STEMSEL Intermediate Project 9: GPS and Navigation

Problem

We want to make a circuit that acts like a cricket. It should chirp to let its friends know where it is, but if it senses danger then it will stop chirping to make itself harder to find.

Background

People have always needed to be able to find their way around in order to find food and water, meet others, or even just go to the shops. Throughout history, people have used many methods and devices to find their way, like maps and compasses, and navigating by the stars and sun. Nowadays, the most convenient and accurate method is GPS, which stands for global positioning system. GPS is made possible by a group of 30 satellites mmaintained by the US government that orbit the Earth and are able to send precise data back to your tranceiver. To see a representation of this, click the following link:
http://upload.wikimedia.org/wikipedia/commons/9/9c/ConstellationGPS.gif

The way GPS works is that each GPS satellite knows exactly where it is, and continuously sends out a signal. Your tranceiver receives that signal and by working out how long it took the signal to travel from the satellite to you, it can work out how far away you are from that satellite. By doing this with 4 or more satellites, it is possible to find your exact position. This is then displayed on a map so that you can see exactly where you are.

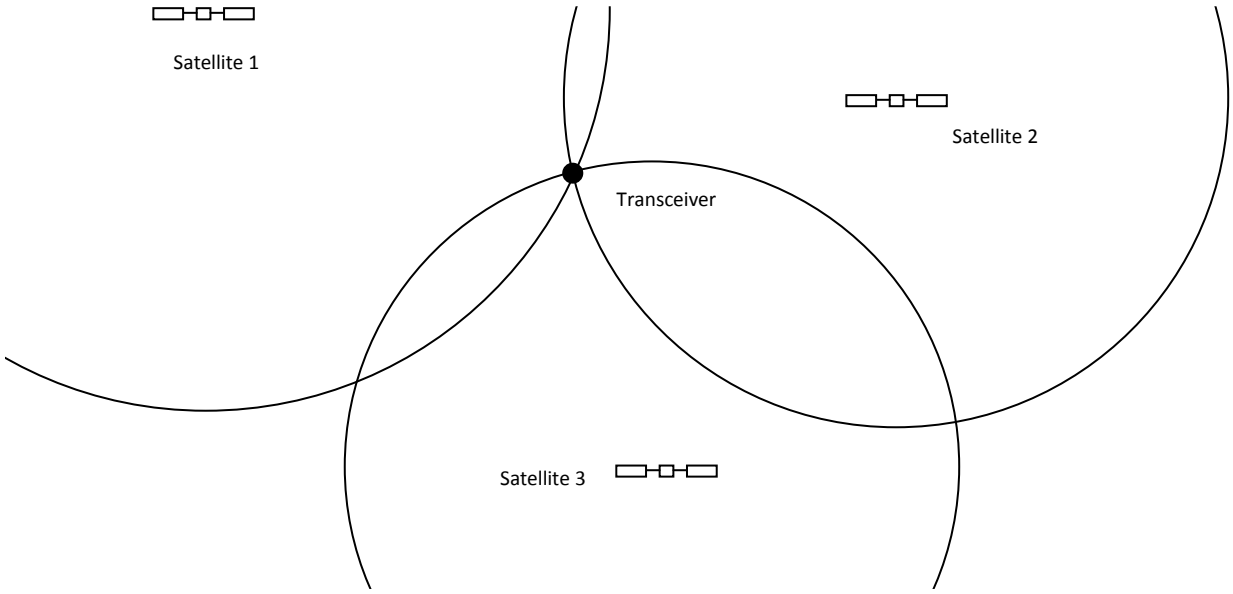

Figure 1: Using data from just one satellite, the tranceiver could be anywhere on a circle. Even with two circles, there are two points where the tranceiver might be, since the circles meet at two points. However, the three circles can only meet at one single point, so this must be where the tranceiver is. For real GPS, a fourth satellite is needed to display how high above sea level the tranceiver is.

Figure 1

Because the signals from the satellites travel at the speed of light, it is very important that the clocks used to measure the signals' travel time are very accurate. An error of just 1 microsecond (0.000001 seconds) will mean that your position will be wrong by 300 metres! It is also important that the maps are accurate and provide correct information about street and building layouts so that it shows your location accurately.

Animals also need to be able to find their way around, especially animals that migrate long distances. Some birds, like homing pigeons, actually have magnetic sections in their brains that work like a compass to help them know which direction to fly in. Other animals like fireflies use light to tell others where they are, so that they can find their way to each other. Many animals use sound, like bats that use sound to 'see' in the dark, and whales that can communicate from hundreds of kilometers away. Frogs, cicadas and crickets also use sound to tell others where they are. However, there is a problem with this, because it also tells predators where the cricket is. For this reason, if a cricket senses danger it will stop chirping until the danger has passed.

The aim of this project is to make an electronic cricket that will chirp to let others know its location, but will stop if it senses danger so that it can't be found by its enemies.

Ideas

What does our cricket need to make sounds and detect predators? How can our cricket use its senses to know if there is a predator? Will a threshold value be sensitive enough, or will we need to use the sensor in another way? What should the cricket do if it senses danger? How long should the cricket wait until it starts chirping again?

Plan

We will use the buzzer to let our cricket chirp, and LDRs so that it can see predators.

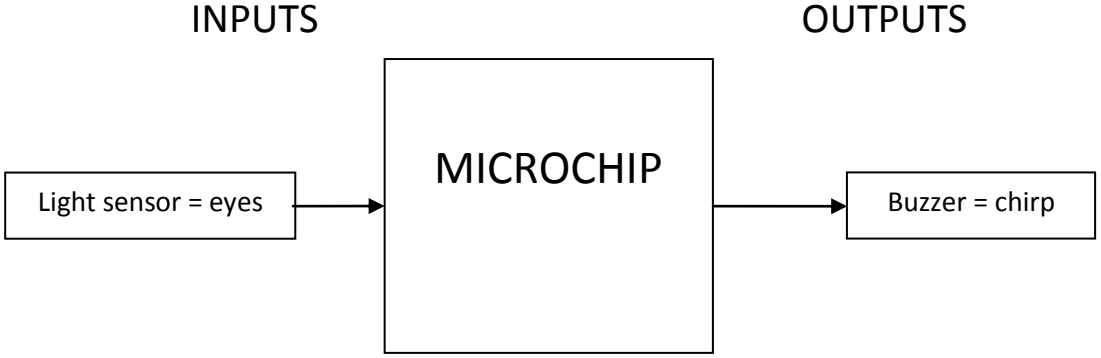

Figure 2: circuit plan

A preset threshold like we have used in other projects may not be accurate enough for the cricket to detect all danger. For example, a shadow causing the light level to fall or a torch being shone on the cricket would both be indications of danger, buts these cannot both be handled by one threshold. Instead, the cricket should compare each light reading with the previous one and if there is a significant change, it will know that there is danger nearby. If the cricket senses danger, it should stop chirping, and only start again if there is no sign of danger for 5 seconds.

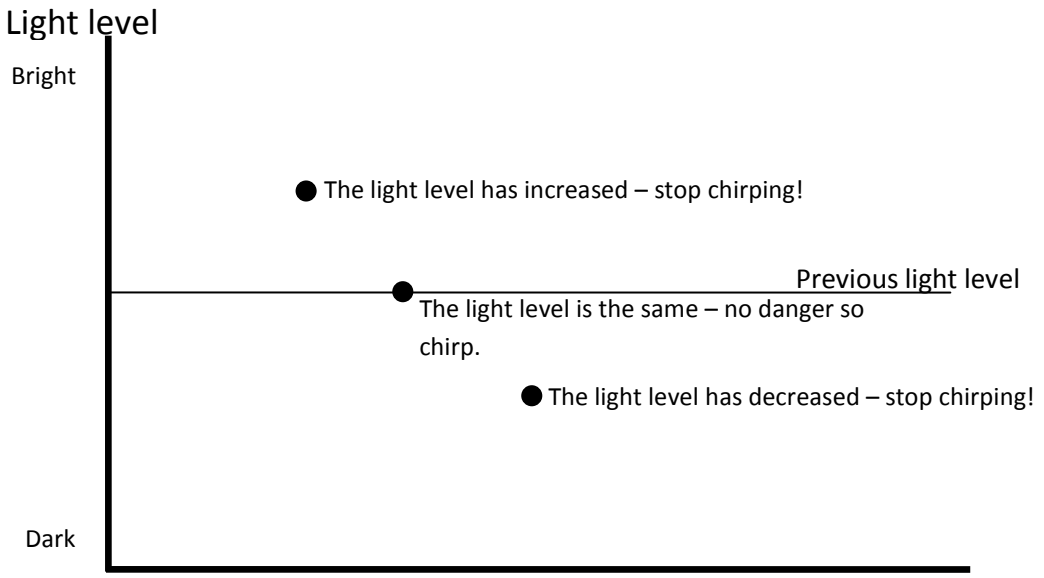

Figure 3: Light level graph

Design

Open ezCircuit designer and start a new STEMSEL project. According to the plan, our cricket needs a buzzer so it can chirp, and a LDR so it can sense danger.

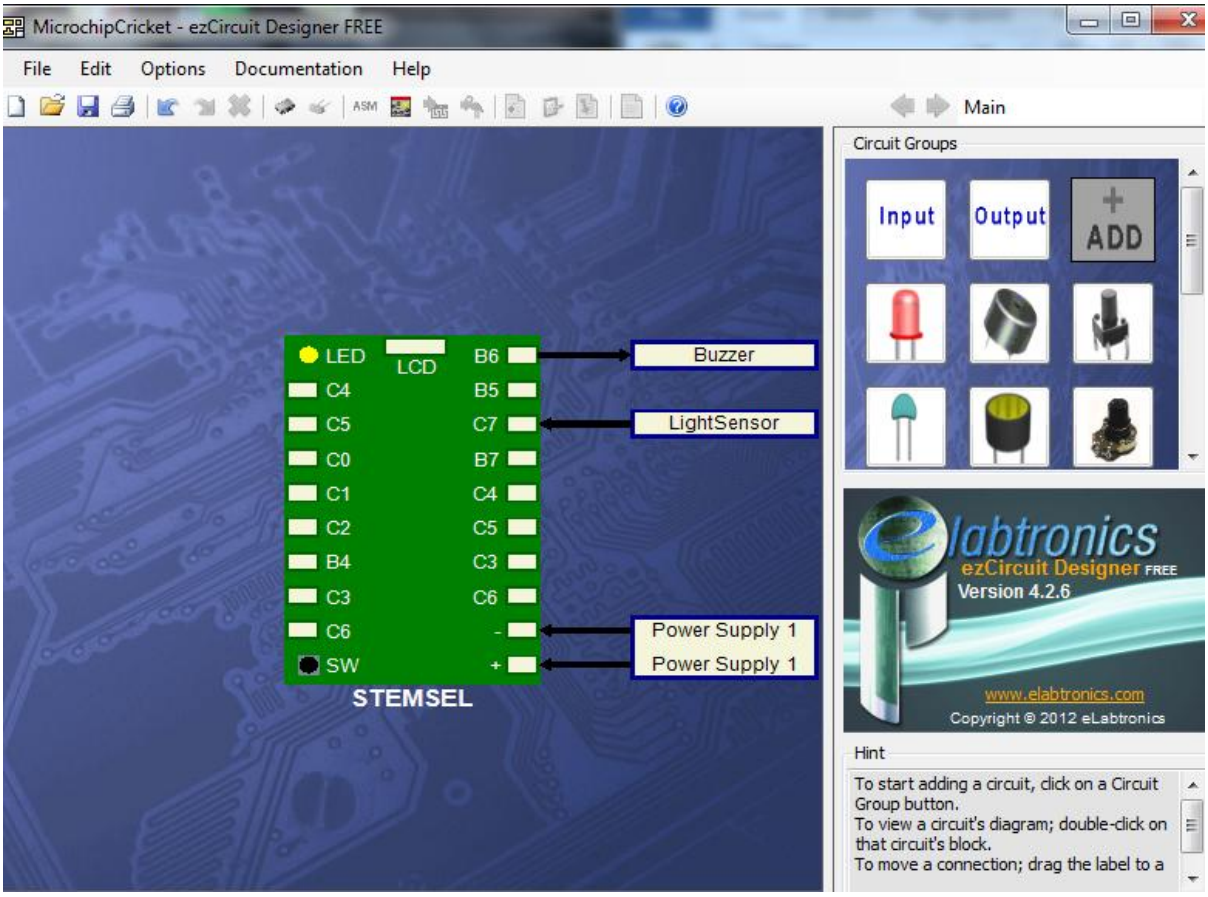

Figure 4: Circuit design

Build the circuit

Next, assemble the project, ensuring all the black wires are in the negative terminal, the red wire is in the positive terminal, and the white wires are in B6 for the buzzer and C7 for the LDR.

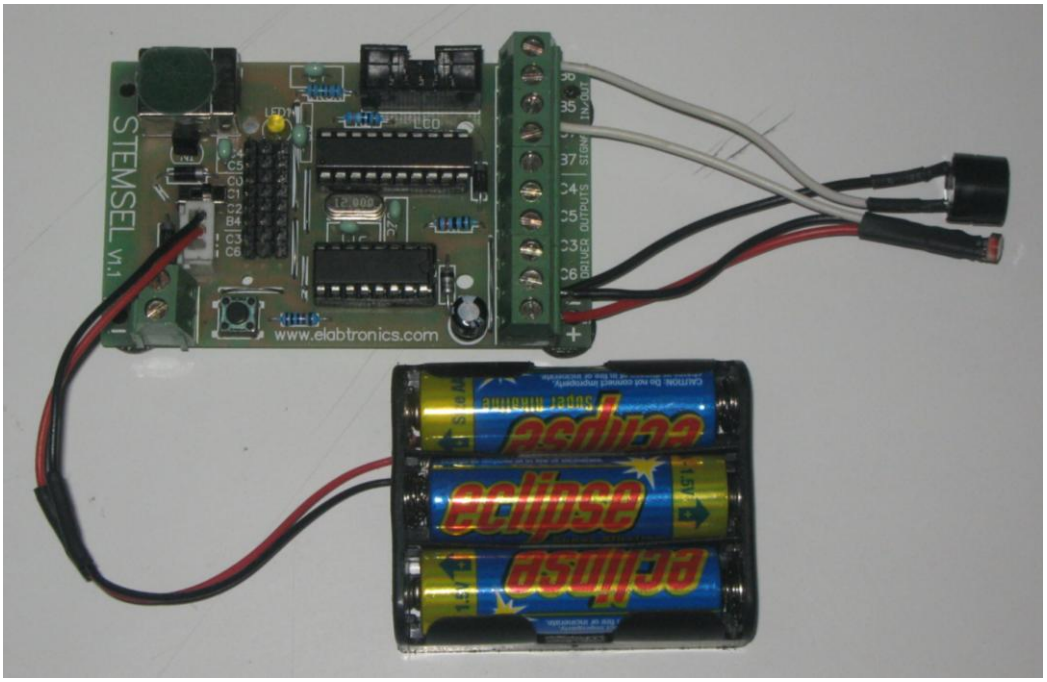

Figure 4: circuit

Programming

Once you have assembled the circuit, send the design to Corechart and run the buzzer test routine. Once you have verified that it is working correctly, delete the test routine so we can start writing our program.

1. According to the plan, the cricket first needs to check if there is any danger. Add an AnalogIn icon to check the initial light level, by saving the LightSensor value as LightVolts.

2. The program will need to loop back to continually check for danger, so add an address called CheckLoop.

3. Now add a short time delay of a quarter of a second, or 25 hundredths of a second.

4. If the light level goes either up or down, it may be an indication of danger like a moving shadow or a torch. Since the light level will never be exactly the same, we will set a small range and check if the light level is within that range. First, set the upper threshold by clicking the **Numbers** button and choosing **Add** from the icon properties list.

5. Double click the new Add icon, and use it to add 10 to LightVolts, and save the result as UpperLimit.

6. Now select Subtract from the **Numbers** menu, use it to subtract 10 from LightVolts, and save the result as LowerLimit.

7. We need to check if the light level has changed since last time, so add another AnalogIn icon and read the value from the LightSensor again, saving it using the same LightVolts variable from before.

8. We will now compare this new reading with our upper and lower thresholds. Add a CompareBetween icon to the program, which can be found by clicking **Numbers.**

9. Open the CompareBetween icon, and use it to compare LightVolts using LowerLimit and UpperLimit in the correct boxes. Finally, tick both the between and Not Between checkboxes, then click OK.

10. If the light level is between our thresholds, it means the cricket can't detect any danger and it is safe to chirp. Use OnOffPin and TimeDelay icons to turn the buzzer on for half a second (50 hundredths) and off for 1 second. Group the four resulting icons together into a subroutine named **Chirp**.

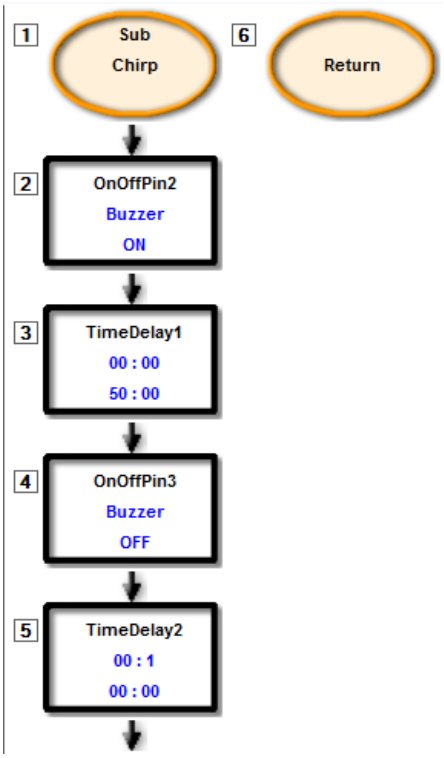

Figure 5: The Chirp group

11. If the light level is not between the thresholds then danger is close! The cricket should wait for 5 seconds, and then see if the danger has passed. Add a TimeDelay of 5 seconds.

12. Finally, put a GOTO icon at the end of the program, making sure it is going back to the CheckLoop address we added earlier. The finished program should look like this:

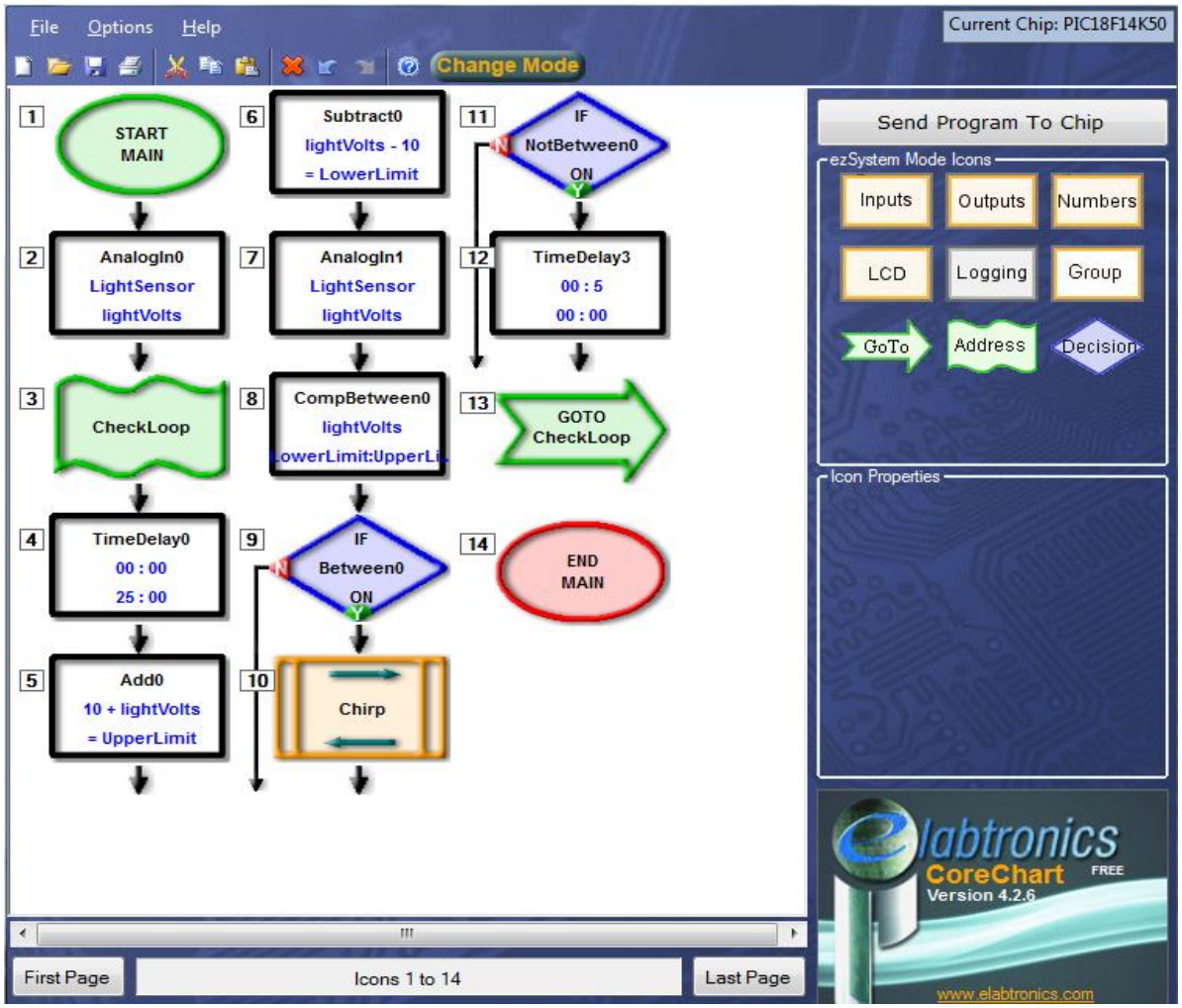

Figure 6: The completed program

13. When you turn it on, the cricket should start chirping. If you cover the light sensor, it will detect the change and stop chirping, only starting again once the light level stays the same for 5 seconds.

Activity

Ask students to hand in their crickets then hide the crickets around the room. The students should then be asked to find the crickets, and the student that finds the most wins. If there are only a small number of students, it may be better to ask one student to hide their cricket then have another student try to find it.

Summary

It has always been necessary for people to be able to navigate, so they have invented many devices to help them find their way. GPS is a very useful tool for helping people find where they are and where they need to go, and works by using satellites in orbit around Earth to accurately locate where you are. Animals also use many different methods to tell others where they are, but may need to stop if they sense danger like a predator. Our electronic cricket uses sound to tell others where it is, but if there is a change in the light level indicating danger then the cricket will stop chirping until the light level stays the same for 5 seconds.