A Kit A Month: parcel 2

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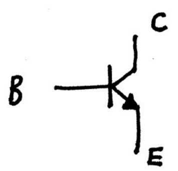
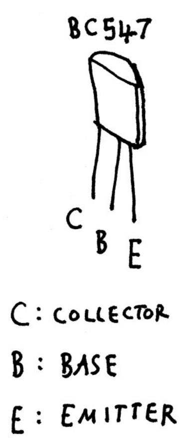
Welcome to parcel 2! Please remember that there won't be a parcel next month and we'll pick-up again in July… that's why you've got the bonus pack this month to keep you busy (either an add-on board for the Raspberry Pi or a pack of assorted LEDs depending on what you opted for).

Our main kit this month is the 'two transistor astable' which you can find out about on the enclosed instruction sheet. The experimenter's pack this time includes some stripboard and the components to make a transistor-based circuit that can be used to test the moisture level of the soil in a plant pot so you know if it needs watering or not.



What is a transistor, then? Well, a Google search will bring up lots of results that you can read but it's a three-legged device that allows a small electrical current to control a larger current. We are going to use an 'NPN' transistor which has the circuit symbol shown above. The particular variety we are using is a BC547 which comes in a small plastic case (left) and has a 'D' shape when viewed from the top.

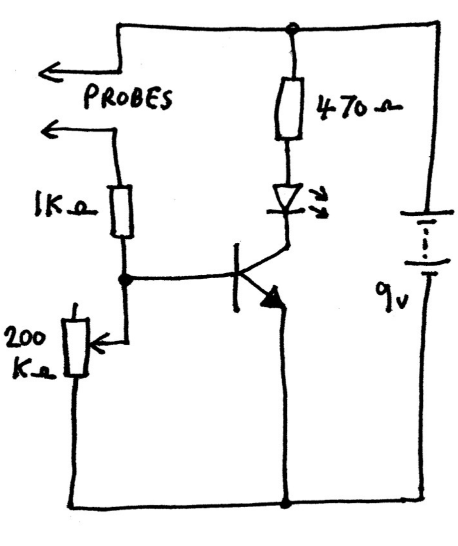


When a small electrical current flows into the transistor's *base* (and out of the *emitter*), it allows a larger current to flow into the *collector* (and, again, out of the *emitter*). The amount of base current determines the amount of current that can flow into the collector: this is why transistors can be used to build amplifiers. In a digital circuit, a transistor is used more like a 'switch' where a small base current is used to turn the larger collector current fully *on* or fully *off*.

In our main kit this month, we have a pair of transistors that are acting as switches and we meet another new component: the *capacitor*. It's a bit of a tricky circuit to understand at first but, essentially, only one transistor is *on* at any one time and one capacitor charges-up whilst the other <u>dis</u>charges. When the voltage on the capacitor that is charging reaches a certain level, the transistors switch state (from *on* to *off* or vice-versa) and this first capacitor now <u>dis</u>charges whilst the second one charges. You don't need to understand how it works to enjoy building the kit but, if you search online for something like '*transistor astable LED flasher*' then you'll find several good explanations.

Easier to understand is the transistor circuit used for the moisture detector. Imagine you pushed two sturdy wires into the soil of a plant pot a centimetre or so apart. Would you expect any electrical current to flow between them (through the soil)? Well, not really: there'd be a small current flowing, but not much. Certainly not enough to light-up an LED. What if you watered the soil? You'd get *more* current flowing, but still not enough to light the LED.

This is a good example of where a transistor is useful: we can use the small current that flows through the wet soil to turn-on the transistor and allow a larger current to flow through the LED.

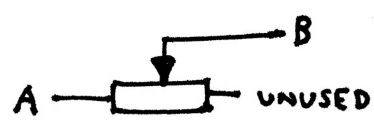


Have a look at the circuit diagram shown here and see if you can see how it works. Hopefully you can recognise the LED and resistor symbols from last month. Those two arrows on the left symbolise the two pieces of wire that you would push into the soil…. I suppose we could have drawn a resistor symbol instead which represented the soil itself: you can think of the soil as a resistor which has a high resistance when it's dry and a lower resistance when it's wet. (The 1KΩ resistor is just so that there is never less than 1KΩ of resistance even if you accidentally touch the two probes together).

You might be wondering why there is a slightly odd-looking 200KΩ resistor in the bottom-left of the circuit. This 'variable resistor', in combination with the resistance of the soil (plus the 1KΩ resistor), forms a circuit known as a 'potential divider'. This lets us choose the moisture level at which the LED lights up (different plants might like a different level of sogginess of soil). The transistor only turns on at a particular voltage and the potential divider lets us turn on the transistor when the soil has reached a particular resistance which we can adjust by altering the 200KΩ variable resistor with a screwdriver.

My preferred symbol for a variable resistor looks like this:

But, because they actually come with three legs (of which we need only two), I've drawn it like this:



That's a bit of a whistle-stop tour of transistors, but hopefully it's enough to encourage you to go on and read some more! Enjoy the kits and I'll see you again in July.

Building a circuit on stripboard

The circuit boards that you have been using so far are called 'printed' circuit boards and you may have been able to see the copper tracks that carry the electrical current on these boards. Now we are going to use a different technique to build a circuit and it's going to be a little tricky so take your time and don't be too disheartened if it doesn't work first time (or at all!).

We are going to use 'stripboard' to build a simple 'moisture tester'. This is a classic hobbyist circuit and it involves pushing two wires into the soil of a plant pot. If the soil is damp then a small current flows between these two wires and, as the soil dries out, the resistance of the soil increases and less current flows through it. Our circuit lights an LED depending on whether the resistance of the soil is above or below a certain threshold (determined by a variable resistor which can be adjusted with a screwdriver).

Because the current flowing through the soil is not sufficient to illuminate an LED, our circuit uses a transistor which allows a small current to control a larger current. In this way, the small current that flows through the soil can be used to turn on/off the larger current than flows through an LED.

OK, so much for the circuit. What is this 'stripboard' stuff? Well, you may have made circuits in the past using something called a 'solderless breadboard', especially if you've experimented with attaching LEDs to a Raspberry Pi (most of the online tutorials recommend using a solderless breadboard, it seems). These are good for prototyping circuits but if you want to make your circuit permanent then stripboard is a good way to do it: like a breadboard it has a grid of holes and a number of strips [or 'tracks'] of copper that you can solder components to.

Sometimes, however, it is necessary to break one of the strips into two or more lengths: you can do this with a craft knife, but it's easier to use a 'track cutter' which is basically a drill bit in a handle: you'll find an economy version in your pack (OK, so it's just a 3.5mm drill bit with a length of aquarium tubing for a handle, but it works!). When you insert the track cutter tip into one of the holes and twist it, the track should be severed in two (obviously you should do this on the copper side of the board). You might be left with a few burrs of copper where you broke the track so use your sandpaper to rub them away. In fact, it's a good idea to gently rub the whole of the copper side before soldering so that it's left shiny.

At this point, I'd suggest you look at the video on my website which might be easier than following these instructions! Here are some brief written instructions, but the diagram is your main source of help: check and double-check that you are inserting the component wires into the very same holes as shown on the diagram!

1) Look at the diagram below which is viewed from the top i.e. the side <u>without</u> the copper tracks. Note the large hole on the right hand side.
2) Firstly break the copper track where the X is shown. This is the middle hole of the third row up from the bottom (but, depending on how you flip the board over, it could be the third whole from the top when you are looking at the copper side).
3) Use sandpaper to gently rub over the copper tracks and make them shiny, ensuring any burrs are removed.
4) Flip the board back over and solder the 470Ω resistor *(yellow, violet, brown)* in place as shown. Then solder the 1KΩ resistor *(brown, black, red)*.
5) Solder the red LED taking care that the long wire goes in the correct hole.
6) Solder the variable resistor as shown.
7) When soldering the transistor, you will need to push the middle leg back a bit. As you push the transistor into the board, don't push it down too far: there should be 5-10mm of leg showing above the board.
8) Solder the battery connector's red and black wires by pushing them up through the large hole from behind and then soldering the red wire to the top track and black wire to the bottom track as shown.
9) There's a piece of wire in your pack to make the moisture probes. Cut this in half to make two wires and then strip approx. 1cm of wire from one end of each wire. Solder these stripped ends to the points shown on the diagram below and then push the remainder of the wire through the big hole.
10) Trim the wires of all of the components if you haven't done so already.
11) Check that there are no small splashes of solder joining any two tracks together.
12) Strip approx. 2cm from the loose end of each moisture probe.

You can now test your circuit! Connect a battery and touch the stripped end of both probes with you finger. Now lick your finger and try again. In one case the LED should be on and in the other it should be off… you can set the moisture threshold/trigger level by turning the variable resistor with a screwdriver.

You may find the sensitivity of this adjustment to be too great in which case you can use the pair of 100KΩ resistors* (or 82KΩ depending on your pack) to adjust this. See the website video for details but, essentially, you can solder one or two of them (mounted vertically/end-on) across the bottom two tracks in the position shown by the rectangles on the diagram.

* 100KΩ: *brown, black, yellow*
82KΩ: *grey, yellow, red*

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View from the top (non-copper) side of the stripboard:

n.b. feed the moisture probe wires and the red/black battery wires through the large hole.