Power sprouts

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Abstract

This paper explains how a large number of sprouts were used as a battery of cells and connected together to power a set of LED Christmas lights. All relevant calculations to find the number of sprouts needed, their arrangement in series and parallel, the charge stored on the required capacitor and the capacitor charging time are illustrated.

Most of us, at some point, will have made a potato or lemon battery using zinc and copper electrodes and perhaps even used it to power a very low current device such as an LCD clock. Last Christmas at school we wondered whether a seasonal favourite vegetable—the Brussels sprout—could be used in a similar way to power a set of LED Christmas lights.

Copper and zinc nails were inserted into a single sprout as electrodes and gave a potential difference of around 0.7 V and a current of 20–30 μA (see figure 1). Our target was to power a set of LED Christmas lights, which required 8–12 V and 400 mA.

When a current flows in the circuit, zinc atoms on the surface of the zinc nail are dissolved into the electrolyte (the slightly acidic moisture in the sprout) as Zn^{2+} ions, leaving two electrons behind on the zinc nail (i.e. the oxidation reaction $Zn \rightarrow Zn^{2+} + 2e^-$, which has an electrode potential of -0.76 V). These electrons flow through the wires connecting the nails and at the copper nail two hydrogen ions from the slight acidity of the electrolyte combine with the two electrons to form a hydrogen molecule (i.e. the reduction reaction $2H^+ + 2e^- \rightarrow H_2$, which has an electrode potential of 0 V).

To achieve 12 V it was calculated that approximately $12/0.7 = 17$ sprouts would be needed.

Figure 1. Copper and zinc nails inserted into a sprout.

By connecting around 15–20 sprouts in series we achieved a potential difference of at least 12 V. The copper nail in one sprout was connected to the zinc nail in the next sprout using a wire and crocodile clips. There were sometimes problems with nails touching within the sprouts or poor connections with the wires; hence the need for occasional additional sprouts. Each set of 15–20 sprouts was set out in a plastic tray.

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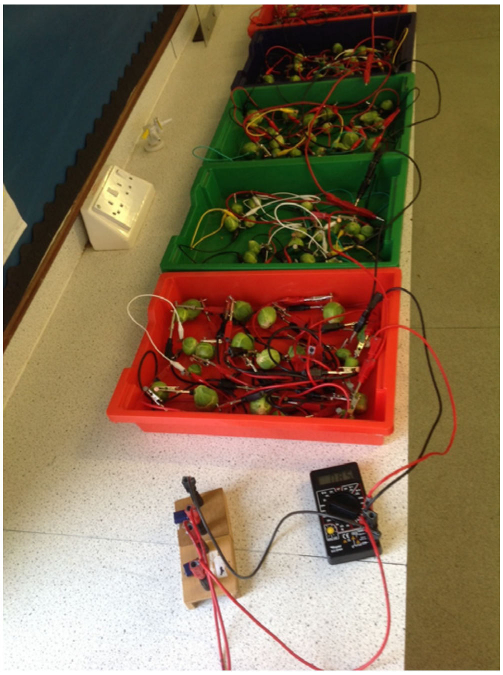

Figure 2. Trays of sprouts charging the supercapacitor (bottom left).

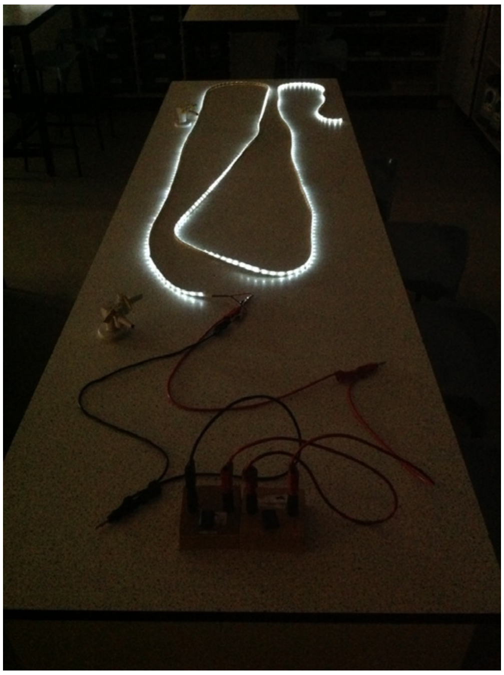

Figure 3. Charged supercapacitors (just visible in bottom centre) powering a string of LED Christmas lights.

To achieve a current of 400 mA, 400 mA/ 20 μA $= 20\,000$ trays would be needed. To make the illuminations more practical we used a supercapacitor. The current produced by the sprouts was used to charge the capacitor over a number of hours, and it was later discharged over a much shorter time through the LED lights. Two 5.5 V 1.5 F supercapacitors were connected in series, producing an 11 V 0.75 F capacitor, which was charged using ten trays of sprouts (see figure 2).

To charge the capacitor to 10 V, a total charge of $Q = CV = 0.75 \times 10 = 7.5$ C needed to be transferred. The maximum charge storable is $Q = CV = 0.75 \times 12 = 9$ C. Solving $Q = Q_0(1 - \mathrm{e}^{-x})$ gives $7.5 = 9(1 - \mathrm{e}^{-x})$ and $x = 1.8$. Therefore, a time equivalent to 1.8 time constants is required to charge the capacitors.

The resistance of a single sprout is about $R = V/I = 0.7/0.000\,02 = 35\,000\ \Omega$. Therefore, a tray has a resistance of $700\,000\ \Omega$. Twenty trays in parallel will have a resistance of $35\,000\ \Omega$. This gives a time constant of about $RC = 35\,000 \times 0.75 = 26\,000$ s. Therefore, the capacitor should take around $1.8 \times 26\,000/3600 = 13$ h to charge sufficiently.

Upper-sixth pupils (age 17–18) completed the above measurements and calculations so that they appreciated the need for the capacitors and number of sprouts, and various classes wired up trays of sprouts. These were then connected to a set of LED lights around a tree in the school grounds and provided excellent photo opportunities for the pupils and school marketing department (see figure 3). The lights were illuminated for approximately 10–15 s.

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