# Circuit Bending Part 2: Experimenting with the Beast

## Objective: Understand the current flow in your toy

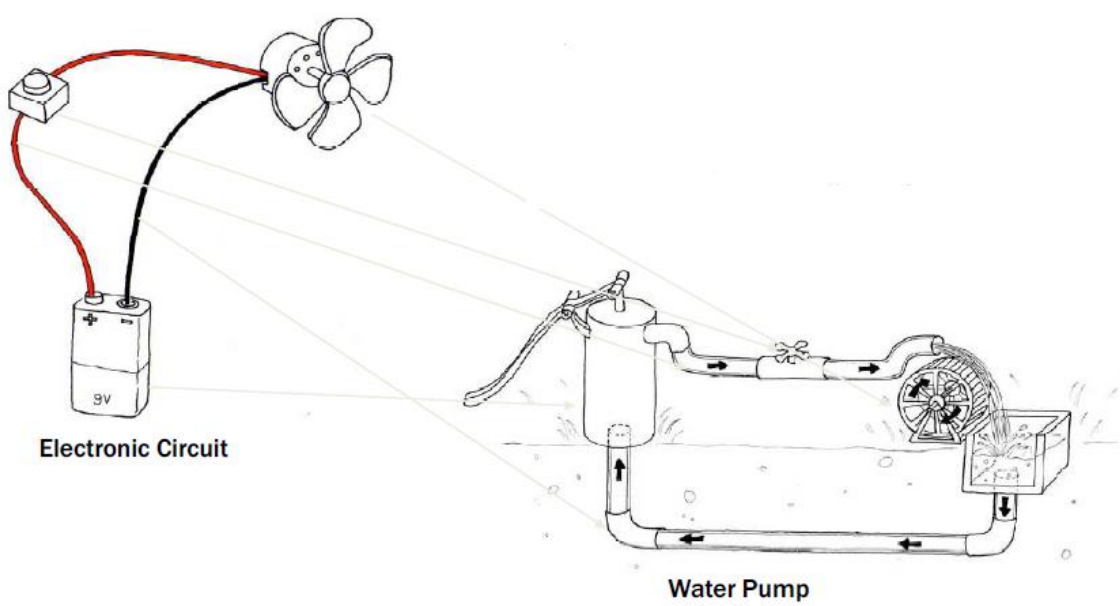
**(1) Learn to use a multimeter**
**(2) Create a map of high and low voltages for the circuit at rest**
**(3) Understand the function of each component**

## Voltage

Now it's time to find out what makes your creature tick. What is it that travels through the pathways and components of your toy? The short answer is *electrons*---negatively charged particles that are the constituents of atoms. Charge particles in motion are referred to as *current*. And what makes charged particles move---that's *voltage*.

Voltage can be thought of as the driving force behind current. It is the electrical potential energy that a charge particle has because of its position relative to other charged particles. Remember from physics there are two kinds of charged particles: positively charged and negatively charged particles. Oppositely charged particles attract each other while particles with the same charge repel each other. To get charged particles to move, put a bunch of similarly charged particles close together and give them another place to go---a place with fewer particles of the same charge. That's what we do when we connect a battery to a circuit.

Let's try the water analogy:



In this analogy, what is the fluid system equivalent of current? Of voltage? What is the equivalent of the battery? What other equivalencies do you notice?

One last (but **important**) word about voltage: Voltage is a relative property---it is the electrical potential energy at one location *relative* to another location. In order for a charged particle to move from pt. A to pt. B, there must be more "pressure" or electric potential energy at pt A than at pt B. The voltage driving the movement of the particle is the **difference** in electric potential energy between pt A and pt B.

## Measuring Voltage

A voltmeter measures the voltage difference between the positive input terminal of the voltmeter and the negative input terminal. That's it. That's what it measures. Nothing more, nothing less - just that voltage **difference**. That means you can measure voltage differences in a circuit by connecting the positive input terminal and the negative input terminal to locations in a circuit. Now listen to your instructor explain how to use a multimeter as a voltmeter.

## Adding Voltage Levels to Your Schematic

Configured your multimeter to measure DC voltage in the range of 3 to 5 Volts. Ask your instructor for help if you are uncertain of how to do this. **You can damage your multimeter if it is not properly configured.**

Make a map of the voltage levels in your circuit---all levels should be relative to *ground* which is the "-" terminal of your battery. This is the point of lowest electrical potential energy in the circuit.

Begin by measuring the voltage difference between the "+" and "-" terminals of your battery. Record the voltage level (i.e., the difference relative to ground) on your schematic at the location of the plus terminal of your battery. Next, move to the ends of the wires that connect the battery to the circuit-board. Check the voltage (relative to ground) at all remaining solder points throughout the toy and record your findings on your schematic. Next check all solder pads on the board (i.e., the "shiny circles").

Remembering that current flows from high voltage to low voltage, what can you infer about the flow of current through the circuit? Can you understand how the switches work?

Try connecting one end of an alligator-clip lead to the positive terminal of the battery housing and then touching different solder pads with the other. Can you explain what you observe?

Finally, working in pairs, measure the voltage at different points in the circuit when the circuit is active. Let one person measure voltage while the other person activates the toy, i.e., makes it play sound. Do you notice anything unexpected or odd?

## Understanding by Investigation---How Does the Creature Work

Based on your voltage measurements, it should be possible to infer how current flows through your circuit. Record your understanding of the circuit and be prepared to participate in the class discussion that follows. In addition to understanding the flow of current, we must also understand how the following components work:

Switches: That's easy. They turn on and off the flow of current. Can you find the switches in your circuit and do you understand how they work? If not, ask your instructor.

Resistor/capacitor circuit: Used as a clock for the IC. The resistor is used to restrict the flow of current into the capacitor, whose job it is to store it. A capacitor stores electricity (i.e., charged particles) and then releases those particles as soon as it builds up enough charge to break-down its internal discharge threshold. The process is repeated time and time again so that the spike of current released by the capacitor can be used as a "clock signal" to trigger other events in the IC.

Magnetic-coil speaker: This is a bit complicated but interesting; check the link.

The custom IC: this component detects the depression of the switches and sends the appropriate electrical signals to the speaker. It is the subject of future explorations.