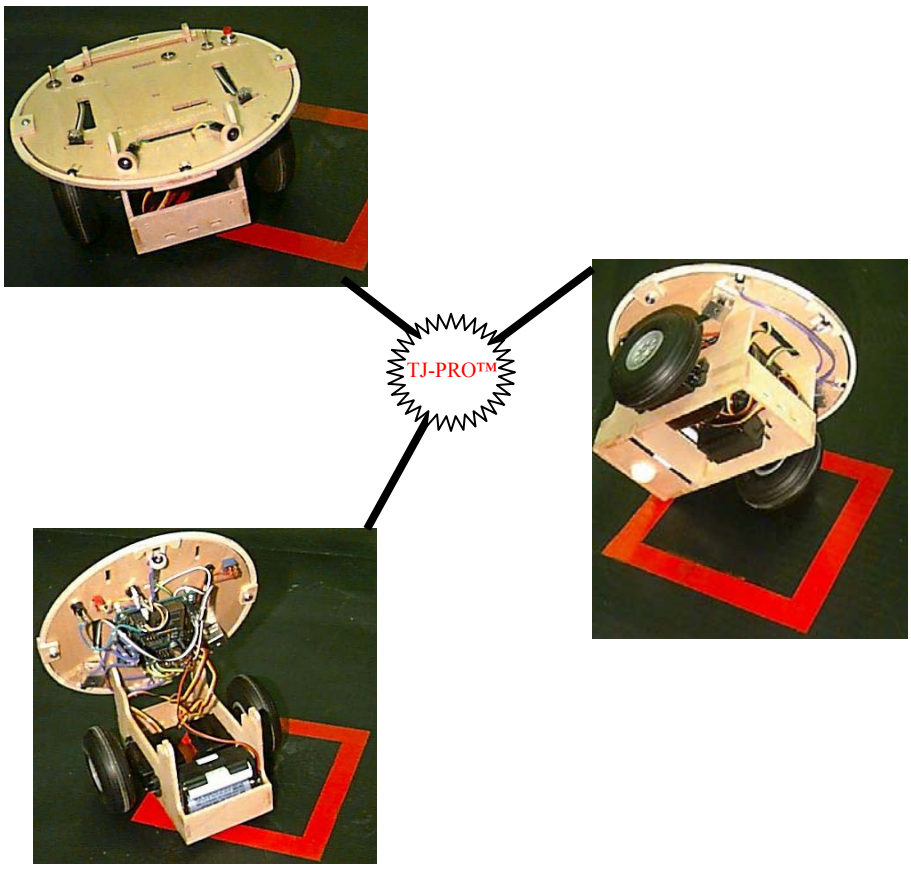
TALRIK JUNIOR PROFESSIONAL™

TJ PRO™
ASSEMBLY MANUAL

by

Keith L. Doty

Version 09d



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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 TALRIK JUNIOR PROFESSIONAL™ GENERAL DESCRIPTION

While the TALRIK JUNIOR PROFESSIONAL™ (TJ-PRO™) shares sibling DNA with TJ™, the TJ-PRO™ has more features and capabilities. A single Mekatronix microcontoller board, the MTJPRO11™, provides all the computational, sensing and control need for sophisticated robot behaviors. The following paragraphs provide a brief description of the TJ-PRO™ technical characteristics.

1.1 Mechanical Structure

1. TJ-PRO™'s body parts may be made from 5-ply, model airplane plywood or from black durable plastic.
2. TJ-PRO™ 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)

1.2 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 PRO™. Do not use alkaline or other battery types. They will destroy the robot electronics.

2. Recharger, 12 volts D.C. rated at 200ma (Sold separately).

1.3 Actuation

TJ-PRO™ can control up to five MS455 servos, either hacked as gearhead D.C. motors or as servos. Two motor control ports are reserved for the wheel motors and two will be used for a pan tilt head on the ARGOS enhancement kit (optional).

Gearhead DC motor drive for each wheel.

1. 5.4- 7.2 Volts.
2. 100 -120 ma under load, 80 ma no-load.
3. 1.25 revolutions/sec at 7.2 volts (full battery charge). Speed decreases proportionally to the voltage as it drops.

1.4 Robot Controller

A Motorola MC68HC11 based microcontroller circuit, the MTJPRO11™, provides, among other features, the brains and communication capability of the TJ-PRO™ and provides exceptional versatility for the robot. Control and communication features include the following.

1. MC68HC11 microcontroller.
2. 32Kbytes of SRAM.

3. Five-volt serial communication interface for downloading and uploading programs and data to a personal computer. The serial bus implements RS-232 protocol except for the voltages. The Mekatronix circuit board MB2325 converts this processor serial bus to a standard RS-232 bus.
4. High speed, 5volt synchronous serial bus. Up to 1 MHz data rate.
5. 5 Volt regulator.
6. Low-voltage-inhibit reset circuit.

1.5 Memory Save Feature

When the power switch is turned off, power is still supplied to the SRAM to prevent loss of code and data in memory. The batteries will be drained after about a day if you do not keep TJ-PRO™ plugged into the charger unit.

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

1.6 Input-Output Expansion Capability

The MTJPRO11™ circuit board provides TJ-PRO™ with exceptional IO power for a robot its size (Mekatronix will offer future enhancement kits based on these capabilities. Check the web site for further details [http://www.mekatronix.com]).

1. Eight digital outputs.
2. Three digital input ports with program-optional automatic digital waveform capture.
3. Hardware generation of a 40KHz signal to modulate IR and sonar.
4. The processor data bus and an 8-bit address decoder port enable expansion up to four external 8-bit Digital Input and four external 8-bit Digital Output ports.
5. Five, eight-bit analog input channels available. Combined with external analog multiplexers and Digital Input address decoding, each analog channel could be multiplexed to as many channels as the external multiplexer allows.

1.7 Memory and IO Mapping for the MTJPRO11™

The 32Kbyte SRAM occupies the upper 32Kbytes of the MC68HC11 address space, namely, from hexadecimal 0x8000 to 0xffff. The MTJPRO11™ provides four, active-low Input-Enables Y1, Y3, Y5 and Y7 and four, active-low Output-Enables Y0, Y2, Y4, Y6. These enables map into memory address space as listed in Table 1.

Table 1 Memory Map of MTJPRO11™ IO Enables

Name	Direction	Memory Address (Hex)
Y0	Output	0x4000
Y1	Input	0x4000
Y2	Output	0x5000
Y3	Input	0x5000
Y4	Output	0x6000
Y5	Input	0x6000
Y6	Output	0x7000
Y7	Input	0x7000

1.8 TJ-PRO™'s Starter Sensor Suite

Every TJ-PRO™ comes with the minimum sensor suite listed in Table 7. These sensors are wired directly to headers on MTJPRO11™ microcomputer circuit board.

These sensors have the following characteristics:

1. Two Forward-Looking IR Emitters, wavelength equals 940nm.
2. One Backward-Looking IR Emitter, 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.
5. One Back Bumper Momentary Tactile Switch
6. User expandable sensors (see Section 1.5 for IO expansion capabilities).

Table 2 TJ-PRO™'s Sensor Suite

TJ-PRO™ Label	Name	Function
IRDLF	Infrared Detector, Left Front	Proximity Sensor
IRDRF	Infrared Detector, Right Front	Proximity Sensor
FBLSW	Front Bumper Left Switch	Front contact Sense
FBCSW	Front Bumper Center Switch	Front contact Sense
FBRSW	Front Bumper Right Switch	Front contact Sense
RBSW	Rear Bumper Switch	Rear contact Sense

1.9 Switches

1. Reset push button
2. Toggle switch: Download Program and Run Program
3. Toggle switch: Off-On.

1.10 System Support Software

TJ-PRO™ programs can be written in MC68HC11 Assembly Language, C, or BASIC.

1. Sensor and motor routines provided in assembly language.
2. A freeware version of the Interactive C (IC), an extremely useful C interpreter by Randy Sargent. Ask your Mekatronix distributors about the up-to-date commercial version of IC.
3. PCBUG11 freeware for downloading Motorola S19 files.
4. Freeware version of Basic for programming TJ-PRO™.
5. Freeware MC68HC11 Assembly Language.

Separate purchase of a commercial C compiler is also available. Contact us for more information

1.11 Applications Software

Mekatronix™ provides an elementary program that allows TJ-PRO™ to explore his environment and avoid bumping into things, most of the time! If TJ-PRO™ does bump into something, his bumpers tell him and he moves away.

You can develop your own applications, limited only by your imagination and 32KB of memory!

1. Make TJ-PRO™ do figure eights, or any other shape, while at the same time avoiding people and furniture.
2. Program TJ-PRO™ to be an artist who draws on cardboard with a pen attached to his body (pen-holder not included) (Be sure TJ-PRO™ stays on the cardboard!).
3. Design an obstacle course for TJ-PRO™ to learn.
4. Scare TJ-PRO™ by blasting him with your TV remote!
5. Write a program so TJ-PRO™ will be attracted to your TV remote!
6. Control TJ-PRO™'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-PRO™'s and program them to follow each other.
8. Get three TJ-PRO™'s and teach them to flock like goslings as they move around together.

1.12 Serial Communication

To develop your applications requires communications between a Personal Computer and TJ-PRO™. The additional purchase of an MB2325 communications board and a 6-wire RS-232C communications cable will provide the hardware for that capability (Figure 1). 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.

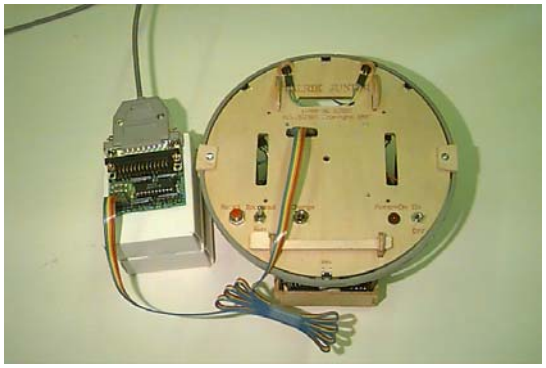


Figure 1 This Photograph shows the gray serial cable from a PC COM port mating with the D-25 connector on the communications board (com-board = MB2325 = the exposed circuit board sitting on the white boxes). The multicolored 6-wire serial cable attaches to the male header on the com-board and into the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

2 INITIAL CONSIDERATONS

While the TJ-PRO™ shares structural DNA with TJ™ and resembles the TJ™ in outward appearance, that is where the resemblance ends. TJ-PRO™ possesses greater memory, IO capability and runs Interactive C.

2.1 What is in your TALRIK JUNIOR PROFESSIONAL™ Expert Kit?

The contents of your TALRIK JUNIOR PROFESSIONAL™ expert kit appear in Table 3 and Table 4 The following sections describe each of the subkits.

Table 3 TJ-PRO™ Expert Kit

Part	Quantity
Assembled & Tested MTJPRO11™	1
TJ-PRO™ Kit Bag	1
TJ-PRO™ Plastic (Plywood) Body	1
Plywood (Plastic) Bumper Girdle	1
Servos plus Mounting Hardware	2
Wheels plus Servo Horns	2
TJ-PRO™ Distribution Software	2

Table 4 TJ-PRO™ 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	6
# 4 Nuts	2
# 4 Lock Washers	2
64-Wire Ribbon Cable	225mm (9")
Battery Holder (6-AA)	1
9V Battery connector	1
Skid	1
150 Ohm Resistor	2

2.2 TJ-PRO™'s Microcomputer Circuit

The Mekatronix microcomputer circuit, the MTJPRO11™, which measures about 2.4 inches by 2.4 inches, constitutes a completely functional microcomputer system useful for a wide variety of embedded applications (Figure 2). The MTJPRO11™ circuit board already comes assembled and tested.

Caution: MTJPRO11™ possesses static sensitive parts. Static discharge can destroy them. Avoid working on carpet and ground yourself properly before touching any of the electronics.

The MTJPRO11™, incorporates an MC68HC11 as the on-board processor. To communicate code and data between the MTJPRO11™ and a personal computer requires the Mekatronix Bidirectional Serial Communications Board (MB2325) [See http://www.mekatronix.com] and Motorola's PCBUG11 freeware, Interactive C (freeware or commercial supported version) or the Mekatronix High-Speed-Down-Loader (HSSDL11).

The MTJPRO11™ provides 32Kbytes of SRAM as well as extensive IO capabilities. This memory capacity is more than enough to program TJ-PRO™ to do incredible stuff.
Table 5 lists the MTJPRO11™ parts and indicates the allocation of the various MC68HC11 ports to sensors and actuators. For example, JP4, a three pin male header connected to PE4, ground and 5-volts, is cabled to the IR detector on the left side of TJ-PRO™. The right wheel motor cable connects to the three pin header JP12 consisting of PA3, ground and 5volts.

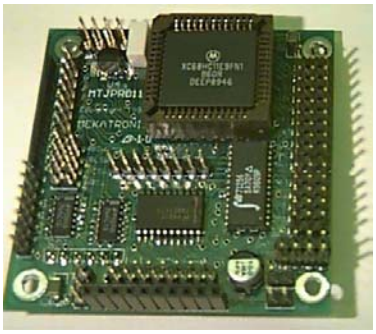


Figure 2 Photograph of the MTJPRO11 board. The large chip at the top is the MC68HC11 processor. The 32Kbyte SRAM is the large, vertically oriented chip at the right. The column of 3-pin male headers along the right side of the chip make the MC68HC11 PortE and PortA available for sensor inputs and motor control outputs.

Table 5 MTJPRO11™ Parts List

DESIGNATOR	VALUE	DESCRIPTION
CAPACITORS		
C1, C4, C7, C8, C9, C10, C11	0.1uf	Bypass Capacitor
C5	470uf	Electrolytic Bypass Capacitor
JUMPERS		
J1	CON2: 2-Pin Male Header	Power On/Off Switch
J2	CON2: 2-Pin Male Header	Download/Run Mod Select Switch
J3	CON2: 2-Pin Male Header	Reset Switch
J4	CON2: 2-Pin Male Header	Power On Red LED
J5	CON4: 4-Pin Male Header	Charge Connector
J6	CON3: 3-Pin Male Header	Select 40KHZ modulation or not for JP1
BATT	CON4: 4-Pin Male Header	Battery Power Cable Connector

HEADERS		
JP1	HEADER 8X2	8-bit Digital Output Port (J6 selects 40KHz modulation or not)
JP2	HEADER 3: PE1	Analog Input Channel 1, Available for expansion
JP3	HEADER 3: PE2	Analog Input Channel 2, IRDRF
JP4	HEADER 3: PE3	Analog Input Channel 3, IRDLF
JP5	HEADER 3: PE4	Analog Input Channel 4, Available for expansion
JP6	HEADER 3: PE5	Analog Input Channel 5, Available for expansion
JP7	HEADER 3: PE6	Analog Input Channel 6, Available for expansion
JP8	HEADER 3: PE7	Analog Input Channel 7, Available for expansion
JP9	HEADER 3: PA0	Input Capture/Digital Input, Available for expansion
JP10	HEADER 3: PA1	Input Capture/Digital Input, Available for expansion
JP11	HEADER 3: PA2	Input Capture/Digital Input, Available for expansion
JP12	HEADER 3: PA3	Servo Connector, Right Wheel Motor
JP13	HEADER 3: PA4	Servo Connector, Available for expansion
JP14	HEADER 3: PA5	Servo Connector, Available for expansion
JP15	HEADER 3: PA6	Servo Connector, Available for expansion
JP16	HEADER 3: PA7	Servo Connector, Left Wheel Motor
JP17	HEADER 2: PE0	FBCSW, Bumper Switch Connector
JP18	HEADER 2: PE0	FBLSW, Bumper Switch Connector
JP19	HEADER 2: PE0	RBSW, Bumper Switch Connector
JP20	HEADER 2: PE0	FBRSW, Bumper Switch Connector
JP21	HEADER 2	Servo Battery Power, Direct feed from batteries
JP27	HEADER 7	IO Header Select Lines, Available for expansion
JP28	HEADER 8	Computer Data Bus, Available for expansion
RESISTORS		
R1	10M	Crystal load resistor
R2	470	Resistor
R3	100K	Resistor
R4	47K	Resistor
R5	20K	Resistor
R6, R7	10K	Resistor
SCI	CON6: 6-Pin Male Header	5 volt RS232 connector
SIP1	9 RESISTORS COMMON PIN 10K	9 Resistors common pin 10k, Pull Ups
SIP2	9 RESISTORS COMMON PIN 330	9 Resistors common pin 10k, Pull Down
SPI	CON7: 7-Pin Male Header	Synchronous Serial Peripheral Interface header
SS	CON2: 2-Pin Male Header	Slave Select jumper
ICs		
U1	68HC11	MC68HC11 Microcontroller
U2	MC74HC573	OCTAL D-TYPE TRANSPARENT LATCH
U3	MC74HC138A	3-8LINE DECODER/DEMULTIPLEXER
U4	MC34064	LOW VOLTAGE INHIBHIT
U5	MC74HC390	DUAL 4-BIT DECADE COUNTER

U6	62256	High Memory 32K SRAM or ROM
U7	MC74HC573	OCTAL D-TYPE TRANSPARENT LATCH
U8	MC74HC10	TRIPLE INPUT POSITVE NAND GATE
U9	8PIN	5-Volt Regulator

2.3 Functional Description of the MTJPRO11™

The MTJPRO11™ on the TJ-PRO™ features (Figure 3, Figure 4) an 8-bit microcontroller with 32Kbytes of SRAM and supporting circuitry, and connectors for extensive digital and analog inputs and digital outputs. In particular, the MTJPRO11™ features:

1. MC68HC11 microcontroller;
2. 32Kbytes of SRAM, hex addresses 0x8000 to 0xffff;
3. Three analog input channels for analog sensor input readings: PE0 for the four bumper switches, PE2 for the right front IR detector, PE3 for the left front IR detector;
4. Five analog input channels available for expansion, PE1, PE4, PE5, PE6, PE7.
5. Right wheel motor control with pulse width modulation (PWM) of PA3 and left wheel motor control with PWM of PA7.
6. Three servo actuation control with pulse-width-modulation on PA4, PA5, PA6;
7. Eight digital outputs enabled by Y6 and optionally modulated by 40KHz to drive IR emitters with 330 ohm current limiting resistors;
8. Three digital inputs PA0, PA1, PA2;
9. Four Input Port enable lines, Y1, Y3, Y5, Y7, with addresses 0x4000, 0x5000, 0x6000, 0x7000, respectively;
10. Four Output Port enable lines, Y0, Y2, Y4, Y6 (Y6 is used by IR emitter latch), with addresses 0x4000, 0x5000, 0x6000, 0x7000, respectively
11. Five-volt serial communication interface (SCI), connects to MB2325 through 6-wire cable;
12. High speed, 5-volt synchronous serial bus (SPI), up to 1 MHz data rate available through a 7-pin connector;
13. 8-bit Data bus output;
14. 40KHZ square wave generator;
15. 5 Volt regulator;
16. Low-voltage-inhibit reset circuit.

A 6-pin male header permits the MTJPRO11™ to serially communicate with other MTJPRO11™ 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 MTJPRO11™ circuit board. This makes the header easily accessible through the opening on the robot top plate during program development.

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

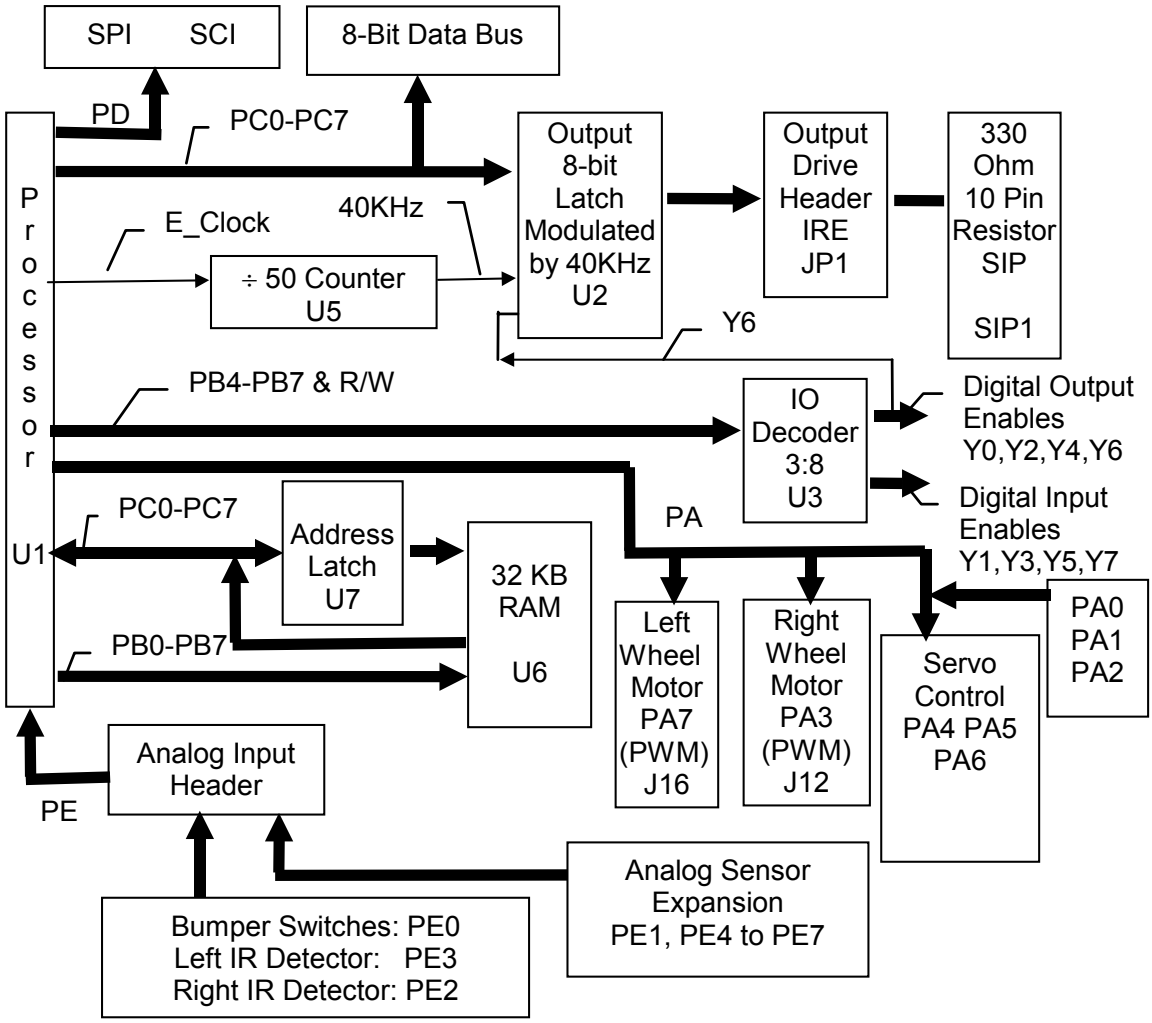


Figure 3 Functional layout of the MTJPRO11™.

2.4 MTJPRO11™ Circuit Schematic

Figure **4** illustrates the MTJPRO11™ circuit schematic and Figure 5 the wiring diagram. The top and bottom silkscreens, showing the circuit component layout, appear in **Figure 6** and Figure 7, respectively. **Figure 6** also illustrates the pad layer in gray. The rectangular pads indicate pin one in each case. The circuit schematic indicates all the electronic components, headers, and their connections. Refer to **Figure 3** for the functional organization of the circuit as you read the following material.

U1 is the MC68HC11 processor. The 8-bit register U7 latches the lower address bus, PC0:PC7, to generate the lower address bits for the 32Kbyte SRAM U6. U3 decodes upper memory addresses to produces the four Output Port enables (Y0, Y2, Y4, Y6 (Y6 is used by IR emitter latch) and four Input Port enables (Y1, Y3, Y5, Y7). JP27 makes the IO enables available

externally. The processor data bus PC0:PC7 is brought out by JP28 and, along with JP27, allows you to easily expand the IO capability of the MTJPRO11™.

The 8-bit IR emitter/digital output latch U2, enabled by Y6 (inverted by U8B) and optionally modulated by 40KHz, drives the three standard IR emitters on the robot. The emitter circuit connects in series with a 330ohm resistor (SIP2) through the 8x2 header JP1. Five connections on JP1 allow for future expansion to more IR emitters or other 10ma digital output loads. The decade counter U5 divides the 2MHz E-Clock by 50 to generate a 40KHz square-wave. Jumper J6 allows the user to select the 40KHz signal to modulate the output of U2. J6 also makes the 40KHz available for external use.

Port-D of the MC68HC11 controls the SCI and SPI serial communications interfaces as described in the Motorola User's Reference Manual. The MTJPRO11™ brings these interfaces out in a 6-pin SCI connector and a 7-pin SPI connector. Gounding the slave-select pin PD5 of the SPI interface by the SS jumper forces serial communications masterhood on the MTJPRO11™. To include the SS as part of the SPI interface, connect a jumper wire between SS pin one and SPI pin one. The MTJPRO11™ now longer becomes fixed bus SPI Master and may be driven as a slave serial device as well. The SCI and SPI connectors are electrically keyed so that reversing the connection causes no electrical damage. The SCI and SPI do not function, however, when the plugs are reversed. In any case, always be sure that the 6-pins mate exactly with the six 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.*

All eight of the analog channels PE0:PE7 connect to 3-pin male headers. Pin 1 of the header connects to an analog channel input, pin 2 to regulated voltage Vcc and pin 3 to ground. The headers JP2:JP7 connect to PE2:PE7. On the TJ-PRO™ robot, PE2 reads IRDRF and PE3 IRDLF, the left and right front IR detector modules. PEO, the bumper sensor for the robot, measure the output voltage in a voltage divider circuit. PE0 connects to a 10K resistor to ground and to pin 2 of the jumpers JP17:JP20. Four resistors of 10K, 20K, 47K, and 100K ohms connect to pin 1 of jumpers JP19 (RBSW), JP18(FBLSW), JP17(FBCSW), JP20(FBRSW), respectively. Momentary push-button switches on the robot bumper connect across these jumpers. Closure of a bumper switch develops a voltage divider circuit from Vcc to ground with PE0 measuring that voltage. The resistor ranges have been so chosen that individual closures can be determined by a single analog voltage measurement.

PA3:PA7 of Port A of the processor, used as pulse-width-modulated (PWM) control signals, can drive up to five servos. TJ-PRO™ uses PA7 to control the left wheel motor and PA3 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. PA4:PA6 will be used to control servos in future expansion kits of the robot. Jumper JP21 brings battery voltage directly to the servos. Regulated voltage Vcc

cannot drive the servos. The high current demand of two or more servos changing speed would depress the regulated voltage temporarily and reset the processor.

The three input capture pins PA0:PA2 can be used as general purpose digital inputs or for recognition of input digital waveforms using the input capture facility.

U9 produces a regulated 5-volt supply Vcc. The low-voltage-inhibit circuit U4 prevents the processor from trashing memory contents when a *Reset* button across connector J3 is pressed. The DPDT power *On/Off* toggle switch connects across J1 and JP21, simultaneously supplying regulated voltage Vcc to the electronics and battery power to the servos. The *Download/Run* toggle switch connects across J2 and determines the processor mode upon reset. The charge jack connects across J5 and the red power-on LED across J4. The electrically keyed 4-pin BATT connector does not cause damage if inadvertently reversed.

***Caution**: The BATT 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.*

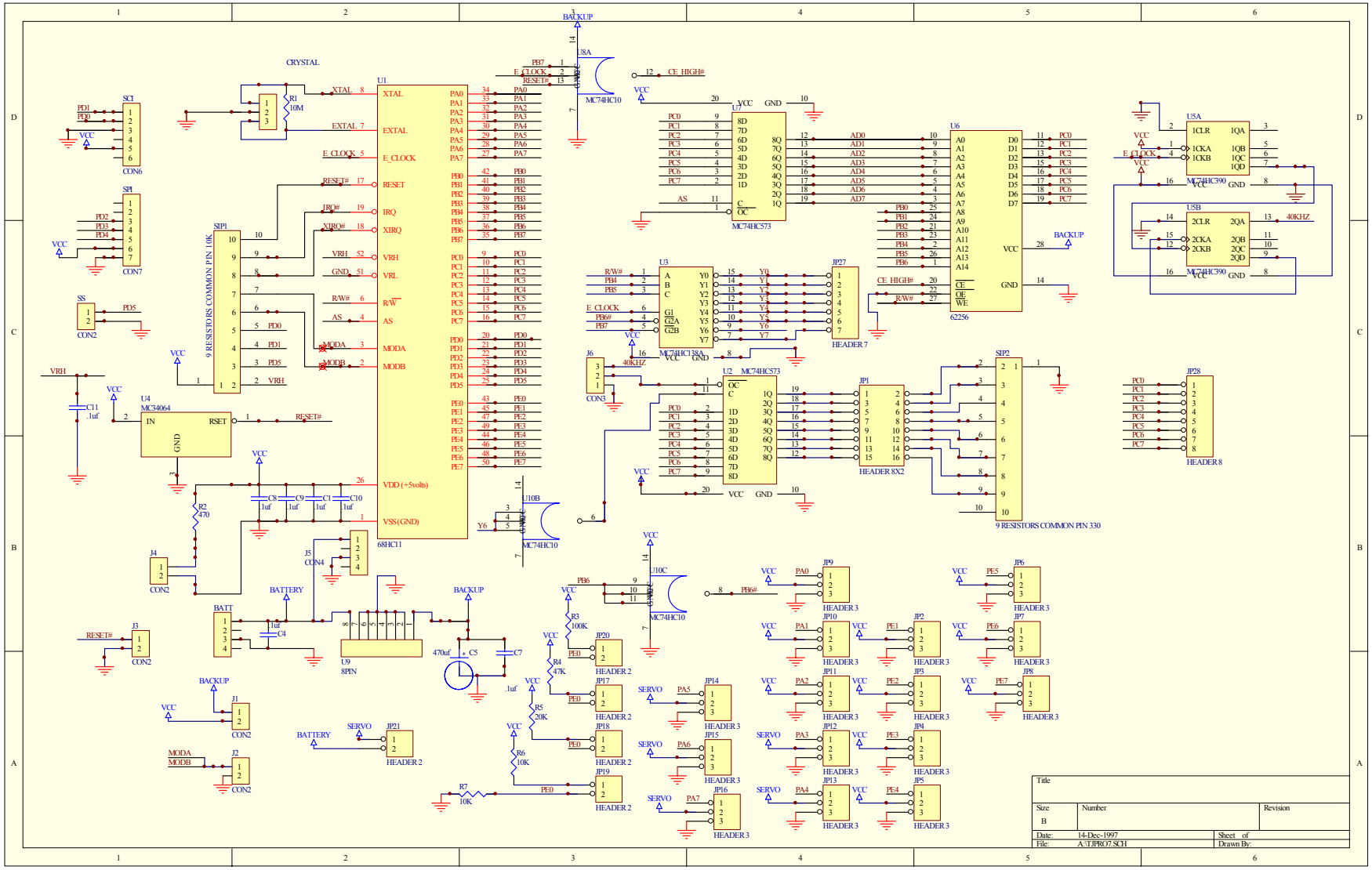


Figure 4 Schematic of the MTJPRO11™.

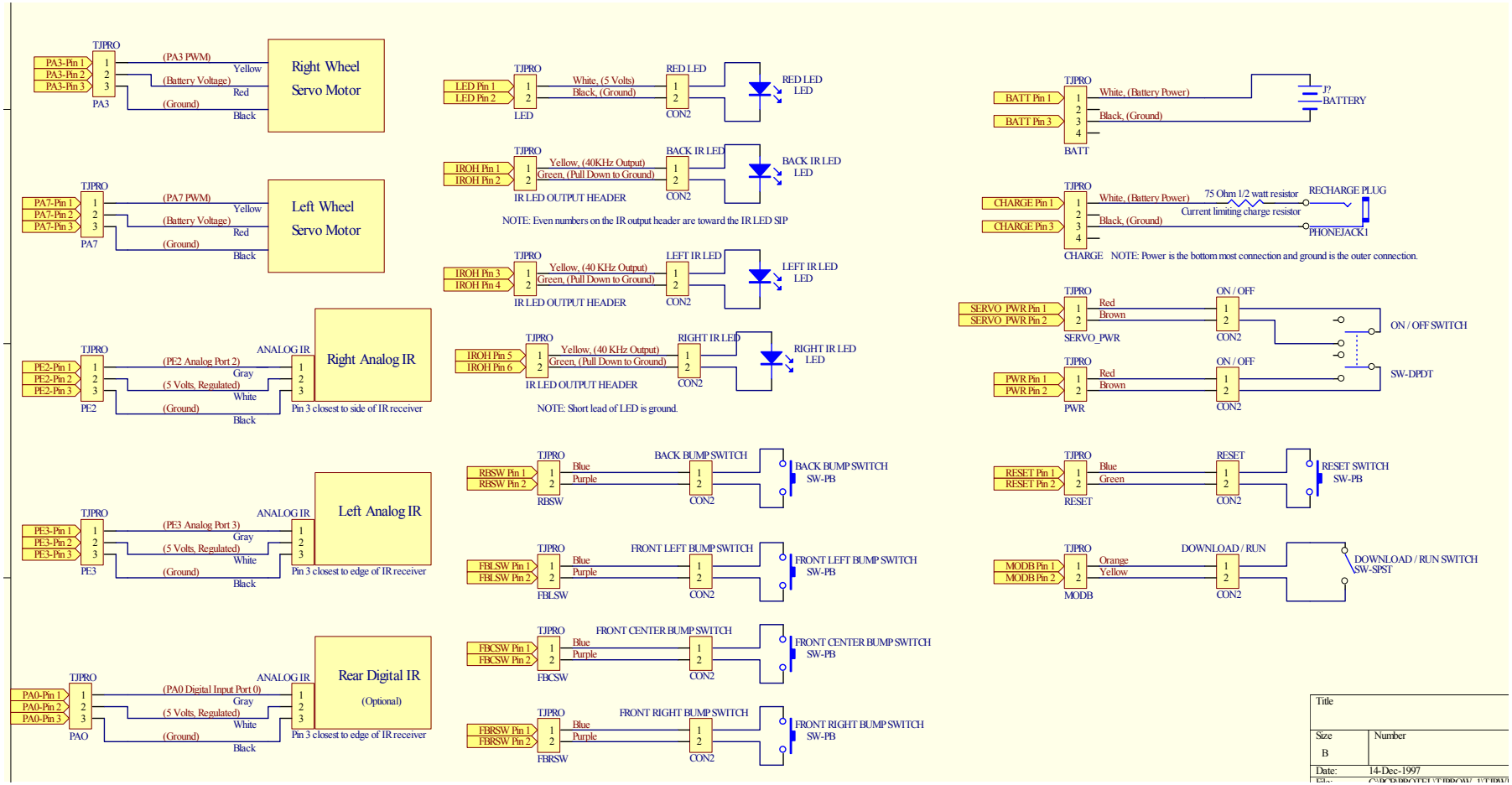


Figure 5 TJ-PRO™ wiring diagram, indicating headers, and suggested wire colors.

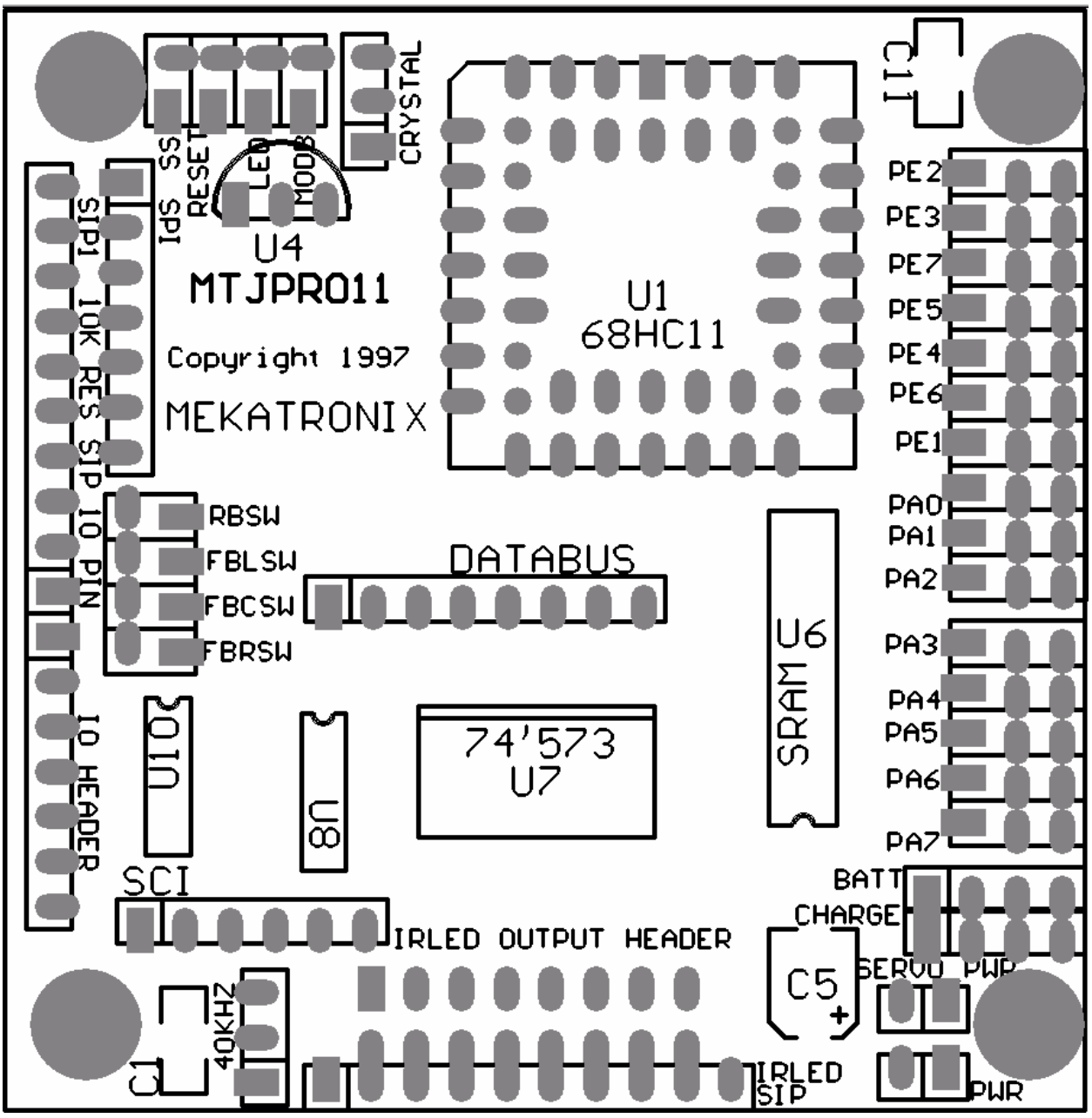


Figure 6 Top silkscreen (black) and pad layer (gray) illustrating the layout of the MTJPRO11™ printed circuit. The rectangular pads indicate pin one in all cases. Note the location of the right and left wheel motor controls, PE3 and PE7, respectively; the right and left IR detector ports PE2 and PE3, respectively; and the bumper ports RBSW, FBLSW, FBCSW, FBRSW near the 8-bit data bus. *Important: the SCI footprint appears on this side of the board but the header mounts on the other side.*

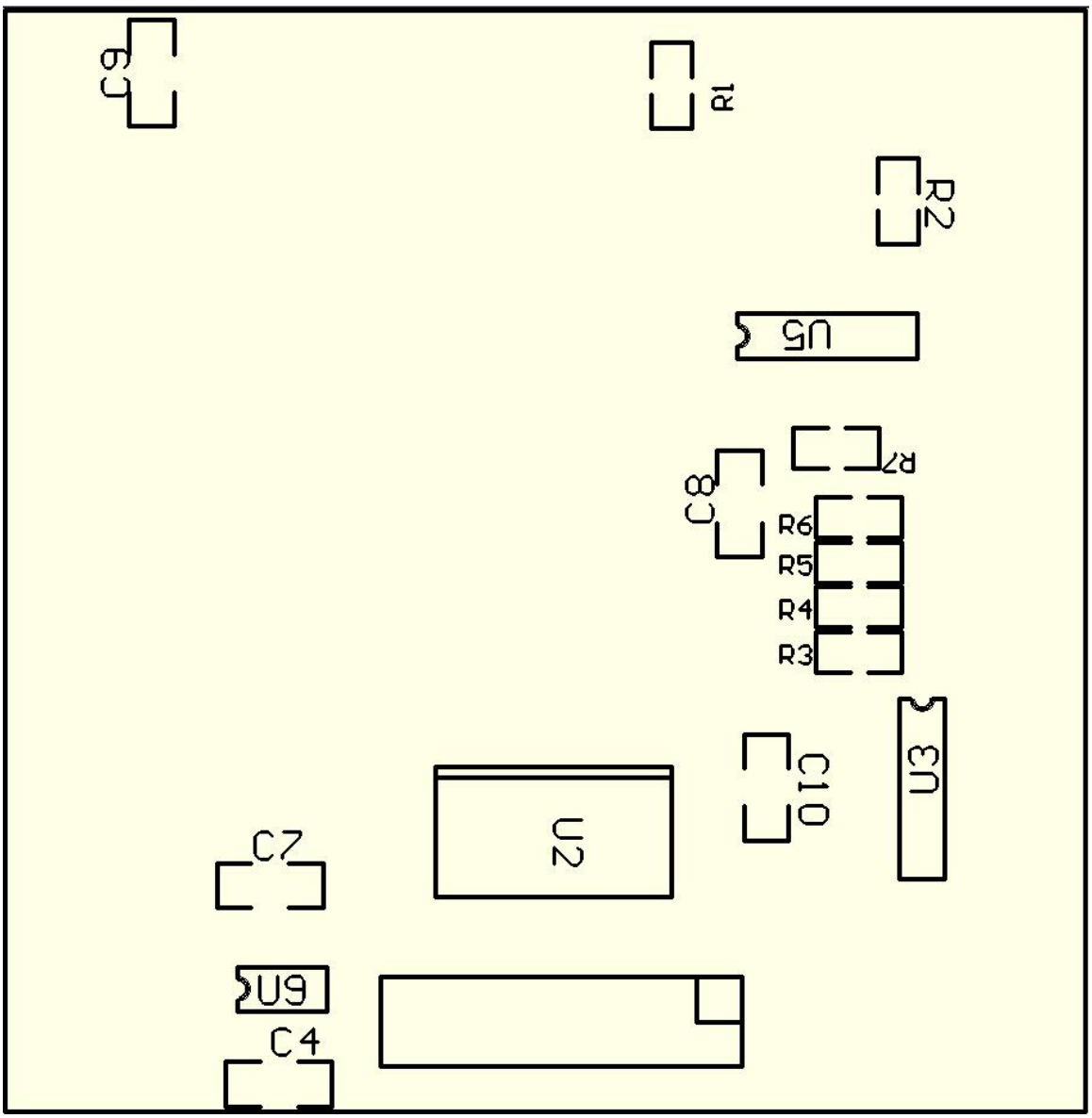


Figure 7 Bottom silkscreen of the MTJPRO11™ circuit board.

3 TJ-PRO™'S MECHANICAL STRUCTURE

A schematic of TJ-PRO™'s structure appears in Figure 8. TJ-PRO™'s wheel axis determines 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-PRO™ 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 MTJPRO11™ printed circuit board (pcb) mounts on the top plate with four ½" 4/40 machine screws. One quarter of an inch hex standoffs on each screw serve as spacers between the PCB and the top plate. These standoffs 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, to about 1/16 inch above the top surface. These projections can be used to attach standoffs to support the Argos™ and MekArm™ attachments. Because of the small tolerances, the screws securely fasten the PCB to the top plate without nuts on top of the plate.

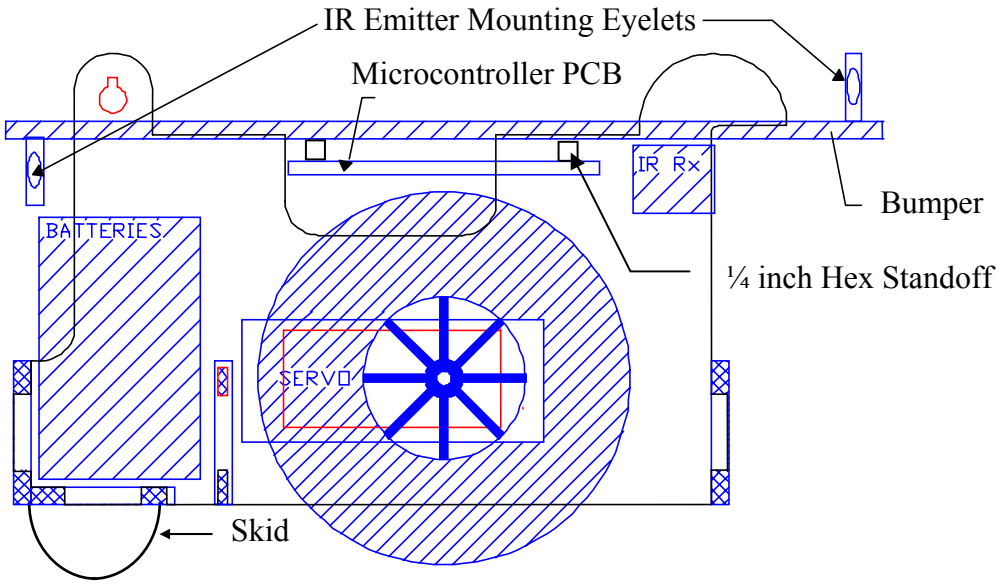


Figure 8 Schematic side view of TALRIK, JR.™

The circular top plate (Figure 9) mounts on the sides similar to a reverse automobile engine hood. The shaped slots on top of the plate are used for wire conduits.

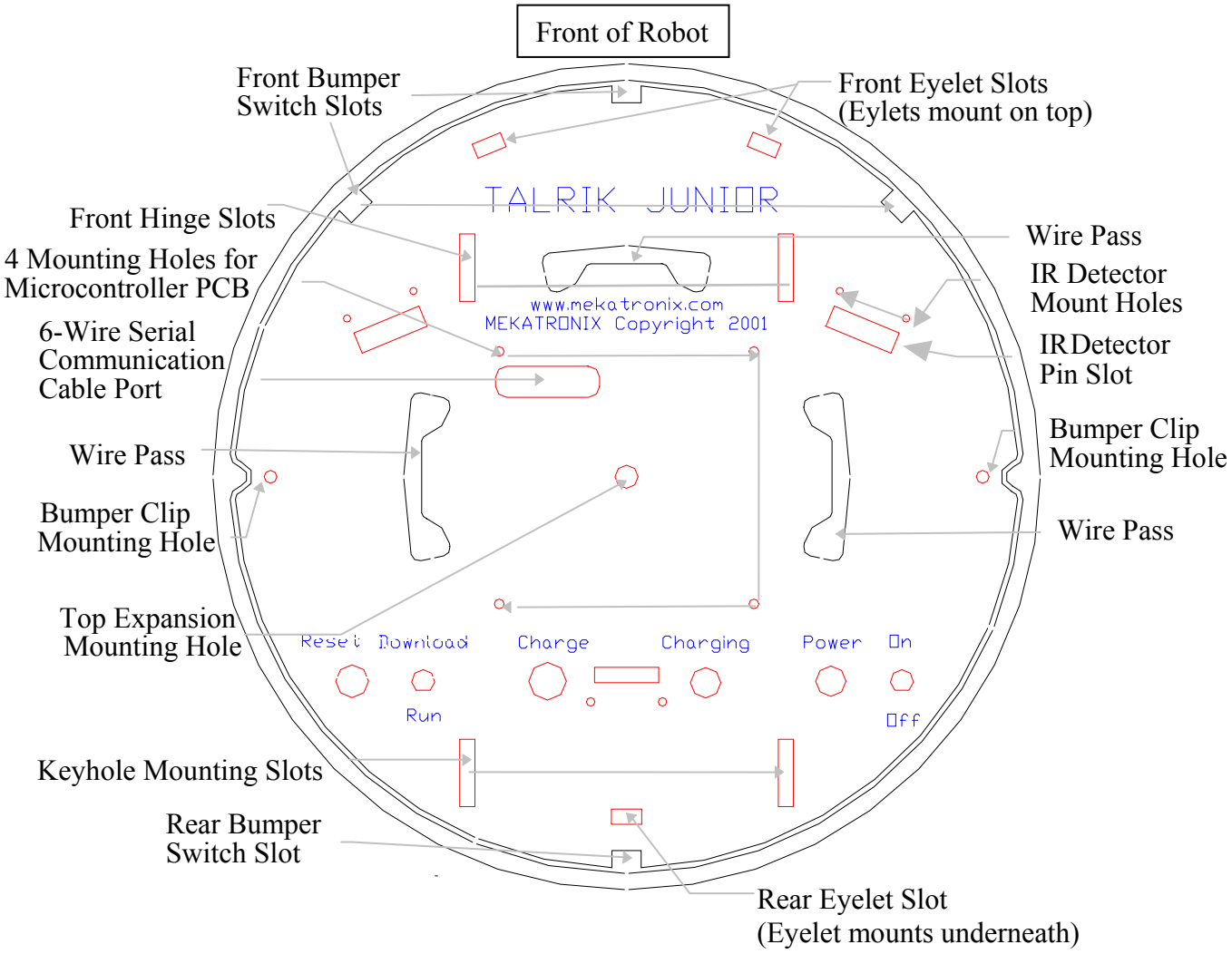


Figure 9 Layout of TJ-PRO™'s Top Plate.

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-PRO™ possesses three switches mounted on the top plate in the rear (Figure 9), 1)*Off/On*, 2) *Download /Run*, and 3) *Reset*. In the *Download* position, the *Download /Run* switch forces the processor in *special bootstrap* mode upon reset. When the processor is in *special bootstrap* mode you can download programs. In *Run* mode the processor changes, upon reset, to *single chip* mode and executes the downloaded program.

The recharge plug is located just to the right of the *DOWN-LOAD/RUN* toggle switch. The 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 9).

Each side piece (TJSIDE55) supports a servo and wheel assembly. The servos slide into the large rectangular opening in each side's center. Four small cross planks hold the sides rigidly apart and simultaneously provide a battery case for the 6 AA battery pack above the nylon skid.

3.1 TJ-PRO™'s Body Parts

Figure 10 illustrates the twelve structural components of TJ-PRO™'s body. The list in Table 6 specifies TJ-PRO™'s body parts, the quantity employed in constructing a TJ-PRO™ frame and the function of each part. The plastic tail-skid is listed as well.

Table 6 TJ-PRO™ Body Parts

Qty	Part Number	Description	Function
5	TJBGUIDE	Bumper guides	Support Bumper, one extra Moves with bumper
2	TJBMPCLIP10	Bumper Clips	Supports bumper, Fix to TJTOP65 with 4/40 screws
1	TJBUMPER70	Floating Ring Bumper	Bumper
4	TJCDS20	TJ-PRO™ CdS cell Holders	Mounts for CdS cells, one extra
4	TJIRE20	TJ-PRO™ IR Emitter Holders	Mounts for IR emitters, one extra
1	TJKEY30	TJ-PRO™ Key, Top Plate Clamp	Locks top plate (TJTOP65) onto the frame.
3	TJPLANK45	TJ-PRO™ Inside & Bottom Planks with two screw holes each for mechanical assembly	Holds two sides of the chassis together underneath and inside, one extra
2	TJPLANK55	Front and Rear Planks with three eyelet holes and two screw holes each for mechanical assembly	Holds sides together at front and back. Two offset screw holes for mounting external hardware.
2	TJSIDE55	TJ-PRO™ Side with four screw holes each for mechanical assembly	Sides of robot. Servo mounts.
4	TJSWSPACER4	Bumper Switch Mount Spacers	Supports bumper switches.
1	TJTOP65	TJ-PRO™ Top	Mounts switches, IR, bumper and other features.
1	TJSKID01	Plastic Skid	Back Skid.

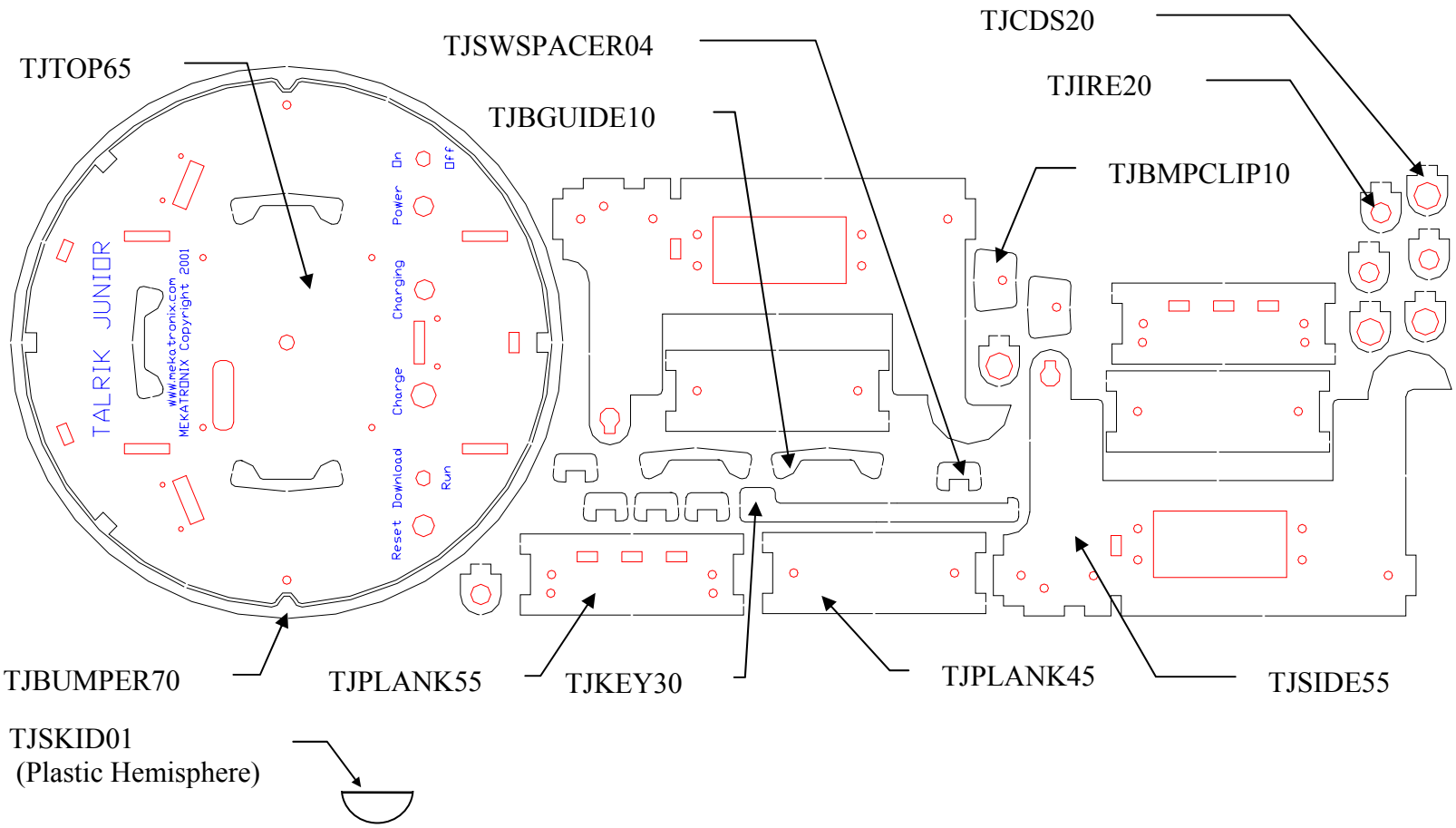


Figure 10 TJ-PRO™'s Body Parts

3.2 TJ-PRO™ Platform Assembly

The completed platform assembly is shown in Figure 11 a with the key inserted and the top plate locked in place. The pictures depict an older version of the robot, but the essentials of assembly have not changed, with one exception. Additional holes in the cross plates and the sides permit a mechanical assembly option that eliminates gluing the body together. A mechanically assembled robot can easily be disassembled. This feature is convenient for classroom reuse.

The IR emitter mounting eyelets, two in front and one in the back, show clearly in Figure 11b and Figure 11c. The bumper mounting clips, fastened to either side of the top plate, also stand out. Figure 11d illustrates how the top plate (Figure 11f) slips onto the goose necks. The completed frame in Figure 11e shows how the plate and sides come together.

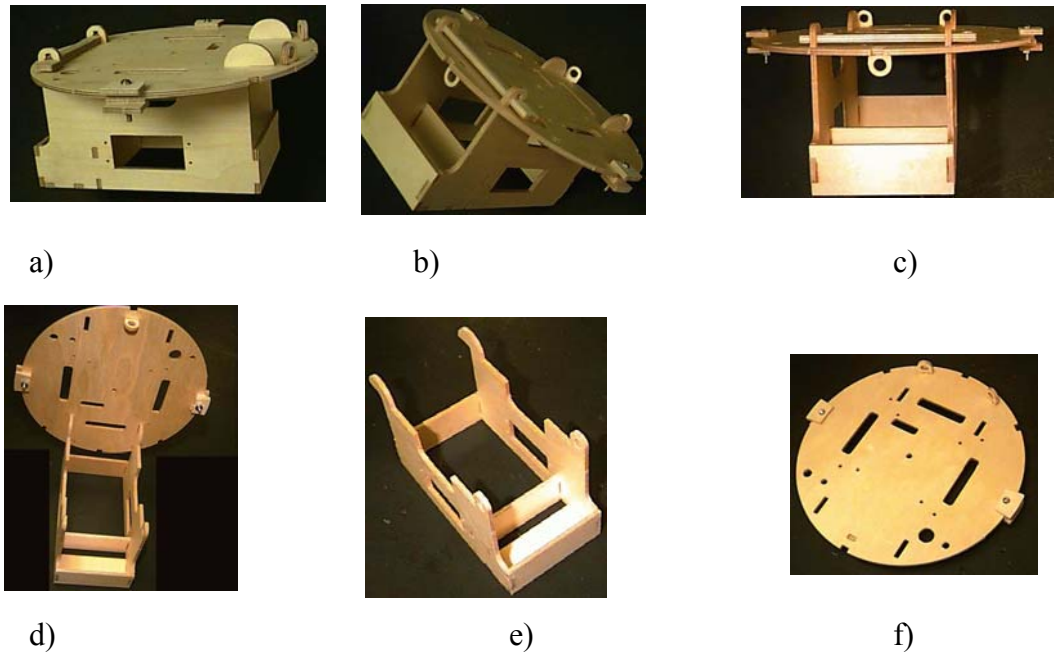


Figure 11 Sequence of photographs of TJ-PRO™'s mechanical structure viewed from a) right side, b) right rear side, c) rear, d) rear with top plate swiveled up. Figure e) shows the chassis as viewed from the rear top and f) pictures the top side of the plate.

4 TJ-PRO™'S SENSOR SUBSYSTEM

Figure 8 and Figure 9 schematizes the standard layout of TJ-PRO™'s sensor suite. Table 7 defines the name and application of each sensor. TJ-PRO™ is not limited to these applications, or in the number of sensors listed. You can devise and implement other schemes, both in layout and in function. Wiring the sensors was discussed previously.

Table 7 TJ-PRO™'s Sensor Suite

TJ-PRO™ Label	Name	Function	Header[1]
IRDLF	Infrared Detector, Left Front	Proximity Sensor	PE3
IRDRF	Infrared Detector, Right Front	Proximity Sensor	PE2
FBLSW	Front Bumper Switch, Left Front	Front contact Sense	FBLSW
FBCSW	Front Bumper Switch, Center Front	Front contact Sense	FBCSW
FBRSW	Front Bumper Switch, Right Front	Front contact Sense	FBRSW
RBSW	Rear Bumper Switch	Rear contact Sense	RBSW

[1] Refer to **Figure 6** for location of headers on the MTJPRO11™ circuit board.

4.1 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 bandpass 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 12 in the following discussion.

Place the can so that the wires point toward you (GP1U58X) or up toward you (GP1U58Y). Cut the trace to the output pin (leftmost inside pin). Soldered 30 AWG wire directly to the top of the 0.1 microfarad capacitor, on the lower left, and to the output pin. Solder the ground pin on the far right to the case with a small piece of wire and a large blob of solder. Be sure to make a good connection. The output pin will now give the analog response. For practicality, it is much easier to solder to the capacitor terminal than the trace itself. Now, close up the can. The hack is complete.

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 A/D converter 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.

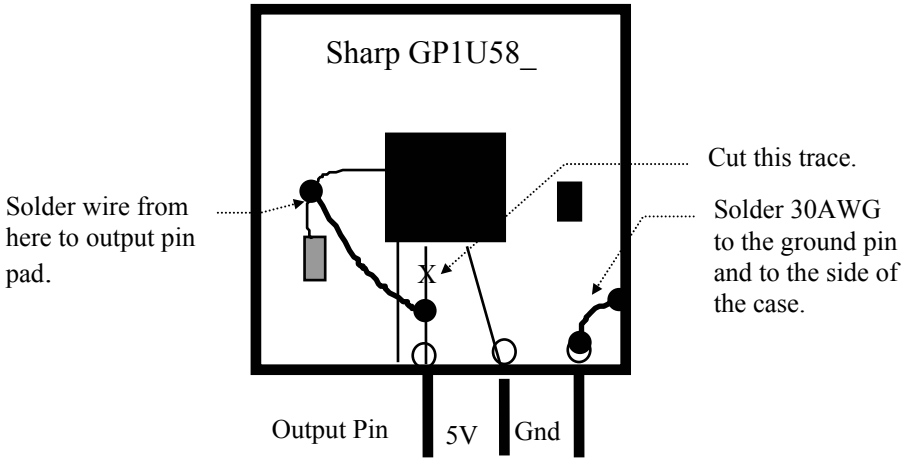


Figure 12 Converting a digital IR sensor to an analog IR sensor requires cutting the trace to the Output pin, soldering the Gnd pin to the side of the case, and connecting the output of the 0.1 μf capacitor to the Output pin.

4.2 Enhanced Sensory Capabilities

Other sensors, such as microphones, photoresistors and digital IR communications, can be added to TJ-PRO™ 's platform. The numerous sensory possibilities and add-on features are limited only by the input/output capability of the MTJPRO11™ and your imagination.

5 MOTOR CONTROL

Programs executing on the MTJPRO11™ control TJ-PRO™'s motors using pusle-width-modulation (PWM). For the software PWM program to work, however, one must first hack the servos.

5.1 Hacking the Servos into DC Gearhead Motors with Controllers

A standard servo can be hacked in the following manner to create a DC gearhead motor. Refer to Figure 13. Mount a servo horn on the output shaft and approximately rotate the servo to the center of its range. Remove the 4 back plate screws. Carefully remove the gear box cover on top. Remove the output gear and with sharp, miniature diagonal cutters, cut off the plastic tab stop. Take the potentiometer lock-tab out of the output gear (Figure 14) so it will not turn the potentiometer shaft. Now, connect the servos to the MTJPRO11™ (refer to Figure 5, **Figure 6** and (Table 13).

To calibrate the wheels (perhaps!) more precisely, assemble the complete robot without mounting the wheels on the platform. Take the gear covers and output gears off each motor. Plug the motor cables into the appropriate MTJPRO11 male headers. Download and execute csrvotjp.s19 (Refer to the TJ Pro Users Manual on how to download). Each wheel will rotate slowly. Manually adjust each potentiometer until the corresponding motor stops.

In the rest of this procedure, avoid rotating the potentiometer shaft from its center position.

Remount the output gear without the shaft-lock tab and reassemble the servo. This (almost) ruins the servo as servo, but in its place you have a DC gearhead motor with electronic control!

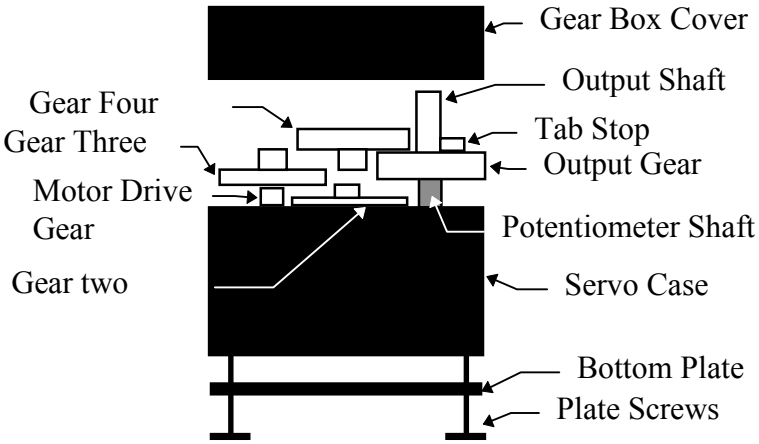


Figure 13 Servo hack: Remove tab stop, remove potentiometer tab inside *Output Gear*, set potentiometer shaft at center setting.

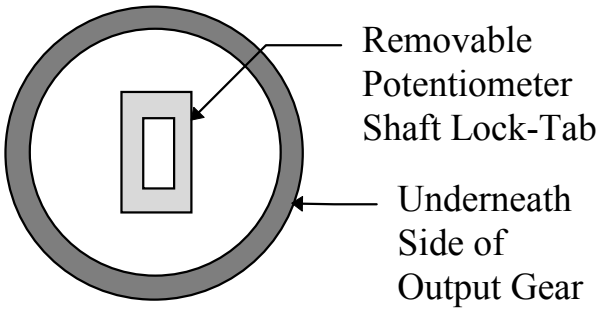


Figure 14 Illustration of the potentiometer shaft lock-tab inside the output gear.

The 3-pin female connector of the Mekatronix servos slip right onto the Port_B male header of the MTJPRO11™ single chip computer board without modification.

5.1.1 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.

Reversal of Motor Wires
If a robot's motor runs in the wrong direction when given a motor command, the motor wiring must be reversed from the standard servos to maintain program code compatibility with standard TJPRO™ libraries and applications. Take the bottom plate off the servo, remove the motor and servo electronics board, unsolder the wires on the motor tabs, reverse the wires to the tabs, solder, and reassemble.

5.2 PWM of the Motors

The MC68HC11 output compare feature generates pulse width modulation for the two DC motors on PA7 and PA3 of PortA (refer to Figure 5, **Figure 6**). The DC motors (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 the motors vary, 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 and 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™ can literally turn 180 degrees in place.

6 ASSEMBLE THE BODY

In the following assembly process, you may need to refer periodically to various tables and figures already presented.

6.1 Unpack The Kit

Carefully unpack TJ-PRO™ and verify the presence of all the parts. Use Table 3, Table 4, Table 6, Table 8, Table 9, and Table 10 to check off items.

Table 8 TJ-PRO™ 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
1	MVLED	Visible LED	Power-on Light
4	SWPBMT100	Tactile PB Switch	Bumper switches
1	SWDPDT	Toggle switch	On-Off and Servo Power
1	SWTGM25	SPST 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	TJDC410	Gear Head Motor, 6V, 42oz-in	Wheel actuators
1	W275T	Pair of 2.75" wheels	TJ-PRO's Wheels.

Table 9 TJ-PRO™ Electronic Parts

Qty	Part Number	Description	Function
1	MTJPRO11™U[2]	Assembled PCB	Microcomputer controller
2	Resistor 150 ohm	¼ watt	Charge current limiting, wired in parallel.
1	FC36	Female connector, 36pins	Cable connectors
1	FC12	Female connector, 12pins	Cable connectors
1	FC2	Two pin jumper	40KHZ jumper
1	BHS6AA	Battery holder, 6-Pack	Holds TJ-PRO™'s six AA NiCd Batteries.
1	BSNAP9V	Battery pack snap leads	Connects Battery to MTJPRO11™
1	SMH4	4-pin straight male header.	Power Header (Glue to TJ-PRO™ plate. Battery plugs onto it)
1		9 inches of 40 wire ribbon cable	Cable wiring.

Table 10 TJ-PRO™ Documentation[3]

Qty	Part Number	Description	Function
1	TJAMV1_Doc	TJ-PRO™ Assembly Manual	Instructions to Assembly TJ-PRO™ robot
1	TJUMV1_Doc	TJ-PRO™ Users Manual	Programming the TJ-PRO™
1	TJPRO11DSv10	TJ-PRO™ Software Distribution Disk (Only with TJ Pro + ICC11 purchase)	Basic TJ-PRO™ device drivers, (Freeware: PCBUG11, Motorola MC68HC11 Assembler).

[1] Refer to Analog Sensor Hack on http://www.mil.ufl.edu/imdl/handouts/Sharp Sensor Hack for Analog Distance Measurement. Pre-hacked IR detectors can also be purchased.
[2] The complete list of parts for the MTJPRO11™E2 kit is listed in the assembly instructions for that kit.
[3] All the manuals are on line in Adobe™ PDF at www.mekatronix.com →manuals.

6.2 Remove Robot Body Parts from Sheet

1. If your TJ PRO™ consists of a 5-ply plywood body, then lightly sand the plywood sheet of precut parts in the direction of the wood grain with vary fine sandpaper (200 grit).

2. To remove the body parts of the TJ-PRO™ kit from the parts sheet, use a sharp knife or safety razor blade to cut the small tabs holding the parts to the sheet. Preassembled kits do not have the extra body parts indicated in Table 6.

3. After removing a part from the parts sheet, peel off the protective layers of masking paper on both sides of the part.

4. With fine sandpaper (150 grit) or file, sand or file tabs smooth. For the wood models, lightly sand the edges of each piece.

6.3 Mechanical Assembly of the TJ Pro™ Body

Depending on the model you have, you can either glue or mechanically assemble the TJ Pro™ body. The mechanical model can also be disassembled, but the glued one cannot, at least not easily! All newer models of the TJ Pro robot allow mechanical assembly, but this option must be elected at time of purchase to get the necessary right-angle brackets and machine screws.

Refer to Figure 10, Figure 15 and Figure 16. Use the right-angle brackets and the ¼ inch 4/40 machine screws to fasten the four cross planks, two of TJPLANK45 and two of TJPLANK55. The two TJPLANK55 fasten in the front and the rear. One TJPLANK45 fastens inside the body sides (TJSIDE55) just far enough from the end cross piece to allow a vertically standing 6-pack battery module to slip between them. The second TJPLANK45 cross piece provides a floor for the battery pack. The four horizontal cross pieces can be seen clearly in Figure 11e and Figure 15.The inside TJPLANK45 cross piece should be inserted first and fastened. The bottom plank can be fastened last.

1. With ¼ inch 4/40 screws snugly attach two right-angle brackets to each cross piece in the orientation shown. The screw heads pass through the body piece and screws into the right-angle bracket. The longer leg of the bracket attaches to the cross piece. The shorter leg of the bracket will fasten to the robots side pieces (TJSIDE55).
2. Insert the interior cross piece (TJPLANK45) into both sides (TJSIDE55) of the robot. Pass ¼ inch 4/40 screws through the robot sides and screw into the right-angle bracket on the cross piece.
3. With ¼ inch 4/40 screws attach the back (TJPLANK55), front (TJPLANK55), and bottom (TJPLANK45) cross pieces.
4. Align the cross pieces, if necessary, as you tighten all screws.
5. Tighten all screw to a snug fit.

The cross pieces will bow slightly when you tighten the screws down. This provides exceptional strength to the robot body. The completed mechanical assembly is illustrated in Figure 16.

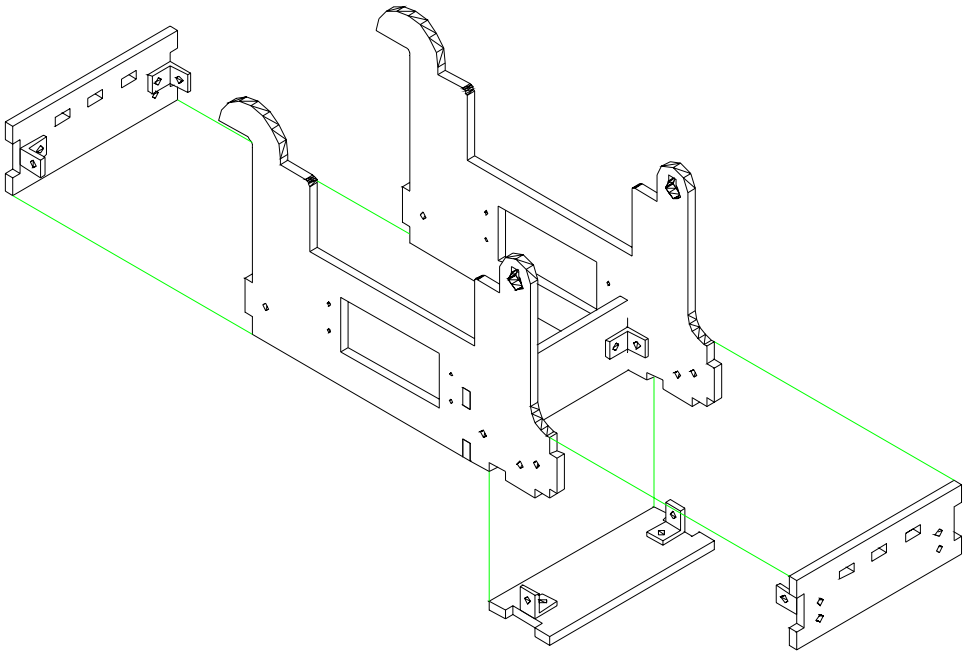


Figure 15 This drawing of TJ-PRO™ frame assembly showing how to connect the four cross planks to the sides. The long side of each angle bracket lies on the crosspiece. The short side of the angle bracket connects to the side pieces of the body with ¼ inch 4/40 machine screws. The screw heads show on the outside.

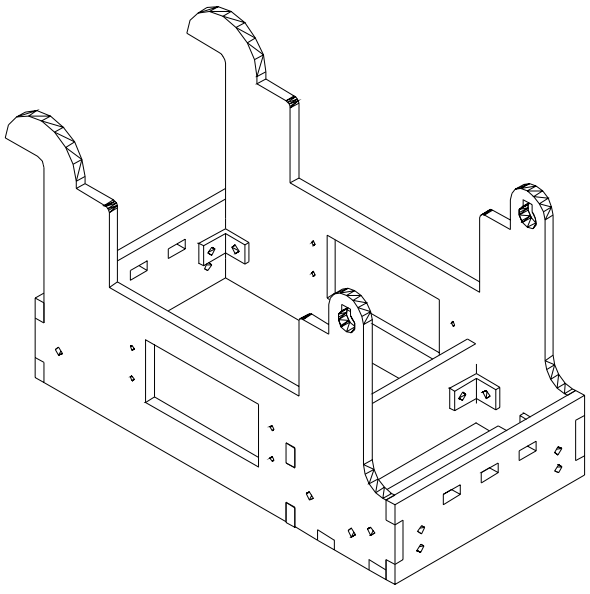


Figure 16. Completed mechanical assembly of the TJ Pro™ robot.

6.4 Glue Assembly Option of the TJ-PRO™'s Body

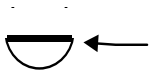
Refer to Figure 10, Figure 15 and Figure 16. Use a quick drying glue (Zap-A-Gap™) to fasten the four cross planks, two of TJPLANK45 and two of TJPLANK55. The two TJPLANK55 fasten in the front and the rear. One TJPLANK45 fastens inside the side planks just far enough from the end cross piece to allow a vertically standing 6-pack battery module to slip between them. The second TJPLANK45 cross piece provides a floor for the battery pack. The four horizontal cross pieces can be seen clearly in Figure 11e and Figure 15.The inside TJPLANK45 cross piece should be inserted first and glued simultaneously with the front and back planks. The bottom plank can be glued last.

6.5 Finish Surfaces

You should lightly sand TJ-PRO™'s wood structures using a very fine grade sandpaper (200 grit). After sanding, we recommend clear-coating TJ-PRO™ 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 assembly, as the wires and electronic components prevent effective finishing later. You can silk screen or paint plastic bodies to taste. In particular, for better visibility, you may wish to use enamel paint to fill in the engraved letters on the top plate.

6.6 Mount Tailskid

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



6.7 Assemble the Top Plate

Refer to Figure 17 and Figure 18.

1. Glue the four switch supports TJSWSPACER4 on the bottom of the top plate TJTOP65. Be sure the TJSWSPACER4 switch slot lines up perfectly with the switch slot on the TJTOP65 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 18. 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.

6.8 Assemble the Floating Ring Bumper® and Mount

Refer to in Figure 18 to visualize the bumper more clearly.

Figure 17 depicts a schematic diagram of TJ-PRO™'s bumper system.

1. Glue two 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.
2. With the plate upside down, place the floating ring bumper around the top plate so that only the guides touch the top.
3. Screw two bumper clips (TJBMPCLIP10) over the bumper with half inch 4/40 screws coming through the top plate. Clamp the bumper clips with a 4/40 lock washer and nut on the underneath side.
4. The floating bumper is free to move but will not fall off or rotate in place!

5. Flip the robot over and glue two bumper guides(TJBGUIDE10) to the top side of the floating ring bumper (TJBUMPER70) above the ones glued on the bottom side of the bumper. You might have to sand the contact surface the TJBGUIDE10 makes with the top plate to reduce friction and allow the bumper to move freely.

6.9 Mount the Microcontroller onto the Top Plate

The MTJPRO11™ printed circuit board (PCB) mounts underneath the top plate (Figure 18). Four mounting holes are provided. The 6-pin serial communications header should be mounted on the non-component side of the MTJPRO11™ PCB. A slot on the top plate provides access to this header. Proper mounting of the PCB on the top plate will recess the serial communications header below the top surface of board.

1. Thread four ½ inch 4/40 machine screws through the top of the PCB into four ¼ inch hex standoffs. Leave about 1/16 inch space between PCB and standoff.
2. Center screws on holes provide in the top plate and 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.
3. 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 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.

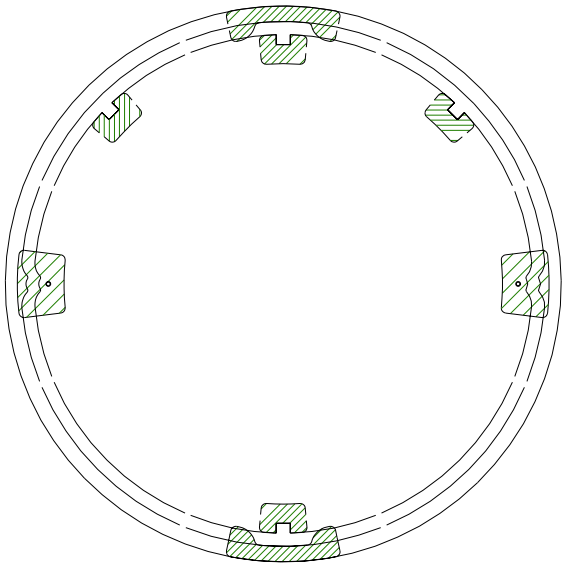
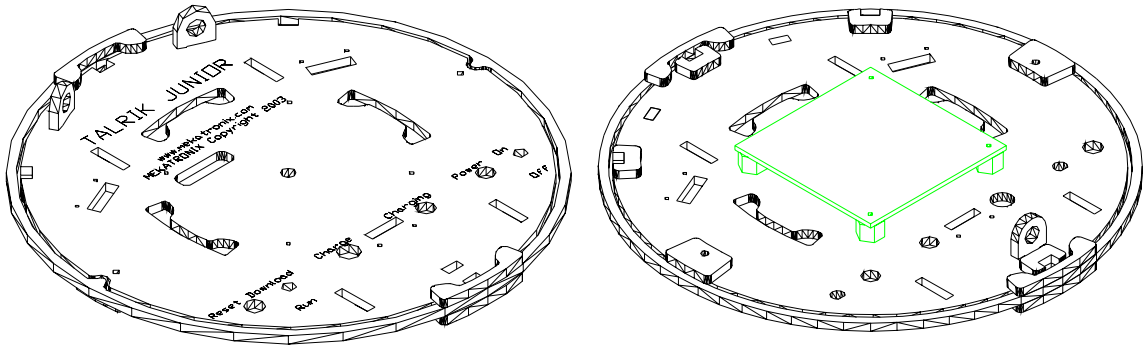


Figure 17 TJ-PRO™'s bumper assembly.



Top Bottom

Figure 18. These two figures present the top and bottom view of the robot's top plate with the bumpers, printed circuit board, and IR eyelets attached.

The orientation of the printed circuit board is shown in Figure 19. The microprocessor is in the upper left and the PortA 3-pin headers, to which all the motors and servos are attached, appear on the right side of the diagram.

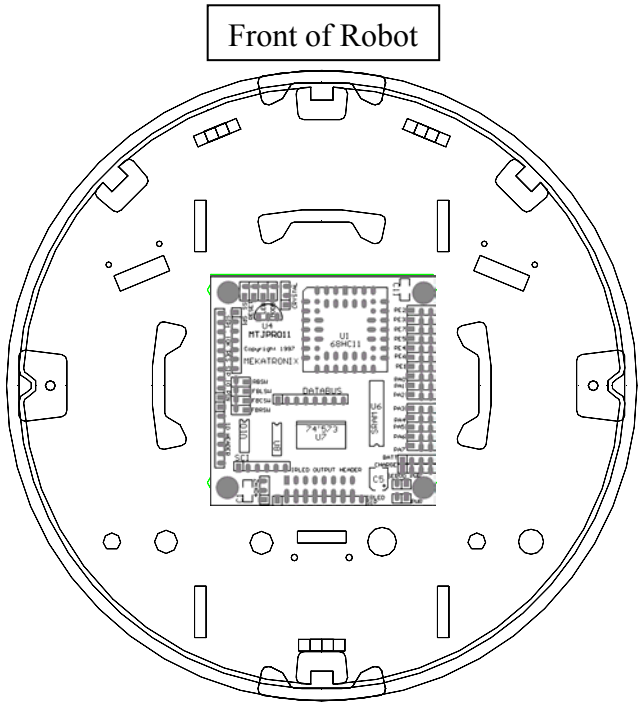


Figure 19. Diagram of the top plate showing the orientation of the PCB on the plate's underside.

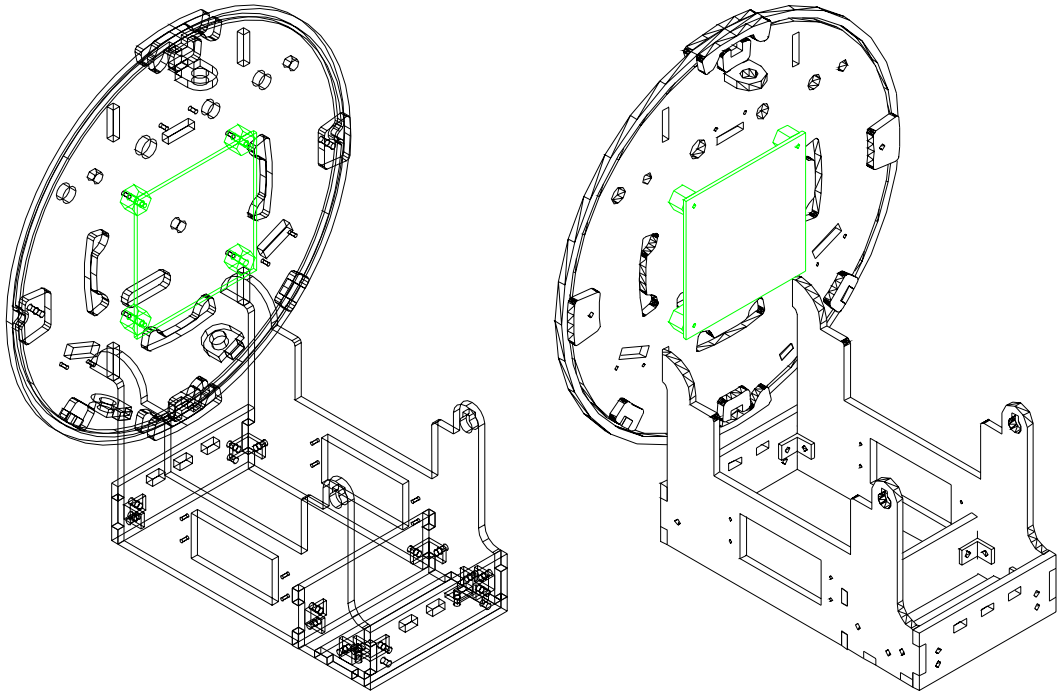
6.10 Completed Body Assembly

The top of the TJ Pro™ body mounts like a rear opening hood of a car.

1. Refer to Figure 20.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 on the front sides.
3. Slip the goosenecks through the plate slots. Be sure to clear all wiring away from the slots.
4. Slowly tilt the plate back towards the rear of the robot.
5. Insert the key holders on the robot's sides through the rear plate slots provided for this purpose.
6. Be sure all wires are cleared and none are being pinched as you push the top down.
7. Secure the top horizontally to the floor and insert the key.
8. 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.



a) wire diagram showing hidden lines **b) normal view, hidden lines removed**

Figure 20. Orientation of top plate for mounting onto the lower body of the robot.

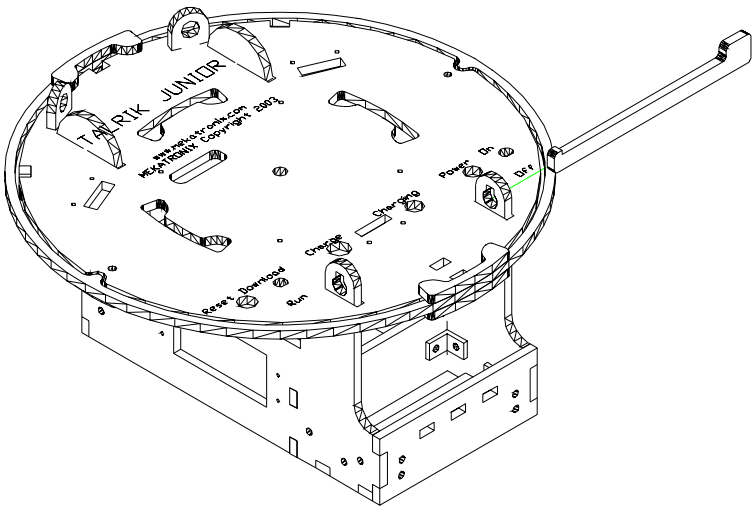


Figure 21. The above drawing illustrates a complete body assembly without cables and connectors.

7 CONSTRUCTING CABLES

All TALRIK JUNIOR PROFESSIONAL™ wiring harnesses are constructed from multi-stranded colored ribbon cable. The basic robot requires a total of 15 cables. Figure 22 and Table 11 illustrate the common cable types used in TJ-PRO™'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, $n \leq k$ and $m \leq k$. 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 22. Table 12 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 in may be longer than needed. You can, of course, cut the cable lengths to suit your requirements.

Figure 22 Illustration of several cable types.

Table 11 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. 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 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 12 Recommended Cables Type and Color-Code for the TJ-PRO™

Cable Name	Cable Type	Color Code
CBATT	W2F4	(red, black) = Pin(1,3)
CCHRGE	W2F4	(white, black) = Pin(1,3)
CDWNRN	W2F2	(orange, yellow) = Pin(1,2)[2]
CFBCSW	W2F2	(blue, violet) = Pin(1,2)[2]
CFBLSW	W2F2	(blue, violet) = Pin(1,2)[2]
CFBRSW	W2F2	(blue, violet) = Pin(1,2)[2]
CIRDLF	F3W3F3	(gray, white, black) = (signal, 5 volts, ground) = Pin(1,2,3)
CIRDRF	F3W3F3	(gray, white, black) = (signal, 5 volts, ground) = Pin(1,2,3)
CIREB	F2W2F2	(yellow, green) = (anode, cathode)=Pin(1,2)[1]
CIRELF	F2W2F2	(yellow, green) = (anode, cathode)=Pin(3,4)[1]
CIRERF	F2W2F2	(yellow, green) = (anode, cathode)=Pin(5,6)[1]
CPWR	W2F2	(red, brown) = Pin(1,2)[2]
CPWRSV	W2F2	(red, brown) = Pin(1,2)[2]
CRBSW	W2F2	(blue, violet) = Pin(1,2)[2]
CREDLED	F2W2F2	(white, black) = (R2, ground) = Pin(1,2)
CRESET	W2F2	(blue, green) = Pin(1,2)[2]

[1] The green wire connects to the header pin on JP1 that is closer to the edge of the printed circuit board.
[2] The switch connectors are bilateral, i.e., it does not matter how you plug them into the header.

7.1 MTJPRO11™ Wiring

The wiring diagram (Figure 5) indicates how to connect all the switches, sensors and actuators to the MTJPRO11™ printed circuit board. The top silkscreen of the MTJPRO11™ shown in Figure 6 indicates all the headers which connect to the IR emitters, detectors, bump sensors and motors on the body of the robot.
names the cables, specifies their lengths and how they are connected. A photograph (Figure 23) of the TJ-PRO™ cables illustrates the connections.

Table 13 Wiring Harnesses for the TJ-PRO™ Robot

Cable Name	From:	To:	Length:
CBATT	Battery	BATT connector/ MTJPRO11™	
CCHRGE	Charge Jack	CHARGE connector / MTJPRO11™	6.5 inches / 162.5 mm
CDWNRN	Download / Run switch	MODB connector / MTJPRO11™	3 inches / 75 mm
CFBCSW	Front center bump switch	FBCSW connector / MTJPRO11™	5.5 inches / 137.5 mm
CFBLSW	Front left bump switch	FBLSW connector / MTJPRO11™	4.5 inches / 112.5 mm
CFBRSW	Front right bump switch	FBRSW connector / MTJPRO11™	7 inches / 175 mm
CIRDLF	Left Analog IR Sensor	PE3 connector / MTJPRO11™	7 inches / 175 mm
CIRDRF	Right Analog IR Sensor	PE2 connector / MTJPRO11™	4.5 inches / 112.5 mm
CIREB	Back IR LED	Pins 1 and 2 IR LED output header / MTJPRO11™	6 inches / 150 mm
CIRELF	Left Front IR LED	Pins 3 and 4 IR LED output header / MTJPRO11™	3.5 inches / 87.5 mm
CIRERF	Right Front IR LED	Pins 5 and 6 IR LED output header / MTJPRO11™	3.5 inches / 87.5 mm
CPWR	Power switch	PWR connector / MTJPRO11™	5 inches / 125 mm
CPWRSV	Power switch	SERVO_PWR connector / MTJPRO11™	5 inches / 125 mm
CRBSW	Back bump switch	RBSW connector / MTJPRO11™	5 inches / 125 mm
CREDLED	Red LED	LED connector / MTJPRO11™	4 inches / 100 mm
CRESET	Reset switch	RESET connector / MTJPRO11™	3.5 inches / 87.5 mm

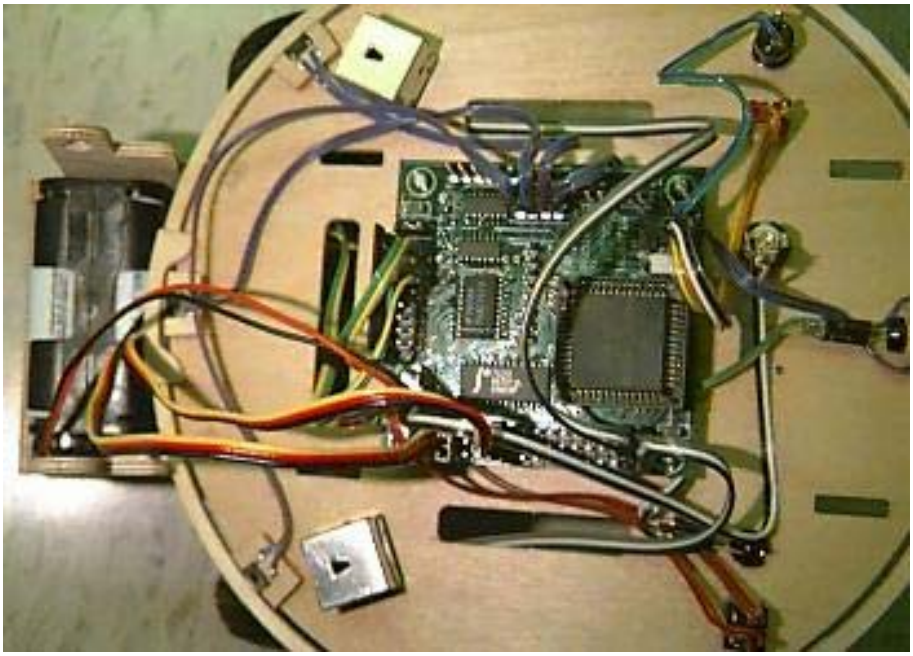


Figure 23 Sensor and actuator cabling of the TJ-PRO™ underneath the top plate. The TJ-PRO™ plate is resting upside down on top of the robot carriage. The front of the plate is to the left of the picture. The bright metal cubes are the IR detectors. The large IC is the MC68HC11 microprocessor.

7.2 Install Mode and Reset Switches

1. Pass the *Download/Run* toggle switch through the hole provided for it (Figure 9). 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 24. Cut the former 3.5 inches and the latter to 3 inches.

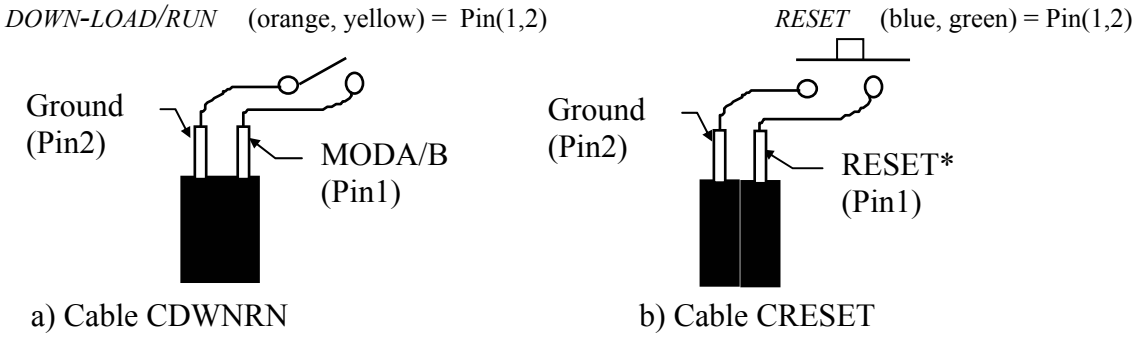
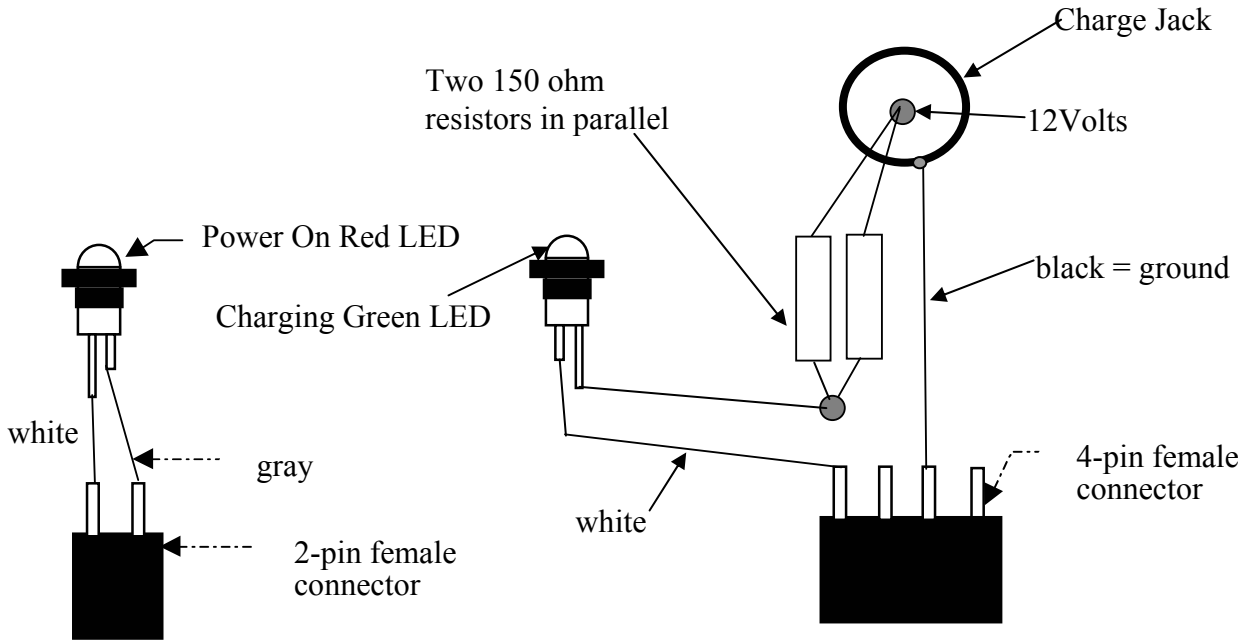


Figure 24 Connectors for the Download-Run and RESET switches.

The switches serve as controllable jumpers, so reversing pins 1 and 2 above does not change the function or cause any problems (Refer to Figure 9 for header connections).

7.3 Power- On LED and Recharge Jack

1. Push the black T1-3/4 LED mounting hardware snap-in clip into the hole provided for the *Power-On* LED (Figure 9). Insert the LED until it snaps into place. Place the black plastic ring over the back of the clip to lock the LED in place, if one is provided.
2. Push the black T1-3/4 LED mounting hardware snap-in clip into the hole provided for the green *Charging* LED (Figure 9). Insert the LED until it snaps into place. Place the black plastic ring over the back of the clip to lock the LED in place, if one is provided.



a) CREDLED, (white, black) = Pin(1,2) b) CCHARGE, (white, black) = Pin(1,3)

Figure 25 Cabling for a) the *Power-On* red LED and b) the *Charging* green LED and the recharge jack with power limiting series resistors.

3. Pass the recharge panel mount power jack through the hole provided (Figure 9). Thread the lock washer and nut on each. Tighten.
4. Wire the Red LED power-on indicator as illustrated in Figure 25 a). The white wire solders to the anode of the LED. Cut length of cable to 4 inches.
5. Cable the recharge jack as shown in in Figure 25 b). Cut wire to 6.5 inches. Wire two 150 ohm resistors in parallel by twisting and soldering their leads together at both ends. Solder one end of the parallel resistors to the external pin of the recharge jack that electrically connects to the pin inside the jack and the other end to the longer lead (anode) of the *Charging* green LED.
6. Solder the white wire of the CCHARGE cable to the shorter lead of the green LED. 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.

7.4 Battery Power Plug

The 9volt snap connector cable CBATT solders to a 4-pin connector as shown in Figure 26. This power connection is electrically, but not mechanically keyed. The red wire is pin 1. The cable is already cut to length.

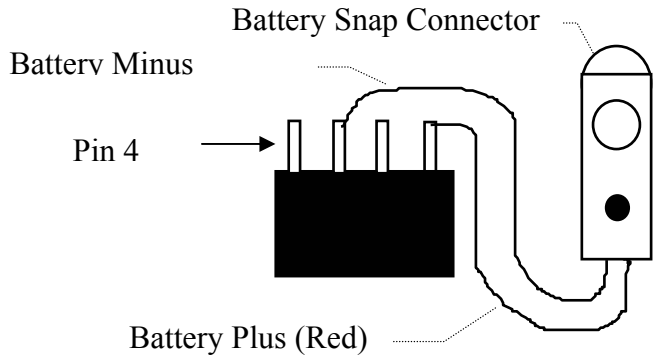


Figure 26 Battery pack snap connector cable CBATT, (red, black) = Pin(1,3) **.**

7.5 Connect the Power-On and Servo-Power Switch

1. Pass the *On/Off* DPDT toggle switch through the hole provided for it (Figure 9). Thread the lock washer and nut on each. Tighten.
2. Cut two (brown, red) cables of 5 inches each.
3. Tin and solder the cables to the DPDT switch as show in Figure 27.

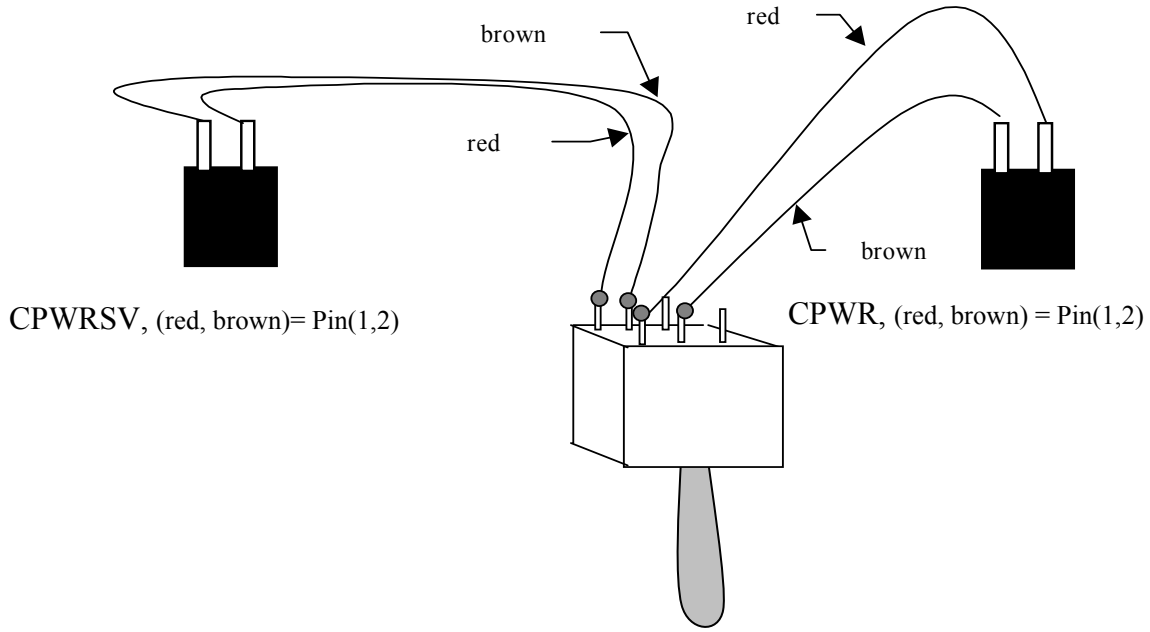


Figure 27 Wiring the Power-On and Servo-Power connectors to the DPDT switch.

Plug the connectors into the PWR and SERVO_PWR headers located on the circuit board by Figure 6.

7.6 Install Front and Back Bumper Switches

Insert the miniature tactile push button switches into the four slots provide for them around the periphery of the top plate (Figure 9). Orientation of the pins are important. From above the top plate you should see two pins attached to the same side of the switch (refer to Figure 28). The top surface of the switch is flush with the surface of the top plate. Be careful not to tilt the switch, keeping the button surface perpendicular to the surface of the plate to insure good contact with the bumper. For the following instructions, refer to Figure 6 for header locations and for cable lengths.

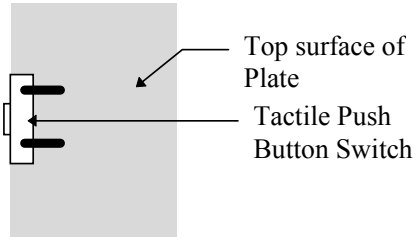


Figure 28. Pin orientation for bumper switches.

1. Attach the small push button switches to the plate with a small amount of glue. Glue three switches in the front and one in back, as indicated in the above instructions. No wire connections are made to the two pins on top of the plate.

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

2. Construct the four, 2-wire switch cables with 2-pin female connectors at one end and the other end soldered to the switch terminals (Blue, Violet). Cut cable lengths of 4.5 inches, 5.5 inches, 7 inches, 5 inches for headers FBLSW, FBCSW, FBRSW, and RBSW, respectively.

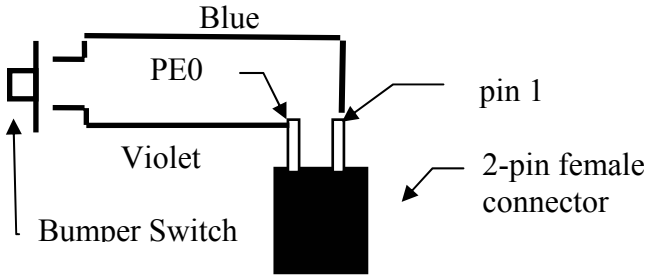


Figure 29 Two-pin female bumper connector and cable CRBSW, CFBCSW, CFBLSW and CFBRSW.

3. Plug the bump switch connectors into MTJPRO11™ male headers FBLSW, FBCSW, FBRSW, and RBSW. To determine the correct orientation of these connectors note that Pin 1 on these headers are closer to the center of the printed circuit board than pin 2.

7.7 Mount IR Emitters

Refer to Figure 30. Push the black T-1 ¾ LED mounting hardware snap-in clip into the two front and the rear eyelets (TJIRE20, Figure 10)provided for the IR emitters (Figure 11 b,c). Insert an LED into each eyelet until it snaps into place. Place about 8mm (1/3 inch) of shrink-wrap tubing over the back of the eyelet, completely covering it. Apply heat. As the shrink-wrap gets hot, use a pair of needle-nose pliers to squeeze it closed across the LED wires to form a seal against back lighting from the LED. Without a proper light seal the IR emitter will adversely affect IR Detector readings. The shrink-wrap will also lock the LED into place.

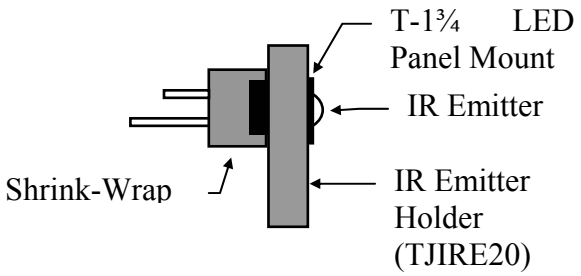


Figure 30 Mounting IR emitters into the IR emitter holders. In the above diagram, the black plastic T-1 ¾ panel mount pushes in from right to left. The LED is pushed in from left to right until it snaps into the flared part of the panel mount. The shrink-wrap slides onto the panel mount from the rear and locks the LED into place and seals the back when heat is applied and the shrink-wrap is pinched together while hot.

7.8 Wire IR Emitters

Construct the three, 2-wire IR emitter cables with 2-pin female connectors at both ends. (green, yellow). Cut two to 3.5 inches and one, the rear IRE connecting cable, to 7 inches.

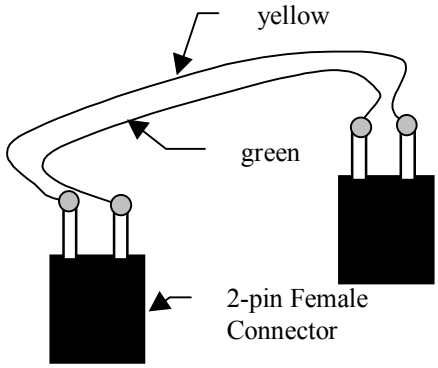


Figure 31 IR Emitter Cables, CIREB, CIRELF and CIRERF, (yellow, green) = (anode, cathode).

7.9 Wire and Install IR Detectors

The two IR detectors (MIR58Y40A) mount on the underside of the top plate with a simple press fit. 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.

For the right IR detector cut a 4.5 inch, 3-wire cable with three hole female connectors at each end (Figure 32). Color code: (Black, White, Gray) = (Ground, 5V, Signal). For the left IR detector cut a 7 inch cable. Connect these cables into the three pins of the IR detector at one end and the appropriate male header on the MTJPRO11™ board indicated by the top silkscreen (Figure 6).

One end of these cables fit into the IR detector cans. The black wire next to the edge of the can. The other end connects into the IRDT male headers on the MTSX01 board. On the MTSX01 assembly manual the Ground pins of each IRDT is specified. The Ground pin corresponds to the Black wire connector hole.

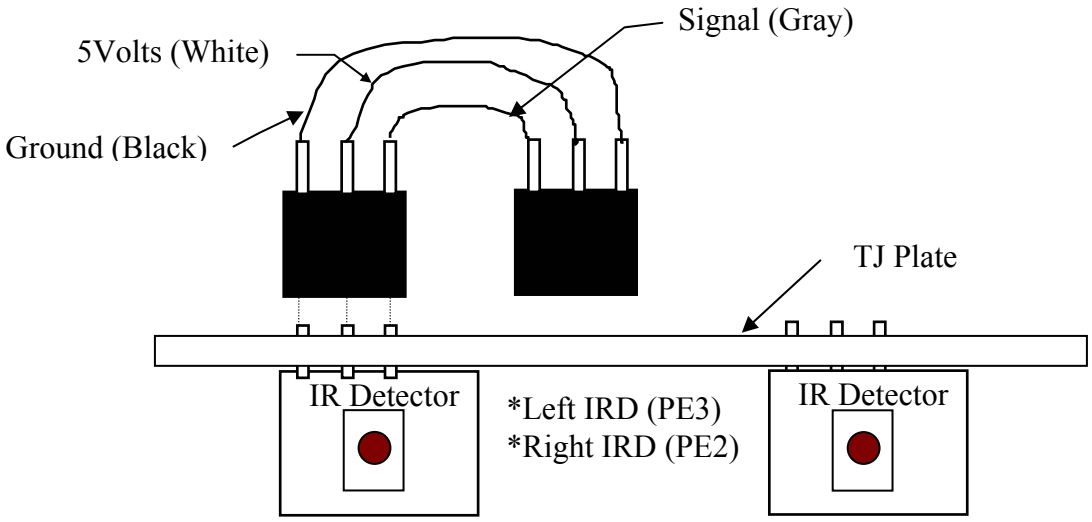


Figure 32 IR Detector Cables CIRDLF and CIRDRF. On the Right IR Detector, in the left of the diagram, the black ground wire is outermost, while on the Left IR Detector, on the right of the diagram, the black ground wire is innermost.

8 MOUNT SERVO HORNS ON WHEELS

The servo mounting hardware comes together in a package.

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, inside the horn, before gluing or screwing the servo horn onto the wheel frame. This screw can be tightened or loosened by a small screwdriver whose blade will fit through the hole in the center hub of the wheel.

***Wheel Assembly Alternative 1**: (Recommended)*

1. *Center and glue a 1 inch washer on the 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 washer center hole.*
3. *Insert the horn center screw into the horn.*
4. *Now center and glue the horn onto the washer. The horn screw is now trapped by the wheel and cannot fall out. The horn can be attached and detached from the servo by means of a small jewelers screwdriver inserted through the wheel shaft hole.*

***Wheel Assembly Alternative 2**:*
Mount the servo horns (Figure 33) onto the wheels with two small horn screws as shown in Figure 34. 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 are self-threading through 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.

***Wheel Assembly Alternative 2**: The wheel can be bonded to the horn with Zap-A-Gap™ adhesive.*

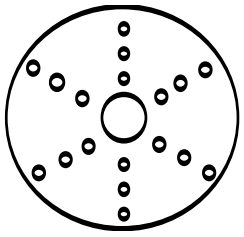


Figure 33 Round servo horn.

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

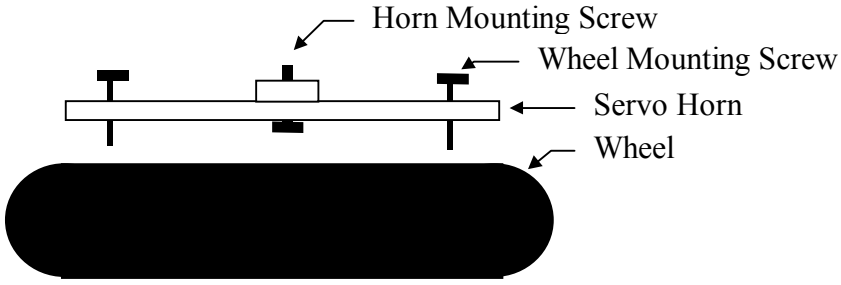


Figure 34 How to mount a servo horn onto a wheel. Be sure the horn mounting screw is placed into the horn before fastening the horn to the wheel with the other two screws.

9 MOUNT BATTERY PACK

1. Load the six 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-PRO™. DO NOT USE ALKALINE OR OTHER BATTERY TYPES WHICH WILL DESTROY THE ROBOT ELECTRONICS.

2. Snap the battery power cable on.

3. Assuming the MTJPRO11™ board has been tested, plug the battery power connector into the male power header BATT. Refer to **Figure 6** for location of the header. The plus side of the header is pin 1, which is marked by a square.

4. Test IR and bumper Sensors.

If the batteries are fully charged and/or TJ-PRO™ is connected to a charger, then run a demo program as explained in a *Read Me* file in *TJ-PRO™'s* software distribution disk. You can use the demo program to test the IR and bump sensors. Play with TJ-PRO™ for a while and observe how TJ-PRO™ perceives the world. The understanding gained by this exercise is invaluable for writing TJ-PRO™ programs that work.

10 COMPLETE THE ASSEMBLY

You have now completely assembled TJ-PRO™ and tested the electronics. Now its time to program him to do things!

Share with other TJ-PRO™ owners your experiences and programs via THE NET. Check
http://www.mekatronix.com
for details.

Enjoy!