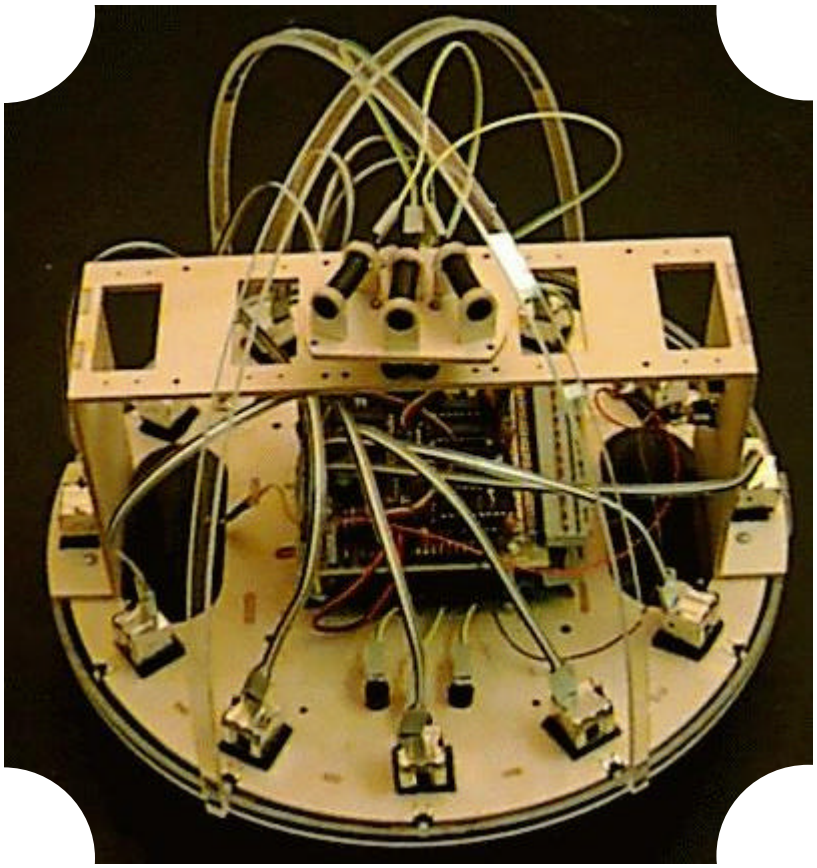
TALRIK^{II} ASSEMBLY MANUAL

by

Keith L. Doty



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MANIFESTO

MEKATRONIX™ espouse 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!

Disclaimer

While MEKATRONIX™ has placed considerable effort into making these instructions accurate, MEKATRONIX™ does not warrant the results and the user assumes the risks to equipment and person that are involved.

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1. ASSEMBLING MEKATRONIX PRINTED CIRCUIT BOARDS

1.1 Skill Level

Assembling the electronic printed circuit boards in this kit requires the ability to solder and modest manual dexterity. If you are inexperienced in soldering or would like a quick review of soldering techniques, refer to *Soldering Note (http://www.mekatronix.com/manuals)* for soldering tips. If you feel uncomfortable with assembling a printed circuit board you might want to consider purchasing one assembled and tested from the factory.

1.2 Personal Safety

Practice safe assembly techniques. When assembling printed circuit boards, be sure to work in a well-ventilated area and wear eye protection. If you have not been instructed in PCB assembly techniques, you should seek assistance from an experienced technician.

1.3 Component Protection

Integrated circuits (IC) and other semiconductor devices are static sensitive. One can easily destroy an IC with static discharge. To protect against static discharge from destroying semiconductor devices, you might want to wear a wrist grounding strap while assembling your board. Axial and radial leaded components, such as resistors and capacitors, while rugged, can be damaged by careless handling. A common failure results when the leads are bent too much and their connection to the component is weakened or broken. Pins on headers and connectors occasionally get bent. To restore the pin to proper function, careful straightening them with needle nose pliers should do the trick, but bending a pin certainly does not improve the pin's performance and can lead to failure.

1.4 Questions and Further Information on the MRSX01

For technical support email all questions to mek_tech@orlandonet.magicnet.net **.**

1.5 Equipment Needed

The following tools and supplies are needed to complete this board. Make sure you have them handy before you start work.

1. Soldering iron
2. 60/40 rosin core 0.032 dia. electronics solder (do not use an acid core solder or acid flux on the board)
3. Diagonal cutters
4. Needle nose pliers
5. Small Phillips screwdriver

6. Wire stripers
7. Sand paper
8. Wood finishing products
9. Fast drying wood model glue

2. TALRIK^{II} TECHNICAL SPECIFICATIONS

The following paragraphs provide a brief description of TALRIK™'s technical characteristics.

2.1 Mechanical Structure

1. All of TALRIK™'s body parts are made from beautiful, strong, durable, 1/8 inch, 5-ply, birch model airplane plywood.
2. TALRIK™ fits into a right circular cylinder 10inches in diameter by 10 inches high. (Volume approximately 785 cubic inches or 0.45 cubic feet)

2.2 Power Requirements

1. Eight AA rechargeable Nickel-Cadmium batteries (sold separately) (ENERGIZER™ or EVEREADY™ recommended), 600 ma-hr, 7.2 volts (Discharged) to 9.6 volts (Nominal Charge).

WARNING!

USE ONLY NiCd BATTERIES FOR TALRIK™. DO NOT USE ALKALINE OR OTHER BATTERY TYPES WHICH WILL DESTROY THE ROBOT ELECTRONICS.

2. Recharger, 12 volts D.C. rated greater than or equal to 200ma (Sold separately).
3. The voltage generated by the eight pack will destroy the control electronics of MS410 and MS455 servos after a few minutes. Therefore, MS410 and MS455 servo electronics must be driven by no more than six NiCd cells. A battery pack tap at six NiCd cells connects to the Servo_PW pin-1 header on the MRSX01 to provide the correct power for the servo electronics on the TALRIK.
4. The battery voltage cable from the eight-pack branches to feed the MRC11 and MRSX01 separately. One branch goes through a power diode (1N4001), wired in-line, and connects to the 4-pin MRC11 male header BATT. The other branch (no diode) goes to the 4-pin male header BATTERY on the MRSX01. This power cabling prevents large motor current demands from dropping the regulated 5 volt electronics power grid.

2.3 Actuation

A gearhead DC motor drives each wheel. The characteristics are

1. Battery Voltage input to the motors,

2. 100 -120 ma under load, 80 ma no-load,
3. 1.5 revolutions/sec at 9.6 volts (full battery charge). Speed decreases as the voltage drops.

Pulse Width Modulation (PWM) on PA5 controls the right wheel motor (Motor0) and PWM on PA6 controls the left wheel motor (Motor1). The directions of the motors are controlled by two bits in the MMR register, which is discussed in Section 2.6.

Pulse Width Modulation (PWM) on PA4 controls one servo (SERVO1) and PWM on PA7 controls another servo (SERVO2). The servos have a turning range of approximately 180 degrees. The pan head servo on the TALRIK bridge is connected to SERVO1. You can add another bridge servo without any further circuitry. Simply connect the servo input to the connector. If both servos are driven at the same time while the robot is moving, the batteries can be pulled down enough by the current surges of changing motor speeds to actually reset the processor. Judicious operation of the motors can avoid this problem.

PA3 can drive a piezo speaker connected to the two pin male header PEIZO.

2.4 MRC11 Robot Controller

The MEKATRONIX Robot Controller, MRC11, enables execution of machine intelligence programs on TALRIK. The MRC11 comes with

1. Motorola MC68HC11 processor,
2. Two 32KB Memory sockets for either RAM or ROM, 64KB total,
3. 5 Volt regulator,
4. Low voltage inhibit reset circuit,
5. Power on LED,
6. 60-Pin Male Header processor / IO bus.

2.5 Sensor Expansion Board

The MRSX01 mates with the MRC11 to provide extensive sensor and control capabilities. The two board stack, MRSX01 and MRC11, furnishes the circuitry that supports all the sensory, motor and cognitive functions for the TALRIK autonomous mobile robot.

The MRSX01 features:

1. Twenty Analog Inputs,
2. Two Digital Inputs,
3. Eight Memory Mapped Digital Outputs
4. Four Memory Addressable Input Device Selects,
5. Three Memory Addressable Output Device Selects,
6. High Memory Select(Address >= b"1111 1111 1011 1xxx"),

7. Two Pulse Width Modulated Outputs for Motor Control,
8. Two Pulse Width Modulated Outputs for Servo Control,
9. One Pulse Width Modulated Output assigned to an optional piezo speaker,
10. A Battery charge circuit (100ma at 12 volts-DC),
11. Battery Voltage Sensor (Analog Input),
12. Charge Current Sensor (Analog Input),
13. Front Bumper Sensor (Analog Input),
14. Rear Bumper Sensor (Analog Input),
15. Forty KHz square wave generator,
16. Processor Data Bus and Ports brought out to a 60 pin Header
17. Battery-Power-In and Battery-Power-Out Headers

Fourteen analog inputs lead out to 3-pin male headers: (pin-1,pin-2, pin-3)=(Signal, 5 Volts, Ground). TALRIK™ uses 12 of these 14 analog inputs to sense IR detector signals. The other two can be used for additional IR or other analog sensors requiring 3-pin connections. Six other analog inputs terminate on 2-pin male headers:(Signal, 5Volts). TALRIK™ employs these 6 analog inputs for light detection with photoresistors.

2.6 IO Memory Addresses and Sensor Selection

The MRSX01 generates four Input Register Select signals (IS0, IS1, IS2, IS3) and four Output Register Select signals (OS0, OS1, OS2, OS3). The Memory Addresses of these signals and their assigned function appears in Table 1. Only OS0 and OS1 have predefined functions. The others can be used to expand the sensory and actuation capability of the TALRIK robot even further. OS1 controls the digital outputs DIG_OUT[1..8] that drive the IR emitters through current limiting resistors. OS0 controls the Multiplexer/Motor_Direction Register (MMR) whose eight bits from the most significant to the least significant are

MMR

7	6	5	4	3	2	1	0
MOTOR1	MOTOR0	OUT1	SEL4	SEL3	SEL2	SEL1	SEL0

OUT1 is simply a Digital Output Bit that appears on IOHEADER[2]. MOTOR0 controls the direction of the right motor and MOTOR1 controls the direction of the left motor. The five select lines SEL0 to SEL4 control the three 8-to-1 Analog Multiplexers that feed into PE0 and PE1.

Table 2 indicates how the SEL bits select the multiplexer inputs. Table 3 indicates which sensor input is selected by the SEL bits and the corresponding A/D_Channel/PortE_Pin on which the sensor data appears. Observe that the 8-pin header ANALOG provides six unallocated analog inputs to PE1 as well as ground (ANALOG[7]) and power (ANALOG[8]). The ANALOG header allows you to readily expand to six more analog sensor inputs.

Table 1 TALRIK IO Memory Addresses

IO Enable Line	Memory Address	Function
OS0	FFB8	Load MMR from Processor Data Bus (PortC).
IS0	FFB8	Input Select 0: IOHEADER[Pin 4]
OS1	FFB9	IR LED DRIVER
IS1	FFB9	Input Select 1: IOHEADER[Pin 5]
OS2	FFBA	Output Select 2: IOHEADER[Pin 3]
IS2	FFBA	Input Select 2: IOHEADER[Pin 6]
OS3	FFBB	Output Select 3: IDC60 Header Pin 55
IS3	FFBB	Input Select 3: IDC60 Header Pin 56

Table 2 Multiplexer Control with MMR SEL Bits

SEL4	SEL3	SEL2	SEL1	SEL0	Enables Multiplexer Input
1	0	0	0	0	MUX0, MUX16
1	0	0	0	1	MUX1, MUX17
1	0	0	1	0	MUX2, MUX18
1	0	0	1	1	MUX3, MUX19
1	0	1	0	0	MUX4, MUX20
1	0	1	0	1	MUX5, MUX21
1	0	1	1	0	MUX6, MUX22
1	0	1	1	1	MUX7, MUX23
0	1	0	0	0	MUX8
0	1	0	0	1	MUX9
0	1	0	1	0	MUX10
0	1	0	1	1	MUX11
0	1	1	0	0	MUX12
0	1	1	0	1	MUX13
0	1	1	1	0	MUX14
0	1	1	1	1	MUX15

Table 3 Sensors Selected by MMR SEL Bits

SEL4	SEL3	SEL2	SEL1	SEL0	Sensor (AN0/PE0)	Sensor (AN1/PE1)
1	0	0	0	0	Charge Voltage Detect	Rear Bumper
1	0	0	0	1	Battery Power Level	Front Bumper
1	0	0	1	0	IRDT7	ANALOG[1]
1	0	0	1	1	IRDT8	ANALOG[2]
1	0	1	0	0	IRDT9	ANALOG[3]
1	0	1	0	1	IRDT10	ANALOG[4]
1	0	1	1	0	IRDT11	ANALOG[5]
1	0	1	1	1	IRDT12	ANALOG[6]
0	1	0	0	0	IRDT13 (Optional)	
0	1	0	0	1	IRDT14 (Optional)	
0	1	0	1	0	CDS1	
0	1	0	1	1	CDS2	
0	1	1	0	0	CDS3	
0	1	1	0	1	CDS4	
0	1	1	1	0	CDS5	
0	1	1	1	1	CDS6	

The first six IRDT input sensor feed directly into the A/D channels AN2 through AN7 on PE2 to PE7. For convenience this information appears below in tabular form:

IRDT6	IRDT5	IRDT4	IRDT3	IRDT2	IRDT1
AN7/PE7	AN6/PE6	AN5/PE5	AN4/PE4	AN3/PE3	AN2/PE2

2.7 Basic Sensor Suite

TALRIK senses its environment with

1. Twelve IR Emitters, wavelength equals 940nm,
2. Twelve IR Detectors for 40KHz modulated 940nm IR,
3. Five Front Bumper Momentary Tactile Switches,
4. Five Rear Bumper Momentary Tactile Switches,
5. Six CdS Photoresistors.

The hardware information required for software access of these sensory inputs is provided in Section 2.6.

2.8 Sensor Expansion

Up to two MSCC11 boards (optional, not included in base kit) mount on the bridge. You can establish communications between the MSCC11 and the MRC11 via either the Serial Peripheral Interface or the Serial Communications Interface. Each MSCC11 provides TALRIK™ with complete MC68HC11E2 processor functionality, for example, 8 analog IO channels, 8 digital outputs, 8 digital inputs, 5 pulse-width modulation controls, and four input signal captures among others. This functionality permits extensive sensory expansion.

2.9 Switches and LED Power-On Indicator

1. Reset push button
2. Toggle switch: Download Program and Run Program
3. Toggle switch: Off-On,
4. Power on Indicator on TALRIK™ Body

2.10 System Support Software

TALRIK programs can be written in MC68HC11 Assembly Language, Interactive C(IC), C, or BASIC.

1. Sensor and motor routines provided in C and S19 files.
2. PCBUG11 freeware for downloading Motorola S19 files.
3. Freeware MC68HC11 Assembly Language.

Freeware version of IC and BASIC exist, but they cannot take full advantage of all of TALRIK's capabilities. Commercial versions of IC and BASIC are also available.

Separate purchase of a commercial C compiler is available from MEKATRONIX. A high speed RAM Downloader (115 Kbaud) that bypasses the 9.6Kbaud PCBUG11 download rate, speeds program development considerably and is also available from MEKATRONIX™.

2.11 Applications Software

MEKATRONIX™ provides a C program that allows TALRIK to explore his environment and avoid bumping into things, most of the time! If TALRIK does bump into something, his bumpers tell him and he moves away.

2.12 Serial Communication Hardware

TALRIK's serial communications require logic signals (5 volts and Ground). Downloading your software applications to TALRIK from a PC requires voltage conversion of the RS232C levels to the TALRIK logic levels. If you do not have this capability already, the additional purchase of an MB2325 communications board and a 6-wire RS-232C communications cable will solve the problem. 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.

3. INITIAL CONSIDERATONS

3.1 What is in your TALRIK^{II} ™ Expert Kit?

The contents of your TALRIK^{II}™ expert kit are described in Table 4 and Table 5.

Table 4 TALRIK^{II} Expert Kit

Part	Quantity
Floating Ring Bumper	1
Rear Caster	1
Robot Controller Board Kit (MRC11)	1
Robot Sensor Board Kit (MRSX01)	1
Servos	3
TALRIK Kit Bag	1
TALRIK Plywood Body	1
Wheels	2

Table 5 TALRIK^{II} Kit Bag

Component	Quantity
IR Detectors	12
IR LEDs	12
LED Mounts	22
Bump Switches	10
Red LED	1
Green LED	1
Velcro Tape	175mm (7")
Velcro Strapping	225mm (9")
Toggle Switches	2
Reset Button	1
Charge Jack	1
5/8" 4-40 Screws	4
1.5" 4-40 Screws	4
1/2" 4-40 Screws	2
# 4 Nuts	26
# 4 Lock Washers	14
Right Angle Plastic Tab	50mm (2")
IDC Strain relief	2
IDC Female	2
IDC Snap-on	2
9V Battery connector	1
CdS Cells	6
Shrink Wrap 3M MW 1/4"	150mm (6")
Wire, 64 pin	900mm (3')
Battery Holder	1
Power Diode	1
Single Row Female Header	6 (6x36pins)
Single Row Male Header	1/2 (18 pins)

3.2 Circuit Board Assembly

Assemble and test the MRC11 circuit board first (Figure 1). Assemble and test the MRSX01 (Figure 3). Stack the MRC11 and the MRSX01 as instructed on page. The circuit diagrams, their layouts (Figure 2 and Figure 4) and parts lists (Table 7 and Table **9**) are provided to facilitate assembly.

Caution: *Only solder the right-angle, 60 pin headers on the MRC11 and MRSX01 with the IDC (Insulation Displacement Connector) already plugged into the header. This technique insures enough spacing between the pcb and male header for the IDC to fit.*

3.2.1 The MRC11

The controller reset header, in the upper left of the pcb, sits next to the mode control inputs MOD_A and MOD_B. On TALRIK™, reset is wired to te RESET push button switch, MOD_A is jumpered to ground, and MOD_B to the Download/Run toggle switch. The right angle header on the 60 pin jumper J1 connects, via

a ribbon cable, to the corresponding right angle male header on the MRSX01. The Serial Peripheral Interface (SPI) connector on the right edge of the MRC11 board provides access to the high speed serial facility on the MC68HC11. The Serial Communications Interface (SCI) brings logic-level (5v-Ground) asynchronous serial communication signals to the MEKATRONIX™ MB2325 serial communications interface board through a MEKATRONIX™ 6-wire cable. The MB2325 connects to a PC COM port, either with a 25 pin RS232C cable or directly plugs into the PC COM connector. Configured in this way the MRC11 board can communicate with your PC using PCBUG11.

3.2.2 The MRSX01

The MRSX01 serves as a general purpose Robot sensor board. The MRSX01 mates with the MRC11 controller to form the complete "neural" capability of the TALRIK™. In Figure 4 the fourteen, 3-pin male headers for the IR detectors along the top edge. The 60-pin male header J1, along the bottom edge of the board, attaches to the computer bus. The 2-pin male headers for the six CDS cells line up along the right side of the board. The charge circuit connector, the battery and servo power connectors, are in the upper left. Along the left side, just below the power connectors, are the motor and servo connectors. Below them you find the digital output enables and the 40 KHz jumper.

***Caution**: Some of TALRIK™'s electronic components are static sensitive. Do not touch these parts without being properly grounded. Static discharge can destroy them.*

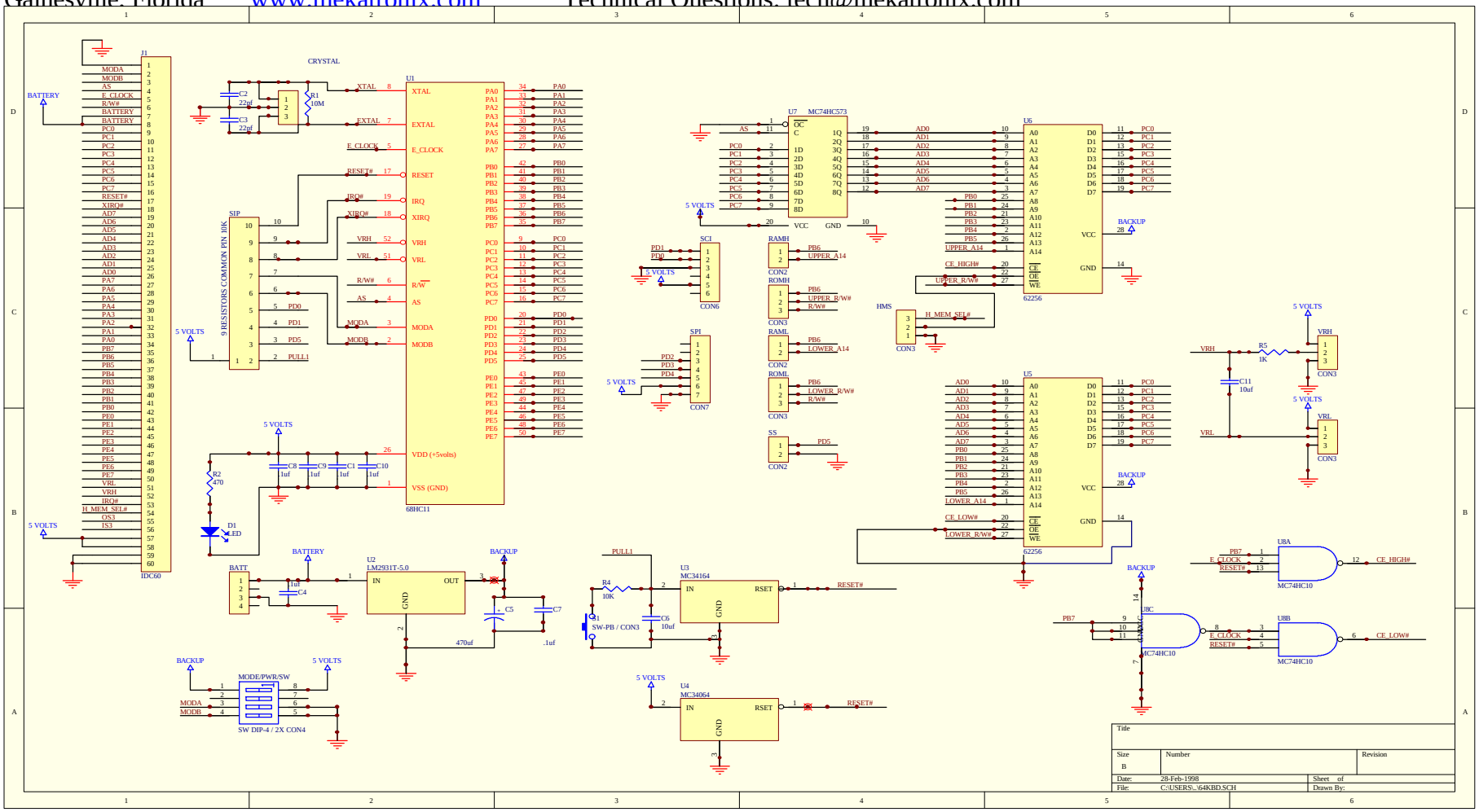

Figure 1 MRC11 circuit board. The dip-switch is not used in TALRIK. The dip-switch connections connect to TALRIK's switches.

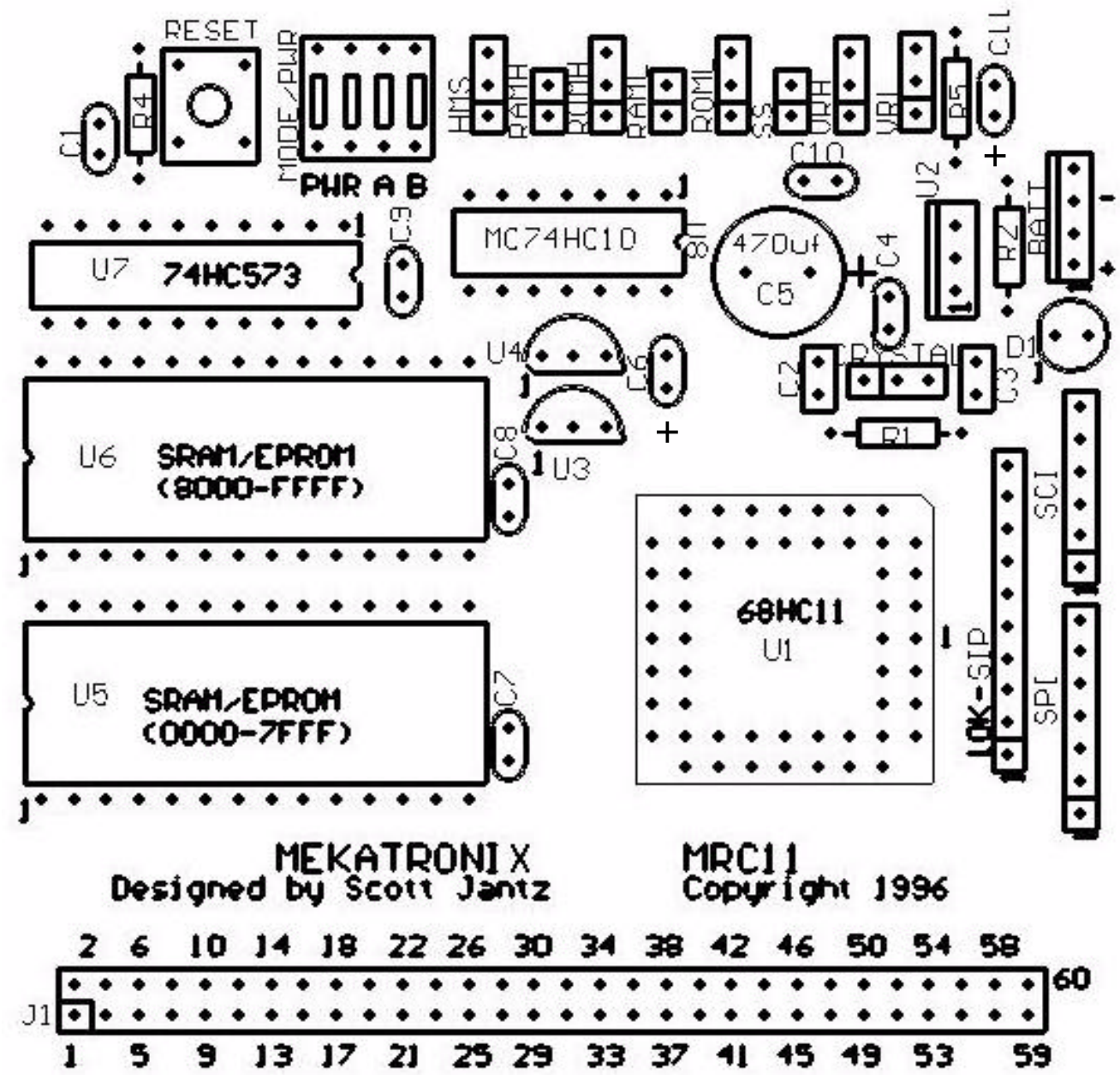

Figure 2 The MRC11 offers an MC68HC11 processor with 64KBytes of RAM/ROM expansion.

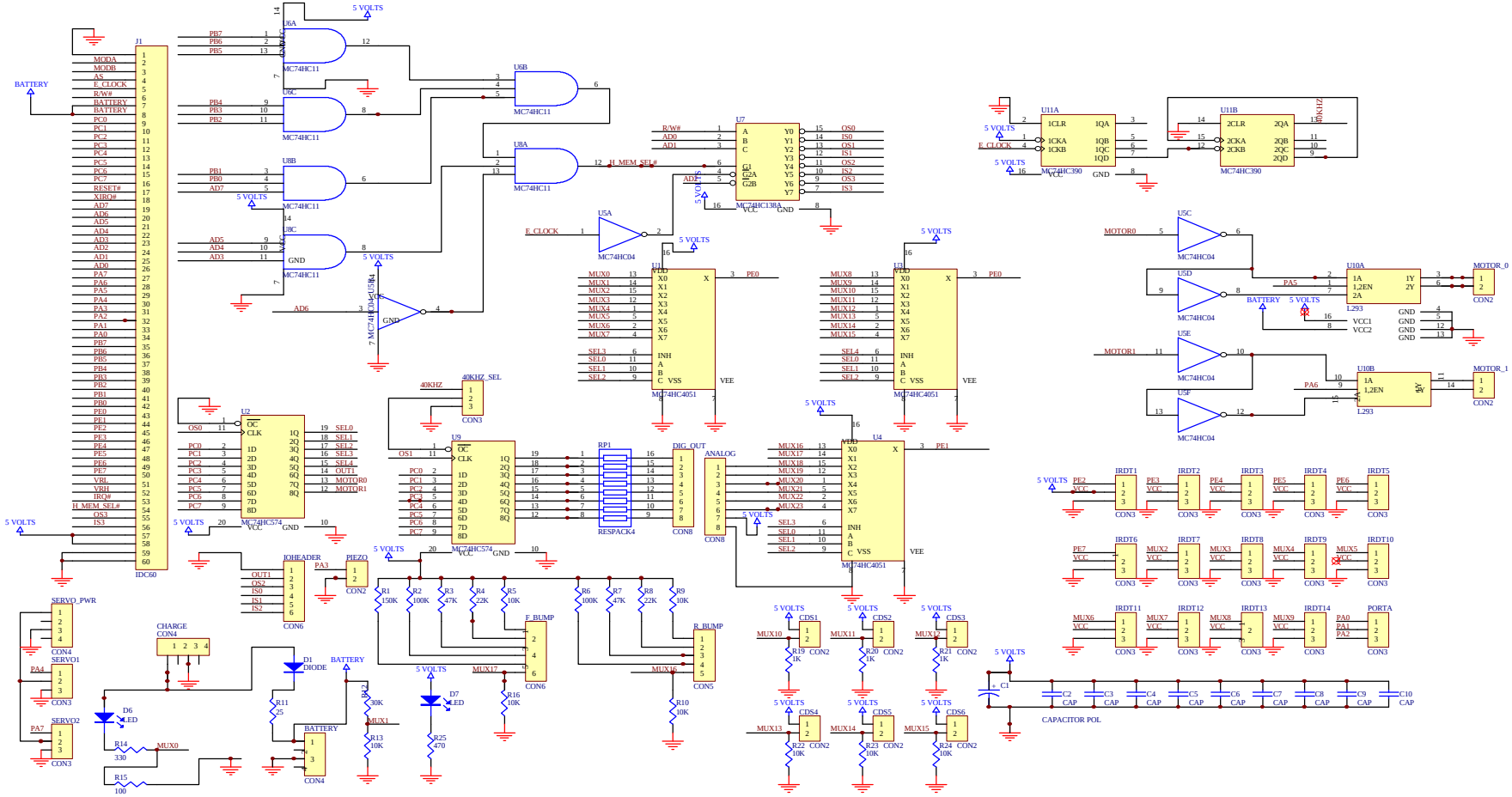

Figure 3 MRSX01 circuit diagram. Elements indicated by CON*j* are connectors with *j* pins.

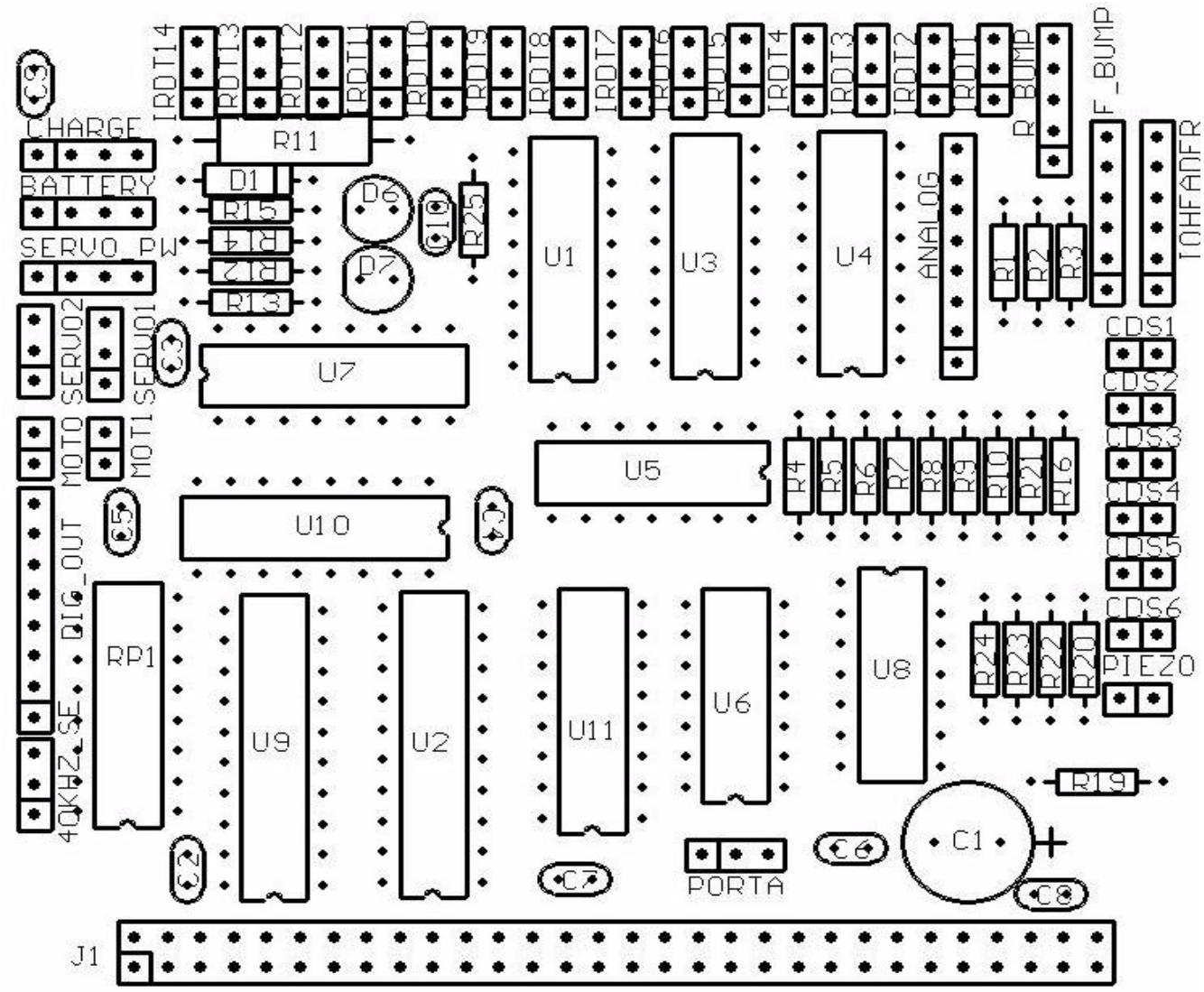

Figure 4 This layout of the MRSX01 locates all the sensor connectors. Pin one of the connectors is designated by a box around the pad. Two pin connectors on this board serve non-polarized devices, so pin number one is irrelevent.

Table 6 Bill-of-Materials for the MRC11 Robot Controller

Qty	Designator	Value	Description
0	(C2 C3)	(22pf)	(CRYSTAL LOAD CAPACITORS: Not included. Not required by the ceramic resonator which replaces the crystal circuit.)
0	(MODE/PWR/SW)	(SW DIP-4 / 2X CON4)	(MODE AND POWER SAVE DIP SWITCH FOOTPAD Switches not included)
0	(S1)	(SW-PB / CON3)	(RESET PUSH BUTTON FOOTPAD Switch not included)
1	BATT	CON4	4-PIN MALE BATTERY HEADER
6	C1 C4 C7 C8 C9 C10	0.1µf	BYPASS CAP
1	C5	470uf	POLARIZED FILTER CAP
2	C6 C11	10µf	POLARIZED TANTALUM CAP
1	D1	LED	VISIBLE LED
5	HMS ROMH ROML VRH VRL	3-PIN MALE HEADER =CON3	JUMPERS TO SELECT RAM OR ROM IN LOW MEMORY
1	J1	IDC60	60 PIN IDC HEADER
1	R1	10MΩ	CRYSTAL LOAD RESISTOR
1	R2	470Ω	RESISTOR, ¼ WATT
1	R4	10KΩ	RESISTOR, ¼ WATT
1	R5	1KΩ	RESISTOR, ¼ WATT
3	RAMH RAML SS	2-PIN MALE HEADER =CON2	JUMPER TO SELECT RAM OR ROM IN HIGH MEMORY, SLAVE SELECT JUMPER
1	SCI	6-PIN MALE HEADER =CON6	5 VOLT RS232 CONNECTOR
1	SIP	9 X 10K SIP	9 RESISTORS COMMON PIN 10K
1	SPI	7-PIN MALE HEADER =CON7	SYNCHRONOUS SERIAL PERIPHERAL INTERFACE HEADER
1	U1	68HC11	MC68HC11 MICROCONTROLLER
1	U2	LM2931T-5.0	5 VOLT REGULATOR
1	U3	MC34164	POWER ON RESET
1	U4	MC34064	LOW VOLTAGE INHIBIT
2	U5 U6	62256	MEMORY 32K SRAM OR ROM
1	U7	MC74HC573	74HC573 ADDRESS LATCH
1	U8	MC74HC10	74HC10 TRIPLE INPUT NAND
1	X1	8 MHZ	CERAMIC RESONATOR

Table 7 Parts List for the MRC11 Robot Controller

Designator	Value	Description
BATT	CON4	4-PIN MALE BATTERY HEADER
C 1	0.1µf	BYPASS CAP
(C2 C3)	(22pf)	(CRYSTAL LOAD CAPACITORS: Not included. Not required by the ceramic resonator which replaces the crystal circuit.)
C 4	0.1µf	BYPASS CAP
C 5	470uf	POLARIZED ELECTROLYTIC FILTER CAPACITOR
C 6	10µf	POLARIZED TANTALUM CAPACITOR
C 7	0.1µf	BYPASS CAP
C 8	0.1µf	BYPASS CAP
C 9	0.1µf	BYPASS CAP
C10	0.1µf	BYPASS CAP
C11	10 µf	POLARIZED TANTALUM CAP
D1	LED	VISIBLE LED
HMS	CON3	3-PIN MALE JUMPER HEADER FOR HIGH MEMORY SELECT
J1	IDC60	60 PIN IDC HEADER
(MODE/PWR/SW)	(SW DIP-4 /2X CON4)	(MODE AND POWER SAVE DIP SWITCH FOOTPAD Switch not included)
R1	10MΩ	CERAMIC LOAD RESISTOR
R2	470Ω	RESISTOR, ¼ WATT
R4	10KΩ	RESISTOR, ¼ WATT
R5	1KΩ	RESISTOR, ¼ WATT
RAMH	CON2	2-PIN MALE JUMPER HEADER FOR SELECTING HIGH RAM
RAML	CON2	2-PIN MALE JUMPER HEADER FOR SELECTING LOW RAM
ROMH	CON3	3-PIN MALE JUMPER HEADER FOR SELECTING HIGH ROM
ROML	3CON3	3-PIN MALE JUMPER HEADER FOR SELECTING LOW ROM
(S1)	(SW-PB / CON3)	(RESET PUSH BUTTON FOOTPAD Switch not included)
SCI	CON6	6-PIN MALE SERIAL HEADER: 5 VOLT RS232 CONNECTOR
SIP	9 X 10K SIP	9 RESISTORS COMMON PIN 10K
SPI	CON7	7-PIN MALE SYNCHRONOUS SERIAL PERIPHERAL INTERFACE HEADER
SS	2-PIN MALE HEADER =CON2	JUMPER HEADER FOR SPI SLAVE SELECT
U1	68HC11	MC68HC11 MICROCONTROLLER
U2	LM2931T-5.0	5 VOLT REGULATOR
U3	MC34164	POWER ON RESET
U4	MC34064	LOW VOLTAGE INHIBIT
U5	62256	MEMORY 32K SRAM OR ROM
U6	62256	MEMORY 32K SRAM OR ROM
U7	MC74HC573	74HC573 ADDRESS LATCH
U8	MC74HC10	74HC10 TRIPLE INPUT NAND
VRH	CON3	JUMPER HEADER FOR HIGH ANALOG REF. VOLT
VRL	CON3	JUMPER HEADER FOR LOW ANALOG REF. VOLT
X1	8 MHZ	CERAMIC RESONATOR

Table 8 Parts List for the MRSXO1, Robot Sensor Expansion Board.

Qty	Designator	Value	Description
9	C2 C3 C4 C5 C6 C7C8 C9 C10	0.1µf	BYPASS CAP
1	R 1	150KΩ	RESISTOR, ¼ WATT
2	R 2 R6	100KΩ	RESISTOR, ¼ WATT
2	R 4 R8	22KΩ	RESISTOR, ¼ WATT
8	R 9 R10 R13 R16 R5 R22 R23 R24	10KΩ	RESISTOR, ¼ WATT
1	R11	25Ω	RESISTOR, ½ WATT
1	R12	33KΩ	RESISTOR, ¼ WATT
1	R14	300Ω	RESISTOR, ¼ WATT
1	R15	100Ω	RESISTOR, ¼ WATT
3	R19 R20 R21	1KΩ	RESISTOR, ¼ WATT
1	R25	470Ω	RESISTOR, ¼ WATT
8	RP1	470Ω	IR CURRENT LIMITING RESISTORS, ¼ WATT
1	C1	470µf	POLARIZED ELECTROLYTIC CAPACITOR
2	R3 R7	47KΩ	RESISTOR, ¼ WATT
6	CDS1 CDS2 CDS3 CDS4 CDS5 CDS6	CON2	2-PIN MALE HEADER CdS PHOTORESISTORS
2	MOTOR_0 & 1	CON2	MOTOR 1 AND MOTOR2 HEADERS
1	PIEZO	CON2	PIEZO SPEAKER HEADER
1	40KHZ_SEL	CON3	3-PIN MALE JUMPER HEADERS
14	IRDT1 TO IRDT14	CON3	IR DETECTOR HEADERS
1	PORTA	CON3	HEADERS FOR PA0, PA1, PA2 OF PORTA
2	SERVO1 SERVO2	CON3	3-PIN MALE SERVO1 & SERVO2 HEADERS
3	BATTERY	CON4	4-PIN MALE BATTERY CONNECTOR
1	CHARGE	CON4	CHARGER CONNECTOR
1	SERVO_PWR	CON4	SERVO POWER CONNECTOR
1	R_BUMP	CON5	5-PIN MALE HEADERS RIGHT BUMPER CONNECTOR
1	F_BUMP	CON6	6-PIN MALE HEADERS FRONT BUMPER CONNECTOR
1	IOHEADER	CON6	BYTE INPUT-OUTPUT HEADER
1	ANALOG	CON8	8-PIN MALE HEADERS, ANALOG INPUTS
1	DIG_OUT	CON8	IR LED OUPUT
1	D1	DIODE	POWER DIODE
1	J1	IDC60	60 PIN IDC HEADER
1	U10	74410NE	QUAD HALF-H MOTOR DRIVER
2	D6 D7	LED	CHARGE LED
3	U1 U3 U4	MC74HC4051	ANALOG 8:1 MUX
2	U2 U9	MC74HC574	OCTAL D-FF SENSOR LATCH
1	U5	MC74HC04	HEX INVERTER
2	U6 U8	MC74HC11	TRIPLE INPUT AND
1	U7	MC74HC138A	3:8 DECODER
1	U11	MC74HC390	DIVIDE BY 2 & 5 COUNTER

Table 9 Individual Parts List for the MRSXO1, Robot Sensor Expansion Board, Ordered by Designator.

Designator	Part Type	Description
40KHZ_SEL	CON3	3 CONNECTOR, IR DETECTOR
ANALOG	CON8	IR LED OUPUT HEADER
BATTERY	CON4	BATTERY CONNECTOR
C1	470µf	POLARIZED ELECTROLYTIC CAPACITOR
C2	0.1µf	BYPASS CAPACITOR
C3	0.1µf	BYPASS CAPACITOR
C4	0.1µf	BYPASS CAPACITOR
C5	0.1µf	BYPASS CAPACITOR
C6	0.1µf	BYPASS CAPACITOR
C7	0.1µf	BYPASS CAPACITOR
C8	0.1µf	BYPASS CAPACITOR
C9	0.1µf	BYPASS CAPACITOR
C10	0.1µf	BYPASS CAPACITOR
CDS1 CDS2 CDS3 CDS4 CDS5 CDS6	CON2	2 CONNECTOR CdS PHOTORESISTORS
CHARGE	CON4	CHARGER CONNECTOR
D1	DIODE	POWER DIODE
D6	LED	CHARGE-ON LED
D7	LED	POWER-ON LED
DIG_OUT	CON8	IR LED OUPUT
F_BUMP	CON6	FRONT BUMPER CONNECTOR
IOHEADER	CON6	BYTE INPUT-OUTPUT HEADER
IRDT1 TO IRDT14	CON3	3-PIN MALE HEADERS FOR THE IR DETECTORS
J1	IDC60	60 PIN IDC HEADER
MOTOR_0 & 1	CON2	2 CONNECTOR, MOTORS 1&2
PIEZO	CON2	2 CONNECTOR, PIEZO SPEAKER
PORTA	CON3	HEADERS FOR PA0, PA1, PA2 OF PORTA
R_BUMP	CON5	RIGHT BUMPER CONNECTOR
R1	150K	RESISTOR, ¼ WATT
R2	100K	RESISTOR, ¼ WATT
R3	47K	RESISTOR, ¼ WATT
R4	22K	RESISTOR, ¼ WATT
R5	10K	RESISTOR, ¼ WATT
R6	100K	RESISTOR, ¼ WATT
R7	47K	RESISTOR, ¼ WATT
R8	22K	RESISTOR, ¼ WATT
R9	10K	RESISTOR, ¼ WATT
R 10	10K	RESISTOR, ¼ WATT
R 11	25	RESISTOR, ½ WATT
R 12	33K	RESISTOR, ¼ WATT
R 13	10K	RESISTOR, ¼ WATT
R 14	330	RESISTOR, ¼ WATT
R 15	100	RESISTOR, ¼ WATT

Table 9(Continued)

Designator	Part Type	Description
R 16	10K	RESISTOR, ¼ WATT
R 19	1K	RESISTOR, ¼ WATT
R 20	1K	RESISTOR, ¼ WATT
R 21	1K	RESISTOR, ¼ WATT
R 22	10K	RESISTOR, ¼ WATT
R 23	10K	RESISTOR, ¼ WATT
R 24	10K	RESISTOR, ¼ WATT
R 25	470	RESISTOR, ¼ WATT
RP1	EIGHT RESISTORS[1]	IR EMITTER CURRENT LIMITING RESISTORS MOUNT IN IC CARRIER
SERVO_PWR	CON4	SEPARATE POWER CONNECTOR FOR SERVOS
SERVO1 SERVO2	CON3	3-PIN MALE SERVO1 & SERVO2 HEADERS
U 1	MC74HC4051	ANALOG 8:1 MUX
U 2	MC74HC574	OCTAL D-FF SENSOR LATCH
U 3	MC74HC4051	ANALOG 8:1 MUX
U 4	MC74HC4051	ANALOG 8:1 MUX
U 5	MC74HC04	HEX INVERTER
U 6	MC74HC11	TRIPLE INPUT AND
U 7	MC74HC138A	3:8 DECODER
U 8	MC74HC11	TRIPLE INPUT AND
U 9	MC74HC574	OCTAL D-FF SENSOR LATCH
U10	74410NE	QUAD HALF-H MOTOR DRIVER
U11	MC74HC390	DIVIDE BY 2,5 COUNTER

[1]Current limiting resistors for the IR emitters ranging from 220 ohm to 10Kohm: the lower the resistance the brighter the IR emitter. Nominal value: 1Kohm.

3.3 Communication with your TALRIK

To communicate with TALRIK from your Personal Computer requires an MB2325 communication board and cable or its equivalent. An assembly manual for the MB2325 is provided with its purchase. Refer to the discussion in the previous section. You can also refer to the MEKATRONIX web site for further information.

3.4 Wiring

All TALRIK™ wiring harnesses should be with multi-stranded colored wire. Ribbon cable is quite useful for making wiring harnesses. We recommend identical color codes for a specific sensor type. Such a color code scheme offers the advantages of being able to identify the sensor and information on the wires by the cable color and the disadvantage that you cannot distinguish between sensors of the same type, for example, between IRD2 and IRD9. We recommend tagging different harnesses for specific identification.

The schematic in Figure 5 depicts all the sensor, power, switches, and LED wiring for the TALRIK^{II} ™ robot and suggests a color code for each of the cables. The diagram designates wire usage in the cable, wire pin assignments to the respective connectors at each end, and where those connectors attach to the MRC11 and MRSX01 circuit boards.

All the IR detector cables are identical, as are the CdS photoresistor wiring. The front and rear bumpers, however, are wired differently. The front bumper can discriminate bumper contact more finely than the back bumper. The 6-wire serial communications interface (SCI) connectors is shown at the lower right of the diagram. The IR emitter wiring can be correlated with the twelve IR emitter locations on TALRIK's circular plate by means of Figure 10.

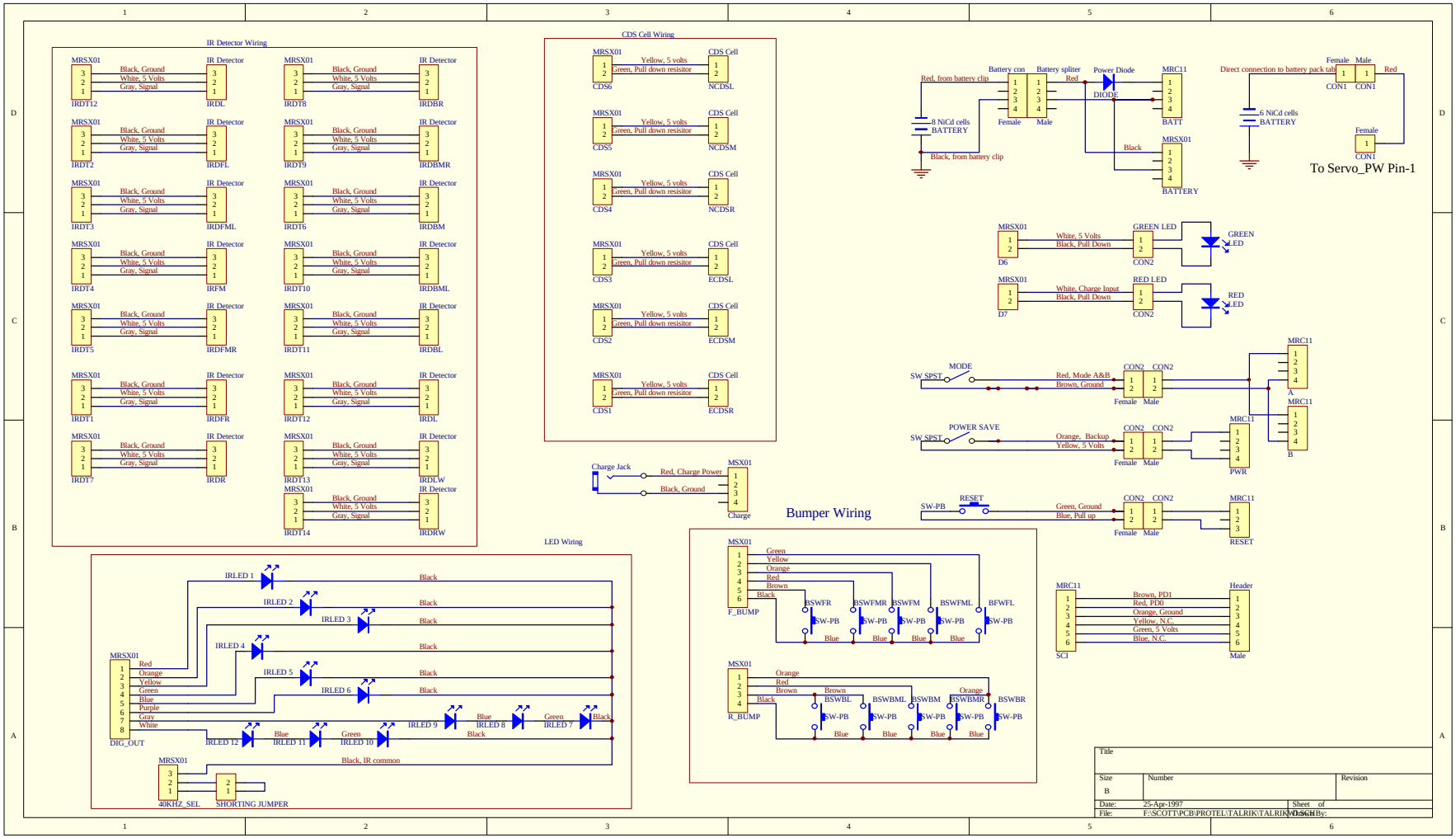

Figure 5 Cabling diagram for the TALRIK^{II} ™ robot showing all the MRC11 and MRSX01 connections to sensors, switches, LEDs, and power circuits.

Table 10 lists suggested wire color code and lengths, in inches and millimeters, for the various TALRIK cables.

Table 10 Recommended Cabling Color Code

Wire Use	Quantity	Length (inch)	Length (mm)	Colors
IRD	14	8	204	Bk,W,Gy
CdS Cells	6	9	229	Gr,Y
Serial (Board Out)	1	2	51	Br,R,O,Y,G,Bl
Power Switch (Board Out)	1	2	51	O,Y
Mode Switch (Board Out)	1	2	51	R,Br
Reset (Board Out)	1	2	51	Bl,Gr
Power Switch	1	2	51	O,Y
Mode Switch	1	2	51	R,Br
Reset	1	2	51	Bl,Gr
Charger	1	6	153	R,Bk
Power LED (Red)	1	7	178	Bk,W
Charge LED (Green)	1	7	178	Bk,W
Diode Fix (to MRC11 Board)	1	4	102	Bk,W
Diode Fix (to MRSX01)	1	6	153	Bk,W
Battery Connector	1	Batt. Wire		N/A
Front Bump Switches	1	12	305	Bk,Br,R,O,Y,Gr
Rear Bump Switches	1	10	254	Bk,Br,R,O
Bump Switches	8	3.5	89	Bl
Rear Bump Switch Pull-up (Right)	1	3.5	89	O
Rear Bump Switch Pull-up (Left)	1	3.5	89	Br
IR LEDs	1	10	254	Bk,W,Gy,P,Bl,Gr,Y,O,R
Front IR LEDs	5	3	77	Bk
IR Common (Jump F to B)	1	6	153	Bk
Rear IR LEDs	2	3	77	Gr
Rear IR LEDs	2	3	77	Bl
Rear IR Common	1	12	305	Bk
Servo Power	1	12	305	R
	Color	**Code**		
	Red	R		
	Orange	O		
	Yellow	Y		
	Green	Gr		
	Blue	Bl		
	Purple	P		
	Gray	Gy		
	White	W		
	Black	Bk		
	Brown	Br		

3.5 Connectors

You can buy slim connectors with 0.100inch centers, or make them from 0.100inch center male headers and female connector. A keyed connector can be made in several ways. One method is to make the mating male and female ends with an extra pin and hole, one more than necessary for the wires in the cable. The extra header pin is clipped off and stuffed into the corresponding hole. The stuffed pin blocks the hole from any insertion except where the cut off pin matches. Of course, the location of the cut off pin should not be at a symmetrical position on the connector, otherwise a 180° twist will permit the connector to fit as well. All TALRIK™'s power and communication cables support this approach. Some connectors, those for the IR detectors and the photoresistors, do not have extra pins. For the 2 wire photoresistors connectors, either orientation works. For the IR detectors, one orientation works and the other does not. While annoying, because the robot does not respond to an incorrectly connected IR detector, no damage to the IR detector has been observed. We suggest, however, you keep to a color coded scheme to help eliminate this annoyance, or, better yet, devise a keyed connector. Refer to the circuit board layout diagrams and schematics to determine how the male and female connectors mate.

Handmade plugs using male headers and female connectors should be mechanically strengthened by coating the soldered wire connections with hot glue. This stabilizes the wires by preventing them from moving back and forth and easily breaking connection.

4. PHYSICAL ORIENTATION

A top view of the TALRIK plate and all the other structural components appears in Figure 6. TALRIK™'s wheel axis determines the robot's left-to-right axis and cuts across the center of the two wheel wells. The diameter perpendicular to the wheel axis determines the front-to-back axis. The "TALRIK™" label appears at the front of the robot. Locations for IR detector mounts, bumper switches, mounting holes for the stacked MRC11 and MRSX01 printed circuit boards, bridge clip mounting holes, and the IR emitter and photoresistor eyelet slots can be determined from Figure 7.

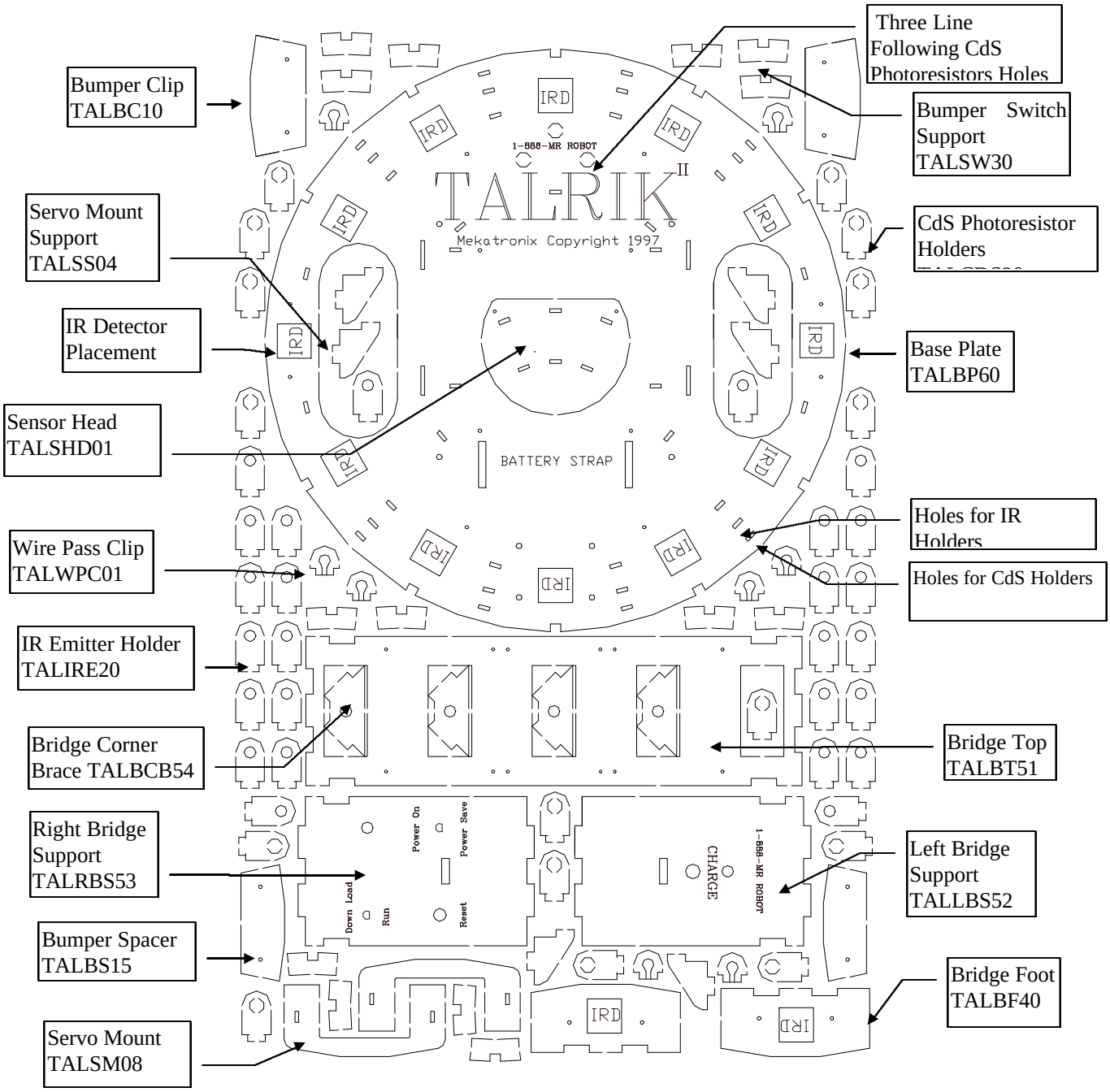

Figure 6 This drawing of TALRIKS body parts shows the recommended locations of the TALRIK™ IR detectors and specifies the MEKATRONIX™ part numbers for the structural components. The recharge jack mounts in the Left Bridge Support (TALLBS52) and the push button *Reset*, toggle *On/Off*, and toggle *Download/Run* switches mount on the Right Bridge Support (TALRBS53).

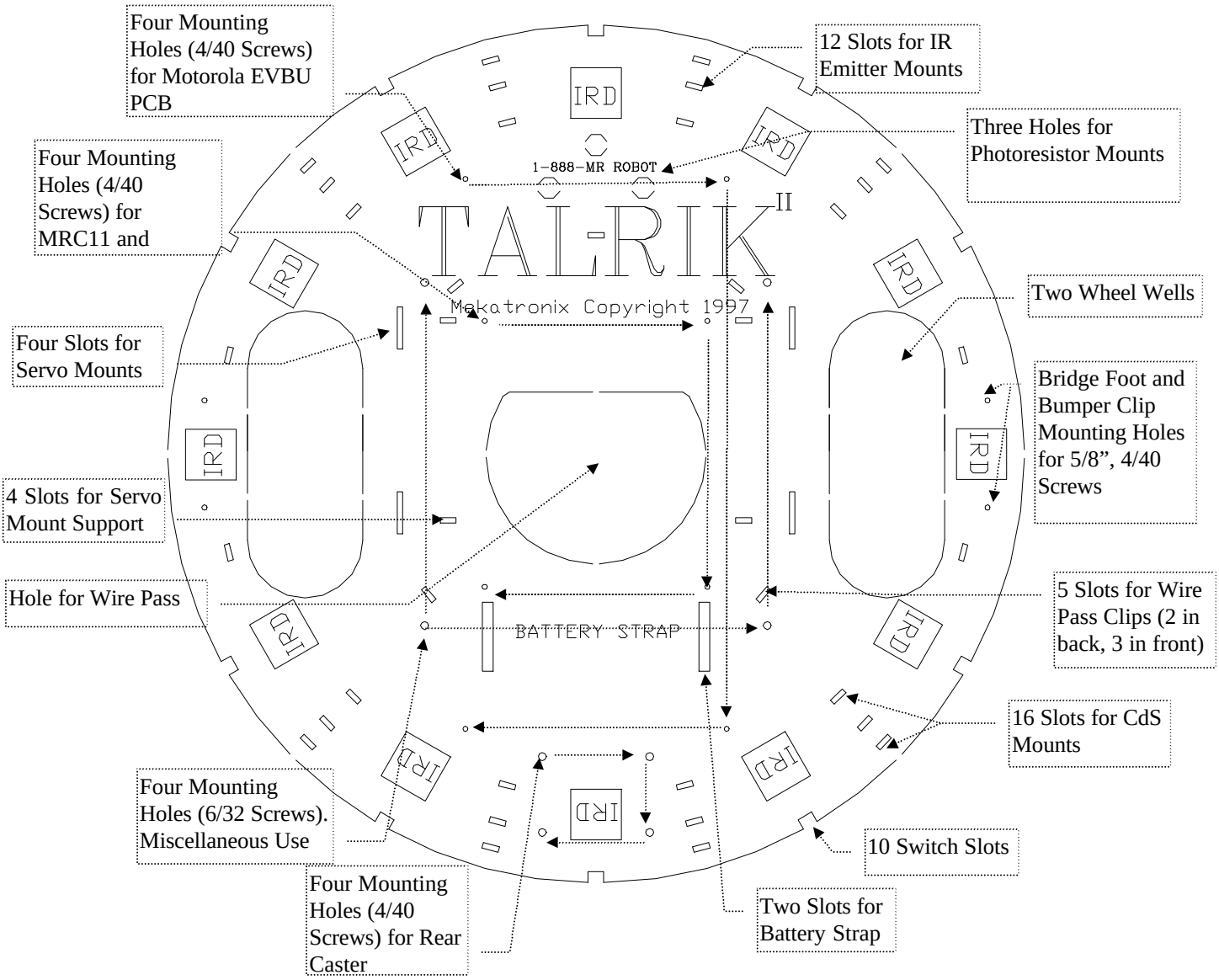

Figure 7 This figure depicts the function of the various holes on the TALRIK plate. TALRIK even accommodates the Motorola MC68HC11 EVBU, as well as the MRC11 and MRSX01. The recessed bumper switch slots, along with the switch supports (TALSWS30), protect the tactile switches while providing a secure mounting. The two inch center cutout allows you to pass wires between the top and bottom layers of the plate. Wire clips (TALWPC01) mount underneath the plate into wire pass clips slots and help tie down switch and IRE wires underneath the plate.

4.1 Bottom Layout

The servos, hacked as gearhead motors, mount on the servo mounts (TALSM08) with four servo wood screws each. The rear castor mounts with two, ½ inch 4/40 machine screws on opposite diagonals

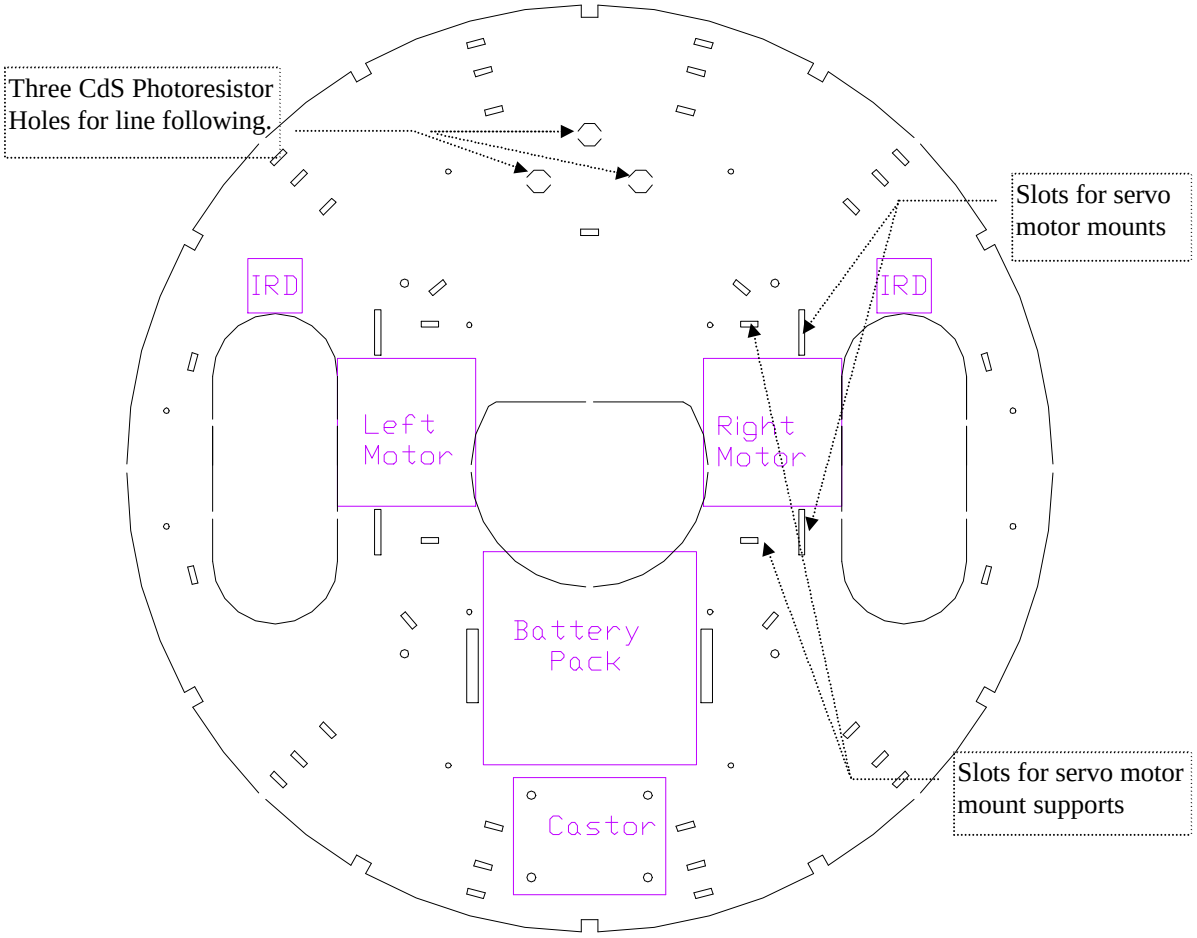

Figure 8 This drawing locates the servo motor mounts, the battery pack, and the caster on the underside of TALRIK™ as seen through the top surface. The IR emitter holders (TALIRE20) mount on the underside in the standard configuration. To minimize interference, the IR emitters should mount on one side of TALRIK™'s plate and the IR detectors should mount on the opposite side. The open end of the VELCRO™ battery strap should fasten on the underneath side while holding the eight AA battery holder in place. The optional placement of IRDs in front of the wheels provide edge (hole) detection. These are called *End-of-the-World*™ detectors.

4.2 The Platform and Bridge

The bridge assembly consists of the left and right feet, the left and right supports, the corner supports, and the bridge cross piece. The function of the holes on the bridge cross piece (TALBCP51) are illustrated in Figure 9. Up to five servos, or three servos and two MSCC11 printed circuit boards, or four servos and one MSCC11 can mount on the bridge at one time.

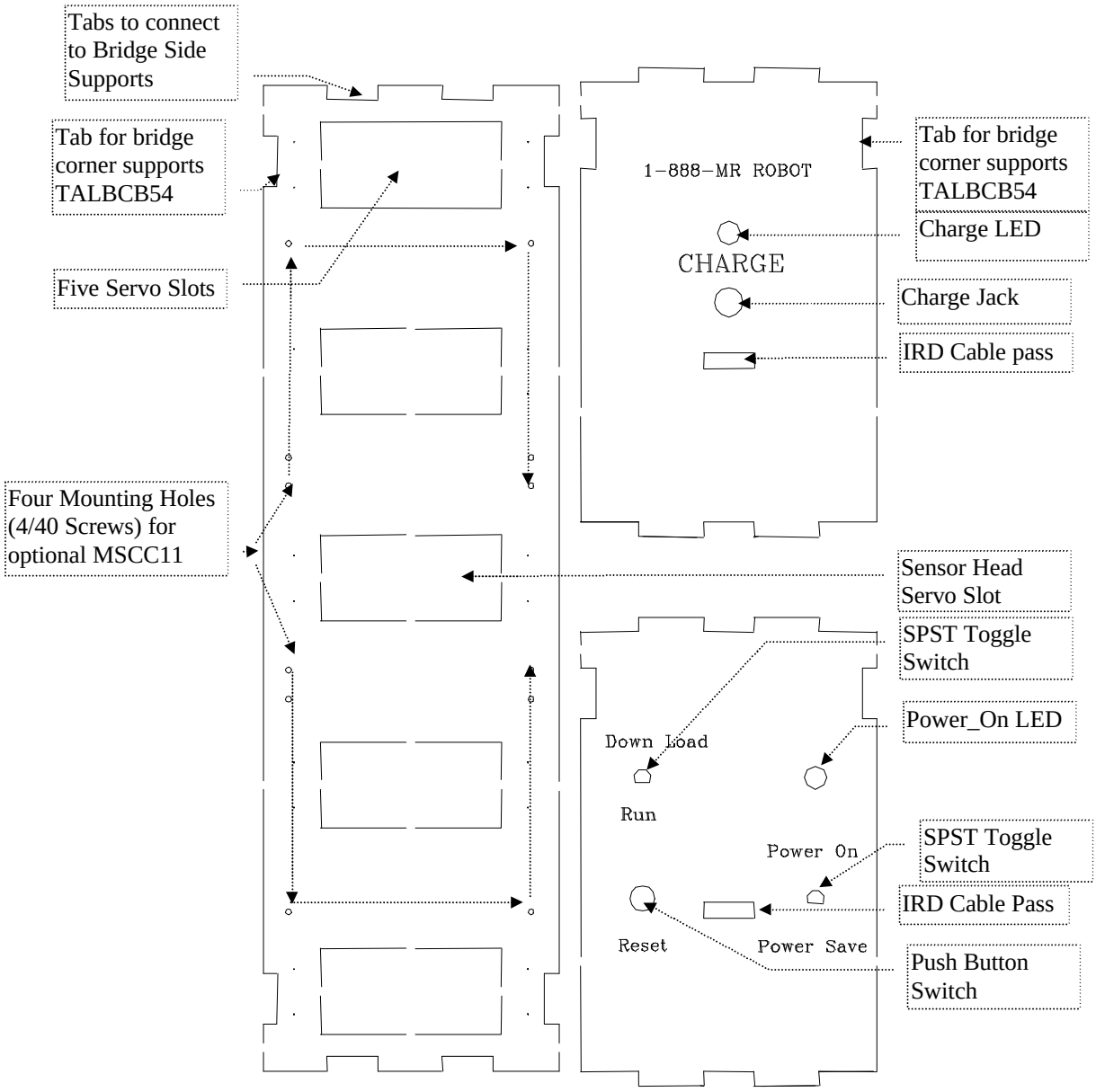

Figure 9 Layout of the bridge cross piece (TALBT51) that illustrating the mounting holes for MSCC11 single chip computer boards and servos. In the standard kit a servo mounts in the center servo slot and the sensor head (TALSHD01) is mounted on the servo horn. The control switches mount on the right bridge support (TALRBS53). The charge jack and indicator mount on the left bridge support (TALLBS52).

4.3 Sensor Layout

Figure 10 schematizes the standard layout of TALRIK™'s sensor suite. Table 11 names the labels, associates the labels with a particular connector on the MRSX01, and suggests a typical application of the sensor. You are not limited to these applications and can devise and implement other schemes, both in layout and in function.

4.3.1 IR Detector Selection

Refer to the circuit diagram of the MRSX01 (Figure 3). The Output-Select-0 (OS0) enables 8-bit latch U2 to store Port_C data lines during the write cycle on decoder U7. The outputs SEL[0,1,2,4] of the 8-bit latch U2 controls U3 which selects one of IRD7 through IRD14 to connect to PE0, Analog Channel Zero, on the MC68HC11.

4.3.2 Photoresistor Selection

The CdS cells connect directly to multiplexed analog I/O ports in a voltage divider arrangement. The outputs SEL[0,1,2,4] of the 8-bit latch U2 controls U3 which selects a CdS cell to connect to PE0, Analog Channel Zero, on the MC68HC11. From the previous paragraph, conclude that:

The CdS cells and the IR Detectors cannot be read at the same time.

In normal operation, since the CdS cells are so slow, the above restriction causes no loss of function.

4.3.3 Comment on the Bumper Switch Operation

The front bump switches tie into one analog variable f_bump and the rear bump sensors into r_bump. Each front bumper switch separately controls one bit of a 5-bit analog value. Each rear bump switch separately controls one bit of a 3-bit analog value. The bit values of each switch is determined by the voltage divider summing junction at MUX17 on F_BUMP for the front bumper and MUX16 on R_BUMP for the back bumper (Figure 3). The outputs SEL[0,1,2,3]of the 8-bit latch U2 controls U4 which selects the bumper input (MUX16 or MUX17) to connect to PE1, Analog Channel One, on the MC68HC11.

Table 11 TALRIK™'s Sensor Suite and MRSX01 Sensor Connectors

TALRIK Label	MRSX01 Connector	Name	Function
IRDL	IRDT12	Infrared Detector Left Side	Left Side Proximity Sensor
IRDFL, IRDFML, IRDFM, IRDFMR, IRDFR	IRDT2, IRDT3, IRDT4, IRDT5 IRDT1	Front Infrared Detector (Left, Middle-Left, Middle, Middle-Right, Right)	Front Proximity Sensors
IRDR	IRDT7	Infrared Detector Right Side	Right Side Proximity Sensor
IRDBL, IRDBML, IRDBM, IRDBMR, IRDBR	IRDT11, IRDT10, IRDT6, IRDT9 IRDT8	Back Infrared Detector (Left, Middle-Left, Middle, Middle-Right, Right)	Back Proximity Sensors
(IRDLW)[1]	(IRDT13)	User Defined-Not Included	User Defined
(IRDRW)[1]	(IRDT14)	User Defined-Not Included	User Defined
NCDSL NCDSM NCDSR	CDS6 CDS5 CDS4	Nose Cadmium Sulfide Photoresistors (Left, Middle, Right)	Line following, Edge Detection
ECDSL ECDSM ECDSR	CDS3 CDS2 CDS1	Sensor Head Cadmium Sulfide Photoresistors	Light measurement, beacon tracking, phototaxis
BSWFL, BSWFML, BSWFM, BSWFMR, BSWFR	F_BUMP4 F_BUMP2 F_BUMP1 F_BUMP3 F_BUMP5	Front Bumper Switch (Left, Middle-Left, Middle, Middle-Right, Right)	Front contact Sense
BSWBL, BSWBML, BSWBM, BSWBMR, BSWBR	R_BUMP2 R_BUMP2 R_BUMP1 R_BUMP3 R_BUMP3	Back Bumper Switch (Left, Middle-Left, Middle, Middle-Right, Right)	Rear contact Sense

[1]Optional, IR detectors purchased separately.

While not strictly binary, the voltage gaps between the individual bump switch sensor voltages are large enough to permit TALRIK™ to test for any combination of simultaneous bump switch closures. This feature provides TALRIK™ with quite a capable somatic ability.

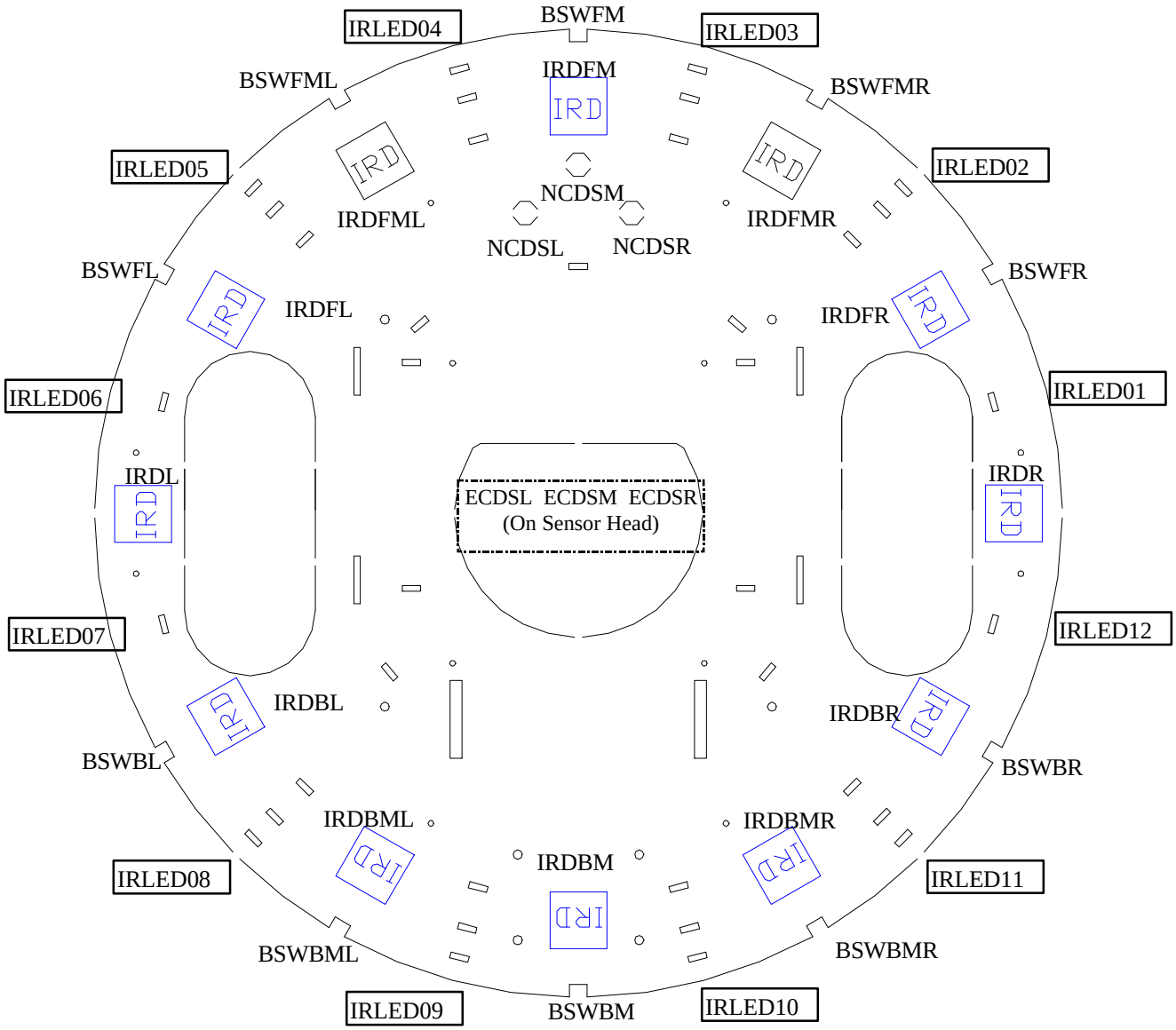

Figure 10 Sensor layout on top of the TALRIK plate. The lead symbols are B= Bumper, N=Nose, IRD = Infrared Detector, IRLED = Infrared LED. The following symbols mean: B = Back, F= Front, SW = Switch, L= Left, M= Middle, R= Right, CDS= Cadmium Sulfide photoresistor, W= wheel. For example, BSWBMR = Bumper-Switch-Back-Middle-Right and IRDFL = IR Detector Front Left; NCDSM = Nose-Cadmium-Sulfide-Middle; IRDLW=IRD-Left-Wheel. Note that IRDLW and IRDRW are on the underside of TALRIK™'s plate while the other IRDs are on the top side. ECDSL, ECDSM, and ECDSR mount on the Sensor Head (TALSHD01)

5. CONVERTING A DIGITAL IR TO ANALOG

All IR device references apply 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

5.1 IR Analog Hack

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 (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 (Figure 11).

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 µf 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.

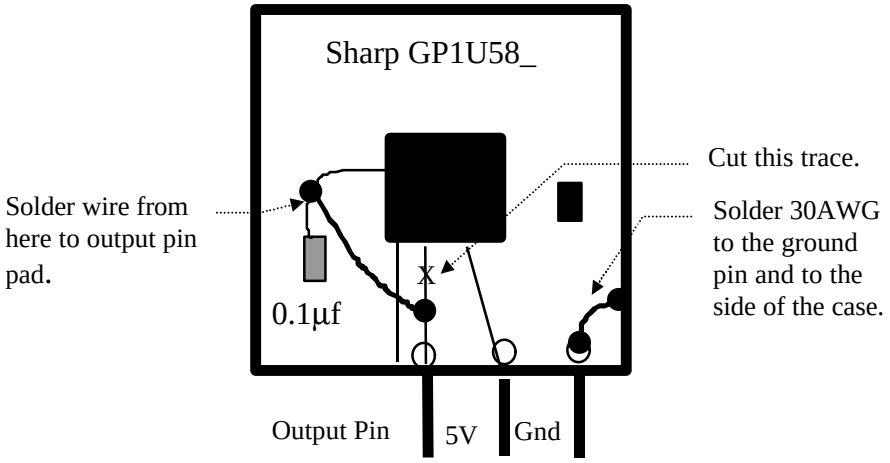

Figure 11 Converting a digital IR sensor to an analog IR sensor requires cutting the trace to the Output pin, soldering the Gnd pin to the side of the case, and connecting the output of the 0.1 µf capacitor to the Output pin.

5.2 Analog IR Characteristics

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.

6. MOTOR CONTROL

Programs executing on the MRC11 control TALRIK™'s motors using pusle-width-modulation (PWM). For the PWM program to work, however, one must first hack the servos into DC gearhead motors.

6.1 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 12. 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 13) so it will not turn the potentiometer shaft. Now, connect the servos to the MRSX01 (refer to). Flip the *Download-Run* switch to *Download*. Use PCBUG11 to load HServo.S19, a program to help you center the potentiometer setting. After loading HServo.S19, put *Download-Run* switch to *Run* and press *Reset* to execute the program. Manually adjust the potentiometer until the 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!

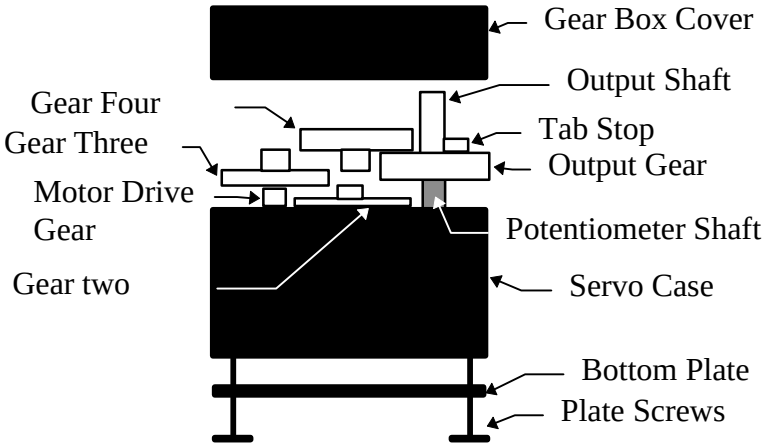

Figure 12 Servo hack: Remove tab stop, remove potentiometer tab inside *Output Gear*, set potentiometer shaft at center setting.

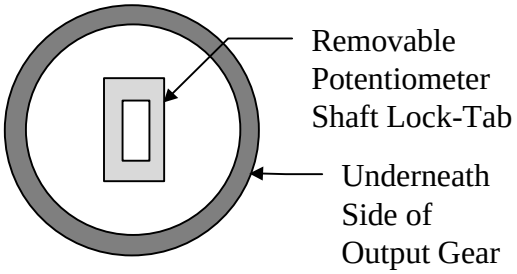

Figure 13 Illustration of the potentiometer shaft lock-tab inside the output gear.

The 2-pin female connector of a hacked Mekatronix servo slip right onto either of the *motor* male headers of the MRSX01™ sensor expansion printed circuit board without modification.

6.1.1 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.

6.2 PWM of the Motors

The output compare function generates pulse width modulation for the two DC motors on PA5 and PA6 of Port_A. The DC motors (MDCM455) 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 provide complete maneuverability. TALRIK™ can literally turn 180 degrees in place.

6.3 Non-Hacked Servo Usage on the TALRIK Bridge

The MRSX01 can drive up to two standard servos on the TALRIK bridge. These servos must be powered by the six NiCd cell battery tap on the TALRIK eight cell battery pack.

CAUTION

Standard, non-hacked servos must not be powered by more than six NiCd cells or the control electronics will burn out within a couple of minutes.

To drive more than two servos, MEKATRONIX recommends expansion with an MSCC11 single chip computer board. These boards easily mount on the TALRIK bridge where mounting holes have been predrilled.

The 3-pin female connector of the MEKATRONIX MS410 and MS455 servos slip right onto the Port_B male header of the MSCC11 single chip computer board without modification. The MSCC11 can be programmed to drive up to 8 servos on PortB (easy) or 16 servos on Ports B and C (requires great creativity and maxes out the processor!). The MSCC11 processor will automatically provide eight more 8-bit analog channels and 5 PWM channels, plus the many other features found on the MC68HC11 processor. You can program serial communications between the MSCC11 and the MRC11 via the SCI or SPI interfaces.

7. ASSEMBLY SEQUENCE

In the following assembly process, the text will make frequent reference to the figures and tables in the previous sections. Refer to Figure 14, Figure 15, and Figure 16 to visualize the assembly.

7.1 Finish Wood Surfaces and Glue Bridge

1. Before cutting the tabs to separate TALRIK™'s parts from the parts sheet, you should lightly sand both sides of sheet using a fine grade (150-200) sandpaper.
2. After sanding, cut the parts away from the sheet by using a sharp knife or blade. Sand or file the tab bumps smooth and parallel with the edges.
3. Glue twelve of the IRE holders (TALIRE20, Figure 6) onto the underneath side of the plate (Figure 16) (yes, there are extras!). Some of these may fit to tightly and require sanding. If the fit is tight enough you may choose not to glue them. This allows you to take them out later and mount them on top, for example.
4. Glue the two side bridge supports (TALRBS53 on the right side and TALLBS52 on the left side, Figure 6) to the bridge cross piece (TALBT51). At the same time glue the corner brace pieces (TALBCB54) that join the side supports and the bridge.
5. Glue the feet (TALBF40, Figure 6) to the bridge side pieces (TALRBS53 and TALLBS52).
6. We recommend clear or natural varnishes or stains to bring out the beauty of the wood. Of course, you can paint wild color schemes to taste! All finishing should be performed before assembly, as the wires and electronic components prevent effective finishing later.

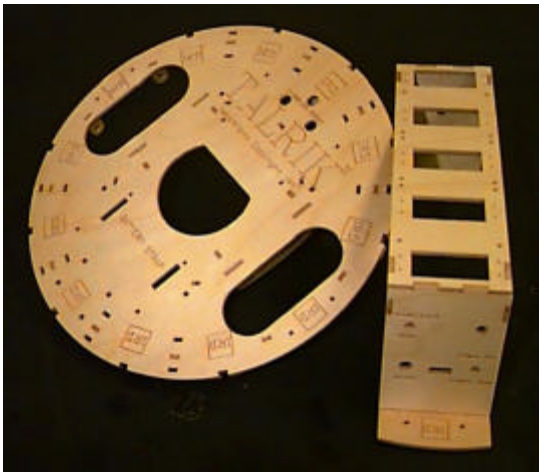

Figure 14 TALRIK Plate and Assembled Bridge. Note the bridge feet orientation. On one bridge support observe the mounting holes for the control switches and the slotted wire pass. The small ½ inch slots on the TALRIK plate allow the mounting of IR emitter and CdS photoresistor eyelets.

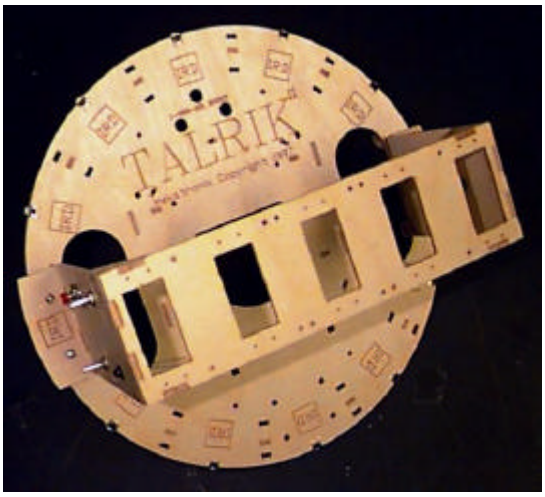

Figure 15 The TALRIK bridge mounts across the center axis of the plate. This picture illustrates a non-standard "lefty configuration" of the bridge with the control switches on the left side of the bridge. The next picture illustrates the standard "righty configuration" of the bridge with the *RESET*, *On/Off* and *Download/Run* control switches on the right side of the bridge. The Power-On light appears above the *On/Off* toggle switch. The screws through the bridge feet hold the bumper clips and spacer in place. The bumper strip, not shown, fits between the upper and lower spacers.

Caution *Specified Wire lengths apply to "righty configuration" only. Lefty configuration is not recommended.*

Figure 16 This underneath view of TALRIK shows twelve IR emitter supports uniformly spread about the plate. The front of the robot is in the upper right corner of the picture. The motor support brackets by the wheel wells are offset to accommodate the offset of the servo output shaft. The results is that the wheel axes align with a diameter of the plate. The lower bumper clip and the bumper switch supports stand out clearly in this picture. The red push-button switch, the two toggle switches, and the LED power indicator can be clearly seen on the right bridge support. The charger panel jack and charge LED mount on the left bridge support. The bumper switches mount into the plate slots with supports that glue underneath. The small loops of wood close to the center hole wire pass serve as wire tires for bumper and IR emitter wires.

7.2 Mount Servo Horns on Wheels

The servo mounting hardware comes together in a cellophane package. Round, two star, and four star servo horns can be used to mount the wheels.

1. Mount the servo horns onto the wheels with two small horn screws as shown in Figure 18. Pilot holes for the screws can be conveniently created by pressing an awl into the wheel plastic at the desired locations or drilling holes about 1.5mm in diameter. The holes do not have to be too deep, since the screws are self

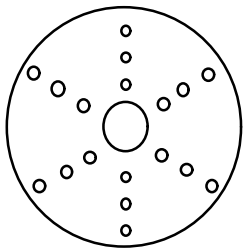

Figure 17 Round servo horn.

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. Each horn has a center tap for mounting the horn on the output shaft of the servo. Before screwing the servo horn onto the

wheel frame be sure that the horn's center screw is in place and centered by a screwdriver whose blade will fit through the hole in the center hub of the wheel. The horn mounting screw can be tightened or loosened by this screwdriver.

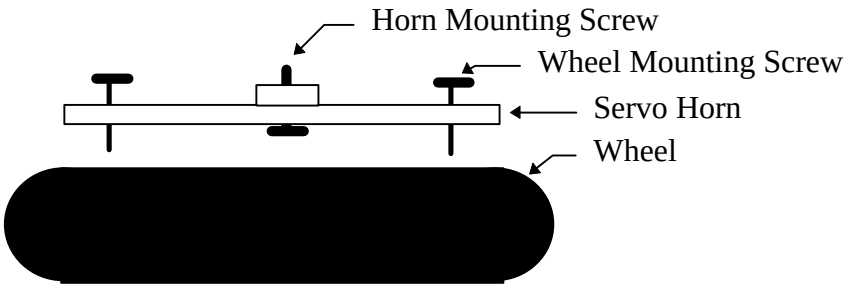

Figure 18. How to mount a servo horn onto a wheel. Be sure the horn mounting screw is placed into the horn before fastening the horn to the wheel with the other two screws.

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.

7.3 Mount Wheels onto the Hacked Servos

1. Refer to Figure 6 and Figure 16 for these instructions. Mount the wood servo mounting brackets on the underneath side of TALRIK^{II} ™'s plate. You will note two rectangular areas routed on the plate, next to the wheel wells. Glue and insert the ends of the servo mounts (TALSM08, Figure 6) into these slots. Two servo mount supports (TALSS04,Figure 6) brace the servo mounts on the inside. Insert and glue the tabs of the TALSS04 into the TALSM08 and the base plate (TALBP60).

2. Insert the hacked servos into the servo mounts. The bottom of the servo, the servo cable and plug on the servo side must be inserted first, slightly tilted. After clearing the grommet on the side of the servo, slightly rotate the servo to square it off and slide the servo snugly against the side of the servo mount. Some sanding of the servo slot may be necessary in some cases.

3. Attach the hacked servos with the four screws provided.

4. Mount wheels onto the hacked servos. Bring the servo wires up through the center hole to get them out of the way. Later, attach them to *motor0* and *motor1* on the MRSX01.

5. Mount the rear caster on the underneath side of the plate by inserting the ½ inch 4/40 bolts through the caster holes and the 4 holes in the plate. Use lock washers and nuts to fasten.

7.4 Install Front and Back Bumper Switches

The bumper switches mount in the small recess in the plate every 30° on the side of the plate. On TALRIK™, all bumper switches mount with two pins on top of the plate and two pins on bottom of the plate. A switch support glues underneath the plate for each switch (Figure 16).

1. Glue the small tactile push button switches to the plate, 5 in front and 5 in back, as indicated in the above instructions.

Be careful not to glue the switches open or closed!

No wire connections are made to the two pin on top of the plate..

2. Wire the front bumper push button switches according to Figure 5.
3. Wire the rear bumper push button switches according to Figure 5.
4. Pass the bumper cables through the center hole and up to the MRSX01 connectors.

7.5 Mount IR Emitters

Refer to Figure 19.

1. Insert the black, plastic T-1 ¾ LED panel mounts into the wooden emitter holders (TALIRE20, Figure 6) underneath the plate (TALBP60, Figure 6). These fit in from the front. Push the flared end, which compresses, into the hole first.
2. Insert the IR emitters into the LED panel mounts from the back side.
3. The short lead on the IR emitter is the cathode of the LED diode.

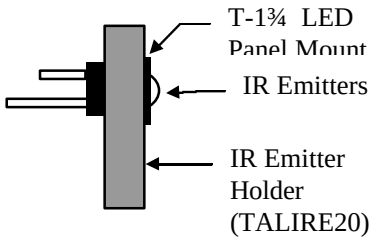

Figure 19 Mounting IR emitters into the IR emitter holders. In the above diagram, the black plastic T-1 ¾ panel mount pushes in from right to left. The LED is pushed in from left to right until it snaps into the flared part of the panel mount.

7.6 Cable the IR Emitters

Wire the IR emitter cables according to the cable schematic in Figure 5.

To make the underneath wiring more secure and esthetic, collect IR emitter and bumper wires into the various wire pass clips provided. Snap the wire pass clips into their assigned slots. Do not glue the wire pass clips.

7.7 Cable and Install IR Detectors

Tape the base of the IR detectors, opposite side of the cube from the pins, with Velcro hooks. Tape fuzzy Velcro squares to the squares labeled IRD on top of the plate. You can tape the fuzzy material at any time and anywhere you choose or experimentally determine as more advantageous locations. To make the IR detector cables refer to Figure 5. For each IR detector make a 3-wire cable with three hole female connectors at each end. One end of the cable fits into the IR detector cans. The other end connects into an IRDT male header on the MRSX01 board (refer to Figure 5).

7.8 Install Mode and Reset Switches

Wire the switches and the Charge LED and the Power Indicator LED (Figure 5).

1. Pass the two toggle switches through the holes provided them in *Right Bridge Support (TALRBS53)*. Thread the lock washer and nut on each. Tighten.

2. Do the same for the red push button switch (No lock washer, however).

3. Wire three, two wire cables from the switches, terminated into female connectors.

POWER-SAVE/ON	(Orange, Yellow)
DOWN-LOAD/RUN	(Brown, Red)
RESET	(Green, Blue)

The switches serve as controllable jumpers, so reversing pins 1 and 2 above does not change the function or cause any problems.

7.9 Wire Battery Connections

Wire the 9-volt battery snap as shown in Figure 5, near the upper right corner of the schematic. TALRIK^{II} ™ requires only a single 8-pack of NiCad batteries. However, the electronics of the non-hacked servos will burn out with an 8-pack, so you will need to tap off at six cells to drive the servo power bus. The CON1 female connector tap from the six NiCad cells in Figure 5 attaches to pin one of the SERVO_PW connector on the MRSX01 (Figure 3).

The battery voltage cable from the eight-pack branches to feed the MRC11 and MRSX01 separately. One branch goes through a power diode (1N4001), wired in-line, and connects to the 4-pin MRC11 male header BATT. The other branch (no diode) goes to the 4-pin male header BATTERY on the MRSX01. The power diode effectively suppresses motor induced noise from disrupting the electronics. The MRSX01 battery connection is not affected.

The voltage generated by the eight pack will destroy the servo motor control electronics after a few minutes. Therefore, MS410 and MS455 servo control electronics must be driven by no more than six NiCd cells. A battery pack tap at six NiCd cells connects to the SERVO_PW pin-1

header on the MRSX01 to provide the correct servo electronics power for up to two servos on the TALRIK.

7.10 Install Line Follow Photoresistors (CdS cells)

Since CdS cell performance varies so widely from cell to cell, and the dynamic range is so large, you will have to play with them in your specific application to find the right resistor values in the voltage divider circuit provided for each cell. To facilitate experimenting with different resistor values we have provided pin mounts for the resistor leads. A general rule of thumb is to measure the resistance of each CdS cell for the ambient light conditions under which it will operate and choose that as the value of resistance to be used. This choice approximately yields an equal sensitivity above and below the ambient lighting.

For line following, the three CdS cells, CdS4, CdS5, CdS6, must be inserted into 40mm black, flexible shrink-wrap tubes with inside diameter of ¼ in. You will have to adjust the depth of the CdS cells based on application requirements. Wire the 2-wire, yellow-green cable with a two hole female connector at one end and the CdS cell at the other (refer to Figure 5). Polarity is not important. These cells employ 10K resistors, which may not be suitable for your application, so you may need to experiment with other values.

The eye CdS cells, CdS1, CdS2, CdS3, mounted on the sensor head *(TALSHD01)* using the CdS holders *(TALCDS20)* do not require much collimation for beacon following. TALRIK provides 1K Ohm resistor for these voltage dividers, but, again, you will need to experiment and determine the right value for *each* cell.

Eight additional CdS cells (not included) can be mounted, four in front of the plate and four at the rear of the plate using the CdS holders *(TALCDS20)*. To do this requires the addition of an MSCC11 or the replacement of IRD sensors with the CdS sensors.

7.11 Stack Electronic Circuit Boards

Assuming that each board has been assembled and tested, stack the boards as in Figure 20.

1. Connect the MRC11 and MRSX01 boards with the 60 wire ribbon cable,
2. Join the boards with 1 5/8 inch 4/40 screws and nuts. Use the nuts to create stand-off distances.
3. Connect and thread all undercarriage wires from the MRSX01 and MRC11 boards through the center hole of TALRIK's plate.
4. Mount the stack onto the TALRIK™ into the holes designated in Figure 7. The ribbon cable should face the bridge support with the charge jack and LED. Mount, but do not fasten down.

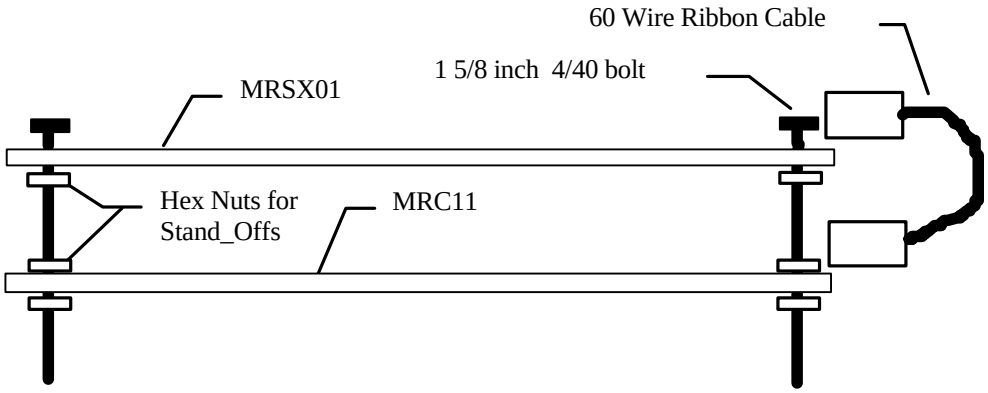

Figure 20 TALRIK™'s circuit board stack assembly seen from TALRIK™'s left.

7.12 Mount Battery Pack

1. Load the eight batteries into the battery pack. Be sure battery polarity is correct. Incorrectly installed NiCad batteries can cause damage to the batteries.

2. Thread the double sided Velcro strap through the slits on the plate with the hooks on the inner surface. Strap the batteries into place as indicated by the routed pattern.

3. Thread the battery power cable through the center hole of TALRIK's plate. Snap the battery power cable onto the eight pack.

4. Mount the robot on a platform so the wheels can spin freely without touching any surface. This prevents TALRIK™ from lurching off the table onto the floor while you perform tests!

5. Insert the charger cable plug into the charge jack.

6. The batteries are now charging. Testing can continue, even if the batteries are not fully charged, as long as the charger is connected.

7.13 Test Sensors

If the batteries are fully charged and/or TALRIK™ is connected to a charger, then run the program *tstsys.c* as explained in the *TALRIK™'s Users Manual* , Sections 4.4, 5.1 and 5.2. You can use *tstsys.c* to test all the sensors individually and collectively. Play with TALRIK™ for a while and observe how TALRIK™ perceives the world. The understanding gained by this exercise is invaluable for writing TALRIK™ programs that work.

7.14 Mount PCB STACK

After testing and verifying the computer and sensor operation. Bolt the PCB stack to TALRIK™ plate using the 4/40 bolts, nuts and screws provided. To avoid shorting connections, disconnect battery snap during this procedure.

7.15 Assemble Bridge

Figure 21 depicts the bridge assembly.

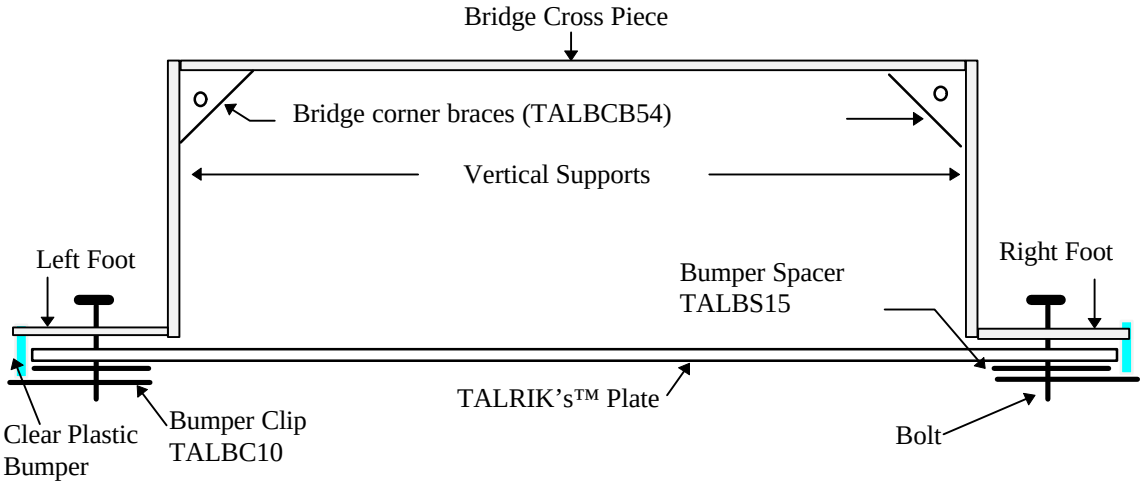

Figure 21 Bridge assembly. The overhang of the bridge feet and the bumper clips, hold the clear plastic bumper ring in place.

To build the bridge refer to Figure 21:

1. Glue the vertical supports perpendicular to the cross member while simultaneously gluing the corner braces. Be sure the supports are in a stable vertical position as the glue dries. Wait until the glue sets.

2. Glue a bridge foot perpendicular to each of the vertical supports, parallel to the cross piece and pointing away from the center of the robot.

7.16 Mount Bridge Servos

The standard head servo and any add-on bridge servo can be inserted into any of the five slots provided. Insert the rubber grommets into the servo screw tabs. Orient the servo so the output shaft is forward. Pass the servo cable through the hole, tilt the servo slightly and let it drop through. Insert the 4 servo screws through the rubber grommets and screw the screws into the bridge holes provided for that function. Connect the servos to the *servo0 and servo1* connections on top of the MRSX01 board. An MSCC11 expansion processor will be needed in order to control more than two servos.

7.17 Mounting Photoresistors (CdS Cells)

Photoresistors can be mounted onto TALRIK's sensor head or round plate. Three can be mounted on the head using the double slots. Four can be mounted in the front and/or the rear by means of the triple ½ inch slots. The technique for mounting them is illustrated in Figure 22.

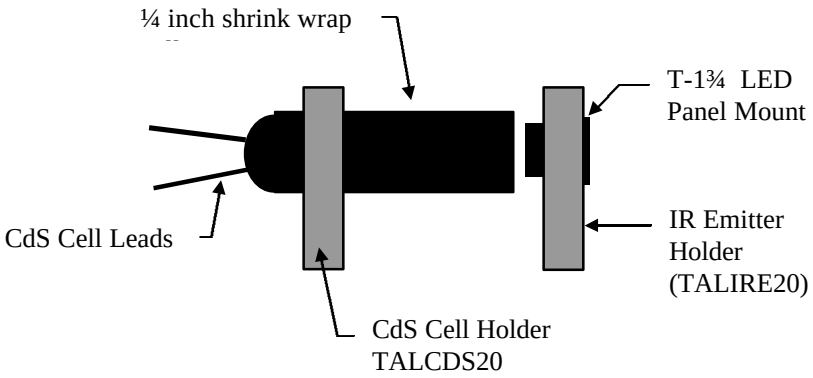

Figure 22 Mounting collimated CdS photoresistors in a cannon configuration. A stiff grade shrink-wrap collimates the light striking the CdS cell. The collimated CdS cell slides through the TALCDS20 and the open-end fits over the LED panel mount in the TALIRE20. This arrangement makes the CdS cell extremely direction sensitive. To obtain less direction sensitivity, you will need to shorten the barrel suitable to your application. In such cases the TALCDS20 must be moved forward, requiring you to cut off the tab and gluing the TALCDS20 to the head. For those cases where you make the barrel extremely short, you will not need the TALCDS20 and you can simply attach or glue the barrel directly to the LED panel mount.

7.18 Assemble the Viking© Bumper (Optional)

The Viking Bumper is an optional enhancement and does not come with an *Assembled Talrik*. You can buy the bumper pieces and easily assemble the Viking Bumper yourself or you can purchase an assembled one. This section show you how to assemble your own.

Important. *The bumper pieces must be joined with a special polycarbonate acrylic bonding agent (Not provided in the kit). Superglue and other types of glues will weaken the material and cause it to break after a few days of use.*

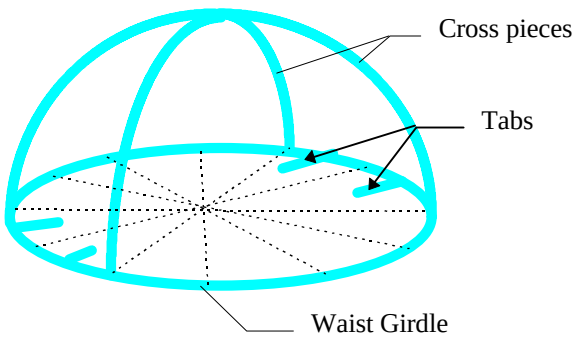

Figure 23 depicts a schematic diagram of TALRIK™'s sophisticated bumper system. The material consists of a flexible, polycarbonate acrylic. The waist girdle equals 828.675mm (32.625 inches). The two cross pieces have the same length of 533.4mm (21 inches). The 4 tabs,

9.525mm (3/8 inches) wide, are cut from right angle plastic.

Figure 23 TALRIK™'s Viking bumper assembly.

If you plan to only use the waist girdle and never attach the cross pieces, then 815.975mm (32.125 inches) will create a closer fit to the bump switches.

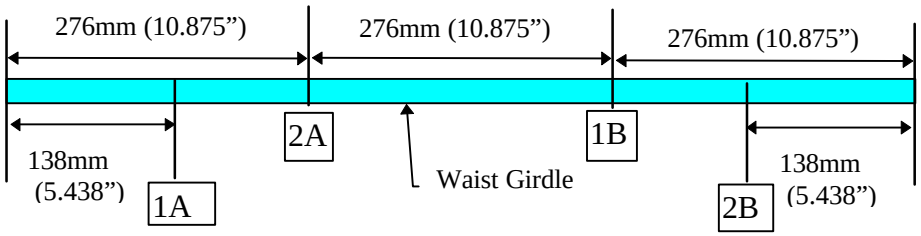

Figure 24 To make the Viking bumper you will attach the ends of one cross piece at 1A and the other end at 1B. The second cross piece ends attach at 2A and 2B.

1. Mark off four cross piece attachment points 1A, 2A, 1B, 2B on the girdle piece as shown in (Figure 24)
2. Wrap the girdle piece into a circle so the ends touch. The spring property of the material maintains a circular configuration automatical-ly. Place a 25mm (1in.) strip of the bumper material across the joint. Bond the strip across the joint with the special polycarbonate acrylic agent and clamp firmly (Figure 25). Wait for the bond to form. The bonding time is specified by the manufacturer of the bonding agent and may vary with temperature and pressure.

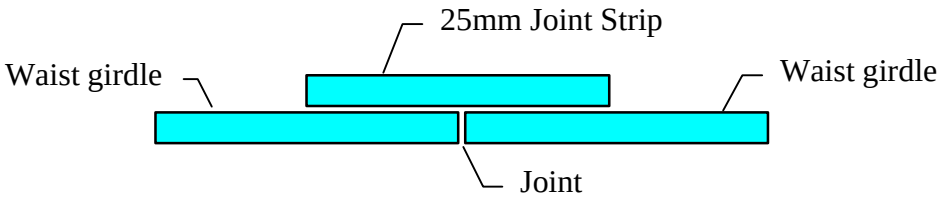

Figure 25 Joining the waist girdle. The joint strip adds strength and stability to the join.

2. With the waist girdle bond set, bond and clamp the two cross pieces at the points you marked earlier (Figure 24)*(One end of a cross piece attaches to the girdle at the position of BSWFMR and the other end at BSWBML. The other cross piece attaches to BSWFML and BSWBMR (Figure 10). These bumper switch locations are 30° either side of the front-to-rear diameter of TALRIK™. If you have enough clamps you can bond all four connections at once.)* Wait until the joints cure.
3. Next, bond and clamp the intersection of the cross pieces at the top. The pieces are quite flexible and will maintain the proper shape on their own. Let the bonding agent set.

Note: Do not bend the bumper material more than 70° as such motions will deform the material permanently.

4. Cut four 9.525mm (3/8 inches) wide tabs from the angle plastic piece provided. Bond and clamp the right angle tabs to the bottom edge of the waist girdle, two in front and two in the back. The positions of the angle plastic tabs are between IRLED04 and BSWFML, IRED03 and BSWFMR, IRLED09 and BSWBML, IRED10 and BSWBMR, respectively. Be sure there is clearance for the tab to slide back and forth under the TALRIK^{II} plate. Let the bonding agent set as directed by the manufacturer.

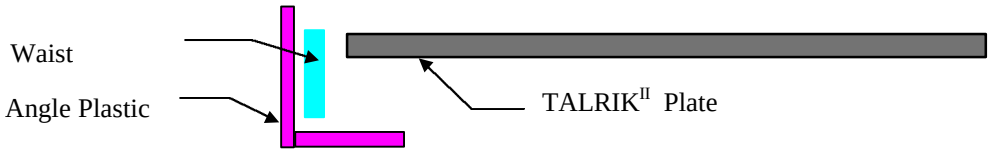

Figure 26 The angle plastic piece is bonded to the bumper and moves freely with it. The underside leg catches on the plate and keeps the bumper from riding up above the bumper switches when the robot hits something high with a cross piece.

A Viking bumper, complete except for the tabs, appears in Figure 27. The bumper backscatters some IR radiation to the IR detectors and increases their readings some. Your programs can accommodate the higher readings easily, but, if desired, you can reduce this effect by spray painting the bumper black.

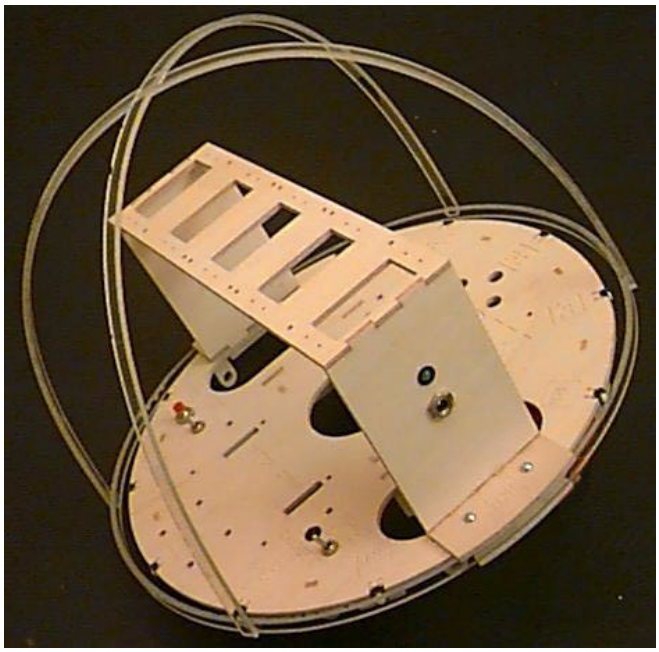

Figure 27 A Viking Helmet without the tabs mounted on an earlier version of the TALRIK.

7.19 Mount the Viking© Bumper and the Bridge

After assembling the bridge and the bumper and having confirmed proper operation of the sensors and processor, you are ready to mount the bumper and the bridge onto TALRIK's frame. Place the bumper about the circumference of the plate, between the bumper clips held loosely by the 4/40 screws, lock washers, and nuts through the bridge feet. Slowly tighten keeping the bumper away from the switches. Use the bumper clips and screws to adjust tension and position of the bumper to obtain clean switching operation when the bumper is pressed. You may need to loosely insert an 10mm (0.4") extra piece of bumper plastic (or piece of wood the width of the bumper) against the plate and between the bumper clips on the side opposite the girdle joint to push the bumper out and away from the switches closest to the bridge.

7.20 Completed Assembly

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

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

Enjoy!