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Sub-$10 sound card photogate variants

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Recently, a simple and very low-cost photogate has been shown by Horton[1] as an efficient experimentation tool in physics education. The photogate connects to the microphone input of a personal computer, and free software can be used to visualize the light interruptions caused by a moving object such as a pendulum. Although the device works properly, there are further possibilities of improvement and similar alternatives also exist. The following brief review may help teachers to pick the one that best fits their needs and possibilities.

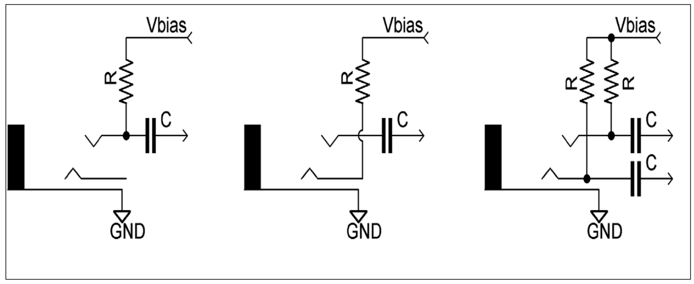

Fig. 1. Simplified microphone input connection possibilities. Typical values are: Vbias= 2.5 V to 5 V, *R* =2*k*, *C*=1 uF. The left two configurations are the most frequent; the "true stereo" microphone input is shown on the right.

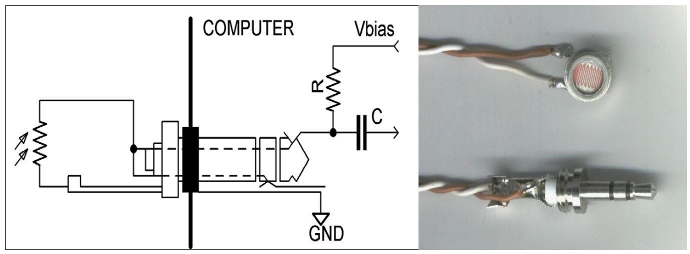

Fig. 2. The photoresistor, the microphone input's internal bias voltage (typically 2.5 V) and the series *R*=2*k* resistor form a resistor divider. The tip and ring of the 3.5-mm jack plug and one pin of the photoresistor should be tied together, as the sleeve and the other pin of the photoresistor.

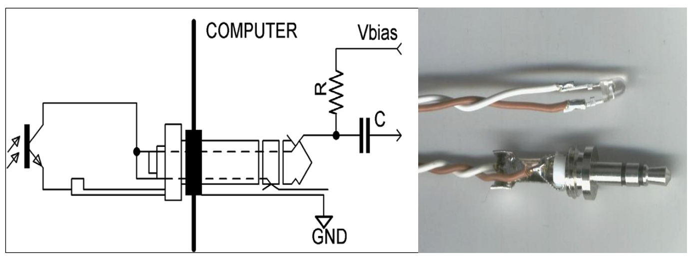

Fig. 3. The phototransistor can be connected directly to the microphone input. The tip and ring of the 3.5-mm jack plug are connected to the collector, and the sleeve is soldered to the emitter.

The simplest photogates ever

The photogate described by Horton is based on a photoresistor,[2] whose resistance strongly depends on light intensity. Since the microphone input can measure voltage only, a battery-driven voltage divider configuration was used to provide voltage depending on the light intensity. On the other hand, PC microphones need bias voltage; therefore, the microphone connector of the sound card has a terminal coupled to a voltage source via a series resistor. The connections are not the same for all computers; Fig. 1 illustrates the possibilities.

This means that the external battery and resistor are not needed; we can get an extremely simple photogate by just connecting the photoresistor directly to the microphone input, as shown in Fig. 2. The computer's internal bias voltage and series resistor form a light-controlled voltage divider with the externally connected photoresistor. This connection will work for all microphone input configurations. Thanks to the minimal number of components, it is very easy to make, very reliable, and costs no more than $2.

Photoresistors are not the only sensors that can be used to detect light. Professional photogates employ phototransistors;[3] they conduct better in the presence of light. Phototransistors outperform photoresistors in several aspects. They switch much faster (within a few microseconds, while photoresistors have rise and fall times in the range of 25 ms to 100 ms), their sensing surface is smaller (the spatial resolution is better), they are broadly available in different wavelengths and sensitivities, and they are offered in optically filtering packages, well documented, cheap, and easy to purchase. Figure 3 shows that this sensor can also be connected directly to the microphone input; the phototransistor works in a common emitter configuration. Phototransistors may have a price down to half a dollar, so the overall cost can be kept below $2 again.

Experimental demonstration

The performance of the photogates based on phototransistors and photoresistors directly connected to the microphone input has been tested and compared by detecting the free fall of a picket fence, often used to determine acceleration due to gravity.[4] A flashlight served as light source and the output signals of the photogates were recorded. The results plotted in Fig. 4 demonstrate the highly accurate response of the phototransistor. They also suggest that the phototransistor is more sensitive. Using the phototransistor the instantaneous velocity[5] can be precisely determined.

In this experiment a TEPT4400 ambient light phototransistor was used (available and well documented at Newark, www.newark.com, part #28M9651); however, almost any phototransistor will work well. Infrared phototransistors can also be used (for example, at Newark, part #93F2635 or at RadioShack, www.radioshack.com, catalog #276-145), provided

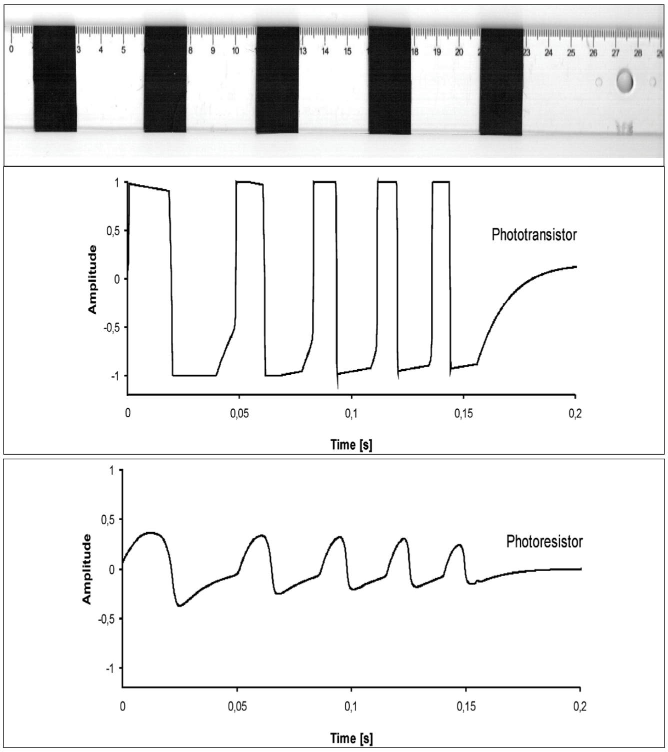

Fig. 4. Photogates detected the free fall of a picket fence made using a ruler and insulating tape. A flashlight served as light source, with a TEPT4400 ambient light phototransistor and a WK65060 photoresistor used as light detectors. Both sensors were directly connected to the microphone input of the computer and the same microphone volume setting has been used.

that the light source has enough intensity in the infrared range. Flashlight is a good choice; LED USB lamps or LED lamps may not be suitable. In most cases, the emitter lead of the phototransistor is longer, however, to be sure one should check the datasheet. Some phototransistors have even a third lead for the transistor's base; it should remain unconnected.

Conclusions

Very simple photogates can be made easily by connecting a single phototransistor or photoresistor directly to the microphone input of a personal computer—no additional components are needed. Although photoresistors work well in most cases, superior performance and better availability make phototransistors the best choice. The cost of such photogates is incredibly low (can be less than $2). Thanks to their simplicity, these photogates are very reliable and easy to use. Students can make their own photogates without considerable effort and can do the experiments at home as a part of a homework assignment or can just have fun by playing with their computer as a motion or light detector. These result in better motivation, with more room for creativity.

Finally, an important warning for all experimenters: it is a must to isolate all electrical connections from the user with insulating tape or heat shrink tubes. User safety and accidental damage to the electronic components via electrostatic discharge (ESD) require the protection from directly touching the wires. To protect the hardware inside of the computer, users may want to avoid using the built-in sound card of the computer and add an external USB sound card instead. This will protect the delicate motherboard of the computer, but will add an additional three or four dollars to the project.

Additional information can be found at www.noise.physx.u-szeged.hu/edudev/.

References

1. M. Horton, "The $10 photogate," *Phys. Teach.* **48**, 615 (Dec. 2010).
2. Photoresistor tutorial, www.instructables.com/id/Photocell-tutorial/.
3. Phototransistor manufacturer examples, catalog.osram-os.com/ and www.vishay.com/photo-detectors/.
4. K. Kopasz, P. Makra, and Z. Gingl, "Edaq530: A transparent, open-end and open-source measurement solution in natural science education," *Eur. J. Phys.* **32**, 491 (2011), arxiv.org/abs/1009.0432.
5. J. Wolbeck, "Instantaneous velocity using photogate timers," *Phys. Teach.* **48,** 262-263 (April 2010).