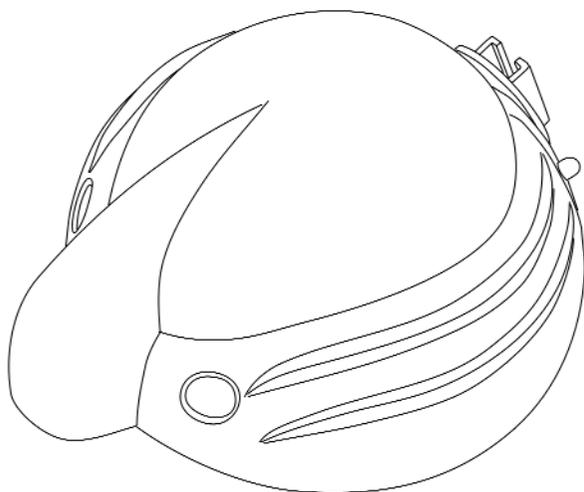


Build your own robot

LINETRACKER 1



Model No: MR1009



Manufactured by iBOTZ Division of Instruments Direct Ltd

The Open University is based at Milton Keynes in the U.K.



Read Before Proceeding

Read this manual carefully before getting started on your robot. Keep this manual for future reference.

- Take care when using sharp tools such as pliers or screwdrivers.
- Keep the robotic parts away from small children. Don't assemble the robot where small children can reach it.
- Keep fingers out of the working parts such as the motors and gears.
- Do not force the robot to move/stop; this could cause the motors to overheat.
- The specifications and anything contained within this manual are subject to change without notice.
- When using batteries:
 - 1.** Use the batteries in the correct polarity (+ -).
 - 2.** Never short circuit, disassemble, heat, or dispose of batteries in a fire.
 - 3.** When the robot is not in use, the batteries should be removed.
 - 4.** If the batteries or robot become wet, remove the batteries from the holder and dry the robot.
 - 5.** Do not mix old and new batteries. Do not mix alkaline, standard (carbon-zinc) or rechargeable (nickel-cadmium) batteries. We recommend the use of alkaline batteries for extended life.

LINETRACKER 1

Product Information

Model: MR-1009

About Line Tracker 1

This robot is a build yourself kit that will follow a black line at least 10mm wide (0.4 inches) on a white background.

Specifications

Power Voltage: 4 x AA Alkaline Batteries

Power Consumption —

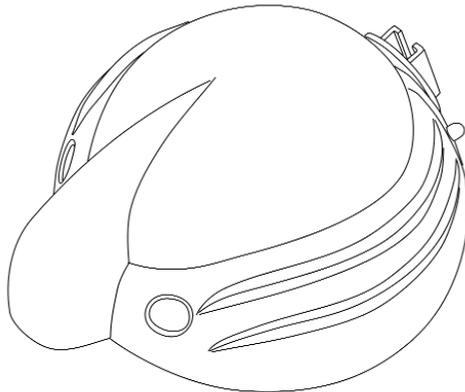
Maximum Current: 280 mA (while operating motor)

Height 70 mm

Length 157 mm

Width 140 mm

Completed Line Tracker 1





This iBOTZ kit is an ideal introduction for someone wanting to investigate the fascinating world of robots and intelligent machines.

The kit introduces the fundamentals of sensor technology and shows how sensors, electronic circuit boards, and motors can be combined with carefully designed mechanical gears and shafts to produce a robot that follows a black line on a white background using its photointerpreter “eyes.” How does it do all that?

By reading this manual you will find out what the components in your iBOTZ Line Tracker 1 do, and how they work together to generate its behavior. In the process you will be introduced to some basic electronics and aspects of engineering design.

We have iBOTZ robots in our laboratory at the Open University, and they are always a big hit with visitors. When you have built and experimented with yours, you will be ready to move on towards the more advanced robots that are used for research. Have fun!

Professor Jeffrey Johnson
Department of Design & Innovation
The Open University
<http://technology.open.ac.uk>

History of Robots

Definition of a Robot

According to The Robot Institute of America (1979) : “A reprogrammable, multifunctional manipulator designed to move materials, parts, tools, or specialized devices through various programmed motions for the performance of a variety of tasks.”

According to Webster’s dictionary: “An automatic device that performs functions normally ascribed to humans or a machine in the form of a human (Webster, 1993).”

A brief review of robot development is important as it puts the current machines and interest in them into an historical perspective. The following list highlights the growth of automated machines that led to the development of the industrial robots available today.

250 BC

One of the first robots was the clepsydra or water clock, which was made in 250 B.C. It was created by Ctesibius of Alexandria, a Greek physicist and inventor.

1801

Joseph Jacquard invents a textile machine that is operated by punched cards. The machine is called a programmable loom and goes into mass production.

1830

American Christopher Spencer designs a cam-operated lathe.

1892

In the United States, Seward Babbitt designs a motorized crane with gripper to remove ingots from a furnace.

1921

The first reference to the word “robot” appears in a play opening in London. The play, written by Czechoslovakian Karel Capek, introduces the word robot from the Czech *robota*, which means a serf or one in subservient labor. From this beginning the concept of a robot takes hold.

1938

Americans Willard Pollard and Harold Roselund design a programmable paint-spraying mechanism for the DeVilbiss Company.

1948

Norbert Wiener, a professor at M.I.T. publishes *Cybernetics*, a book which describes the concept of communications and control in electronic, mechanical, and biological systems.

1954

After the invention of the transistor in 1948, many robots were used in conjunction with the computer. The first patent for a computer controlled industrial robot was developed in 1954 by George Devol. Devol created a computerized memory and control system called “universal automation.” Devol co-founded the Unimation industrial robot company, and “started the industrial robot revolution” by selling designs of powerful assembly line arms to General Motors.

1959

Planet Corporation markets the first commercially available robot.



History of Robots, Continued

1960

Unimation is purchased by Condec Corporation and development of Unimate Robot Systems begins. American Machine and Foundry, later known as AMF Corporation, markets a robot.

1962

General Motors installs the first industrial robot on a production line. The robot selected is a Unimate.

1968

Stanford Research Institute at Palo Alto, California (SRI) builds and tests a mobile robot with vision capability, called Shakey. It was a small unstable box on wheels that used memory and logical reasoning to solve problems and navigate in its environment. Besides moving between rooms and avoiding objects, Shakey II was able to stack wooden blocks according to spoken instructions. It looked to see if the blocks were properly aligned, and if not, it adjusted the stack. Shakey was once asked to push a box off a platform, but could not reach the box. The robot found a ramp, pushed the ramp against the platform, rolled up the ramp, and then pushed the box onto the floor.

1970

At Stanford University, a robot arm is developed which becomes a standard for research projects. The arm is electrically powered and becomes known as the Stanford Arm.

1973

The first commercially available minicomputer-controlled industrial robot is devel-

oped by Richard Hohn for Cincinnati Milacron Corporation. The robot is called the T3, "The Tomorrow Tool."

1974

Professor Scheinman, the developer of the Stanford Arm, forms Vicam Inc. to market a version of the arm for industrial applications. The new arm is controlled by a mini-computer.

1976

Robot arms are used on Viking I and II space probes. Vicarm Inc. incorporates a microcomputer into the Vicarm design.

1977

ASEA, a European robot company, offers two sizes of electric powered industrial robots. Both robots use a microcomputer controller for programming and operation. In the same year Unimation purchases Vicarm, Inc.

1978

The Puma (Programmable Universal Machine for Assembly) robot is developed by Unimation from Vicarm techniques and with support from General Motors.

1980

The robot industry starts its rapid growth, with a new robot or company entering the market every month.

A Brief Overview

The parts of many modern robots can be generalized into four categories: the **base**, **object manipulator**, **primary control**

History of Robots, Continued

system, and **sensory system**. The **base** is usually a metal or plastic frame that supports the robot's components. Most industrial robot bases are stationary, although the arms move about. Other bases move about by treads, wheels, or legs. Wheel driven bases have various configurations. Some have two big rear wheels, and a small front balancing wheel, while others have four equally sized wheels.

The second part of the modern robot is the **object manipulator**. Basic grasping and manipulation requires a large amount of memory, due to the requirements of smoothness and sensitivity during operation. The minimum number of fingers necessary to grasp an object, hold it securely, and manipulate it smoothly was found to be three.

The third part of the modern robot is the **control system**. Primary systems include the remote control, driver circuit, or computer. Quite often, the control system consists of a primary control and secondary, application-specific controls. The primary control executes the main program, calling individual functions or reading resultant data, while the secondary control systems determine how those functions are processed.

The final part of the modern robot is the **sensory system**. The sense of touch is used for object recognition or collision avoidance. For example, a robot hand, equipped with a rubber skin of micro-switches, can recognize objects such as screws, pins and washers.

When, in 1954 George C. Devol filed a U.S. patent for a programmable method for transferring articles between different

parts of a factory, he wrote: "The present invention makes available for the first time a more or less general purpose machine that has universal application to a vast diversity of applications where cyclic control is desired."

In 1956 Devol met Joseph F. Engelberger, a young engineer in the aerospace industry. With others, they set up the world's first robot company, Unimation, Inc. and built their first machine in 1958. Their initiative was far ahead of its time; according to Engelberger, Unimation did not show a profit until 1975.

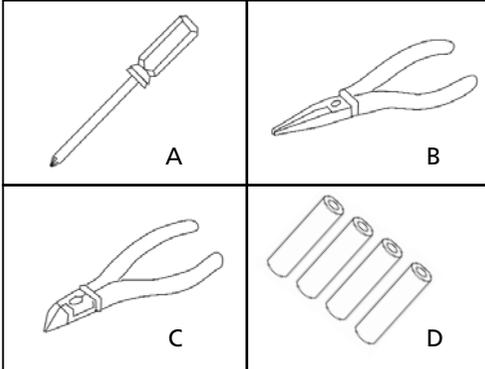
The first industrial robot saw service in 1962 in a car factory run by General Motors in Trenton, New Jersey. The robot lifted hot pieces of metal from a die-casting machine and stacked them.

Japan, by comparison, imported its first industrial robot from AMF in 1967, at which time the United States was a good 10 years ahead in robotics technology. By 1990, there were more than 40 Japanese companies producing commercial robots. By comparison, there were approximately one dozen U.S. firms, led by Cincinnati Milacron and Westinghouse's Unimation.

The Future of Robots

Robots and the robotics industry will continue to grow at a rapid rate. As technology advances, so will the robots that rely so heavily upon these advances. Robots will become more technical until one day they will become as powerful as we are. ■

Tools Needed for Assembly



- A) Small Phillips Screwdriver
- B) Long Nose Pliers to Handle Small Parts
- C) Cutting Pliers for Cutting Plastic Parts
- D) 4 x AA Batteries

Helpful Hints Prior to Assembly

Removing Parts from Plastic Frame

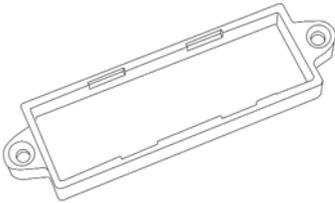
Use the cutting pliers to remove the individual parts from the plastic frame. Remove any burrs or flashing left on the parts.

Screw Sizing

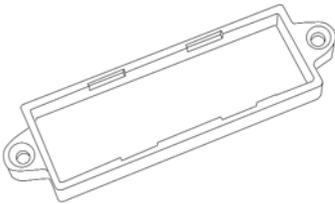
The size of the screws is expressed in thickness and length. Type A Screw marked M3 x 10 is 3mm thick and 10mm long.

Parts List

- | | | | |
|---|---|---------|----------------------|
|  | A | Screw A | Ø2.8 x 8 PB — 10 pcs |
|  | B | Screw B | Ø2.6 x 6 PB — 3 pcs |
|  | C | Screw C | Ø2.3 x 5 PB — 4 pcs |



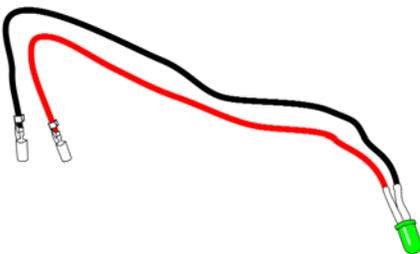
Right Gear Box Cover 1 pc



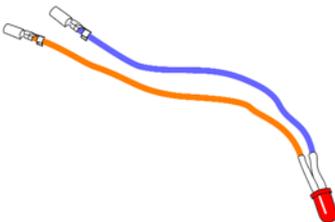
Left Gear Box Cover 1 pc



Battery
Compartment
Cover

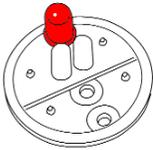
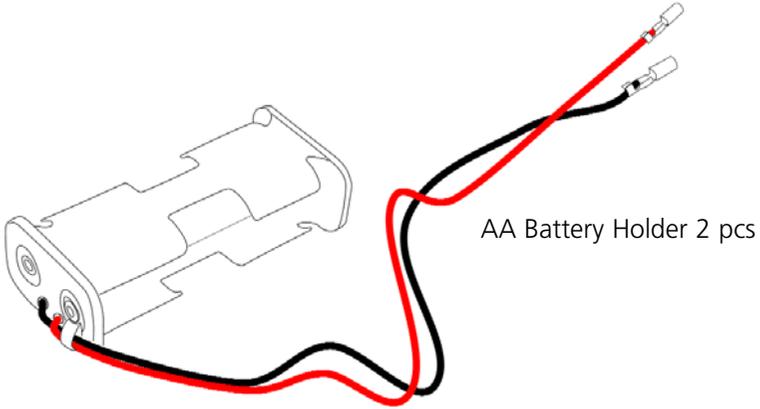


Green LED 2 pcs —
Red & Black Leads

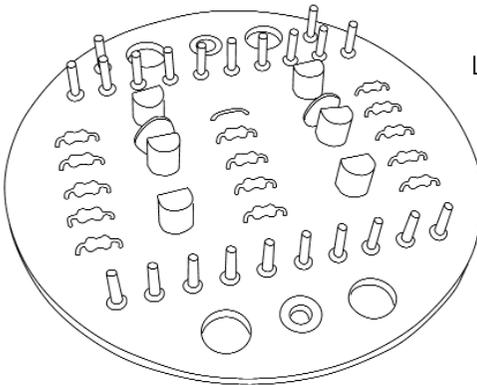


Red LED 2 pcs —
1 Blue & Brown Leads
1 Orange & Purple Leads (Shown)

Parts List, Continued



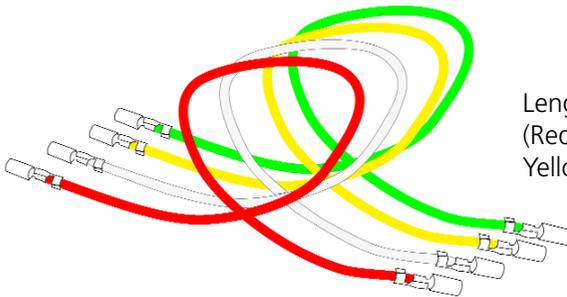
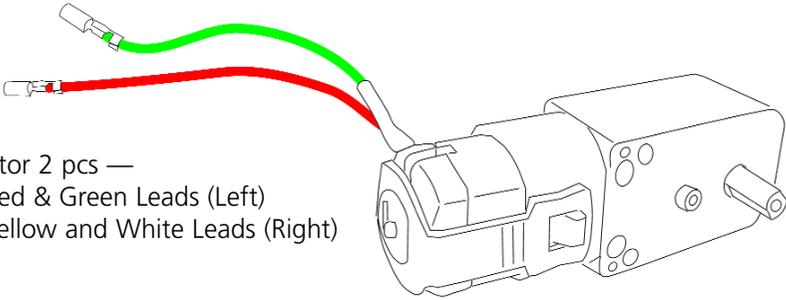
Small Circuit Board (PCB-2)



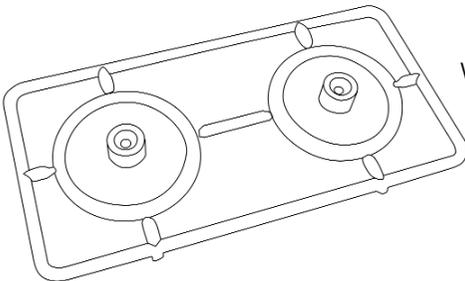
Large Circuit Board (PCB-1)

Parts List, Continued

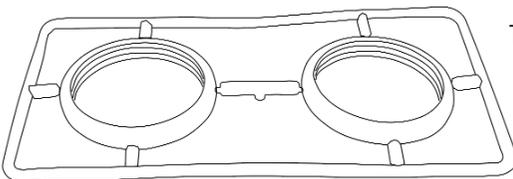
Motor 2 pcs —
1 Red & Green Leads (Left)
1 Yellow and White Leads (Right)



Lengths of Wire:
(Red, White,
Yellow, Green)

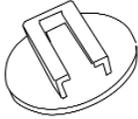


Wheel Set

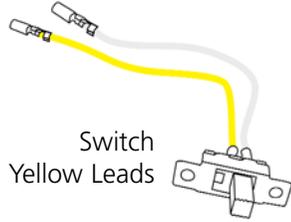


Tyre Set

Parts List, Continued

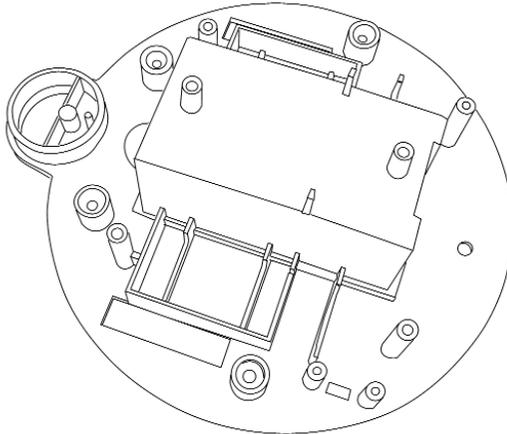


Accessory Bracket

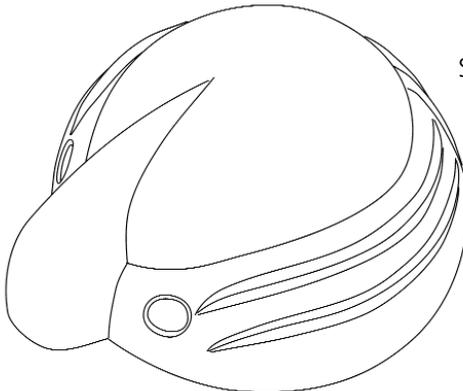


Switch
White and Yellow Leads

Robot's
Front



Robot Base / Top View

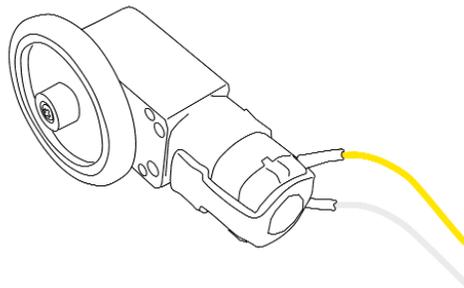
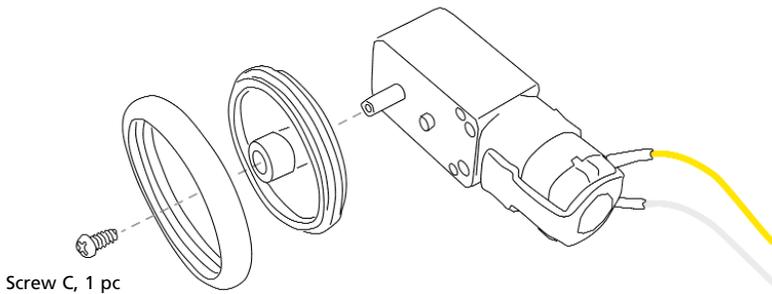


Shell Cover

Assembly Step 1

Assembling Wheels and Attaching Wheel Assemblies to Motors

Apply rubber Tyre to plastic Wheel and firmly push Wheel onto the axle of the Right Motor (Right Motor has Yellow and White wires). Using a Phillips Screwdriver and one Type C Screw, screw the wheel assembly to the Motor axle. Repeat this step for the Left Motor (Left Motor has Green and Red wires).

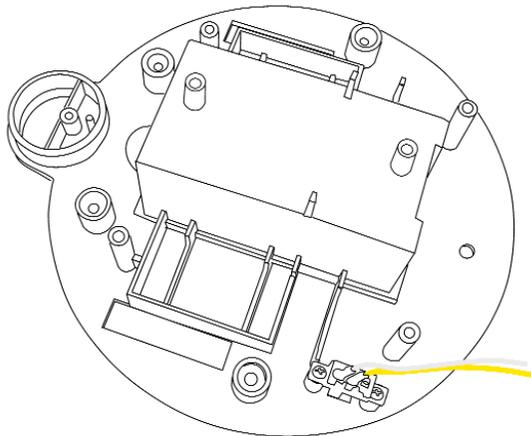
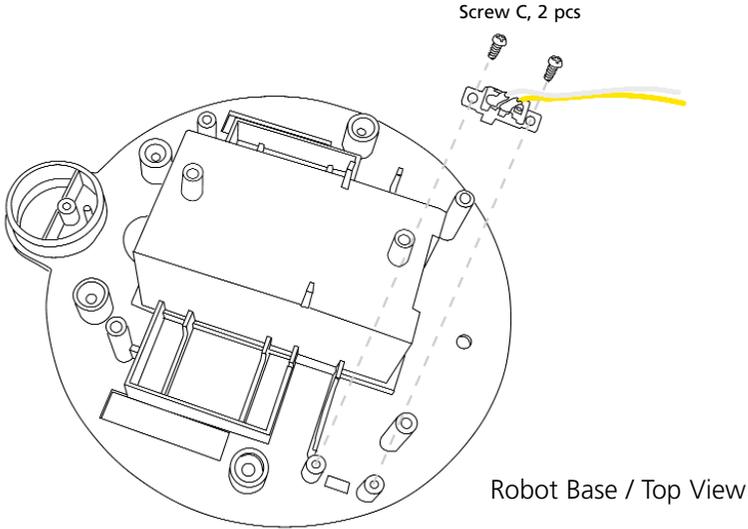


Right Motor and Wheel Assembly Shown

Assembly Step 2

Attaching the Switch

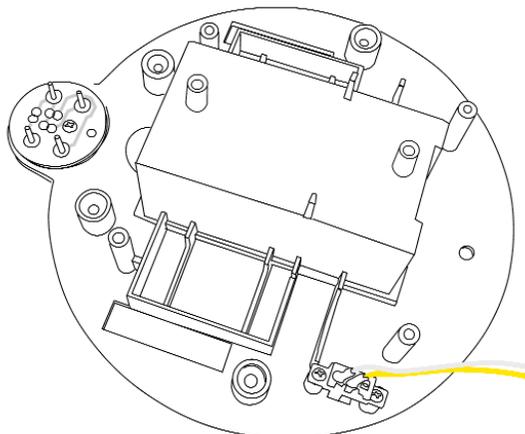
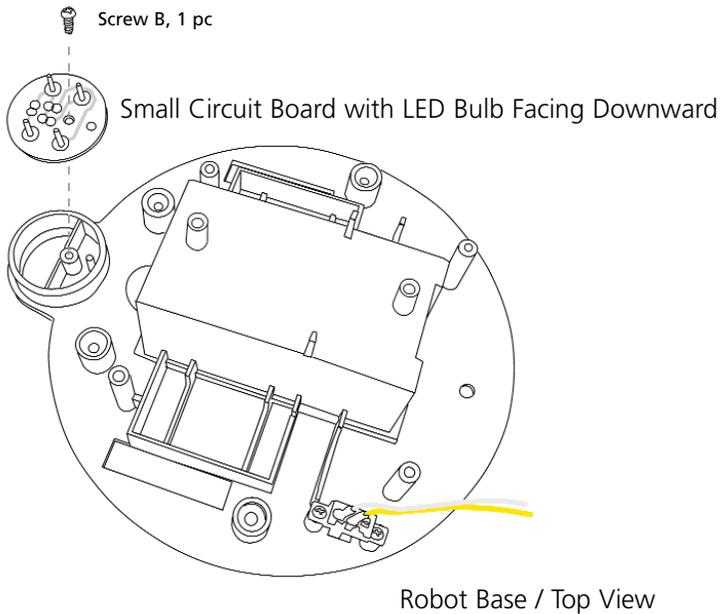
Using a Phillips Screwdriver and two Type C Screws, attach the Switch in its position on the left side of the Robot Base, as shown.



Assembly Step 3

Attaching the Small Circuit Board

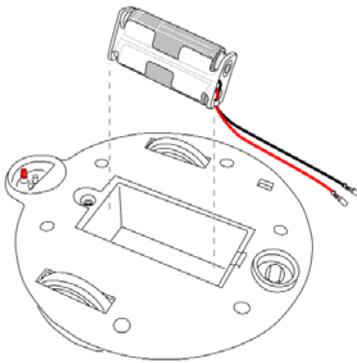
Place the Small Circuit Board into position on the front of the Robot Base as shown. Using a Phillips Screwdriver and one Type B Screw, attach the Small Circuit Board to the Robot Base. (The Red LED on the Circuit Board should protrude towards the flat (bottom) side of the Robot Base.)



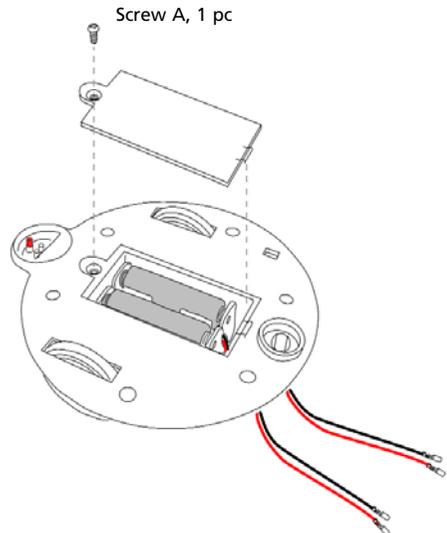
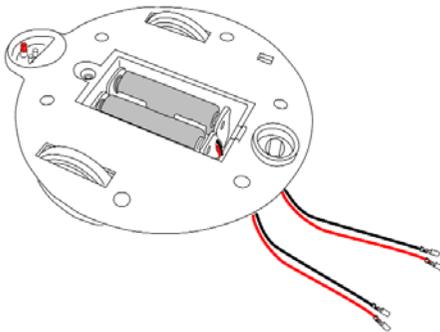
Assembly Step 4

Installing Battery Holder Assemblies

Insert the AA Batteries into the Battery Holders. With the Robot Base in an inverted position (flat side up), place the Battery Holders into the Battery Compartment, with wires feeding out of the Battery Compartment through the hole towards the rear of the Robot Base. Using a Phillips Screwdriver and one Type A Screw, attach the Battery Compartment Cover and screw it into place as shown. (Be sure to slide the tab of the Battery Compartment Cover (opposite the Screw) into the slot when you attach the Battery Compartment Cover.)



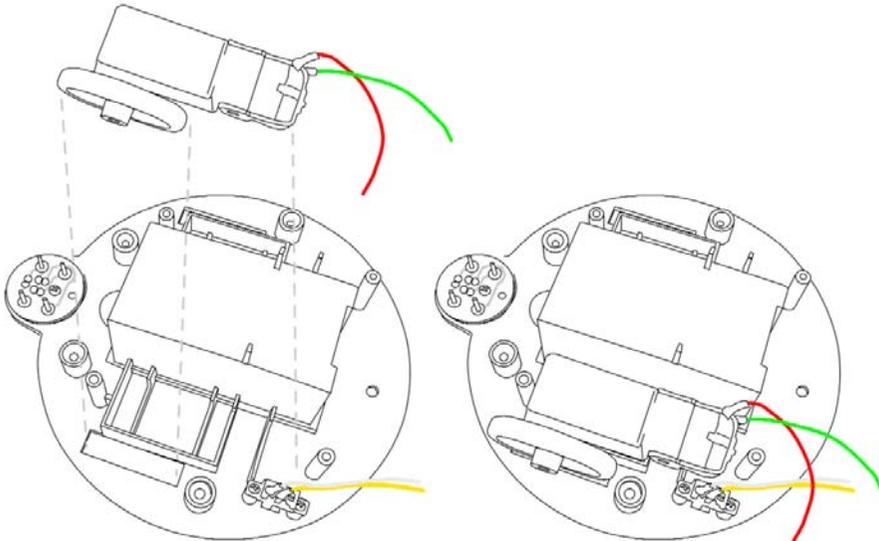
Robot Base / View from Bottom



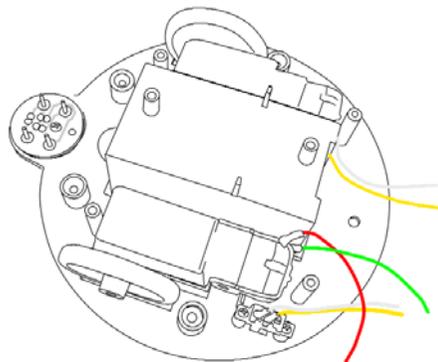
Assembly Step 5A

Inserting Motor and Wheel Assemblies into Robot Base

With the Robot Base in an upright position (flat side down), insert the left and right Motor and Wheel assemblies into position on the Robot Base as shown (left Motor has green and red wires; right Motor has yellow and white wires).



Left Motor in position.



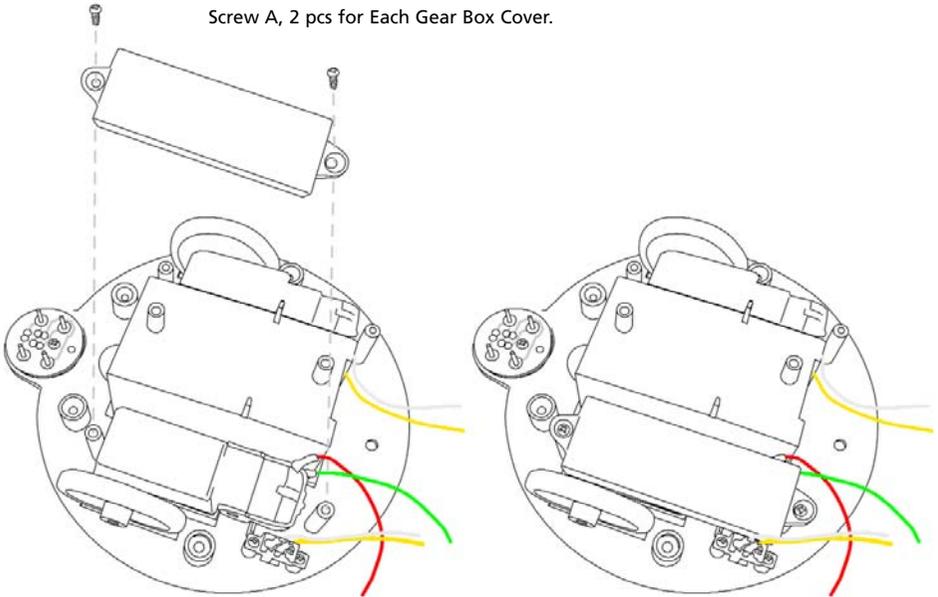
Both Motors in position.

Assembly Step 5B

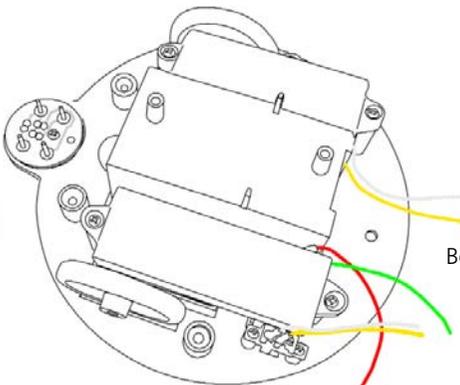
Attaching Gear Box Covers to Robot Base

Place the left and right Gear Box Covers into position over the Motors and using a Phillips Screwdriver, attach the Gear Box Covers to the Robot Base, each with two Type A Screws as shown. Make sure all Motor wires are extended outward towards the rear of the Robot Base.

Screw A, 2 pcs for Each Gear Box Cover.



Left Gear Box Cover in Place.



Both Gear Box Covers in place.

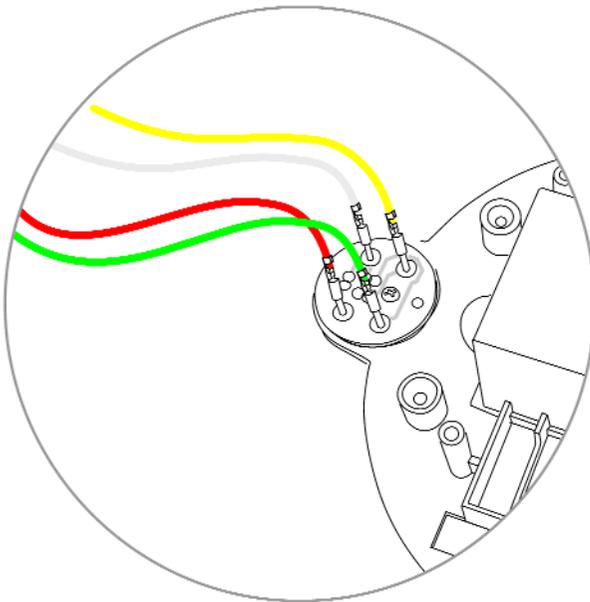
Assembly Step 6

Wiring the Small Circuit Board

Using a pair of Long Nosed Pliers, affix one end of each of the Lengths of Wire to the wiring pins on the Small Circuit Board at the front of the Robot Base, as follows:

WIRING TABLE

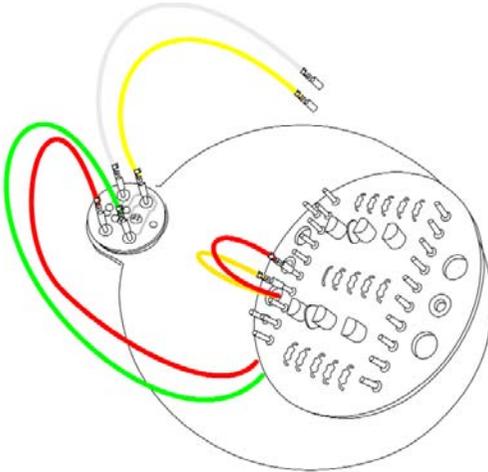
Red Wire	to pin RAY
Yellow Wire	to pin CL
White Wire	to pin G
Green Wire	to pin CR



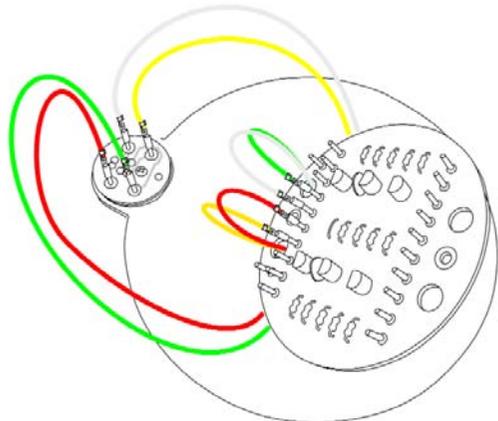
Assembly Step 7

Incorporating the Large Circuit Board

With the Large Circuit Board oriented with its front edge towards the front of the Robot Base, feed the Red and Yellow wires from the Small Circuit Board upward through the front left large hole in the Large Circuit Board as shown (details of Robot Base are omitted for clarity). Using a pair of Long Nosed Pliers, affix the wires to their pins, following the wiring table in Step 6. Next, feed the Green and White wires from the Small Circuit Board upward through the front right large hole in the Large Circuit Board and affix the wires to their pins, following the wiring table in Step 6.



(Details of Robot Base are omitted for clarity.)



Assembly Step 8

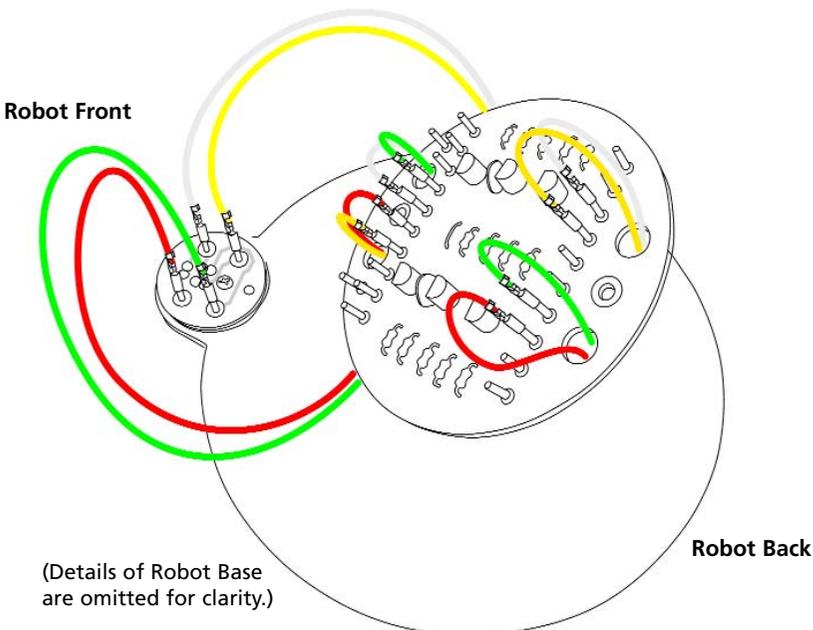
Wiring the Motors to the Large Circuit Board

You will now attach the Wires from the left and right Motors to their wiring pins on the Large Circuit Board. Feed the yellow and white Wires from the right Motor towards the back of the Robot Base and up through the right rear large hole in the Large Circuit Board. Using a pair of Long Nosed Pliers, affix the ends of the wires from the right Motor to their corresponding wiring pins on the rear of the Large Circuit Board, taking care to affix them in their assigned locations on the Large Circuit Board, as follows:

White Wire to pin MR-
Yellow Wire to pin MR+

Next, feed the Red and Green Wires from the left Motor towards the back of the Robot Base and up through the left rear large hole in the Large Circuit Board. Using a pair of Long Nosed Pliers, affix the ends of the wires from the left Motor to their corresponding wiring pins on the rear of the Large Circuit Board, taking care to affix them in their assigned locations on the Large Circuit Board, as follows:

Red Wire to pin ML+
Green Wire to pin ML-

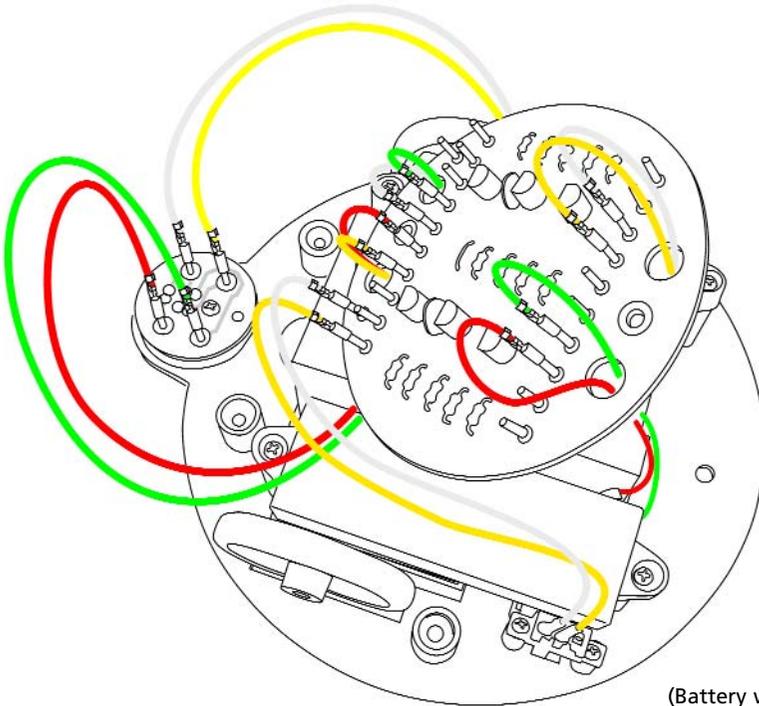


Assembly Step 9

Wiring the Switch to the Large Circuit Board

Bring the White and Yellow Wires from the Switch forward across the top of the left Motor and using a pair of Long Nosed Pliers, affix the ends of the wires from the Switch to their corresponding pins as shown at the front edge of the Large Circuit Board, as follows:

White Wire to pin SW-2
Yellow Wire to pin SW-1



(Battery wires are omitted for clarity.)

Assembly Step 10A

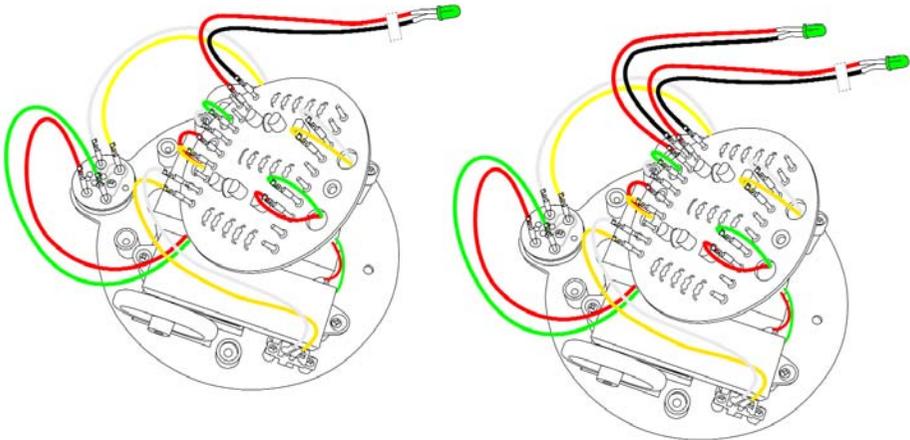
Attaching the Green LEDs to the Large Circuit Board

Attach one of the Green LEDs to the Large Circuit Board onto the corresponding wiring pins which are to the right front edge of the P.C. Board, using a pair of Long Nosed Pliers. Do not in this instance feed the wires through the holes. A small tab of tape may be handy in marking this pair of wires for future reference. This will be the Left Green LED on the rear of the Robot.

Black Wire to pin LED4 -
Red Wire to pin LED4 +

Repeat as above to attach the remaining Green LED onto the corresponding wiring pins, also to the right front of the P.C. Board. This will be the Right Green LED on the rear of the Robot.

Black Wire to pin LED5 -
Red Wire to pin LED5 +



(Battery wires
not shown.)

Assembly Step 10B

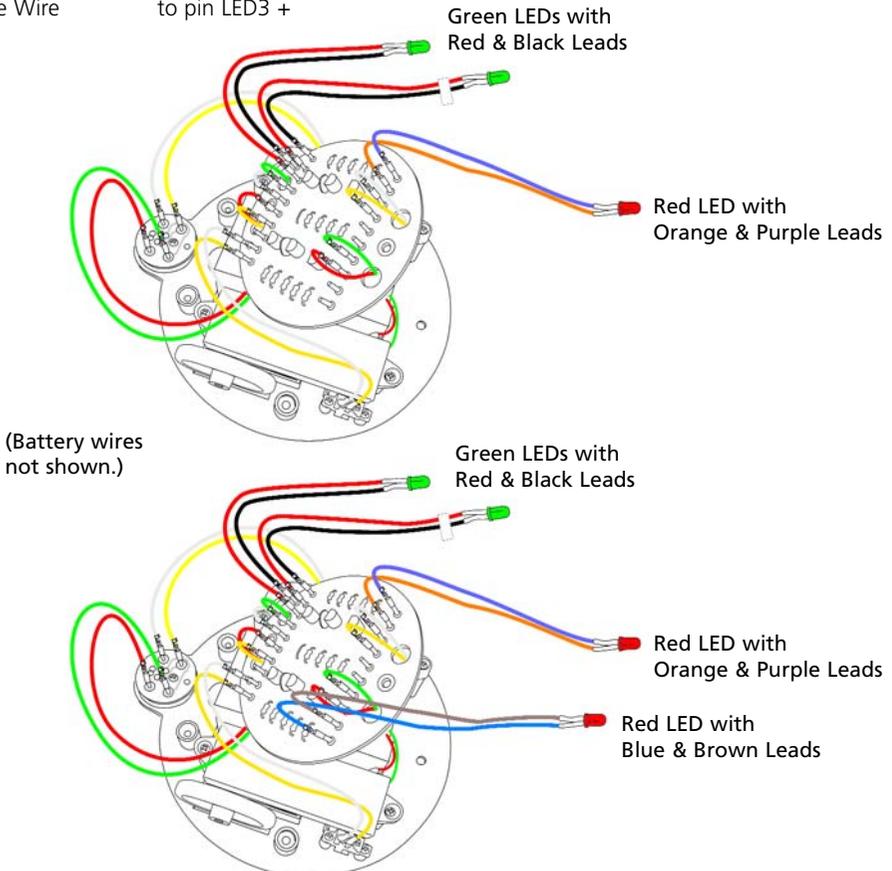
Attaching the Red LEDs to the Large Circuit Board

Again using Long Nosed Pliers, attach the Red LED with the Purple and Orange wires to the Large Circuit Board onto the corresponding pins located on the right rear edge of the Large Circuit Board, as below. This will be the Right Red LED on the rear of the Robot.

Purple Wire to pin LED2 -
Orange Wire to pin LED2 +

Repeat as above to attach the remaining Red LED with the Brown and Blue wires to the corresponding wiring pins located on the left rear edge of the Large Circuit Board, as below. This will be the Left Red LED on the rear of the Robot.

Brown Wire to pin LED3 -
Blue Wire to pin LED3 +



Assembly Step 11

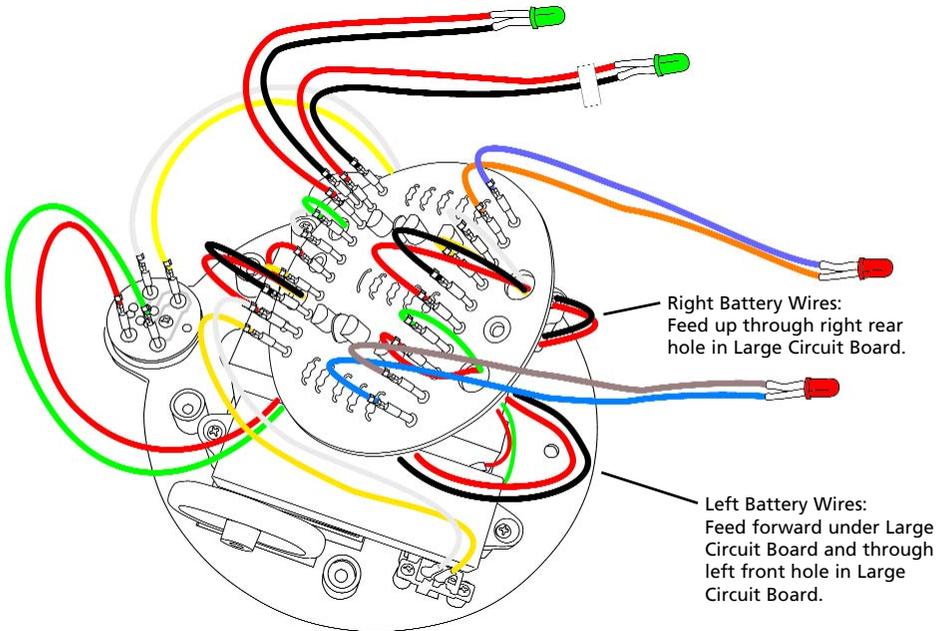
Attaching the Battery Wires to the Large Circuit Board

Feed the pair of Red and Black wires from the Battery Holder on the right side of the Robot Base upward through the right rear large hole in the Large Circuit Board. Using a pair of Long Nosed Pliers, affix the ends of these wires to their corresponding wiring pins on the Large Circuit Board, as follows:

Black Wire to pin 3V-M -
Red Wire to pin 3V-M +

Feed the remaining pair of Red and Black wires from the left Battery Holder upward through the left front large hole in the Large Circuit Board. Using a pair of Long Nosed Pliers, affix the ends of these wires to their corresponding pins on the Large Circuit Board, as follows:

Black Wire to pin 3V-S -
Red Wire to pin 3V-S +

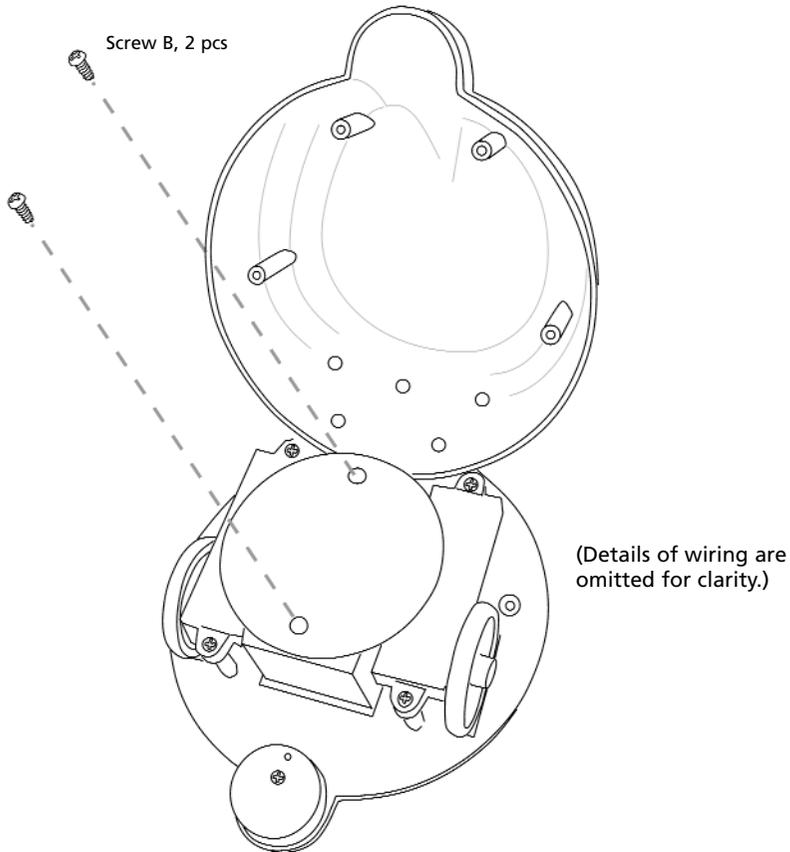


Assembly Step 12

Attaching the Large Circuit Board to the Robot Base

You are now ready to attach the Large Circuit Board to the Robot Base.

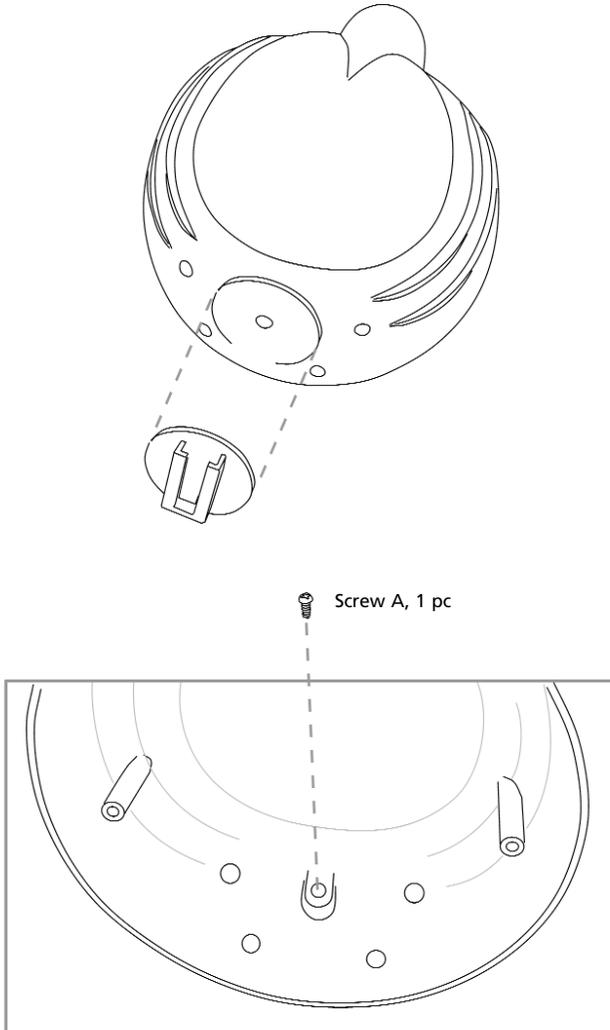
First, all wires except for those leading from the Small Circuit Board and those leading to the Switch should be run under the Large Circuit Board and towards the rear of the Robot Base. Namely, all the LEDs should be extended towards the rear of the Robot Base, with their wires running beneath the Large Circuit Board, as shown. Using a Phillips Screwdriver and two Type B Screws, affix the Large Circuit Board to the Robot Base, as shown.



Assembly Step 13

Attaching Accessory Bracket to Shell Cover

Using a Philips Screwdriver and one Type A Screw, attach the Accessory Bracket to the Shell Cover, as shown.



Assembly Step 14

Installing the LED Lights

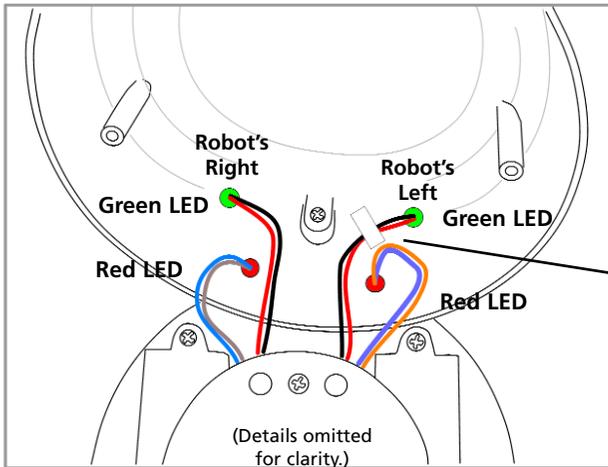
From the inside of the Shell Cover, push the Red and Green LEDs through the four holes at the rear of the Shell, as shown:

Red left (Purple and Orange wires) to robot's lower left.

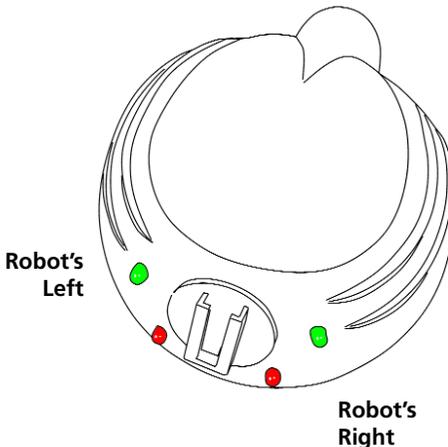
Red right (Brown and Blue wires) to robot's lower right.

Green left to robot's upper left (Black and Red wires: no small tab of tape).

Green right to robot's upper right (you may use the small tab of tape from Step 10A to identify this set of wires, but be sure to remove the tab before continuing).



Remember to add a small tab of tape to secure the LEDs in place if required.

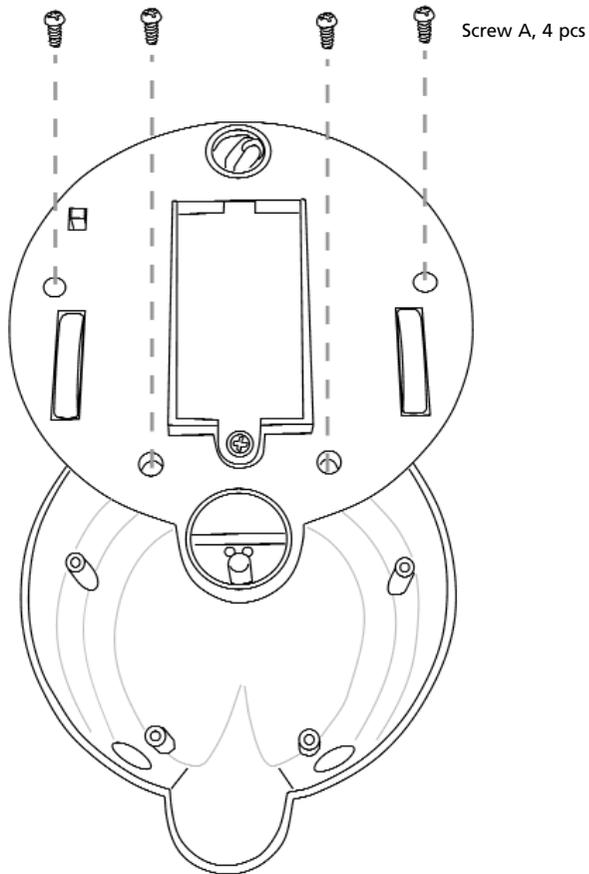


View of installed LED lights from exterior of Shell Cover.

Assembly Step 15

Attaching the Shell Cover to the Robot Base

With robot inverted, carefully tip the Robot Base into position over the Shell Cover, taking care to keep all wires to the inside of the Shell. Using a Phillips Screwdriver and four Type A Screw, affix the Shell to the Base from the underside, aligning each of the four posts and holes for the screws. Tighten screws in an alternating pattern until the Base is fully attached to the Shell.





Your LINETRACKER 1 is ready to go!

How to Operate LINETRACKER 1

1. If you have not already done so, install the AA batteries into the left and right battery holders.
2. Draw a line with a black marking pen on paper. (The line can be as long as you like, but it should be 3 to 8mm wide.)
3. Turn the switch (SW1). Two red LEDs will light up, indicating that Line Tracker 1 is ready.
4. Place Line Tracker 1 on the paper, positioning the centre of the sensor PC board right on the black line. Line Tracker 1 will move forward and follow the line!

Explanation of the Circuits / How Line Tracker 1 Works

Refer to the Block Diagram on the following page.

Power LED Section

This part consists of resistor R12 and LEDs LED4 and LED5. The LEDs light up whenever Line Tracker 1 is switched on.

Tracker Sensor Section

Line Tracker 1 detects a black line using red LED (LED1) as a light source, and two phototransistors (PTR1, PTR2). A white surface reflects light but black absorbs light, so Line Tracker 1 uses this principle to detect the position of the black line. The phototransistors detect the reflected light from the white paper produced by LED1, and so the black line is found when no light is detected.

Tracker Sensor and Amplification Section

This section consists of transistors: TR1, TR2, resistors: R2, R3, R4, R5, R6, R7, diodes: D1, D2 and capacitors: C7, C8. These form a modified bistable multi-vibrator circuit.

When the black line is straight and both phototransistors are on the line, all transistors are turned on, both motors are activated, and Line Tracker 1 runs directly ahead on the straight line.

When Line Tracker 1 wanders off to the right of the black line, the reflected light turns on phototransistor PTR1, and TR2 turns off. At the same time, TR4, TR6 and LED3 (in the amplification and the motor drive section) are turned off. The left motor stops and the robot starts to steer back on course. Should the robot continue to move further off course, both phototransistors see white paper and turn on. However the multi-vibrator circuit “remembers” the original error and keeps the left motor turned off until the line is regained. The left motor only turns on again when both phototransistors once again see black. The same procedure is followed for the other transistors and the right motor when the robot veers to the left of the line.

How to Operate LINETRACKER 1

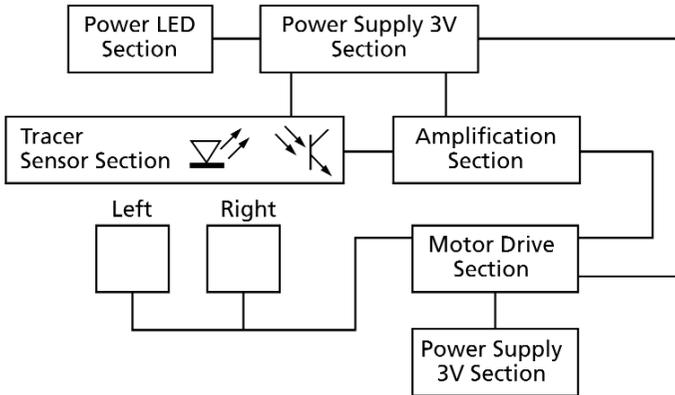
Amplification and Motor Drive Section

The electrical current supplied by the Tracker sensor and amplification section is not enough to rotate the motors. Since a large amount of current is necessary to turn a motor, the transistors TR3 and TR5 amplify this current to rotate the right motor (MR), and transistors TR4 and TR6 amplify the current to rotate the left motor (ML). LED2 and LED3 light when the corresponding motor turns on.

Power Supply Section

Two "AA" batteries in series power the tracker sensor, power LED, and amplification sections. Another two "AA" batteries in series power the motor drive section and the motors.

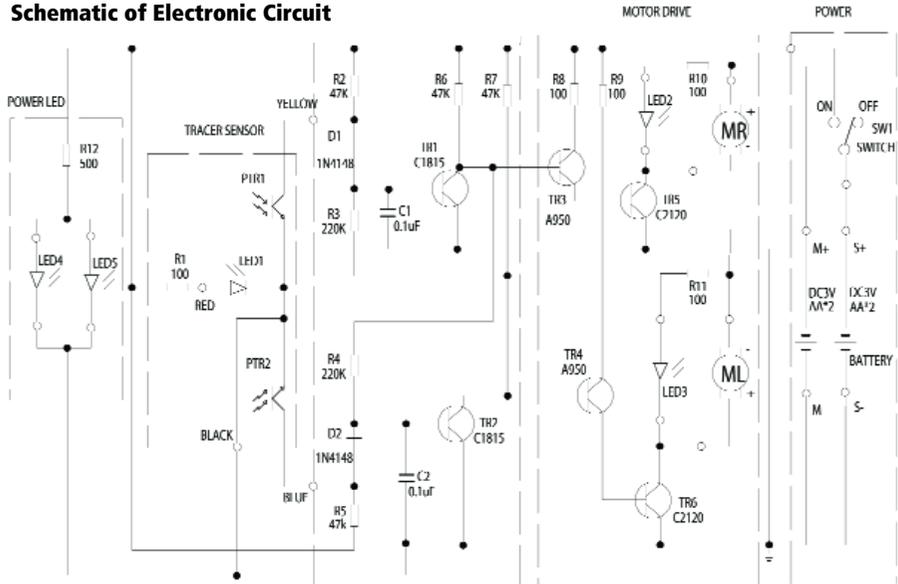
Block Diagram



Line Tracker 1 has two battery holders with two AA batteries (total of 3V) in each. One pair of batteries is for driving the motors, and the other pair is for circuits. Because the power consumption differs, the batteries used for the motors will run down faster than the ones used for the circuit. If the motor batteries become weak, its running speed becomes slower. If the circuit batteries become weak, Line Tracker 1 does not function. In either case, change the weak batteries.

How to Operate LINETRACKER 1

Schematic of Electronic Circuit



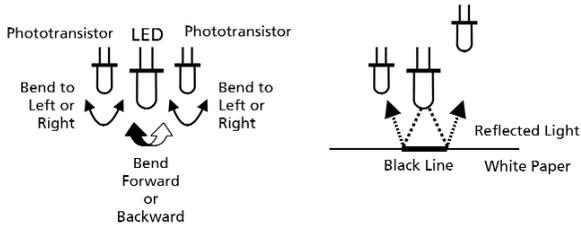
Wiring Table for Line Tracker 1

Wire Colour	Marking on the Printed Circuit Board	Wire Colour	Marking on the Printed Circuit Board
Yellow	SW1	Black	LED4 -
White	SW2	Blue	LED3 +
Red	3V - S +	Brown	LED3 -
Black	3V - S -	Red	ML +
Yellow	CL	Green	ML -
Red	Ray	Red	3V - M +
White	G	Black	3V - M -
Green	CR	Yellow	MR +
Black	LED5 -	White	MR -
Red	LED5 +	Orange	LED2 +
Red	LED4 +	Purple	LED2 -

How to Operate LINETRACKER 1

Tuning the Sensor

Line Tracker 1 detects the line with two phototransistors (light sensors) sensing the reflected light so that its movement depends on how the sensors receive the light. If the Line Tracker 1 does not follow the line, adjust the LED and phototransistors properly. (See the illustration below).



Line Tracker 1 Comes with Its Own Track, or You Can Make One!

Line Tracker 1 is supplied with a ready-made track for use in line tracer mode. Note the dotted lines on the back of the track. For some definite fun, try this: Cut the track into sections following the dotted lines. You now have a large track puzzle! Put Line Tracker 1 on one section of the puzzle and begin operating in line tracer mode. Can you complete the puzzle, section by section before Line Tracker 1 runs off the edge of the paper? Try making your own courses and puzzles with white paper and a black felt tip pen. It is important that the track is laid on a flat surface so that the joints are as smooth as possible.

Use this chart to diagnose any problems:

Problem	Solution
The motor is not spinning.	Check that the wiring is correct. Check the polarity of the batteries. Insert new batteries.
Line Tracker 1 falls off the line easily.	Tune the LED and phototransistors. Insert new batteries.

Learn All About the Electronic Parts Used in Robots

What Is “Electronics”?

We all know that atoms are made up of protons, neutrons and electrons. The electrons are tiny particles that orbit about the nucleus (made up of protons and neutrons) and have a special electrical property of **charge**. The protons in the nucleus have a positive (+) charge whilst those interesting electrons have a negative (-) charge. This charge is what electronics is all about. When electrons move together in a similar way, we say there is a **current** flowing. The electrons are actually moving all the time in materials like metals, but they are moving in all sorts of directions; it is only when they all get together and move in the same direction we say that we have a current flowing. However, electrons can't flow through every material. Materials that allow a current to flow easily are called **conductors**. Materials that don't allow a current to flow are called **non-conductors** or **insulators**. Metals are the most common conductors, whilst plastics are typical insulators.

In order to get electrons to flow in a certain way, they need to have an “energy” given to them. Batteries are designed in such a way as to give that “energy” for electrons to flow between a negative and a positive side (or electrode). This creates something like a pressure or force, and this is called the **voltage**. The bigger the voltage, the greater the pressure or force available to the electrons. This force is sometimes called **potential difference**. A typical battery will give a flow (or **voltage**) of 9 volts (9v). Before an electric current can go anywhere, it needs to be given a road or path to follow. This is what you see on our printed circuit board and it is called a **circuit**. By connecting a battery to a circuit we can get a current to move and perform the function we want. The battery will eventually run out of energy as it pushes the electrons out from one side and collects them at the other. This will eventually result in the battery running down.

Current and Amps

So, how do we measure current? Currents are measured in **amps**, and voltages are measured in **volts** (after the scientists Ampère and Volta). Voltages are sometimes called **potential differences**, or **electromotive forces**. Current flows into a component and the same amount of current always flows out of the component. As current flows through a component it will cause a reaction of some kind, for example a bulb getting brighter.

Resistors and Resistance

Any material that hinders the movement of electrons is called a resistor. Electrons move more easily through some materials than others when a voltage is applied. We measure how much opposition there is to an electric current as **resistance**. Components that cause a resistance are hence called **resistors**. The higher the resistance value, the more it restricts the flow. The resistor will give the circuit a stable current thus giving protection to sensitive elements within a circuit from damage.

Resistance is measured in **ohms** after the discoverer of a law relating voltage to current. Ohms are represented by the Greek letter omega: Ω . The main function of resistors in

Learn All About the Electronic Parts Used in Robots

a circuit is to control the flow of current to other components. Take an LED (light emitting diode) for example. If too much current flows through an LED it is destroyed. So a resistor is used to limit the current.

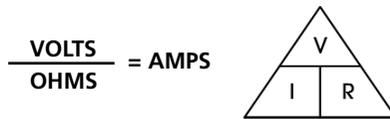
What Is Ohm's Law?

Ohm's Law basically brings together the relationship between Voltage (V), Resistance (R) and Current (I) as follows:

$$\text{Resistance (R) (Ohm } \Omega \text{)} = \frac{\text{Potential Difference (V) in Volts}}{\text{Current (I) in Amperes}}$$

Ohm discovered that if you double the voltage across the resistor then the current through it also doubles. If you halve the voltage then the current is halved. This means that the current is **proportional** to the voltage. Not surprisingly, the opposite to this also happens! Ohm also found that if you double the value of the resistor, then the current through it is halved. If the value of the resistor is halved, the current is doubled. Thus the current is **inversely proportional** to the resistance.

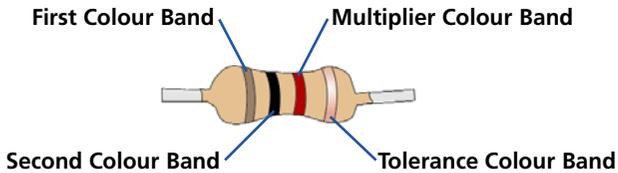
If all this is a little hard to take in, here's a handy way to remember Ohm's Law:



How Do You Determine the Resistance of a Resistor?

Resistors are colour coded for easy reading. To determine the value of a given resistor, look for the gold or silver **Tolerance Colour Band** and rotate the resistor as in the picture on the next page (placing the Tolerance Colour Band to the right). Look at the first colour band and determine its colour. This may be difficult on small or oddly coloured resistors. Match the first colour band with its colour on the chart under **First and Second Colour Band**. Find the corresponding **Digit It Represents** in the second column on the chart and write this number down. Now look at the second colour band, and match that colour to the same chart. Following the same process, find the Digit It Represents and write this number next to the first digit. The last colour band is the number by which you will multiply the result. Match the third colour band with its colour on the chart under **Multiplier**. This is the number by which you will multiply the other two numbers. Write it next to the other two numbers with a multiplication sign before it. Example: 2.2 x 1,000. To pull it all together, simply multiply the first two numbers (first number in the tens column and second in the ones column) by the Multiplier. The result is expressed in Ohms.

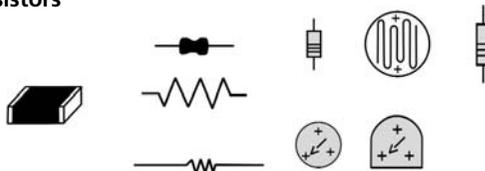
Learn All About the Electronic Parts Used in Robots



Resistor Colour Code Chart

First and Second Colour Band	Digit It Represents	Multiplier
BLACK	0	X1
BROWN	1	X10
RED	2	X100
ORANGE	3	X1000 or 1K
YELLOW	4	X10000 or 10K
GREEN	5	X100000 or 100K
BLUE	6	X1000000 or 1M
VIOLET	7	Silver is divide by 100
GREY	8	Gold is divide by 10
WHITE	9	— Tolerances — Gold = 5% Silver = 10% None = 20%

Common Symbols Used for Resistors

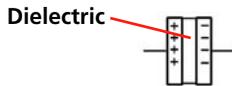


Learn All About the Electronic Parts Used in Robots

Capacitors and Capacitance

Capacitors are like tiny batteries in a circuit storing charge. Like tiny batteries, they can cause a current to flow in a circuit. But they can only do this for a short time — they cannot deliver a sustained current. They can be charged up with energy from a battery, then return that energy back later. The **capacitance** of a capacitor is a measure of how much energy or charge it can hold.

Essentially, capacitors consist of two metal plates separated by a small gap. The plates will have different electric charges (just like a battery). You can increase the capacitance by putting a non-conducting material between the plates. This is called a **dielectric**.



When a capacitor charges up, the protons and electrons in the dielectric separate out and move to the plates thereby giving more charge than usual. Dielectrics are made of various materials, ceramic being the more common. When a capacitor is connected to a battery it begins to charge. The current flows rapidly at first. Charge builds up on the two plates, negative charge on one plate and the same amount of positive charge on the other. The positive charge results from electrons leaving one of the plates and leaving positively-charged protons behind. But as the capacitor fills with charge it starts to oppose the current flowing in the circuit. It is as if another battery were working against the first. The current decreases and the capacitor charges more slowly.

Capacitance is measured in **Farads**. A unit of Farad is represented by μ , but most capacitors have much smaller capacitances, and the microfarad (a millionth of a Farad) is the commonly used practical unit. One Farad is a capacitance of one Coulomb per volt. For practical purposes the microfarad (one millionth of a Farad, symbol: mF) is more commonly used. The Farad is named after English scientist Michael Faraday.

Capacitors come in two types: **electrolytic** and **non-electrolytic**. Electrolytic capacitors use a special liquid or paste, which is formed into a very thin dielectric in the factory. Non-electrolytic capacitors have ordinary dielectrics.

Electrolytic capacitors can store more charge than non-electrolytic capacitors but there are a couple of problems. They must be connected the right way around in a circuit or they won't work. They also slowly leak their charge, and they have quite large tolerances.

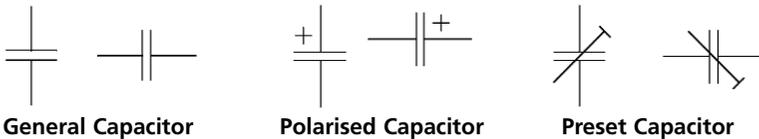
We've seen that when a capacitor is fully charged the current stops. In other words, a continuous current cannot flow forever through a capacitor. A continuous current is called a **direct current** or d.c. An **alternating current** (a.c.) however, can flow through a capacitor. An alternating current is one of which is continually changing its direction. Mains is a.c. and changes its direction 50 times a second. An alternating current continually charges and discharges a capacitor and hence is able to keep flowing. Electrolytic and Mylar capacitors are used in this electronics kit. We use a combination of resistors and capacitors to suppress

Learn All About the Electronic Parts Used in Robots

voltage fluctuations in the power supply and set the time period on the timer. Capacitors can also be used to remove any alternating current components within a circuit.

Mylar™ capacitors have an insulator, which is a flexible Mylar film, so a large area can be rolled up into a compact package. They do not have a polarity. Capacitors with large values are usually **electrolytic**. They have a **polarity** (or direction) and are sensitive to levels of voltage.

Typical symbols for capacitors in circuits:



Transistor

The discovery of semiconductors was the most revolutionary change in electronics in the last century. Without this discovery we wouldn't have televisions, computers, space rockets or transistor radios. Transistors underpin the whole of modern electronics. They are very useful in computers, cars, washing machines and just about everywhere. In fact, you see a lot of them in the iBOTZ™ robots!

It is easier to consider the transistor as a switch — **simply switching currents on and off**. They can also work as **amplifiers**, where they **increase** the current. Transistors are made of three slices of semiconductor material, two of one type and one of another. Therefore it is not surprising that it should be 2 x n-types plus one p-type or the other way around. This “sandwich” gives two junctions. If the thin slice is n-type, the transistor is called a p-n-p transistor, and if the thin slice is p-type it is called a n-p-n transistor. The middle layer is always called the **base**, and the outer two layers are called the **collector** and the **emitter**.

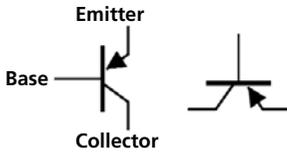
It is important to remember that a transistor is a semi-conductor with the ability to amplify current. The “tiny sandwich” mentioned above is usually germanium or silicon, alternate layers having different electrical properties because they are impregnated with minute amounts of different impurities. A crystal of pure germanium or silicon would act as an insulator (non-conductor). By introducing impurities in the form of atoms of other materials (for example, boron, arsenic, or indium) in minute amounts, the layers may be made either n-type, having an excess of electrons, or p-type, having a deficiency of electrons. This enables electrons to flow from one layer to another in one direction only.

As mentioned above, each transistor has three terminals called the Emitter, the Base and the Collector. When current flows into the base the emitter or the collector changes the current to a higher level.

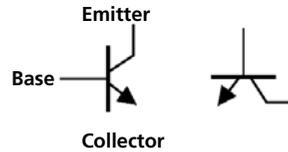
We use the transistors in this robot to turn on the LED (Light emitting diode) into a pulse form. We also use them to control the rotating director of the left motor. The transistors amplify the signal from the sensor to rotate the motor and could also be used to cause the LED to flash.

Learn All About the Electronic Parts Used in Robots

p-n-p Type Transistor

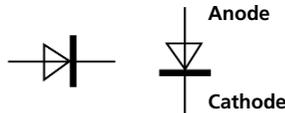


n-p-n Type Transistor



Diode

The diodes used in this circuit allow the flow of electrons one way only. This flow is from the anode to the cathode. Therefore, diodes are basically a one-way valve for electrical current. They let it flow in one direction (from positive to negative) and not in the other direction. Most diodes are similar in appearance to a resistor and will have a painted line on one end showing the direction or flow (white side is negative). If the negative side is on the negative end of the circuit, current will flow. If the negative is on the positive side of the circuit no current will flow.



LED

LED stands for Light Emitting Diode and it emits a light such as green or red. LEDs are simply *diodes* that emit light of one form or another. They are used as indicator devices. Example: LED lit equals machine on. They come in several sizes and colours (colors). Some even emit Infrared Light that cannot be seen by the human eye.

Integrated Circuits (ICs)

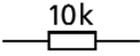
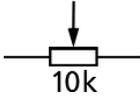
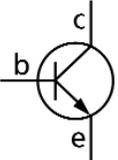
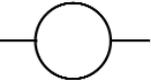
Integrated Circuits, or ICs, are complex circuits inside one simple package. Silicon and metals are used to simulate resistors, capacitors, transistors, etc. They are a space saving miracle. These components come in a wide variety of packages and sizes. You can tell them by their "monolithic shape" that has a ton of "pins" coming out of them. Their applications are as varied as their packages. It can be anything from a simple timer, to a complex logic circuit, or even a microcontroller (microprocessor with a few added functions) with erasable memory built inside. The ICs used in this robot amplify the output voltage from the sensor and send these signals to the circuit controlling the left motor. Basically, they are amplifying the weak signals from the light sensor or phototransistor, and they then send them to the motors for controlling the robot's movements.



Learn All About the Electronic Parts Used in Robots

Know Your Symbols

The different types of components we have encountered each have a symbol to represent them in a circuit diagram. Please see the actual circuit diagram of Line Tracker 1 to see where the symbols are located.

 <p style="text-align: center;">10k</p> <p style="text-align: center;">Resistor</p>	 <p style="text-align: center;">10k</p> <p style="text-align: center;">Preset Resistor</p>	 <p style="text-align: center;">1μF</p> <p style="text-align: center;">Non-electrolytic Capacitor</p>	 <p style="text-align: center;">100μF</p> <p style="text-align: center;">Electrolytic Capacitor</p>
 <p style="text-align: center;">— LED —</p> <p style="text-align: center;">The arrows show the direction in which conventional current can flow.</p>	 <p style="text-align: center;">— Transistor —</p> <p style="text-align: center;">The arrow shows the direction in which conventional current flows.</p>	 <p style="text-align: center;">Sound Sensor</p>	 <p style="text-align: center;">9V</p> <p style="text-align: center;">Battery (9V)</p>



Missing Parts? Please Do Not Contact the Shop!

Building robots can be exciting and rewarding, and it is with these principles in mind that we design our robots. We hope that you have enjoyed the building experience of LINE TRACKER 1, and that you will have many hours of fun with it.

We will be developing more and more exciting and innovative robots to add to the iBOTZ range for you to build and program. If you experience any difficulty building this robot, you can go to our web site and see additional assembly photographs and frequently asked questions at www.iBOTZ.com.

If any components are missing, or have been lost by you, don't worry! We will send them to you for free! All we ask is that you tear off the form on the following page and send it to us together with a stamped, self-addressed envelope.

If you are in the USA, Canada, or South America, please contact our office at:

iBOTZ
Division of Instruments Direct Limited
Spares Department
10 Brent Drive
Hudson, MA 01749

Telephone 978 568 0484
Fax 978 568 0060

For all other locations across the world, please contact:

iBOTZ
Division of Instruments Direct Limited
Spares Department
13-14 Worton Court
Worton Road
Isleworth TW7 6ER

Telephone 020 8560 5678
Fax 020 8232 8669

sales@iBOTZ.com

IMPORTANT

If you have a problem, please do not contact your local shop!

Call our technical support line instead at:

020 8560 5678 (UK)

or

978 568 0484 (USA)

Spare Parts — How to Use the Spare Parts Service

1. Cut out or photocopy this page.
2. Identify and indicate which spare parts you require on the form below.
3. Fill in your mailing address below.
4. Mail the page to our USA or UK office (see previous page for addresses) together with a self-addressed envelope.

Your Mailing Address:

Part No.	Description	Qty
Plastic Parts		
1009-001	Shell Cover	
1009-002	Robot Base w Castor	
1009-003	Battery Compartment Cover	
1009-004	Case Cover	
1009-005	Left Wheel	
1009-006	Right Wheel	
1009-007	Left Gear Box Cover	
1009-008	Right Gear Box Cover	
1009-009	Tyre	
1009-010	Screw-A (Ø2.8 x 8 PB)	
1009-011	Screw-B (Ø2.6 x 6 PB)	
1009-012	Screw-C (Ø2.3 x 5 PB)	
1009-013	Left Motor & Gear Box w Wires (3V)	
1009-014	Right Motor & Gear Box w Wires (3V)	
1009-015		
1009-016		

Part No.	Description	Qty
Electric Parts		
1009-017	Large Circuit Board (PCB-1)	
1009-018	Small Circuit Board (PCB-2)	
1009-019	3V Battery Holder	
1009-020	Switch	
1009-021	Red LED	
1009-022	Green LED	
1009-023	Lengths of Wire (Red, White, Yellow, Green)	
Sets		
1009-024	Shell Cover	
1009-025	Robot Base w Castor	
1009-026	Battery Compartment Cover	
1009-027	Wheel Set	
1009-028	Tyre Set	
1009-029	Puzzle Paper	



A Message from the Development Team at iBOTZ

We hope you have enjoyed building this robot as much as we did designing it. If you have any comments or suggestions please send them to iBOTZ — they will be very pleased to hear from you. We are particularly interested to hear from you if you have any suggestions on how we can improve the robots or improving our design or instruction manual.

We will be developing more and more exciting and innovative robots for you to build and programme. If you experience any difficulty building this robot please contact us on

020 8560 5678 (UK & EU)
978 568 0484 (USA)

If any components are missing, or you have lost them, don't worry! We will send them to you for free! All we ask is that you fill in the form at the back of this manual saying what's missing and send it to us with a self-addressed stamped envelope.

If you find robots as fascinating as we do, there are many other things you can do.

Join RoboFesta! This is an international movement of people interested in robots. There are events all over the United Kingdom — check out their web site to see what's going on:

<http://www.robofesta-uk.org>

RoboFesta recommend the RoboCupJunior robotics competitions, including robot soccer, robot dance, and robot rescue — the UK champs include boys and girls of all ages. If you are more ambitious, you could join the adult RoboCup competitions — their ambition is to have a team of humanoid robots beat the world champion soccer players by 2050!

<http://www.robocup.org>
<http://www.robocupjunior.org>

If you want to study robots further, there are many courses available for you. We particularly recommend the courses offered by the Open University that allow you to study in your own home at your own pace, to your own level. They run easy beginners courses, and also more advanced courses. Some of these can lead to certificates and qualifications.

There is a short self-assessed course on robotics that tells you something of the background, and the exciting future world of Artificial Intelligence, Artificial Life, and Robotics. This course was specially made by the Open University, and the iBOTZ team consider it to be a good foundation for future robotics activities.



A Message from the Development Team at iBOTZ

Check out the Open University on:

<http://www.open.ac.uk>

or read what they have to say about themselves on the following pages.

With best wishes,

Maureen Devonshire; Gerry Donnelly; Gwen Routledge; Steve Emery; Dr Colin Clarke; Peter Hicks; Vincent English; Bryan Holledge; Deva Sisodia; Dr Bill Marshall; Don Tyler; Dave Montgomery; Frank Garrison; Attar Mau; John Orchard-Lisle; Dr Eric Yueng.

— the iBOTZ Team



A Message from the Team at The Open University

We are delighted that by building your iBOTZ robot, you have taken the first step into the fast-moving world of robotics and intelligent systems.

In collaboration with the iBOTZ Team, we have developed some extra educational materials on robotics to accompany this package, including a specially designed mini-course for beginners wanting to enter this fascinating world. See our website:

<http://robots.open.ac.uk>

You don't need any previous knowledge or experience of robotics, just an interest and spirit of fun and adventure. If you enjoyed building this robot, we're sure you'll enjoy looking at our mini-courses.

We look forward to hearing from you,
on behalf of the robotics and education team

A handwritten signature in black ink that reads 'Jeff Johnson'.

Professor Jeff Johnson
Department of Design and Innovation
The Open University
robots@open.ac.uk



Courses at The Open University

The Open University produces many courses covering a wide range of study areas. Examples of entry-level courses include:

T184: Robotics and the meaning of life

This is an exciting new course for anyone who wants to know how robots work and how they are increasingly affecting our lives. The course gives an understanding of the technology behind intelligent machines, and how humans can interact with them.

A178: Perspectives on Leonardo da Vinci

Leonardo was one of the greatest painters, scientists, engineers, and architects of all time. He lived from 1452 to 1519, and for centuries people have marvelled at his achievements, from his painting to designs for helicopters, submarines, aeroplanes. This course traces the many dimensions of Leonardo's life and achievements, but assumes no prior knowledge in art or the sciences.

T183: Design and Web

This course is for those who want to know how to make well-designed web pages and web sites, without having to learn lots of technicalities. It focuses on design and design principles, and is intended for those who have never made a web site before, and those who want to improve their design skills.

All these courses can be studied by themselves, or they can count towards an certificate or a even a university degree. The Open University has many more courses.

For more information see

<http://tscp.open.ac.uk/t184>

<http://tscp.open.ac.uk>

<http://technology.open.ac.uk>

or call 01908-653231 (outside UK +44-(0)-1908-653231) and quote ref no TFD8TZ.



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