

## Penguin Robot Kit

(Red #27313)

(Blue #27314)

(Nickel #27315)

(Black #27316)

The Penguin Robot is a precision-machined 4" tall biped. Similar to the Parallax Toddler, Penguin walks forward with a tilt-stride action and turns by sweeping both feet on the ground in opposite directions. Individual movement segments are linked together for this robot to walk. This basic biped design functions best in the Penguin's small scale. The Penguin mechanics have a close-tolerance fit and are designed to provide precise electronic control.



The Penguin's microcontroller is an embedded BASIC Stamp2px24 module, the fastest and most powerful BASIC Stamp in the Parallax lineup. The Penguin requires three hours to assemble, after which it is a PBASIC programming challenge to exploit all of the robot's capabilities.

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## 1.0 INTRODUCTION

### 1.1. AUDIENCE

The Penguin isn't a beginner's robot. The Penguin is a small desktop robot, not intended for long-distance adventuring. The Penguin's electronics are fully assembled and wired to an assortment of I/O devices. Additionally, it has a fairly complex programming process which is more difficult to understand than a two-wheeled robot. For example, Penguin's walking steps must be linked and the compass sensor must be calibrated. For these reasons we recommend this robot for the hobby robotics enthusiast or collector who have an extended interest in PBASIC programming.

### 1.2. FEATURES

- BS2px24 module chipset
- CNC-machined 6061 aluminum parts available in four color schemes
- (2) micro servos
- Hitachi HM55B Digital Compass sensor
- Blue seven-segment LED for feedback
- (2) photoresistors
- (2) infrared emitters and one detector
- Piezospeaker in body, underneath battery pack
- Power switch located adjacent to battery pack
- FTDI 232RL mini USB programming port
- (2) CR123 batteries for 6V power supply
- Blue power indicator LED
- expansion I/O port, Vss and Vdd header for Ping))) distance sensor or RF modules

### 1.3. SYSTEM AND SOFTWARE REQUIREMENTS:

- PC running Windows XP/Vista, with an available USB port
- BASIC Stamp Editor Software v 2.3 or higher - download from [www.parallax.com/downloads](http://www.parallax.com/downloads).
- USB VCP Drivers - these can be installed automatically via the BASIC Stamp Editor v2.3 installer, or you may download the latest version separately from link on [www.parallax.com](http://www.parallax.com) home page.
- Penguin Test and Sample Programs - test programs are included in this document; all programs listed may be downloaded as .bpx files from Penguin product page at [www.parallax.com](http://www.parallax.com).

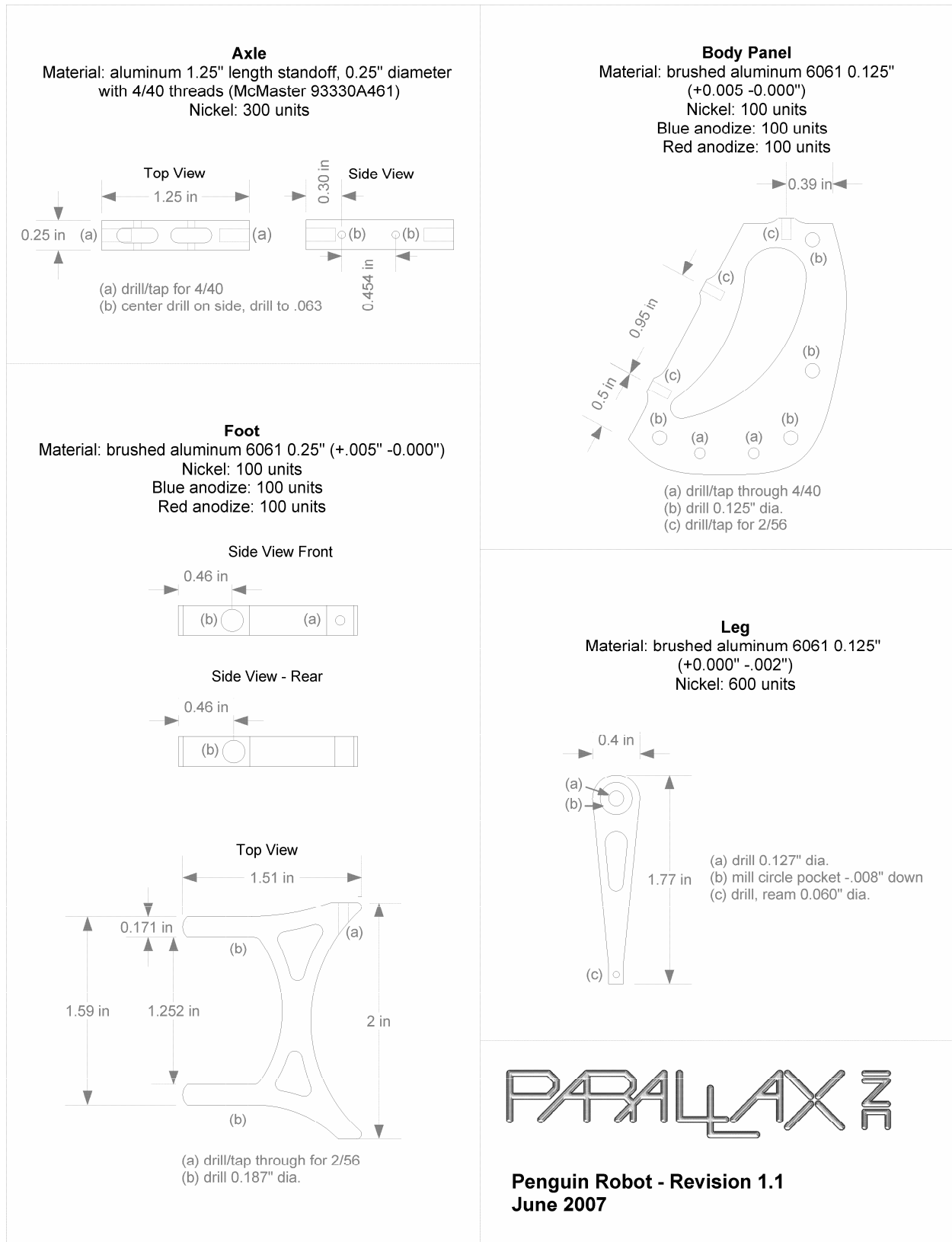
### 1.4. BILL OF MATERIALS

Part #	Description	Quantity
<b>Penguin Body Kit</b>		
720-27313	Red Anodized Penguin	1
720-27314	Blue Anodized Penguin	1
720-27315	Nickel Plated Penguin	1
720-27316	Black Anodized Penguin	1
Each of the above includes:		
--	Body panels	2
--	Leg pairs attached to ankle	2
--	Feet	2
--	4-40 5/8" long standoffs, with machined flat space	4
<b>Penguin Hardware Package</b>		
720-00013	Stride linkage, Delrin 1.4" square rod	1
720-00015	2-56 threaded rod 2.5" long	2
710-00013	4-40 1/8" long, 0.149" diameter stainless steel shoulder screw	4
710-00010	4-40 1/8" long, 1/8" diameter stainless steel shoulder screw	4
710-00011	4-40 1/4" button socket cap stainless steel screw	12
710-00012	2-56 1/4" button socket cap stainless steel screw	2
710-00014	2-56 1/4" flathead stainless steel screws	4
725-00016	2-56 ball links for 2-56 threaded rod	2
725-00062	1/16" hex key	1
725-00063	0.05" hex key	1
725-00064	5/64" hex key	1
725-00067	1.5 mm hex key	1
725-00018	1/16" ball links for 2-56 threaded rod	2
<b>Electronics</b>		
555-27313	Penguin BS2px printed circuit board	1
Each of the above includes:		
--	BS2px24 circuit board	1
--	Flat white ribbon cable to connect the boards	1
--	Power pack board	1
<b>Miscellaneous</b>		
700-00064	Parallax dual-head screwdriver	1
752-00003	CR123 Batteries	2
805-00010	USB A to Mini B programming cable	1
900-00014	Grand Wing Naro standard servo	2



**Missing parts?** Your Penguin experience should be nothing short of complete success and satisfaction. If you encounter a missing part contact us immediately and we'll put it in the mail for you. The best way to do this is by e-mail to [sales@parallax.com](mailto:sales@parallax.com), or you can call us at (888) 512-1024.

## 1.5. BODY KIT MECHANICAL DRAWINGS



## 2.0 ASSEMBLY

### 2.1. TOOLS REQUIRED

The Penguin kit includes a portion of the tools required to build the robot (the hex keys a screwdriver). You will need to provide these additional tools to finish assembly, which are not included in the kit:

- Small pliers
- Ruler or calipers
- Handheld drill or small drill press with 1/16" drill bit
  - or -
  - X-Acto® knife
- Small adjustable crescent wrench (or 3/16" socket)
- Safety glasses



**Safety first!** Taking basic safety precautions is absolutely necessary when building a Penguin. The assembly process includes several steps where you will be exposed to danger. You will be using a sharp drill bit or X-Acto knife to enlarge a tiny hole, and tiny pieces may fly. You will be pressing ball joints together, where a small slip can puncture your skin. These dangers are minimized by wearing safety glasses and using the right tools for the job.

### 2.2. ASSEMBLY INSTRUCTIONS

#### Step 1: Attach standoffs to servos

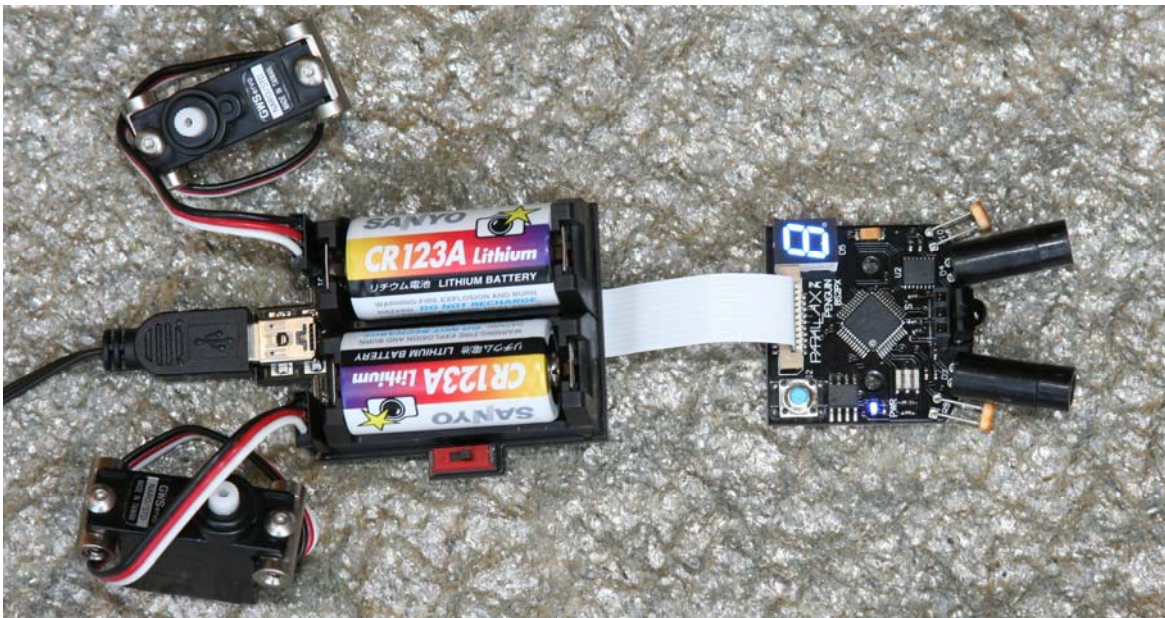
Connect (4) of the 4-40 1/4" button socket cap stainless steel screws to the middle of the 5/8" 4-40 standoffs. The standoffs have a machined flat space in the middle against which the servo tab will be seated when the screw is tightened. Press the standoffs against the servo body when tightening the screws. This will ensure proper spacing when the servos are mounted in the Penguin body panels.



## Step 2: Center the servos using the BASIC Stamp Editor

This step centers the servos, so that further mechanical tuning will be minimized once the Penguin is assembled. It also ensures that you won't need to take the Penguin apart once you start programming it. The servos need to be centered with a 1.5 ms pulse, following the directions below:

- Connect the Penguin boards together using the flat ribbon cable. The blue-tipped side of the cable faces away from both boards (blue side is facing down in this photo).
- Insert two (2) CR123A batteries into the power pack. A line drawing on the inside of the battery holder shows how the batteries are oriented.
- Plug two servos into the bottom of the power pack, being careful to orient them correctly. From the perspective of this photo, the servo's white leads are on the bottom, or the right side of each servo connector as viewed behind the Penguin.
- Download and install the BASIC Stamp Editor and FTDI USB VCP drivers software if you have not done so already.
- Plug the mini USB cable into the power pack.
- Plug the other end of the USB cable into your PC.
- Turn on power to the board (red switch).
- Open the BASIC Stamp Windows Editor and run the Penguin Servo Centering.bpx program.
- The servos are now centered. Disconnect the servos first, and then remove the batteries and USB cable from the power pack board.



```
' Parallax Penguin Robot
' Penguin-CenterServos.bpx
' {$STAMP BS2px}
' {$PBASIC 2.5}

Center      CON      1875      ' Centered servo pulse
StrideServo PIN      6
TiltServo  PIN      7

DO
  PULSOUT StrideServo, Center      ' Center stride servo (J1)
  PULSOUT TiltServo,   Center      ' Center tilt servo (J2)
  PAUSE 15
LOOP
```

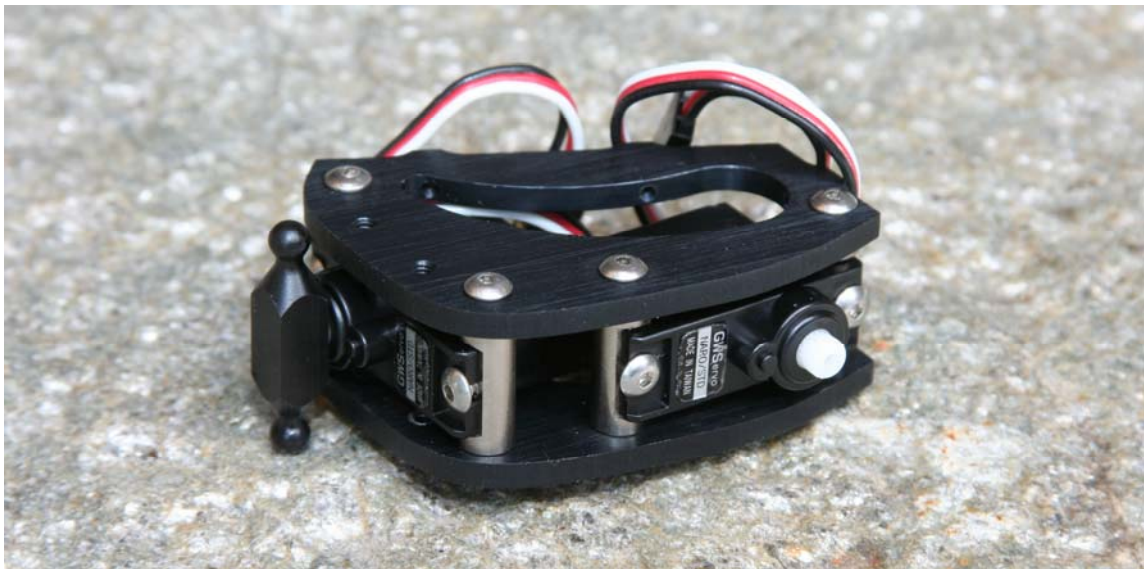
### Step 3: Assemble the Penguin body

Install the servos into the Penguin body using (8) 4-40 1/4" long button socket cap stainless steel screws and the 1/16" hex key. The picture shows how the servo splines are oriented: the stride (bottom) servo spline is near the rear of the Penguin; the tilt (top) servo spline is near the top of the Penguin. Tighten the screws.



### Step 4: Install stride linkage on the stride servo

Locate the small black plastic stride linkage, which will be the stride mechanism in the Penguin's rear leg. This part is machined on a lathe from a 1/4" square rod to 1 1/4" long with two ball-shaped ends (on the left side of the picture). The stride linkage has the reverse shape of the servo spline machined into the middle. Press it onto the servo so that it is as close to cross-wise to the Penguin body as possible, it may not be perfectly perpendicular because the spline is toothed. For fine-tuning, this can be corrected with calibration-in-software using sample code available for free download from the Penguin product page.



### Step 5: Attach legs and ankles to body

The Penguin's legs and ankles come pre-assembled since they required a specialized tool to properly insert small dowel pins through the round ankle. Each Penguin has a pair of left and right legs. Also notice that there's a round machined recess with a diameter slightly larger than the shoulder screw head on each pair of legs. The recess faces out towards the shoulder screw, and the shortest part of the ankle faces forward. Shoulder screws have a 1/8" diameter smooth stainless steel surface upon which the legs will rock back and forth.

To install the leg assemblies on the Penguin, use the (4) 4-40 1/8" long shoulder screws and the 5/64" hex key. The ball-shaped ends of the stride linkage fit within the matching oval cutout in the rear legs.

The legs should move freely when assembled, and you will hear the stride servo's gears moving at the same time. If it takes force to move the legs you have one of two problems: either the metal parts have bound, or the screws are too tight into the body panels. Tighten everything enough to remove "slop" but not so tight that parts are unable to move freely.





### Step 6: Mount Penguin feet to the ankles

The Penguin kit has (4) 4-40 1/4" long, 0.149" diameter stainless shoulder screws which are used to attach the feet to the ankles. The head of these screws provides a bearing surface for the ankle so it may rotate freely within the foot when Penguin leans from side to side.

Each foot has an additional 2-56 threaded hole where the Penguin's ball joints mount for the threaded rod which connects to the tilt servo (the ski poles). These threaded holes denote the front of the foot.

Carefully drop the ankles into the foot. This is a close-tolerance fit; the ankle will only fit into the foot if it is inserted squarely. Next, use the 1.5 mm hex key to tighten the 4-40 long 0.149" diameter stainless steel shoulder screws into the ankle.

Then Penguin will now stand up without assistance.



### **Step 7: Screw 2-56 ball links into feet**

The Penguin kit contains two different sizes of ball links. The 2-56 threaded ball links are used in this step (the 1/16" ball links are used in a subsequent step). Open the package and thread the 2-56 ball link post into the front of each foot. You can tighten them using a 3/16" socket or small wrench. Be careful not to scratch the feet as you tighten the ball links. The threaded portion of the ball link will not screw all the way into the foot because it has a small non-threaded portion between the threads and the hex-shaped post. Don't force it beyond the point at which the ball link is easily screwed into the foot.



### Step 8: Attach plastic ball sockets to 2-56 threaded rod

Now you're ready to thread the four (4) plastic ball sockets onto each end of the 2-56 threaded rod. Twist both ends on evenly until the rod length is about 3.4" long. If this is too difficult to do with your hands, consider carefully holding the threaded rod with pliers. Use a small rag to prevent it from being scratched.



### Step 9: Drill a 1/16" hole in the servo horn

Each servo package includes an assortment of servo horns. We'll use the widest servo horn in this step. If you make a mistake it's okay because there's a second one in the other servo package.

Put on your safety goggles. Using a 1/16" drill bit or an X-Acto knife, very carefully enlarge the two outermost holes on the servo horn. If using the knife, insert the tip in the hole and rotate it while applying slight pressure, to bore out the hole. If you are using a drill, run it very slowly to prevent it from feeding into the hole too quickly. If you run it too fast the drill will plunge into the plastic and you'll crack the servo horn. Take your time and use a low drill speed.



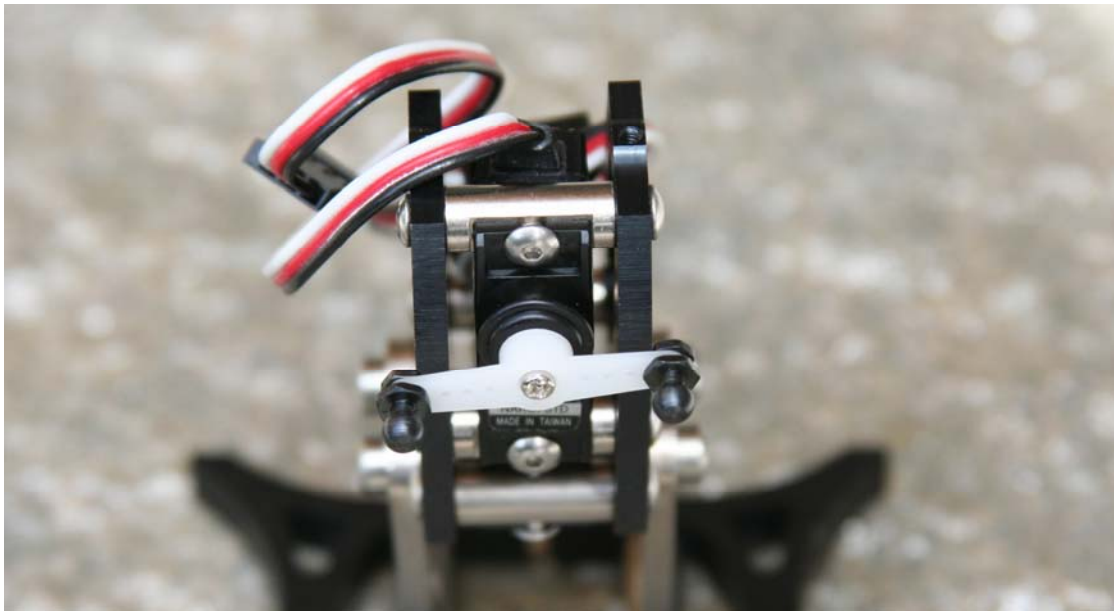
### Step 10: Connect the 1/16" ball links to the servo horn

Install the two 1/16" ball links on the servo horn. Tighten carefully but don't deform the plastic.



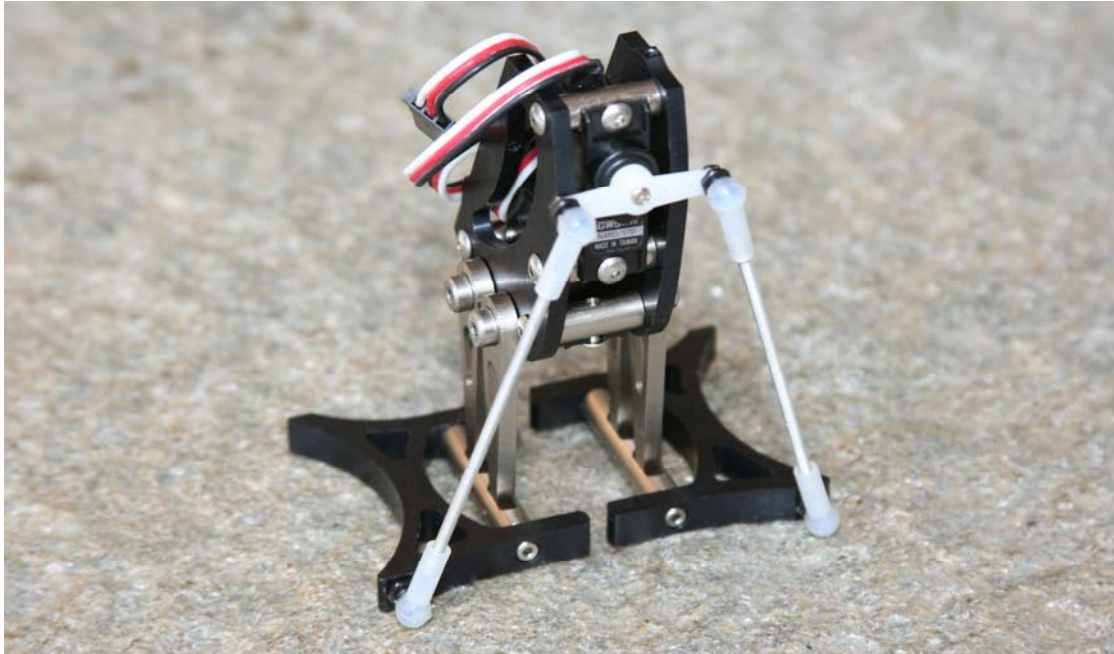
### Step 11: Attach the servo horn to the tilt servo

Press the assembled servo horn onto the tilt servo, positioning it cross-wise to the Penguin body. Do not over-tighten the screw; you may need to take off the horn and re-center the servo if it gets moved during the next step.



## Step 12: Connect the tilt servo horn and feet with the threaded rods

Now you're ready to snap the two threaded rods onto the front of the Penguin. The ball joints can be snapped onto the feet by hand. Attaching them to the servo horn ball joints is a bit more difficult. For this you can use a small pair of pliers. Place one jaw of the pliers behind the ball link's post, and the other on the outside of the plastic ball socket. Future adjustments can be made quite easily by disconnecting the ball link socket from the feet only. To disconnect them use a small screwdriver as a lever against the foot. Cover the foot with a cloth to prevent scratching.



**Bad Penguin Posture?** You may have rotated the tilt servo off-center while attaching the linkages. If the servos are centered, the Penguin will have its feet close together and will be standing straight up, and the tilt servo horn will be horizontal. If the tilt servo is not horizontal, remove the screw and very gently pull the horn off of the spline. Re-run Penguin-CenterServos.bpx, which should bring the feet together. Replace the horn on the spline, and replace the screw.

### Step 13: Attach BASIC Stamp 2px24 board to the Penguin body

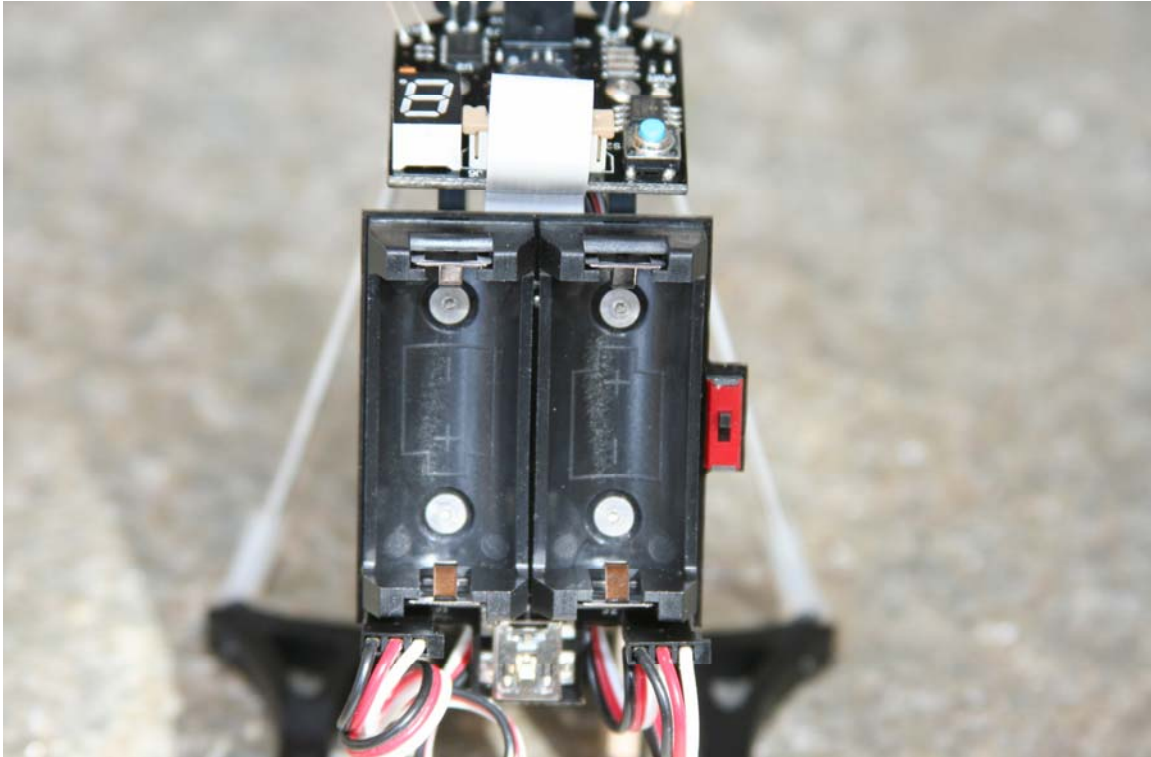
The Penguin's top board contains the BASIC Stamp 2px24 circuitry. It is mounted on the top of the Penguin using (2) 2-56 1/4" button socket cap stainless steel screws and the 0.050" hex key. You'll need to fold the tilt servo's wire over to tighten the board against the top of the Penguin.



### Step 14: Attach Power Pack board to the Penguin body

The Penguin's power pack board is installed using (4) 2-56 ¼" long flathead screws and the 0.050" hex key. When you mount this board be sure that the servo wires are not preventing it from properly seating into position.

Plug the servos back in. Connect the stride servo to J1 and the tilt servo to J2; make sure the white leads are on the right as shown in the photo.



### Step 15: Install batteries and tidy servo wires

Install (2) CR123 batteries into the Penguin's power pack. The batteries will be oriented in opposite directions according to the pictorial molded into the bottom battery holder's plastic surface. Coil up the servo wires behind the robot. It's also possible to hide them in the Penguin's body, but that requires substantial attention to detail considering the lack of free space.



### Step 16: Penguin is finished





Congratulations. Your Penguin is complete and ready for programming!





## 2.3. MECHANICAL TROUBLESHOOTING GUIDE

The Penguin is made from CNC-machined aluminum, molded plastic, screw-machine shoulder bolts, and a variety of electronic components from different factories. There's always the possibility that something will go wrong and parts will bind or move with limited freedom – it's nearly impossible to test every single sub-assembly. For example, tolerances on the shoulder screws and plastic sockets can vary from batch to batch or a shoulder screw bolt could have a slightly larger diameter shaft. It is imperative that your Penguin operate smoothly and without friction to be an effective walker. Contact us if you have any problems. Below are examples of common Penguin assembly difficulties and solutions to them.

Problem	Explanation	Picture
<p>Ball link sockets are tight or binding.</p>	<p>The ball link sockets are molded parts and they may vary in tolerance though we've chosen a supplier that offers a consistent product. The socket and ball should move freely without any friction when assembled. If you need to loosen up tight-fitting ball links:</p> <p>(a) Use an X-Acto knife to remove any plastic burrs inside the plastic socket.            (b) Add a drop of oil into the socket.            (c) Reassemble the ball links and check for friction.</p>	
<p>Legs move too much from left to right.</p>	<p>Pressing the left and right legs together should create no more than 1/8" to 1/4" of movement (or "slop" as it is called by a machinist). If a particular leg seems to have too much side-to-side play, you can fix this by tightening the shoulder screw down another 1/4 turn. If the problem persists, you can gently chamfer the threaded body panel with a drill to sink the shoulder screw further into the body. Be careful if you choose this option because you can remove too much metal and the leg will tighten against the body!</p>	
<p>Ankles are too tight within the feet.</p>	<p>The ankles are the 1 1/4" long by 1/4" diameter round standoff with two channels machined between. The legs are pinned in these channels. If the round ankle binds inside the foot, slightly shorten the ankle by rubbing the end of it on a piece of sandpaper. Insert the leg assembly back into the foot and check the fit.</p>	
<p>Legs are too tight against the body.</p>	<p>The correct adjustment for the legs depends on the shoulder screws being tightened gently. If the leg is binding against the body, back off the shoulder screws so it can move. Use a dab of Loc-Tite on the threads of the shoulder screw so it stays screwed into position in the body panel.</p>	

## 3.0 PROGRAMMING THE PENGUIN

### 3.1. PROGRAMMING CONCEPT

Programming the Penguin is very similar to the Parallax Toddler Robot, except that it uses the most capable BASIC Stamp. The BS2px24's higher speed is useful for computations and the expanded memory and RAM eliminates some of the issues with limited resources that the Toddler has with the BASIC Stamp 2. An improved walking algorithm has been created for the Penguin and its BS2px24 chipset.



**Close the Debug Terminal before downloading a new program, disconnecting the USB cable, or switching off the power to your tethered Penguin!** If you fail to close the Debug Terminal before any of these actions, the port may hang up and the BASIC Stamp Editor will freeze when you next try to program your Penguin. If this happens, close the Editor with the Task Manager.

### 3.2. SERVO CALIBRATION

The Penguins servos must be calibrated before the Penguin can walk. This is a crucial step and the Penguin will not walk without it.

- 1) Run Penguin-ServoCalibration.bpx
- 2) Click in the white transmit area at the top of the Debug Terminal.
- 3) Press 'Enter' to enable the servos
- 4) Press + and - to adjust the tilt servo
- 5) Press the space bar to switch to the stride servo
- 6) Press + and - to adjust the stride servo
- 7) Press 's' to save the new settings
- 8) Listen for the long beep to ensure that the settings were saved

**Tip: Pressing 1 through 5 changes the coarseness of the adjustments**

### 3.3. PENGUIN'S BASIC STAMP 2PX24 PINOUT

I/O Pin	Description	Direction
P0	Photoresistor – right	Output
P1	Photoresistor – left	Output
P2	Infrared emitter – right	Output
P3	Infrared emitter – left	Output
P4	Infrared receiver	Input
P5	I/O expansion port	Input/Output
P6	Servo stride	Output
P7	Servo tilt	Output
P8	7-segment LED A	Output
P9	7-segment LED B	Output
P10	7-segment LED C	Output
P11	7-segment LED D	Output
P12	Speaker	Output
P13	Hitachi HM55B Compass – CLK (clock)	Output
P14	Hitachi HM55B Compass – CS (chip select)	Output
P15	Hitachi HM55B Compass – DIN/DOUT (data in/out)	Input/Output

### 3.4. EXAMPLE PROGRAMS

Download the following test programs from the Penguin product page at [www.parallax.com](http://www.parallax.com) and test that each Penguin subsystem is working properly. Complete code listings are also included in this document.

- Penguin-CenterServos.bpx, page 6
- Penguin-SpeakerTest.bpx, page 20
- Penguin-IRTest.bpx, page 20
- Penguin-7SegmentLEDTest.bpx, page 21
- Penguin-PhotoresistorTest.bpx, page 21
- Penguin-CompassTest.bpx, page 22

Once you are familiar with the I/O capabilities of the Penguin, the following programs can be used to demonstrate all of the Penguins abilities. Download from the Penguin product page at [www.parallax.com](http://www.parallax.com).

- Penguin-AutonomousNavigation.bpx
- Penguin-MigrateNorth.bpx

### 3.5. COMPASS CALIBRATION

To improve the accuracy of the compass, the calibration routines for the Hitachi HM55B Compass Module have been ported to the Penguin. With the calibrated compass routines added to the Penguin's control code, extra RAM and code space is required. Separate versions of the following programs have been created to allow for either more available resources or a more accurate compass.

Original Code	Code Incorporating a Calibrated Compass
Penguin-CompassTest.bpx	Penguin-CalibratedCompassTest.bpx
Penguin-AutonomousNavigation.bpx	Penguin-AutonomousNavigation-CalibratedCompass.bpx
Penguin-MigrateNorth.bpx	Penguin-MigrateNorth-CalibratedCompass.bpx

Before the calibrated compass routines can be used, Penguin-CompassCalibration.bpx must be run to record the compass calibration data. For more information about compass calibration, please read HM55BModDocs.pdf and the associated code available from the Hitachi HM55B Compass Module product page at [www.parallax.com](http://www.parallax.com).

### 3.6. OTHER HELPFUL DOCUMENTATION

The following materials are helpful documents for programming the Penguin:

- Advanced Robotics with the Toddler (a Stamps in Class Text)
- BASIC Stamp PBASIC Syntax Guide (on-line version of help file installed with the BASIC Stamp Windows Editor)
- HM55B Compass Documentation
- HM55B Graphical Viewer for the HM55B
- Smart Sensors and Applications (a Stamps in Class Text)
- IR Remote for the Boe-Bot Text (a Stamps in Class Text)
- Ping))) Ultrasonic Sensor Documentation

### 3.7. TEST CODE LISTINGS

```
' Parallax Penguin Robot
' Penguin-SpeakerTest.bpx

' {$STAMP BS2px}
' {$PBASIC 2.5}

Speaker          PIN      12

i                VAR      Byte
Freq            VAR      Word

'Inverse of 12th root of 2 multiplied by 65536
'Used to divide by one semitone in a 12 note octave
Scale           CON      61858

Freq = 659
FOR i = 1 TO 12
  FREQOUT Speaker, 600, Freq
  Freq = Freq ** Scale
NEXT
' Frequency of an E5
' 12 semitones = 1 octave
' Play the frequency
' lower frequency by 1 octave
```

```
' Parallax Penguin Robot
' Penguin-IRTest.bpx

' {$STAMP BS2px}
' {$PBASIC 2.5}

REmitter        CON      2
LEmitter        CON      3

IrInput         VAR      IN4

LeftIr          VAR      Bit
RightIr         VAR      Bit

DEBUG CLS
DEBUG "Infrared sensor status:", CR,
      "Left:", CRSRXY, 15, 1, "Right:"
DO
  GOSUB ReadIr
  DEBUG CRSRXY, 6, 1, DEC LeftIr
  DEBUG CRSRXY, 22, 1, DEC RightIr
  PAUSE 150
LOOP
' Prepare debug screen
' Update debug screen with
' status of IR sensors

ReadIr:
  FREQOUT LEmitter,1,6300
  LeftIr = ~IrInput
  FREQOUT REmitter,1,6300
  RightIr = ~IrInput
RETURN
' Modulate emitters at 38KHz
' and check for reflections
```

```

' Parallax Penguin Robot
' Penguin-PhotoresistorTest.bpx

' {$STAMP BS2px}
' {$PBASIC 2.5}

REmitter      PIN      2
LEmitter      PIN      3
IrInput       PIN      4

LeftLDR       VAR      Word
RightLDR      VAR      Word

OUTPUT lEmitter      ' Set IR LEDs as outputs
OUTPUT rEmitter      ' and the IR receiver as
INPUT IrInput        ' an input

HIGH LEmitter        ' Charge capacitors for
HIGH REmitter        ' photoresistor R/C circuit

DEBUG CLS           ' Prepare debug screen
DEBUG "InfraRed sensor status:", CR,
      "Left:", CRSRXY, 15, 1, "Right:"

DO
  GOSUB READLDR      ' Update debug screen with
  DEBUG CRSRXY, 6, 1, DEC LeftLDR, " " ' status of photoresistors
  DEBUG CRSRXY, 22, 1, DEC RightLDR, " "
  PAUSE 150
LOOP

ReadLDR:
  RCTIME 0, 1, LeftLDR      ' Read R/C time for each
  HIGH 0                    ' photoresistor then recharge
                              ' their capacitors

  RCTIME 1, 1, RightLDR
  HIGH 1
RETURN

```

```

' Parallax Penguin Robot
' Penguin-7SegmentLEDTTest.bpx

' {$STAMP BS2px}
' {$PBASIC 2.5}

LEDDisplay    VAR      OUTC      ' The LED display mirrors OUTC
DIRC = %1111  ' Set LED

DO
  FOR LEDDisplay = 0 TO 9      ' Write directly to LEDDisplay
    PAUSE 750                  ' to change the number displayed
  NEXT
LOOP

```

```

' Parallax Penguin Robot
' Penguin-CompassTest.bpx

' {$STAMP BS2px}
' {$PBASIC 2.5}

Compass      PIN      15      ' Transceives to/from Din/Dout
Clock        PIN      13      ' Sends pulses to HM55B's Clock
Enable       PIN      14      ' Controls HM55B's /Enable

Reset        CON      %0000   ' Reset command for HM55B
Measure      CON      %1000   ' Start measurement command
Report       CON      %1100   ' Get status/axis values command
Ready        CON      %1100   ' 11 -> Done, 00 -> no errors
NegMask      CON      %1111100000000000 ' For 11-bit negative to 16-bits

x            VAR      Word     ' x-axis data
y            VAR      Word     ' y-axis data
Heading      VAR      x        ' Store Heading measurement
status       VAR      x        ' Status flags

DEBUG CLS, "Heading:"

DO
  GOSUB ReadCompass
  DEBUG CRSRXY, 9, 0, DEC Heading, "° "
  PAUSE 150
LOOP

ReadCompass:
HIGH Enable      ' Compass module subroutine
LOW Enable       ' Send reset command to HM55B
SHIFTOUT Compass, Clock, MSBFIRST, [Reset\4]

HIGH Enable      ' HM55B start measurement command
LOW Enable
SHIFTOUT Compass, Clock, MSBFIRST, [Measure\4]

status = 0      ' Clear previous status flags

DO
HIGH Enable: LOW Enable ' Measurement status command
SHIFTOUT Compass, Clock, MSBFIRST, [Report\4]
SHIFTIN  Compass, Clock, MSBPOST, [Status\4] ' Get Status
LOOP UNTIL status = Ready ' Exit loop when status is ready

SHIFTIN  Compass, Clock, MSBPOST, [x\11,y\11] ' Get x & y axis values
HIGH Enable ' Disable module

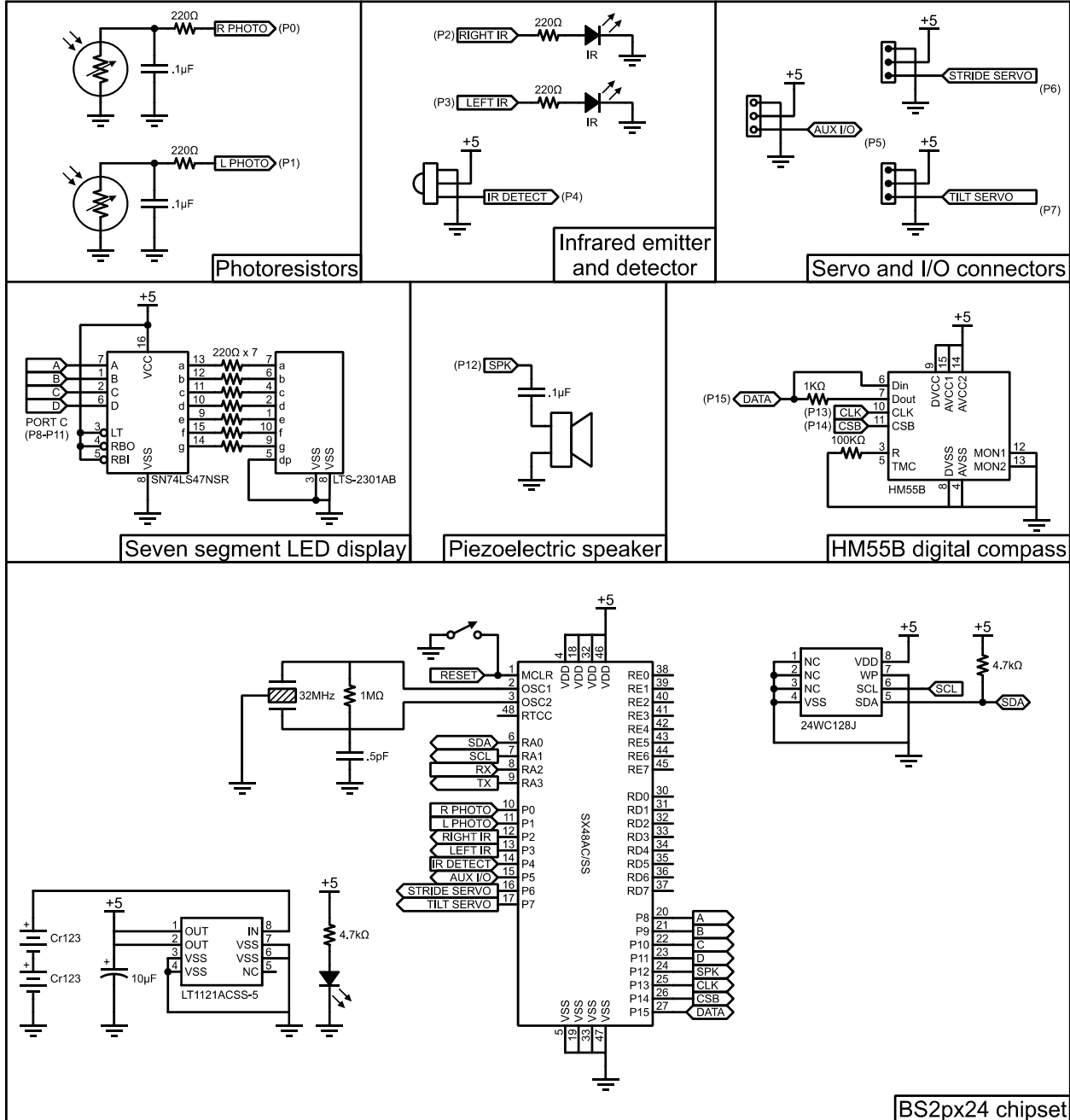
IF (y.BIT10 = 1) THEN y = y | NegMask ' Store 11-bits as signed word
IF (x.BIT10 = 1) THEN x = x | NegMask ' Repeat for other axis

Heading = x ATN -y ' Convert x and y to brads
Heading = Heading */ 360 ' Convert brads to degrees
RETURN

```

# 4.0 ELECTRONICS

## 4.1. PENGUIN SCHEMATIC



## 4.2. CR123 BATTERIES

The Penguin uses CR123 batteries (sometimes also referred to as size "N"). Quality CR123 batteries provide up to one amp-hour of power. CR123 batteries are truly overpriced from readily available sources (drug stores, grocery stores). For example the Energizer and Duracell CR123s are priced around \$12.00 per pair.

Parallax has tested all major brands of CR123 batteries (summarized below) and we buy them in bulk. In our tests, we used a fixed current draw of 200 mA at 6V. We measured the time required for the battery voltage to drop below 2.75V. Surprisingly, the tests showed almost no correlation between cost and performance!

The batteries we are selling (Rayovac and Panasonic) have approximately the same capacity as the more expensive ones and they're sold by Parallax at less than half the price of retail outlets! Don't be fooled into paying high prices for CR123 batteries. If you don't buy your CR123 batteries from Parallax then check eBay for the same brand we are selling (usually Rayovac or Panasonic). Pay no more than \$2-3 each. The Penguin's current draw during full operation is around about 150 mA. With two Rayovac CR123 batteries it should run for at least six to eight hours.

CR123 Manufacturer	Discharge time
Energizer	270 mins / 4.5 hours
Rayovac	240 mins / 4.0 hours
Duracell	225 mins / 3.8 hours
Panasonic	210 mins / 3.5 hours
Sanyo	150 mins / 2.5 hours
Chinese-label	5 mins / 0.1 hours

### CR123 Battery Test with 200 mA Current Draw

Conducted by Tigerbotics and Parallax June 2007

