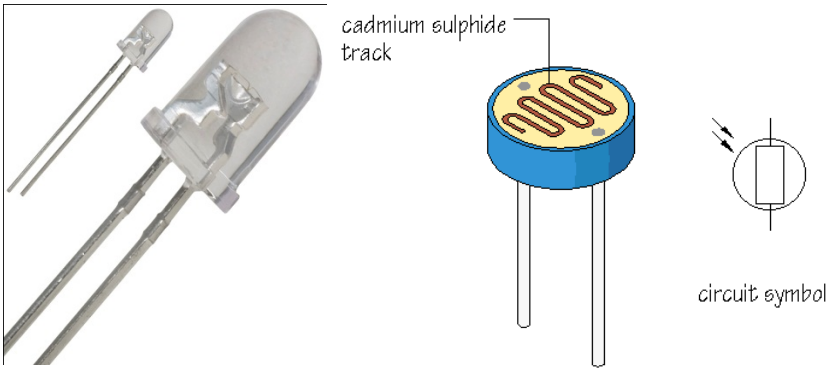
Line Following: A Basic Tutorial

Line following is one of the most popular beginner's choice in hobby robotics, it being both interesting and having vast usage in industry. Line following consists of a machine (or any part of it) that detects a path and follows it till it receives any further information. The path could be a black line on a white surface (or vice-versa), it could be a source of light (lasers) or even a magnetic field (or a magnetisable surface). Here we will be discussing the basic idea behind a line follower and how to go about building one.

The Idea:

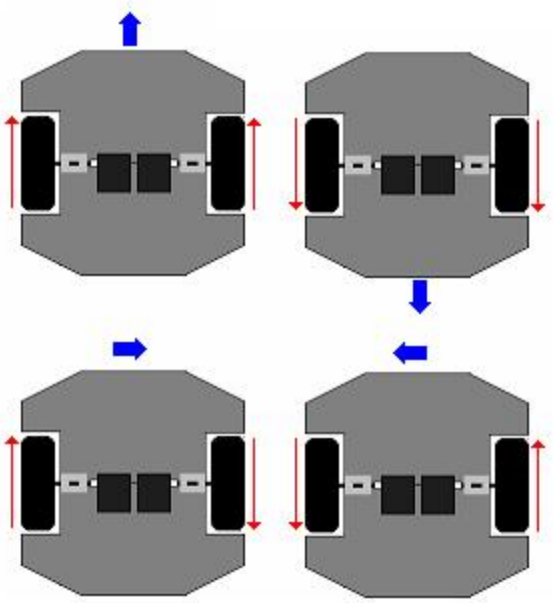
A line follower is basically a robot or a machine that takes external inputs (sensory feeds) and decides whether it is on the path or off it. As a point of approach let us consider that we are trying to follow a certain white line on a black background. How would the bot decide whether it is on the white line? The sensors come into the picture here. For detecting a white line on a black surface the bot must be able to distinguish between the colours. In an electric circuit distinguishing a difference in any field is achieved using difference in voltages. The sensors basically provide this voltage difference.
Here we take the example of a differential drive with a LED-LDR sensor array for line following.

The LED and The LDR



Before we start off into this, what is a differential drive?
A differential drive contains two wheels and two separate DC motors driving them. This allows it perform both translation and rotation using the direction of rotation of the dc motors. For example if the motors are both rotating in the same directions then it translates in a particular direction whereas if they are rotating in opposite directions then it rotates on the spot.

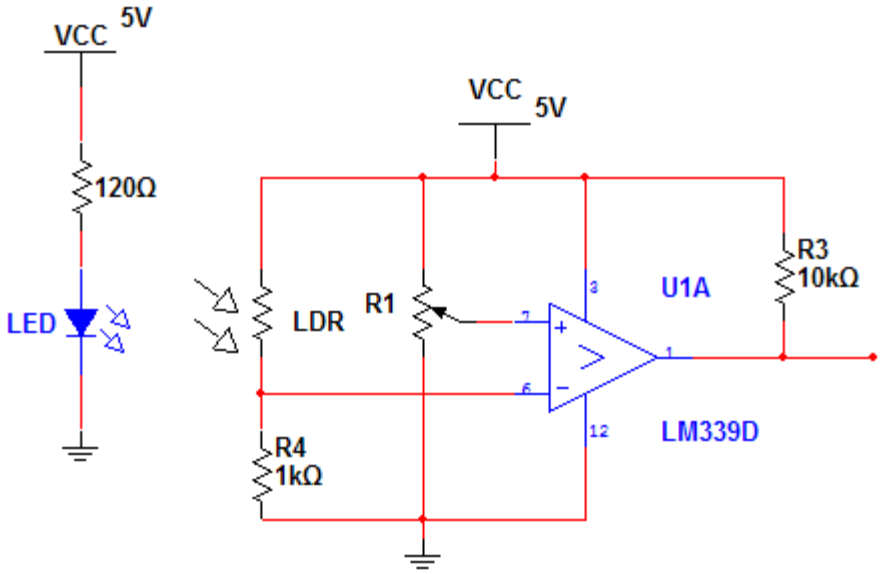
A Differential Drive :



The differential drive is perhaps the most used drive when it comes to the field of robotics.

Now coming back to the line follower, the LED-LDR sensors are used to differentiate between white and black. Two or more such pairs are arranged to form an array which is placed near the surface. The Light Dependent Resistor (LDR), as the name suggests, changes its resistance depending on the intensity of light that is incident on it. Therefore with light (from the LED) reflected from the white surface being more brighter (i.e. more intense) than the light being reflected from the black surface the LDR provides two separate resistances, hence two different voltages, thus separating white from black. Using these two voltages a mean voltage is decided which is used as the “reference” voltage. This is termed as calibration. The reference voltage is used in the comparator circuit which converts these voltages into “highs” and “lows”.

The Comparator



Circuit:

The comparator circuit is a crucial part of the line follower. In the image provided you can see two lines numbered six and seven leading out from the comparator (the triangle). The line seven is connected across a potentiometer which is used to provide the calculated reference voltage, whereas the line six is connected across the LDR. When the voltage on line seven (+ve marked) is higher than the voltage on line six (-ve marked) the comparator gives an output of a "high" (it being the value of the VCC, i.e., the source voltage) and vice-versa. Here we take the outputs "high" as a 1 and "low" as a 0.

These comparator outputs can now be connected directly to a motor driver circuit or used as inputs to a microcontroller which provides further instructions to the bot depending on the program burnt on it.

Now to check whether the bot is on the line we can use a minimum of two such LED-LDR pairs. Here we use five such pairs for precision, their outputs being '1' if a particular pair is on the white line and '0' if it is on the black line. (Note that the width of the line and the separation between sensors also affect the logic behind the following charts)

See the following chart.

SENSOR 1	SENSOR 2	SENSOR 3	SENSOR 4	SENSOR 5
1	1	0	0	0

The chart shows us that the bot is right now lying on the right side of the white line and thus it should take a turn left to centre back on the line.

SENSOR 1	SENSOR 2	SENSOR 3	SENSOR 4	SENSOR 5

0	1	1	0	0

This chart shows us that the bot is near-centred on the white line and thus it should move forward. Other cases of turning right are also solved similarly.
Finally, a unique case:

SENSOR 1	SENSOR 2	SENSOR 3	SENSOR 4	SENSOR 5
0	0	0	0	0

1. What should the bot do in such a case? This problem can be solved in many ways. If the microcontroller used has stored its previous bits ,for example in case one it knows that previously the bot lay on the right side of the line so it must turn towards the left till it encounters the line again. Or the program could have a solution by just rotating on the spot till the sensors detect the line again.