ROBOBUG
Assembly Manual

by

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

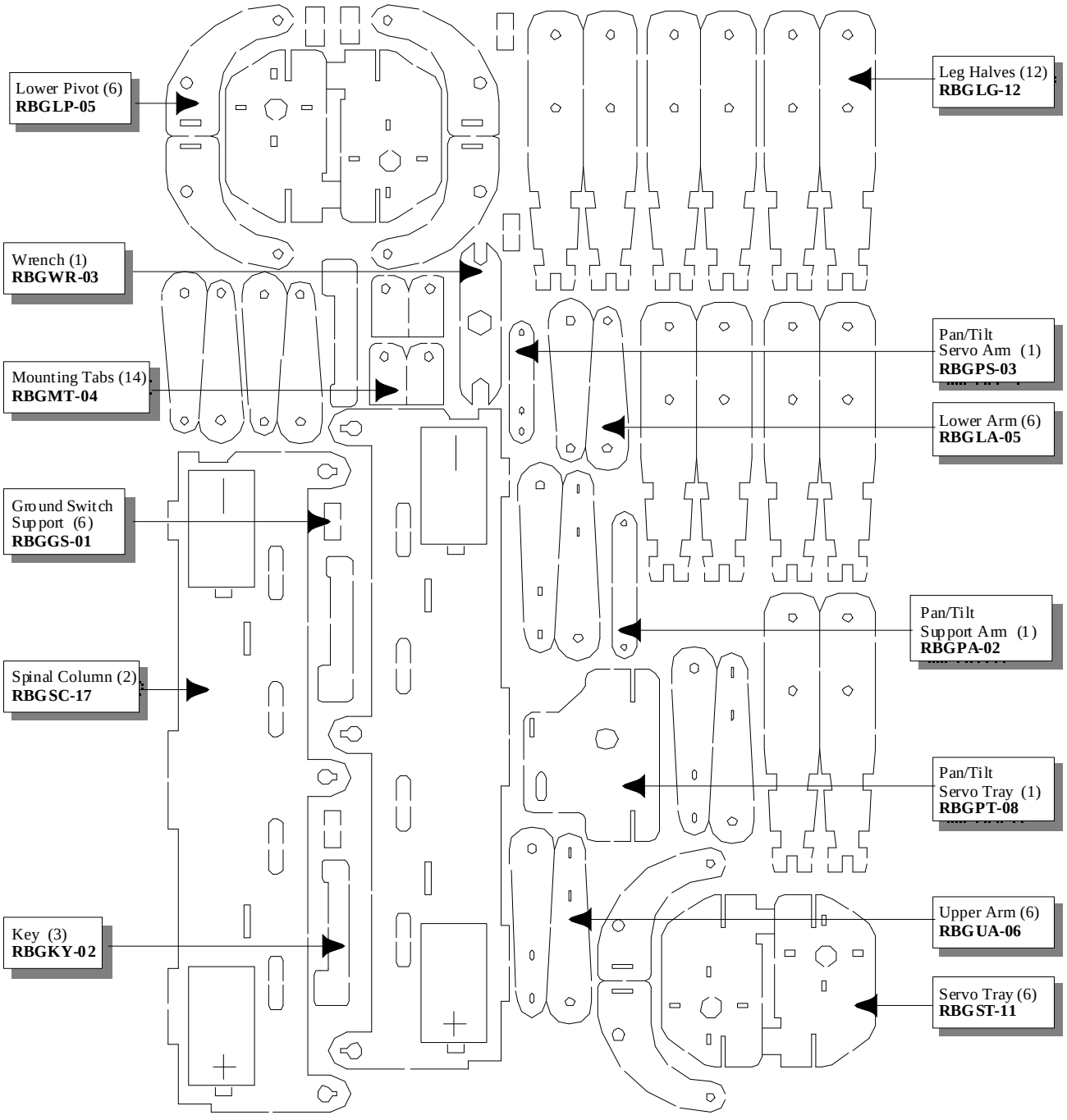
1 INTRODUCTION

This manual provides instructions for the mechanical and electrical assembly of Mekatronix's six legged walking robot RoboBug™.

2 MECHANICAL ASSEMBLY

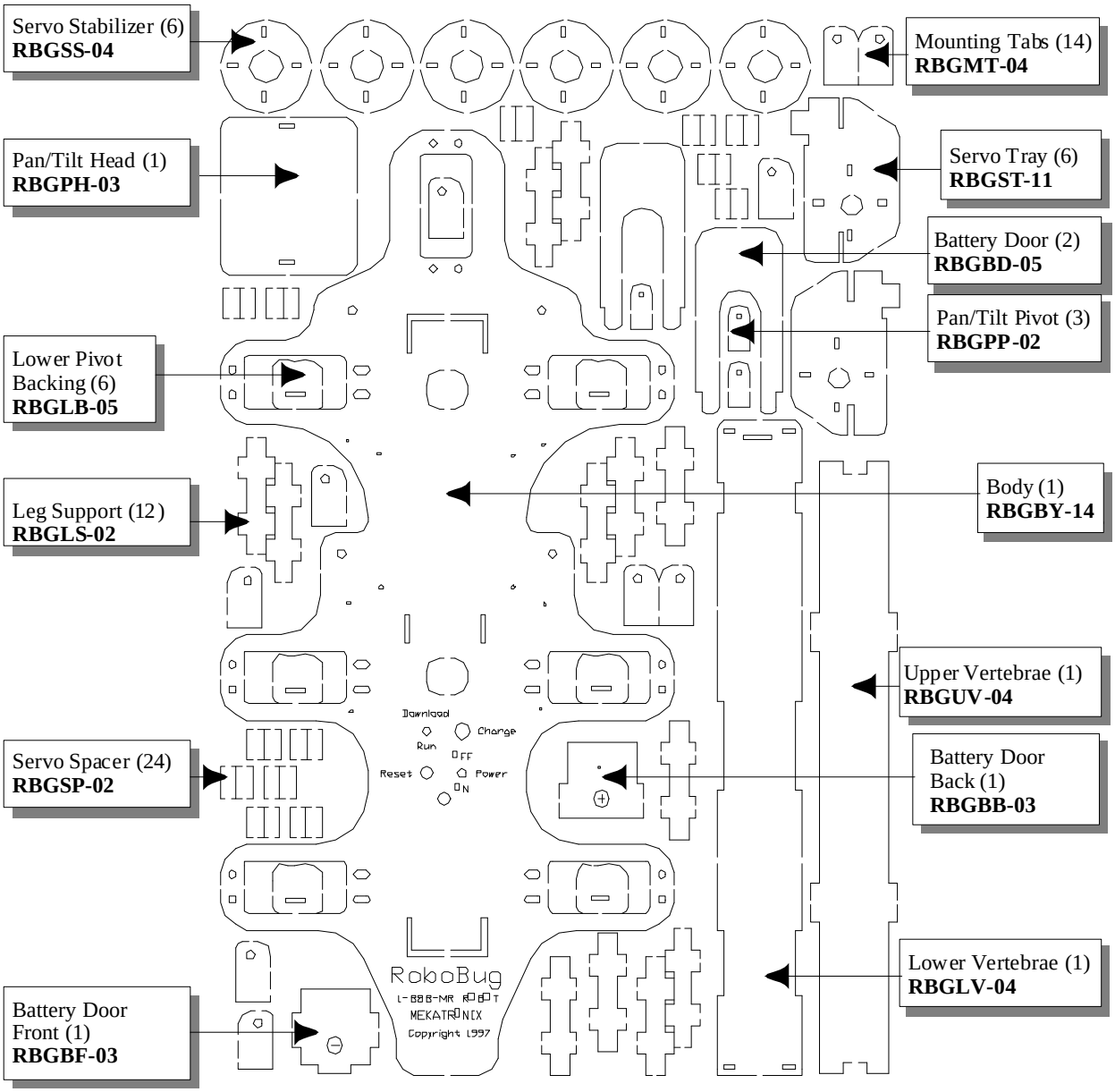
The next two pages depict the parts cutout sheets for RoboBug™'s mechanical parts. Table 1 itemizes various hardware parts.

RoboBug Part Layout and Labeling - Sheet 1



Note: 2 of **RBGST-11** and 10 of **RGBMT-04** are on sheet 2

RoboBug Part Layout and Labeling -Sheet 2



Note: 4 of **RBGST-11** and 4 of **RGBMT-04** are on sheet 1

Table 1 Miscellaneous Hardware

RBGSRV	Remote Control Servo	12-14
RBG623S	#6-32 x ½" Stainless Steel Phillips Head Machine Screw	51
RBG632N	#6-32 Nylon Insert Lock Nut	51
RBG2STS	#2 x ¼" Stainless Steel Slotted Head Self Tapping Screw	14
RBG8NWW	#8 Nylon Wide Flat Washers	24
RBG2NRS	#2 x ½" Nylon Round Spacer	12
RBG6NSI	#6 x 1/8" Nylon Screw Insulator (Shoulder Washer)	12
RBGBPT	Battery Positive Terminal	1
RBGBNT	Battery Negative Terminal	1

2.1 Tools and Stuff

- Small flatblade screwdriver
- Phillips screwdriver
- Knife (sharp, preferable)
- Wrench for the #6-32 nuts – one end of the wooden wrench included in the kit, **RBGWR-03**, will work if you don't have one of your own.
- Small file and/or sandpaper
- 5 C size rechargeable batteries
- Glue – I recommend using a *wood glue* for securing the wooden pieces together. Since the wood is porous, a regular *SuperGlue* will probably wick into the wood, and not work at all. While a gel SuperGlue would probably work, SuperGlue sometimes fails under repeated stress. However for securing the nylon pieces to the wood, something other than wood glue should be used. This is where you can use either a gel SuperGlue, or an epoxy.

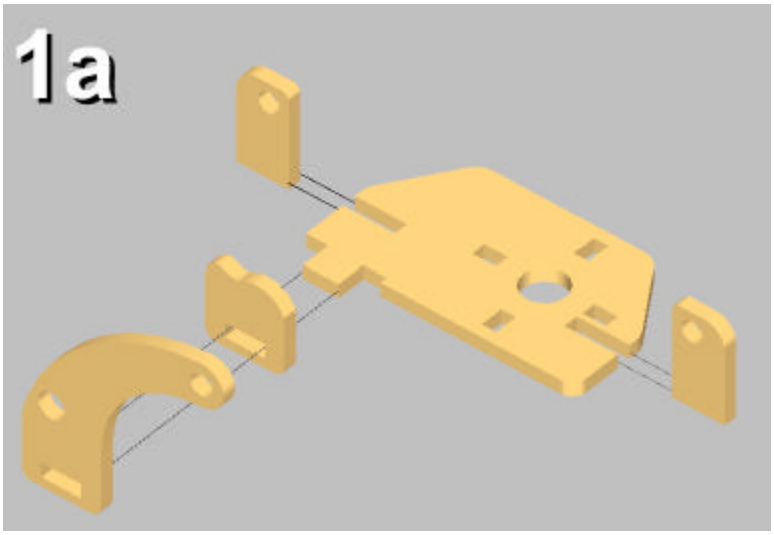
2.2 General Assembly Tips

- Use the knife to separate the pieces from the wooden sheets. Place the knife along the edge of the piece to cut the tabs, and set it free. By placing the knife as close as possible to the edge of the piece, you remove most of the tab from the piece, reducing the amount of time you have to sand (a good thing).
- Check the fit before applying the glue. For most of the assembled pieces, they should fit just snugly together. However due slight differences in bit sizes, the pieces may require a good amount of force. Use the file or sandpaper to improve the fit on pieces which are just a little too tight, and smooth any rough edges where needed.
- For all of the pieces within the kit, if it looks symmetric, it is. If there is only one way for a piece to fit, it is apparent (or it's suppose to be) in which direction it should go. The only exception (and you knew there had to be one), it between the pieces **RBGGS-01** (Ground Switch Support) and **RBGSP-02** (Servo Spacer). The way to tell them apart is that **RBGGS-01** is tabbed on the sides, while **RBGSP-02** is tabbed on the top and bottom (and the fact that they are also on separate sheets).
- And, as always, read through the directions and dry fit everything before applying glue and messing something up. You have been warned…

2.3 Step 1: Assembly of the servo carrier

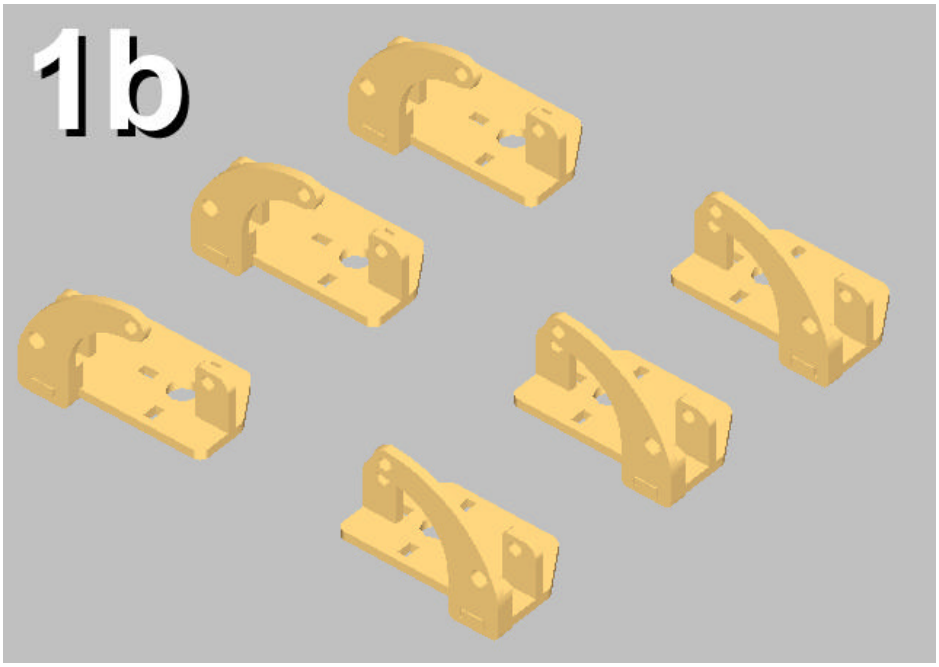
Remove 12 of the Mounting Tabs (**RBGMT-04**), all 6 of the Servo Trays (**RBGST-11**), all 6 of the Lower Pivot Backing (**RBGLB-05**), and all 6 of the Lower Pivots (**RBGLP-05**).

The most important step in this process, is placing 3 of the Servo Trays in the direction shown in figure 1a, and the other 3 a mirror image to what is shown in figure 1a. See figure 1b for more clarification.



There is a definite way the lower pivot backing should go. It should not, in any way, cover up the hole in the lower pivot. Be sure to glue the lower pivot backing to the lower pivot, and both to the servo tray.

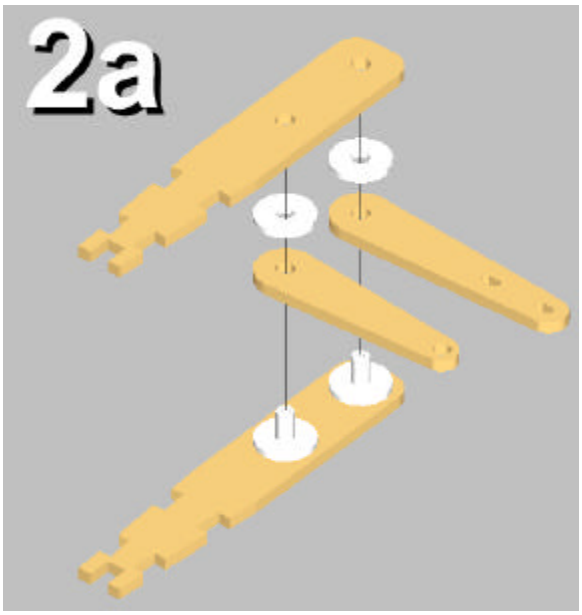
When gluing everything together, the mounting tabs should be flush with the bottom of the servo tray. The lower pivot backing, and the lower pivot assembly should be perpendicular to the servo tray. Since they may tilt a little, watch them as they dry.



2.4 Step 2: Assembly of the legs

Remove all 12 of the leg halves (**RBGLG-12**), all 6 of the Upper Arms (**RBGUA-06**), all 6 of the Lower Arms (**RBGLA-05**), all 12 of the leg supports (**RBGLS-02**), and gather together all 12 of the #2 x ½" nylon round spacers (**RBGNRS**) and all 24 of the #8 nylon wide flat washers (**RBG8NWW**).

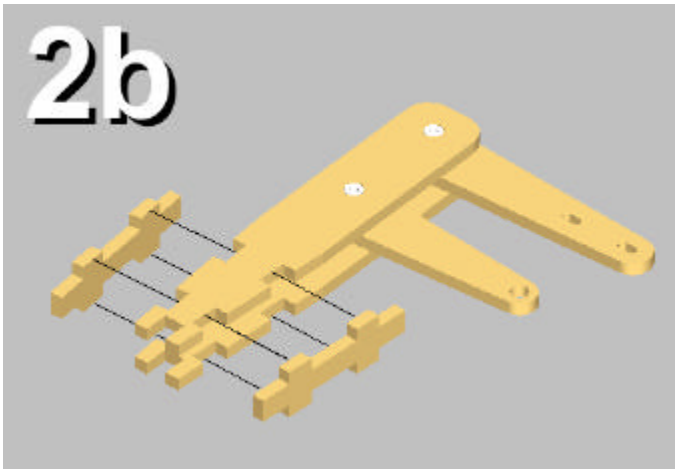
Check the fit between the nylon round spacers and the holes in the leg halves and the upper and lower arms. The fit should be snug, but not tight, since the arms do need to rotate freely.



Break out your gel SuperGlue, or epoxy. At this step, you'll have to work fast, since either one of these products tends to set fast. To increase the hold between the nylon and wood, you can roughen up the very ends of the nylon round spacers (the tips that are inserted into the holes of the leg halves), so that the glue has something to grip onto.

This should all be done as quickly as possible. Referring to figure 2a, place a drop of the glue within each of the holes on the leg halves, and working on a flat surface, place the nylon round spacers within the hole, pushing them flush, and place 1 nylon flat washer over each of the spacers. Be sure not to glue the leg half to your working surface. It's all right to glue the nylon flat washer to the leg half. Place the upper arm on the upper nylon spacer, and the lower arm on the lower spacer, add two more nylon washers, and finally the upper half of the leg half.

While the glue is drying, work the upper and lower arms back and forth. This is done for two reasons: So that if there was glue on the arms, they wouldn't dry in place; and to be sure there's enough clearance between the assembly for the arms to rotate freely, but not a lot of play that would allow a sloppy fit.



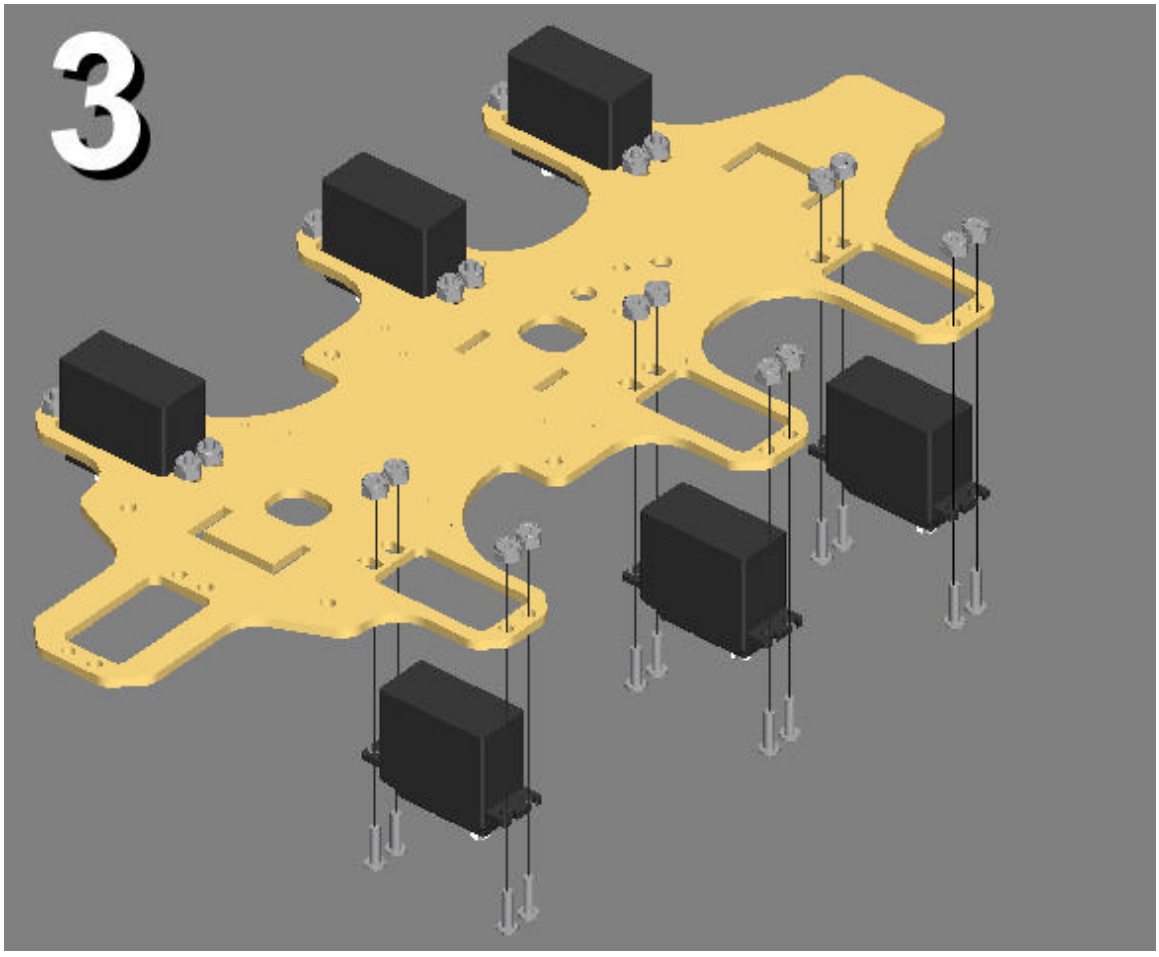
When step 2a is dry, the last step, is to glue (you can go back to wood glue now, if you were using it), the leg supports to the lower portions of the legs, see figure 2b.

2.5 Step 3: Insertion of swing servos on body

Remove the robot body (**RBGBY-14**) and gather together 6 servos (**RGBSRV)**, 24 #6-32 x ½" Stainless steel Phillips head machine screws (**RGB632S**), and 24 #6-32 Nylon insert lock nuts (**RGB632N**)

Insert the servos from the underside of the body. If you can see the writing, then you are looking at the top of the robot (not shown in figure). The output shaft and the wires of the servo should be on the outside, facing away from the body. To get the servo wires neater, route the wires back toward the body, and through the space between the servo and the rectangle you just inserted the servo through (not shown in figure).

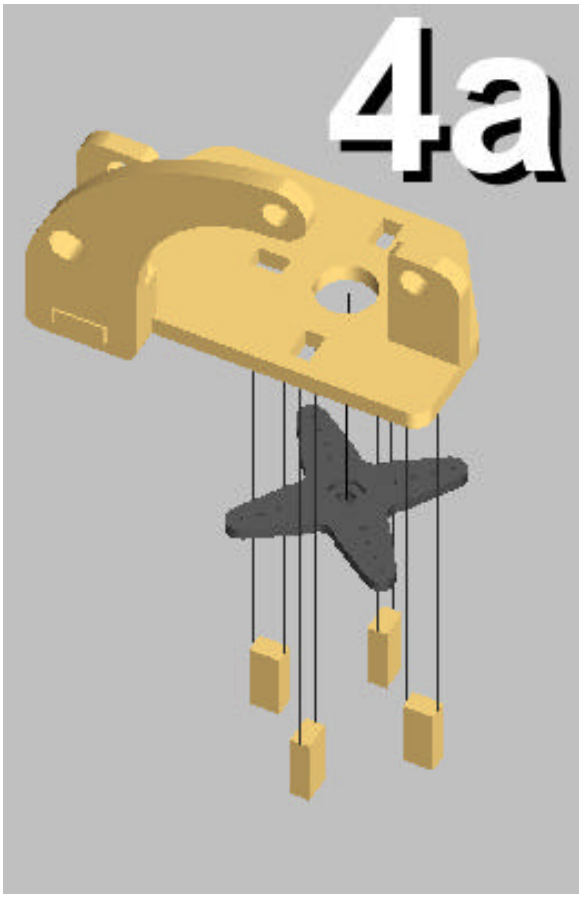
Secure the servos with the screws and nuts as shown in figure 3. The #6-32 nuts should be on the top of the body, to allow for clearance for the lift servo.



2.6 Step 4: Assembly of the servo carrier

Gather together the 6 servo carriers that you built in step1, 6 of the four-armed servo horns, all 24 of the Servo Spacers (**RBGSP-02**), all 6 of the Servo Stabilizers (**RBGSS-04**), and the robot body with the six servos.

This is another place where you'll be using either gel SuperGlue, or epoxy. Roughen up the top surface of the servo horn so that the glue has a place to hold. Spread the glue along the top of the servo horn, and press the servo against the bottom of the servo carrier, making sure that you don't cover up and of the rectangular holes on the servo carrier (that would be bad for the next step). Center the servo in the hole of the servo carrier.



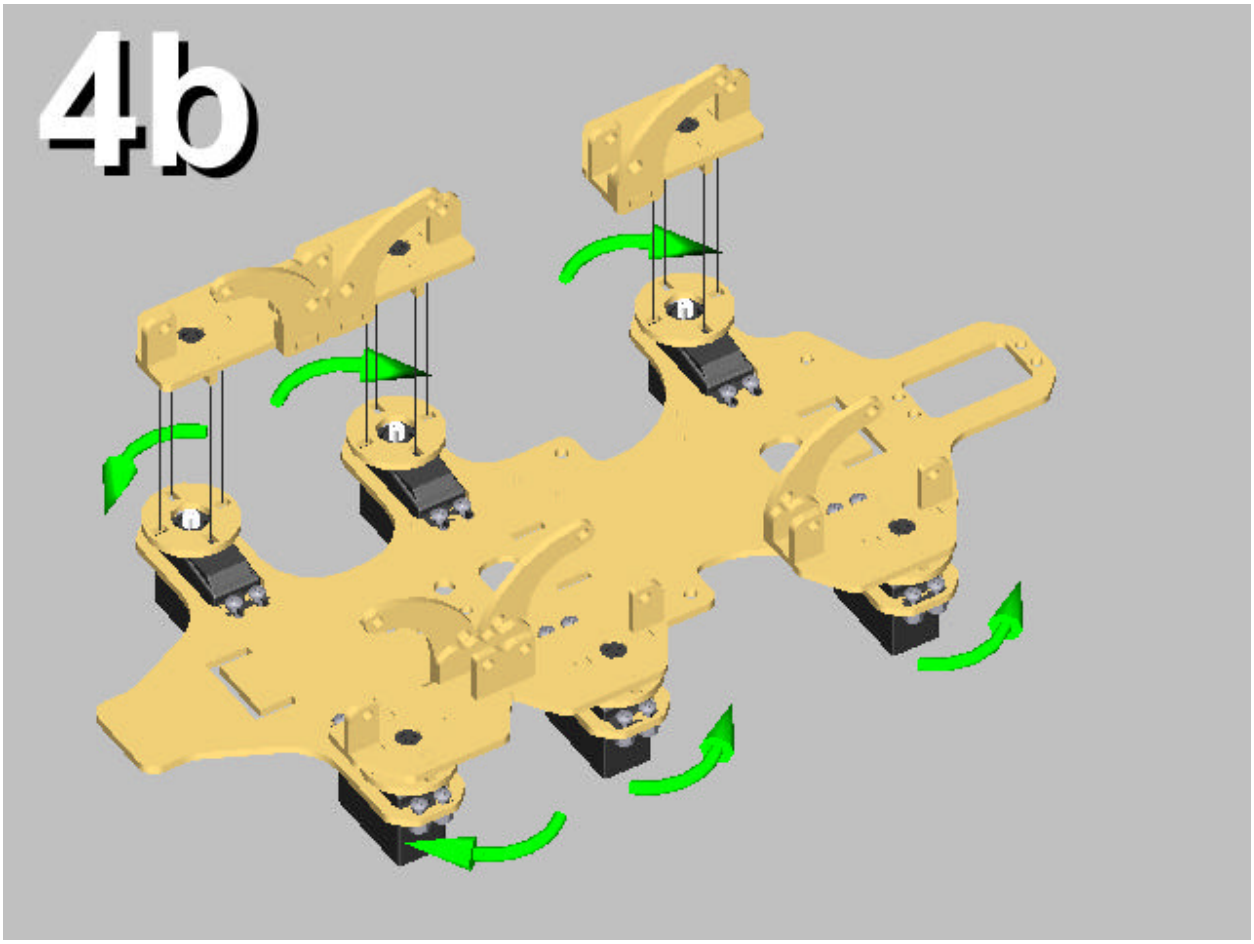
Before applying any glue in the next step, dry fit all of the servo spacers in their holes in the servo carrier, and in their holes in the servo stabilizers. Do this now, because if you wait, you'll have to work mighty fast to remedy the situation if they don't fit.

Moving back to the wood glue, see figure 4a, place a small amount on one end of each of the servo spacers (working in groups of four at a time, of course). Insert them into their holes in the servo carrier, and while the set of four is drying, place the servo stabilizer on other ends to be sure that they will dry properly aligned.

After the glue has dried, place the 6 servo stabilizers on top of the servos that you have secured to the robot body. Place a servo carrier on top of each of the servos, and rotate in the direction shown in figure 4b. This will assure that you have plenty of movement with the legs. The front 4 arc to the front, while the back 2 arc to the rear.

This next step is important, if the servo stabilizers are to work properly. Place glue on the exposed end of each of the servo spacers (again working in groups of four). Press the servo horn into the swing servo shaft, while inserting the servo spacers into the servo stabilizer. Stop just before you push the servo horn all the way onto the shaft. The purpose of the servo stabilizer is to supply support to the swing servo. This is required since the legs apply an off-axis force to the swing servo. To work properly, the servo stabilizer should rest lightly on the servo without resisting the rotational motion of the servo. This is why you stopped just before the servo horn was all the way on the shaft. By tightening the screw that secures the servo horn to the servo

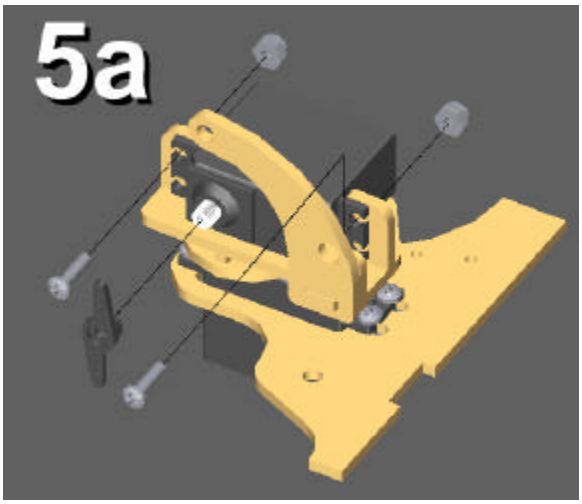
shaft, you can adjust the servo stabilizer. You want it tight enough to help support the servo, but not tight enough to resist the rotation of the swing servo.



2.7 Step 5: Attachment of the lift servo

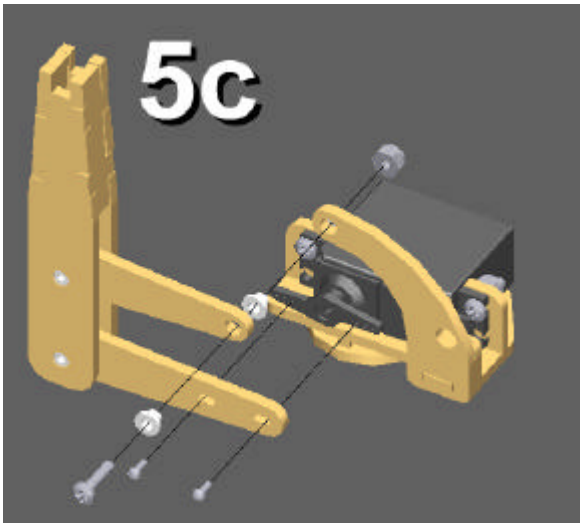
Gather together 6 servos (**RBGSRV)**, 18 #6-32 x ½" Stainless steel Phillips head machine screws (**RBG632S**), 18 #6-32 Nylon insert lock nuts (**RBG632N**), 12 #2 x ¼" Stainless steel slotted self tapping screws, 6 of the two-armed servos horns, all 12 #6 x 1/8" Nylon screw insulator (**RBG6NSI**), and the 6 legs that you assembled in step 2.

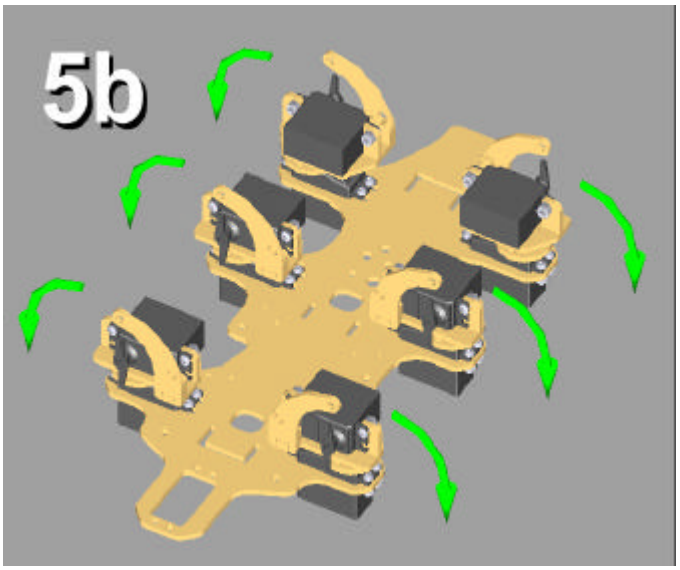
Secure the lift servo as shown in figure 5a. The hole in the lower pivot is there so that a small Phillips screwdriver can be inserted through to tighten the screw.



Rotate and reposition the lift servo's horn as shown in figure 5b. This will assure that you have plenty of movement with the legs.

Secure the lift servo horn with it's screw (not shown), and rotate the servo horn back by 90°. Fasten the leg to the lift servo as shown in figure 5c. The #2 self tapping screws which screw into the servo horn should be tight, but be sure not to over tighten them, or they could strip out of the plastic. As usual, the #6 screw and screw insulators should be tight enough, so that there isn't any play, but not too tight as to inhibit the movement of the leg.



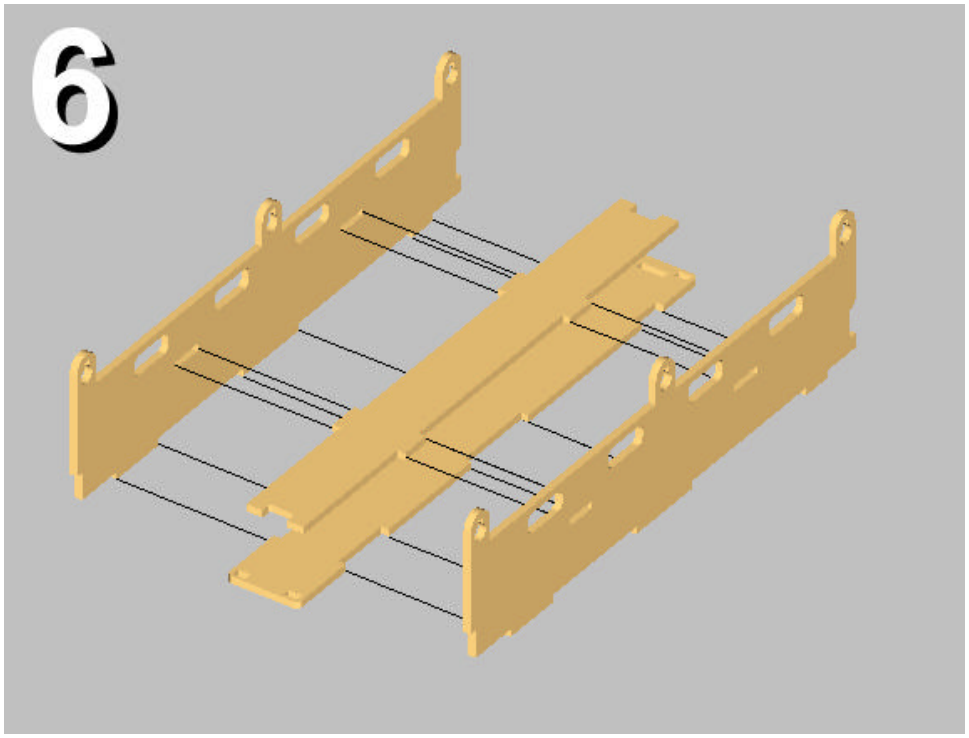


2.8 Step 6: Assembly of the battery box and wire conduit

Remove all 2 of the spinal columns (**RBGSC-17**), the lower vertebrae (**RBGLV-04**), the upper vertebrae (**RBGUV-04**), and gather at least 2, or all 5, C size batteries.

There is a definite front and back to the spinal columns and the lower vertebrae, while the upper vertebrae is symmetric. Glue the pieces together as shown in figure 6. While the glue is drying, insert 2 to 5 C size batteries within the battery box. This is done because the upper vertebrae may have a slight bow to it, and would cause the fit to be tight, making removal of the batteries difficult. Making room for the batteries now while the glue is drying, will make it easier to remove them later. You may want to insert the drying spinal column tabs into the robot body's slots (similar procedure that was done in step 4) so that you know the tabs will line up properly, and the spinal column pieces will dry straight.

The area above the upper vertebrae will become the wire conduit once the battery box is positioned on the body of the robot.

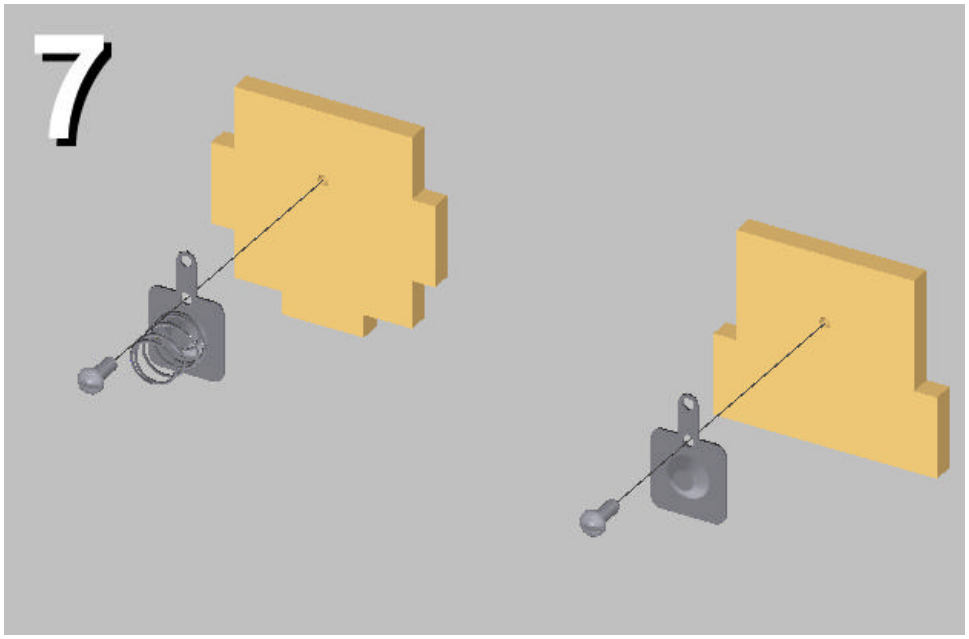


2.9 Step 7: Assembly of the battery doors

Remove the battery door front (**RBGBF-03**), and the battery door back (**RBGBB-03**), and gather together 2 #2 x ¼" slotted self tapping screws, the battery positive terminal (**RBGBPT**), and the battery negative terminal (**RBGBNT**).

For the best fit, drill out the second hole from the top of the battery terminals (both positive and negative), so the #2 screw body passes through (but not the head). Solder a length of wire (different colors) to the upper hole on both of the terminals. The wires feed through the cut outs on the ends of the upper vertebra, meet somewhere in the middle of the wire conduit, and exit from one of the wire pass-throughts on the robot's body. You can bend the tab on the battery terminals out slightly so that is it not resting on the wood.

The front of each door of the doors has either a text "+" or a "-" with a circle on it. Pass the screw through the, now bigger, second hole on the terminal and screw it into the **back** of the wood. The end of the screw will stick out passed the wood. You can keep it like this, so that you have access to the robots power supply, or you can put a bead of hot glue on the end (or file them down), so that you don't short out the batteries, or scratch yourself on the screw points.

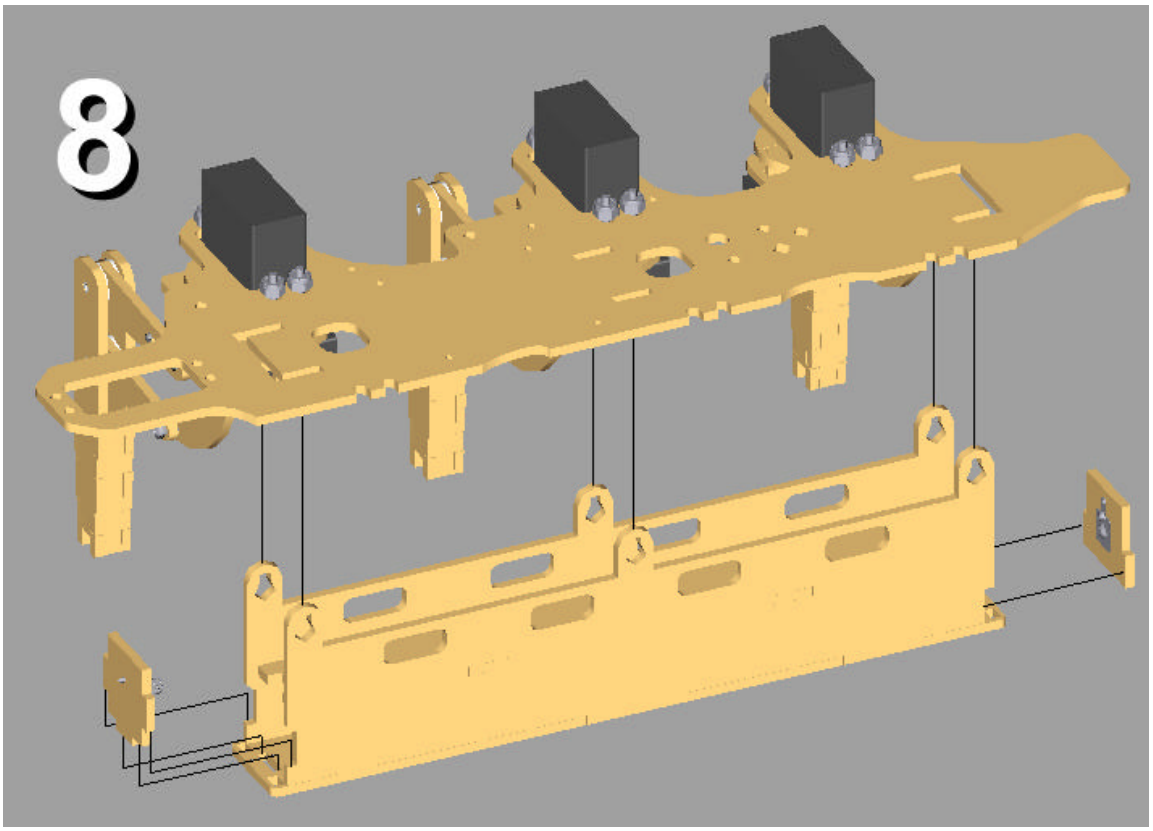


2.10 Step 8: Inserting the spinal column on the body

Gather together the spinal column, the battery doors, and the robot body.

Pass all of the servo wires through the appropriate wire pass-throughs on the side of the spinal column along the wire conduit, and out one of the wire pass-throughs in the body. Insert the front battery door on the front of the spinal column, and the back battery door on the back of the spinal column, as shown in figure 8. It should be obvious which is which. Run the battery wires along the conduit (not shown).

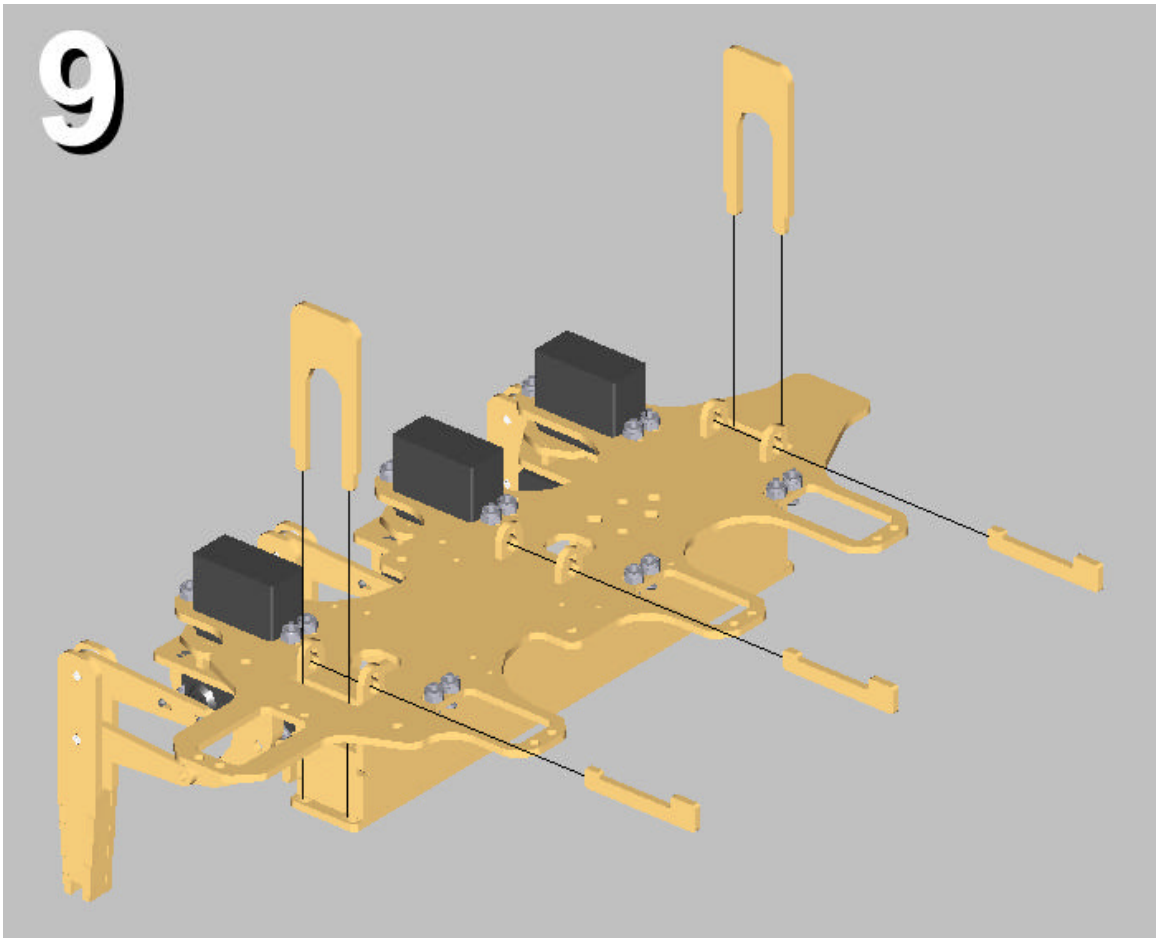
Insert the top tabs of the spinal column through the slots on the robot's body. Be sure the front of the spinal column is facing the front of the robot body.



2.11 Step 9: Locking it all together

Remove all 2 of the battery doors (**RBGBD-05**), all 3 of the keys (**RBGKY-02**).

Slide the battery doors through the body and insert the keys through the tabs in the spinal column, as shown if figure 9 (the servos were removed to clarity of the picture, you don't have to, and I don't recommend removing them). The keys can be inserted through either side. The easiest way to change the batteries is through the rear door (the "+" side).



Add batteries (and secure the battery door), a microprocessor (and program).

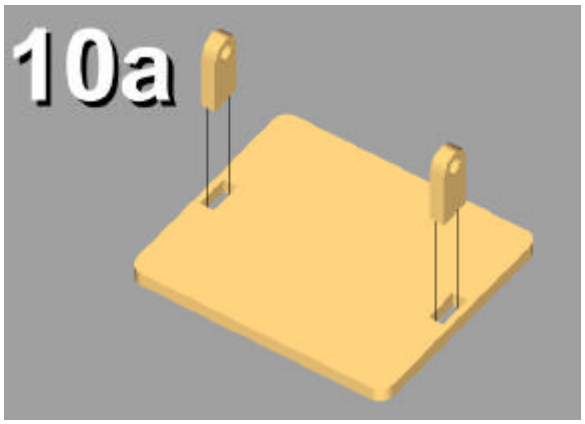
Congratulations! If you've followed these steps correctly, you should have a walking robot in your hands.

2.12 Step 10: Assembly of the Pan/Tilt head

(Additional hardware required)

Remove the pan/tilt head (**RBGPH-03**), all 3 of the pan/tilt pivots (**RBGPP-02**), the pan/tilt servo tray (**RBGPT-08**), the remaining two mounting tabs (**RBGMT-04**), the pan/tilt support arm(**RBGPA-02**), the pan/tilt servo arm (**RBGPS-03**), and gather one of the four-armed servo horns, two servos (**RBGSRV**), 5 #6-32 x ½" Stainless steel Phillips head machine screws (**RBG632S**), 5 #6-32 Nylon insert lock nuts (**RBG632N**), 2 #2 x ¼" self tapping screws (**RBG2STS**) and a one- or two-armed servo horn.

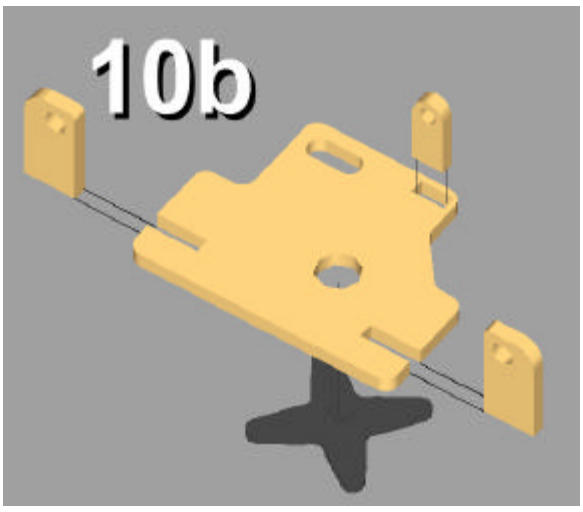
Glue 2 of the pan/tilt pivots to the pan/tilt head, shown in figure 10a.

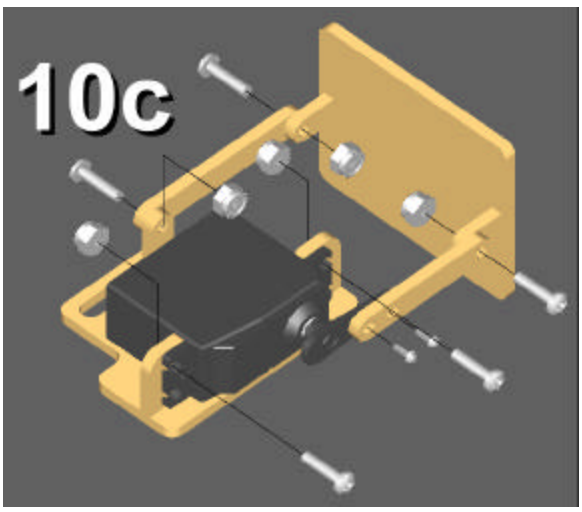


Similar to step 4, roughen up the top of the four-armed servo horn, and glue it to the servo tray using gel SuperGlue or epoxy. Glue the pan/tilt pivot and the mounting tabs, shown in figure 10b, as you've done before with the other servo carriers.

Install hardware as shown in figure 10c. Be sure that the nut and bolt on the pivot located on the servo tray is tight enough so there is no play in the structure, but loose enough so that it does not hinder rotation.

The pan servo which is mounted to the robot's body can either be installed similar to the swing servos (upside down), or right side up. You decide which is best for you.





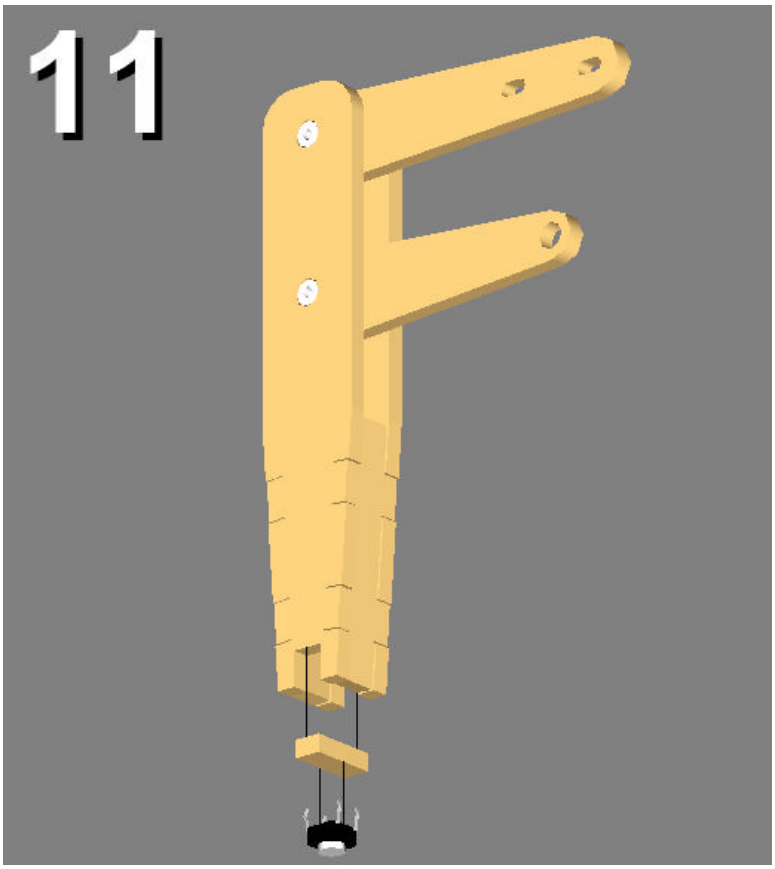
2.13 Step 11: Assembly of the ground contact switch

(Additional hardware required)

Remove all 6 if the ground switch supports (**RBGGS-01**), and gather together all 6 of the ground switches.

Solder wires to two of the switch pins. The wires should be long enough to feed through the leg, have enough slack to allow the leg to move, feed through the wire pass-through on the spinal column, along the wire conduit and out the body wire pass-through to the microprocessor. Glue the switch to the center of the switch support. You can use the leg as a guide to find the center, just be sure not to glue the support to the leg, or the button on the switch.

Feed the wires through the leg, and secure the switch/support assembly to the leg with a small amount of tape. If you pass the tape over the switch, be sure that the switch is not closed because of the tape. The support is not fixed to the leg, so that a repair can be easily accomplished.



3 ASSEMBLY OF ROBOBUG'S BRAINS

Assemble and test RoboBug™'s MSCC11E2 microcontroller circuit board. You program this microcontroller to control the walking gaits for the bug. A separate assembly manual is provided for the MSCC11E2. This Chapter provides MSCC11E2 assembly information for your convenience.

Caution: MSCC11E2 possesses an MC68HC11 processor which is static sensitive.[1] *Do not touch this part without being properly grounded. Static discharge can destroy it. Avoid working on carpet and do touch a grounded metal object before touching any of the electronics.*

3.1 Single Chip Microcomputer Circuit

The Mekatronix Single Chip Computer (MSCC11), incorporates an MC68HC11E2 as the on-board processor, serves as RoboBug™'s controller . To communicate code and data between the MSCC11E2 and a personal computer requires the Mekatronix Bidirectional Serial Communications Board (MB2325) and Motorola's PCBUG11 freeware. The MSCC11, which measures about 2.4 inches by 2.4 inches, constitutes a completely functional microcontroller useful for a wide variety of embedded applications. The MSCC11E2 provides 2Kbytes of EEROM, more than enough to program RoboBug™ to do incredible stuff.

Table 2 lists the MSCC11 parts and Figure 1 illustrates those parts.

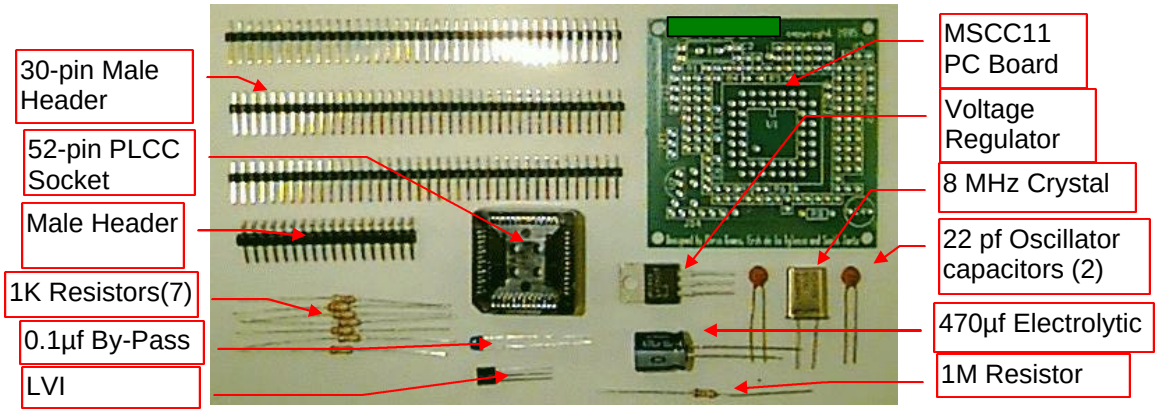


Figure 1 The MSCC11 parts inventory: 3 30-pin male headers in the upper right.

[1]TALRIK JUNIOR and TALRIK are trademarks of Mekatronix Corporation.

Table 2 MSCC11 Parts List

Label	Value	Component Description
C1-C2	22pf	Capacitor
C3	0.1µf	Capacitor
C4	470mf	Electrolytic capacitor (Polarity marked correctly in Fig. 1, but incorrectly on some PC boards.)
J1-J16	3 files of single row Male Headers	Power(middle rail), Ground (outer rail), Signal for digital/servo output (inner rail, processor pins 9 to 16 and 35 to 42). Mounted as required by the user's application.
J38	2 pin Male Header	MODE B jumper
J39	2 pin Male Header	MODE A jumper
J42	3 pin Male Headers	VRH A/D voltage reference high pull up
J43	3 pin Male Headers	VRL A/D voltage reference low pull down
J41	3 pin Male Header	Jump 5 volt regulated power to Port B and Port C Power Rails
J44-J51	3 pin Male Headers Constructed from male header strips	Analog/Digital-Input for sensors on PortE . A 3 pin header consists of a processor PortE pins 43 to 50 (inner rail), V_{dd} (middle rail) and ground (outer rail).
J52	4 pin Male Header	Power Connector
J53	4 pin Male Header	Select regulated power or alternate power source For J1-J16
J54	6 pin Male Header	RS232C Serial communication pins
PLCC	Socket	52 pin plastic leaded chip carrier for microprocessor
R1	10MΩ	Resistor
R2-R8	10KΩ	Resistor
U1	MC68HC11	Microprocessor IC
U2	MC34064	Low voltage inhibit IC
U3	LM2931T	5 volt regulator
X1	8MHz	Crystal
F1X30	Female Connect. x 2	Cut to make various connectors.

3.2 Functional Description of the Single Chip Computer

The MSCC11E2 on RoboBug™ features (Figure 2) 1) eight 3-wire inputs (5volts, ground, analog signal) on Port_E via connectors J44 through J51, 2) eight 3-wire powered digital outputs on Port_B via connectors J9 through J16, and 3) eight 3-wire powered bidirectional digital signals on Port_C via connectors J1 through J8. A number of jumpers provide a variety of options for the user. Jumpers can separate unregulated and regulated power rails. Specifically, RoboBug™ employs the unregulated voltage power rail to drive the leg servos attached to

Port_B (See **Error! Reference source not found.**). The regulated voltage rail always drives the microcontroller and the eight powered digital/analog inputs attached to Port_E. Up to eight 3-wire powered analog sensor connectors may be attached directly to Port_E. A 6-pin male header permits the MSCC11E2 to serially communicate with other MSCC11s or personal computers via a 6-wire cable to the bidirectional serial communications board (MB2325). The 6-pin male, serial communications header mounted on top of the MSCC11E2 circuit board make it easily accessible during program development.

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

3.3 Single Chip Computer Circuit Schematic

Figure 2 illustrates the MSCC11E2 circuit diagram and Figure 3 the circuit layout on the printed circuit board. Refer to this figures in the following discussion. The MSCC11E2 possess a 5 volt regulator (U3) and a Low Voltage Inhibit device (U2) in addition to the central processor. A key feature of the circuit is that all computer Ports are brought out to male headers whose pins are indicated in Figure 3. To reduce clutter, only pin 9 in the upper left of Figure 3 illustrates the multi-pin male header numbering scheme. Pin 9-1 is connected to Pin 9 of the processor. Pin 9-2 is connected to power and pin 9-3 is connected to ground. Only the processor pins on the other headers, the inside pins, are labeled and are considered to have the suffix *-1*. As one moves outward from the processor pin, on the same header, the suffix become *-2* then *-3*, if there is a second and third pin. For three pin male headers, pin *N-2* is connected to power and *N-3* to ground. These male headers enable you to create and easily connect your own sensors to RoboBug™ 's brain. Table 4 lists the MC68HC11 pin assignments and Table 5 the ones used in the basic RoboBug configuration. The unused pins are reserved by Mekatronix for future expansion.

Table 4 MC68HC11Processor Pin Assignment

Pin No.	Port Pin	Pin No.	Port Pin	Pin No.	Port Pin
1	VSS	19	IRQ*	37	PB5
2	MODB	20	PD0	38	PB4
3	MODA	21	PD1	39	PB3
4	STRA	22	PD2	40	PB2
5	E	23	PD3	41	PB1
6	STRB	24	PD4	42	PB0
7	EXTAL	25	PD5	43	PE0
8	XTAL	26	VDD	44	PE4
9	PC0	27	PA7	45	PE1
10	PC1	28	PA6	46	PE5
11	PC2	29	PA5	47	PE2
12	PC3	30	PA4	48	PE6
13	PC4	31	PA3	49	PE3
14	PC5	32	PA2	50	PE7

15	PC6	33	PA1	51	VRL
16	PC7	34	PA0	52	VRH
17	RESET*	35	PB7		
18	XIRQ*	36	PB6		

Table 5 RoboBug Processor Pin Function

Pin No.	Port Pin	Pin Drives
31	PA3	Two IR LEDs
29	PA5	Two IR LEDs
40	PB3	Head Pan Servo
39	PB2	Head Tilt Servo
38	PB4	Front-Right-Bottom Servo
37	PB5	Front-Right-Top Servo
36	PB6	Middle-Right-Bottom Servo
35	PB7	Middle-Right-Top Servo
9	PC0	Back-Right-Bottom Servo
10	PC1	Back-Right-Top Servo
11	PC2	Back-Left-Bottom Servo
12	PC3	Back-Left-Top Servo
13	PC4	Middle-Left-Bottom Servo
14	PC5	Middle-Left-Top Servo
15	PC6	Front-Left-Bottom Servo
16	PC7	Front-Left-Top Servo
43	PE0	E-Switch
44	PE4	Front IR Detector
2	MODB	DOWNLOAD/RUN Switch Connection
3	MODA	Short to Ground
17	RESET	Reset Switch Connection

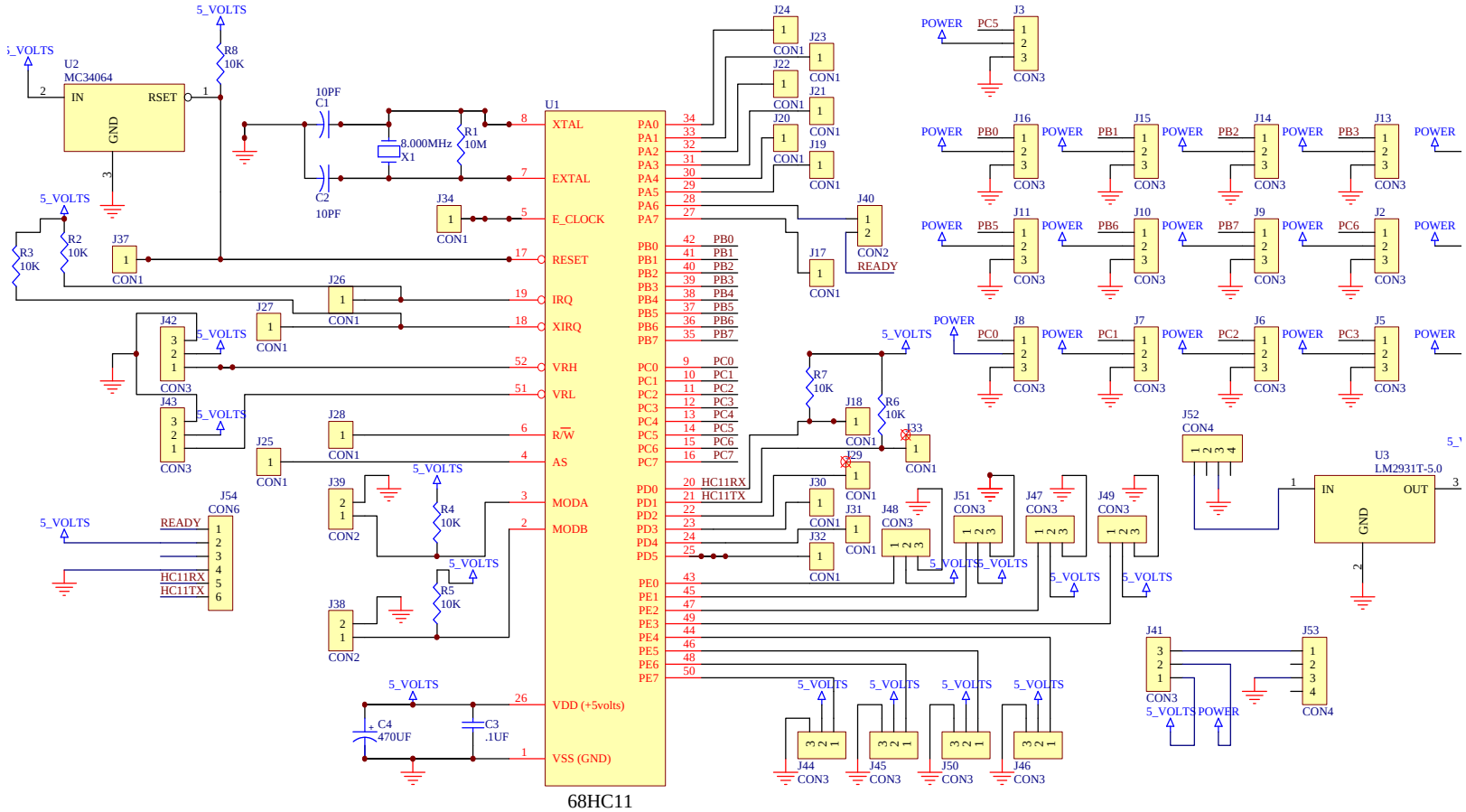


Figure 2 Schematic of the MSCC11.

Jumpers J42 (VRH) and J43 (VRL) permit you to establish different voltage reference levels for the A/D converter. The RS232 6-wire cable connects to J54 and permits serial communication with the processor. Jumpers J38 and J39 allow you to control the processor mode upon reset. The usage of these and other jumpers in RoboBug™ are illustrated in **Error! Reference source not found.**.

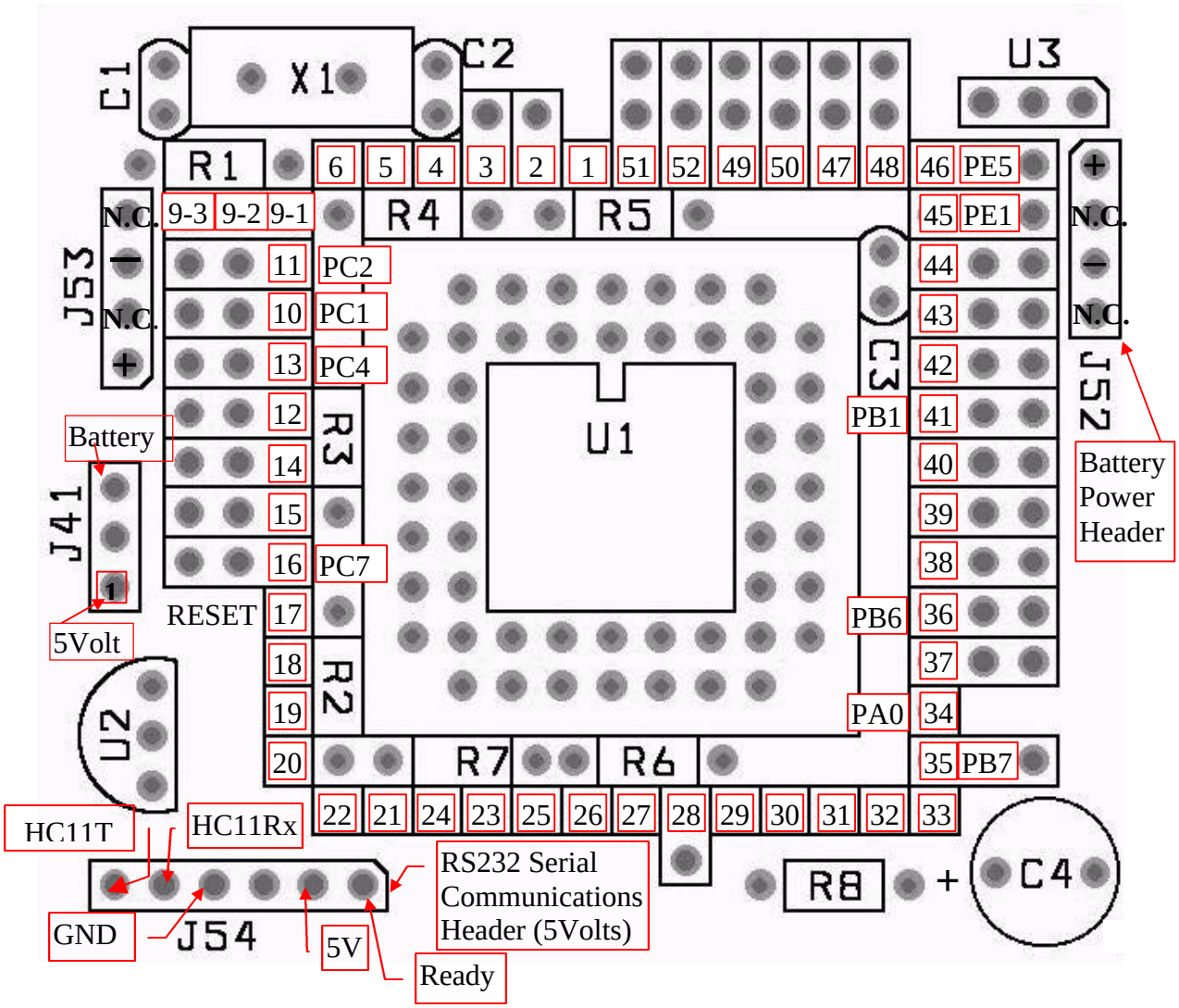


Figure 3 Layout of the MSCC11E2. Pin numbers refer to MC68HC11 pins.

3.4 Wiring Diagram for the Servos.

The figure on the next page (Figure 4) illustrates how to wire the servos, sensors, LEDs and switches to the MSCC11 board. Table 5 summarizes the microprocessor pins that drive the various servos and other non-processor system components.

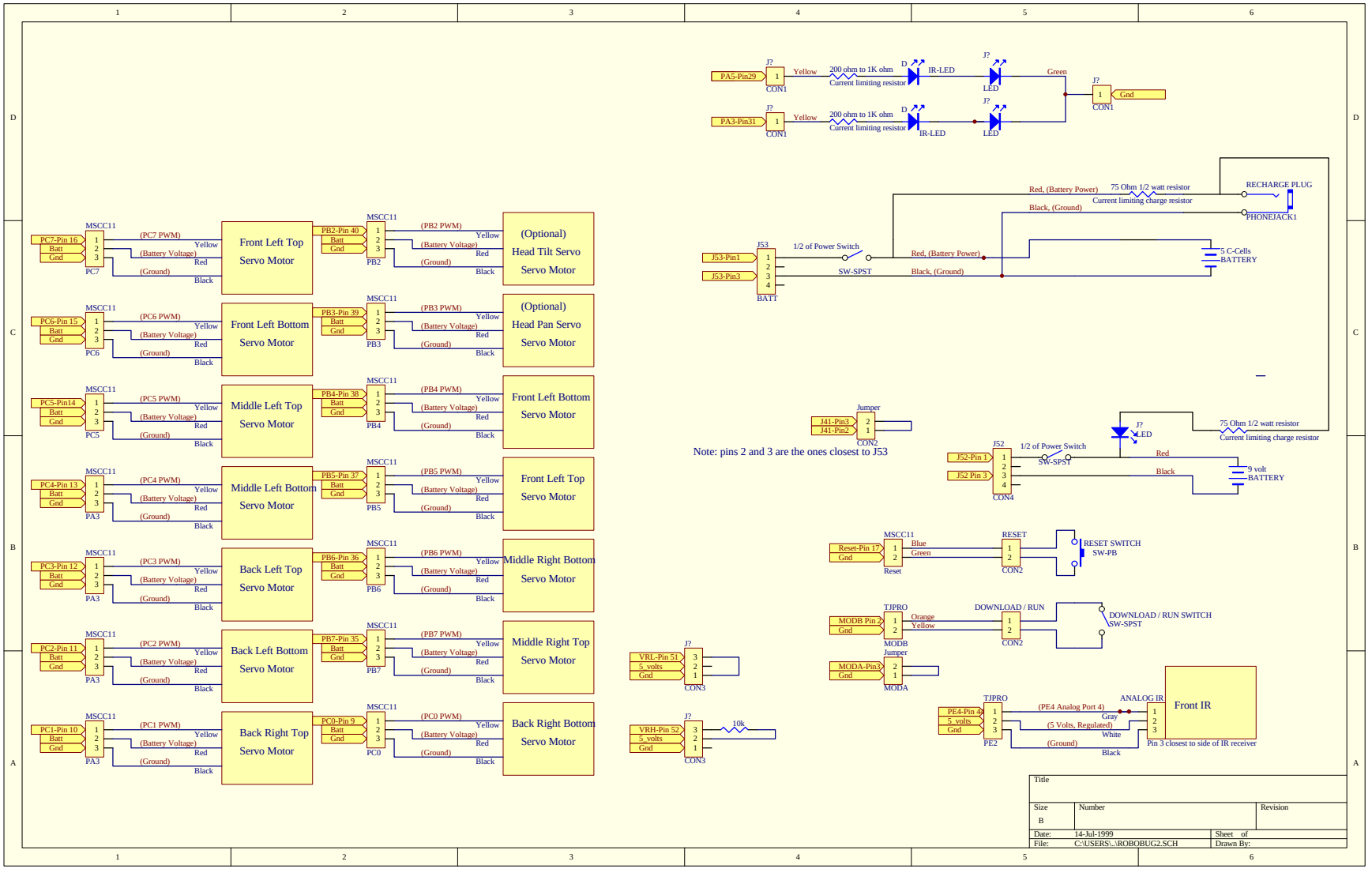


Figure 4 Wiring Diagram for the RoboBug Servos, Switches and Sensors. Note: Future versions will not use the E-switch.