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Lab 03

Potato Clock

1. Principles of Operation:

Two different metals in an electrolyte will form an electrical cell. There will be a voltage difference between the metals and if a resistance is placed between the metals, there will be current flow.

So long as they are different, any two metals will do the job. However, because of their placement on the *electromotive table (see right insert)* some metals will produce more voltage than others. In particular, zinc (potential -0.76 volts relative to hydrogen) and copper (+0.34 volts relative to hydrogen) will give us a cell voltage of nearly one volt… if the cell were perfect, which it is not. In practice, the zinc-copper battery will give somewhere between 0.6 and 0.9 of a volt depending on the leakage current of the electrolyte.

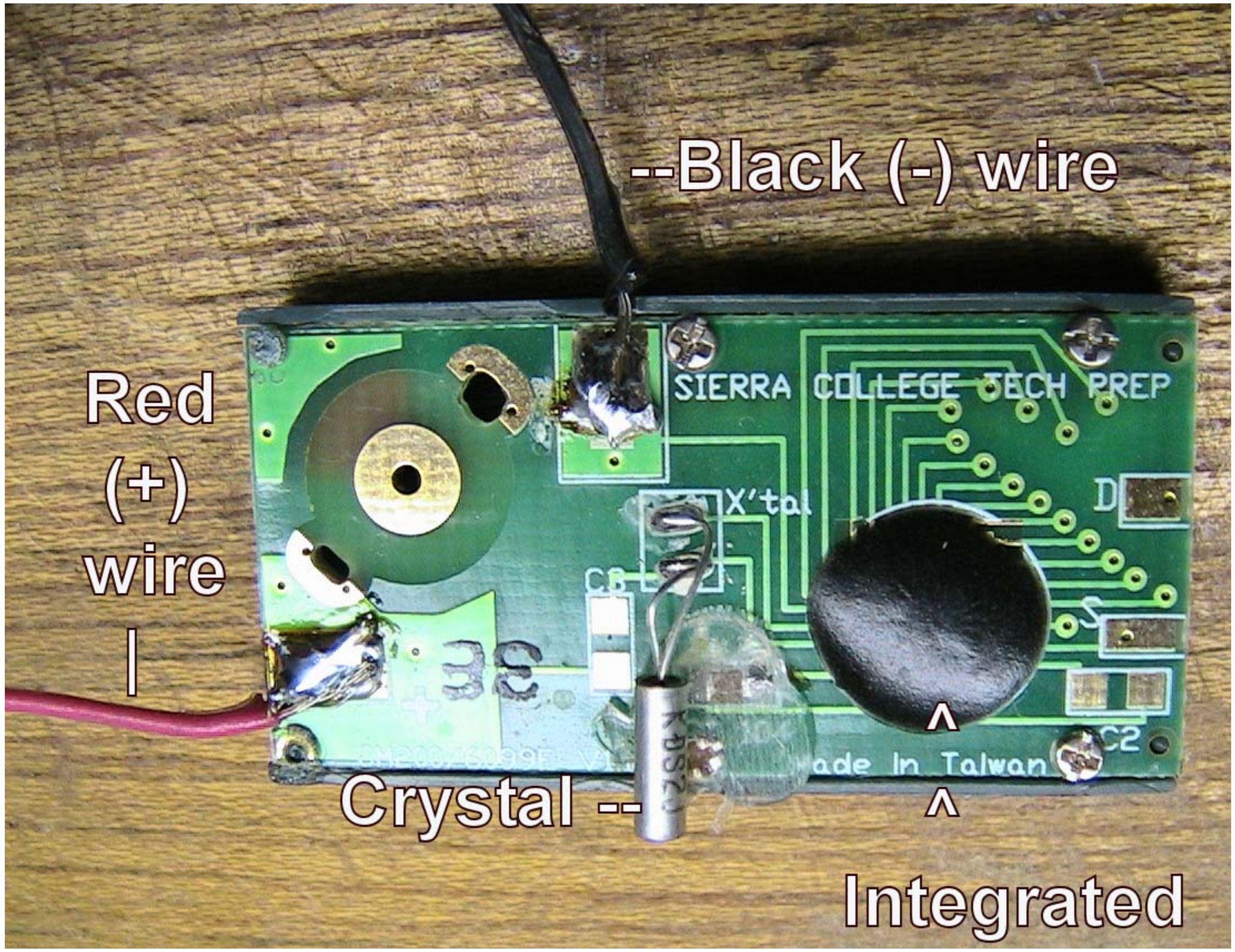
The higher (most negative) of these elements will be oxidized (corroded) to provide the electrons to do the work, so the zinc will be consumed over time to make the cell do its work. The electron flow is FROM the copper cathode TO the zinc anode. Since the copper is now deficient in electrons (less negative) it becomes the positive terminal of the battery. The zinc, having an excess of electrons is the negative terminal of the battery.

The *electrolyte* needs to provide hydrogen for the electron transfer process to work. In general, acid is used to provide the hydrogen ions. A potato has a small amount of citric and phosphoric acids ($C_6H_8O_7$ and H_3PO_4) that will provide enough hydrogen ions for the cell to function. However, a potato is an organic compound comprised of a fair amount of water, and this water will evaporate over time, leaving us with a "dead" cell. We will have to "feed" the potato water from time to time to keep the reaction going. It might be instructive to experiment with a weak vinegar solution (acetic acid - $C_2H_4O_2$) to not only preserve the potato but to add a little more acid each time we "water" the potato.

Element	Electrode Potential (Volts)
Lithium	-3.04
Rubidium	-2.92
Potassium	-2.92
Calcium	-2.87
Barium	-2.80
Sodium	-2.71
Magnesium	-2.37
Aluminium	-1.67
Mangnesium	-2.34
Zinc	-0.76
Chromium	-0.74
Iron	-0.44
Nickel	-0.24
Tin	-0.14
Lead	-0.13
Hydrogen	+0.00
Copper	+0.34
Iodine	+0.54
Silver	+0.80
Gold	+0.80
Mercury	+0.80
Iodide	+0.54
Bromine	+1.07
Chlorine	+1.36
Fluorine	+2.87

In addition, impurities in the potato (residual dirt, salt, other conductors) will cause the cell to be somewhat "leaky", and force current through the potato rather than through the external circuit. In fact, if you were to simply put the copper strip and the zinc strip into the potato without any external circuit, over a few months time (providing you kept the potato watered) the zinc would be totally consumed.

The current from our potato cell will be rather weak (microamperes if we are lucky) and less than one volt will not operate the "load" (clock module) that we have chosen for our circuit. In order to turn the one volt *cell* into a two volt *battery* we will simply put the two cells in *series* so that the cell voltages will add. In fact, the cell voltages will be somewhere around 0.8 volts (imperfect electrolyte) so that the resultant voltage will be somewhere around 1.6 volts. The clock module requires at least 1.5 volts, so we should have a little voltage to spare.



The digital clock module is a fairly simple timekeeping circuit comprised of one integrated circuit (IC) that does the entire job of setting the time, keeping the time, and driving the digits display -- all on a few microwatts of power (micro - one millionth).
The clock is shown here. Note that the integrated circuit is hidden under a lump of black sealant. This is generally done to prevent "reverse engineering" of a product (i.e. stealing somebody else's design and using it yourself).

The timekeeping is kept constant by a vibrating quartz crystal. The quartz crystal uses the *piezoelectric effect* where a voltage is used to excite the crystal into vibration. The crystal is cut from the quartz blank so that it oscillates exactly at 32768 Hz., which divided by 32768 ($32768 = 2^{15}$) gives a one pulse per second "beat" (tick- - -tock) to keep the clock on time.

2. Construction

Parts List

Quantity	Part Number	Description
1		Wooden Base
1		Digital Clock Module
1		Popsicle Stick
2		Small Red Potato
2		Copper Strip
2		Zinc Strip
2		Plastic Cup
1		Wire, stranded, black
1		Wire, stranded, red
1		Wire, stranded, violet
4		Paper Clip

Assembly

1. Insert one of the copper strips into the side of each potato. Leave about one inch of the copper strip exposed.

2. Similarly, insert one of the zinc strips into the same side of each potato. Do not let the copper and zinc strips contact each other, either inside of or outside of the potato. Use a digital multimeter to measure the voltage between the copper and zinc strip of each potato "cell". Which strip is positive and which strip is negative on each cell?

3. Strip about 0.12" of the insulation from both ends of all three wires. (0.12" is about 40 pages of your textbook.) This length, within reason, is not critical. With a hot soldering iron, melt a small amount of solder onto the stripped ends of these wires. This is called "tinning" the wire.

4. Use a piece of scrap paper. Put a paper clip on this paper the way you would use the clip to hold pages together. Leave about half of the paperclip above the edge of the paper. Bend a tiny hook into the tinned ends of the violet wire (both ends). Hook this tinned wire onto the free end of the paperclip at the top and solder the wire to the paperclip. Similarly, use another paperclip and solder the violet wire to that paperclip. You should have a violet wire with paperclips at both ends.

5. Similarly, hook ONE end of the red wire onto a paperclip and solder it. Hook ONE end of the black wire onto the remaining paperclip and solder it.

6. Clip the free tinned ends of the red and black wire to about half of the tinned length (0.06" or so).

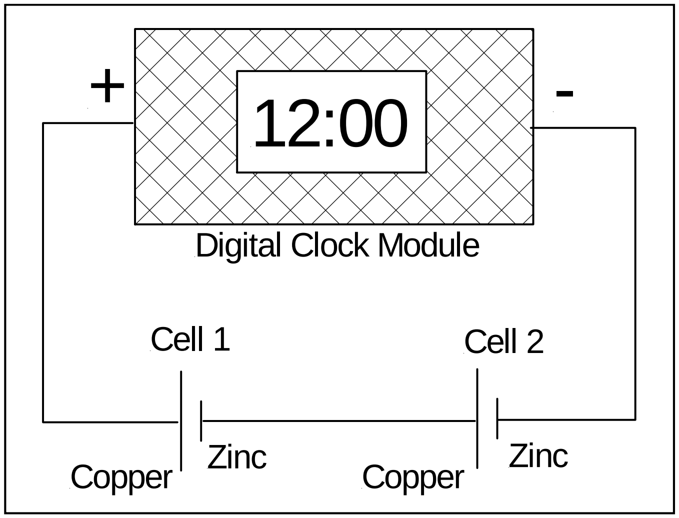
7. Tin the "pad" area on the back of the clock module board marked with a white + sign. Tack-solder (i.e. no mechanical hook or other attachment, just the solder) the red wire onto the tinned portion of the + pad. Use the minimum amount of heat necessary to get the solder to flow. Examine the joint under a magnifying glass. If there are any loose strands of wire, reflow (i.e. remelt) the solder, adding a bit more solder so that all strands are soldered to the pad.

8. Similarly, attach the black wire to the - pad.

9. Connect the violet wire paperclips from the copper strip of one cell to the zinc strip of the other cell. Is this a parallel or series connection? Is this configuration now a "battery" as we have defined it?

10. Temporarily connect the red wire-paperclip to the free copper strip. Connect the black wire-paperclip to the free zinc strip. Did the clock digits "light up"? If not, check your wiring carefully. (What should have happened is that the clock came up at 12:00 and the colon symbol should be flashing at a one Hz. (one flash per second) rate. After a minute, the clock should read 12:01, and so forth.)

11. Schematic:



12. Hot glue a popsicle stick to the back edge (centered) of the wooden base. Be sure that the stick is vertical and at right angles to the base.

13. Hot glue a plastic cup onto the top surface of the base, one on the left side centered front to back and one on the right side centered front to back.

14. Remove the red wire from the copper strip and the black wire from the zinc strip.

15. Hot glue the clock to the top of the popsicle stick. If you forget which way "up" and "down" are, the little pushbuttons on the front of the clock should be at the bottom edge of the clock.

16 Reconnect the red wire to the copper strip. Insert a microammeter between the black wire and the zinc strip. The microammeter should read somewhere around one microamp of current.

17. Reconnect the black wire to the zinc strip and remove the red wire from the copper strip. Insert the microammeter between the red wire and the copper strip. Did it give the same reading as when it was connected between the black wire and the zinc? What do you think would happen if you broke the connection between the violet wire and either of the strips it is connected to? Do you remember reading that current in a series circuit is everywhere equal?

18. Reconnect all red, black, and violet wires. Set the clock for date and time using the next page.

17. We said in Lab 1, that there were four elements to any circuit -- Source, Load, Conductors, and Control. In this lab it should be pretty easy to figure the SOURCE of electrical current, the LOAD doing the work, the CONDUCTORS that we soldered together, but what is the CONTROL? Hint … switches are where you find them.

3. Setting The Clock

1. Press S2 twice within a couple of seconds. Press S1 to set the month.

2. Press S2 again and set the date with S1.

3. Press S2 again and set the hour with S1.

4. Press S2 again and set the minutes with S1.

5. Press S2 and the hour/minutes that you set above will show. Press S1 to start the clock running. The colon will begin flashing.

6. To set the display to alternate between date and time, press S2. To return to month, date, or time only, press S2 again and again to cycle between these displays.

7. To display date for approximately one second and then return to time, press S1.