The Alarm, Sensor & Security Circuit Cookbook

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Introduction

MOST PHYSICAL PHENOMENA CAN BE DETECTED BY SENSORS, monitored by amplifiers and trigger circuits, and then presented by meters, bells, sirens, chart recorders, or personal computers. Measurement and protection systems utilize sensors and detectors that can be used to detect light, temperature, pressure, speed, vibration, proximity, infrared, metal/magnetism, acceleration, and toxic gases.

One of the aims of this book is to present the many types of sensors that can be used in measurement and protection circuits in a "cookbook" of ideas and circuits that can be called upon when a particular problem or application arises. This book should appeal to engineers, technicians, alarm installers, and hobbyists.

Many new ideas and integrated circuits are introduced, so you can become familiar with the latest sensors, detection circuits, and integrated circuits available. The scope of this book includes both sensing and measurement devices, as well as stand-alone alarm circuits. Many of the sensors shown can be wired together to form more complex protection or alarm circuits.

The first chapter begins with the high-gain amplifier and how it can be used in a multitude of sleuthing applications, including detecting light, sound, motion, radiation, magnetism, and rf energy. You might not have realized just how many phenomena can be sensed with the lowly amplifier. Following the high-gain amplifier, many types of sensors are shown, such as a static-electricity detector, light and heat detectors, temperature sensors, and metal and magnetic sensors. The measurement-bridge circuit is described next and it is shown in a variety of different configurations. An ac Maxwell bridge follows. It can measure unknown capacitance or inductance. It is shown as an automobile metal sensor, which can detect cars passing over a driveway. Hall-effect sensors are presented next; and they can detect metal, magnetism, speed, pressure, and current flow. The next detectors include a pyroelectric or infrared body-heat sensor, pressure sensors, a toxic-gas detector, optical encoders, and tiltmeters.

Chapter 2 presents the revolutionary piezoelectric film. This new material can be used in a spectacular array of sensing applications. The piezo film is now used in many types of sensors including vibration switches, magnetic switches, infrared sensors, fluid sensors, microphones, hydrophones and accelerometers, and the list is growing. We will suggest how you may obtain a sample of this amazing material. Chapter 2 also introduces the new force-sensing resistance sensors.

Chapter 3 introduces a number of new integrated circuits that can be used to build low-cost, minimum-component sensing systems, such as a proximity sensor, speed detector, smoke detector, and precision position detector. We also present a new video transceiver chip, which can be configured into a high-resolution videophone or the unique video sentry described in Chapter 8. Chapter 3 also discusses gas sensors and recent trends in gas-sensing technology.

Chapter 4 is devoted to computer interfacing. A number of low-cost methods are described to help you interface sensing and measurement circuits to the personal computer so you can collect, store, and display your measurement data.

Chapter 5 surveys some of the most often used alarm-system sensors. An overall view of each sensor is presented, and strengths and weaknesses are discussed. Recommendations are made for the most suitable use for each device.

Chapter 6 is a short course on the philosophy of alarm-system design. Useful tips are discussed, as well as the pitfalls of alarm systems. Thoughts on how burglars think and how to outsmart the common thief are presented.

Chapter 7 includes diagrams of alarm systems that can protect your home or office. Shown first is the basic latching alarm, which is the heart of most alarm systems. Next, is a remote sensing system that can be used to take measurements of light, temperature, and speed and send the data over a wire or radio-frequency (rf) link to a remote monitoring site. A low-cost window/door alarm is shown, which can be configured to protect most doors and windows. Next is a unique security system that displays each alarm location and status. It can call the local police department. Next is a multipurpose, dual-channel alarm system that can monitor both fire and alarm conditions. Last, a number of circuits, including low-cost automobile alarms, emergency lighting, strobes, sirens, phone circuits, and motion sensors are presented.

In the last chapter, a number of novel, high-tech detection and alarm projects are covered. Each circuit includes a circuit board layout to aid in constructing the particular project. The first circuit is a sensitive piezoelectric vibration sensor, which can be implemented as a complete stand-alone travel alarm or wired with other sensors for a more complex alarm system. The next project is a self-contained camping alarm system, followed by a pyroelectric infrared body-heat detector. The pyroelectric sensor is one of the most sensitive and trouble-free detectors available. It can sense humans or large animals up to 50 feet away.

A unique high-chimney alarm is the next project. The chimney alarm senses an overheating chimney, triggers the alarm, calls the fire department, and extinguishes the chimney fire, all simultaneously. The tone-identification alarm is a useful project that identifies a particular location which has been activated by sending a Touch Tone signal from one of the trigger modules to the decoder/display unit. The beauty of this system is that it can be used over either a hard-wire or rf link.

The portable alarm is one of my favorite projects. It is a wireless infrared system that alerts your friends or neighbors when an intruder has entered your home or cabin. A pyroelectric sensor that can detect humans up to 50 feet is used to trigger a transmitter that sends an alerting tone to an FM receiver or scanner for 20 seconds. After the 20-second time period, a sensitive microphone is connected to the transmitter, allowing your neighbor or friend to "listen in" to your home for up to five minutes, at which time the system resets. During this five-minute period, your neighbor could investigate or call the police, if necessary.

Next is the storm-warn project. It can disconnect computers or antennas during an electrical storm.

The last project is the video sentry, a sophisticated audio/video security/surveillance system that permits you to monitor both audio and video from a distant location where the video sentry is installed, using the public telephone network. You can monitor your office while you are away or keep tabs on your babysitter or old folks as well. This modern-day infinity transmitter operates over any geographic distance and it is simple to operate. Simply dial the phone number where the video sentry was installed, press a Touch Tone function key on your phone, and the video sentry at the remote location will instantly and automatically answer the phone line without even ringing the phone. The video sentry also allows you to control remotely a number of devices such as bells, sirens, tape recorders, lamps, and home appliances. The video sentry is possible because of a new videophone chip, which sends high-resolution still pictures over a twisted pair in less than 12 seconds. The PMC videophone chip produces the best picture of any videophone offered to date.

❖ 1

Sensors and detection circuits

SENSORS ARE THE WINDOWS TO THE WORLD! THE HUMAN SENSES are limited to a narrow range of audio and video frequencies. For us to detect the broad range of physical phenomena all around us, we often rely on the magic of electronics. Electronic sensors provide us with the means to augment the human senses to detect pressure, motion, radiation, infrared, gases, etc.

High-gain amplifier

A simple but highly effective means to sense or monitor physical phenomena can be accomplished by using a high-gain amplifier, as shown in Figs. 1-1 and 1-2. You can easily become a real sleuth using the sensitive amplifier. This lowly device can monitor all sorts of things. Everyone is aware that connecting a microphone to an amplifier permits you to listen to nearby sounds and placing a microphone at the focus point of a parabola allows you to hear distant sounds. But did you know you could connect a small crystal earphone to the input of a high-gain amplifier and by epoxying the earphone to a nail pounded halfway through a wall you would have an extremely powerful listening device, one that could listen through walls?

Have you ever thought about connecting a ceramic phono cartridge to a high-gain amplifier? You can epoxy an 8 to 10 inch brass rod to a phono cartridge to create a vibration monitor, which you could use to listen for a bad bearing in a motor. Try winding a small 100-turn coil of 28-gauge enameled wire around a ferrite or iron core. Connect the coil to your high-gain amplifier and you can "listen in" to ac wiring inside walls to help locate hidden wiring (see Fig. 1-3). If you placed the same coil near a telephone,

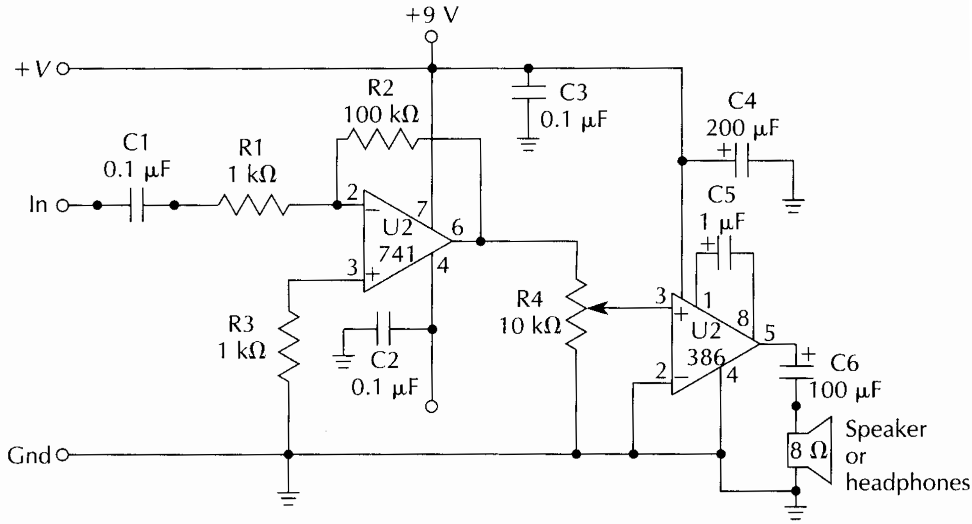

Fig. 1-1 High-gain amplifier.

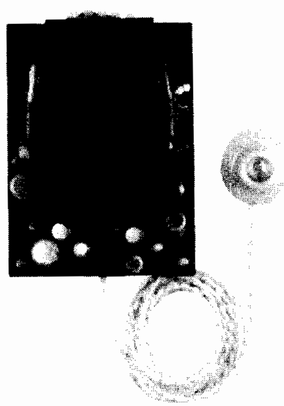

Fig. 1-2 Microphone and high-gain amplifier.

you would have a telephone amplifier that would amplify a long-distance phone call or perhaps provide a remote ringer in another room. If you placed a magnet at a 30 to 40° angle as shown in Fig. 1-4, you could listen for hidden nails in a plaster wall.

Listening to nature's sounds can be accomplished quite easily by connecting six to eight turns of 26-gauge wire wound on a 3 × 5-foot loop placed outside. You can listen to a "dawn chorus" or lightning flashes, atmospheric whistlers, even auroras. The basic high-gain amplifier can also be used to detect radio frequency (rf) energy from radio or television transmitters, so you

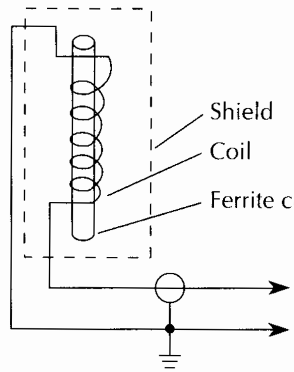

Fig. 1-3 *Telephone listening coil.*

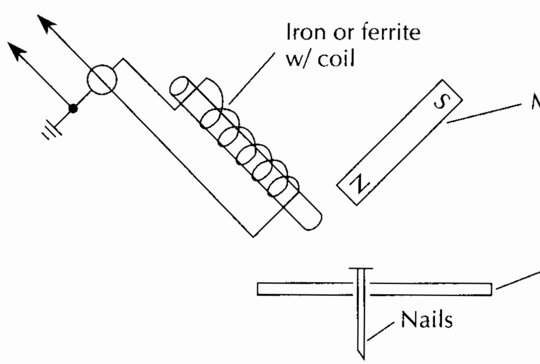

Fig. 1-4 *Metal detector.*

now have a "bug" detector or a field-strength meter. Connect a single loop coil antenna to a high-frequency diode to the input of your high-gain amplifier. As shown in Fig. 1-5, you can sniff rf energy. By connecting a hydrophone (a ceramic underwater microphone) to the high-gain amplifier, you can construct a fish finder, a pool splash detector, or a marine engine detector.

If you connect a solar cell as a sensor to the high-gain amplifier as shown in Fig. 1-6, you can use the silicon solar cell to sense the speed of a propeller or any rotating object by shining a light on the rotating object and placing the solar cell in view of the rotating object. A solar-cell detector can be used to detect lights in the night sky by placing a telescope or lens in front of the solar cell. You can also "listen" to airplane strobe lights or perhaps you could construct a moonlight detector to steer your telescope.

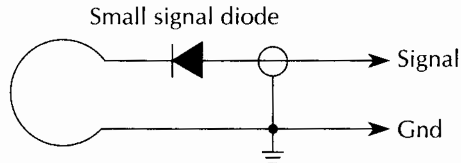

Fig. 1-5 rf detector.

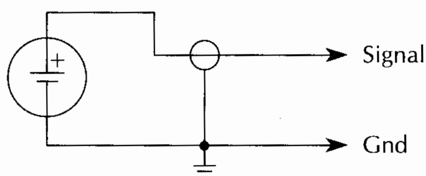

Fig. 1-6 Light detector.

You can even measure radiation with the aid of a high-gain amplifier. One of the most sensitive forms of radiation detectors is the scintillator. When radiation strikes a crystal, it scintillates, emitting a small amount of light. That light can be detected by a silicon solar cell, as shown in Fig. 1-7. A simple detector can be constructed by using two microscope slides, a solar cell, and some zinc sulfide, which is easily obtainable. Mix the zinc sulfide into a slurry, using ordinary tap water. Then place the slurry on one of the microscope slides. When the slide is dry, place the other slide over the coating and tape the two slides together at the edges. Then position the scintillator in front of the silicon solar cell and place the detector in a dark enclosure. Allow 10 minutes to recover from the ambient light. This detector arrangement allows you to detect gamma rays by listening to clicks in a headphone connected to your high-gain amplifier.

The next time you need to sniff out a problem, don't forget your trusty friend, the high-gain amplifier.

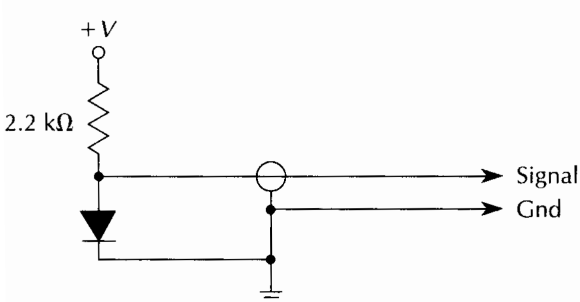

Fig. 1-7 Radiation detector.

High-gain amplifier parts list

Quantity	Part	Description
2	R1, R3	1-kΩ, ¼-W resistor
1	R2	100-kΩ, ¼-W resistor
1	R4	10-kΩ potentiometer, ½W
3	C1, C2, C3	0.1-μF, 25-V capacitor
1	C5	1-μF, 25-V capacitor
1	C6	100-μF, 25-V electrolytic capacitor
1	C4	200-μF, 25-V electrolytic capacitor
1	U1	UA741 op amp
1	U2	LM386 audio amplifier
1	SP	8-Ω speaker

Touch switch

A touch switch is a useful circuit that can be used to detect humans or protect small objects, such as antiques. It can be used to turn on a lamp or as an annunciator to sound a buzzer when someone comes near a door or table. The touch switch, or capacity switch, can also be used to start a moving display sign. A touch switch is shown in Fig. 1-8, and it can be activated by touching a small metal plate connected to pin 2 of the 555 timer chip. Once triggered, the load remains on until reset. A low logic level applied to pin 4 resets the circuit. The output is on pin 3, which is used to drive an LED.

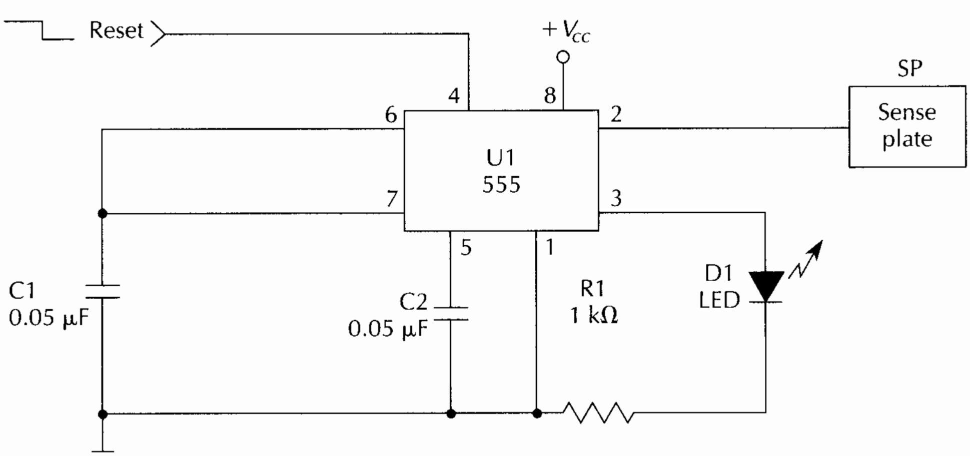

Fig. 1-8 *Touch switch—manual reset.*

Another variation of the touch switch is depicted in Fig. 1-9. This touch switch also uses the ubiquitous 555 chip. The circuit is configured as a monostable multivibrator. The load remains on for a time period determined by the R1/C1 combination. After the time period elapses, the circuit turns off until triggered again. The sense plate is connected to a capacitor placed in series with pin 2 of the IC timer to increase the charge accumulation.

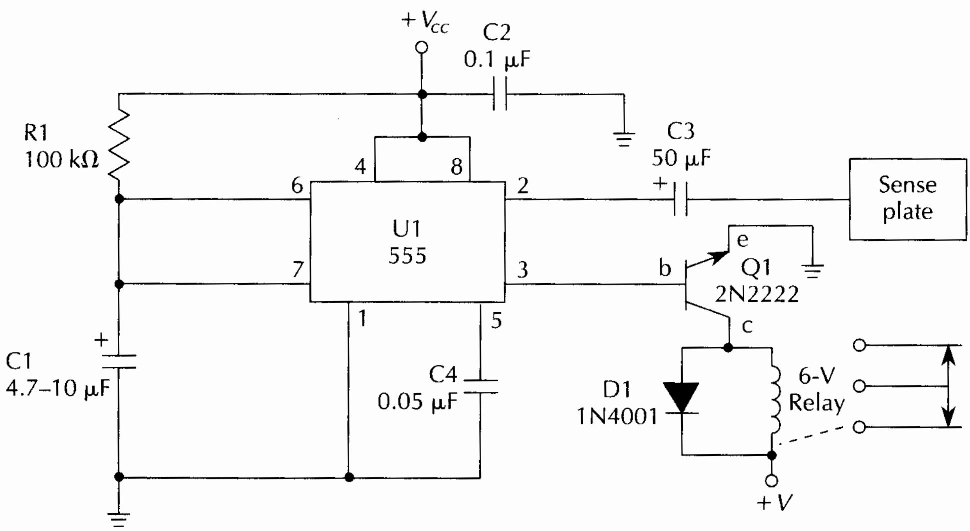

Fig. 1-9 *Touch switch.*

The touch switch relies on the "stray capacitance effect" of a human body from the sense plate to a lower potential, i.e., ground. By completing a path to ground through the human body, the switch magically appears to turn on a light or external load. Always power your touch switch either with batteries or with a power supply that uses a transformer to ensure you are not in the direct path to a 110-V_{ac} line.

Touch switch with manual reset parts list

Quantity	Part	Description
1	R1	1-kΩ, ¼-W resistor
2	C1, C2	0.5-µF, 25-V capacitor (disk)
1	D1	Red LED
1	U1	555 timer IC
1	S1	Sense-plate copper circuit board

Touch switch parts list

Quantity	Part	Description
1	R1	100-kΩ, ¼-W resistor
1	C1	4.7–10-μF, 25-V electrolytic capacitor
1	C2	0.1-μF, 25-V capacitor
1	C4	0.05-μF, 25-V capacitor (disk)
1	C3	50-μF, 25-V electrolytic capacitor
1	D1	1N4001 silicon diode
1	Q1	2N2222 pnp transistor
1	U1	555 IC timer
1	Ry-1	6-V SPST relay
1	S1	Sense-plate copper circuit board

Static-electricity detector

The static-electricity detector shown in Fig. 1-10 is a simple tester designed to detect nearby static-electricity fields. You can easily demonstrate a static field by walking across a carpet and then touching the sensor probe. When the detector is placed next to a television screen or computer monitor, it is activated by the high voltage that accelerates electrons in the picture tube. A cellophane tape roll also generates a static charge. Place the probe wire near where the tape comes off the roll. Then pull the tape through the dispenser and the meter will move.

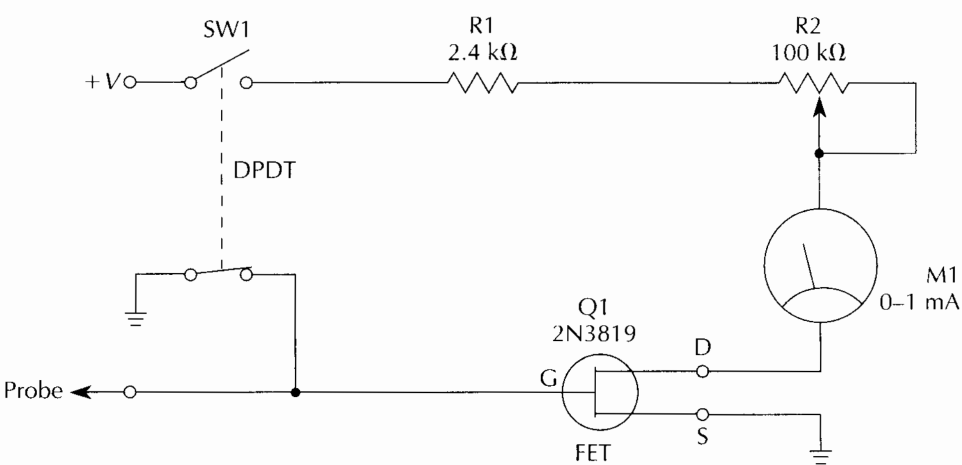

Fig. 1-10 *Static-electricity detector.*

A 2N3819 field-effect transistor is used as the static field sensor. A shore wire or small telescoping radio antenna is connected to the gate of the FET. The source lead is connected to ground and the drain lead is connected to a 0–1-mA meter. The remaining meter lead is coupled to a 3.3-k Ω resistor, which is fed to the positive post of a 9-V transistor-radio battery. Note that the FET can be easily damaged with a high static field while it is being handled. The FET leads should be shorted together as it is soldered in place and a grounded soldering pencil should be used. A grounded wrist band is also recommended. The static sensor would make a great addition to any static-electricity science-fair project, or could be a handy sensor on your test bench.

Static-electricity detector parts list

Quantity	Part	Description
1	R1	2.4-kΩ, ¼-W resistor
1	R2	100-kΩ, ¼-W resistor
1	Q1	2N3819 FET
1	M	0–1-mA meter
1	SW-1	DPST toggle switch
1	ANT	Whip antenna or wire

Electroscope

The electroscope pictured in Fig. 1-11 can be used to display static energy charges from sources such as TV sets, electrostatic generators, carpet cruising, and hair combing. The electroscope is the sophisticated cousin of the static-electricity detector shown in Fig. 1-9. The electroscope would make an excellent science-fair project or addition to your electronics bench.

The heart of the electroscope circuit is the two FETs, Q1 and Q2, connected in a balanced bridge configuration. The gate of Q1 is connected to the wire pick-up antenna via a 1.5-Ω resistor, and the gate of Q2 is tied to the circuit's common ground through the other 1.5-Ω resistor. This type of bridge circuit offers excellent temperature stability. Q1 operates in an open-gate configuration. The 500-Ω potentiometer balances the null bridge circuit. The 5-kΩ potentiometer and capacitors C1 and C2 help reduce stray 60-Hz pickup and increase the stability of the circuit. The 1-mA meter connected between the drain pins of Q1 and Q2 indicates an electrostatic field. The electroscope requires little current consumption, and therefore, it can be operated from a 9-V transistor-radio battery.

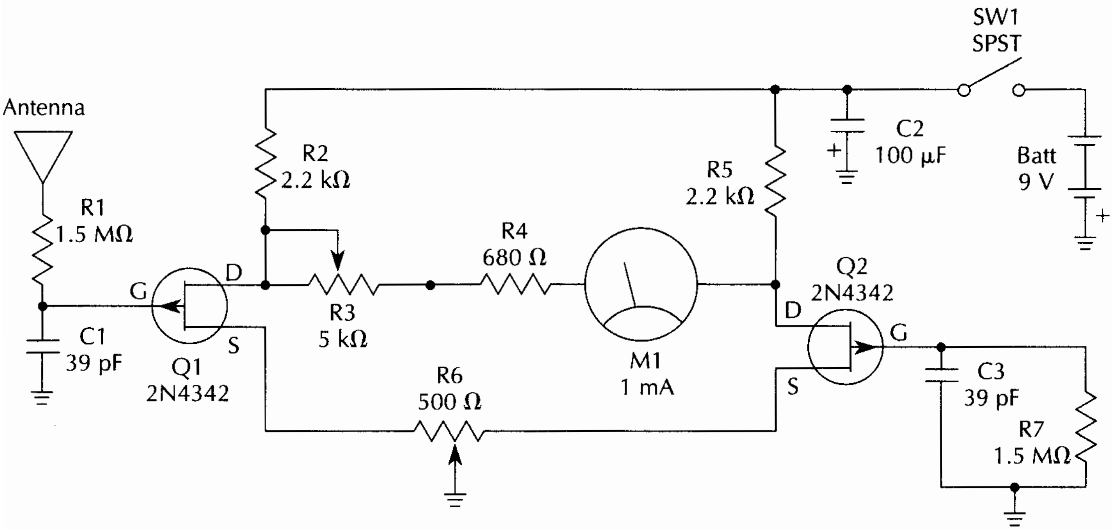

Fig. 1-11 Electroscope.

Electroscope parts list

Quantity	Part	Description
2	R1, R7	1.5-Ω, ¼-W resistor
2	R2, R5	2.2-kΩ, ¼-W resistor
1	R3	5-kΩ, ¼–12-Watt potentiometer
1	R4	680-Ω, ¼-W resistor
1	R6	500-Ω, ¼-Watt potentiometer
2	C1, C3	39-pF, 25-V capacitor
1	C2	100-µF, 25-V electrolytic capacitor
2	Q1, Q2	2N4342 FET
1	M	0–1-mA panel meter
1	SW-1	SPST toggle switch
1	ANT	Telescoping whip antenna
1	BATT	9-V transistor-radio battery

Light/dark switch

The light/dark switch can be used in many sensing or alarm circuits. The light/dark switch shown in Fig. 1-12 can detect an intruder passing through a light beam or a person moving through a normal ambient-light room by keeping the lighting constant. The light/dark detector can also be used as an annunciator to inform you of an approaching customer in a retail store. The circuit can

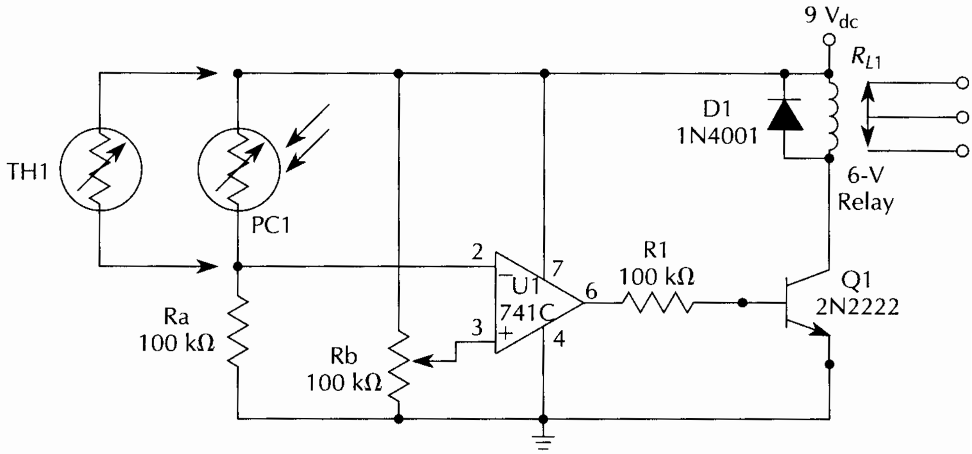

Fig. 1-12 Light/dark detector.

also detect your automobile headlamps as you approach your home and turn on your home's lights. The light/dark sensor can wake you at dawn or start your coffee pot in the morning. You can use the light/dark sensor as the heart of a laser tag game for your children. Various types of light sensors are shown in Fig. 1-13.

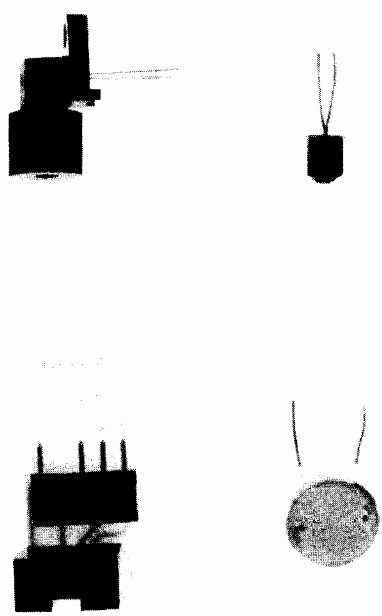

Fig. 1-13 Light detectors.

The light/dark switch uses an LM741 op amp as a comparator. You can substitute an LM339 or any general purpose op-amp pin in this design. The adjustable-threshold detector is controlled by Rb, a 100-kΩ potentiometer. Rb sets the threshold value between the voltage divider of PC1 and Ra, a 100-kΩ resistor. When the light intensity at PC1 is increased, its resistance decreases. This increases the voltage on pin 2 on the op amp's inverting-input pin. When the reference voltage at pin 3 has been exceeded by the input voltage on pin 2, the comparator will present an output on pin 6. The output drives Q1, a 2N2222 transistor, which can be used to drive a small relay. To make your detector more efficient, consider using a black plastic or cardboard tube with the sensor mounted at one end of the tube (see Fig. 1-14). The tube reduces the field of view and helps to prevent unwanted ambient light from reaching the detector. To use the sensor with ambient light as the input source, use a small light tube. To create a "beam type detector" system, use a long light tube. To construct a long-range detector, place a lens in front of the detector inside the light tube. The focal distance is determined by the lens you select. The same light/dark sensor circuit can also sense temperature by using a negative-temperature coefficient thermistor. A room-temperature resistance of 20–50 kΩ is needed for the thermistor. The accuracy of your temperature switch is determined by your selection of components and the method of calibration.

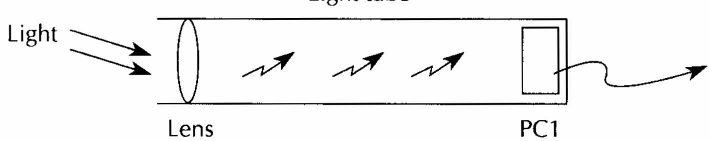

Fig. 1-14 *Light tube.*

A light-detector circuit that detects specific levels of light is shown in Fig. 1-15. When the light level goes above or below the desired set values, the window comparator circuit activates a low-current relay, which can be connected to an alarm buzzer. The window comparator circuit uses two sections of an LM339 op amp to act as a specific-level light detector. R1 and R3 are the high/low-value potentiometers. The op-amp outputs are wired

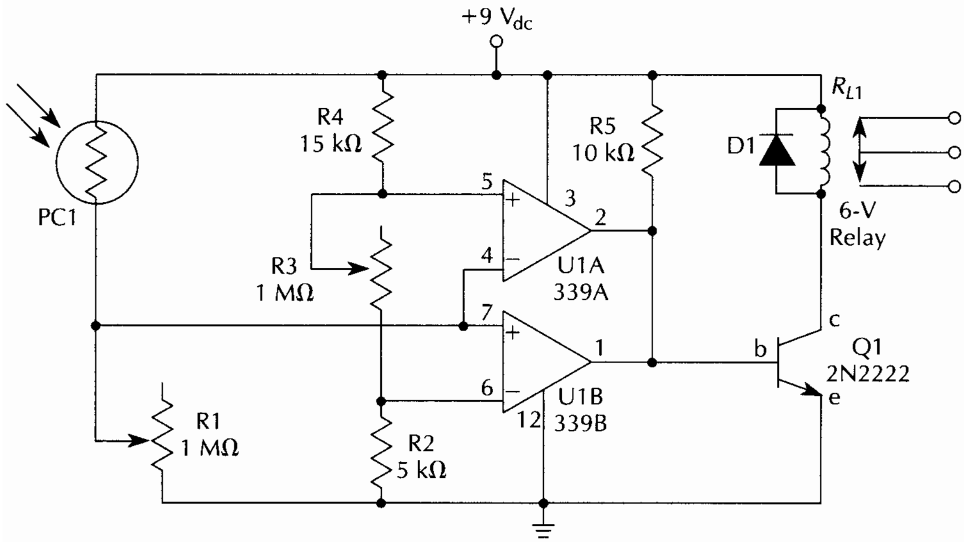

Fig. 1-15 Light-level detector.

together and drive a 2N2222 transistor, which can drive a low-current relay. The comparator circuit can be powered by a 9 to 12-V power source or a common 9-V battery, if desired. Simply adjust R1 and R3 to the set-point values so that the relay pulls in when the light level at PC1 is above or below the desired value.

Light/dark detector parts list

Quantity	Part	Description
1	TH1	Thermistor
1	PC1	Cadmium photoresistive cell
3	RA, RB, R1	100-kΩ, ¼-W resistor
1	D1	1N4001 silicon diode
1	Q1	2N2222 pnp transistor
1	U1	UA741C op amp
1	RY-1	6-V SPST relay

Light-level detector parts list

Quantity	Part	Description
2	R1, R3	1-MΩ potentiometer (trim)
1	R2	5-kΩ, ¼-W resistor
1	R5	10-kΩ, ¼-W resistor
1	R4	15-kΩ, ¼-W resistor