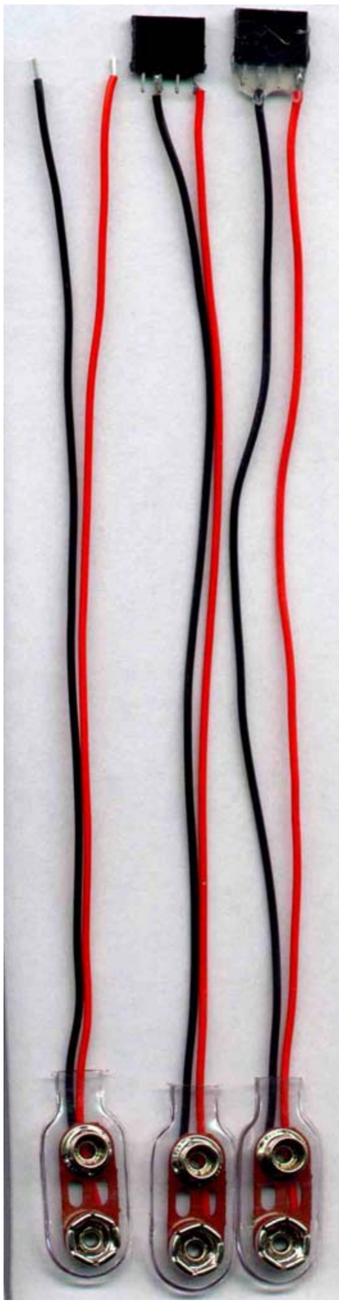

Figure 32. F4W2 BATTERY CABLE: CBATT (6 inches, pre-cut and attached to snap connector at one end).

For **Figure 32**,

1. CUT WIRE TO LENGTH. STRIP AND TIN LEADS

2. SOLDER 4-PIN CONNECTOR TO LEADS: BLACK WIRE TO PIN-2 RED WIRE TO PIN-4

3. HOT-GLUE CONNECTOR TO FINISH CABLE.

Picture of MAVR128™ with all the cables connected

Figure 33. Sensor and actuator cabling of the TJ-AVR™ underneath the top plate. The TJ-AVR™ plate is resting upside down on top of the robot carriage. The front of the plate is to the left of the picture. The bright metal cubes are the IR detectors. The large IC is the MC68HC11 microprocessor.

15. INSTALLATION OF CABLES AND ELECTRICAL COMPONENTS

After you have constructed the cables in Section 14 or have purchased factory-made cables, you will be ready to connect them to the various switches, sensors and LEDs at one end and to the MAVR128™ headers at the other end.

15.1 Install Mode and Reset Switches

Refer to **Figure 34, Figure** 22, **Table 13**, and **Table 14**.

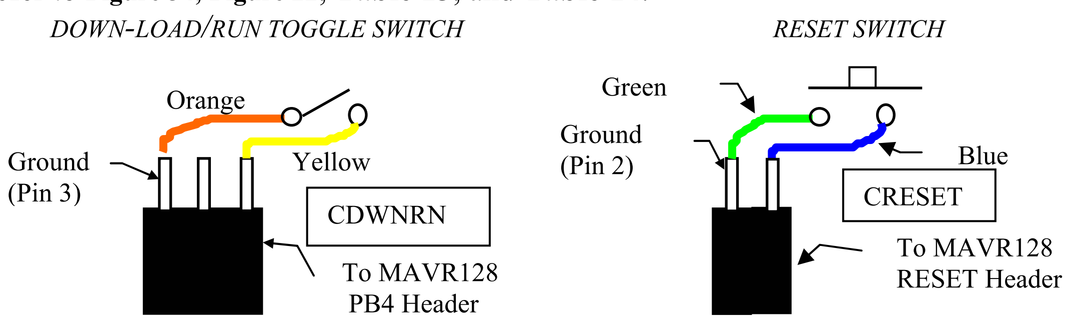

Figure 34. Solder CDWNRN to the Download/Run toggle switch and CRESET to the red push button switch and connect to MAVR128™ Headers PB4 and RESET, respectively.

1. Pass the *Download/Run* toggle switch through the hole provided for it (**Figure 3**). Thread the lock washer and nut on each. Tighten.
2. Do the same for the red push button switch and the recharge panel mount jack.

3. Cable the push button *Reset* and the *Download-Run* switches according to the circuit in and **Figure 34**. Use CRESET (**Figure 25**) and CDWNRN (**Figure 24**) cables, respectively.
4. Plug CDWNRN into 3-pin PB4 Header on the MAVR128™ (refer to **Figure 22**), with pin 1 of the connector and header being aligned.
5. Plus CRESET into the 2-pin RESET Header on the MAVR128™ with pin 1 of the connector and header being aligned.

15.2 Cable the Power- On LED, Charge LED and Recharge Jack

Refer to **Figure 35, Figure** 22, **Table 13**, and **Table 14**.

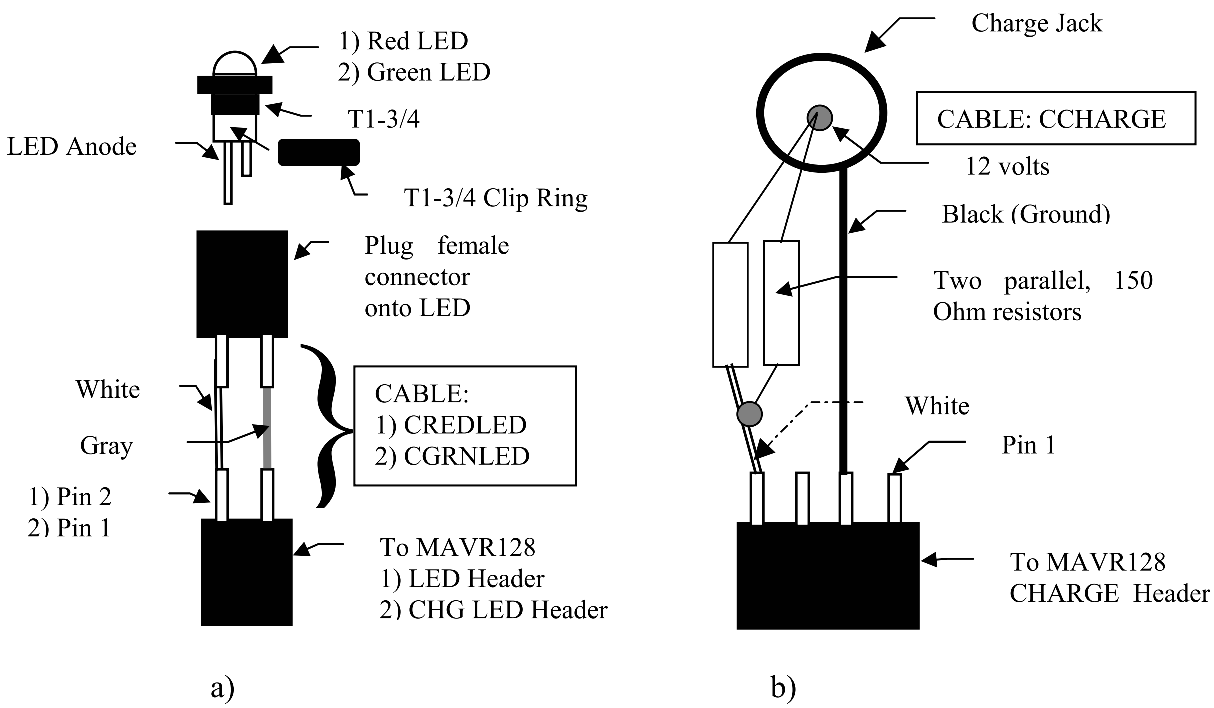

Figure 35. Connect a) the Power-On Red LED and Charge Green LED with CREDLED and CGRNLED, respectively. Connect the other ends of these cables to the MAVR128™ LED and CHG LED Headers, respectively. Solder b) the recharge jack to the free end of CCHRGE and plug the connector into the MAVR128™ CHARGE Header.

1. Push the black T1-3/4 LED mounting hardware snap-in clip into the hole provided for the red Power-On LED and the green Charge LED on the robot's top plate (**Figure 3**). Insert the LEDs until they snap into place. Place a black plastic clip ring over the back of each T1-3/4 to lock each LED into place.
2. Insert the power jack through the hole provided on the top plate (**Figure 3**). Thread the washer and nut. Tighten.
3. Plug in the red LED power-on indicator and the green LED charge indicator at one end of the CREDLED and CGRNLED cables, respectively, as illustrated in **Figure 35** a). In each case the LED anode inserts into the pin soldered to the white wire.

4. Cable the recharge jack as shown in **Figure 35** b). Solder the parallel resistors end of CCHRGE to the external pin of the recharge jack that electrically connects to the pin inside the jack. Solder the black (ground wire) to the external pin on the jack that electrically connects to the inside surface of the jack.

Warning! *The two 150 ohm resistors, in parallel, must be in series with the recharge jack's white wire and the pin inside the jack. Failure to do so will cause excessive currents to flow into the battery during recharge and possibly cause the batteries to rupture or explode if connected too long.*

5. Attach CREDLED and CGRNLED to their respective MAVR128™ headers, LED and CHG LED (refer to **Figure 22**). Note, the white wires are closest to MAVR128™ in both cases.
6. Plug the 4-pin female connector into the CHARGE Header on the MAVR128™. Be sure to align pin 1 of connector and header.

15.3 Cable the Power-On Toggle Switch

Refer to **Figure 36, Figure** 22, **Table 13**, and **Table 14**.

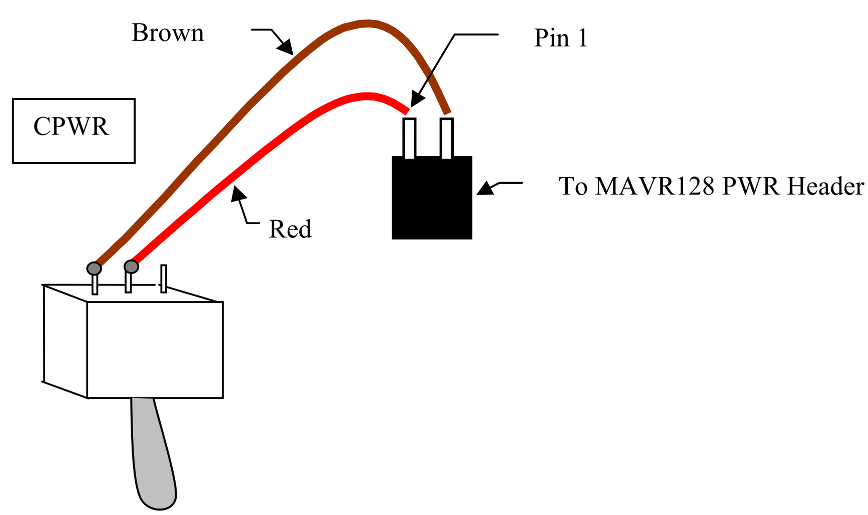

Figure 36 Wire the Power-On toggle switch to CPWR and connect to MAVR128™ PWR Header.

1. Pass the *On/Off* toggle switch through the hole provided for it (**Figure 3**). Thread the lock washer and nut. Tighten.
2. Solder the ends of CPWR to the switch as shown in **Figure 36**.
3. Plug the connector into the PWR Header located on the MAVR128™ circuit board with pin 1 of the connector and header aligned.

15.4 Install Front and Back Bumper Switches

Refer to **Figure 37**, **Figure** 22, **Table 11**, **Table 13**, and **Table 14**. Insert the miniature tactile push button switches into the four slots provide for them around the periphery of the robot's top plate (**Figure 3**). From underneath the top plate you should see two pins attached to the same side of the switch. This orientation of the switch is important. Be careful not to tilt the switch. Keep the button's bottom surface perpendicular to the edge of the plate. This will insure good contact with the bumper during operation.

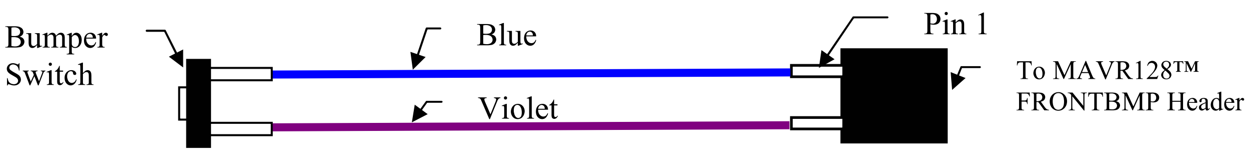

Figure 37. Solder the bumper switches to the bump switch cables.

1. Attach the small push button switches into the slots around the edge of the top plate with a small amount of glue. Glue three switches in the front and one in back, in the orientation described above. No wire connections are made to the two push-button pins on top of the plate.

***Caution**. Do not to glue the switches open or closed!.*

2. Solder the cables to the front-left, front-center, front-right, and rear bumper switches, respectively.
3. Connect the cables CRBSW, CFBLSW, CFBCSW, and CFBRSW to the FRONTBMP Header on the MAVR128™, pins 9-10, pins 7-8, pins 5-6, and pins 3-4, respectively. For consistency, match socket 1 of the connector to the odd-number header pin in each case. To determine the correct orientation of these connectors note that the odd numbered pins on the FRONTBMP Header are nearer to the microcontroller chip than the even-numbered pins. Hence, the blue wire will be closer to the microcontroller.

15.5 Mount and Connect IR Emitters

Refer to **Figure 38**, **Figure** 22, **Table 13**, and **Table 14**.

1. Push the black T1-3/4 LED mounting hardware snap-in clip into the two front and the rear eyelets (TJIRE20) provided for the IR emitters.
2. Insert an LED into each eyelet until it snaps into place. Place the T1-3/4 lock ring over the LED pins and snap it to the T1-3/4 (optional).
3. Connect the appropriate IR emitter cable, CIRELF, CIREB, or CIRERF, to its appropriate IR LED, be sure the LED anode pin inserts into socket 1 connected to the yellow wire.
4. Attach the other end of the IRE cables, CIRELF, CIREB, or CIRERF, to the MAVR128™ FM1, FM2 and FM3 Headers, respectively. The PB4-RAIL pin of FM Headers mates

with socket 1 of the connector. If you reverse this connection the LED will be backed biased and will not emit light.

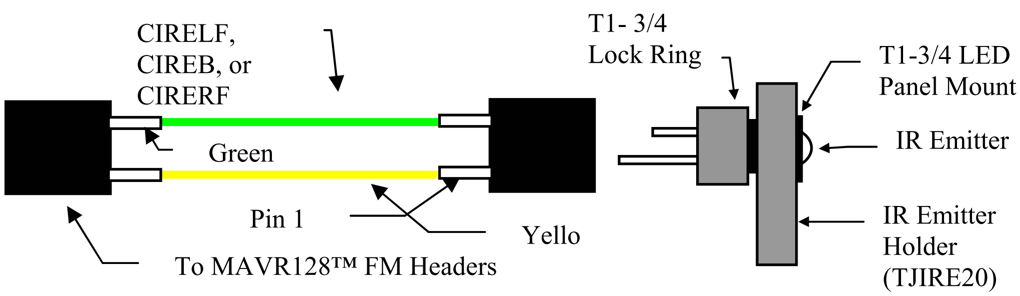

Figure 38. Mount IR emitters into the IR emitter holders. The black plastic T1-3/4 panel mount pushes in from right to left. The LED is pushed in from left to right until it snaps into the flared part of the panel mount. Slide the lock-ring onto the panel mount from the rear to lock the LED into place. Slide one of the 2-pin CIRE-- cable connectors onto the LED with the anode entering socket 1.

15.6 Connect the IR Detectors

Refer to **Figure 39**, **Figure 22**, **Table 11**, **Table 13**, and **Table 14**.

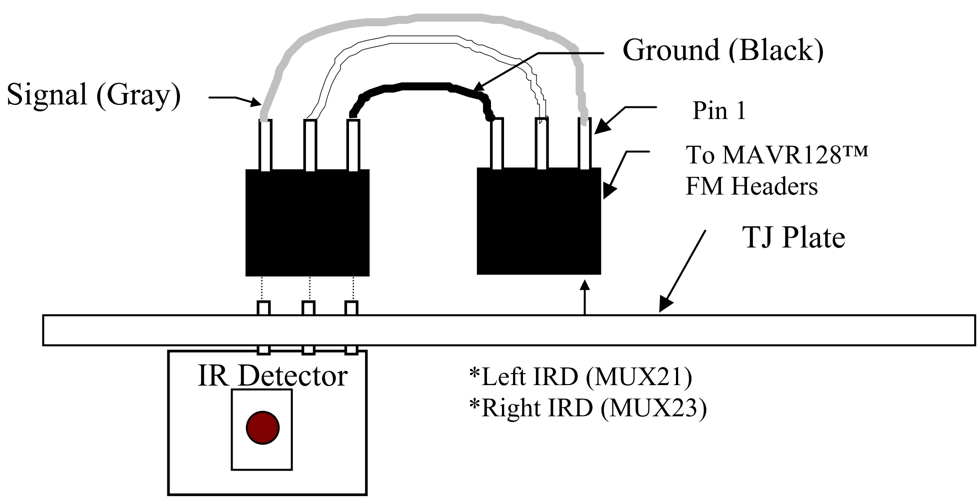

Figure 39. Connect CIRDLF and CIRDRF to the IR detectors and to the microcontroller.

1. The two IR detectors (MIR58Y40A) mount on the underside of the robot's top plate with a simple press fit.
2. The two IR detector mechanical mounting pins fit into the two small holes provided. With the 3 electrical pins of the detector aligned with the cutout hole, carefully press the square mechanical mounting pins into the round holes. This provides a secure fit for the detector. Gluing will not be required in most cases. If you take the detector out of the

mounting holes and remount several times, then gluing with hot glue may become necessary. This mounting precisely determines the IR detector geometry.

3. Connect one end of the cables CIRDLF and CIRDRF into the three pins of the left and right IR detectors, respectively. The black wire (pin 3) must be connected to the pin next to the edge of the can.
4. Plug the connectors at the other end of the cables CIRDLF and CIRDRF into the MAVR128™ MUX21 and MUX23 Headers, respectively. The signal wire (pin 1) of each cable connects to the inside pin of its respective MAVR128™ Header.

15.7 Cable the Battery Power Plug

Refer to **Figure 40, Figure** 22, **Table 13**, and **Table 14**. A stylized figure of CBATT appears in **Figure 40**. The 4 pin female power connection is electrically, but not mechanically keyed.

1. Snap the battery connector onto the battery pack.
2. Insert 6-AA NiCd batteries into the pack (purchase separately).
3. Turn Power switch on robot top plate to *Off* position.
4. Plug in the CBATT connector into BATT header on the MAVR128™. Be certain pin 1 of connector and header match.

WARNING! WARNING! WARNING!

As a safety precaution, always snap the battery pack connector on a full battery pack BEFORE inserting the female connector onto the BATT male header of the MAVR128™ controller. Even a momentary touch of the snap connector terminals to the wrong polarity of the battery pack terminals may cause damage to the circuits.

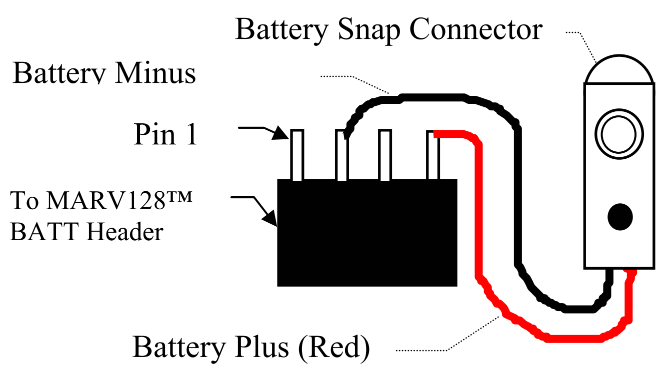

Figure 40. Battery-pack snap connector cable CBATT.

16. MOUNT WHEELS

After attaching the servo horns to the wheels (refer to Section 10) and mounting the servos onto the robot as described in Section 11.1, mount the servo horns onto the servo output shafts. The horn, hence, the wheel, may be attached and detached from the servo output shaft by tightening or loosening the Phillips-head horn screw with a small jeweler's screwdriver inserted through the wheel shaft hole.

17. MOTOR CONTROL

Interrupt drivers executing on the MAVR128™ control TJ-AVR™'s motors and servos using pulse-width-modulation (PWM). The servos on the wheels must be hacked to create D.C. geared motors. The TJ-AVR™ servo/motor control is extremely versatile. You can assign any servo slot to either drive servos or hacked servos.

17.1 Associate Motor Direction with Rotation Sense under Software Control

If a robot's motor runs in the wrong direction when given a motor command, you do not have to reverse the motor wiring to maintain program code compatibility with standard TJ-AVR™ libraries and applications. Just complement the value of the bit associated with the wheel in the constant `const unsigned char MOTOR_DIRECTION_A`, if a PortA pin drives the motor (hacked servo), or in the constant `const unsigned char MOTOR_DIRECTION_C`, if a PORTC pin drives the motor. These constants must be changed in the header file <servo.h> found in the folder <Include_Meka>. A portion of this header file appears in **Figure 41**.

17.2 Servo and Motor Control Setup and Defaults

The constants SERVO_ENABLE_A and SERVO_ENABLE_C in **Table 15**, defined in the C-header file <servo.h> (**Figure 41**)

```
const unsigned char  SERVO_ENABLE_A = 0xff;
const unsigned char  SERVO_ENABLE_C = 0xff;
```

determine whether the PORTA and PORTC pins, respectively, control servos or can be used for general digital IO. The default value for both constants is 0xff, meaning that all the PORTA and PORTC pins control servos. For the right wheel, SERVO_ENABLE_C = 0x02. For the left wheel, SERVO_ENABLE_C = 0x01. To control both wheel motors, therefore, SERVO_ENABLE_C = 0x02 || 0x01 = 0x03, i.e., the logic *or* of the two servo enable bit values constitutes the enable value for the combination. If you change SERVO_ENABLE_C from the default 0xff to 0x03, you will disable all PORTC servos except PC1 and PC0. In general, I do not recommend changing the default values except in those situations where you know you will permanently assign a PORTA or PORTC pin to digital IO. In those cases, zero the bit in SERVO_ENABLE_A or SERVO_ENABLE_C corresponding to the port pin location you wish to use as digital IO.

Additional constants, MOTOR_ENABLE_A and MOTOR_DIRECTION_A for PORTA and MOTOR_ENABLE_C and MOTOR_DIRECTION_C for PORTC, must be assigned before a program can control a hacked servo as a D.C. motor. The header file <servo.h > defines these constants as well. The default values are

```
/*
       Servo indices 0 to 7  refer to servos connected to PA0 to PA7
       Servo indices 8 to 15 refer to servos connected to PC7 down to PC0

       Pin Bit assignments for SERVO_ENABLE_X, MOTOR_ENABLE_X, and MOTOR_DIRECTION_X,
                               X = {A|C}

       Bit7    Bit6    Bit5    Bit4    Bit3    Bit2    Bit1    Bit0
       -------------------------------------------------------------
       PA7     PA6     PA5     PA4     PA3     PA2     PA1     PA0
       PC7     PC6     PC5     PC4     PC3     PC2     PC1     PC0


*/

/*
   To disable a PORTA or PORTC pin for digital IO, put a zero in the corresponding bit
   position.
   To enable a PORTA or PORTC pin for servo control, put a one in the corresponding bit
   position.
*/


const unsigned char  SERVO_ENABLE_A = 0xff;         // Enable servo control on all PORTA pins
const unsigned char  SERVO_ENABLE_C  = 0xff;        // Enable servo control on all PORTC pins

/*
    MOTOR_ENABLE_X (X= {A|C}) indicates which servos are hacked into DC motors using the drive
    electronics of the servo itself. If a bit in MOTOR_ENABLE_X is set then the corresponding
    bit in SERVO_ENABLE_X must also be set in order for the motor to function.

    A bit set in MOTOR_DIRECTION_X tells the function motor_hs(index, percent) to change the
    sign of the percent parameter. For example, if percent = 100% turns the motor full speed in
    the clockwise direction when a bit in MOTOR_DIRECTION_X is 0, then if that same bit is set
    to 1, the motor will turn full speed in the counterclockwise direction, which normally
    requires percent = -100%.

    Usage:
    If you enable opposite directions for wheel motors on opposite sides of a robot, the motors
    will rotate in opposite directions for the same percentage specification in motor_hs(), but
    will generate robot motion in the same direction.

    For Mekatronix two wheeled rolling robots, PC1 and PC0 will connect to servos hacked to
    function like D.C. gearhead motors. PC1 will be on the right side and PC0 on the left.

*/
 const unsigned char  MOTOR_ENABLE_A   =      0x00;
 const unsigned char  MOTOR_DIRECTION_A =     0x00;

/*
 Left wheel motor connected to PC0. Left motor (hacked servo) spins counterclockwise with +%.
 Must put a one in corresponding MOTOR_DIRECTION_C variable.

 Right wheel motor connected to PC1. Right motor (hacked servo) spins clockwise with +%. Must
 put a zero in corresponding MOTOR_DIRECTION_C variable.
*/
 const unsigned char  MOTOR_ENABLE_C   =      0x03;
 const unsigned char  MOTOR_DIRECTION_C =     0x01;
```

Figure 41. An excerpt from the header file <servo.h> illustrating the `const unsigned char` **variables** **`MOTOR_ENABLE_C`** **and** **`MOTOR_DIRECTION_C`** **used to control the wheel motors on the TJ-AVR™.**

```
const unsigned char  MOTOR_ENABLE_A   =   0x00;
const unsigned char  MOTOR_DIRECTION_A =  0x00;

const unsigned char  MOTOR_ENABLE_C   =   0x03;
const unsigned char  MOTOR_DIRECTION_C =  0x01;
```

The constants `MOTOR_ENABLE_A` and `MOTOR_ENABLE_C` determine which servo headers drive a hacked servo as a D.C. motor. The default values indicate that only `PC1` and `PC0` drive hacked servos. The constants `MOTOR_DIRECTION_A` and `MOTOR_DIRECTION_C` determine which sense of rotation is considered positive when executing the C-function

```
void motor_hs(unsigned char index, int percent).
```

A positive percent drives the wheel forward and a negative percent drives it backwards.

The left wheel motor, which is connected to `PC0`, must spin counterclockwise for a positive percent (forward motion) in the function `motor_hs()` while the right wheel motor, which is connected to `PC1`, must spin clockwise for a positive percent (forward motion). Since the motors turn in the opposite directions for the same command, the motor control program must change the sense of rotation for one of the wheels. For the standard Mekatronix servo, the positive percent turns the servos clockwise; hence, the sense of rotation must be changed on the left wheel motor. You accomplish this when you put a one in the `MOTOR_DIRECTION_C` control bit corresponding to `PC0`. On the other hand, the right wheel motor, you must put a zero in the corresponding control bit of `MOTOR_DIRECTION_C` so that the program will not change the sense of rotation for a designated positive (forward wheel motion) or negative (backward wheel motion) percent.

17.3 PWM of the Motors

The MAVR128™ generates pulse width modulation for the two D.C. motors on PC1 and PC0 of PORTC. The D.C. motors (hacked Mekatronix servos, e.g., the MS410 or the premium MS455) output 42 oz.-in. of torque. A pulse width command of approximately 1.5ms will stop the motor. Actually, since

1. the motors vary,
2. the manual setting of the center point of the potentiometer is only approximate, and
3. the motor electronics drifts as it heats up with use,

the exact duty cycle for no motion should be determined experimentally. Duty cycles less than 1.5ms, but greater than 1ms, drive the motor in one direction. A duty cycle greater than 1.5ms, but less than 2ms drives the motor in the opposite direction. The PWM period can vary from 18ms to 20ms. Differential control of the motors provides complete maneuverability. TJ-AVR™ can literally turn 180 degrees in place.

18. CONNECT SERVOS AND MOTORS

The basic TJ-AVR™ system utilizes two wheel motors. Connect the right-wheel servo cable to the PC1 HEADER on the MAVR128™ and the left-wheel servo cable to the PC0 HEADER on the MAVR128™ (refer to **Figure 22**). The ground wire (brown or black, depending on the servo) connects to pin 3, the pin furthest away from the microcontroller chip. In **Figure 22** , this pin is part of the ground rail, blue colored in the figure. The signal wire (orange or yellow) connects to pin 1, the pin closest to the microcontroller chip. The center pin connects to the power rail, red colored in the figure.

18.1 Servo and Motor Header Assignments

The table in Section 18.1 lists all the servo-motor numbers, corresponding port pins and assigned functions in the TJ-AVR™ robot. You may assign servo numbers 4 through 13, ten in all, to either control servos or hacked servos for your own personal applications. You can also use those PORTA and PORTC pins for general digital IO. Mekatronix, however, may assign future uses for these servo slots and cannot be responsible for conflicts with your assignments.

Table 15. Mekatronix TJ-AVR™ Servo Pin Assignments

SERVO NUMBER	PORT PIN	SERVO_ENABLE_X X = A for PortA X = C for PortC	TJ-AVR™ Servo/Motor
0	PA0	0x01	Argos Pan Servo
1	PA1	0x02	Argos Tilt Servo MekArm Shoulder
2	PA2	0x04	MekArm Wrist
3	PA3	0x08	MekArm Gripper
4	PA4	0x10	User Assigned
5	PA5	0x20	User Assigned
6	PA6	0x40	User Assigned
7	PA7	0x80	User Assigned
8	PC7	0x80	User Assigned
9	PC6	0x40	User Assigned
10	PC5	0x20	User Assigned
11	PC4	0x10	User Assigned
12	PC3	0x08	User Assigned
13	PC2	0x04	User Assigned
14	PC1	0x02	Right Wheel
15	PC0	0x01	Left Wheel

19. PROCEDURES FOR CHANGING BATTERIES

Keep the charger plugged into the robot during programming. Typically, this will allow you to program all day without having to switch batteries. After you have finished, the batteries will continue to fully charge overnight, so that the next day you will again have fresh batteries.

During program development, therefore, there is seldom need to change batteries. Sometimes, however, during demonstrations and extensive trial runs, the batteries become discharged. At that point you will have to change the batteries. Several options are available to you since the TJ-AVR™ battery packs allow you to change out individual batteries or the entire pack. Unless a cell dies completely, it is better to keep the same batteries with each other while charging and discharging. This means keeping spare packs that can be charged separately and switched out with discharged packs on the robot. You can purchase a Mekatronix 4-pack charger or build the simple charger circuit that we use on the robot so you will always have spares on hand.

19.1 Changing Battery Packs

Rather than change-out discharged batteries from your battery pack, change out the pack with a spare pack with charged batteries. All your battery packs should have their own CCHRGE cable attached.

Refer to **Figure 22** for location of the BATT HEADER on the MAVR128™.. The plus side of the header is pin 4 and the ground is pin 2. Pin 1, which is marked by a square, and pin 3 are not connected, yielding an electrically keyed connector.

1. Turn off power switch.
2. Remove key on top plate and lift the plate up and forward.
3. Unplug CBATT from the BATT HEADER on the MAVR128™.
4. Remove discharged battery pack from the robot.
5. If the charged battery pack does not have its own CBATT cable, then snap the one from the discharged pack onto the terminals of the charged pack.
6. Plug the 4-pin female connector of the CBATT cable of the new pack into the CBATT HEADER on the MAVR128™.
7. Insert the charged battery pack. Into robot battery compartment.

   The plus side of the header is pin 4 and the ground is pin 2. Pin 1, which is marked by a square, and pin 3 are not connected, yielding an electrically keyed connector.

CAUTION*! Be sure pin 1 of the CBATT female connector and pin 1 of the BATT HEADER mate.*

8. Place the battery pack into the TJ-AVR battery compartment.
9. Lower the top plate without pinching any wires.
10. Insert the key and lock the top plate to the undercarriage.

19.2 Changing Batteries in a Pack

The preferred method of changing out discharged batteries is to change out battery packs (refer to the previous section). In those cases where you only have one pack, then use this method.

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Refer to **Figure 22** for location of the BATT HEADER on the MAVR128™.. The plus side of the header is pin 4 and the ground is pin 2. Pin 1, which is marked by a square, and pin 3 are not connected, yielding an electrically keyed connector.

1. Turn off power switch.
2. Remove key on top plate and lift the plate up and forward.
3. Unplug CBATT from the BATT HEADER on the MAVR128™.
4. Remove discharged battery pack from the robot.
5. Remove discharged batteries from the pack.
6. Load six recharged batteries into the battery pack. Be sure battery polarity is correct.

__Caution!__ Incorrectly installed NiCad batteries can cause damage to the batteries and the electronics.

WARNING!

USE ONLY NiCd BATTERIES FOR TJ-AVR™. DO NOT USE ALKALINE OR OTHER BATTERY TYPES AS THEY MIGHT DAMAGE THE ROBOT ELECTRONICS.

7. Plug the 4-pin female CBATT connector onto the male power header BATT.
8. Place the battery pack into the TJ-AVR battery compartment.
9. Lower the top plate without pinching any wires.
10. Insert the key and lock the top plate to the undercarriage.

20. RUN A DEMO PROGRAM

You have now completely assembled the TJ-AVR™. Now is the time to test the robot system and program it to do things!

1. Be sure the robot has a charged battery pack.
2. Keep the charge jack plugged. The green LED should light.
3. Switch the robot to download mode.
4. Turn on power. The red LED should light.
5. Connect the robot with the serial port of your personal computer (refer to Section 6.15).
6. Download the demo program `tjavr_test.hex` as explained in a *Read Me* file in *TJ-AVR™'s* software distribution disk. You can use the demo program to test the IR and bump sensors as well as the motors. Play with TJ-AVR™ for a while and observe how TJ-AVR™ perceives the world. The understanding gained by this exercise is invaluable for writing TJ-AVR™ programs that work.

Enjoy!