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An Inexpensive Alternative to Commercial Infrared Sensors

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Infrared sensors, commonly used to detect the position of an animal subject in a maze or runway, are reliable and unobtrusive, but expensive if purchased commercially. I describe a functional equivalent to commercial sensors, available at a fraction of the cost. With only a few inexpensive components and the ability to solder, an investigator can create inexpensive sensors that work with commonly used commercial equipment.

Key words: infrared detectors; photodarlingtons; behavioral neuroscience

Investigators who use mazes, runways, or open fields often employ infrared technology to sense the position of their subjects. Infrared switches are superior to mechanical switches in many ways: they are reliable, silent, and their activation is undetectable by the subjects. Their major drawback is cost: the least expensive sensors provided by the most popular modular behavioral equipment suppliers cost more than $50 each, and many are more than $100. An investigator using an eight-arm radial maze who wants to monitor a rat's entry into and completion of each arm would require 16 sensors, at a commercial cost of at least $800 for the sensors alone. I suggest an inexpensive alternative that is compatible with the interfacing equipment provided by both Med Associates and Coulbourn Instruments. (Please note that I am an experimental psychologist with no formal training in electronics. The techniques discussed herein have worked for me but you should consult a skilled technician if you have any doubts about their safety or applicability in your laboratory.)

The technology underlying infrared sensors can be quite simple or very complex. Infrared remote controls typically pulse an infrared emitting diode (IED) at a high frequency, and modulate that frequency to encode specific commands for the receiving unit. This approach has two main benefits: the frequency modulation allows a single sensor to receive multiple and varied commands, and the pulsing of the IED allows it to operate at high power for the very brief duration of the pulse, typically much higher than is possible if the IED were operated continuously, yielding a greater effective distance. In addition, the sensor can be adjusted to ignore pulsed frequencies other than the one used by the IED, allowing it to screen out extraneous interfering infrared signals. Personal communication from Med Associates suggests that most of their sensors use pulsed technology. Maksik (1991) described a pulsed infrared circuit that can be easily constructed by an investigator. Infrared devices have also been addressed by Batson and Turner (1986), Clarke et al. (1985, 1988), and Robles (1990).

At the other extreme, an infrared sensor can simply detect infrared radiation and switch current flow upon its detection. This approach is not practical in most commercial applications because of the potential for interference from unintended infrared sources. In a laboratory setting, however, such interfering sources can readily be eliminated. Thus in many behavioral settings this simple technology is sufficient. Coulbourn Instruments (personal communication) has indicated that their infrared sensors use this approach. Since the early 1990s I have used such technology to detect the position of rats in mazes and runways; the technology is reliable, effective, and cheap (c.f., Wilson, 1996; Wilson et al., 1992, 2000).

Commercial interfaces that allow computers to monitor switch closures are digital devices: they expect to see the presence (switch closed) or absence (switch open) of a particular voltage (e.g., 28 V for Med Associates). Infrared phototransistors respond to infrared radiation by closing a circuit, allowing current to flow from one lead to another. Photodarlingtons consist of a phototransistor and transistor in series: the phototransistor's output is used to switch the transistor on and off. The result is more sensitive infrared detection (increasing the effective distance between the IED and the detector). Phototransistors are not perfect switches. When not illuminated by infrared (i.e., when a mechanical switch would be open), some current typically leaks through the circuit. However, the digital nature of the interface hardware causes it to "classify" a small amount of current as absence of a signal; only when the current flow exceeds a particular value will the interface recognize the presence of a signal. The actual threshold at which this occurs varies across commercial suppliers, but is irrelevant to our purpose because the threshold is much higher than the residual current that leaks through the photodarlington. We have tried to use the cheaper and less sensitive phototransistors in place of the photodarlingtons with no success. They apparently allow enough current to flow, even when they are in infrared shadow, that the computer interfacing equipment detects the current as a switch closure.

Infrared Detection

If a sensitive infrared photodarlington is placed in series with the switch input of the computer interfacing equipment it will act in a manner similar to a mechanical switch. When the sensor is in infrared shadow, the circuit is open; if infrared radiation falls on the photodarlington the circuit will close. We have found that an Optek OP830WSL photodarlington (typically less than $2.50) and an appropriate infrared source (we use Fairchild QED123-ND, typically less than $1.00, but nearly any other IED should work) can be used in place of the commercially available infrared beam inputs for both Med Associates and Coulbourn Instruments equipment.

Using with Med Associates Interface

The Molex connectors used for input on the interface panels have three pins. Wire the photodarlington to a Molex plug with the emitter lead of the photodarlington attached to the #1 pin, and the collector lead to the #2 pin. The base lead of the photodarlington is not used (Figure 1). (The emitter, collector, and base leads are identified on the packaging or information sheets that accompany the photodarlingtons; for the Optek OP830WSL the emitter is the lead closest to the metal tab on the case, and the collector is the lead farthest from the tab. Consult the documentation for your component to identify these leads.) When the photodarlington is aimed at an infrared source, the equipment will register a switch closure.

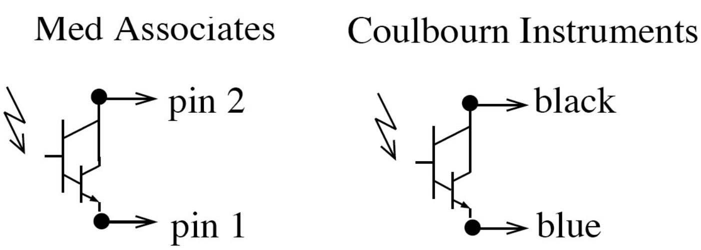

Figure 1. Wiring the photodarlington to Med Associates or Coulbourn Instruments interfaces.

Using with Coulbourn Instruments Interface

Coulbourn interface panels use six-conductor phone plugs as connectors. The emitter of the photodarlington is wired to the blue wire and the collector to the black wire. The base lead is not used (Figure 1). When aimed at an infrared source the equipment will detect a switch closure.

Using with Other Interfaces

The infrared detectors described here should work with other commercially available interfaces or with “homegrown” equipment. As described above, the photodarlington is simply substituted for a switch. It has worked at voltages ranging from 5 V (Coulbourn) to 28 V (Med Associates). I do not know the minimum workable voltage, but it is likely that any interfacing system would have operating voltages within the 5 to 28 V range.

Shielding

The photodarlington’s are very sensitive, and will respond to overhead fluorescent lights and other potentially interfering sources. I mount the photodarlington inside an opaque tube (an opaque plastic ballpoint pen body, small diameter plastic tubing, or whatever is convenient), approximately two cm long. A small amount of silicone adhesive (e.g., GOOP™) will ensure that the photodarlington remains in place.

Infrared Source

IEDs are relatively inexpensive and readily available. Like light emitting diodes, IEDs must be connected in series with a resistor in order to limit the current flowing through them, and they must be connected with the proper polarity. The anode (longer of the two wires coming out of the IED) must be attached to the positive side of the circuit; the cathode (shorter wire) is attached to the negative side. If it is wired incorrectly it will not work, and because you cannot see infrared you will not realize the problem. Infrared-emitting diodes typically require a voltage of about 1.5 V, and are rated for a maximum current of 100 mA. I can power eight of these (at less than maximum current) in series, using a single 330 ohm, 1 W resistor, from a single 28 V stimulus output on a Med Associates interface panel (Figure 2). Be sure to calculate the appropriate resistance for your application using the formula:

$$R = \frac{(\text{Supply voltage} - \Sigma(\text{LED voltages}))}{(\text{desired current of LED in A})}$$

where A is the current measured in amps (typically less than 100 mA for an IED). Using a desired current less than the rated maximum current will ensure a long life (probably more than 100,000 hr) for the IEDs. Note that while incandescent bulbs are typically wired in parallel (so that when one burns out the others remain lighted) it makes good sense to mount LEDs or IEDs in series. They have such a long life that it is unlikely that one will fail. Mounting in series ensures that the same current flows through each diode, yielding similar output intensities, and also reduces the number of resistors required (one per series instead of one per IED).

I have used IEDs with a narrow output beam (8° -- Fairchild QED123-ND). This concentrates the infrared radiation on the photodarlington, and increases the separation distance possible between the two (IEDs with wider beams can be used, but the separation distance might be decreased). Our detectors will readily respond to a strong infrared source (e.g., overhead fluorescent lights) from a distance of 3 m or more. The considerably weaker IEDs that we use give us a maximum range of about 0.5 m with careful positioning — more than sufficient for most behavioral work with rats or mice. If a greater range is required the investigator can use lenses to focus the beam, or use a more complex pulsed circuit like that described by Maksik (1991). If accurately aligning the IED and the photodarlington becomes difficult, a video camera attached to a monitor or a digital camera with an LCD screen can be used to detect the infrared beam. Position a sheet of white paper near the photodarlington and view the paper with the camera. Because the transducer in the camera responds to infrared the region “illuminated” by the IED will be visible on the display. This should allow the user to reposition the IED so that the beam falls on the photodarlington.

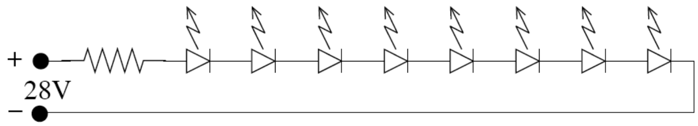

Figure 2. Schematic demonstrating how to drive eight infrared-emitting diodes from a single 28 V stimulus control output of a Med Associates interface.

Availability of Components and Ease of Construction

I have purchased the electronic components from Newark electronics (www.newark.com) and from Digi-Key (www.digi-key.com). They should be readily available at many other hobbyist electronic locations. The specific parts that I have used are the Optek OP830WSL photodarlington and Fairchild QED123-ND IED. Total construction time for the infrared detector is neglible: solder on the appropriate connector and plug it into the interface equipment. Wiring the IEDs requires calculating the appropriate resistance that is needed (dependent on the voltage available and the number of IEDs as described above) then connecting the resistor and IEDs in series and connecting to the power supply. This might take as long as 1 hr for an inexperienced builder, but will be completed in 10 min by someone who has even limited electronic experience.

Conclusion

Commercial suppliers produce excellent interfacing hardware and software that would be very difficult for an investigator to produce; money invested in these items seems well-spent. However, given the ease with which simple infrared sensors can be implemented, investigators would be wise to consider making their own rather than purchasing functionally equivalent and much more expensive commercial sensors.

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