Photogate Timing with a Smartphone

Kyle Forinash and Raymond F. Wisman

Citation: The Physics Teacher 53, 234 (2015); doi: 10.1119/1.4914566
View online: http://dx.doi.org/10.1119/1.4914566
View Table of Contents: http://scitation.aip.org/content/aapt/journal/tpt/53/4?ver=pdfcov
Published by the American Association of Physics Teachers

Articles you may be interested in
Looking into the Eye with a Smartphone
Phys. Teach. 53, 106 (2015); 10.1119/1.4905811

Smartphone astronomy
Phys. Teach. 52, 440 (2014); 10.1119/1.4895369

Color reproduction with a smartphone
Phys. Teach. 51, 440 (2013); 10.1119/1.4820866

Instantaneous Velocity Using Photogate Timers
Phys. Teach. 48, 262 (2010); 10.1119/1.3361999

A stopwatch-based photogate timer
Phys. Teach. 38, 405 (2000); 10.1119/1.1324526
Photogate Timing with a Smartphone

Kyle Forinash and Raymond F. Wisman, Indiana University Southeast, New Albany, IN

In a previous article we demonstrated that a simple, passive external circuit incorporating a thermistor, connected to a mobile device through the headset jack, can be used to collect temperature data. The basic approach is to output a sine wave signal to the headset port, through the circuit, and input the resulting signal from the headset microphone. By replacing the thermistor with other variable resistors, the circuit can perform other data measurements. A photoresistor in the circuit will change the amplitude of the returning signal by varying the resistance, depending upon the intensity of light reaching it. The circuit used is shown in Fig. 1 (a discussion of alternative circuits is given in Ref. 2). Two or more photoresistors can be placed in series to form multiple photogates, as shown in Fig. 2. The photoresistors used here have a resistance of about 120 kΩ in the dark and 5 kΩ under lamp light. Ordinary household lamps were used as light sources.

The signal does not drop instantly when the resistor is blocked but rather tapers off to a minimum while blocked. Also, due to hysteresis effects, the dip in the graph when the photoresistor is blocked is slightly asymmetric. To avoid these problems we used a double flag method where the time from the beginning of two separate dips is used for timing purposes. In this method two blockages of the gate are used to make a single velocity measurement. This can be done using a piece of Plexiglas with two tape strips (as shown in Fig. 2) or a card with a notch cut out, placed on the moving object so that two dips are produced at each photoresistor when the object passes and blocks the light to each resistor. The Android app AudioTime+ marks the gate as blocked at the time when the amplitude of the gradual signal drop is 80% of the maximum, unblocked signal. The time interval from the 80% mark at the first dip to the 80% mark at the second dip is the length of time the object takes to pass the photoresistor.

Average velocity at each resistor is calculated from
\[ v_{av} = \frac{d}{\Delta t}, \]
where \( d \) is the distance from the leading edge of the first flag (or card) to the leading edge of the second flag (trailing edge of notch). The time \( \Delta t \) from when the card enters the gate until the notch has passed is measured from the app. Figure 3 shows the amplitude of the recorded return signal from a notched card passing a single photoresistor using the Android app AudioTime+. In the figure the time when the signal drops by 80% as the first flag passes the resistor is 1.1318 s and 1.2352 s as the trailing flag passes. The time interval for the card to pass the resistor is given at the bottom right of the screen as 0.1035 s.

Acceleration can be determined from the equation
\[ v^2 - v_0^2 = 2ax, \]
where \( v_0 \) is the average velocity at the first photoresistor, \( v \) is the average velocity at the second photoresistor, and \( x \) is the distance from the first to second photoresistor. A small error is introduced by assuming the average velocity is equal to the instantaneous velocity at the middle of the card, which is not the case since the card is accelerating. Letting the object move a distance equal to several times the width of the card before entering the first gate reduces the error to an accept-

![Fig. 1. Circuit used for photogate timing.](image1)

![Fig. 2. Two photoresistors connected to a tablet.](image2)
and angular acceleration can be measured from the length of time of the amplitude dips in the output signal. Due to the portability and simplicity of the measurement apparatus, this works for a mounted wheel in a science lab or the wheel of a moving object such as a student’s bicycle.

As a final example, a photoresistor/phone combination attached to an object (bicycle, car, runner) moving past a series of openings of known spacing (openings in a picket fence, telephone poles, etc.) could be used to measure speed and acceleration. Because the apparatus is mobile, the exploration of the movement of many objects outside the ordinary classroom laboratory becomes possible.

References

Raymond Wisman is an associate professor of computer science at Indiana University Southeast, where he regularly teaches courses on mobile computing. Current interests include the use of mobile devices in science education.

Kyle Forinash is professor of physics at Indiana University Southeast in New Albany, IN. He has published technical papers in non-linear dynamics in addition to pedagogical papers about the use of computers and cell phones for data collection in student laboratories. His current interests include applications of physics to environmental issues and open source computer simulations for the physics classroom.

Indiana University Southeast, Department of Physics, New Albany, IN 47150; http://homepages.ius.edu/kforinas/Forinash.html; kforinas@ius.edu