MY EXPERIENCE IN AUTONOMOUS ROBOTICS

by

BIBIN JOHN
This is not a professional book. In this I concentrate on sharing my experience on robotics and a book for beginners in robotics. This book is dedicated to all Indian robotics newbies. In this book I will talk about the electronics basics you should know in robotics. The main reason for writing this book is that newbies face a lot of trouble with circuits and most of them use ready made circuits they get from Internet and they waste time over it because they don't know how to troubleshoot the circuit. I faced same problems many times. So in this book I am telling the practices which I followed and troubleshooting techniques which I used for circuits.

This book consist of ideas of my colleagues of Robotics Club, MNNIT Allahabad. I thank my teachers of MNNIT and my colleagues Anil K.M, O.P.K Reddy, M. Satish, Vigith Maurice and many other members of Robotics Club, MNNIT Allahabad. This is my final year and I thought of some contributions to the robotics beginners, that resulted in this book. So I feel this book can guide you through troubleshooting electronic circuits in robotics and understanding the basic electronics. I thank my teachers of THSS Muttom, Thodupuzha from where I learned the very basics of electronics. If you find any problems put a post in Yahoo group-booksbybibin or in roboticsindia.

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http://www.hamradioindia.org
Www.machinegrid.com
for workshops for beginners in robotics see
www.triindia.co.in
magazine: Robotics For You (RFY), Electronics For You (EFY)
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**BREADBOARD**

Breadboard is used to make circuits. But mostly after testing your circuits on breadboard you will be making PCB. But I never made PCB for any of my circuits. Normally everyone says that if you connect on breadboard then wires may get loose and circuit will get disturbed due to shock. But no such problem occurred to me, all you have to do is to do a good wiring. Then you can gain time for making PCB's.

![Breadboard diagram](image)

**Figure 1:** How the holes in a breadboard are connected electrically

Above diagram shows how breadboard connections should be made. So all you require is to do a good wiring. First I will tell about which breadboard should you use. The breadboard is different mainly according to the size of their holes. The breadboard in Figure.1 has the smallest hole size.

This breadboard has a medium sized holes. I mostly prefer this one. But I have not seen this breadboard nowadays. The one which is available nowadays is given below. Breadboards costs from Rs.80-120 (depends on place where you are in India). The main problem with small holes is that, it will be tough to insert IC's like 7805, power transistors so on. Even there is problem with size of wires also.
WIRING

Following figures show good wiring practices you should follow so that your circuit won't be disturbed by any shocks.

In this you can see that the length of the wires used are of exact length between two points. If you do this type of wirings then no problems occur. But in this you can see that resistor is not properly inserted, for this you should cut the leads of the resistor so that its body is just touching (or touching the breadboard).
Above figures shows how to make good connections. In last one you can see how they made connections so that no problems will occur. Below you can see what connections you should not have to do.
Here are some figures from google, so that you can understand how to connect properly.
PROBLEMS OCCURING WITH BREADBOARD

1. As I said above some breadboards will be difficult to insert IC's like 7805, LM317 etc., due to the small sized holes.

2. I bought a new breadboard for Rs.80 in which some parts of the breadboard is not working. So you should be careful about it.

3. Some part of the breadboard may suddenly create problem. This problem will mostly eat your time. I have connected full circuit for my project and it was working properly two months ago. The ckt consist of a 7805 which convert adapter DC to 5V. Now when i switch ON power supply, the circuit is not working. On examination i found that the output voltage of 7805 is 1.1V even though input voltage to 7805 is >7.5. I was surprised to see this because i had done same ckt a month ago and no changes made in ckt. Then i used another breadboard specially for 7805 to make connections, surprisingly it is working fine giving 4.8-5V. Then i connected the output from that breadboard to my original board where ckt was connected. It is working fine. Then I again tried in same position it is not working giving output of adapter 3-4V and output of 7805 1.1V. I doubted if the voltage regulator input is low to regulate, so i increased the adapter to 9V from 7.5(my adapter has varying voltage starting from 1.5V,3V..). Then the light of the adapter went off. Then I again increased voltage to 12V. Then also light is off. Now I decided for a new position of breadboard, where it worked properly. Then I increased voltage up to 13.5V. For all these input voltages to 7805 the input of 7805 still remained 3.5-3.7V and output .7-.8V. Finally I got a position of the breadboard where it worked fine. The problem was of the position in the breadboard which i used.

4. One similar problem occurred when I connected LM324 with its input a variable resistor. I rotated the knob of the potentiometer( it has one end on Vcc=10v, other end on ground and middle end is connected to the LM324), the voltage output of the potentiometer is suddenly increasing from .5 to 8.8V suddenly with a small rotation of the knob. I tried to rotate shaft by connecting the middle end to another portion of the breadboard, there it worked fine. I used the same portion of the breadboard where i connected first and tried the same after removing LM324, then also it is working fine. Then i again connected LM324 in same position, still the old problem came. Then I changed the full circuit to another position of the breadboard, it worked fine.
RESISTOR

Resistors offers a resistance to the flow of current. Mainly resistors are classified according to their resistance values and their power ratings. Resistances range from 10 ohm to 56Mohm(or more) and power ratings from 1/8W to 20W. We mostly use resistance in this range even though more power rating high value resistors are available. So when you select a resistor its value and power rating should be the deciding parameter. Normally available resistors are 1/8W, you can see this type of resistors in the resistance box which contain resistances from 10 ohm to around 56Mohm, costs around Rs.30. But this resistor leads are flexible such that it will get bend easily. These 1/8W resistors are used in low power devices. The one which available in shops are of 1/4W which we mainly use. P=I^2 * R, heat dissipation on resistor depends on the current flowing through it. Therefore for high current operations we use resistance of higher current ratings. The size of the resistor determines its power rating. Suppose if u put a resistor series with a motor which have a rating of 250mA(DC motor) -600mA(Stepper motor), then you can see that P=I^2R=.25^2*R=.0625R. Assume R=10 ohm then P=.625W >1/2W. In this case you have to use a resistor of about 1W or more. There are two types of resistors - fixed and variable.

[Fixed Resistor Diagram]

[Variable Resistor Diagram]
Now let's see how you can measure the resistance of a resistor. This is done by color coding over the resistor or you can multimeter to measure resistance. As a beginner you should use color coding. See the following diagrams carefully, you can see that 4-band code, 5-band code and 6-band code (see next diagram). But we mainly get resistors of 4-band code. You can get a 1/4W resistor for Rs.20 irrespective of the value of its resistance. Due to the aging and other temperature effects, value of a resistor will change. That change is indicated using tolerance. The following figure show how to bend a resistor so that you can insert it in a breadboard. Don't bend too much close to the body of the resistor because it will leads to the breaking of the leads. So bend carefully. Sometimes you have to cut the leads of the resistor by some amount so that it can easily inserted properly. See in the following figure (resistor in the breadboard). In this case cut the leads of the resistor so that body of resistor just touches the breadboard (see in the PCB).
<table>
<thead>
<tr>
<th>COLOR</th>
<th>1st BAND</th>
<th>2nd BAND</th>
<th>3rd BAND</th>
<th>MULTIPLIER</th>
<th>TOLERANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1Ω</td>
<td>± 1%</td>
</tr>
<tr>
<td>Brown</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>10Ω</td>
<td>± 1%</td>
</tr>
<tr>
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<td>2</td>
<td>2</td>
<td>2</td>
<td>100Ω</td>
<td>± 2%</td>
</tr>
<tr>
<td>Orange</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>1KΩ</td>
<td>± 2%</td>
</tr>
<tr>
<td>Yellow</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>10KΩ</td>
<td>± 0.5%</td>
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<tr>
<td>Green</td>
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<td>5</td>
<td>100KΩ</td>
<td>± 0.5%</td>
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<tr>
<td>Blue</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>1MΩ</td>
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</tr>
<tr>
<td>Violet</td>
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<td>7</td>
<td>10MΩ</td>
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</tr>
<tr>
<td>Grey</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>0.1</td>
<td>± 0.05%</td>
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<tr>
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<td>9</td>
<td>9</td>
<td>0.01</td>
<td>± 0.25%</td>
</tr>
<tr>
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<td></td>
<td></td>
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<td>± 0.5%</td>
</tr>
<tr>
<td>Silver</td>
<td></td>
<td></td>
<td></td>
<td>0.01</td>
<td>± 10%</td>
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</table>

0.1% 0.25% 0.5% 1% 5-Band-Code

237Ω ± 1% 5-Band-Code
Remember that all the values of fixed resistances are not available. Suppose if you want a 2Kohm resistor in your circuit, you can use a variable resistor (potentiometer) or two 1Kohm resistor in series. Only the following resistances are available.
<table>
<thead>
<tr>
<th>1R8</th>
<th>10R</th>
<th>100R</th>
<th>1K0</th>
<th>10K</th>
<th>100K</th>
<th>1M0</th>
</tr>
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<tr>
<td>1R5</td>
<td>12R</td>
<td>120R</td>
<td>1K5</td>
<td>12K</td>
<td>120K</td>
<td>1M5</td>
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<td>1R8</td>
<td>15R</td>
<td>150R</td>
<td>1K8</td>
<td>15K</td>
<td>150K</td>
<td>1M8</td>
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<td>1R2</td>
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<td>180R</td>
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<td>270R</td>
<td>2K8</td>
<td>27K</td>
<td>270K</td>
<td>2M8</td>
</tr>
<tr>
<td>1R9</td>
<td>33R</td>
<td>330R</td>
<td>3K3</td>
<td>33K</td>
<td>330K</td>
<td>3M3</td>
</tr>
<tr>
<td>1R2</td>
<td>39R</td>
<td>390R</td>
<td>3K9</td>
<td>39K</td>
<td>390K</td>
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<td>470R</td>
<td>4K7</td>
<td>47K</td>
<td>470K</td>
<td>4M7</td>
</tr>
<tr>
<td>5R6</td>
<td>56R</td>
<td>560R</td>
<td>5K6</td>
<td>56K</td>
<td>560K</td>
<td>5M6</td>
</tr>
<tr>
<td>6R8</td>
<td>68R</td>
<td>680R</td>
<td>6K8</td>
<td>68K</td>
<td>680K</td>
<td>6M8</td>
</tr>
<tr>
<td>8R1</td>
<td>82R</td>
<td>820R</td>
<td>8K2</td>
<td>82K</td>
<td>820K</td>
<td>8M2</td>
</tr>
</tbody>
</table>
Resistors of different wattage ratings
**POTENTIOMETER ('POT')**

Potentiometer is a variable resistor which is used to vary the resistance by rotating the shaft. Potentiometers are available from 100 ohm to 470Kohm (or more). Cost depends on the size of potentiometer, vary from Rs.4 onwards.

Potentiometer is used as a voltage divider. If we connect Lead A to Vcc and Lead B to ground then you can get voltages from 0 to Vcc by taking voltage at Lead W and Lead B. Mainly potentiometers are used to generate reference voltage for LM324. Suppose if you couple potentiometer to the shaft of a motor, then we can measure the angle moved by shaft by connect the output of Leads W and Lead B to an ADC to get a digital reading of angle. i.e a shaft encoder, but there is a limitation, we can't get
rotation >270 degree and also number of rotations since potentiometer shaft can only move from A to B.

Above figure shows different types of potentiometers available in market. Second and third potentiometers are mainly used when you want to change the value of resistance rarely and first one used when you had to vary resistance frequently. Second and third one are easy to be inserted in breadboard and they remain fixed. Resistance is varied by rotating the shaft in the body of the potentiometer.
CAPACITOR
A capacitor is used to store charge. Like resistors there is fixed as well as variable capacitor also. But we mostly use fixed capacitor in robotics, variable capacitors are mainly used in analog communication. There are capacitors with no polarity and polarity. Ceramic and Mica capacitors available are of no-polarity, but electrolytic capacitors are of polarity. There is a variation in their symbols also.

In the above figure we can see that the different symbols for capacitors. Mica and ceramic capacitor don't have polarity while electrolytic have polarity, so one lead of electrolytic capacitor is bend(-ve lead). We can identify negative lead of electrolytic capacitor by checking the length of the lead, one with less length is -ve. On the body of electrolytic capacitor -ve symbol is shown. Be careful about electrolytic capacitor because inverting polarity can make 'explosion' (not firing) of capacitor(sometimes it can hurt your body). Every capacitor has two factors - value of its capacitance and other the maximum voltage rating.
The Capacitor:

![Image of a capacitor](image)

The wafer-like ceramic capacitor common in the lab.

Determining the value of a capacitor:
The value of the wafer-like capacitors are coded using three digits as shown above:

1. The first two digits are the most significant digits of the value.

2. The 3rd digit is the number of zeros that come after the first two numbers of the value.

Note:
These capacitors are coded in picofarads (pF).

---

### Chart

<table>
<thead>
<tr>
<th>Rated Voltage (V)</th>
<th>0.01</th>
<th>0.1</th>
<th>1.0</th>
<th>2.5</th>
<th>33</th>
<th>63</th>
<th>100</th>
<th>200</th>
<th>330</th>
<th>470</th>
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<tr>
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</table>

This figure shows the capacitances available.
Important Things about Capacitor:
Capacitances vary from 22pF to about 15000uF. Values <.1uF are mainly mica and ceramic capacitors and C>=1uF are electrolytic capacitors. See the maximum voltage ratings of capacitor when you select electrolytic capacitors. Electrolytic capacitor 'explode' when you invert polarity of capacitor and applying voltage about maximum rated voltage. When you see circuit, be careful about the symbol of capacitor used to choose which one you require (Electrolytic or ceramic).
MULTIMETER

Multimeter is used to measure different parameters like voltage, current, resistance etc... In robotics you should use a multimeter which is capable of measuring voltage, resistance, continuity test, transistor(hfe). Cost of a multimeter depends on the number of quantities it can measure, even some multimeter's can test whether a diode is of Ge or Si. But we don't want that much costly multimeter. A cheap one which i use is about Rs.300 which has all the necessary facilities which we commonly use (voltage, resistance, continuity). See my multimeter.

Suppose if you want to measure output voltage of an adapter, see what is the maximum voltage of adapter (mostly around 15V). Then put the needle to 20V (a voltage greater than 15V). A display of '1' on multimeter means that it is not able measure the quantity in that position of the needle. Suppose if you want to measure a resistance and you put the needle to the 20Kohm, then if multimeter shows '1' then put the needle to 200Kohm, because the resistance is greater than 20Kohm. Same with all the measurements like voltage, current etc.. **When you are buying a multimeter you must see that multimeter should be able to do continuity test(it is the most important one),** voltage measurement and resistance measurement. These three are the important quantities you measure in robotics. If you want to study more about multimeter see the following links

http://en.wikipedia.org/wiki/Multimeter
http://mechatronics.mech.northwestern.edu/design_ref/tools/multimeter.html
http://www.doctronics.co.uk/meter.htm
**DIODES**

Diodes are two terminal devices which conduct electricity in one direction. Current flows from anode to cathode when the diode is forward biased. In a normal forward biased diode, energy is dissipated as heat in the junction, but in LED's energy dissipated as visible light. In robotics we use normal diodes as free wheeling diodes or to make power supply. LED's are of two types - IR led and normal LED. IR LED emits Infra Red radiations while normal LED emit visible light. So first talk about a normal diode. Mostly we use 1N4001 or 1N4007 as free wheeling diodes for motors or relays, sometimes in H-bridge also.

![Diagram of diodes](image)

From the above figure try to find out which diodes are forward biased and which are reversed biased. You can see that a) is represents symbol of a diode b), d) are forward biased and c) is reverse biased(voltage at the P junction should be greater than N junction by .7V).

![Normal diodes](image)

Figure shows normal diodes with different power ratings. I don't know about the transistor type diodes. High power rating diodes are used for high power motors. The following figure shows the normal diode available in the market.
Above figure shows how to bend the leads of a diode and a resistor so that a properly inserted into breadboard or PCB. But remember not to bend too close to body. But there are different diodes - LED, IRLED, Photo Diode, Zener Diode. But in robotics we use LED, IR LED's, Photo Diodes. Diode and Zener diodes are used, but rarely.

Can u tell the voltage, \( v \). Vcc ranges from 0-50 (it can go up to 200v also, for high power). \( v \) range from .65 to .8 depending on series resistance (.7V).
ZENER DIODE

A zener diode works in reverse biased region. In reverse bias it gives fixed output voltage. The following diagram shows a normal connection for the zener diode. The current limiting resisting should be chosen properly. Let's take an example for the use of zener diode, USB port gives Vcc=5V, but it takes input voltages around 3.3V. So we apply this circuit with zener diode, Vz=3.3V, (because most embedded systems work at 5V) to get voltage=3.3V. In forward bias it works as a normal diode. See the link http://www.allaboutcircuits.com/vol_3/chpt_3/9.html http://hyperphysics.phy-astr.gsu.edu/hbase/electronic/zener.html http://www.phys.ualberta.ca/~gingrich/phys395/notes/node60.html

NOTE: If current limit resistor is not connected or it is not of proper value, then it cause heating of the zener diode. So remember about this before touching zener diode. If the input voltage is less than Vz then output voltage will be zero (ideally).
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LIGHT EMITTING DIODE (LED)

Now let's see LED's. The main specification of LED are its current rating=20mA, typical cut in voltage=2V, life time=2lakh hours, max. voltage is around 4.5V. There are different color LED's depending on the semi conducting material.

LED has two leads - cathode and anode. They are identified by the length of the lead. Cathode lead is of lesser length. But I have seen some LED's with manufacturing defect having cathode lead longer. So in order to identify the cathode of the LED see the figure below. In that you can see that cathode is of broader filament. I got some white LED's of cathode of small filament. So this convention can be right or wrong. Check LED in both ways to see that LED is good.

Don't connect LED to Vcc. Suppose if you connect the output of 7805 directly to an LED then the voltage output of 7805 reduces to 3.85V from 5.02 voltage output of 7805 (I checked it with a white LED producing green light). So when you connect LED to the output of any IC connect a series resistor with it. The brightness of LED is controlled by the series resistance. If you want a good brightness use R=100,150ohm. If you want a medium
light series resistance=330ohm. The maximum value of 470ohm can be inserted for a small light.

What is the difference when u connect resistor at anode side and resistor at cathode side. There is a difference in case of 7-segment displays.
See in the above diagram, you can see that resistance is connected at common cathode only. There is a difference between two. 7Segment display consist of 7 led's. Connecting a resistor in series with every LED and connecting a resistor in series with all LED's have a difference. In first case every LED has a series resistor, in this case the brightness of all LED's will be same, but in second case a series resistor with all LED's cause a different brightness with all, since all LED's are not identical. But in case of small 7segment LED's it won't create much problem, will have same brightness. But in case of big 7segments in railways etc.. will have problem, causing some slightly different brightness. But in student case, second is good instead of 7 resistors. Suppose if you apply Ohm's law in the diode connected series resistor, then you can see voltage across LED is very low because the forward resistance of the diode is very low. But in case of diode we can't apply Ohm's law because diode is a non-linear device.

**IR LED**

The main difference between LED and IR LED is that IR LED emits Infrared Radiations, which we cannot see by our visible eye. The second difference is that IR LED takes a lot of current and damage fastly than LED's. I will explain more about 38KHz IR transmission and reception in Sensor's section. But we can use IRLED with photo diode as a sensor, which makes less prone to external light effects compared to LDR+LED combination. As you know IR radiations are heat emitting radiations, so be careful when you touch the IRLED's light emitting portion. I got 5-7cm clearance when i used IRLED+photo diode combination for edge detection. That is if I height is greater than 7 cm no reflection will come from ground, if it is less than 7cm then reflection will come from ground and photo diode detects it.

**NOTE:** IR LED become heated fast. Remember that IR LED always creates too much problems, most of the time it won't lit, that means the voltage across IR LED should be >2V for it to lit('lit' means produce IR radiations).

**ANALYSIS:** Here I connected the output of 7805 directly to LED then voltage output of 7805 become 3.85V for LED and 1.5V for IR LED (previously without connecting any load it was 5.02V). If I connect a 330 ohm resistor series with IRLED and LED then voltage output becomes 4.95V
POWER SUPPLY

We require DC supply for our circuits which should be obtained from 230V, 50Hz AC line. There is two way to get DC supply, one from DC battery and second from adapter or SMPS. Normally we use adapter for our circuits. When you go for troubleshooting power supply is another headache in robotics after sensor problems. The best way to avoid this problem is to use one SMPS instead of adapter. Normally adapters available for 12V, 500mA ratings. With that you can run DC motors. For beginners this 12V, 500mA adapter is enough, but better you try to get a second hand SMPS. The main thing you have to note when you buy one adapter is that

1) it should have variable shaft to get voltages from 3 to 12V.

2) It should be of a good company.

3) The light(LED) of adapter should be good

My adapter is a 3V to 12V variable adapter, 500mA. There is one LED over the adapter. This LED will be useful when you troubleshoot circuits to detect short circuits, overload detection etc... But some adapter's LED won't be able to detect short circuits. I have a Panasonic adapter (black color) which is able to detect short ckt, but my friend has Panasonic adapter (White in color) which is not able to detect short circuit, overload detection. **Suppose if you short circuit +ve and -ve of adapter the LED will OFF, if some overload comes then the brightness of the LED decreases which will be helpful in troubleshooting.** But better acquire an SMPS which will become shut down when short circuit occurs. If you have an SMPS then no problems with power supply occurs, better not to use the output of adapter of your Computer, buy one second hand SMPS even though it is of a 486 computer.

But when you are making robots for competition in which robots run on battery, you should be careful because power supply problem also creates and your robots won't acquire the desired speed. If you are using SMPS and replace SMPS with battery in robots, you won't be getting better speeds because SMPS have good current driving capability while battery won't have it. Even SMPS of Pentium1 systems have a power capability of about 40W.
Here is the adaptor, the one which my friend has. I got it from google images. This adaptor is good except the LED of the adapter won't show any short circuit identification, overload by diminishing light. I am having a black color one of same company.

**NOTE**: use separate power supply for the controlling circuit(microncontrollers, power transistor,sensors etc..) and motor circuit because motor will always draw current and the controlling circuit won't get enough power for its working. You will mostly get a 9V battery for Rs.15. Buy three and use one 9V for the controlling circuit, other two 9v for motor driving. Use 78xx voltage regulators to get 5V,12V,24V etc...

http://nod.phpwebhosting.com/~robotics/modules.php?name=Forums&file=viewtopic&t=743

http://www.roboticsindia.net/modules.php?name=Forums&file=viewtopic&t=366&p=6973
SMPS

Above diagram shows Switched Mode Power Supply. If you want tutorials on it try in google, Wikipedia etc.. You will get +5V, -5V, +12V, -12V from SMPS. Different SMPS have different power ratings, depends on the processor and other peripherals. But old SMPS will be sufficient for us. There are four wires which should be short circuited properly to switch ON the SMPS. These wires goes to the power button of the computer, remaining wires goes to the peripherals of the computer. The way in which you short circuit these four wires is written over the SMPS. So do it first to make the SMPS work. Now come to the wires to the peripherals, you can see that there are wires of different colors.

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<tr>
<th>Color</th>
<th>Voltage</th>
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<tr>
<td>BLACK</td>
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<tr>
<td>RED</td>
<td>+5V</td>
</tr>
<tr>
<td>yellow</td>
<td>+12V</td>
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</table>

Some SMPS have written the voltage corresponding to the colors over it. You measure it using a multimeter and identify the color for the corresponding voltage. The fan of the SMPS should run for the working of the SMPS. In SMPS the main problem you will face is that fan will not run. This is because of

1) the wires you have short circuited may not be proper or they are not short circuited tightly. Shake that short circuited wires, sometimes that will run the fan.

2) Short circuit in your circuit. Suppose if you connected +5V and ground(say for example).
POWER SUPPLY CIRCUIT

Above circuit shows how to produce +/-12V, 5V from 230V AC line. It basically consist of a bridge rectifier with a capacitor filter and a voltage regulator.

If you invert polarity of the capacitors then sometimes it will burst because all the capacitor here are electrolytic capacitors. If you invert the polarity of the diodes then this circuit won't work. See the pins of voltage regulators. Here you can see that -12V is with respect to ground, remember that we measure all quantities with respect to ground. Suppose if you want -12V, don't say that you connect 0V to +ve and 12V to -ve lead because we say -12V with respect to ground and ground(0V) is a common terminal.

The main troubleshooting in circuit is to

1) check that your power supply, whether it will be able to provide the sufficient power to the circuit, controlling as well as motor driving circuit.

2) check the polarity of the power supply.

3) See the light of the adapter,

4) if it is OFF then you check whether your switch (power switch) is ON

5) If it is still OFF even though the power is ON then you check for the short circuits in the circuit.
6) If the light is DIM then you can infer that the adapter is not able to drive the circuit. When I connected a 3V DC motor from a toy car directly to adapter the light of the adapter becomes DIM. When I connected the output of adapter to input of 7805 and the output of 7805 directly to IR LED then the light of the LED DIM. Suppose if you connect the output of the adapter to 7805 and short the second and third pins of 7805(Vcc and gnd) then the light of the adapter will goes OFF.

**VOLTAG REGULATORS**

Voltage regulators produce fixed DC output voltage from variable DC (a small amount of AC on it). Normally we get fixed output by connecting the voltage regulator at the output of the filtered DC(see in above diagram). It can also used in circuits to get a low DC voltage from a high DC voltage (for example we use 7805 to get 5V from 12V). There are two types of voltage regulators

1. fixed voltage regulators(78xx,79xx)
2. variable voltage regulators(LM317)

In fixed voltage regulators there is another classification

1. +ve voltage regulators
2. -ve voltage regulators

**POSITIVE VOLTAGE REGULATORS**

This include 78xx voltage regulators. The most commonly used ones are 7805 and 7812. **7805 gives fixed 5V DC voltage if input voltage is in (7.5V,20V)**. You may sometimes have questions like, what happens if input voltage is <7.5 V or some 3V, the answer is that regulation won't be proper. Suppose if input is 6V then output may be 5V or 4.8V, but there are some parameters for the voltage regulators like maximum output current capability, line regulation etc., that parameters won't be proper. When I applied 3.55V input, i got around 3.5V. Remember that electronics components should be used in the proper voltage and current ratings as specified in datasheet. You can work without following it, but you won't be able to get some parameters of the component.
Get datasheet from google by searching '7805 datasheet' or from www.alldatasheet.com

Next task is to identify the leads of the 7805. So first you have to keep the lead downward and the writing to your side, see the figure below. You can see the heat sink above the voltage regulator. (1-input, 2-gnd, 3-output)

![Image of 7805 voltage regulator](image)

This is the same way of lead identification for all 3 terminal IC's (for eg. Power transistor).

![Diagram of 7805 voltage regulator](image)

The above diagram show how to use 7805 voltage regulator. In this you can see that coupling capacitors are used for good regulation. But there is no need for it in normal case (I never used these capacitors). But if you are using 7805 in analog circuit you should use capacitor, otherwise the noise in the output voltage will be high. The mainly available 78xx IC's are 7805, 7809, 7812, 7815, 7824
NEGATIVE VOLTAGE REGULATORS

Mostly available -ve voltage regulators are of 79xx family. You will use -ve voltage if you use IC741. For IC741 +12v and -12v will be enough, even though in most circuits we use +15v and -15v. You can get more information about 7905 from the following link.


7805 gives fixed -5V DC voltage if input voltage is in (-7V,-20V)

The mainly available 79xx IC's are 7905, 7912
1.5A output current, short circuit protection, ripple rejection are the other features of 79xx and 78xx IC's
VARIABLE VOLTAGE REGULATORS

Most commonly variable voltage regulator is LM317 although other variable voltage regulators are available. The advantage of variable voltage regulator is that you can get a variable voltage supply by just varying the resistance only.

http://focus.ti.com/docs/prod/folders/print/lm317.html
http://www.electronics-lab.com/articles/LM317/
3V ≤ (VIN − VOUT) ≤ 40V, Vout=1.25 V

\[ V_{OUT} = 1.25V \left( 1 + \frac{R2}{R1} \right) + I_{ADJ}(R2) \]

From the above the equation you can see that output voltage is proportional to R1 and R2. But in the above equation we can neglect Iadj
So \( V_{out} = 1.25(1+\frac{R2}{R1}) \). If you put \( R1=R2=1 \)Kohm \( V_{out}=2.5V \). LM317 can be used to drive motor because it can handle output current up to 1.5A.

In some low power devices like image sensor or USB we require 3.3V, in that circuit we use LM317. In a line follower we introduce some speed variations for motor for different bendings, you can do it by either using PWM or using the above circuit.

**NOTE:**
Remember about the input voltage limitations.
Remember about the heat sink of the voltage regulators before touching the voltage regulator IC because it will be in the heated state normally.

Your hand will get burned(not big burn, some small) if we touch the heat sink of the voltage regulator. So first touch the heat sink gently and confirm it is not heated, then only remove the IC from the breadboard.

If you are driving high power circuits and motors from the output of the voltage regulator screw an external heat sink to the voltage regulator. Size of the heat sink depends on the output power driving.
RELAYS

You have seen controlling home equipments such as light, fans and equipments that run on 230V using parallel port of computer or a microcontroller or any other digital IC's. This is possible through relays. Relay is an electromagnetic device which work on magnetic field. If you apply proper low voltage on one side the metal will get contacted.

[Diagram of SPDT Relay]

You will get better tutorials here:
http://www.1728.com/project3.htm
http://www.the12volt.com/relays/relays.asp
http://electronics.howstuffworks.com/relay.htm
http://www.kpsec.freeuk.com/components/relay.htm
The relays mostly available are of 12V, 196 ohm relays, if you use D880 transistor for driving it then remember the resistance at the base of the transistor should be around 1Kohm. I will explain this in Transistor section briefly. You can hear a sound when the relay got activated.

**Checking a relay circuit:**

1. First check the relay is good and test whether your relay work with the Vcc you use. So first you connect Vcc and gnd between two ends of the relay. If it is activated you can hear sound. If not see the voltage rating of the relay and increase voltage. This is the most problem occurring with relays. For a 6V, 100ohm relay it required 6.86V to make it work. If Vcc=5v then you can hear a small sound that means that magnetization is not enough.

2. See the connections properly because on the other side of the relay you might be using 230V, so be careful when you touching the relay.

3. See the voltage of the other circuits and sensors when you connect relay (whether they are getting proper voltages).

4. Remember to put the protection diode.

5. Touch the heat sink of the transistor to see if the transistor is getting heated or any faults.

6. See the value of the resistor connected in the base of the transistor. I will explain about it in Transistor section.

Here it is a small relay representation (a diagram of relay I have). The other side of the relay can be 230V or even 5V (no restriction), but we normally get 230V relay, means voltage <= 230 (on the 230V side). You can use this in the last stage of a line follower (assume that line follower has more than 2 LDR’s), when last sensor go out of the line, you can use relay mechanism to provide Vcc to the other lead of the motor so that motor start to rotate backward.

**NOTE:** The switching speed (around 100ms) of relay limits its application in high power circuits (so SCR and Triac came).
TRANSISTOR

When we talk of transistor in robotics, we talk about the cut off and saturation region only, while in your course you study transistor in active region. So here I am talking about transistor as a switch. When we say transistor as a switch, we talk of cut off or not because the typical cut off voltage is around .5V and the saturation voltage(vbe) is around .8V. There is regions between them. Let's start with transistor to glow an LED.

Connect this ckt and see. Connect multimeter at the base of the transistor and see the voltage. In this circuit we can see that Ve=Vbe. For the transistor to be switched ON Ve=.5V. Vary the potentiometer to make Vbe=.5V, you can see that LED starts glowing (but it is less brightness). Vary the potentiometer to make Vbe to around .8V, you can see that the LED brightness increases. This is because when Vbe=.5V it starts with cut off and when Vbe=.7V in active and Vbe=.8V it become saturation region. Transistor is a current controlled device. In active region Ic=hfe Ib and in saturation region Ic>hfeIb. That is why the brightness of the LED changes.
This circuit is used to turn on or turn off relays. Suppose if you use an LDR and a series resistor to turn ON and OFF light in your room, if the intensity of the light become LOW. Now let's discuss about the circuit to turn ON/OFF relays using a microcontroller or a computer.

Here you can see that I am using a 6V,100ohm relay. The circuits given in this book are all tested. The output voltage of my adapter when I put it into 6V is 6.86V. A 6V relay will switch properly only when Vcc>6V. If you use the output of 7805 then you can hear only a small sound or sometimes no sound meaning that relay is not getting enough magnetisation. So remember it. See the relays troubleshooting section. Now come to the series resistor in the base of the transistor. It can vary from 100ohm to 10Kohm. But 1Kohm is good. If I use a 100ohm resistor in series then the relay won't be switched properly. If you use 10Kohm then also relay will not be switched. If Rb<100ohm then you can see that the adapter light dims(Ic=Ib). You can verify it by connecting and removing the base voltage to Vcc. If it is not switching then your circuit is not working. You can see that Ic=Ib and Ic=hfelb are the limits.
Here we can see we are using a protection diode, sometimes called a free-wheeling diode. The purpose of the protection diode is to protect the transistor from the burning of the transistor because relay is a coil, i.e., an inductor, the property of the inductor is to oppose its cause. So when you switch off the circuit, the discharging of the inductor occurs in opposite direction (remember the properties of inductors), so if you use a protection diode, then it will discharge through the relay + diode circuit, otherwise transistor got damaged. But if you use a power transistor, this problem won't occur.

**WHY POWER TRANSISTOR??**

Mostly we use power transistors in robotics because it is to drive high power circuits like motors, relays. Let's compare normal transistor BC548 and power transistor D880 (datasheet).

**BC548 (NPN Epitaxial Silicon Transistor)**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>hfe-110</td>
<td></td>
</tr>
<tr>
<td>Maximum Collector to Base Voltage (VCBO)</td>
<td>30V</td>
</tr>
<tr>
<td>Maximum Collector to Emitter Voltage (VCEO)</td>
<td>30V</td>
</tr>
<tr>
<td>Maximum Base to Emitter Voltage (VBE0)</td>
<td>6V</td>
</tr>
<tr>
<td>Maximum Collector Current (Ic)</td>
<td>100mA</td>
</tr>
<tr>
<td>Maximum Power Dissipation</td>
<td>500mW</td>
</tr>
<tr>
<td>Case: TO-92 Plastic Package</td>
<td></td>
</tr>
<tr>
<td>Weight: approx. 0.18 g</td>
<td></td>
</tr>
</tbody>
</table>

**KSD880 (Low Frequency Power Amplifier)**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>hfe-60-300</td>
<td></td>
</tr>
<tr>
<td>Maximum Collector to Base Voltage (VCBO)</td>
<td>60V</td>
</tr>
<tr>
<td>Maximum Collector to Emitter Voltage (VCEO)</td>
<td>60V</td>
</tr>
<tr>
<td>Maximum Base to Emitter Voltage (VBE0)</td>
<td>7V</td>
</tr>
<tr>
<td>Maximum Collector Current (Ic)</td>
<td>3A</td>
</tr>
<tr>
<td>Maximum Power Dissipation</td>
<td>30W</td>
</tr>
<tr>
<td>Maximum Base Current</td>
<td>.3A</td>
</tr>
</tbody>
</table>

You see that hfe is low in power transistor. In the above transistor circuits we have seen that we normally connect motor or relay in between collector and base. You see the max. Ic of the transistors, D880 = 3A and BC548 = .1A
Normal DC motor have current rating of 250 mA. So if I connect the this motor to the collector of BC548 then it will not able to drive the motor because max. Ic of BC548 is 100mA. But a D880 can drive this motor. This is the main reason we use power transistor. Second is the probability of damage because of the heat sink of the power transistor. If some short circuit occurs the heat sink will get heated, it won't get damaged. See the maximum voltage ratings of the power transistor. So if you are using some other transistor, see it's datasheet first to see that it will be able to be used in that circuit. The main thing you have to note is max. Ic and hfe(VCEO,VCBO see this also to choose Vcc).

See this circuit. In this we connected Vcc directly to the base without a resistor. If you connect like this adapter light will go off and circuit won't work properly. Remember that transistor is a current controlled device

NOTE:

● When using transistor first see the ratings of the transistor from its datasheet.
● See the ratings of the device connected in the collector of transistor and match it with maximum Ic of the transistor.
● Remember that transistor is a current controlled device. So connect an appropriate resistor in the base.
● When you check whether the circuit with transistor will work in saturation region measure Vbe first and see if it is in saturation region. I will explain it in H-bridge.
This is a circuit which is used to switch on an equipment when the intensity of light is less. An LDR is a device whose resistance decreases as light increases. So adjust 10Kohm resistance so that, equipment will turn off when the light intensity is above desired level (this level is set by you). This circuit can be used for automatic switching of streetlights.

Here is another circuit which can be called as a basic burglar alarm. So when a thief passes a way it cuts the light and resistance of LDR increases to make the buzzer to beep. Here I put 10Kohm resistor because the value of resistance of the LDR is around 10Kohm. First test the value of LDR resistance and put the resistance so that when light is there the transistor is cut off and when dark the voltage drop increases and transistor become saturated and the buzzer beeps. Normal buzzer beeps when voltage >7V mostly. See the relay troubleshooting. Mostly relays are of 6V and 12V. Be careful about that. The resistance in series with LED should be proper so that LED will not be burned.
**OPAMPS(IC741,LM324)**

As the name implies it is an operational amplifier. It performs mathematical operations like addition, subtraction, log, antilog etc. The main reason for OPAMPS used over transistors is that transistor can only amplify AC while OPAMPS can amplify AC and DC. You can get good amplifier gain in OPAMPS. The most commonly used OPAMPS are 741 and 324. IC741 is used in close loop configuration and LM324 in open loop configuration. i.e LM324 mainly used as comparator while 741 for amplification, addition etc...

**COMPARATOR(LM324)**

Comparator is a digital IC. The difference between the analog IC and digital IC is that in digital IC the output has only two states, while in analog IC it has more than two states. IC7404, it has two states LOGIC HIGH and LOGIC LOW, IC555 is also digital IC. IC741 is an analog IC because it has output voltage vary from -12V to 12V.

Comparator has only two states +vcc or -vcc. But LM324 we normally apply Vcc=5V and -vcc=0. So output will have only 5V and 0V. But LM324 output LOGIC HIGH will be around Vcc-1.5V and LOGIC LOW around .2V. So if you use Vcc=5V then LOGIC HIGH=3.5V and LOGIC LOW=0V. But LOGIC HIGH for a digital circuit is a voltage greater than 2.4V and LOGIC LOW is less than .8V.

Above figure shows the general circuit diagram of a general comparator. If V1>V2 then Vout=+Vcc and if V1<V2 then Vout=-Vcc. Suppose if V1=V2, then output will be +vcc or -vcc theoretically. But practically no such condition exist, because an operational amplifier has a gain of 10^6, so there is no condition exist.
Supply voltage – 3 v to 32v
output voltage swing – 0 to V+ -1.5V

LET'S START:

1. Insert IC properly into the breadboard.
2. Apply Vcc=+5v and -Vcc=0V
3. This circuit is used to test 324 the four operational amplifiers before using in the circuit.
4. Vary V1 and V2 to see the Vout.
5. Use multimeter or LED to see Vout and test the conditions of a comparator.

Here you can use 1Kpot or 10Kpot instead of 470ohm potentiometer.
Connect this circuit and start testing comparator LM324.

Normally we apply +vcc=5v and -vcc=0v
This circuit is used to turn ON light or any equipment if the light intensity is below a level. This level is set by 470ohm pot (i.e, V2 is the reference). You can make the same circuit using power transistor, but difference between two.

When Vcc=5V and I apply v+=10v and v-=4.5 then output is 3.84
when Vcc=12V same input o/p 11.45
so be careful of vcc of Lm324

TIPS:
1. When u connect Vcc of Lm324 to gnd, then it will easily get heated.
2. The input cannot be greater than Vcc
3. You should remember that when using multiple voltages, Vcc should be greater than maximum voltage. Otherwise you will get wrong results.

Why Comparator is preferred over Power Transistor?
In robotics we require only two levels, active HIGH or active LOW that exist in comparator, but in power transistor there is regions between cut off and saturation, so that output varies with the input voltage at the base.
Second thing is that power transistor is a current controlled device. But we always require voltage comparison, so we prefer comparator. But comparator outputs cannot be connected directly to the relay or motors. I will explain in H-bridge section.
We mostly use IC 741 as amplifier, adder, subtractor, adder cum subtractor. I am not giving more explanation because you can easily get circuit in internet or normal class texts. See the circuits of amplifier, adder, subtractor. I will give more examples in Sun Tracker and Light Following Robot.

http://www.uoguelph.ca/~antoon/gadgets/741/741.html

Power supply voltage +/-3V to +/-18V
Maximum differential input voltage 30V
Maximum voltage to either input 15V
Maximum power dissipation 500mW
Open-loop voltage gain 100,000
Input Resistance 2Mohm
CMRR 90dB
Slew Rate .5V/μS

The 741 has two inputs and one output. The difference between these two inputs is amplified and that is what appears at the output. For this reason, the 741 is sometimes called the DIFFERENCE AMPLIFIER or COMPARATOR.

Normally we use -Vcc = -12V and +vcc= +12V which is preferred over +/-15V because it is easy to generate for us. See the power supply section for the ckt to generate +/-12v from 230V AC.

Why LM324 is preferred over IC741?

1. If you use IC741 as comparator with Vcc=5V and -Vee=0 then for HIGH=4.5V and LOW=1.52, so in both condition transistor will be saturated, so in order to use IC741 as a comparator better apply -15,+15.

2. When LM324 is used with Vcc=5V then HIGH=3.6V (but this is the logic high for digital circuit) and LOW=0. So this will be better, you won't be able to get HIGH=5V.

3. In 741 when Vcc=5V,Vee=1.33V then HIGH=4.0 and LOW=0V. This is the reading which i got.

4. The best way of checking IC741 and IC324 is by using comparator configuration. But remember in checking case the input voltage to the comparator should be less than the supply voltages used. The output voltage will be some Vcc-2V and -Vee+2V at max.

5. You can used Vcc/ Vee to +/-9V at min for good response
I think everybody knows about IC555. It is used by most of the hobbyists. There is a book named “Engineer's Mini-Notebook - 555 Timer IC Circuits” by Forrest M Mimms which gives so many applications of 555. But in robotics, we normally use 555 for generation of clock and pwm generation. Mostly 555 is used to generate 38KHz to IR sensor.

**ASTABLE MULTIVIBRATOR**

Figure shows the circuit of an astable multivibrator. The name 'astable' implies that this circuit has no stable state. This circuit will always produce pulse output whose timing can be varied with Ra,Rb,C. In order to test a 555 whether the IC is good or bad, we use above circuit with Ra=10kohm,Rb=470Kohm,C=1uF. So if this circuit blinks the LED, then we can assure that 555 is good. In circuits we normally avoid the connection of pin 4 to Vcc and pin5 capacitor to ground. Pin4,5 are normally left open in most of the practical circuits. But no problems occurred to me till now by leaving this two pins open. Now let's see what is happening in IC555
The above figure shows the internal circuit diagram of 555 as an astable multivibrator. In this there are two comparators with its $+V_{cc}=V_{cc}$ of 555 and $-V_{cc}=gnd$. See comparator explanation in opamp section. Next comes the R-S latch. Pin 4 of 555 is reset which will reset the latch irrespective of the inputs (R,S), i.e Q=0 and Q'=1

<table>
<thead>
<tr>
<th>R</th>
<th>S</th>
<th>Q</th>
<th>Q'</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>PREVIOUS VALUE</td>
<td>PREVIOUS VALUE</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

When R=S=0 then the output will remain same as the previous value. A latch is used to store one bit of information, so if no input then output will remain as the previous value, no input means R=S=0. When R=S=1 then Q=1 and Q'=1, this is not a desired case because when Q=0, Q'=1 and when
Q=1,Q'=0 according to the logic.

Now let's start analyzing Where to start is one of the problem. See the capacitor first. The voltage at \( V_c = 0 \) or \(<1/3V_{cc} \) because if you keep a charged capacitor for sometime, it's charge will be lost because of its internal impedance and we normally use capacitors of 1uF,10uF as \( C \) in the circuit, so they will lose their charge in seconds and if some charge exist, it will be so minute compared to \( 1/3V_{cc} \). So we start with \( V_c = 0 \). Now what about \( Q \), it can be 0 or 1, we can't say surely that at the starting \( Q=0 \) or \( Q=1 \).

Now let's start with \( V_c = 0 \) and \( Q=0 \). Then voltage at pin2 become 0 and the output of comparatorII is HIGH(1) and voltage at pin6 is 0 so the output of comparatorI is LOW(0), thus \( S=1 \) and \( R=0 \) which makes \( Q=1 \) and \( Q'=0 \). If in the starting \( Q=1 \), then no difference will come because \( Q \) becomes HIGH again. Now let's see what the limits \( 1/3V_{cc} \) and \( 2/3V_{cc} \). So we have 3 states \( V_c>2/3V_{cc} \), \( 1/3V_{cc}<V_c<2/3V_{cc} \), \( V_c<1/3V_{cc} \). Now let's see what will happen \( 1/3V_{cc}<V_c<2/3V_{cc} \), which is the next state. Pin2 become \( V_c>2/3V_{cc} \) makes comparatorII to LOW and Pin6<2/3VCC make comparatorI to LOW(0). That is \( R=S=0 \), then output will be previous state, previous state was \( Q=0,Q'=1 \) thus present state become \( Q=0,Q'=1 \). Now \( V_c \) starts increasing and \( V_c>2/3V_{cc} \) then PIN2=2/3Vcc and ComparatorII becomes LOW(0) and PIN6=2/3VCC makes comparator I to HIGH ie, \( R=1 \) and \( S=0 \) makes \( Q=0 \) and \( Q'=1 \). Till this time capacitor was charging because capacitor has not got a way to discharge because a capacitor discharge requires a closed circuit. Now when \( Q'=1 \) this makes a discharge path for the capacitor because C one lead is to ground and other to resistor and resistor's one end to C and other end to ground which forms a closed circuit, see the discharging circuit of a capacitor. Now \( V_c<2/3V_{cc} \) and \( >1/3V_{cc} \) because capacitor is discharging, so voltage \( V_c \) will decrease. At this state \( R=0,S=0 \) makes \( Q=0 \) and \( Q'=1 \)(ie previous state). So capacitor still got a discharge path and continue to discharge till \( V_c<1/3V_{cc} \). At \( V_c<1/3V_{cc} \) \( R=0 \) and \( S=1 \) makes \( Q=1 \) and \( Q=0 \), so the charging path of capacitor is lost and capacitor starts charge again. Now it charges to \( V_c>1/3V_{cc} \), \( V_c<2/3V_{cc} \) and continue till \( V_c>2/3V_{cc} \) and starts discharge till \( V_c<1/3V_{cc} \). This cycle repeats again. i.e capacitor charges and discharges between \( 2/3V_{cc} \) and \( 1/3V_{cc} \). Only at the starting capacitor starts from 0 to \( 2/3V_{cc} \), remaining time it will be from \( 1/3V_{cc} \) to \( 2/3V_{cc} \).

Now analyze the charging path, it consist of \( Ra,Rb \) and \( C \) and discharging path has only \( Rb,C \). During charging time \( Q=1 \) and \( Q=0 \) when capacitor discharges. Thus charging time
charging time = time required to charge from 0 to 2/3vcc – (time required to charge from 0 to 1/3vcc)

discharging time = time required to discharge up to 1/3Vcc from 2/3Vcc

charging equation \( V = V_{cc}(1 - e^{-t/RC}) \)

charge from 0 to 2/3vcc
\( 2/3vcc = vcc(1 - e^{-t/RC}) \) \( \rightarrow 1/3 = e^{-t/RC} \) \( t = RC \ln 3 \)

charge from 0 to 1/3vcc
\( 1/3vcc = vcc(1 - e^{-t/RC}) \) \( \rightarrow 2/3 = e^{-t/RC} \) \( t = RC (\ln 3 - \ln 2) \)

charging time, \( t_1 \) = charge from 0 to 2/3vcc – charge from 0 to 1/3vcc
\( = \ln 2 RC = .693 (R_a + R_b)C \) because capacitor charges through \( R_a \) and \( R_b \)

discharging time
\( 1/3Vcc = 2/3Vcc \exp(-t_2/RC) \)
\( t_2 = \ln 2 RC = .693 R_b C \)

Duty cycle = \( t_1 / (t_1 + t_2) = (R_a + R_b) / (R_a + 2R_b) \)

frequency = \( 1.44 / (R_a + 2R_b)C \)

Now you try for a circuit which produce 50% duty cycle using \( R_a = R_b \) and a diode. First you try and see the circuit diagram below
Here you can see that we just connected a diode in between pin7 and pin6, see the directions of the diode. Now when charging occurs capacitor charges through Ra only because forward resistance of the diode is very small and current will flow through the path of minimum resistance, so no flow through Rb during charging. During discharging no current flow through the diode because the capacitor is already charged with +ve on Rb side and -ve on ground side. We normally use electrolytic capacitor as C, we use ceramic also. So the diode is reverse biased during discharging making a high resistance compared to Rb, so discharging time depend on Rb. You can think this way also, Rb << diode reverse resistance and Rb and diode in parallel, when two resistors are in parallel the effective resistance will be the resistance of the lowest one(here diode reverse resistance is too high).
In this circuit Ra=Rb. Then only you get 50% duty cycle.

You can connect the output of the astable multivibrator to a speaker( i am talking about a small buzzer normally works with voltage greater than 7V, ideally 12V) through a capacitor(capacitor should be of high value 10uF etc..) then you can hear sound. If you change frequency then you can hear a different sound, change duty cycle also and see the variation in sound.

Monostable multivibrator is another used configuration of 555. You can get circuit in internet, start analyzing yourself following previous methods. Monostable multivibrator is used to eliminate keydebouncing problems, delay generation and so many applications. But the trigger pin(pin2) is a mysterious one, it mostly accepts input from a digital IC. I tried to debounce a switch using monostable, by keeping one end of switch in gnd and other to the trigger of pin2, but i was not able to get key debouncing. One of my friend had done metal detection using this. His aim was to detect a metal, if detected robot has to stop for 3second. So he used conductor strip to test the metal. He kept metal strip on the lower portion of robot touching the ground, so that if a metal comes on way current flow through the circuit. He connected it to the trigger of monostable to produce delay of 3seconds. But it does not worked properly. Supply voltage – 4.5V to 15V, max. frequency – 500khz to hours, maximum output current- 200 mA
TROUBLESHOOTING IC555

1. In astable multivibrator first see you have short circuited pin2 and pin6.
2. See the voltage of at pin8
3. See the voltage at pin 7 and pin 5 and pin 4 and LED should glow
4. The only way to test 555 is by astable multivibrator with F=1Hz so that you can see. In this case Rb>Ra to make OFF time and ON time to be close which make things clear.
5. First test this, then only connect the circuit. i.e, first test IC555 before making 38Khz wave.

See this circuit and tell about the timings. Try to do yourself.

Here charging time = .693 R1*C2
discharging time = .693 R2*C2

This circuit has another advantage,
If you want to make duty cycle=50% then you can do it without diode.
This is another circuit of astable multivibrator.
MOTORS

As a beginner we mostly use DC motors, stepper motor and servo motor will come later. As everybody know DC motor has two leads. If we apply +ve to one lead and ground to another motor will rotate in one direction, if we reverse the connection the motor will rotate in opposite direction. If we keep both leads open or both leads ground it will not rotate (but some inertia will be there). If we apply +ve voltage to both leads then braking will occurs. You can test this, first without applying any voltage you rotate the shaft of the motor, then apply ground on both lead and try to rotate the shaft. Both will almost remain same, but if we apply both lead +ve voltage (+12V) and try to rotate the shaft, you can feel the difference between the previous one. You have to apply more force to rotate the same rotation in previous connection. So we take this condition as braking, because if we want to stop the motor suddenly then this is the better way which is easily possible. There are methods to brake motor fastly, like shorting two leads, applying negative polarity exists, but we won't use this in robotics. We apply (1,1) condition to break the motor fastly (see H-bridge section for more about it).

The main things about a DC motor are Voltage rating, current rating, Torque, Speed. Remember Torque is inversely proportional to speed. So we had to get a good speed motor to get good torque because we can operate the good speed motor in slow speed to get good torque. So maximum speed of the motor should be as high as possible.

Normally available DC motors (without gears) have **12V, 250mA, 2400rpm** (may change) ratings. But it is better to have a geared motor, because you should make gears to get a good torque to drive robot. Normally we get Speed/9 reduction gears to reduce speed and get a good torque. Put three gears to reduce speed to 2400/27 (calculation is taken avoiding gear loss). So we get a speed of 80 rpm. I used DC geared motor of 12V, 250mA, 60-80rpm, 2kgcms Torque costs Rs. 380 and another one of 12V, 250mA, 60-80rpm, 1Kgcms Torque costs Rs. 135. So as a beginner it is better to have a geared motor than a normal motor because you have to make gears. O.P.K Reddy used 12V, 250mA, 60-80rpm, 2kgcms motor to make a rope climbing robot. So better get a pair of good geared motor.
SPEED CONTROL OF DC MOTORS

There are mainly two ways of controlling speed of DC motor

1. varying the supply voltage
2. pulse width modulation

First method is by varying the supply voltage, ie voltage across the motor. But this is a somewhat a tough task because we mostly microcontrollers to vary the supply voltage and to generate variable supply voltage we should go for analog circuit, then come analog to digital conversion and other steps which makes the task tedious. See the line follower project to see how to vary supply voltage to switch motor from one speed to another. But the switching time of motor is less in this case compared to PWM case. Switching speed of the motor is the time taken for the motor to change from one speed to another.

Advantage of pwm is that it is easy for driving analog circuits with digital outputs.

See the above diagram, we can see three pulse having duty cycle(ton/T) of 10%, 50%, 90%. In all three cases total time, T remains same irrespective of value of t1,t2. This is a PWM signal. A PWM signal is one in which total time always remain same and ton and toff vary. Now you apply this output to a transistor circuit shown below
Then the transistor continuously switch ON and OFF and the effective voltage across the motor become

\[ V = \frac{\text{Ton}}{\text{Ttotal}} \times Vcc \]

In PWM case Ttotal remains same, only Ton will vary which makes a varying voltage across the motor. PWM can be easily generated by any digital circuit (microcontroller used mostly). In PWM switching speed is comparatively slow because we continuously switch ON and OFF motor. A motor is basically an induction, it takes some time to charge and discharge. So if the quality of motor is good, then you can get a good PWM response. The inductance of the motor limits the selection of Ttotal. I used Ttotal=10ms for the 2kgcmsRs.400 motor and it gave a good response.

**Generation of PWM:**

PWM can be generated using IC555 or using microcontroller or computer parallel port. Now you try to generate PWM using IC555, remember that Ttotal should remain constant.
Here you can see that I applied a variable resistor. So when charging occurs it charge through upper part of variable resistor, diode and capacitor path. When discharging occurs it discharge through lower part of variable resistor and capacitor. So the total $R = R_a + R_b =$ variable resistance, so $T_{\text{total}}$ remains same.
In the above circuit you can see that charging will occur through $Ra, Rb1, C$ path and discharging occurs through $Rb2, C$ path, because during charging the diode in series with $Rb2$ is reverse biased and no current will flow through that path and the charging occurs through $(Ra+Rb1)C$ and during discharging the diode in series with $Rb1$ is reverse biased and no current will flow through that path, thus discharge path becomes $Rb2C$.

Charging time = $0.693(Ra+Rb1)C$
Discharging time = $0.693Rb2C$
$T_{total} = 0.693(Ra+Rb1+Rb2)C$
$Rb1+Rb2=$ total resistance of variable resistor which won't change and $Ra$ is a fixed resistor, so $T_{total} =$ constant.
Suppose if you connect the output of the PWM to a relay circuit and the other side of the relay is connected to fan, then if you vary variable resistance then the speed of the fan will change. You have seen blinking lights at Christmas, you can make this using a 555 astable by connecting the output to a relay.

Another one is this
http://www.nomad.ee/micros/pwm555.html

Here i have explained PWM not in much detail(compared to communication side). So more explanation can be obtained from
STEPPER MOTORS

Stepper motors will move only through a fixed angle. One step is the least count of a stepper motor. Stepper motors are used where accuracy is needed. Stepper moves only a fixed angle. Stepping angles available are 3.5, 7.5, 1.5 degrees etc... There are two types of stepper motors

1. bipolar stepper motor
2. unipolar stepper motor

The disadvantage of a stepper motor is that it is having a less torque, even though the movement is accurate. So if you want good torque and accurate movement we require servos. See the comparison in the following link

http://www.robotics.com/motors.html
http://tigoe.net/pcomp/motors.shtml

You can get stepper motor from an old floppy drive. But hard disk motor is not a stepper. More about floppy drive motor, you can find in this link

http://www.doc.ic.ac.uk/~ih/doc/stepper/flpystpr/flpystpr.txt
http://jewel.morgan.edu/~tmalone/dskdrv/dskdrv.html
I bought two stepper motors Rs.210 for each motors, look like the figure below. But mine was a unipolar stepper motor, 24V,600mA,3.5 degree, min delay=4ms (i will explain in next page). But it was not able to give enough torque to drive a robot because of its less torque. For power supply i had to keep three 9V battery with a 7824 voltage regulator. That is too heavy for the motor to carry even though the robot was too small, consisting of one microcontroller PCB and a fiber glass base. My aim was to make a micromouse. So if you buy stepper motor buy motor of good torque, small voltage and current ratings. I heard of 5V steppers available in India. So better go for a floppy drive motor or stepper motor available in printers for making robots.

![Stepper Motor Image]

Delay time is the delay which should be applied between two sequence. That is it is the delay between the two steps. If the delay time applied is less than the minimum delay time, then the rotor of the motor slips (i.e it misses the sequence), you can understand it by touching the rotor of the motor. Second thing, higher the delay time between the two steps, better the torque will be. Bipolar motor have better torque than unipolar motor.

Stepper motors are available with 4 wires, 5 wires, 6 wires. Wires are not like a DC motor. 4 wire stepper motor is surely a bipolar motor, 5 wire motor will be surely a unipolar motor and 6 wire motor can be used as a unipolar motor as well as a bipolar motor. If you short two pins of 6 wire motor it become unipolar and if you leave two wires open then it become bipolar motor. The next task is to identify the leads of the stepper motor. Let's start with a 6 wire motor. First take a multimeter having continuity test and resistance testing.
The inside of a 6 motor stepper wire is like this. Every wire has different colors. So take a paper and note down the color. Now start identification, it is a logical task. You can see that resistance between (a,f),(a,d),(d,b),(b,f),(c,d),(c,f),(e,c),(e,a) are infinite because there is no connection between them. So first identify the wires which are having infinite impedance between them. The two coils are identical and let the resistance of the coil be X so the resistance between (a,c),(d,f) will be X. Second thing is that resistance between (d,e),(e,f),(a,b),(b,c) are X/2. Do these analysis and identify the lead and give the terminal names a,b,c,d,e,f. Now you got the wire color and terminal names. Do the analysis carefully, by applying some logic.

If you short circuit (e,b) then the motor will be unipolar and if you leave (e,b) open then the motor will be bipolar. The motor i have got is having resistance ,X=30 ohm. You can do same analysis for bipolar as well as unipolar motors. For a bipolar (a,c),(d,f) coils exist and the resistance between (a,c) and (d,f) is X and high impedance between (a,f),(c,f),(a,d),(c,d). For unipolar motor the one i used is having resistance X=30 ohm . In that case first find the common lead,B

You can see that resistance between (B,a),(B,c),(B,d),(B,f) will be X/2 and resistance between (a,c),(d,f) will be X ,same with (a,d) and (c,f). So you should first identify the common lead. Another way of identification is given in the following link
http://wwwhomes.doc.ic.ac.uk/~ih/doc/stepper/others/
http://www.ece.ualberta.ca/~schmaus/elcts/mtest.html
There are two steppings for a stepper motor
   1. half stepping
   2. full stepping
An animation of half stepping is in the following link

Half and full stepping table is available in the following link
http://www.doc.ic.ac.uk/~ih/doc/stepper/control2/sequence.html
http://www.imagesco.com/articles/picstepper/05.html
http://www.cctc.demon.co.uk/stepper.htm

I will explain how to drive a stepper motor in H-bridge section. More stepper motor links
http://www.imagesco.com/articles/picstepper/02.html
http://www.cs.uiowa.edu/~jones/step/types.html
http://www.doc.ic.ac.uk/~ih/doc/stepper/
http://www.epanorama.net/circuits/diskstepper.html
http://www.doc.ic.ac.uk/~ih/doc/stepper/control2/connect.html
MOTOR DRIVING CIRCUITS (H-BRIDGE)

In roboticsindia and many other forums i have seen questions about connecting motors directly to parallel port, output of IC555, opamp etc. The answer is that if you connect motor directly to parallel port, 555, 324 etc. then the IC may be damaged, same with parallel port (sometimes burning your motherboard). So if you want to connect motor to the output parallel port etc., you should have a motor driving circuitry. The reason is that a normal motor current rating is greater than 250mA, for steppers it is 600mA. The output current capacity of these IC's are very low. For IC555 the maximum output current is 200mA. So if you connect a 250mA motor to the output, it drives more current from the IC and the IC is not able to provide enough current motor requires and finally this may result in the burning of IC. So if you start with an IC, see its maximum voltage, current ratings etc. Same problem occur with 741, its maximum power dissipation is 500mW and the voltage of 741 is about 12V. For DC I=P/V=500mW/12v which is less than 100mA, so it is not able to drive a motor. A parallel port basically consist of digital IC's of 74LS series having maximum source current of 2mA and sink current 24mA (see IBM definitions for parallel port). In digital IC's there are two current source current, i.e., when output is LOGIC HIGH and sink current when output is LOGIC LOW. So if you want to drive a motor the output should be LOGIC HIGH, if you use parallel port voltage for the motor. You can do other way connecting external voltage at one terminal and other terminal of motor to parallel port. In this case output should be LOGIC LOW (0) to the motor to run. But in both cases the required current is greater than the source and sink current, so it is not possible to drive. But in case of a power transistor you can see that we connect motor at the collector side and maximum collector current in the range of Amperes. So a power transistor is able to drive the motor. See the other parameter VCEO it is greater than 50V for a normal power transistor. Therefore a power transistor ratings is decided by comparison between the maximum voltage and current ratings of the motor and VCEO (max) and maximum collector current of transistor. Here we are talking about driving a DC motor. Stepper motor driving will be discussed later. In DC motor driving H-bridges are used. While choosing an H-bridge compare the maximum current and voltage ratings of your motor and that of H-bridge.
Figure shows the representation of a DC motor. If you apply Vcc to A and gnd to B then motor will rotate in clockwise direction (assume the direction as clockwise). If you apply Vcc to B and gnd to A then motor will rotate in anticlockwise direction. If you apply gnd to A and B then motor will stop, but some movement is there due to inertia. If you apply Vcc to both A and B then motor will break suddenly, only very small movement due to inertia. That is why if A,B=Vcc it is called breaking. Here Vcc refers to the voltage applied to the motor and it should not be greater than maximum voltage rating of motor. We normally apply 12V to the motor, Vcc=12V. So now your aim is to make a circuit which will drive motor with the output of parallel port or a microcontroller.

<table>
<thead>
<tr>
<th>l1</th>
<th>l2</th>
<th>A</th>
<th>B</th>
<th>motion</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>stop</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>vcc</td>
<td>0</td>
<td>clockwise</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>vcc</td>
<td>anti-clockwise</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>vcc</td>
<td>vcc</td>
<td>brake</td>
</tr>
</tbody>
</table>
Here I1 and I2 are the outputs of parallel port or a comparator or a microcontroller. So now your aim is to design a circuit which perform this function

This is an ideal H-bridge using 4 transistors. This circuit is called H-bridge because, it has a shaped of 'H' with central limb as motor. A transistor become saturated when Vbe>.8V and in cut off when Vbe<.5V (normally). Suppose I1=12v(logic HIGH of a digital circuit) then transistorQ1 is cut off Vbe1=Vb1-Ve1= 12-12=0V . So transistor Q1 is in saturation because it is a PNP transistor. When I1=0v(logic LOW) Vbe1=0-12v=-12V , it is in saturation. When I1=0V Vbe3=0-0=0V make Q3 in cut off. When I1=12V then Q3 is saturated. When I1=HIGH and I2=LOW then Q3 and Q2 are ON and the current flow in one direction while I1=LOW and I2= HIGH Q1 &Q4 become ON and current flow in other direction. When I1=I2=LOW, then Q1 and Q2 are ON and motor get's braking. When I1=I2=HIGH then Q3,Q4 become ON and the motor gets normal stopping. So this is not an ideal H-bridge because when you apply (1,1) then the motor is not braking. Now you try to make it ideal H-bridge so that when (1,1) come motor will brake and (0,0) the motor will stop. Try to make and see the circuit below.
Here you can see that I just interchanged the position of transistors. Remember that transistor is a current controlled device. The switching speed of a transistor is around 10Khz. So if you want more switching speed you have to go for MOSFET which is having speed around 100K. Second thing MOS is a voltage controlled device. Suppose if a device you are using have high voltage and current rating(suppose if you are driving a big motor), then you can use relay circuit to make H-bridge. Try to make the circuit and see what are the practical limitations.
In this circuit you can see two relay driving circuitry. This circuit has a limitation of relay contacts in default position. In default position it should be connected to ground, so that when I1=I2=0 motor get's zero. I assumed the motor will be DC motor of high ratings. This circuitry can be applied to small 12V DC motor, but the main problem coming is about the switching speed of the relay. It is around 10ms at maximum. So the circuit won't switch fastly compared to H-bridge using transistor or mosfets. This is one of the limitation of this circuit, second limitation is that when connecting the default position would be gnd for both relays.

H-bridge tutorials
http://www.4qdtec.com/bridge.html
http://www.solarbotics.net/library/circuits/driver_4varHbridge.html
http://www.mcmanis.com/chuck/robotics/tutorial/h-bridge/

H-bridge circuits
http://home.cogeco.ca/~rpaisley4/HBridge.html
http://www.robotroom.com/HBridge.html
The most commonly used H-bridges are L293D and L298. L293 have maximum current rating of 600mA while that of L298 is 2A. L293B and L293D are available in market. If you use L293B you have to put 4 protection diodes while in L293D, diodes are inside the IC. L298 requires external protection diodes. Let's start with L293D

L293D has two channels. i.e, you can connect two motors to the same bridge. I have driven 4 motors of 250mA using L293D, with 2 motor in each channel. Now let's see the ratings of L293D
Output Current 1 A Per Channel (600 mA for L293D)
Peak Output Current 2 A Per Channel (1.2 A for L293D)
Maximum VC – 4.5 to 36V (>VSS)(it should be greater than or equal the supply voltage, vss)

**input side**(input to L293D from parallel port or microcontroller)

- **VIH** High-level input voltage (a voltage which L293D takes input as **HIGH(1)**)
  
- **VC ≤ 7 V** (2.3 to VC)
- **VC ≥ 7 V** (2.3 to 7 V)

- **VIL** High-level input voltage (a voltage which L293D takes input as **LOW(0)**)
  
- **VC ≥ 7 V** (-.3 to 1.5V), remember that **VIL should not be less than -.3V**

**output side**(output of L293D to motor)

- **VOH** High-level output voltage (VCC2 – 1.8, VCC2 – 1.4)
- **VOL** Low-level output voltage (1.2V, 1.8V)

If you want to use PWM to control L293D then apply PWM output to the chip inhibit of the IC.
Remember all these parameters when you connect L293D in circuits. L293B are available, if you use it use 4 external protection diodes. L293D costs around Rs.90. I have seen too many post about the problems occurring L293D, so here i am explaining things in more detail, how to connect L293D in circuit so that it won't create any problems to you.

**TROUBLESHOOTING L293D:**

1. Insert IC into the breadboard. Make sure that IC is inserted properly into breadboard. You can verify it using continuity test in the multimeter. Test continuity between the pins of the IC and the holes of the breadboard. If you get a beep then you can sure that **IC is fitted strongly into breadboard and the portion of breadboard you are using is good**.

2. Test the continuity in the 16 pins of the IC and the breadboard holes, to make sure that nothing goes wrong. You should be thorough with the steps you are taking.

3. Apply Vss=5V(Pin 16). The first thing to apply when you connect an IC is applying Vcc and ground. Remember Vss should be in the range of 4.5V to 7V.
4. Now connect ground at Pins 4, 5, 12, 13. Remember if you use multiple supplies, you should short circuit all grounds and this ground is applied to the Pins.
5. Now Vss and Gnd applying is over.
6. Now apply +5V to chip enable pins. Chip enable pins are pin1, 9.
7. Here we are trying to use both channels, atleast test both channels of the IC so that we can test whether IC is good or not.
8. Apply Vc at Pin8. For testing the IC you can apply Vc=Vss=5V. When you connect the motor you should apply Vc>Vss or may it can be equal also. I have tested it.
9. The following test are done for each channels separatively. In the following explanation I refer '1' as +5V(Vss) and '0' as ground.
10. Apply Input 1 = Input 2 = 0( ie,ground ) and connect multimeter to output 1 and ground of the circuit. Now test output1 and output2 voltages. Both should be zero at this condition.
11. Apply Input1=1 and Input2=0 and check voltages at output1 and output2. Remember your multimeter's one lead should be ground. Then you should get one output= Vc and other output = 0. Suppose if you got output1=Vc and output2=0.
12. Apply Input1=0 and Input2=1 and check voltages at output1 and output2. Then output1=0 and output2=Vc. That is this case is should be reverse of the previous case, motor will rotate in opposite direction.
13. Apply Input1=1 and Input2=1 and check voltages at output1 and output2. Then output1= output2=Vc. This is the braking case.
14. Test conditions 10-13 for both channels to test the IC is good. You should test it thoroughly so that a repetition is not needed. If your IC is not working, repeat steps 1-13 to make sure IC is bad.
15. The most problems occurring are breadboard problems, IC not inserted properly, applying Vss and Vc wrongly(this can sometimes cause problems to IC), not disabling chip inhibit, absence of common ground.
16. If you are applying Vc=Vss = +5V, then you can use two LED's to see outputs.
17. When chip inhibit is enabled, ie chip is not working the outputs will be high impedance, you can test high impedance using an LED. First connect the cathode of LED to ground through a series resistor of 330ohm and test the output. LED will not glow. The apply 5V to the anode of the LED and apply output to the cathode through a series resistor of 330 ohm. Now also LED won't glow. Now you can assure that the output is high impedance.

18. Before connecting motor to the outputs of L293D, first test the motor is working with the desired VC by applying VC and ground directly to the two leads of the motor. Confirm this first, then connect the motor.

19. L293d has a thermal shutdown function. So see it is working in all conditions of the circuit and robot

Links:
http://www.me.umn.edu/education/courses/me2011/robot/technotes/L293/L293.html
For high current ratings up to 2A we use L298. The specialty of L298 is that it have odd number of pins(15) while every IC has even number of pins, second is that we have to use free wheeling diodes.

http://www.iitk.ac.in/eclub/Circuit/l298.htm
http://members.tripod.com/RoBoJRR/Motor%20III.htm
http://www.ece.cmu.edu/~ece578/lecture-notes/Motor-drive-lecture/sld009.htm
Here there might be problems with inserting the IC in the breadboard and some pins may not be inserted properly. So first test that using continuity test between the pins of the IC and breadboard. The identification of the pins is the next. In the datasheet you can see that pin with short lead is pin 1. So remember this while connecting. The main problems occurring are IC is not inserted properly, absence of free wheeling diodes, pins are identified incorrectly.

Apply motor voltage to Vs and logic voltage +5v to Vss. Make enable to +5v and ground current sense pins. The remaining tests are same for L293D since we are using DC motor. For high current rating above 2A use LMD18200T H-bridge.
DRIVING STEPPER MOTORS

There are two different circuits required for driving stepper motors. First let's start with unipolar stepper motors. You can use ULN2003, L293D and L298 to drive unipolar stepper motors.

For ULN2003 this circuit is nice

The sequence to apply (a,b,c,d) – (1,0,0,0), (0,1,0,0),(0,0,1,0),(0,0,0,1), the motor rotates in one direction if we apply (1,0,0,0),(0,0,0,1) then motor will rotate in other direction. A good parallel port circuit diagram is in the link http://electronics-diy.com/stepper_motors.php

A sample program vary the delay in the program and see the variations in torque of the motor and see whether it losses the sequence. Change delay(4) to delay(50) and see the torque at the rotor. The following program exits when u press ESC key.
```c
#include<dos.h>
#delay D delay(4);
void main()
{
  int i=1;
do
  { D
    outportb(0x378,i);
    i*=2;
    if(i>8) i=1
    ch=getch()
    while(ch!=27);
  }
}

here is another circuit
http://home.cogeco.ca/~rpaisley4/Stepper.html

one with L293D

The following circuit diagram is for bipolar stepper motor. But connections remains same for unipolar except connecting common of the unipolar motor to +V(Pin8 of L293D). The logic voltage (pin16) given +5V and to enable pins(1,9).

![Bipolar Stepper Motor Circuit Diagram]
But all these circuits have problems because we had to generate sequence using any other circuit. In order to avoid circuits to generate sequence, we use a sequence generator IC L297 with L298 to drive motor [http://home.att.net/~wzmicro/l298.html](http://home.att.net/~wzmicro/l298.html)

![Motor Driving Circuit Diagram]

Here is one motor driving circuit. This will work surely because I used this circuit too many times. Don't apply P=Q=1 because this cause short circuit of the full circuit. This is why it is not called an H-bridge. I am using it because, I used this circuit when I started with robotics, a time when I don't know about L293D and L298. In this motor driver ckt, I just short ckted the two ends of motor, i.e shorting Vcc and gnd, Then power transistor got heated up. That is one of the advantage of power transistor. But power still remain without any problem. So be careful to touch the power transistor in the H-bridge circuits.
SENSORS

Temperature sensor:

Commonly available temperature sensors are LM35, DS1621, thermistor. Thermistor gives resistance proportional to the temperature. But accuracy is not good in thermistor. DS1621 gives digital output in I2C format, so you require a microcontroller to interface to see the temperature. Thermistor require accurate resistance in series to get good reading with accuracy. The resistance of thermistors are 100ohm, 1Kohm (the one I have heard). But thermistor creates some headaches although it costs Rs.5. LM35 have 3 terminal Vcc, ground, Vout. So it is easy and gives analog output and it costs Rs.50

LM35:

The most commonly available LM35 is LM35DZ measures temperature from 0 to 100 degree. Normally sensors become inaccurate with age. But LM35 will not have this problem. We get LM35 in TO-92 package, just like small transistors like BC547. The main problem you will be creating is interchanging leads. Vs ranges from 4V to 30V. Output is 10mV* degree in Celsius. That is if the temperature is 29 degree then Vout = .29V. Let's try for a circuit which will glow an LED if the output voltage is greater than some voltage. Use comparator with a reference voltage at one end and LM35 output at other end, so that comparator become high when the temperature is above reference. More Links:
http://www.facstaff.bucknell.edu/mastascu/elessonshtml/Sensors/TemperatureLM35.html
http://www.cjseymour.plus.com/elec/tempsens/tempsens.htm
LIGHT SENSORS

Light sensors are used to measure the intensity of light. Mostly available sensors are Cadmium Sulphide LDR sensor, IR sensor like photo diode, photo transistor, TSOP1738. For beginners LDR is easy to handle. So as a beginner better start with LED+LDR combination or IR LED+photo diode. LDR is economical than other sensors and easy to handle.

LIGHT DEPENDENT RESISTOR(LDR):

LDR is basically a resistor whose resistance varies with intensity of light. More intensity less its resistance (i.e, in black it offers high resistance and in white it offers less resistance). This is the basic sensor which beginners should start with, which is having cost less than Rs.6. Figure below show some of the pictures of LDR which i obtained from some site.

![Fig.1](image1.png)

![Fig.2](image2.png)
Fig.1 shows LDR's with greater surface area, Fig.2 shows the LDR's which are available about Rs.5, which is commonly used. Greater surface area, better the sensing will be. The sensing material is made of Cadmium Sulphide.

**resistance : 400ohm to 400Kohm**

*normal resistance variation: 1Kohm to 10Kohm (in the robots which i used for line following for identifying black and white strips)*

**sensitivity: about 3msec** *(Sensitivity is defined as the time taken for output to change when input changes, i got this reading by verifying with ADC interfaced with parallel port, sensitivity of LDR’s is in milli seconds. This is the best sensitivity obtained to me).*

**Voltage ratings:** I used it on 3V, 5V and 12V

**Practical application in Line follower Robots:**
LED's are used with LDR which will act as a source of light for LDR because we are placing the LDR below the robot where light is not present. If we want to identify Black and White strips we add a light source with LDR and the white strip reflects light while black won't reflect light.
Above figure shows how LED is placed with LDR. Here LDR is covered because we want light reflections from ground only, not from sides of LED. Also cover the LED so that the light will move pointed, so that reflection will directly go to LDR. When you attach LED and LDR to the body of the robot, use tape to paste the sensors. Remember if you robot body is of aluminum, then some short circuit or current flow can occurs through the body. So apply tape perfectly so that no short circuit problems occurs. Remember that LDR is a resistor and have no polarity while all other sensors have.

PROBLEMS: LDR is mainly used with visible light. So the problem of external light will affect the LDR. The affect of visible light is more in LDR then comes Photo diode, then TSOP1738.
http://www.technologystudent.com/elec1/ldr1.htm
http://www.kpsec.freeuk.com/components/other.htm
http://www.mstracey.btinternet.co.uk/technical/Theory/theorysensors.htm
http://www.tpub.com/neets/book7/26g.htm

PHOTO DIODE
Here is some link for photo diode:
http://www.radio-electronics.com/info/data/semicond/photo_diode/photo_diode.php
http://en.wikipedia.org/wiki/Photodiode
http://www.lasermate.com/PR.htm

Photo diode works in reverse biase region. A photo diode leads can be identified by seeing the length of the leads. Short lead is the cathode connected to greater voltage. The current flowing through the photo diode changes with intensity of the light. You can use it for edge detection. I tried to do edge detection of a table, i got range about 7cm. IR LED is used for producing light. When you are using IR LED be sure that it is working properly by measuring the voltage across the IR LED, should be greater than 2V. When connecting IRLED the voltage of the circuit drops, so be careful that voltage to other circuits won't fall below the level.
Photo diode and IR led looks same. The only difference is in its color IR LED is some dark in color. If you still can't identify. See this post http://nod.phpwebhosting.com/~robotics/modules.php?name=Forums&file=viewtopic&t=435

PHOTO TRANSISTOR

I haven't used photo transistor. But a photo transistor is one in which base is like the receiver of light. When light falls there will be a short circuit between collector and emitter. This can be used in optical communications. I heard that you can make a photo transistor by cutting the upper portion of transistor BC107 and leaving the base. You can use either IR or laser (cheap one available). But in case of transmission we require line of sight propagation. Here is a circuit for detection of IR using photo transistor. http://www.kmitl.ac.th/~kswichit/LFrobot/LFrobot.htm
Here when light is not there then the resistance of transistor will be high, so the $V_-(\text{pin2}) > V_+(\text{pin3})$ making output of comparator LOW. That is when no reflection from ground or any obstacle on the IR. When light is there then the resistance will be very less and $V_+ > V_-$. So output of comparator is HIGH. Suppose if you are using it for line detection, then there is reflection of IR from the white surface, but IR radiations are absorbed by black surface, so no or less reflection from the surface in black strip. Remember to check the voltage across IR to see whether IR LED is working or not and it should be greater than 2V. When black strip comes, output of comparator become 0V and the LED glows (visible light LED).

**TSOP1738**

Supply Voltage (Pin 2) $V_S$ –0.3...6.0 V
Supply Current (Pin 2) $I_S$ 5 mA
Output Voltage (Pin 3) $V_O$ –0.3...6.0 V
Output Current (Pin 3) $I_O$ 5 mA
Continuous data transmission possible (up to 2400 bps)
Suitable burst length .10 cycles/burst
cost-Rs.15
DISTANCE MEASUREMENTS
For a small distance measurement we can use a photo diode or photo transistor, but only distance up to 5-7cm. You just connect the output to ADC or any comparator to measurement. Suppose if we use one LM324 for distance measurement, you can measure 1cm, 2cm, 3cm, 4cm. You just connect a 330 ohm in series with IR LED. At the other end use a photo diode in reverse region.
http://www.multyremotes.com/IRSw.htm
http://www.roboticsindia.net/modules.php?name=Forums&file=viewtopic&t=410
http://www.windowschallenge.com/Final%20Reports%5CFINAL%20REPORT-FINAL.doc
http://www.robotroom.com/Infrared555.html
http://www.students.uwosh.edu/~piehld88/laser.htm
http://www.wanyrobotics.com/distance.html#
If you want a good distance then you should use 38Khz modulated IR with TSOP1738 detector. Use IC555 to generate 38Khz square wave. Better tutorials available in roboticsindia, see
http://www.roboticsindia.net/modules.php?name=News&file=article&sid=32&mode=&order=0&thold=0
http://www.roboticsindia.net/modules.php?name=News&file=article&sid=35&mode=&order=0&thold=0
You can get range about 1 Meter. If you want to measure various distance then you should vary Ra of the IC555. Suppose if you want to measure distance from a fixed point, then you have to vary the frequency of IC555. You can do it fixing Rb>Ra and vary Ra so that frequency will vary slightly from some 36Khz to 40Khz and find corresponding reading. You can do it by using the following technique
Suppose if you want to measure distance from a fixed point. This is done by varying the frequency. When S1=1 then 
\[ \text{Raeq} = \frac{\text{R1}}{\text{Ra1}} = \frac{\text{R1}}{(\text{Ra1}+\text{R1})} \]. So this will produce a different frequency some between 36 to 40Khz. When S2=1 \( \text{Raeq} = \frac{\text{R1}}{\text{Ra2}} \). And when S1=S2=1 then \( \text{Raeq} = \frac{\text{R1}}{(\text{Ra1}+\text{Ra2})} \). By varying S1,S2 you can measure the distance from it. But this mostly require the need of some circuitary. Better go for a microcontroller. Adjust Ra1,Ra2 so that desired frequencies are obtained.

About the range of IR sensor
http://www.triindia.co.in/forums/viewtopic.php?t=12
http://www.triindia.co.in/forums/viewtopic.php?t=4
http://users.triera.net/zupanbra/senzor.html

**COLOR SENSING:**

I haven't heard of availability of color sensors. But we can make it from scratch. Suppose if you want to sense the color of ball. First thing you have to bring robot near the ball. The distance of the ball from the robot should be fixed. Second thing the effects of external light. First make the robot a fixed distance from the ball. This is made by using a IR LED+photo diode combination. Bring robot close so that you will get a good response. For sensing color you use LED+LDR combination. But the problem with external light will be higher in this case. So you should provide some mechanical mechanism to hide external light. Photo diode or modulated 38Khz+TSOP is used for distance measurement. But photo diode is enough to get distance about 5cm or near. Use comparator output to the output of photo diode for distance measurement. Use LDR to sense the color. But the accuracy is a real problem.

**RANGE FINDING:**
http://www.roboticsindia.net/modules.php?name=Forums&file=viewtopic& t=148
SONAR
http://www.leang.com/robotics/info/articles/minison/minison.html
ANGLE MEASUREMENT

Suppose if your robot is going over an inclined plane and we want to measure the inclination of the plane then we should go for angle measurement. This is done simply using the principle of a pendulum. If you goes up an inclined plane a pendulum kept perpendicular to the gravity will change its angle with normal. Attach a somewhat heavy ball to the shaft of the variable resistor(potentiometer). When robot goes up the plane, the inclination of the pendulum changes and the shaft of the variable resistor will vary. You connect the output of the variable resistor to ADC to get reading. Instead of pendulum and variable resistor keep a source of light perpendicular to the ground and keep some LDR's in the robot so that the light source moves and the reading of a LDR's will change. Keep some 5 LDR's for good accuracy. The robot will go up and down an inclined plane. So greater the number of LDR's greater will be accuracy. Suppose if you use one LDR and connecting LDR output to ADC and measuring angle is not good because it won't be able to detect whether robot is going up or down in an inclined plane( the readings will remain same for both side. Suppose if we take +20 degree then the LDR reading will be same for -20degree). So it is better to use some LDR's or potentiometer shaft attached with a heavy ball and output of potentiometer to ADC.

BEFORE STARTING

In the following robot making I assume that you are having a robot with two motors, mostly at the back side . You can use 2 tyres at the front or an ideal wheel at the front, which moves all direction. Mostly use a DC geared motor with ratings around 12V,250mA(same for all geared motor),1Kgcm/s,80rpm costs around Rs.120. This must be good for beginner, but better to have a good motor of good torque. You can use a toy car for this purpose, but afterwards for your robots you require geared motors.
LIGHT FOLLOWER ROBOT
The aim of light follower is to follow light. So LDR can be used for good response because we are using visible light. So I assume that you are having a robot having two motors. We start with two LDR sensors assuming that you are applying light from front.

Here I am just showing an overview of the robot. So let's try to make one using LDR, comparator and some transistor or L293D.
Here is a simple block diagram. Here first part is an LDR circuit which senses the light. LDR circuit is having one series resistor with LDR and output taken across LDR. The output of two LDR's is applied to a difference amplifier. Difference amplifier is a subtractor with some amplification. The output of the amplifier is having some gain. This output is applied to a motor driving circuit. The first one is using PNP transistor with its motor in collector. The second one is NPN transistor motor. This complementary transistors are used because the output of the difference amplifier is +ve or -ve. If +ve NPN transistor will become and active and motor connected to the collector of that NPN transistor will work, while the PNP transistor is OFF and motor in collector of motor is OFF. If -ve PNP transistor is saturated and motor connected to collector of PNP will run while that of NPN which is cut off will not run.

This circuit is a closed circuit, but this circuit is not stable because there is no condition exist the motor will stop. You can see that the output of the difference amplifier will be +ve or -ve at any time. Both motors will stop when voltage is in range of +.5v and -.5V. Because in this range both motor will be cut off. But remember the factor of inertia. So when the motor is just to stop due to inertia it moves some distance, this makes a small difference in the LDR reading and this reading will be get amplified and motor will start rotating again.

CIRCUIT 2:

Here is the circuit. But here i am using L293D. Here you can make a good circuit. Here I am using stopping and moving motor. But here i am not using breaking. You can use breaking to stop, but only invert the motor leads. Here the voltage between two LDR's is subtracted and amplified and verified with a reference voltage for sensitivity. Here if sensitive voltage is less motor will stop.
But this circuit is having a disadvantage of multiple power supplies especially 12/-12V. So you can do it without multiple supply. The following circuit avoid the use of multiple power supply. But in this LM324 reference voltage is used for adjusting the better resolution. So now you have understood the different ways of making circuits. Choose the circuit according to your requirement and sensitivity.
HAND DRIER

You have seen in hand driers in good hotels. The aim of the hand drier is to dry your hand after you wash your hand. There are two types of hand driers, one is manually operated through a switch, other is one automatic. Here we are going for automatic one. Hand drier consist of a motor for producing heat air. Hand drier produces dry air when your hand is below a specified height of the hand drier. You can hear the switching sound of the relay when you put your hand under the hand drier. So now you try to make the circuit. The possible configurations are IR LED+photo diode(or photo transistor)+relay+motor and 38KHz modulated IR+TSOP+relay+motor. Using photo diode you can get up to 7cm. I think photo diode is enough for this purpose than going for TSOP.
Here the height of the hand below the drier is decided by the voltage reference. When hand is not there, there is no reflection. So the current through the photo diode is low making the transistor OFF and when you bring hand below, there is reflection which makes relay to switch to drive the motor or any other circuit for producing dry air.

Here a bit of troubleshooting is possible. The LED will glow when the hand will not under the drier.
PARALLEL PORT

There are a number of projects using Parallel port. I will explain about in my new book.

MY EXPERIENCE IN PARALLEL PORT INTERFACING

If you want to join the Yahoo group-parallelport
Download from files
par.pdf
dd.pdf
pforu.pdf
lpt.exe
userport.zip

Install userport.zip according to instruction from pforu.pdf and start reading dd.pdf, par.pdf.

LINE FOLLOWER ROBOT

As the name implies, the aim of the line follower robot is to follow a predefined line. Mostly the line is made of black or white. There will be different curving's like 90 degree curving, some cutting in the line, sometimes the way may be inclined depending on competition.

There are different ways of solving line follower robots. Here I am explaining it with analog circuit. I heard someone done it using Matlab, by inferring the equation of the line and moving the robot according to it.

In that case first robot should remember the line, then next time it will follow the line fastly and perfectly. The main concern of the line follower robot is how fast it is. Here I will talk about white strip and black strip.

Mostly the strip or line will be black and the background is white. So when I am talking about white strip take it as background and black as line. Some events have white trip also.
The basic line follower is one in which consist of two motors. For taking turn we stop one motor and run the other motor. This makes the robot to take a turn. You should keep the sensors with LED to sense dark and white. The sensor and LED should be covered properly to produce sharp sensing. Let's start with LDR which will be good for beginners. Use LED+LDR
combination or IR LED+Photo diode(photo transistor) or 38Khz modulated IR+TSOP1738 to sense white and black strip.

Figures shows a simple circuit diagram. The basic principle is the switching action of power transistor. When LDR is in white, there is reflection from the ground and the resistance of the LDR is very less and Ve >.8V makes the transistor to saturation. When LDR is in dark the LDR resistance become high and Ve<.5(adjust like that) which makes the transistor to cut off and the motor stops. The 10Kpot is adjusted in such a way that transistor will be cut off when it is white strip and cut off when it is in black strip. This circuit is made for both motors.

DISADVANTAGES:
1. Here there is normal stopping occurs with motor. We should require breaking to stop motor abruptly.
2. The motor speed should be limited, because if the speed is higher then robot will cross line due to inertia.
3. There is some time take to stop motor in ‘stopping’ (braking is other).
4. Even though it sensed black, then also it crosses the line due to high speed, therefore speed should be limited.
5. Maximum speed of the robot obtained by the robot using this circuit will be very less. I think maximum up to 20cm/s and that to depend upon the way.

Now let's go for a circuit which uses breaking of motor
Here I used relay. Suppose the above position show when LDR is in white strip (white background), then the motor will get 12V on one terminal and 0V on other terminal. When black comes then the relay loses contact and motor will get 12V on both terminals and breaking action occurs. So the motor will stop abruptly and the speed obtained is somewhat improved compared to other one. The relay get activated when the LDR is in white strip and motor is in default position (in figure). The motor will run on white strip and stop on black strip.

DISADVANTAGES:

1. The switching speed of the relay is very slow about .1 sec
2. Power transistor sometimes creates problem
3. It is very difficult to adjust according to different light situation
4. The job is very boring because we should adjust the pot to make the motor run.
5. The adjustment is done by the following way. First put the sensor on black strip and adjust the potentiometer such that motor will stop. See when you put on white strip motor will run. All these settings should be done when you kept the robot in ground, not on hand or table, i.e., in the arena
6. The adjustment will vary with outside light.
As I told you there will be regions in between saturation and cut off of a power transistor where the current $I_c$ will change. The other thing about the above circuit is that it will be difficult to adjust because we should bring down the voltage to .5V, this is a big task and sometimes won't be practical. Although above circuits worked for me, but troubleshooting them is a headache. So let's go to comparator.

Here it is somewhat good to adjust. You can connect motor directly at the collector instead of using relay. Here i had drawn the reference voltage using two 10Kohm, but you better use a potentiometer (variable resistor). The 10Kpot series with LDR is varied to adjust. Here you can use a 9V or 12V relay. But using 12V relay will sometimes won't work because Vcc won't be exactly or greater than 12V.

The adjustment is done by the following way. First put the sensor on black strip and adjust the potentiometer such that motor will stop. See when you put on white strip motor will run. All these settings should be done when you kept the robot in ground, not on hand or table, i.e, in the arena http://www.roboticsindia.net/modules.php?name=News&file=article&sid=126&mode=&order=0&thold=0
SOME IMPORTANT THINGS ABOUT LINE FOLLOWERS WITH TWO SENSORS

1. The above circuits use switching OFF and ON the motor. This is not a good method because motor is basically an inductor. The time taken for the motor to attain full speed from OFF condition is too much (ie in milliseconds depends on quality of motor). Suppose if we use two sensor for each side and when first sensor goes into black then motor speed will be 50% then the time required for a motor to charge to full speed = time required to charge to 100% speed - time required to charge to 50%. But in the previous robots it is the time required to charge up to 100% speed. But this time is always in 10ms or more for charging up to 100% speed. I don't remember the charging and discharging equation of inductor. Do some calculation and see the difference. So the difference is above 10ms. This is a good time we are wasting.

2. Here we are stopping motor completely for a simple turn, so the time lost will be high. Think of a train going at 100kmph, which had to stop at a station for a 2sec. The time lost in its run will be around 7-10sec, if it had stopped at a station compared to normal running of train. The same case with a robot motor stopped completely. So we should avoid this.

3. There are some switching time with power transistor, relays. The switching time of power transistor around .1ms while that of relay is about 100ms(not accurate, but greater than 10ms). So the time will be lost in the switching time of these components. So it is better not to use relays to drive motors. But if you are using big motors of high rating, then you can use relay because they will move at low speed. But the robots we make are so small, so we should try to avoid using relays in the circuits because of its switching speeds.

4. We require high speed devices. Motor switching speed cannot be controlled very much, because it is basically an inductor and we can do nothing to it except buying a costly motor. So here cost will become high, if you go for good mechanical parts and motors. So let's think of reduced cost and good speeds. Instead of power transistor you can use MOSFET's speed around 100K (switching speed). So it is better to use MOS than power transistor in motor driving circuitry.
5. Figure shows the motion of a normal robot

http://www.geocities.com/laosoh/robots/linefollow.htm. See from the site how the robot moves in different bendings. Here the blue line represents the path in which the robot has moved. You can see for a small bend how much time it switched. So if you use a relay the time lost will be great will come around 2sec(or more) for a normal path. You can see that as the number of bends increases the time for the robot to cover increase. Suppose if the distance the robot has to move is of good length (suppose 5m), then the time lost will be around 10sec(or more). If your arena has only bends and having sharp bends with some cutting, then the time lost will be too much with the above circuits. The time will be number of switching*(s/w of transistor+relay+motor). This will come in minutes if you had to travel a path having irregular bends and of good length.

6. The sensitivity of the LDR is another factor. I got up to 3ms, but that is a rare condition. When come to practical it will go around 10ms or below. So this is another factor. If you use IR with photo diode then you will get good sensitivity.
7. There will be problems with external light. This problem will be too much with the above circuits. IR will provide a better performance to external light, but they also have some effect. You should provide a good source of light with the sensor like LED+LDR, but to get good performance use a source of light with good brightness. If the brightness is good then better will be the sensitivity of the LDR and the adjustment work will be somewhat reduced. I am talking about the light on the robot. You should make the external light effect to be as small as possible. So provide a good source of light on robot itself. When you provide a good source of light, it will increase the weight of the robot and the power consumption of robot and the requirement of the number of batteries.

8. Better keep the LDR+LED combination to be less affected with external light. The way you use will affect the performance of the robot.

9. See something about positioning sensors

Here you can see that robot is going forward to take the turn. This will increase the time for the journey. This should be avoided by putting LDR in the front of the robot. Put sensor in the front, so that normal bending occurs without loosing time. But you should see the effect of external light in that case.
So in order to attain good speed use good motors (motors of good rpm, see the motor he used [http://www.robotroom.com/Jet.html](http://www.robotroom.com/Jet.html)). The second thing is to reduce speed so that the robot will not stop for all bends. If you increase number of sensors then the response will be good because we won't stop the motor for all bends. The above circuit stop the motor for all bends. For small bends we should have to reduce the speed of one motor very less, so that bending will occur fast. If the bend angle increase then the voltage of one motor should remain same, while the other should be decreased so that turning will occur. The greater number of sensor the more accurate it will be. Now let's talk about controlling motors. The two ways are varying the voltage and PWM. For making PWM without any microcontroller is a tough task. We can use 555 for that.

If you are using line follower robot you can apply this as one input and other input ground (or VCC).

If you are using this for other circuits, give this output to enable of L293D, so that we can move in both directions.

Here the sensor output is the comparator outputs. Comparator output should be HIGH (5V) or LOW (0) for proper working, so that transistor switching takes place. If you use LDR, connect a series resistor and give this output to Lm324 with other input as a reference voltage, Vref so that white and black strip are detected.
This is the circuit for one motor. You can connect the output of 555 as one input of H-bridge with other input as ground. But it is better to use other input as Vcc so that breaking will occur fast. I haven't used this circuit because PWM is not fast compared to varying voltage across motor. This is because of the performance of the motor. The motor is an inductor, so there will be time for charging and discharging, if PWM is so fast then the motor won't get enough time to charge and the torque will be get reduced because it is getting enough time to charge to maximum voltage.

Remember in the above circuit

\[
Ra1+Rb1=Ra2+Rb2=Ra3+Rb3=Ra4+Rb4=R \\
T=1.4RC^2
\]

Here the \(T=10\text{ms}\) (the one I used), but depends on motor quality, adjust according to your performance and needs. This is the circuit for one motor only. Here we are using four sensors for each side S1, S2, S3 and S4. If you use power transistor sometimes you need a base resistor (I haven't tested this circuit, but this circuit will work). Better to use a power mosfet mostly used one IRF540. Remember that here I assumed that only one sensor will be at the black strip. Suppose if two sensors are in black strip then \(Ra=Ra1//Ra2=Ra1Ra2/(Ra1+Ra2)\) and \(Rb=Rb1//Rb2\), but \(Ra+Rb\) won't be equal to \(R\). So you should be through with this assumption. You should see all practical possibilities of your track before using this circuit. Thus this circuit uses 8LDR+2 IC555 +L293D as main components.

Next way is to vary the voltage across the motor. This is one which is better than PWM. You can vary voltage using zener diodes and variable voltage regulator, LM317. See LM317 for more explanation. LM317 have a good current driving capability more than 1A which is enough for one motor. The mostly available zener diode have ratings of .5W, 1W etc. Here we use a DC motor of 250mA. So for a zener diode of 1W it can carry about 4V.
The mosfet used is IRF540. Mos have better switching speed. It is used inside L293D. Here DC motor is running at 17V, which is greater than the maximum allowed voltage of DC motor. Higher voltage, greater the speed will be. So when first sensor S1 goes to black strip the voltage across the motor will be 4*3.3V=13.2V. If the sensor4 goes to black then voltage across the motor will be 3.3V. What will happen if we use another mosfet to short between Vin and ground so that both ends will be shorted for the motor and motor will stop. But this case is somewhat dangerous and the resistor, R should have enough power rating to carry that whole current, because whole current flow through the resistor.

1n4728 having Vz=3.3V
You use Vin=17V. It will make the speed of a 12V motor to high speed.
Connect 12V output of SMPS to Vin and -5V of SMPS to gnd
Here you can see that the voltage is varied by using the resistors. The voltage, \( V_{out} = 1.25(1 + \frac{R_2}{R_1}) \). Here \( R_2 \) will become \( R_2 \parallel R_{21} \) if first sensor output will become high. You can remove \( R_2 \) from the circuit. But in that case voltage will become low. When \( R_{21} = 1 \) then the voltage should drop to some 9V. Assume that \( R_2 = 9R_1 \). So when no sensors in black strip \( V_{out} = 12.5 \) and motor will run at the maximum speed. When \( R_{21} = 1 \), ie first sensor is at black then voltage should drop some less say 9V. i.e, \( Req = \frac{R_2}{R_{21}} = \frac{R_2R_{21}}{R_2 + R_{21}} \) is such that \( V_{out} = 1.25(1 + \frac{Req}{R_1}) \).
So adjust the Req so that the desired speed reduction is obtained for each sensor. Suppose you make Vout=9V when first sensor goes out, Vout=6V for second and Vout=4.5 for third one and Vout=2.5 for the last sensor. You first decide the value of R1 and R2 and from that decide the values of R21,R22,R23,R24. If your line follower is still losing the line decide which point it is losing line and which sensor is going to dark line. Adjust Vout for that sensor. You adjust the resistance values such that line follower won't lose the line and it will go with maximum speed. Suppose if two sensors are in dark(such condition normally won't exist), then Req=R2//R21//R22(assume first two sensors are in black). If you have want speed and good braking then add one more sensor with a relay such that good breaking occurs. Suppose if S4 is in black and due to speed or some problems your line follower leave the line, then add one more sensor such that its output is driving a relay and the common of relay is connected to the one end of motor(ground end shown in above diagram) and the other ends are connected to ground and Vcc(12V). The default position of the relay should be ground so that motor should run properly. Suppose the S4(sensor 4) left the black line, then sensor connected with relay enters the black line and it activates the relay and Vcc(12V) will reach the ground end of the motor. At that time the voltage at other end(LM317 output) will be around 2.5V and will become 12V because Sensor 4 left the black line. Thus both ends get 12V and this is (1,1) condition of H-bridge and braking of the motor occurs.
LINE FOLLOWER USING STEPPER MOTORS

You can use a stepper for good accuracy and speed, but the problem with torque. I have seen some students working with steppers in the 'Printer'. But the problem of high power supply. You should use L298 with heat sink and a good power supply. The torque problem is a great headache. So your robot won't be moving so fast as you required even though your logic is good. So if you are going for steppers in line followers you should go for a small stepper and the power supply should be of small battery, stepper of good torque and speed. Then you can win the race. But the cost will increase drastically because we mostly use two 9V battery costing Rs.15 each for most robots, but getting good batteries of low size is a costly affair. The the second thing is the cost of stepper you are using, it will be going above Rs.500.

WHY MICROCONTROLLER IN LINE FOLLOWER ROBOTS?

See this track, there is a number of crossing. There are cuttings in the way and some extra lines are added in the track to mislead the robot. See what happens when you use the above circuits. The analog circuits above cannot take a decision. If they loose the way, they cannot come back to the track. Then the speed will be reduced at the crossing. Analyze the circuit yourself. Sometimes your robot looses the way in crossings and cuttings and no way exist to bring back the robot back to the track. If you want to do this then you had to add extra circuits and complexity of circuit increase with the path. But if you use a microcontroller then this problem will be solved and the requirement of processing circuits also avoided. A
microcontroller circuit can trace back the path which it followed. It can avoid the situation of external light. If we use ADC for the LDR readings then the external light problem will be avoided. External light affect the readings almost equally in all sensors, so it equally in ADC reading. We can subtract the reading to avoid this problem. Suppose if we use 4 sensors on each side. Then from the following circuit diagram you can use PWM to control the H-bridge by connecting PWM output to enable of H-bridge. Then the PWM can be controlled by the following way. If ADC1 readings increase then PWM will be reduced from 100% to 90%. Assuming that ADC1 reading is the front LDR (ldr1). Suppose if ldr1 crosses line then we can detect it and we can reduce pwm to 80%. But in analog case this was not possible. We can determine the instant position of the ldr's and take appropriate decisioning while that is not possible in analog circuits. This make the robot to get a proper movement.

Suppose if we use microcontroller just like a parallel port and the sensor readings are inputted to the microcontroller and LM317 circuit is connected to another port. You can see that there are $2^4$ combinations of voltage are possible with that circuit, but with the analog circuit we are able to use only about 4 voltages. We can use 16 different voltages using a microcontroller. This 16 different voltages are applied to the motor using the ADC readings of the sensor(1-4). Thus we can get voltages from 1.25 to 12V with 1V difference and better control is possible and we can determine the position of sensors, so that we can get a robot with good speed by adjusting voltage with better precision.
**SUN TRACKER**

Sun Tracker is a mechanism which keep Solar Panels always perpendicular to Sun. The maximum radiation is obtained when Solar panel is perpendicular to sunlight, so maximum power. Everyday sun moves from East to West and a lateral shift of 23.5 degree on both sides of normal (i.e., change with seasons like summer and winter). See [http://www.eaas.co.uk/news/seasons.html](http://www.eaas.co.uk/news/seasons.html). So we need two axis tracking. Sun sets at west and our system shuts down automatically when a particular intensity of light is reached (i.e., in night and in rain time). When it sets at west and during morning it had to come back to east i.e., in morning it had to shift 180 degree. Sun Tracker should work perfectly with Sunlight and in darkroom in presence of sodium vapor lamp.
Sun rotates 180 degree in 12 hours time. So we require the movement should be slow in both axis. So first go to mechanical model. This is the first model. The circuit will remain same for both axes. For each axis 4 sensors are used. First about choosing of sensors. LDR is the cheap one and better sensitive to visible light. Photo diode, photo transistor, camera are other options, but they are costly and we don't require that much sensitivity.

**WORKING**

Suppose the following condition,

In this condition light intensity for LDR(4+3) will be greater than that for LDR(1+2). Therefore, voltage across LDR(4+3), V4+3 > Voltage across LDR(1+2), V1+2

We can see in the circuit diagram that voltage across LDR 4 and 3 are added to form V4+3, similarly for V1+2. Now these signals are fed to a differential amplifier whose gain almost 100. This gain is the factor which will depend the efficiency of this system (maximum efficiency implies it will be strictly perpendicular to sun rays), ie with high efficiency even a small inclination can be tracked out. Therefore here, Y4+3 >Y1+2 IMPLIES Yd = A(Y4+3-Y1+2). So in this case Yd will be positive. This positive voltage will drive output of opx to positive saturation and output of opy to negative saturation ie Md = +Vcc to opx. Also Mu = -Vee to opy.
Thereby motor will rotate in such a way that \( gd \) will decrease, and until \( gd < V_{\text{min}} \), motor will rotate. \( V_{\text{min}} \) is the voltage given to inputs of opamp (other than output from differential amplifier). This is done because, due to inertia the mechanism move some more extra distance, This makes the opx to \(-V_{\text{ee}}\) and \( V_{\text{ee}} \) to opy, this process continues just like a damping motion. This is avoided in such a way that a small voltage difference will be set between the sensors. That voltage will decide the preciseness of ckt. Less voltage more precise it will be. The same circuit is provided for the second direction.

When \( P=1 \) and \( Q=0 \) (\( gd>V_{\text{min}}, \ gd >0 \)) then motor will rotate in one direction, \( P=0 \) and \( Q=1 \) (\( gd<0 \)) then motor will rotate in opposite direction. When \( gd<0 \) and \( gd>V_{\text{min}} \) then \( P=Q=0 \) then motor will stop. There is no condition with \( P=Q=1 \) (\( gd>V_{\text{min}} \) and \( gd<0 \)) and this condition won't exist. If \( P=Q=1 \) in the below circuit then short circuit occurs.
2. MOTOR DRIVING CIRCUIT

Here is another driving circuit.

Here is my suntracker
http://www.geocities.com/njbibin/robotics/suntracker.html
This is another good model

Here LDR4 and LDR3 are subtracted and this output is used to drive motor for one axis. LDR1 and LDR2 are subtracted and this output is used to drive motor for other axis. Making mechanical model is one of the tough job. The thread arrangement is not so good. You should use another arrangement. One axis we should motor should carry the motor and other mechanisms for the other axis. So the first axis motor should be of good torque enough to rotate the other axis mechanisms. If you use pulley arrangement for the main axis (the axis at low level) then the probability of slackening is there because of the weight of the motor of the other axis and it should rotate 180 degree. So the force will be there. In all these circuit we should first arrange the sensors readings first to make solar panel perpendicular to sunlight. This is a tedious task. You should require a magnetic compus to align the sun tracker in proper direction, i.e for determining north, south, east and west direction. You can use the comparator circuit with a relay to switch OFF the power supply to the motor and the remaining control circuit when the light intensity if less. This condition exist in night and rain conditions. In that case light will be less, the difference between effective power we receive and we spend on turning the tracker will not be good. Suppose the condition when sun set at west and next day tracker should start from east, then also this circuit work.
IDEAL SUNTRACKER

So think of making an ideal suntracker. The first problem is that when you shift sun tracker from one position to another position, you have to arrange the sun tracker so that it remain perpendicular to light. In the above circuit you should adjust the variable resistor in series with LDR to make sun tracker perpendicular to light. There should be an option for suntracker to align automatically. Think you are having a company of making Sun Trackers. In that case this circuit is a big disadvantage. The other disadvantage is the use of multiple power supplies +/-12V. Mainly the problem of generating -ve voltage. In this case you require two 12V battery to do this. This increases the cost of the circuitary. Third is the power consumption, here we are keeping the tracker is kept ON all the day, but the sun changes a degree in 12/180 hour (assuming the whole day is 12hour). So this situation has to be solved to make an ideal suntracker.

Now let's talk of microcontroller especially atmega32 which contains 8 analog to digital converters which will convert the analog voltage to digital voltage for microcontroller. If you don't know what is a microcontroller then you just think of parallel port of a computer. In that you run a C program to control port. The case is almost same with microcontroller. But you use ADC to convert analog input to digital input. But this ADC in inside this chip. If you use microcontroller then the adder cum subtractor circuit and the reference voltage circuit will come inside the microcontroller. Second thing you can program the microcontroller in such a way that first it will test for the direction of maximum intensity. So you write algorithm so that first it test the direction of maximum intensity first for both the axis and align. The Vmin(sensitivity) is adjusted inside the microcontroller. There is sleep mode in a microcontroller. So you have to start the timer inside the microcontroller and put microcontroller to sleep mode so that after a time of 1 degree change the microcontroller will wake up and the direction is changed. In sleep mode of microcontroller the power consumption of the microcontroller is too low. Therefore the circuit using microcontroller avoid the requirement of manual adjustment to the sun(a very boring task), power consumption low and avoid the usage of multiple power supplies. Power consumption of microcontroller is less than the chips we used. Here is a block diagram. If you don't know about microcontroller see my book MY EXPERIENCE IN PROGRAMMING AVR USING AVRGCC.

So microcontroller is always favored than other analog circuit because of
WHY DIGITAL PREFERED OVER ANALOG IN ROBOTICS

- The main reason is the effect of noise is less in digital. Suppose if you take a TTL (5V) circuit. Logic HIGH v(1) > 2.4V (it is not accurately 5V) and Logic LOW v(0) < .8V. For example in communication, analog voltage 3.4V might be received as 3V or some other voltage not exactly 3.4V, but in case of digital communication Logic HIGH is greater than 2.4V (if you send Logic HIGH it has more probability of receiving Logic HIGH than analog communication).

- Easy for circuit debugging digital circuit than analog circuit, because in analog circuit you mostly require multimeter, mostly CRO. But in digital circuit we require LED and multimeter. So it is easy to do in room itself.

- Easy processing and computation with microcontrollers. More help will be available in internet and more support in forums and yahoo groups.

- When you use digital circuit you should be careful about the power supply you are using, otherwise the IC will get burnt, sometimes due to under voltage or mostly due to over voltage. If you use analog circuit you should not get bothered about the power supply because...
A normal transistor D880 works with Vcc=1.5V to 60V and any voltage between these two are acceptable. But digital circuit there is some limit for LOGIC HIGH and LOGIC LOW.

- Power consumption of digital circuit is less compared to analog.
- The use of multiple power supplies and the circuit making burden can be avoided.

**MAP PLOTTING ROBOT**

The aim of the robot is to plot the map of the way you are going. You can do this in a very simple way. First you can do it without any reading. Just put optical mouse under the robot. Suppose if the robot goes on an inclined plane, then it should plot height also. So first aim is to measure the speed of the robot. If you use a stepper motor, then this will be easy, only thing left is to measure angle which can be measured using a potentiometer. If you have a synchronous motor of a constant speed, then also you can measure the distance moved easily, because synchronous motor moves with constant speed. Angle measurement will remain same for all motors. Now the task is to measure the speed of DC motor. You can measure it by connecting a spike like setup to the shaft of the motor so that it will count the number of spikes on the motor shaft to measure the distance. All spikes will be equidistant. Increase the number of spikes for good accuracy. You see the setup in a wheeled mouse. They use the same technique. Do processing with a computer.

**ABOUT BUYING COMPONENTS**

Better to buy components from metro near your place. Some shops gives components on courier. See the cost of components from this post and compare the prices in your local market.

http://www.roboticsindia.net/modules.php?name=Forums&file=viewtopic&t=73

see the online shops in India. You can get the list from RoboticsIndia see this post if you buy components from outside India

http://www.roboticsindia.net/modules.php?name=Forums&file=viewtopic&t=142
GENERAL TROUBLESHOOTING TIPS

Here I am putting some general troubleshooting tips which I followed and I got from experience. After you connected the circuit, see the main things:

1. See the adapter light, if it is off then some short circuit problem, if light dims then overload problem.
2. If you have noise problem in the power supply connect the filter capacitors.
3. Touch the IC's and heatsinks of the regulators, transistors etc., see whether they are heated.
4. If they are heated switch off the power supply and see the connections of the circuit.
5. If you connected Vcc pin of the IC to ground or vice versa, then IC will get heated and sometimes chips will get burned.
6. If you connected any input to an output pin then also IC will get heated.
7. Measure the power supply voltage using a multimeter to see whether the voltage is above the desired voltage level.
8. If you are seeing the connections first check the part of the breadboard where you connected the IC is working or not.
9. Use multimeter to check the continuity test, to see the connections in the breadboard.
10. Sometimes your IC must not be inserted properly in the breadboard.
11. Check for the loose connections in the breadboard.
12. Don't keep the circuit in the heated condition, because IC's will get burned.
13. Before connecting the IC check whether the IC is working properly by verifying the truth table.
14. See the maximum current ratings of the IC's you use.
15. Be careful about the motor ratings, whether the IC's and transistors you use would be able to drive motor.
16. See the motor is working by connecting it directly to the supply (remember not to exceed the voltage ratings).
17. I connected a PIC16f628 to make a programmer, but the circuit is working (adapter light went OFF). Then I removed all the connections and just connected Vcc and GND of PIC, but still the adapter light remains OFF. From that I can infer that PIC is not good.
Don't connect Vcc of PIC to Gnd of the supply.
18. See whether the IC is inserted properly into breadboard. You can check it by using continuity test between IC and the breadboard pins.
19. Use notch to identify numbering of the leads. First notch is preferred then dot preferred. See the diagram of IC741 to make things clear.
20. Use separate power supply for control circuit and motor.
21. See the input voltage of 7805 >7.5V for normal operation.
22. See the loose connections in soldering.
23. Check the voltage of chips in all conditions and see whether it is working properly.
I am winding up this book hoping this book will help newbies to start with robotics. Most of them face difficulties in troubleshooting circuits properly. Second thing is that a newbie start from basic robots which which are available from Internet and start wasting time on the beginning side. I don't want to waste their time on basic robots. The main time will be required to start with robotics and they won't be able to make good robots because mostly of the robot makers are students are engineering students and their robotic life ends in 4 years. I want you to put your circuits ,designing , some troubleshooting and problems of your robotics in your own website and actively participating in Indian forums. See the robotics competitions in various technical festivals in different colleges in India. Try to solve the robotics problems, then you can do things better.

BIBIN JOHN