NAME PERIOD DATE

THE TRANSISTOR AS AN AMPLIFIER

How can a transistor be used as an amplifier in a circuit?

Objectives

- Investigate the characteristics of a transistor used as an amplifier.
- Build a circuit that uses an amplifier to detect infrared signals from a remote control.

Materials and Equipment

- Data Collection Software
- PASCO Essential Physics Modular Circuit Kit
- PASCO Wireless AC/DC Module
- PASCO Advanced Expansion Kit for Modular Circuits
- Infrared Remote Control

Safety

Follow regular laboratory safety precautions.

Procedure

1. Turn on the wireless AC/DC module, the wireless current module, and the wireless voltage sensor.

2. Construct the circuit shown in Figure 1 using the circuit modules, wireless current sensor module, and the wireless AC/DC module. Note the polarity of wireless current module, wireless AC/DC module, and battery connections. Leave the switch open for now.

3. Find an NPN transistor in the components bag and connect it to the transistor module. It is labeled 2N3904, you may need a magnifying glass to read it. The flat side should face away from the letter B on the module. See Figure 1.

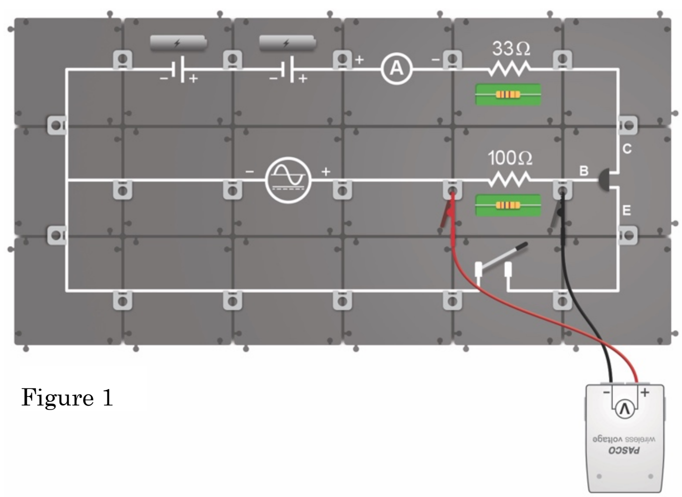


Figure 1

4. Connect the wireless voltage sensor across the 100Ω resistor, making sure the + lead is connected to the side closest to the + terminal of the wireless AC/DC module.

5. Start your data collection software and connect it to the wireless AC/DC module, the wireless current module, and the wireless voltage sensor.

6. Create a graph showing 3 plot areas, output voltage sensor voltage, wireless voltage sensor voltage, and wireless current module current, all on the same horizontal time axis as shown in Figure 2.

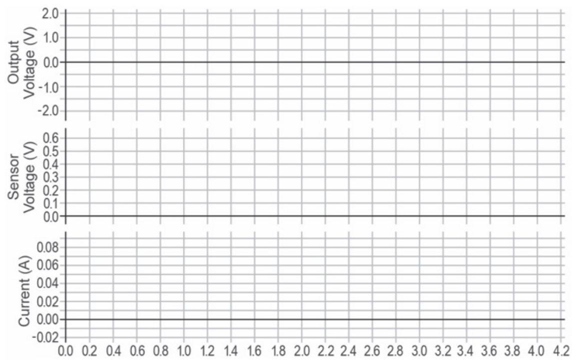


Figure 2

7. Zero the wireless current module and voltage sensor using the data collection software.

8. Select a common rate for data collection of 200 Hz using the data collection software.

9. Configure the wireless AC/DC module output using the signal generator menu. Select triangle for the waveform, 0.5 Hz for the frequency, and 1.5 V for the amplitude. Click the On button and close the signal generator tab.

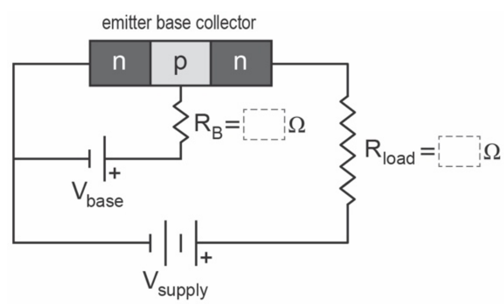
10. Close the switch on the circuit and start data recording. Click stop after about 4 seconds.

11. Open the switch. Check to make sure that when the output voltage sensor reading (top graph) is positive that the voltage sensor reading (middle graph) and the current (bottom graph) are also positive. If not, double check your circuit and sensor connections and repeat the data collection.

12. Adjust the vertical axes limits of your graphs so that the data fills up most of the screen. Change the x axis so only the first 4 seconds of data is displayed.

Questions and Analysis

1. The circuit you built is diagramed at right. Trace your circuit and identify the resistors shown in the diagram. Label them with their resistance in ohms. It will help to know the transistor module labels the transistor pins "E" for emitter, "B" for base, and "C" for collector. V_{base} is from the AC/DC module and V_{supply} is from the 2 batteries connected in series. Using the information on the graphs, draw arrows to represent the direction of the current of the 3 pins of the transistor.



2. Study the graph of output voltage (top graph). This is the voltage generated by the wireless AC/DC module. The pattern is known as a triangle wave. It is a type of alternating current (AC). Using the tools of your data collection software, determine the period, frequency, and amplitude of this wave. Show your work and results below.

3. Study the graph of current (bottom graph). This is the current that goes into the collector pin of the transistor, or the collector current. When the output voltage (top graph) is negative, what is the collector current (I_C)? Does the I_C have this value at any time where the output voltage is positive?

4. Study the graph of the voltage sensor voltage (middle graph). This is the voltage drop across the 100Ω resistor connected to the base pin of the transistor. How is it similar to the graph of the output voltage (top graph)? How is it different?

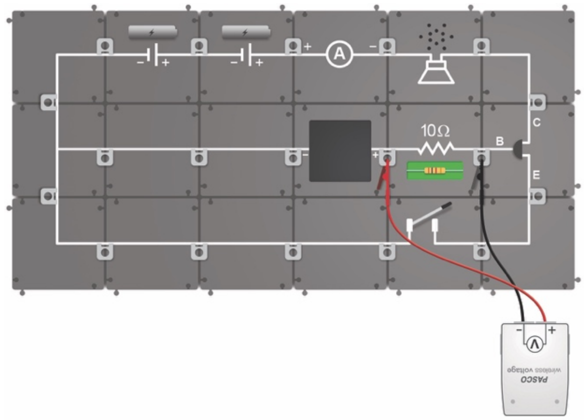
5. The current in the collector of the transistor, I_C, (bottom graph) becomes non-zero when the output voltage (top graph) rises above a minimum value. Use the tools of your data collection software to find this minimum voltage and record it below. When the output voltage reaches this value, what happens to the current going into the base pin of the transistor (I_B)? Hint: What happens to the voltage sensor voltage (middle graph) at this point?

6. The current in the collector of the transistor, I_C, becomes non-zero when the output voltage (top graph) reaches the value found in question 5. This is why a transistor is like a switch. Apply a voltage to the base pin above this value and the current in the collector and the load turns on. Reduce it below this value and it turns off. Increase it above this value and the graph of I_C rises quickly and then starts to flatten out. The transistor is said to be saturated as it flattens out or "plateaus". Use the data collection tools to find the value of I_C just before the graph plateaus and record it below. Use the data collection tools of your software to find the value of the voltage sensor voltage (middle graph) just as I_C plateaus and record it below.

7. The current in the base pin of the transistor, I_B, is the same as the current in the 100Ω resistor. I_B can be found using the voltage across the 100Ω resistor (middle graph) and Ohm's Law. Find I_B using the value of the voltage sensor voltage that you found in question 6. Show your work below.

8. A transistor works as an amplifier because the voltage applied to the base pin can cause a large current in the collector. The amplification factor β is the ratio of the collector current, I_C, to the base current, I_B. Find β using the value for I_C from question 6 and I_B from question and show your work below.

9. A transistor works as a power amplifier because the power dissipated by the load on the collector is more than the power dissipated by the load on the base. Power can be calculated using the equation $P = IV$ or $P = I^2R$. Find the power of the collector load (the 33Ω resistor) and the base load (the 100Ω resistor) using the values for current and voltage found in questions 6 and 7.



10. One application of a transistor is to amplify a signal. Build the circuit shown in Figure 3 where the solar cell module replaces the AC/DC module, the speaker module replaces the 33Ω resistor, and the 10Ω resistor module replaces the 100Ω resistor module. Connect the wireless voltage sensor across the 10Ω resistor. Add an FFT to your display. Increase the sample rate from 250 Hz to 500 Hz and click record.

11. As you observe the graphs, adjust the limits of the vertical axes of the voltage and current so the data fills the screen. There is variation in the values because the overhead fluorescent lights are rapidly turning on and off. Sometimes it can be heard in the speaker if the solar cell is not too far away from the lights. The FFT can measure this frequency. Adjust the horizontal axis of the FFT graph so that 0 to about 200 Hz is displayed. The fluorescent light frequency will show as the tallest column. Write this frequency below.

12. Click stop, then record again and observe the trace of voltage and current on the screen. Use your hand to alternately block and unblock the solar cell from the overhead lights. Describe what you observed below. Which displayed the greatest range of variation?

13. By blocking and unblocking the solar cell, the voltage applied to the base pin of the transistor is changing. This changes the current of the collector pin. Since this current is amplified, it shows a greater variation. This can't be heard in the speaker because you can't block and unblock it quickly enough. A light flashing at a high frequency could be heard in the speaker. A remote control sends out a quickly flashing infrared light. It can’t be seen but it can be heard if you point it into the solar cell. Try it using several different buttons on the remote and describe what you hear below.

14. A remote control sends pulses of infrared light to a device as a carrier signal. The frequency of the carrier signal is the same for every button on the remote. The brightness changes of each pulse and can be read as zeros and ones. You can see the carrier signal and the changes in brightness in the current graph. Record a few seconds of the signal from the remote control and zoom in on 10 pulses. Notice the variation in the height of each pulse. This carries information about the button pressed. Find the frequency of the carrier wave, they are typically between 20 and 60 Hz. Show your work below. You can verify your calculation using the FFT graph. The highest column is the carrier signal. The other columns will vary for each remote control button and could be sued to identify which button is pressed.