

The Alarm, Sensor & Security Circuit Cookbook

Thomas Petruzzellis

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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 trans-

mitter 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.

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,

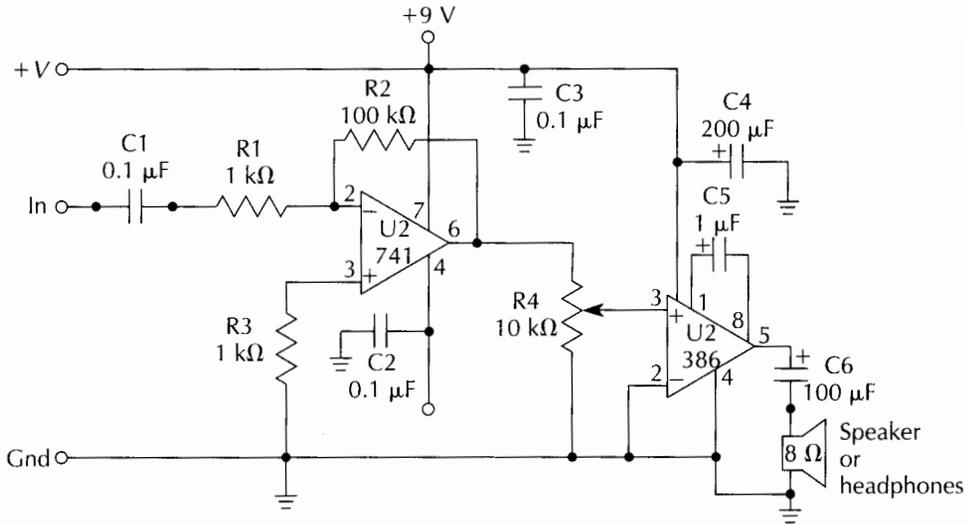


Fig. 1-1 High-gain amplifier.

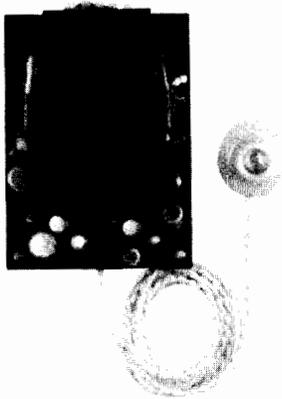


Fig. 1-2 Microphone and high-gain amplifier.

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.

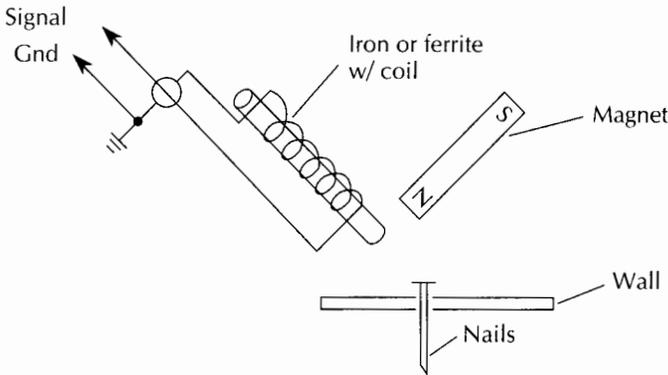
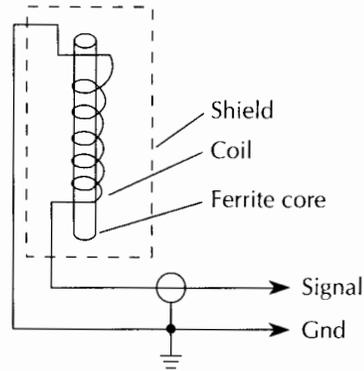


Fig. 1-4 Metal detector.

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.

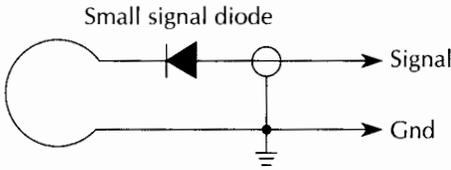


Fig. 1-5 rf detector.

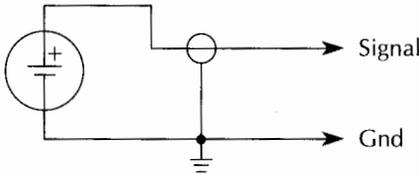


Fig. 1-6 Light detector.

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.

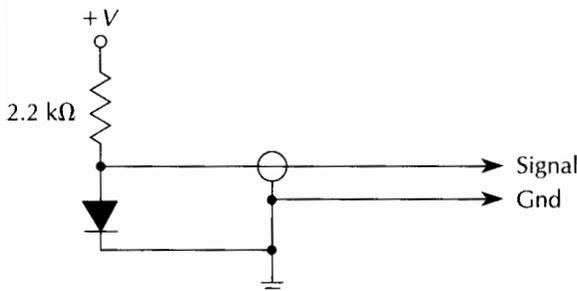


Fig. 1-7 Radiation detector.

High-gain amplifier parts list

Quantity	Part	Description
2	R1, R3	1-k Ω , ¼-W resistor
1	R2	100-k Ω , ¼-W resistor
1	R4	10-k Ω potentiometer, ½W
3	C1, C2, C3	0.1- μ F, 25-V capacitor
1	C5	1- μ F, 25-V capacitor
1	C6	100- μ F, 25-V electrolytic capacitor
1	C4	200- μ F, 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.

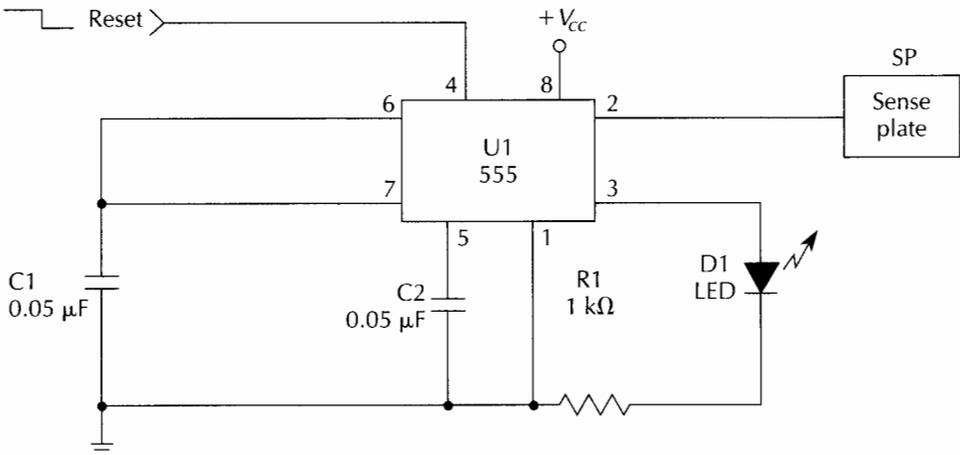


Fig. 1-8 Touch switch—manual reset.

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.

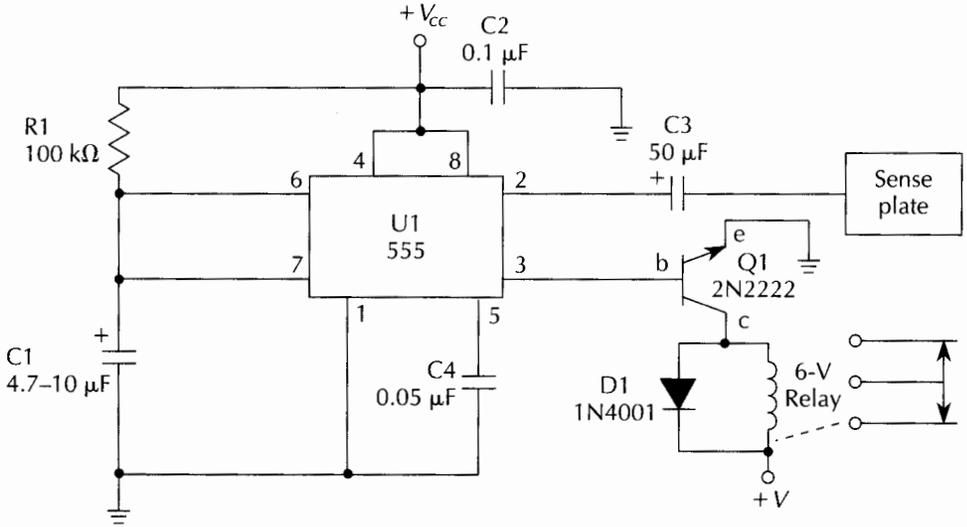


Fig. 1-9 Touch switch.

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-k Ω , ¼-W resistor
2	C1, C2	0.5- μ F, 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-k Ω , ¼-W resistor
1	C1	4.7–10- μ F, 25-V electrolytic capacitor
1	C2	0.1- μ F, 25-V capacitor
1	C4	0.05- μ F, 25-V capacitor (disk)
1	C3	50- μ F, 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.

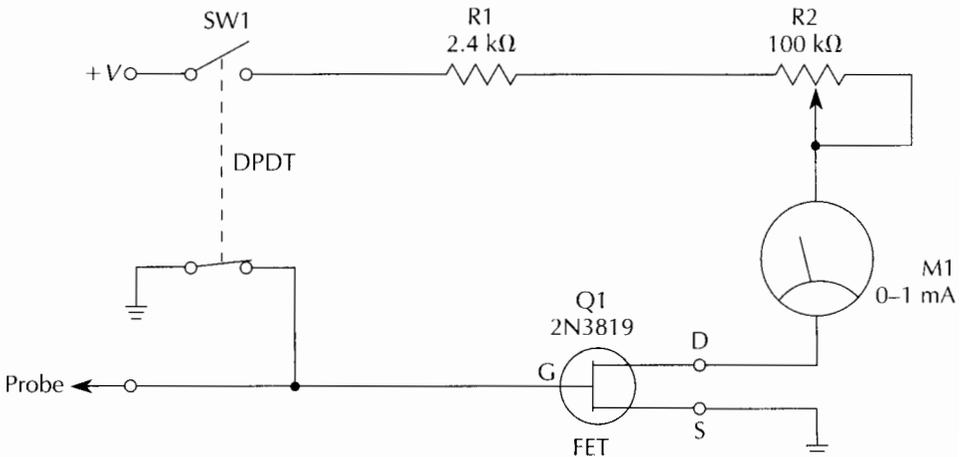


Fig. 1-10 Static-electricity detector.

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-k Ω , ¼-W resistor
1	R2	100-k Ω , 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-k Ω 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.

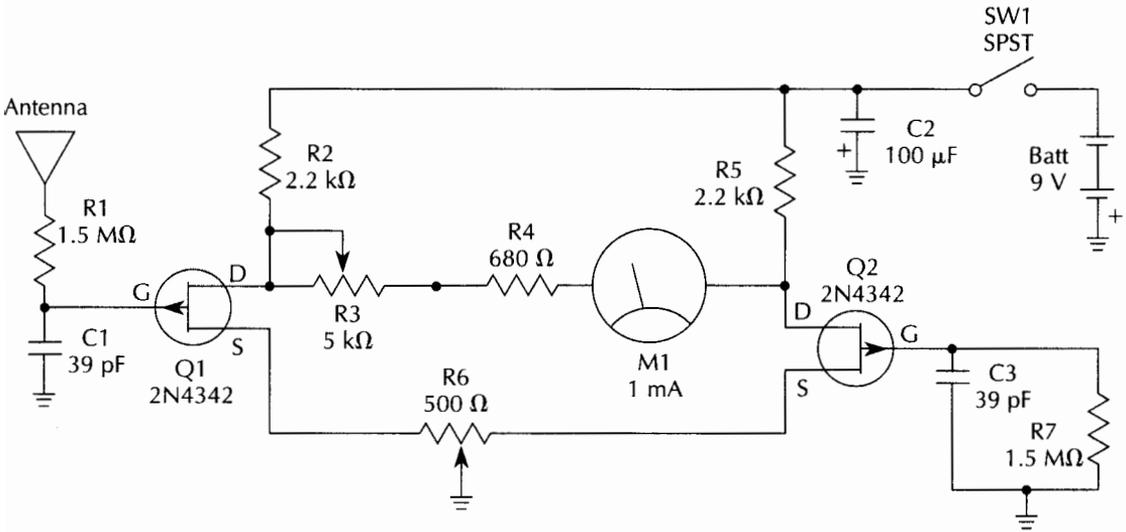


Fig. 1-11 Electroscope.

Electroscope parts list

Quantity	Part	Description
2	R1, R7	1.5- Ω , $\frac{1}{4}$ -W resistor
2	R2, R5	2.2-k Ω , $\frac{1}{4}$ -W resistor
1	R3	5-k Ω , $\frac{1}{4}$ -12-Watt potentiometer
1	R4	680- Ω , $\frac{1}{4}$ -W resistor
1	R6	500- Ω , $\frac{1}{4}$ -Watt potentiometer
2	C1, C3	39-pF, 25-V capacitor
1	C2	100- μ F, 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

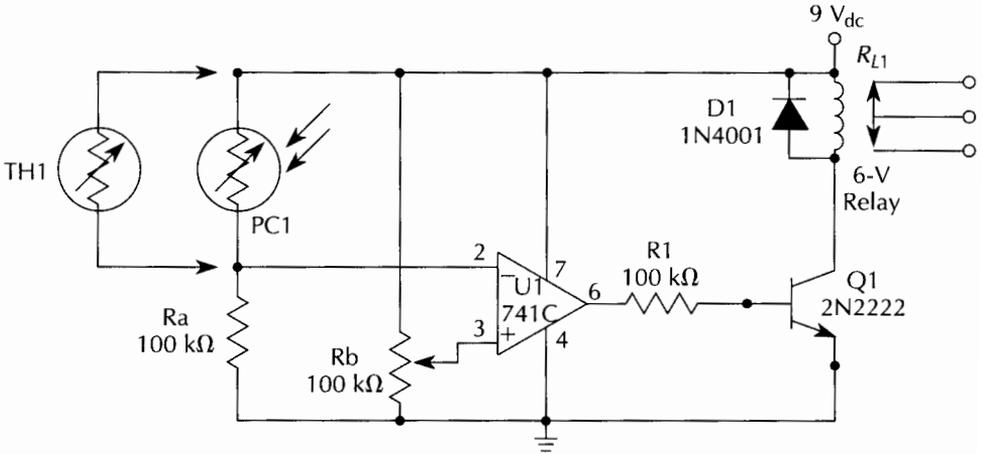


Fig. 1-12 Light/dark detector.

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.

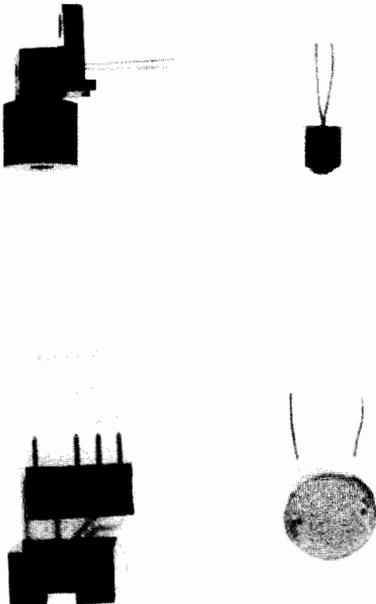


Fig. 1-13 Light detectors.

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-k Ω potentiometer. Rb sets the threshold value between the voltage divider of PC1 and Ra, a 100-k Ω 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 k Ω is needed for the thermistor. The accuracy of your temperature switch is determined by your selection of components and the method of calibration.

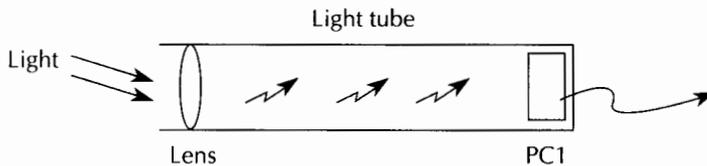


Fig. 1-14 Light tube.

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

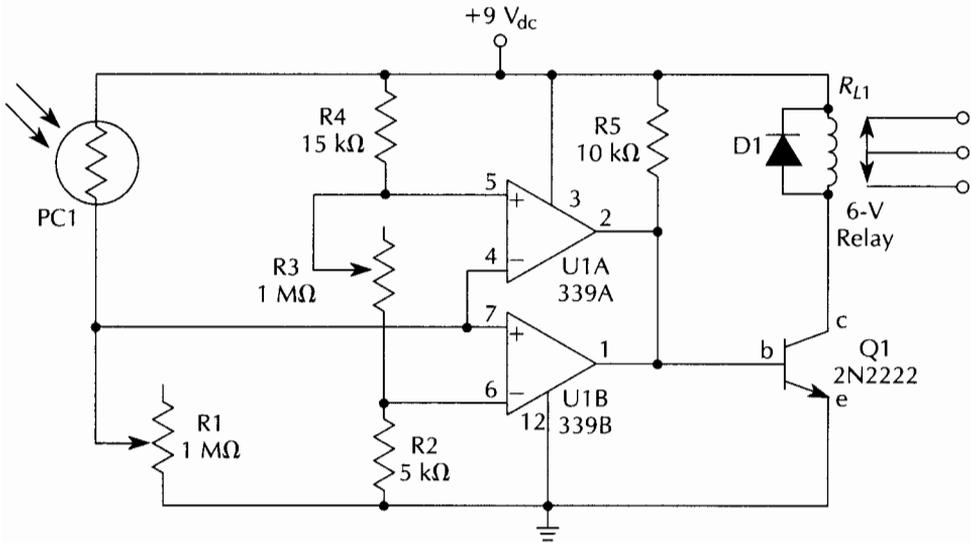


Fig. 1-15 Light-level detector.

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

1	PC1	Cadmium photoresistive cell
1	D1	1N4001 silicon diode
1	Q1	2N2222 pnp transistor
1	U1	LM339A comparator IC
1	RY-1	6-V SPST relay

Temperature sensors

The need to measure temperature often arises and temperature sensing has become easy with many new precision temperature sensors. Figures 1-16 and 1-17 illustrate a number of thermistors and thermocouples. The LM34 is a precision Fahrenheit temperature-sensing IC and the LM35 is a precision centigrade temperature sensor. Both sensors require no external calibration and have accuracies of better than $\pm 1.2^\circ$ at room temperature. The LM34/35 draws only $70 \mu\text{A}$ and has a low output impedance. Both sensors operate from 5 to $30 V_{\text{dc}}$.

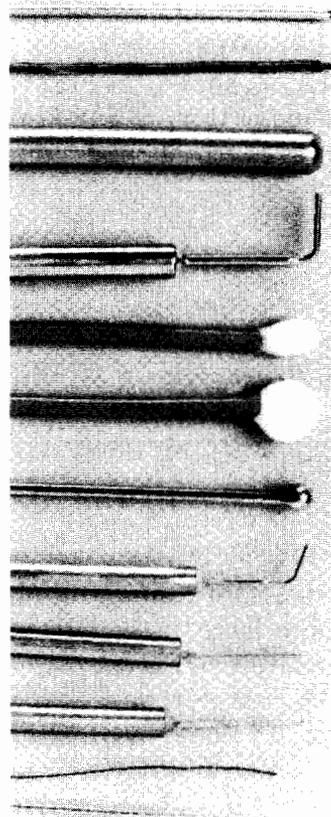


Fig. 1-16 Thermistors.

good thermal-transfer characteristics to bond the sensor to the heat-source surface.

Figure 1-21 depicts how the LM34/35 temperature sensors could be connected to a personal computer via a parallel data input. An LM34 is connected to a signal conditioner, such as a 75- Ω resistor and 1- μ F capacitor. An op amp sets up a voltage reference to the A/D converter, an ADC0804 8-bit A/D chip. A parallel data stream and the control signals \overline{CS} , \overline{RD} , \overline{WR} , and \overline{INTR} are sent to the computer.

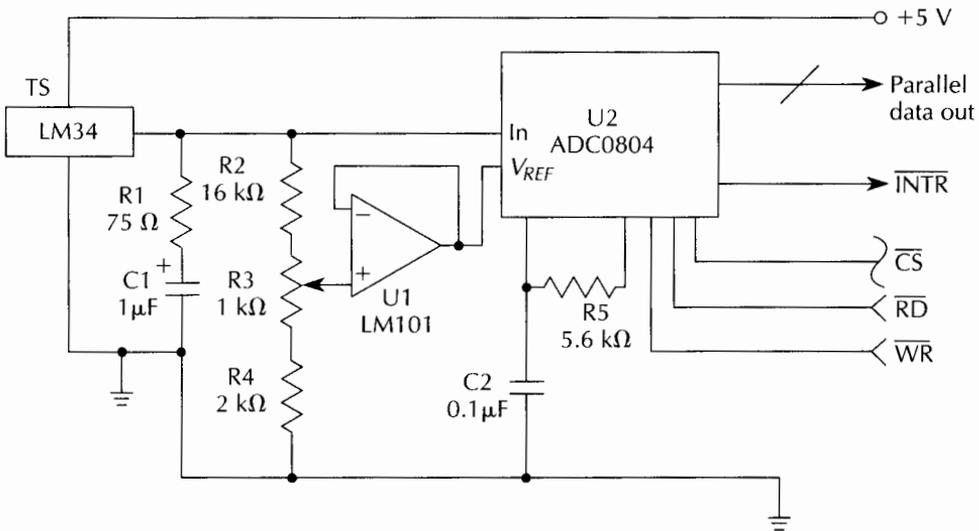


Fig. 1-21 Computer interface for temperature sensor.

Next, a high-precision temperature sensor, an LM135, operates as a zener diode. The LM135 has a breakdown voltage directly proportional to absolute temperature 10 mV/ $^{\circ}$ K. The device has a 1- Ω impedance and operates from 400 μ A to 5 mA with less than 1 $^{\circ}$ C error over a 100 $^{\circ}$ C range. The low output impedance and linear output make this detector a good choice for temperature-sensing applications (see Fig. 1-22).

Calibration of the LM135 requires a 10-k Ω potentiometer placed across the sensor, as shown in Fig. 1-19. The calibration voltage should be 2.98 V at 25 $^{\circ}$ C.

The last example of a temperature sensor circuit uses the LM335 precision temperature sensor, which is coupled to an LM311 op amp via pin 3. A voltage reference and adjustment is

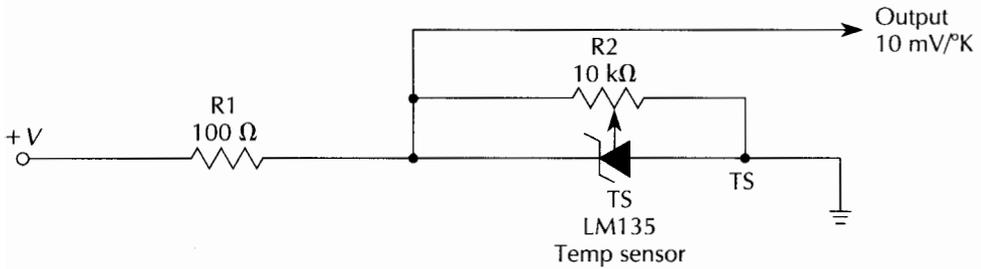


Fig. 1-22 Adjustable temperature sensor.

set up using an LM329 electronic zener diode and a 10-k Ω potentiometer connected to pin 2 of the IC (see Fig. 1-23). The output of the LM311 is then coupled to an LM395 power npn transistor, which can drive a heating element or motor. Further application assistance can be obtained by calling National Semiconductor at 1-800-272-9959.

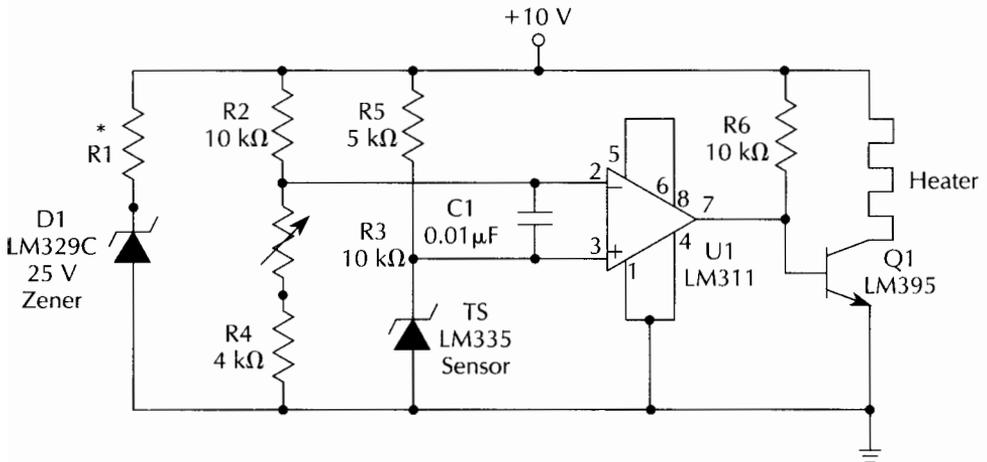


Fig. 1-23 Temperature-controlled heater.

Temperature sensor parts list

Quantity	Part	Description
1	TS	LM34 temperature sensor (National Semiconductor)
1	R1	10-k Ω , 1/4-W potentiometer
1	M	100- μ A panel meter

Extended-range temperature sensor parts list

Quantity	Part	Description
1	TS	LM34 temperature sensor (National Semiconductor)
1	R1	2-k Ω , ¼-W resistor
1	R2	10-k Ω , ¼-W resistor
1	R3	260-k Ω , ¼-W resistor
1	D1	2.5-V sensor diode
1	M	0–100-mA panel meter

Computer interface for temperature sensor parts list

Quantity	Part	Description
1	TS	LM34 temperature sensor
1	R1	75- Ω , ¼-W resistor
1	R2	16-k Ω , ¼-W resistor
1	R3	1-k Ω , ¼–½-W potentiometer
1	R4	2-k Ω , ¼-W resistor
1	R5	5.6-k Ω , ¼-W resistor
1	C2	0.1- μ F, 25-V capacitor
1	C1	1- μ F, 25-V capacitor
1	U1	LM101 op amp
1	U2	ADC0804 A/D converter (National Semiconductor)

Adjustable temperature sensor parts list

Quantity	Part	Description
1	R1	100- Ω , ½-W resistor
1	R2	10-k Ω , ½-W potentiometer
1	TS	LM135 temperature sensor (National Semiconductor)

Temperature-controlled heater parts list

Quantity	Part	Description
1	TS	LM335 temperature sensor (National Semiconductor)
1	R1	100–500- Ω , ½-W resistor
1	R2	10-k Ω , ½-W resistor
1	R3	10-k Ω , ½-W potentiometer
1	R4	4-k Ω , ½-W resistor
1	R5	5-k Ω , ½-W resistor

1	C1	0.01- μ F, 25-V capacitor (disk)
1	D1	LM329C zener diode (National Semiconductor)
1	Q1	LM395 transistor (National Semiconductor)
1	H	Heater coil

Hall-effect metal/magnetic sensors

The Hall-effect sensor can detect the presence or absence of magnets or metal surfaces and can solve a number of measurement and alarm problems. We will illustrate some of these applications. Three different types of Hall-effect sensor are presented. Hall-effect sensors can be used for tilt switches, counters, proximity detectors, metal detectors, pressure sensors, current sensors, and gaussmeters.

A basic low-cost Hall-effect sensor is the Sprague UGN3020T, shown in Fig. 1-24. This sensor includes a Hall cell, voltage regulator, signal amplifier, and Schmitt trigger. The circuit shown can protect instruments, antiques, or windows/doors by placing a small magnet on the item you wish to protect. The sensor is then placed in close proximity to the magnet. When the magnet is moved past the sensor, an output activates a relay. The sensor drives a 2N5812 transistor for an on-off type output. A DPST relay could be used to sound a local alarm, or the circuit could be con-

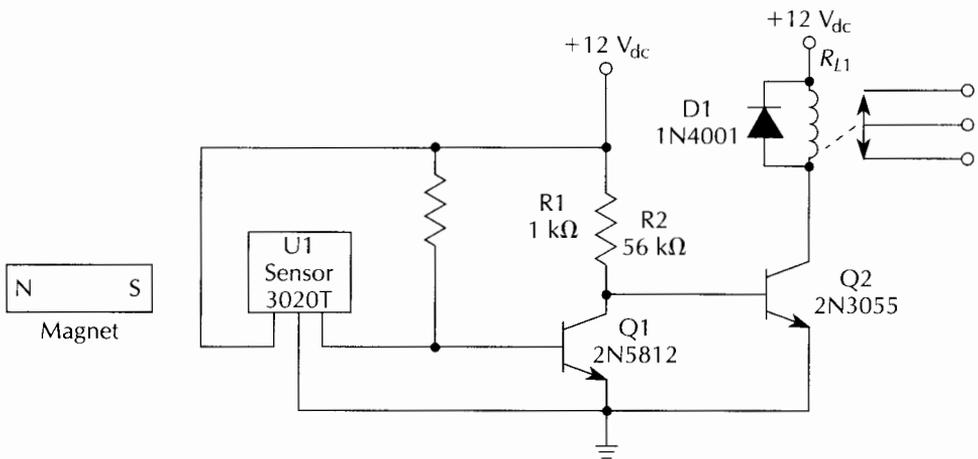


Fig. 1-24 Hall-effect switch.

nected to a central alarm panel. The same basic Hall sensor could be used for counting moving objects or as a wind-speed indicator.

The diagram in Fig. 1-25 depicts an ac Hall switch that can control 115-V_{ac} loads such as motors and lamps, upon detecting the presence or absence of a magnet. The Sprague UGN3501T Hall sensor is more flexible because it provides an analog output. The 3501T Hall sensor is a single-ended output device, which can sense small changes in a magnetic field. The 3501T includes a Hall cell, linear amplifier, emitter-follower output, and a regulator.

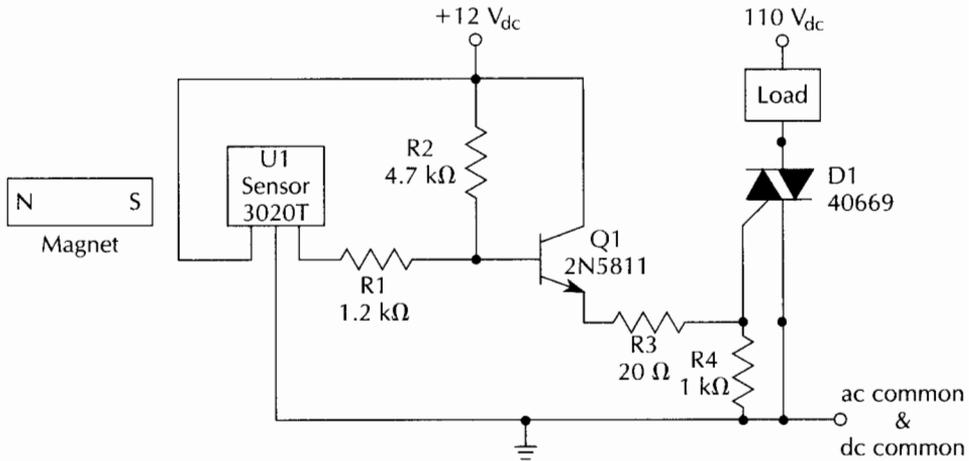


Fig. 1-25 Hall-effect ac switch.

A ferrous metal detector, shown in Fig. 1-26, can detect metal objects passing the sensor. A magnet is placed with its north pole facing the 3501T sensor. As a metal object passes the detector assembly, the signal is amplified by an LM741C op amp. The output drives a relay. This detector circuit can be used for sensing or counting metal parts, as well as pressure sensing. The output is linear and can provide a continuous display output. The 3501T sensor can also detect the absence of metal objects, as shown in Fig. 1-27. The 3501T can also be used for a tilt-angle sensor, as well as a vibration sensor.

The next Hall-effect sensor is the UGN3501M, which is ideal for accurately measuring and controlling current, velocity, position, weight, and thickness. The UGN3501M is a linear differential-type sensor that includes a Hall cell, a differential amplifier, an emitter follower, and a regulator. Figure 1-28 illustrates a cur-

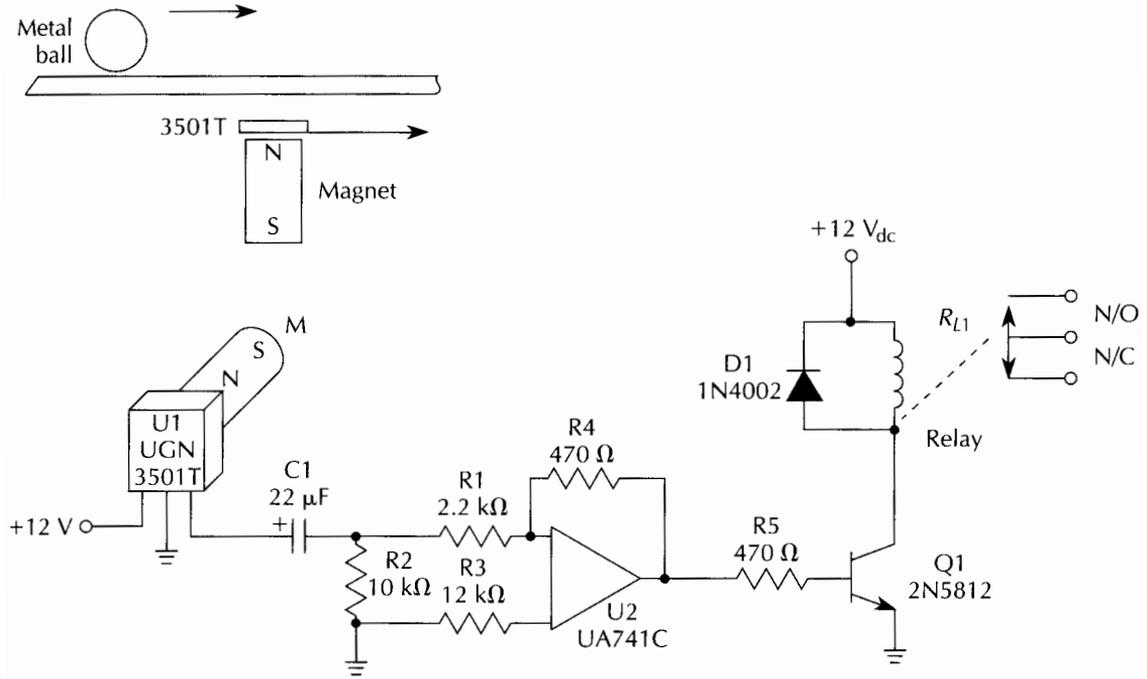


Fig. 1-26 Hall-effect metal-presence switch.

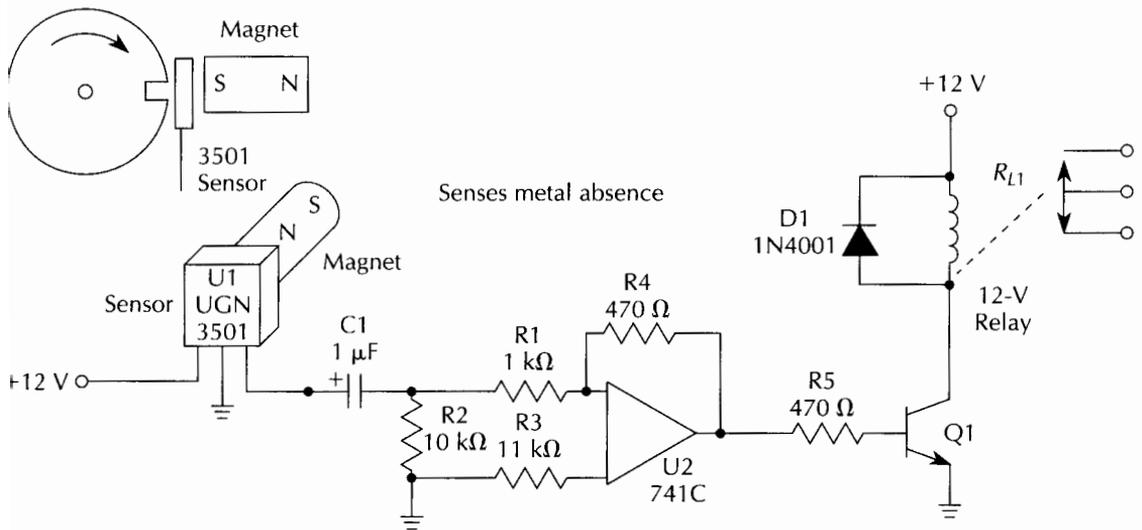


Fig. 1-27 Hall-effect metal-absence switch.

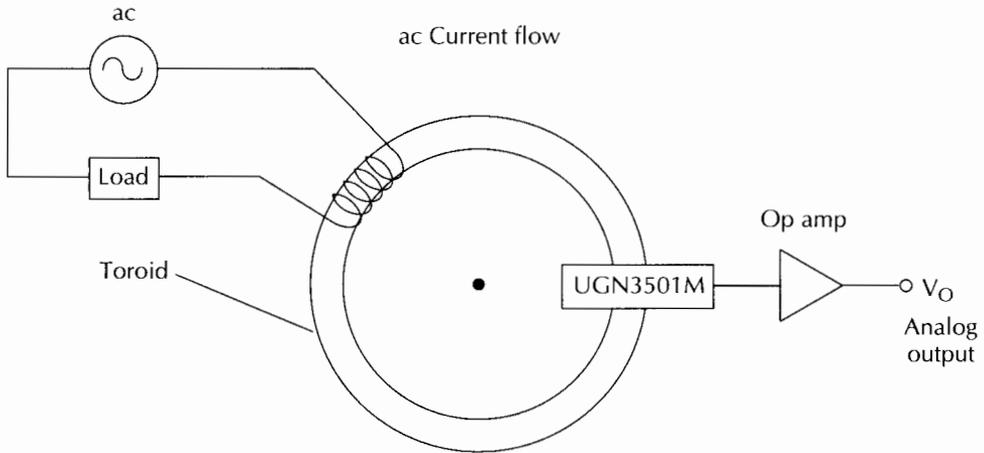


Fig. 1-28 Current-sensing Hall-effect sensor.

rent-measurement circuit using the UGN3501M sensor. A wire carrying ac current connected in series with a load is wrapped around a toroid. A UGN3501M sensor is placed on the toroid and its output drives a 741 op amp. The resultant output can indicate the varying current when connected to a current meter, or the signal could be applied to an analog-to-digital (A/D) converter card in a personal computer. The differential sensor can also be used as a basic gaussmeter, as shown in Fig. 1-29. As the magnetic field is moved closer to the Hall sensor, an output can be displayed on a voltmeter. A 200- Ω potentiometer zeros the cir-

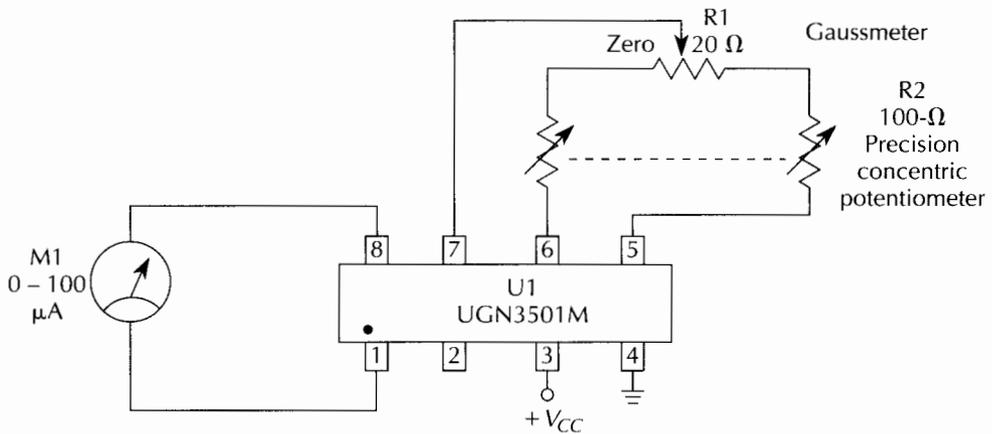


Fig. 1-29 Gaussmeter.

cuit. This simple gaussmeter is suited to many ac field applications and can be constructed quite inexpensively.

The output of the gaussmeter is on pin 3 and pin 1 of the UGN3501M. The output could also drive an op amp such as an LM741, which will amplify the output of the sensor. A pressure sensor could be fabricated by attaching a linear Hall-effect sensor to a magnet, as shown in Fig. 1-30. As the metal disk travels toward the sensor, a proportional pressure output is displayed. A pressure sensor of this type would be used in a nonmetallic tank or vessel. The linear Hall-effect sensor can also be used for an analog tilt indicator or vibration sensor.

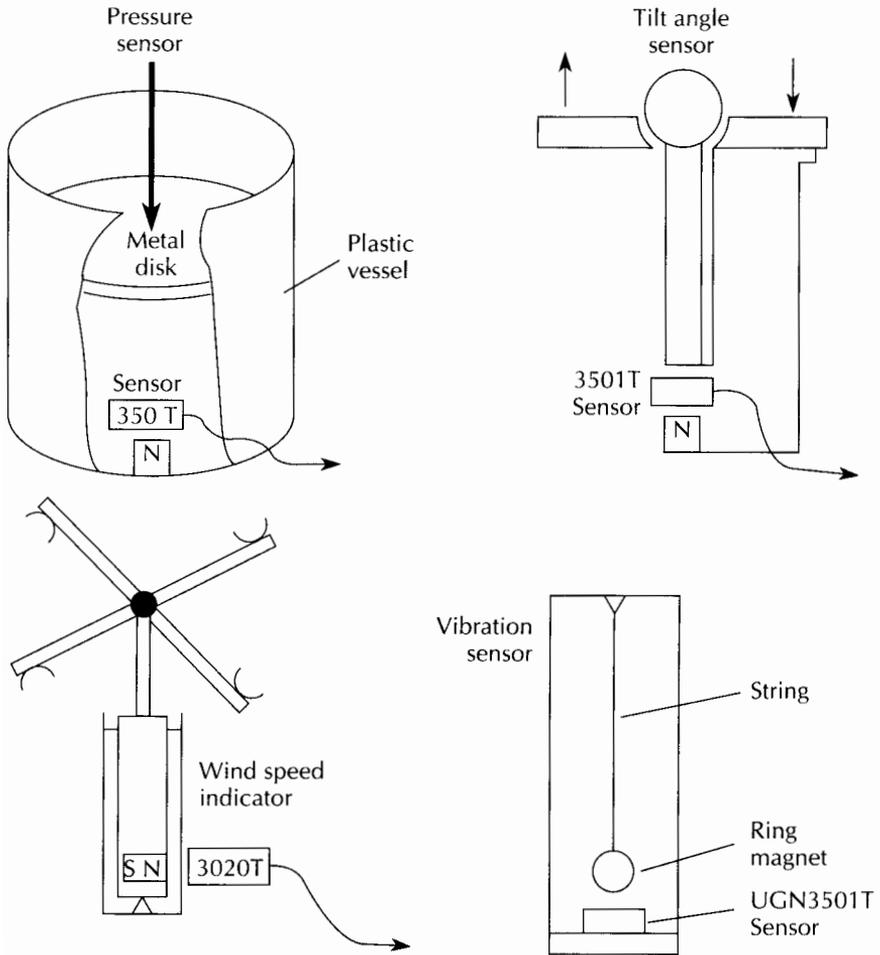


Fig. 1-30 Hall-effect sensor applications.

The Hall-effect sensor can be used in many applications in self-contained systems, or the sensor outputs can be connected to a central alarm panel, such as in a security system.

Hall-effect switch parts list

Quantity	Part	Description
1	R1	1-k Ω , ¼-W resistor
1	R2	56- Ω , ¼-W resistor
1	D1	1N4001 silicon diode
1	Q1	2N5812 transistor
1	Q2	2N3055 transistor
1	U1	UGN3120 Hall cell (Allegro Microsystems)
1	RY-1	9–12-V relay
1	MAGNET	Bar or cylinder magnet

Hall-effect ac switch parts list

Quantity	Part	Description
1	R1	1.2-k Ω , ¼-W resistor
1	R2	4.7-k Ω , ¼-W resistor
1	R3	120- Ω , ¼-W resistor
1	R4	1-k Ω , ¼-W resistor
1	Q1	2N5811 transistor or equivalent
1	D1	40669 triac
1	U1	UGN3120 Hall switch (Allegro Microsystems)

Hall-effect metal presence switch parts list

Quantity	Part	Description
1	R1	2.2-k Ω , ¼-W resistor
1	R2	10-k Ω , ¼-W resistor
1	R3	12-k Ω , ¼-W resistor
1	R4	470-k Ω , ¼-W resistor
1	R5	470- Ω , ¼-W resistor
1	C1	22- μ F, 25-V electrolytic capacitor
1	D1	1N4002 silicon diode
1	Q1	2N5812 transistor
1	U1	UGN3503 5-V Hall cell (Allegro Microsystems)
1	U1	UGN3501 12-V Hall cell (Allegro Microsystems)

1	U2	UA741 op amp
1	RY-1	5–12-V relay
1	MAGNET	Bar or cyclinder magnet

Hall-effect metal absence switch parts list

Quantity	Part	Description
1	R1	1-k Ω , ¼-W resistor
1	R2	10-k Ω , ¼-W resistor
1	R3	11-k Ω , ¼-W resistor
1	R4	470-k Ω , ¼-W resistor
1	R5	470- Ω , ¼-W resistor
1	C1	1- μ F, 25-V capacitor
1	Q1	2N5812 transistor or equivalent
1	U1	UGN3501 12-V Hall cell (Allegro Microsystems)
1	U1	UGN3503 5-V Hall cell (Allegro Microsystems)
1	U2	UA741C op amp
1	D1	1N4001 silicon diode
1	RY-1	5–12-V SPST relay
1	MAGNET	Bar or cylinder magnet

Gaussmeter parts list

Quantity	Part	Description
1	R1	20- Ω , ¼-W resistor
1	R2	100- Ω , precision concentric potentiometer
1	U1	UGN350M Hall cell (Allegro Microsystems)
1	M	0–100- μ A panel meter

ac-magnetic field detector

A magnetic field detector is a sensitive indicator of a moving or dynamic ac field. This detector might be of interest if you are concerned about radiation from magnetic fields for safety reasons. The magnetic field detector is shown in Fig. 1-31. The detector can also indicate if a relay is energized or if a high-voltage transformer is operating. Any device with a transformer may be detected readily. The ac-magnetic field detector measures a single-axis field. Therefore, position the detector in each desired axis or build two similar coils and either switch them into the circuit or build three display units to monitor all three axes at once.

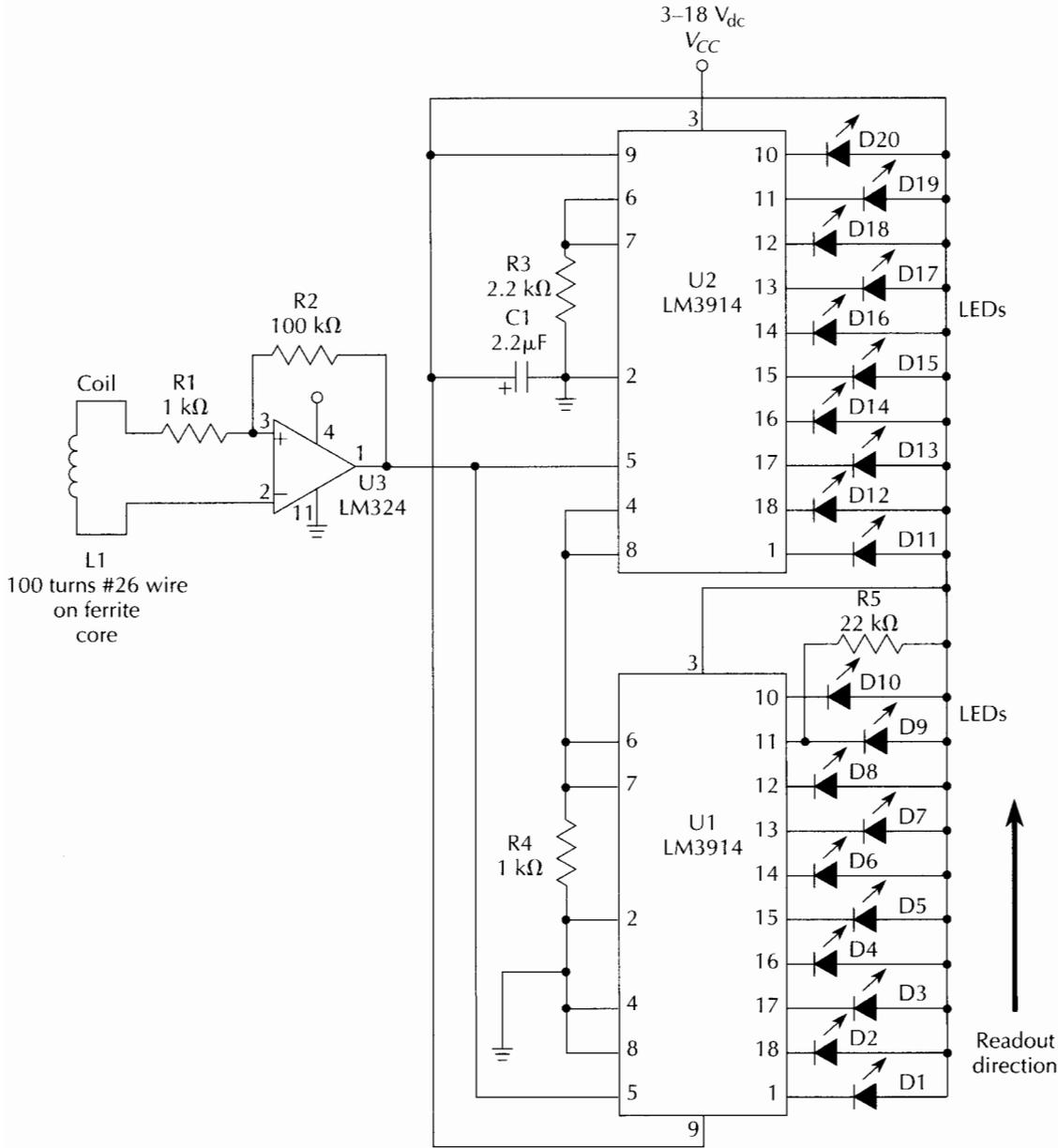


Fig. 1-31 Bar-graph ac magnetic field detector.

The experimental field detector begins with a sense coil. The sense coil consists of 100–200 turns of 28-gauge enameled wire wound on a plastic form covered with aluminum foil and placed inside a plastic film container. The coil is coupled to an LM324 op

amp via a 1-k Ω resistor. A 100-k Ω feedback resistor is connected between pins 1 and 3. By switching in different feedback resistors, various sensitivity ranges can be selected. The heart of the ac field meter is two LM3914 DOT/BAR display driver chips, wired so that the first chip drives the second one for a 20-LED sequential display. Two 10-position LED display packages can simplify construction. The LM324 was used because it is a single-supply device. Power is applied to pins 4 and ground to pin 11. The gaussmeter can be powered by a 9-V transistor battery.

Calibration of the ac field meter is accomplished by connecting an ac milliammeter, an 8.2 V_{ac} transformer, and a 100- Ω potentiometer in series with a calibration coil. A calibration coil consists of 110 turns of 26-gauge enameled wire. The sensor coil is placed inside the calibration coil. The calibration formula is: gauss equals turns per meter times the ac amperes of coil current. Then, coil amperes equals gauss divided by the number of turns per meter, multiplied by 20. For example, 110 turns \times 20 = 2,200 turns per meter. (Note: a 5-cm coil is 5% of a meter.) Now, 2,200 turns per meter times the ac current in milliamperes equals the field in gauss. The gaussmeter can detect the presence of magnets, but, since it is not a moving field, you have to sweep the magnet or the coil past each other to see an indication.

Bar-graph ac-magnetic-field meter parts list

Quantity	Part	Description
2	R1, R4	1-k Ω , 1/4-W resistor
1	R2	100-k Ω , 1/4-W resistor
1	R3	2.2-k Ω , 1/4-W resistor
1	R5	22-k Ω , 1/4-W resistor
1	C1	2.2- μ F, 25-V electrolytic capacitor
1	L1	100 turns 26-gauge enameled wire on ferrite core
2	U1, U2	LM3914 display drive ICs
20	D1-D20	Red LEDs

Bridge sensors

A bridge circuit measures the electrical property of a circuit element indirectly by comparing against a known similar element. The two primary ways of operating a bridge circuit are as a null detector and as a device that directly reads a voltage or current.

Null detectors are primarily used in feedback systems involving electromechanical movement. These systems seek to force the active resistive element, such as a thermistor or strain gauge which is connected to a mechanically coupled potentiometer, to balance the bridge. The null is independent of the excitation voltage.

A basic bridge is shown in Fig. 1-32, and illustrates a null condition when $R1/R4 = R2/R3$. Figure 1-33 shows a bridge with all resistors equal, but one of them, R1, is a variable active sensing element, such as thermistor or light-sensitive resistor.

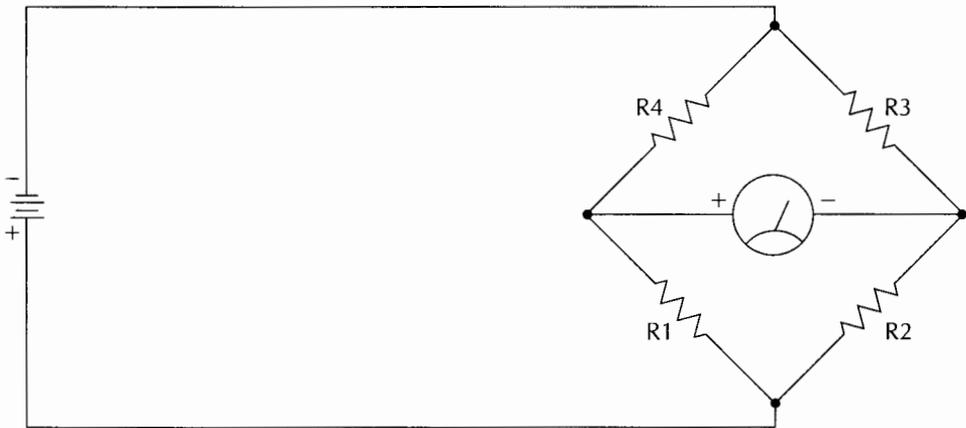


Fig. 1-32 Simple dc bridge circuit.

The sensitivity of a bridge is the ratio of the excitation voltage to the maximum change in the output of the circuit. The sensitivity can be doubled if two identical variable elements are used in positions R1 and R3, as shown in Fig. 1-34. An example would be two identical strain-gauge resistive-type sensors aligned in a single pattern. The resultant output would be double.

A special doubling configuration is shown in Fig. 1-35, which consists of four variable resistive sensor elements. Two of the elements increase, i.e., R1 and R3, as the other two elements, R2 and R4, decrease in the same ratio. Two identical two-element strain gauges or sensors are attached to opposite faces of a thin carrier or substrate to measure its bending properties. The output of such a bridge arrangement would be four times the output of a single-element sensor. The complementary resistance changes would result in a linear output.

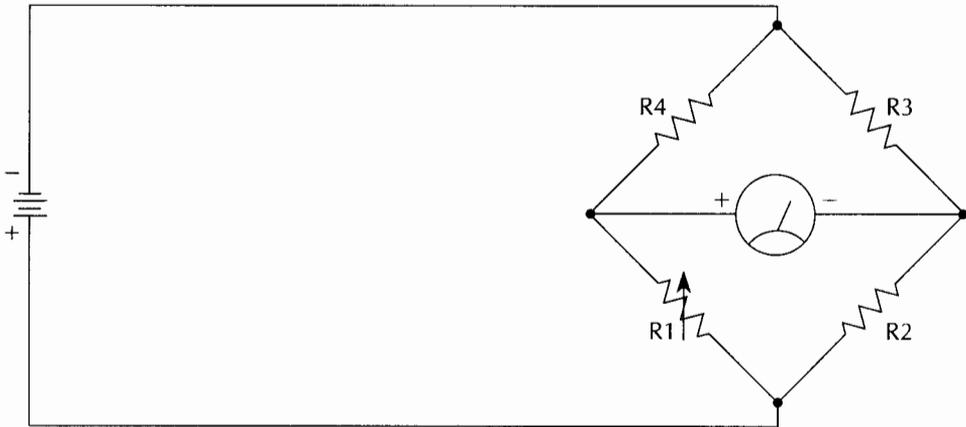


Fig. 1-33 Single variable dc bridge.

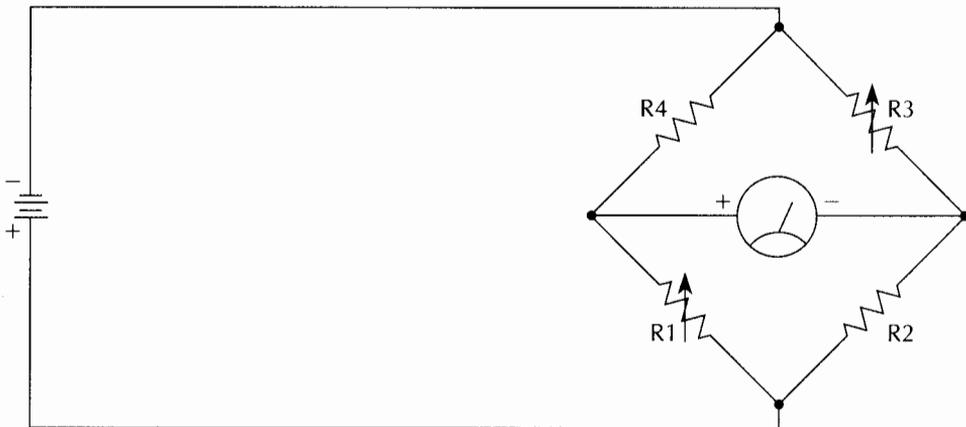


Fig. 1-34 Dual variable dc bridge.

Most instrumentation systems rely on a form of the basic bridge circuit to monitor all types of physical phenomena, using light-sensitive resistors, RTD sensors, and pressure, strain, and flow sensors. Many precision instrumentation systems utilize a precision op amp or chopper-stabilized amplifier. The output of the op amp can be directed to a digital panel meter or an A/D converter card inside a personal computer.

A precision instrumentation bridge circuit is shown in Fig. 1-36. A resistive sensor, R_4 , unbalances the bridge, producing a

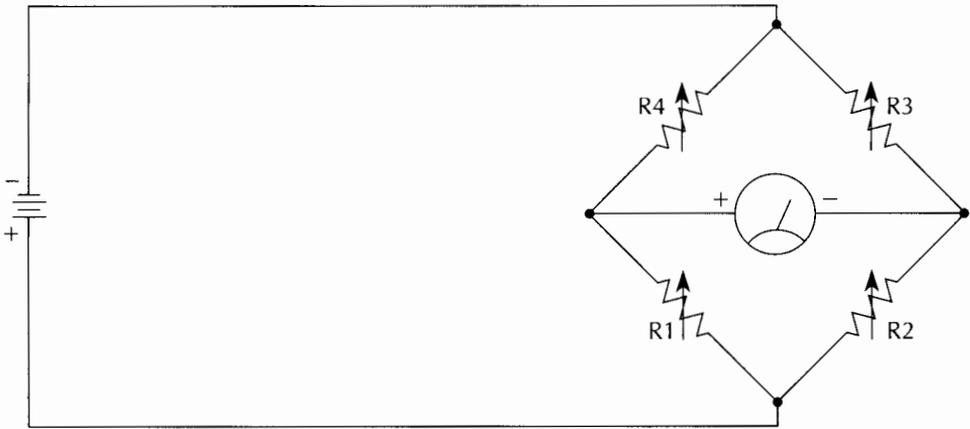


Fig. 1-35 Quad variable dc bridge.

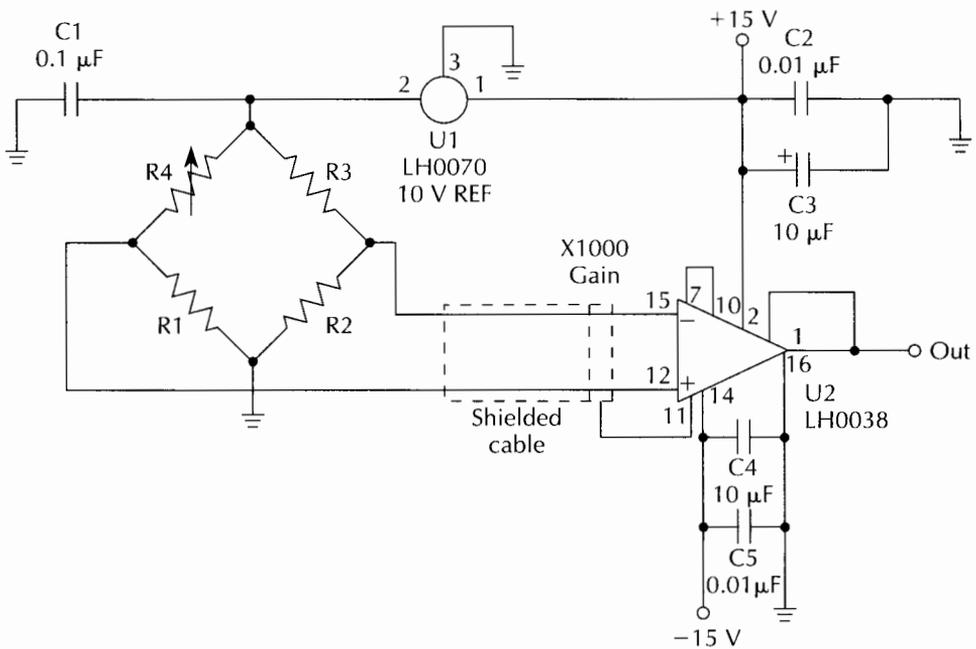


Fig. 1-36 Instrumentation-grade bridge circuit.

tiny output that is coupled to a National Semiconductor LH0038 three-stage precision instrumentation-amplifier chip with internal gain resistors. The amplifier has a gain factor up to 2000. A 10-V reference produced from the LH0070 is applied to the bridge to provide an accurate source voltage or reference. The system has

excellent common-mode rejection and can be used in precision measuring applications. A shielded cable should be used when connecting the sensor if it is not located near the electronics. Any resistive-type sensor could be substituted for a strain gauge, such as a pressure sensor or light-detection circuits. The bridge amplifier is used in many precision measurement circuits, including seismology, water/resource management, ballistics, etc.

Instrumentation-grade bridge amplifier parts list

Quantity	Part	Description
3	R1, R2, R3	10-k Ω , 1/4-W resistor
1	R4	10-k Ω resistive sensor
2	C2, C5	0.01- μ F, 25-V capacitor (disk)
1	C1	0.1- μ F, 25-V capacitor
2	C3, C4	10- μ F, 25-V electrolytic capacitor
1	U1	LH0070 10-V reference (National Semiconductor)
1	U2	LH0038 instrumentation amplifier

Maxwell bridge

The basic bridge circuit is not limited to resistive dc circuits. A device called the Maxwell bridge can measure an unknown capacitance or inductance. A Maxwell bridge is shown in Fig. 1-37. IC1 and IC2 form an oscillator that can be made to oscillate between 1 and 10-kHz. A small 3:1 ratio transformer couples the drive circuit to the measuring circuit. An unknown coil value can be determined by placing the coil at LX. The value of an unknown capacitor can be measured by connecting the capacitor to A and B.

Generally, an analog meter would be connected to points x and y as shown. The null value can then be determined on the meter. Calibration is performed with RA and RB. A null or fine tuning is then accomplished with potentiometer R3.

We can construct a metal detector or automobile/truck sensor with this bridge. A coil or pickup device can be constructed by winding 75 to 100 turns of 26-gauge enameled wire, random wound on a 1-foot square coil form. The coil should be constructed so that it is protected from the elements, because it is intended to be buried in a driveway. Connect an LM311 comparator, as shown, to points x and y. The LM311 is coupled to a 2N3904 npn transistor, which can drive a small relay (Radio Shack 275-240). After connecting the coil, a null first must be obtained by ad-

