# Fastastic Frequencies

**Subject Area(s)** mathematics, physics

**Associated Unit** None

**Associated Lesson** None

**Activity Title** Fantastic Frequencies

**Header**

**Image 1**
**ADA Description:** Students working with the Basic Stamp 2
**Caption:** Students working with the Basic Stamp 2
**Image file name:** student.jpg
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**Grade Level** 10 (9-12)

**Activity Dependency** None

**Time Required** 75 minutes

**Group Size** 2

**Expendable Cost per Group** US$0

**Summary** Students will use a resistor- capacitor circuit to explore the concept of frequency. Students will learn to build with resistors, capacitors, and light emitting diodes on a prototyping board. By investigating the formula for the time constant of the system, students will be able to explore the physical concept of frequency.

**Engineering Connection** The relationship between electicals and mathematics is fundamental. Components like resitors, capacitors, and inductors can be interpreted mathematically to build circuits representing higher mathematical objects like differential equations. In fact, before computers, mathematical problems like differential equations were solved numerically using circuits! Studens will use these componenets as a tool to learn more about frequency,a concept originally introduced via periodic and trigonometric fucntions

**Engineering Category** (2) relates math concept to engineering

**Keywords** Frequency, RC circuit, time constant

**Educational Standards**

- State technology:

    - 5.2 (Tools, resources, and technological processes)- test, use, and describe the attributes of a range of material, information, and energy resources
- State science:
    - 4.4 (Physical Setting)- Energy exists in many forms, and when these forms change energy is conserved
- State math:
    - 1.1 (Mathematical Analysis)- abstraction and symbolic representation are used to communicate mathematically

**Pre-Requisite Knowledge** Features (frequency, period) of periodic functions, like sine, cosine, and square waves

## Learning Objectives

After this activity, students should be able to:

- Read the resistance of a resistor and the capacitance of a capacitor
- Build an RC circuit on a prototyping bread board
- Calculate the resonant frequency of an RC circuit
- Relate the resistance and capacitance of an RC circuit to its resonant frequency

## Materials List

Each group needs:

- Basic Stamp 2 microcontroller and Board of Education prototyping board, with power supply (9 volt battery or wall plug)
- Various resistors and capacitors (suggested: 100, 1K, 10K, 100K Ω resistors and 1, 1, 10, 100 F capacitors)
- Light emitting diode
- Jumper wires
- 220 Ω and 470 Ω resistors
- Potentiometer (suggested: 5KΩ)

To share with the entire class:

- Computer with PBasic software
- USB cable

## Introduction / Motivation

Electrical circuits have been used by mathematicians to understand model complex equations since before the invention of computers. Basic electrical elements, like resistors and capacitors, have mathematical analogies that enable mathematicians to actually "build" equations. We will channel this idea today to explore the concept of frequency through an electrical circuit. This activity not only exemplified and allows students to physically interact with abstract concepts, but it give them a chance to create and gain familiarity with basic electrical elements present in

nearly every electronic device, from cell phones and iPods to the blinking lights on children's shoes.

## Vocabulary / Definitions

| Word | Definition |
|---|---|
| Current | Rate of flow of electric charge, expressed in amperes |
| Periodic | Having a structure over a fixed interval which is repeated, like a sine wave |
| Frequency | Number of times of an occurrence in a unit of time, like having a heart rate of sixty beats per minute |
| Voltage | Force or potential between two points that would drive an electric current, expressed in volts |

## Procedure

### Background

Today we are going to explore frequency in an exciting way. We all remember the relationship between frequency and period in functions like sine and cosine. Now let's interpret frequency physically. We can observe the charging and discharging of this capacitor by the blinking of the LED. From the frequency of blinking, we will begin to understand the relationship between elements in this circuit and the time it takes for the capacitor to discharge. Let's see!

### Before the Activity

- Program the BS2 microcontrollers with the attached program.
- Prepare a set of the basic components for the circuit in Fig.1 for each group.

### With the Students

1. Explain the basic components of voltage, current, a resistor, and a capacitor to the students. A useful analogy is water, wherein current is flow of water, voltage is tank of water which has potential by gravity, a resistor is like rocks in a pipe, and a capacitor is like a pump with a rubber diaphragm and a plunger which can be "charged" by pressing the plunger towards the diaphragm.
2. Explain briefly the concept of a potentiometer, a variable resistor, and a light emitting diode (LED).
3. Teach students how to read the resistance of a three-band resistor using the chart below. The resistors actually have four bands, but the last one is silver or gold and denotes the tolerance of the resistor. From the metallic band, students can determine the order of the colored bands. To read the resistance, the first two bands are digits, and the last is the multiplier, that is, the number of zeros following the first two digits. For example, brown-black-red is a 10,000 Ohm resistor.

| Band color | Digit | Multiplier |
|---|---|---|
| Black | 0 | X1 |
| Brown | 1 | X10 |
| Red | 2 | X100 |
| Orange | 3 | X1000 |
| Yellow | 4 | X10000 |
| Green | 5 | X100000 |
| Blue | 6 | X1000000 |
| Purple | 7 | X10000000 |
| Grey | 8 | X100000000 |
| White | 9 | X1000000000 |
| Silver | - | x.01 |
| Gold | - | x.1 |

4. Once students are familiar with the parts, they can build the circuit in Figure 1. The BS2 should be programmed with the attached program.
5. Explain the program to the students, that it drives the pin high and charges the capacitor. Once the capacitor is charged, the pin is driven low and the capacitor discharges. The discharge lights the LED. This process is repeated, which results in blinking.
6. Explain the frequency of blinking. Loosely speaking, when we turn the potentiometer to a higher resistance, it makes the capacitor take longer to discharge, so the blinking is slower. Formally, introduce the formula: $f=1/(2\pi RC)$, where $f$ is the frequency of blinking, R is the resistance, and C is the capacitance of the circuit. From this formula, students can directly see how changing the potentiometer changes the frequency.
7. Ask the students to experiment with the circuit, change the potentiometer and capacitor (leaving the 220 Ohm resistor to protect the pin though!) and see how this changes the frequency of blinking.

**Figure 1** [left justified]

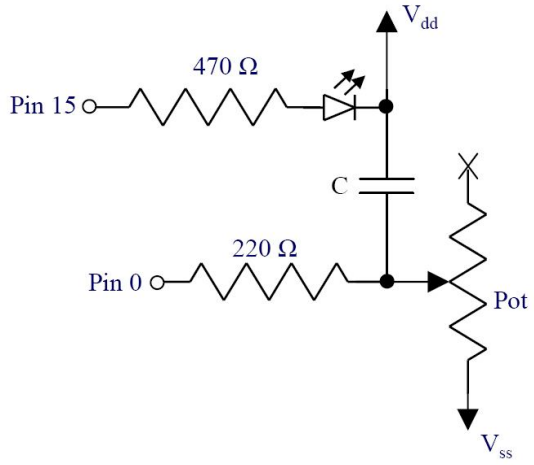


**Figure 1**
**ADA Description:** Circuit diagram for blinking LED
**Caption:** Figure 1: Circuit diagram for blinking LED
**Image file name:** circuit.jpg


## Attachments
RC circuit program (program.bs2)

## Safety Issues
- Always use caution around electronics!

## Troubleshooting Tips
Make sure potentiometers have a wide range. If the resistance is too low, the blinking may be too fast to see.

## Investigating Questions

## Assessment

**Pre-Activity Assessment**
*Title: What's in a circuit?*
Consider the circuit diagram presented with this activity. What do the elements do? Why is there another resistor besides the potentiometer? Why is there a resistor in series with the LED?

**Activity Embedded Assessment**
*Title: Experiment*
Ask the students to experiment with the circuit based on the presented formula. Have them write down their hypotheses before every trial. Were their hypotheses correct? Why or why not?

**Post-Activity Assessment**
*Title: Big Ideas*

Ask the students to write in words the rules governing the behavior of the circuit, like "If the capacitance is increased,…", "If the resistance is increased,…". How does this relate to their study of periodic functions?

## Activity Extensions

None

## Activity Scaling

- For lower grades, use the same activity without the framing of periodic functions. The activity can be used to demonstrate electricity and potential.
- For upper grades, provide the PBasic software and allow the students to learn through tutorials how to program the Basic Stamp for themselves.

## Additional Multimedia Support

## References

## Other

**Redirect URL** http://gk12.poly.edu/amps-cbri/

**Owner** Nicole Abaid

**Contributors** Nicole Abaid



**Version: October 2010**