Design and use of a light-seeking robot

By Alex P. Martinez

Description of the robot:

The robot is based on the Herbie circuit, designed on the principles of BEAM robotics. More information on the circuit can be found on: http://www.tombot.net/beam/robotcircuits.html, under the heading 'Herbie robot circuits and other related circuits'
More information on BEAM robotics can be found on:
http://www.solarbotics.net/

The circuit works by having an op-amp compare two voltages (by connecting it in a certain way; op-amps can do a lot of different things) and if the difference between them is positive or negative, a voltage is given to either one of the motors. In other words, it works as a comparator. More information is given at:
http://en.wikipedia.org/wiki/Comparator
Its information sheet can be found at:
http://www.national.com/mpf/LM/LM386.html

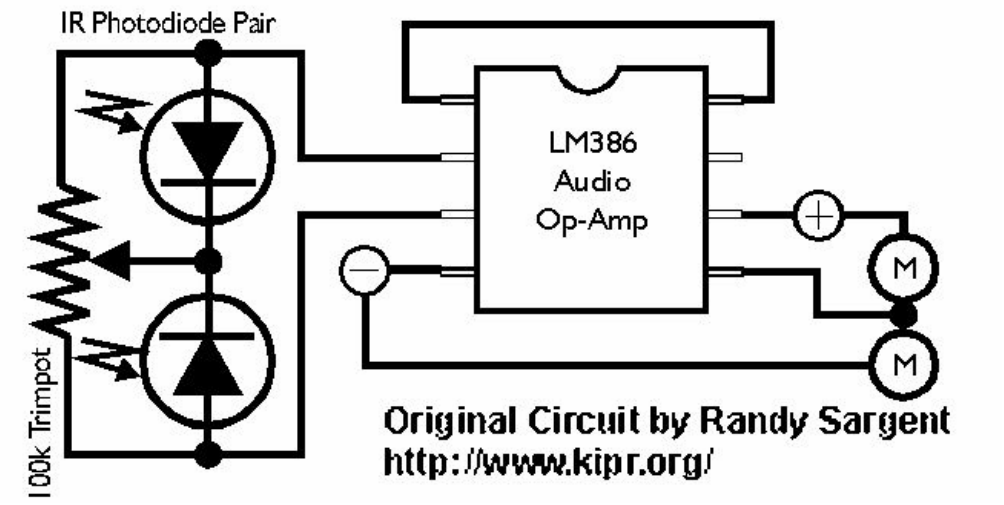

Fig 1: Original Herbie circuit

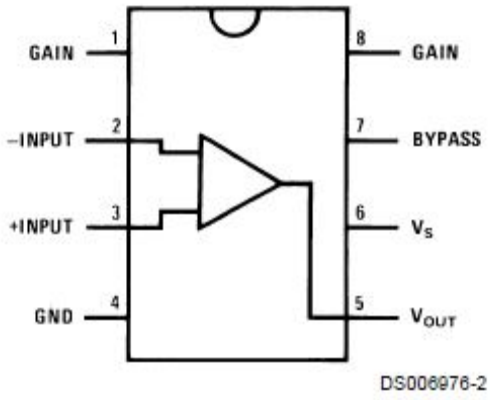

Fig 2: Connection diagram from op-amp information sheet

Fig 1 shows the original Herbie circuit. Besides using voltage dividers connected to inputs 2 and 3 instead of the original circuit shown, the cable connected from gain 1 to 8 is not used. Based on the op-amp information sheet, this cable is used to increase the gain of the op-amp (which means the robot will react more sharply to light changes), but in practice the difference of the robot's behavior is not very large.

The op-amp serves 3 purposes:

- To compare the voltages
- To provide more current than possible with the voltage divider circuit described below
- To 'shield' the op-amp and motors part of the circuit from the voltage dividers: the voltage and currents in the motors do not change the voltage on the input to the op-amp, only the opposite happens unlike other circuits that don't use op-amps

In the 'classic' implementation of the Herbie circuit, the robot only moves towards the light. It is not entirely clear in the diagram given in http://www.tombot.net/beam/robotcircuits.html (Fig 1) how the components for the voltage dividers are connected to produce the desired behavior. This part of the diagram was modified to a more conventional setup with one CDS photocell and a resistor for one voltage divider and one CDS photocell and a variable resistor for the other voltage divider. More information on voltage dividers can be found at: http://en.wikipedia.org/wiki/Voltage_divider. A variable

resistor is used for the following reason: the final voltages given by the voltage dividers will be different even if the robot is pointing straight towards a light source. This is because even if the rating of the electronic components it's the same, they are still slightly different. Also a double pole, double throw or DPDT switch was added between the voltage dividers and the op-amp. This causes the robot to either move towards the light or away from the light. More information about this switch and how it can be wired to make a reversing switch is given at:
http://www.kpsec.freeuk.com/components/switch.htm

This addition was made to make the robot have more behaviors and for more interesting group behaviors as described below. To make sure the robot has the appropriate behaviors it should be calibrated. This is done by switching the DPDT switch to the light following behavior and pointing the robot towards a small but bright light source in a dark room. In this situation the robot will have one motor spinning. Then the screw of the variable resistor should be turned either clockwise or counterclockwise until the other motor starts spinning. To test it, tilt the robot and check that the right motor turns on. Otherwise change the motor polarities by switching the wiring of the motor.

To allow the robots to interact with each other, a white LED was added to the robots. Two switches are being used: one for the LED and the other one for the modified Herbie circuit. The source power for both is a 9V battery. More information about LEDs and how to use them with different batteries is given at:
http://www.kpsec.freeuk.com/components/led.htm

For the LEDs to radiate light away from the robot in the plane of the robots motion, a cardboard cone with aluminum tape was used. The cone was attached with a thick metal solid cable so that it can be adjusted to be above the LED to radiate light in the right direction. This is important since the robot should sense the light from other robots as far a possible. The final circuit is shown in Fig 3 below.

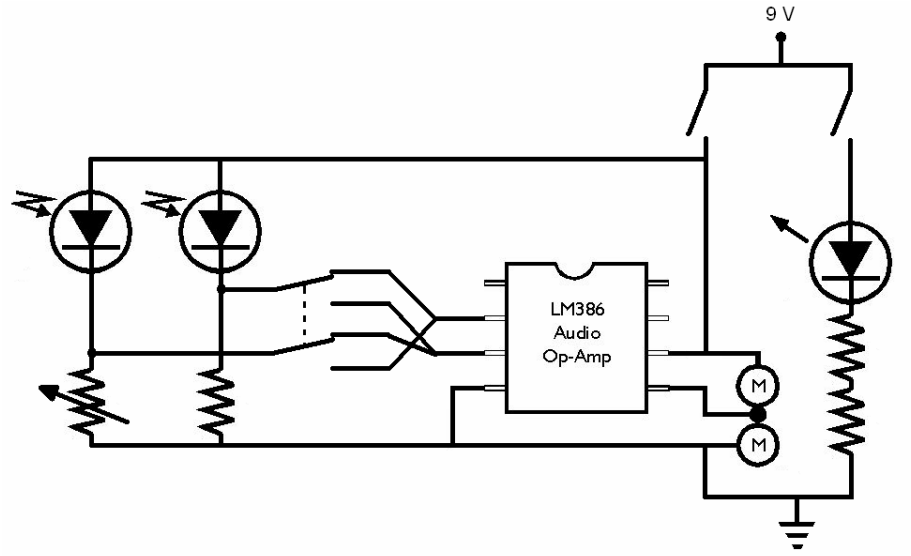

Fig 3: modified Herbie circuit with DPDT switch.

The robots in theory could distinguish between 2 different light sources with different frequencies (colors) but there is always an overlap in the ‘response curves’ for sensors that work close to the visible range (the cheapest ones). Another way to allow the robots to sense ‘different’ kinds of light is to polarize the light. This is done with a special film (polarizing film) also used in sunglasses that allows light with a certain polarization to pass though this is measured as an angle measured in the plane of the film. If two films are arranged 90 degrees to each other they will filter all the light. This can be used to control 2 different robots with 2 light sources with a polarization difference of 90 degrees. This solves the problem given by the response overlap discussed above. More information is given at: http://en.wikipedia.org/wiki/Polarization_(waves)

What the robot can do:

- Single behavior: a robot will move towards or away from a light source depending on the DPDT switch. Notice that in this case the LED circuit is not needed.
- Group behavior: the robots can be made to attract each other by turning all their switches on and the DPDT switch in the right direction. This behavior is entertaining to watch but does not have any real applications. But if they are made to repel each other, the robots can be placed in an area bounded by aluminum tape. This causes the robots to repel each other and the boundary, causing them to ‘fill’ the area. This behavior is wanted in some actual robots to separate the robots at a uniform distance to take measurements for example. This is better than explicitly programming the robots to be at a certain location since that depends on the specific boundary being used. This is similar to how molecules in a gas expand to fill the whole container they are in. Also the robots can be made to leave the area by opening the boundary.
- Robot game: the polarizing film explained above can be used to control 2 different robots using LEDs around a boundary. The robots can be moved in this area to move a ping pong ball to different parts of this area in a game similar to soccer.

Where to obtain materials to make the robot:

- Home depot; for saws and other building tools
- Rona; has longer operating hours than the Home depot and sells the small wooden sticks used in this and the other projects. Good for obtaining the building materials.
- SAYAL electronics: sells the needed electronics for the lowest price. But some parts are not available there. Company site: http://www.sayal.com/
- Creatron Inc: good for finding hard to find components like the small geared motors and the matching wheels. But the prices are really high. Other places can be found, possibly online, that sell the motors and matching wheels. Do not accept any advice from the store owner on a project if it's not going to save you money. Store site: http://www.creatroninc.com/
- Efston science: good store for finding had to find science related materials like polarizing film. Store site: http://www.escience.ca/

Materials for one light-seeking robot				
Common name	Name	Specs	Quantity	Source
Switch	SPST slide switch	Should be small (~1cm) And should fit on breadboard 0.2A, 30VDC (approx.)	2	Creatron
Resistor	Resistor	300 ohms	2	Sayal
LED	LED	White, cheap (not narrow beam) 3.2V, 20mA (approx.)	1	Creatron
Amplifier	Audio Op-amp	Type LM386 or LM386N	1	Sayal
Double switch	DPDT switch	The switch should fit on the breadboard	1	Creatron (from lab-easy.com)
Variable resistor	Variable resistor	10K ohms (approx.) Ceramic, high precision, 0.5W	1	Creatron
Resistor	Resistor	5K ohms (approx. half of above)	1	Sayal
Photoresistor	CDS photoresistor	Dark > 20M Light < 300 ohm (approx.)	2	Creatron
Motor	Small geared motor	3.7-4.8VDC, 40RPM, 207mA (approx.)	2	Creatron
Wheel	Wheel	Wheel should fit motor	2	Creatron
Miscellaneous	Wood stick, tie wraps, cardboard aluminum tape, solid wire	N/A	1 of each (except tie wraps; 4 needed)	Rona