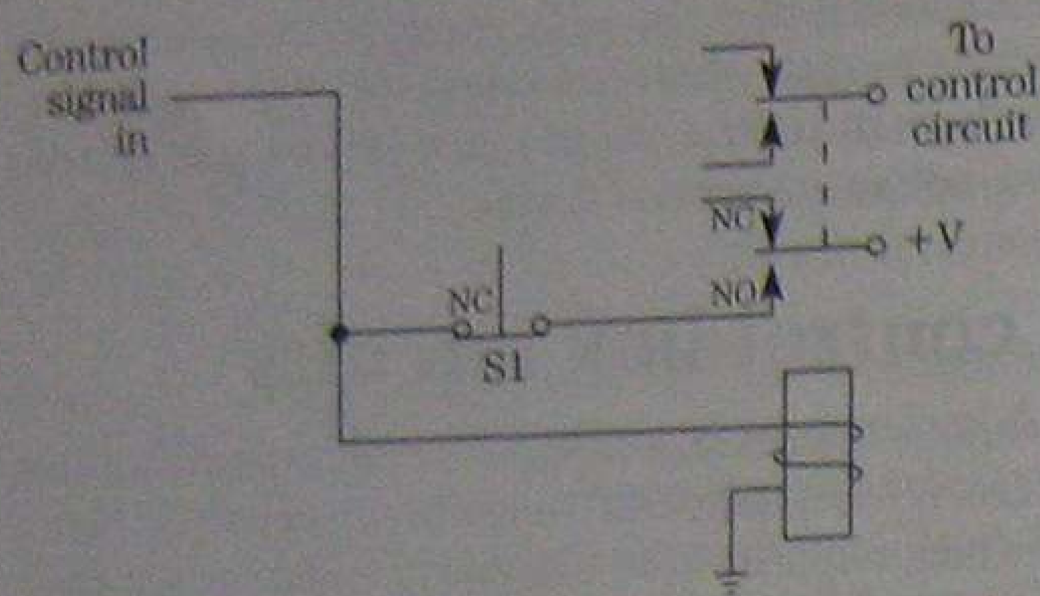


2-9
Double-pole, double-throw relay wired to simulate a latching relay.

throw) relay. The first set of switch contacts are used in the ordinary way to control whatever the relay is being used for. The second set of switch contacts are used for the latching function. At first, assume the relay is unactivated. All switch contacts are in their normal positions. When a control signal passes through the relay coil, all the reed switch contacts go to their activated positions. The controlled device or circuit is turned on (or off, as appropriate). At the same time, the second set of switch contacts close to complete a circuit that feeds a voltage back into the relay coil. If the original control signal is removed, this feedback voltage continues to pass through the coil, maintaining an active magnetic field. All the switch contacts in the relay remain in their activated state. This condition can be held indefinitely. To release the relay, the momentary action normally closed switch (S1) must be pressed. This action breaks the circuit. While this switch is open, no feedback signal can reach the coil. The magnetic field collapses, and the relay switch contacts are released to their normal, unactivated states. Releasing S1 does not restore the feedback voltage to the relay coil, because the circuit is now broken because the second set of relay switch contacts are open.

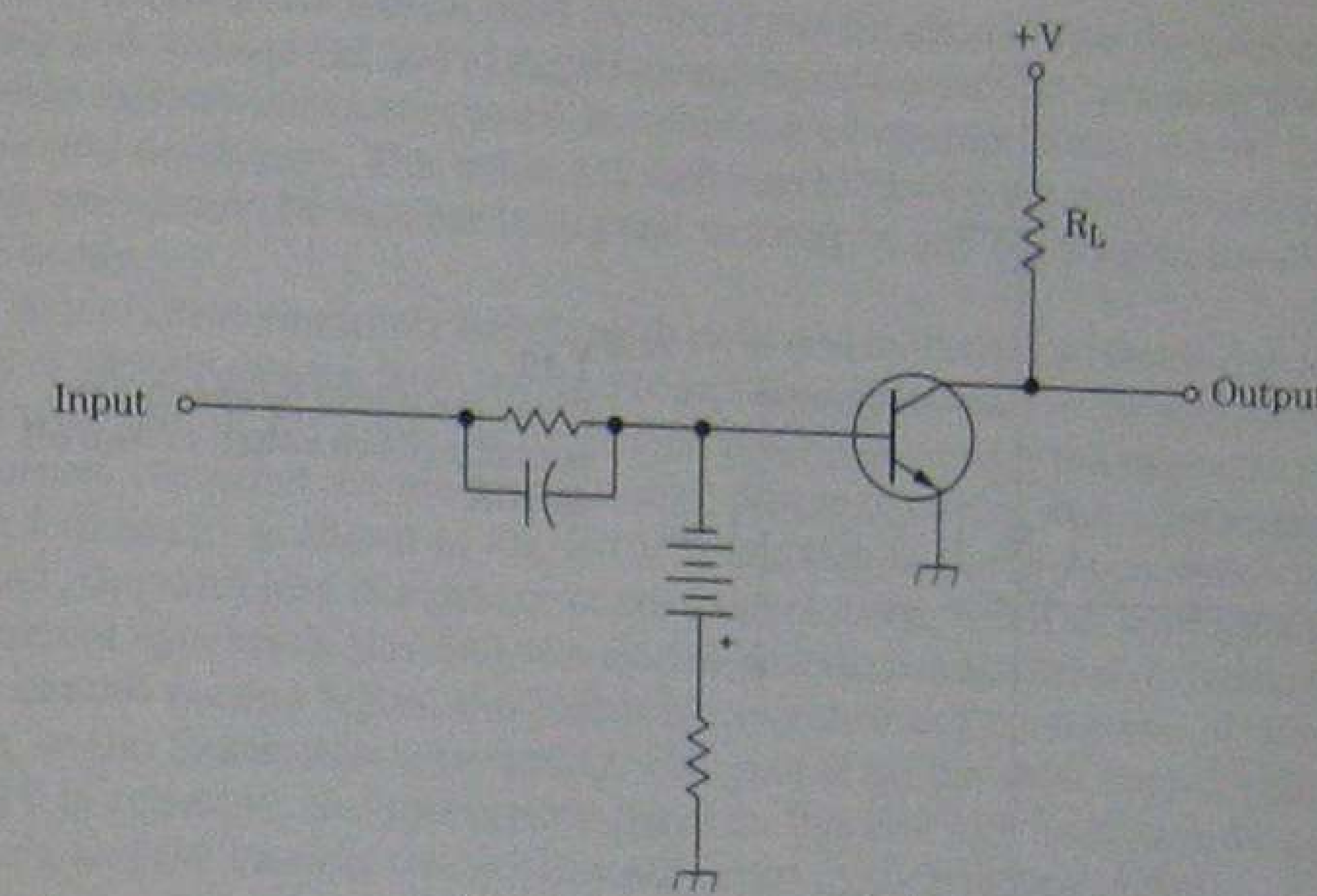
Of course, a second relay (or other electronic switch) can be used in place of the manual NC release switch assumed here. This relay permits automation of the release function, if that is appropriate to the specific application at hand.

Similar tricks can be used with other types of electronic switches to provide a latching function that might otherwise be difficult to implement.

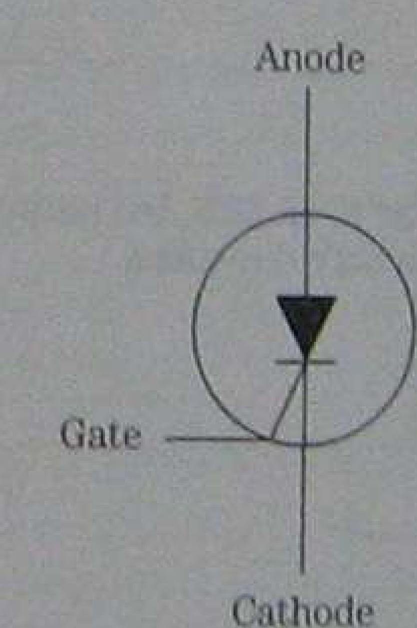
Although relays make the basic concepts easy to understand, and generally require very simple circuitry, they are rarely used in modern alarm systems. For one thing, relays are relatively large and bulky, especially if they must carry any significant amount of current. Although the circuitry is simpler, relays are usually much more expensive than most other types of comparable electronic switches. As mentioned, latching relays tend to be particularly expensive and difficult to find. The main reason relays are rarely used today, however, is their lower general reliability. Relays are electromechanical devices with small moving parts that can jam or stick. Relays tend to fail much more often than a purely electronic switching circuit.

There are a number of options available in purely electronic switching. There are transistor switch circuits, like the one shown in Fig. 2-10.

SCRs, or silicon-controlled rectifiers (shown in Fig. 2-11) are well suited to this application. Ordinarily, a SCR blocks current flow from cathode to anode. When a



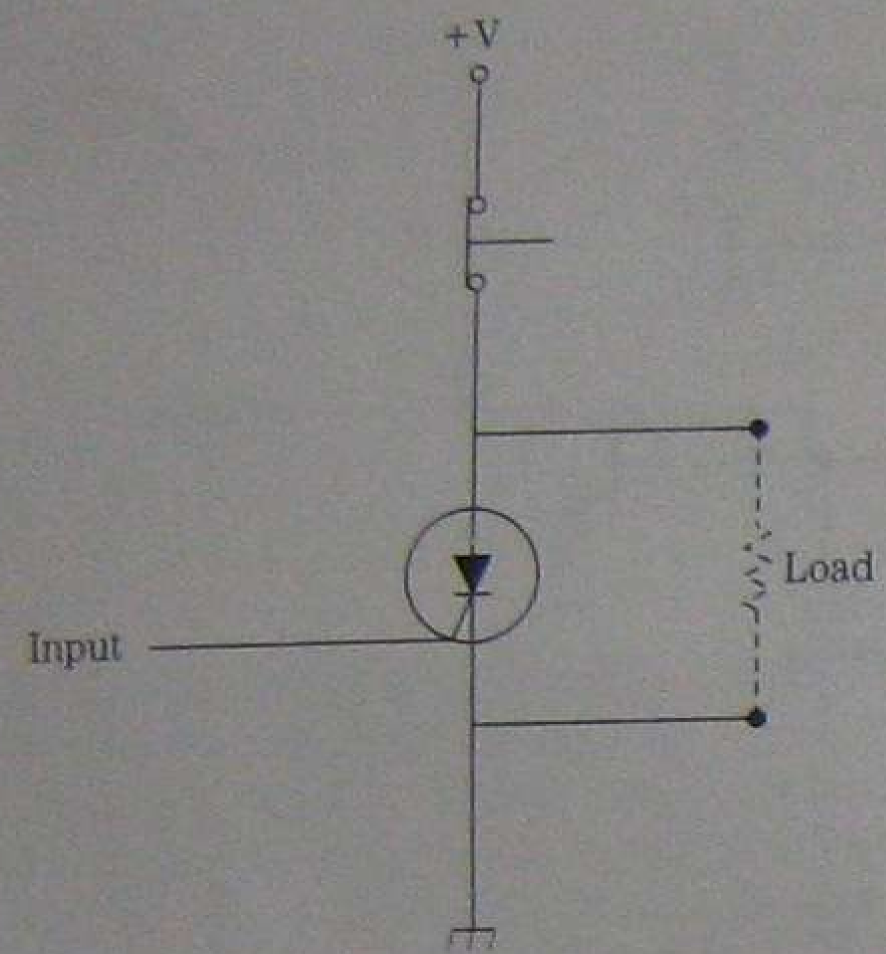
2-10 Transistors often are used for switching.



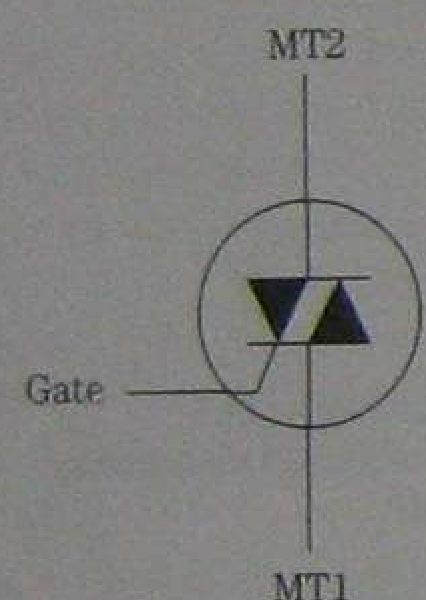
2-11
An SCR (silicon-controlled rectifier) is in effect an electrically switchable diode.

sufficient control signal pulse is fed to the gate lead, the SCR is turned on, permitting current to flow from cathode (negative) to anode (positive). Like any standard rectifier, current flow in the opposite direction (from anode to cathode) is blocked. Only a brief pulse at the gate is required to switch on a SCR. Once it is turned on, it stays on, even if the control signal is removed from the gate. To turn off the SCR after it is triggered on, the input current must be reduced below a critical threshold level. The easiest way to do this is to briefly break the circuit and interrupt the current flow altogether. This action is shown in Fig. 2-12. As in the pseudolatching relay circuit discussed earlier, this can be a manual normally closed momentary action switch, or it can be a second electronic switch circuit.

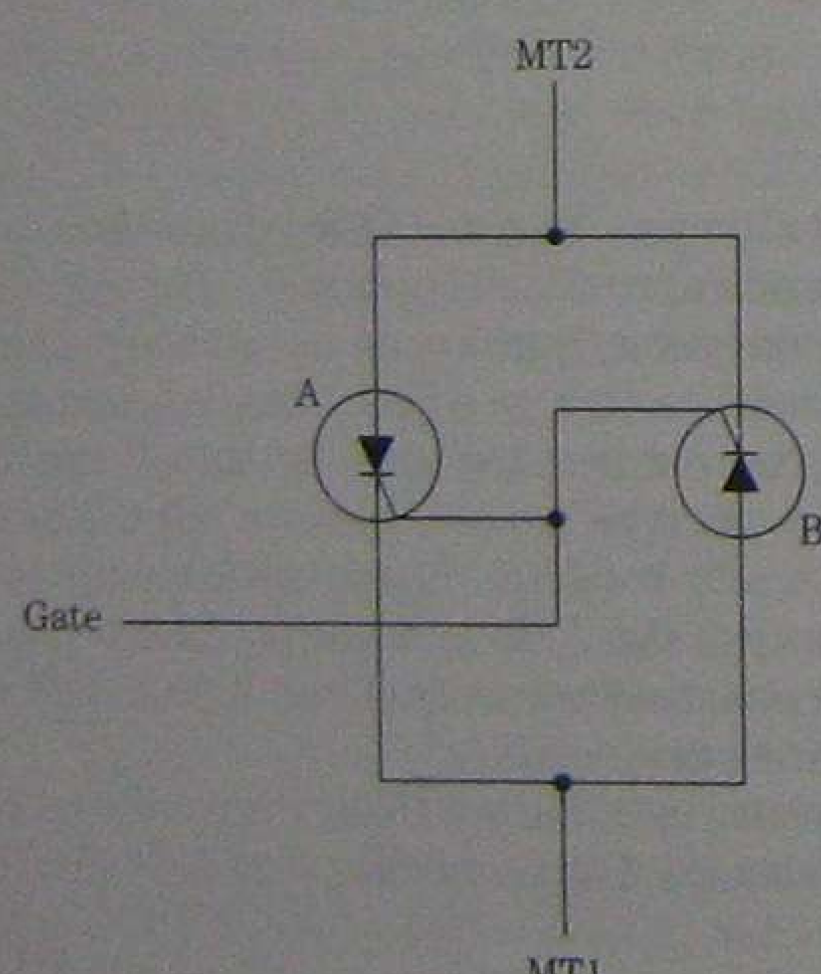
Triacs (shown in Fig. 2-13) are similar to SCRs, but they permit current flow in both directions. In fact, a triac can be simulated by connecting a pair of SCRs back to back, as shown in Fig. 2-14.



2-12
Break the circuit by opening the normally closed switch to turn off an SCR.



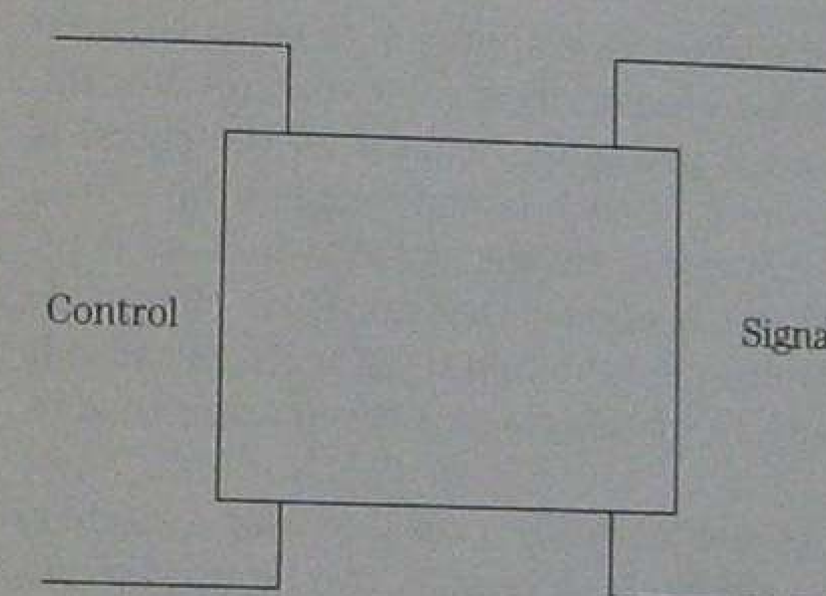
2-13
A triac is similar to an SCR, but permits current flow in both directions.



2-14
Simulated triac using a pair of back-to-back SCRs.

Digital gates also can be used for electronic functions. With the increasing popularity and widespread use of digital circuitry, this is rapidly becoming the de facto norm in modern electronics work. It would not be appropriate to discuss digital gating in any depth here. This subject is well covered in a great many existing publications, and should be familiar to anyone working in any capacity in the electronics field today.

Any of these electronic switching devices and methods can be used in a wide variety of circuits ranging from the simple and straightforward to the very complex and sophisticated. In any case, the functional principles remain the same. So in a *block diagram*, represent any electronic switch device or circuit with a generalized block with four leads, as shown in Fig. 2-15. In addition to the obvious switch input and output, the third lead is a gate or control signal input. When an appropriate voltage or current appears on this lead, the electronic switch is activated. In most alarm system central control boxes, the electronic switches will need to be of the latching type, so the fourth lead is necessary. This lead is for the reset control signal. If the switch is activated, the appropriate signal on this line will deactivate the electronic switch, and the internal connections will revert to their normal states.

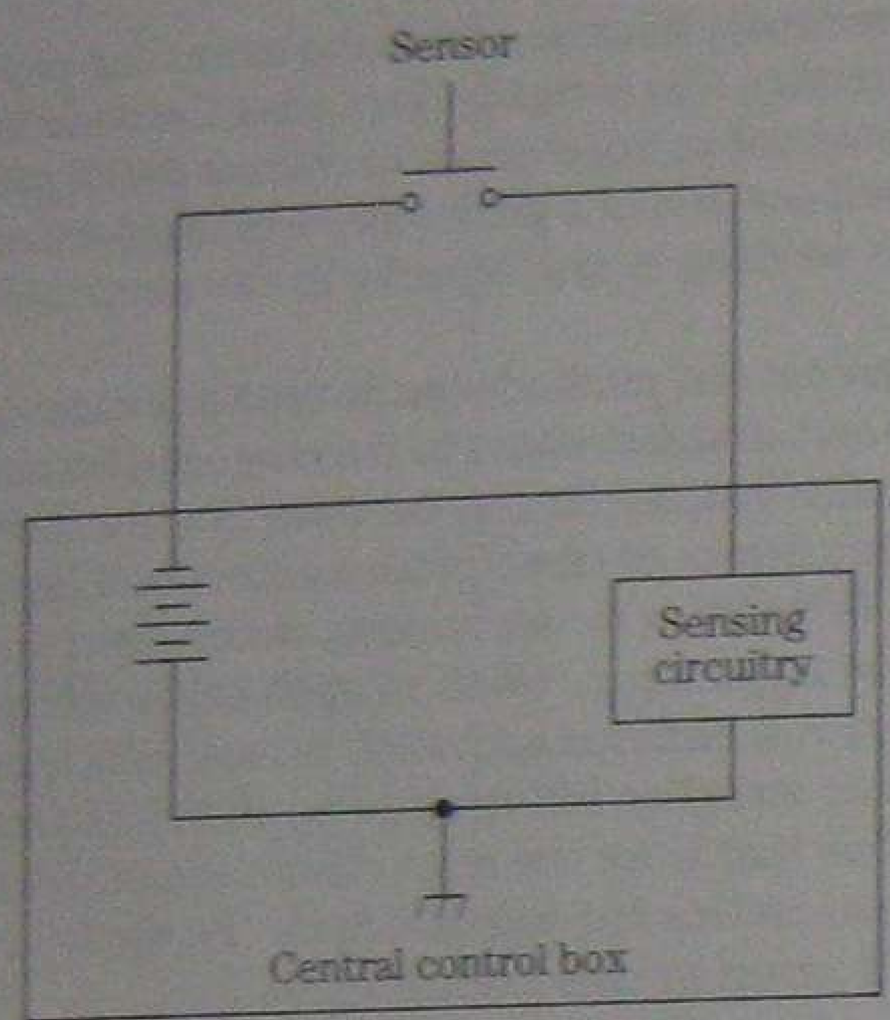


2-15
Any electronic switch can be generalized as a simple functional block with four leads.

In most cases, an electronic switch will perform a SPST function, so only two switch contacts are used. If a more complex switching function, such as SPDT (single-pole, double-pole), or DPDT (double-pole, double-pole) is implemented in the electronic switch circuit, additional switch input and output lines will be added to the block, as necessary.

Unless otherwise noted, assume all electronic switches throughout the following discussion will be SPST and normally open. This switch is the type of electronic switch circuit you most commonly encounter in a practical alarm system central control box.

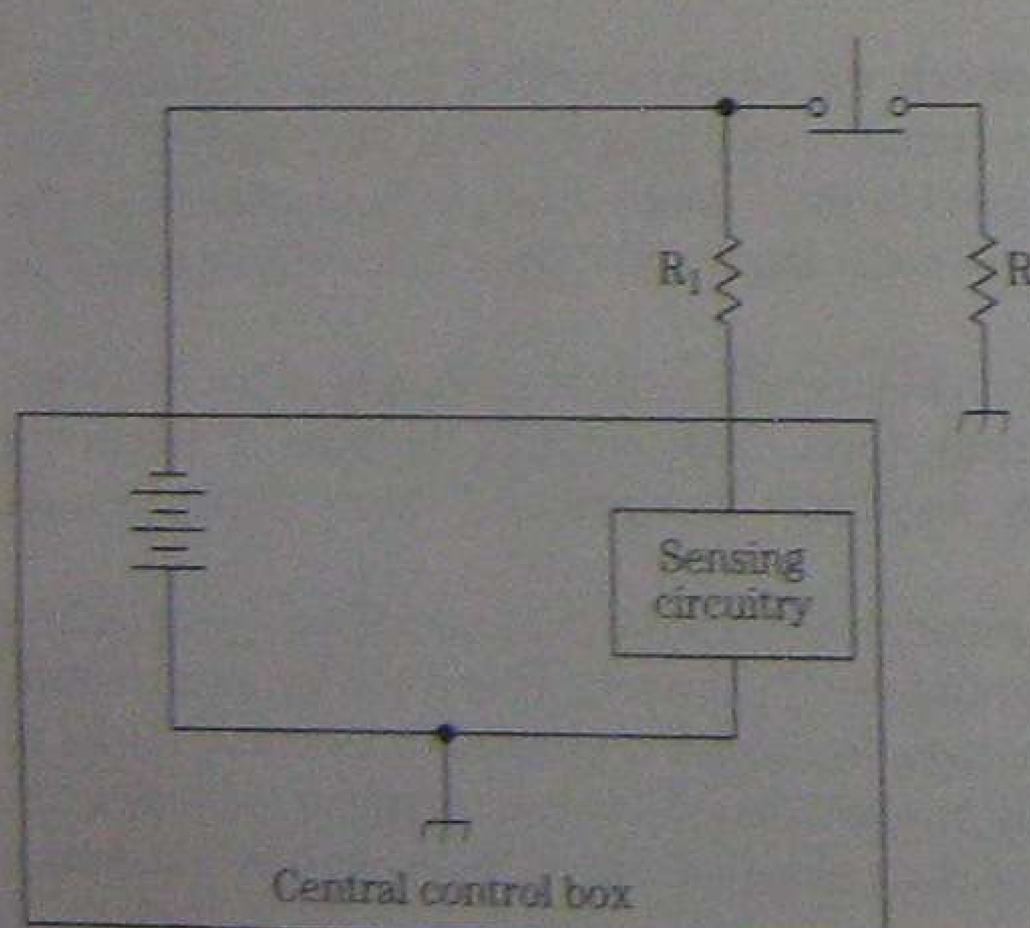
In a home alarm system, the primary electronic switch(es) will be controlled by signals from the various sensors throughout the system. It is certainly easy enough to derive the control signal from the sensors. Recall that virtually all sensors used in home alarm systems are functionally just switches. They can complete or break a circuit carrying the required voltage or current signal. Fig. 2-16 shows how this works for normally open sensors.



2-16 A normally open sensor easily can be adapted to create a suitable control signal.

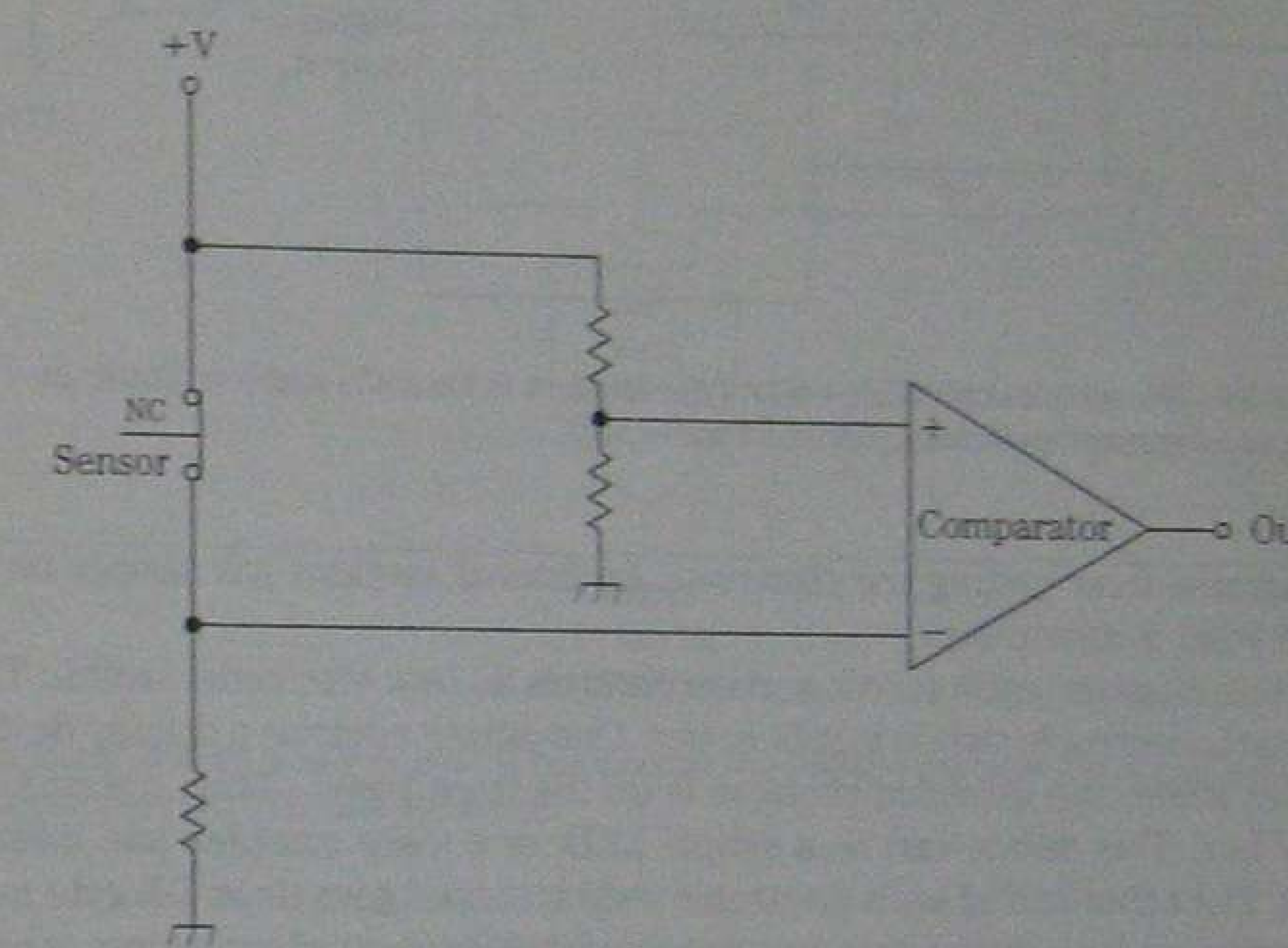
Normally closed sensors are a little bit trickier. One approach to using NC sensors is shown in Fig. 2-17. Here resistor R1 has a much larger value than resistor R2. When the sensor switch is closed (its normal position), virtually all the signal is shunted through resistor R2 to ground. There is a much larger voltage drop across resistor R1. Very little voltage or current can reach the electronic switch, so it remains unactivated. But when the sensor switch is opened, resistor R2 is effectively removed from the circuit. All of the signal must pass through resistor R1, because it has nowhere else to go. Enough of the complete signal gets past this resistor to activate the electronic switch.

There are more sophisticated ways to use normally closed sensor switches, which waste less signal power. An inverter circuit, for example, can be used to re-



2-17 This simple circuit demonstrates a simple way to use normally closed sensors.

verse a LOW (0) voltage and a HIGH (triggering) voltage. A comparator circuit also can be used. The comparator is designed to produce a high voltage when its input voltage drops below some specific value. A circuit of this type is shown in Fig. 2-18. In this circuit, the comparator sees a relatively large input voltage when the sensor switch is closed (its normal state), so the output of the comparator is zero. But when the sensor switch is triggered, or opened, this voltage drops to zero, tripping the comparator to produce a high level output, which can activate the electronic switch.

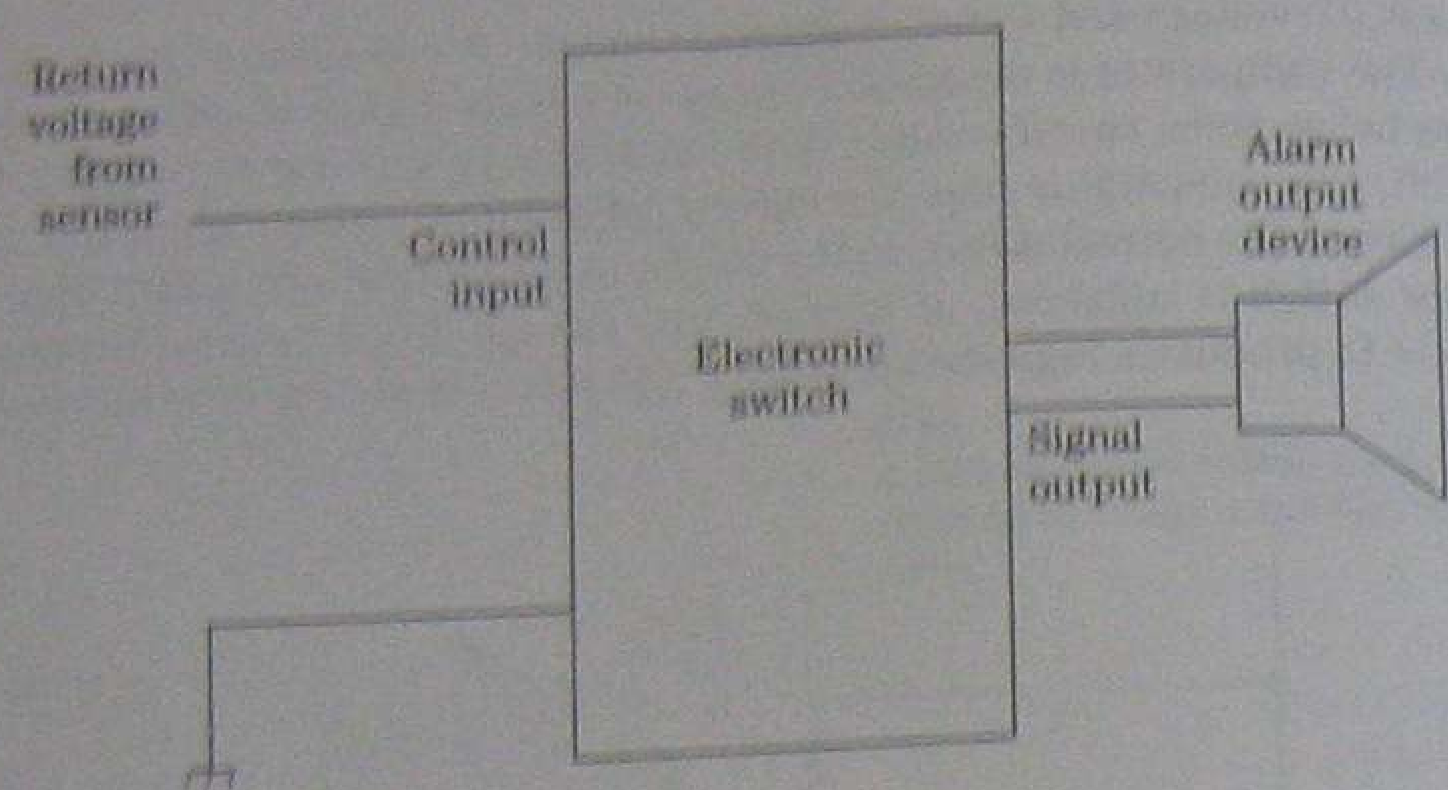


2-18 A comparator can adapt the output of a sensor to a more suitable control signal.

Digital gating also can be used to produce a HIGH signal when a normally closed sensor switch is opened. Other approaches also are possible, though less obvious and less commonly used.

The simplest possible central control box for an alarm system is simply a single electronic switch (of whatever type), as shown in Fig. 2-19. When an appropriate signal is received from one or more of the sensors, the electronic switch is activated, turning on the output alarm device. The alarm will continue to sound until the reset switch is manually operated. This would be a very crude alarm system, of course, lacking in any special features or versatility. But this basic circuit can easily be expanded into a very powerful system.

As mentioned, in a home of any size, the sensors should be grouped into semi-independent sections. An alarm system for a small apartment might have just a single electronic switch as shown here, but most alarm systems will give better results with multiple electronic switches. For example, a central control box circuit for three sensor sections is shown in Fig. 2-20. More sections can easily be added in exactly the same way. Limit the hypothetical system to just three sections here to keep



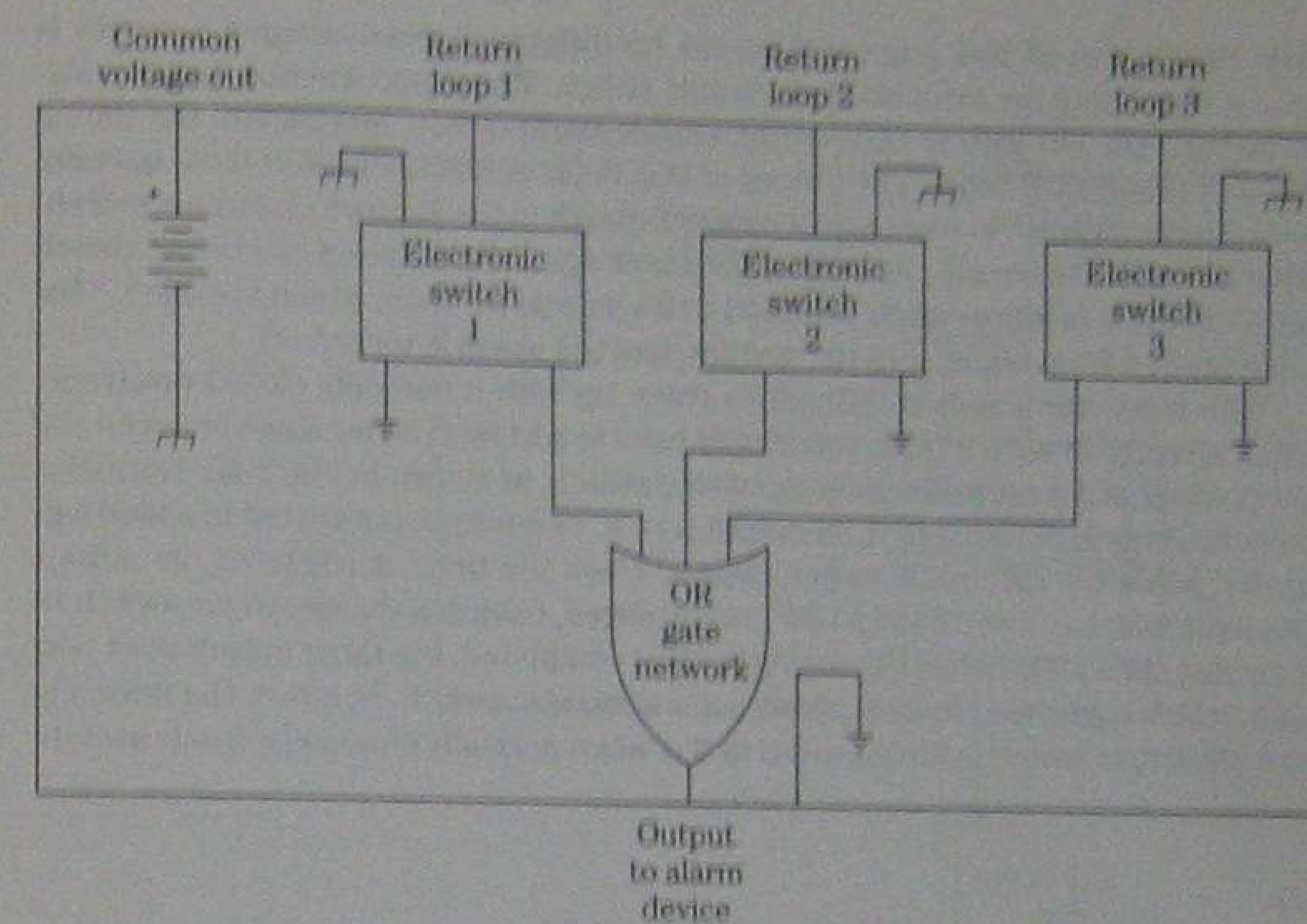
2-19 The simplest possible central control box is basically just a multiple-input electronic switching device of some sort.

the diagrams from getting too cluttered. Additional sections will simply be repetitions of what is shown here.

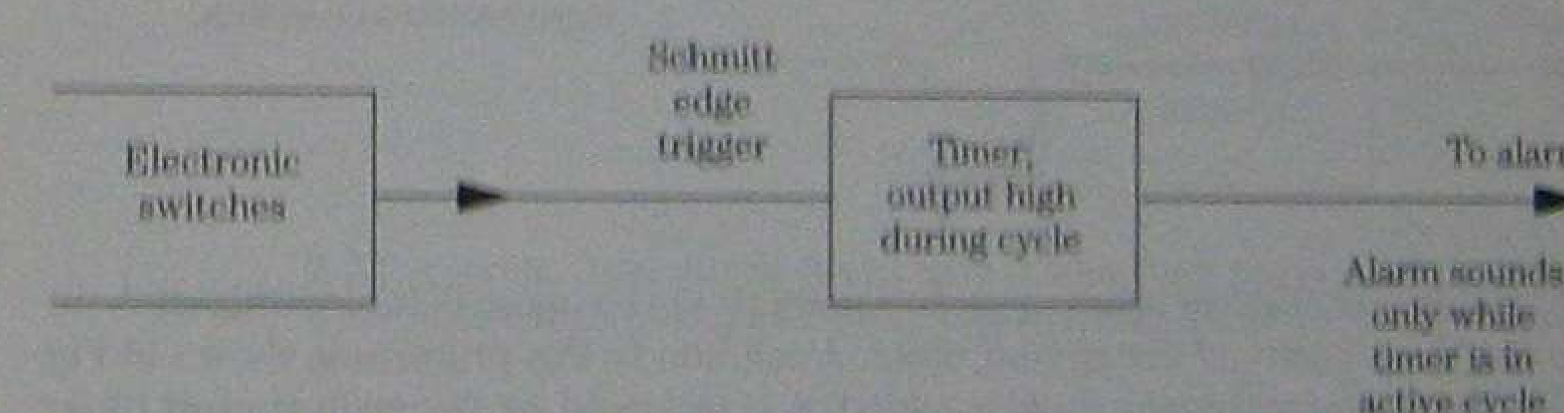
In this diagram, each sensor section controls its own electronic switch. The output of each electronic switch is split in two. One output controls a display device that indicates where the detected problem is on the front panel of the system's central control box. This device can be a simple LED, or a more complex and informative display. The other half of each electronic switch output goes to an OR gate network. This circuit can be a digital gate, or an analog mixing circuit of some type. Analog OR gates can be simple passive resistor networks, or sophisticated amplified multiplexer or mixer circuits. The specific circuitry used is not of concern here. Only be concerned with the functional operation of the circuitry—what it does, rather than how it does it.

An analog OR gate works in the same way as a digital OR gate. For the three OR gate inputs shown in Fig. 2-20, the output of the OR gate will go HIGH if, and only if, input A OR input B OR input C is HIGH. The output is LOW only if all inputs are LOW. The output of each electronic switch is LOW when the electronic switch is off (deactivated) and HIGH when it has been triggered on by an appropriate signal from its input sensor network. As long as all of the electronic switches are deactivated, the output of the central control box is LOW, or zero. No voltage is fed into the output alarm device, so it remains silent. As soon as one (or more than one) of the electronic switches is turned on, the central control-box output goes HIGH, feeding a voltage to the output alarm device, causing it to sound. Because the electronic switches are of the latching type, the alarm will continue to sound until the system is reset. (At this point, assume the reset function is accomplished only by a manual switch.)

A practical home alarm system should always have a timed shutoff feature, as emphasized elsewhere in this book. It is generally easy enough to add such a feature. The basic idea is shown in Fig. 2-21. Here is simply added a standard timer circuit. It derives its trigger input from the output of the central control OR gate, effectively in



2-20 An alarm system of any degree of complexity will require multiple electronic switches in a central control box. This one has three.

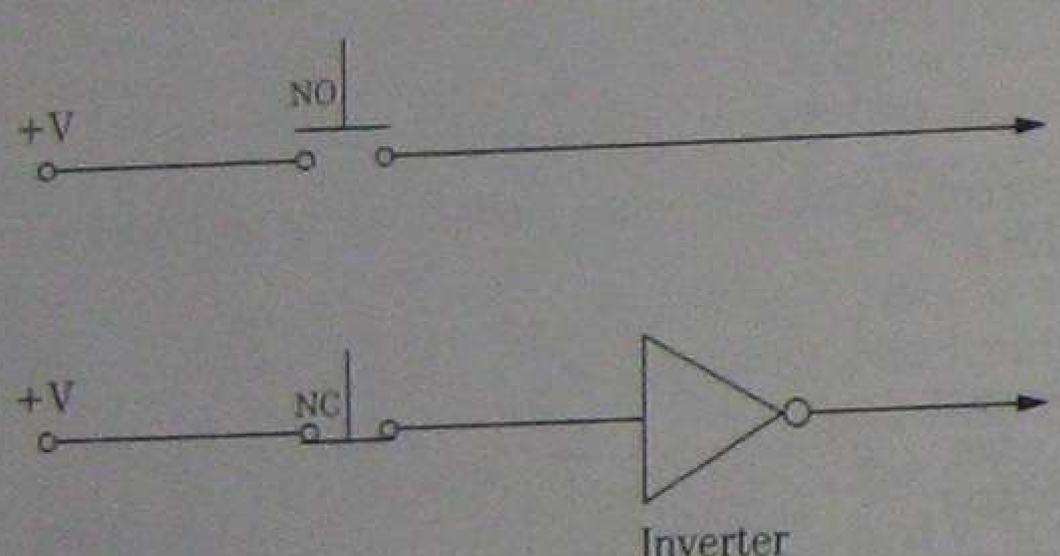


2-21 A practical home alarm system should always have a timed shutoff feature.

parallel with the output alarm device(s). In many practical circuits, greater reliability will be achieved by adding a Schmitt trigger stage as shown here. This stage will not always be required. With some timer circuits, additional circuitry to convert the continuous alarm output signal into a brief trigger pulse. Other timer circuits can use this signal directly, if they trigger on the LOW to HIGH transition, rather than the absolute HIGH state.

The output of this timer drives a nonlatching electronic switch that is in parallel with the manual reset switch. Opening either (or both) of these switches will reset the alarm system. Normally, when no sensor is triggering an alarm condition, the state of these switches is irrelevant. They are, in effect, ignored by the rest of the circuitry in the system. The electronic switch controlled by the shutoff timer is normally closed, but at this point this makes no difference. Now, assume a sensor is tripped, activating the associated electronic switch. The tripping action passes a signal through the OR gate to turn on the output alarm device, and initiate the timing period of the shutoff timer. The output of this timer immediately goes HIGH, opening its electronic switch. No reset signal passes through to the sensor's electronic switch. When the timer times out, its output goes LOW again. Because its electronic switch doesn't latch, it is immediately released to its normal position, which is closed. This action feeds a reset signal into the system, and the alarm is turned off.

With some circuits, it is difficult to come up with a normally closed electronic switch directly. In such a case, you simply have to add an inverter stage between the timer output and a normally open electronic switch, as shown in Fig. 2-22. Normally, when the timer is not activated, its output is LOW. This output is inverted to a HIGH signal that holds the electronic switch closed. When the timer is triggered, its output goes HIGH, which is inverted to a LOW control signal, releasing the electronic switch to its normal open state. After the timing cycle is completed, the timer output goes LOW again, which is inverted to HIGH, closing the electronic switch. In effect, the normally open electronic switch is forced to act as if it was a normally closed electronic switch.

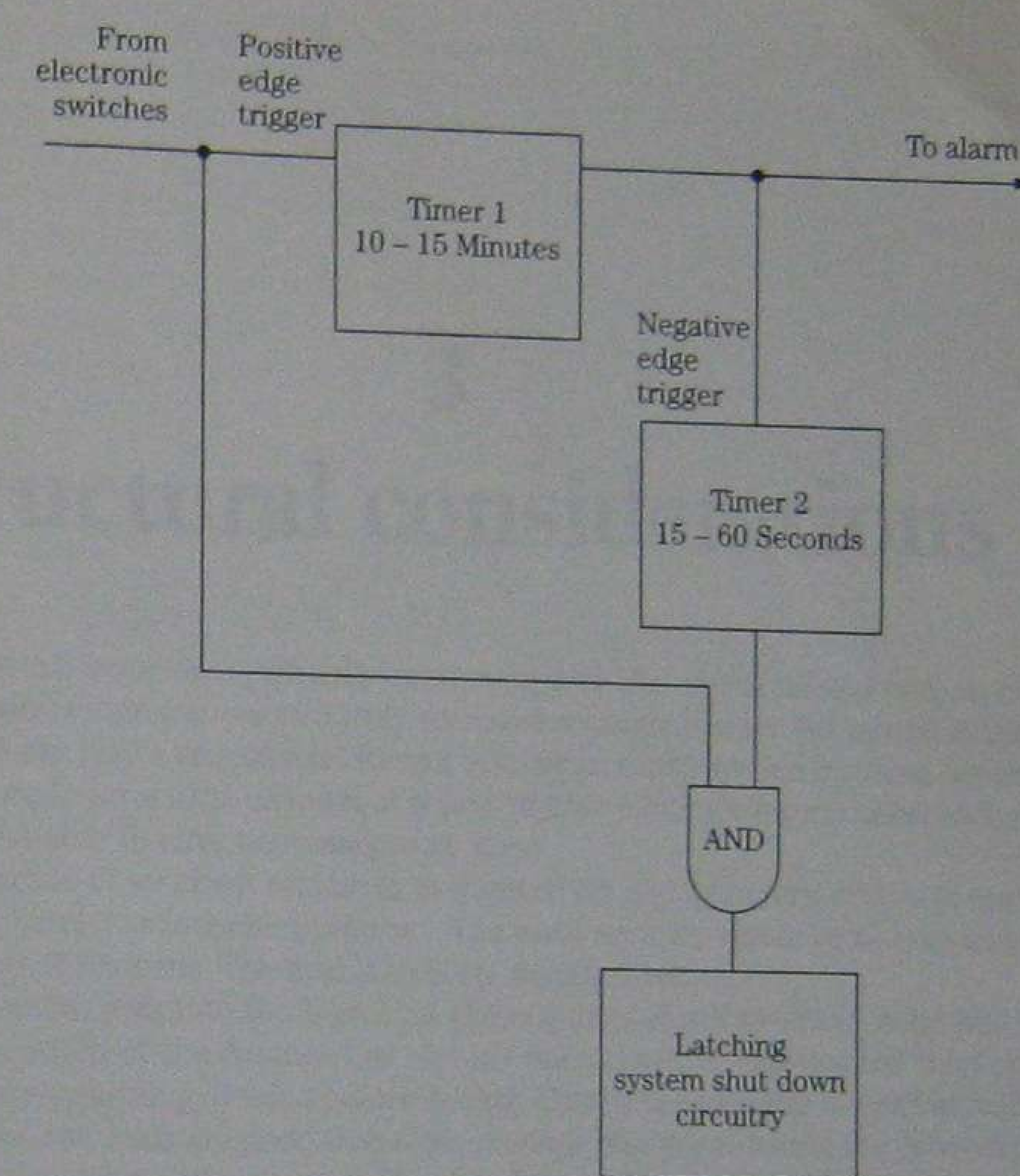


2-22
An inverter stage can sometimes be used to simulate a normally closed electronic switch.

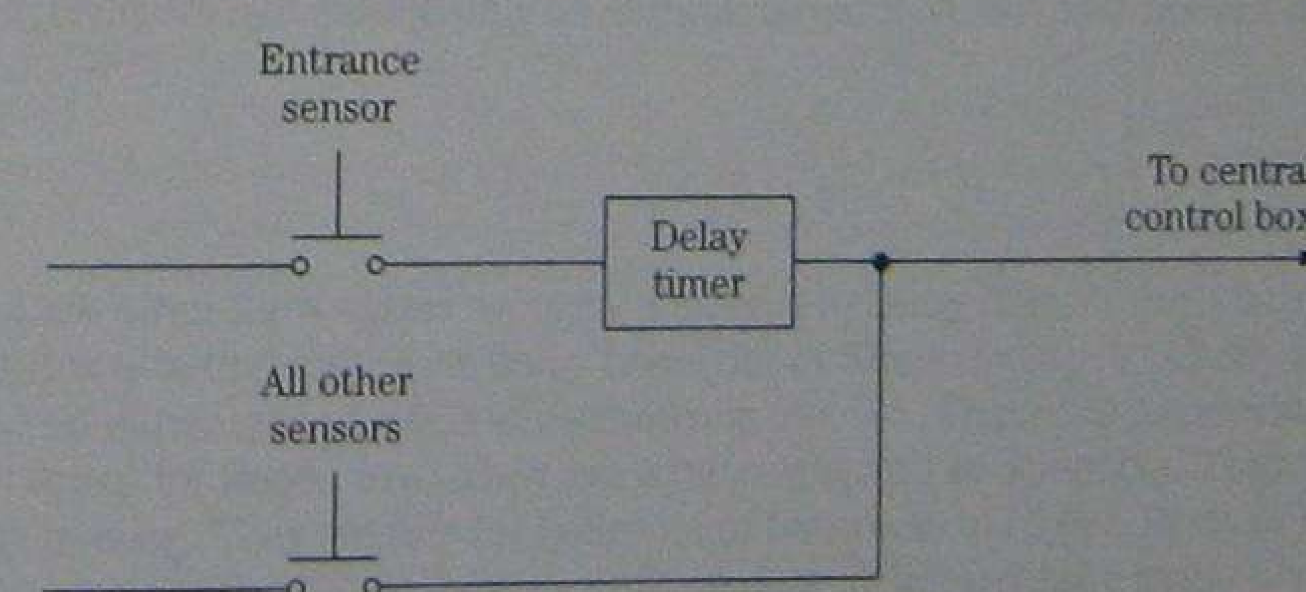
If a door or window is left open, the alarm would be immediately retriggered, defeating the purpose of the shutoff timer. A solution to this problem is shown in Fig. 2-23. Here a second timer stage is added; it is triggered by the main shutoff timer. This timer has a very short timing cycle—just a second or two is enough. Some simple gating circuitry is added to the system so if the alarm is retriggered before this second timer times out, another latching electronic switch disables the output alarm device until it is manually reset.

Recall the discussion of the importance of an entrance delay timer to permit the legitimate occupants a chance to get in and out of the house without setting off the alarm. This delayed-response entryway sensor is fed to its own electronic switch with a timer at its input, as shown in Fig. 2-24. The alarm will not be set off unless this sensor is still in its triggered state when this timer completes its timing cycle. A timing period of 30 to 50 seconds is typical for this timer.

Many additional features can easily be added to the alarm system. The block diagram approach makes design of the central control box very easy. First determine what functional blocks are needed, then plug in the appropriate subcircuits, which are usually simple in themselves.



2-23 A second timer circuit can be used to shut down the system completely if it is immediately retriggered due to a stuck sensor from an open door or window.

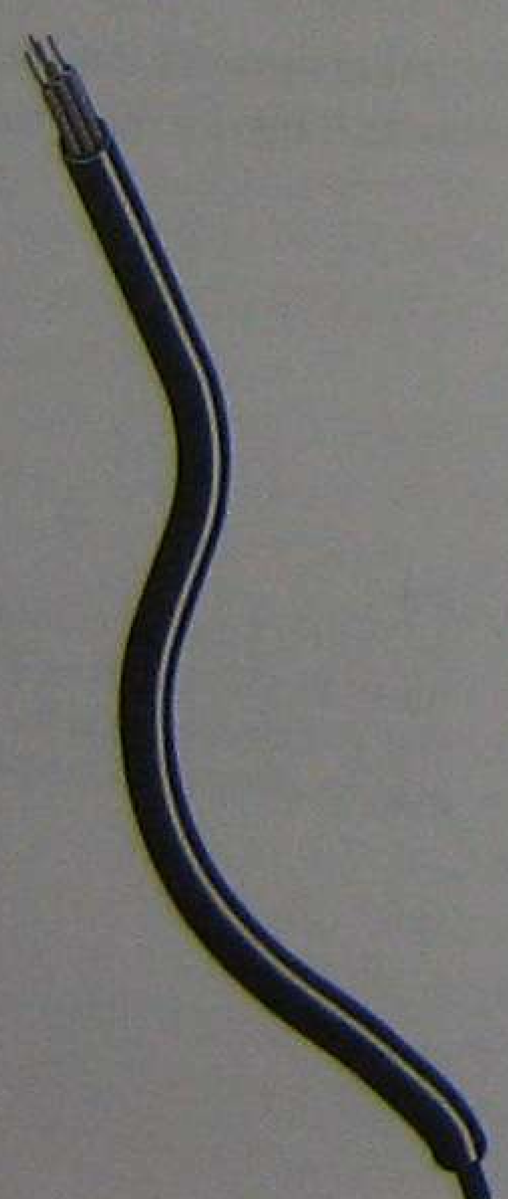


2-24 A delayed-response entryway sensor is fed to its own electronic switch with a timer at its input.

used to hold the wires as tight as possible. Don't permit wires to sag between support points. The sagging is unattractive, and it also invites stress to the wires that could eventually cause problems. Loosely mounted wires also can be tripped over, or something could get caught in them. Proper mounting will hold the wires tight enough that someone would have to deliberately work at it to get anything caught between them.

Another way to keep things as tidy as possible, which can be combined with any of the earlier techniques, is to use multiconductor cable for places where several wires must be run together over some distance. This cable is just two or more individually insulated wires bundled together in a single insulated jacket. A typical cable of this type is shown in Fig. 4-4. There is no need to use shielded or coaxial cables for most alarm system applications, because the wires aren't carrying any data other than simple on/off switching states. Either the switching voltage is present (switch closed), or it isn't (switch open). Electrical or *RF* (radio frequency) interference is highly unlikely to be a problem. Certainly coaxial or other shielded cables will do the job, but they will tend to be thicker and bulkier for a given number of internal conductors, and they will surely be significantly more expensive per foot than simple unshielded multiconductor cable. Because a typical home security system installation will require at least a couple hundred feet of room-to-room cable, using unnecessarily shielded cable can result in a noticeably higher overall materials cost for the installation, without offering any practical advantage.

A typical home alarm system includes dozens of separate sensors. A moderately large house could need more than a hundred sensors. Each individual sensor in the system needs at least two wires leading back to the control center. A few specialized sensors might require more than two wires, but usually each system will be some form of SPST switch, opening or closing an electrical circuit, as shown in Fig. 4-5.

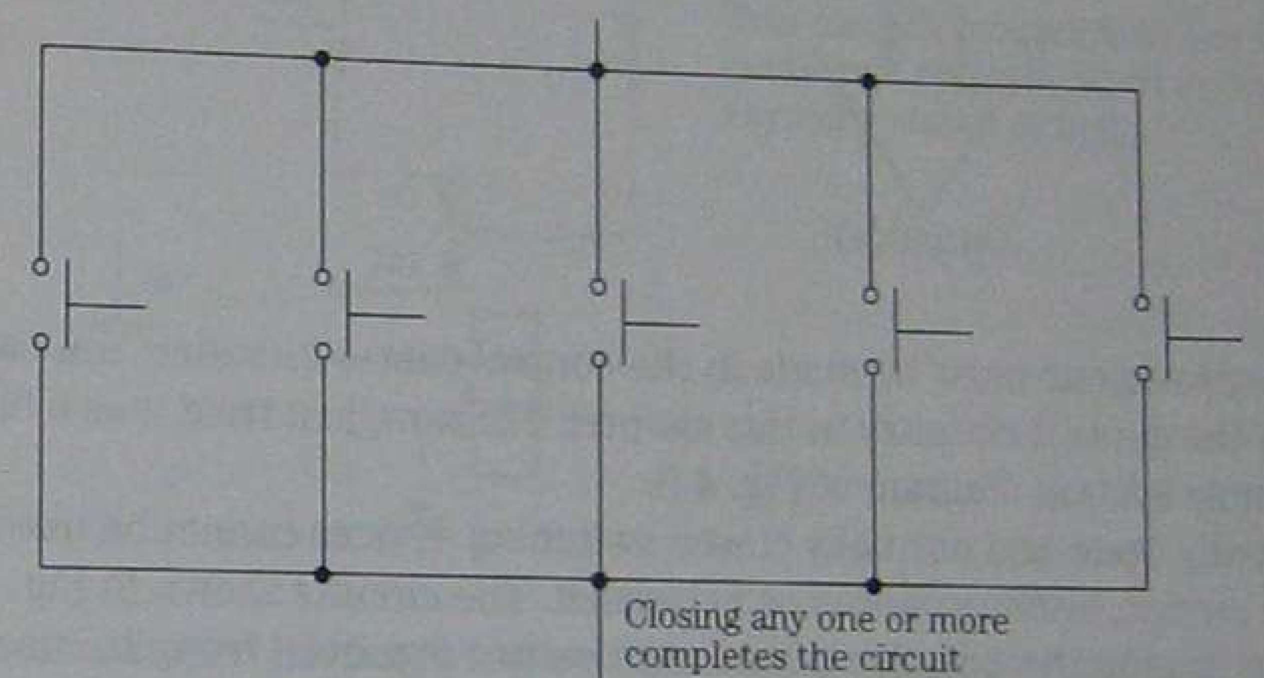


4-4 A multiconductor cable is just two or more individually insulated wires bundled together in a single insulated jacket.

4-5 Most sensors used in practical alarm systems are specialized SPST switches.

Obviously even a fairly simple home alarm system is going to call for a lot of wires running from room to room. The installation will be made a lot easier and less expensive if you can find ways to reduce the number of wires in the lengthy room-to-room runs. Fortunately, there are a number of fairly simple tricks that can reduce the wire count considerably in most home alarm systems.

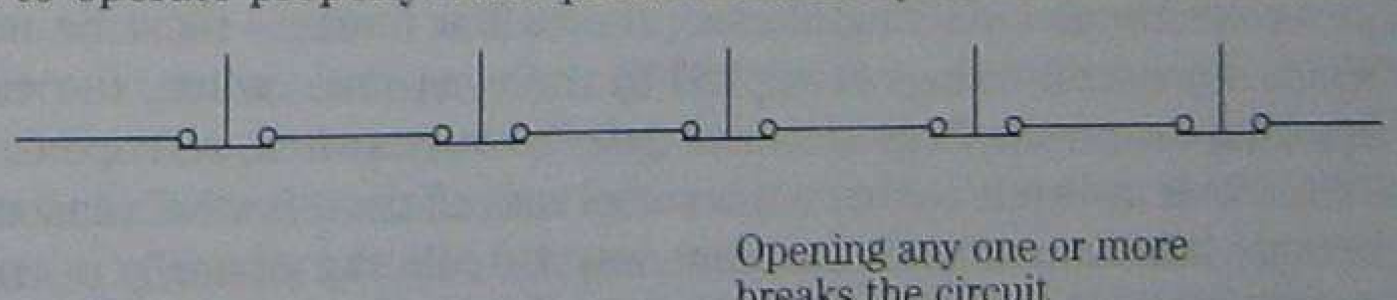
One of the most obvious of these tricks is to wire multiple sensors in series or parallel, depending on the type of sensor used. Multiple normally open sensors can be wired in parallel as shown in Fig. 4-6. Closing any one (or more) of these sensor switches will trigger the alarm. You can add as many NO sensors in parallel as you want, and it will only take one of them to complete the circuit that activates the alarm.



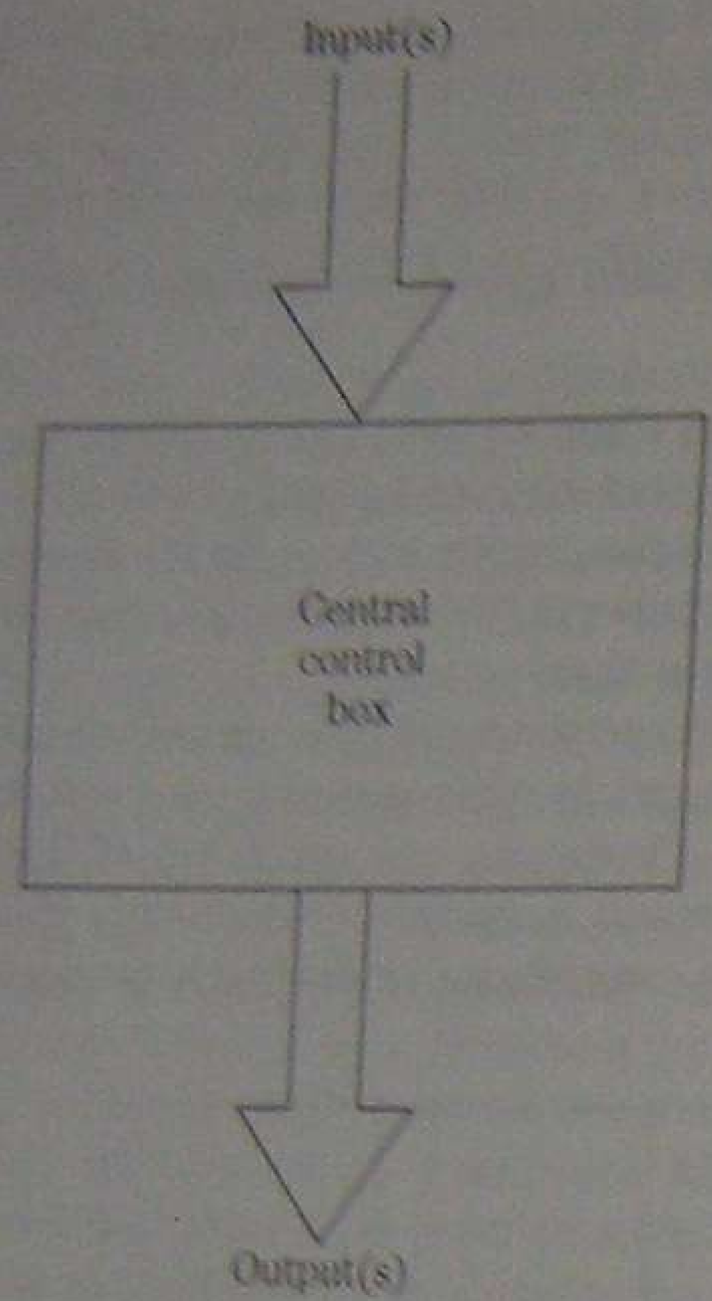
4-6 Multiple normally open sensors can be wired in parallel.

Multiple normally closed sensors, on the other hand, must be wired in series, as shown in Fig. 4-7. In its normal state, an NC sensor acts as part of a complete circuit. Tripping the sensor opens the circuit, activating the alarm. Opening any one (or more than one) NC sensor in a series string will be sufficient to set off the alarm, regardless of how many individual sensors there are in the circuit.

Normally open sensors and normally closed sensors trigger the alarm in exactly opposite ways. Different control circuitry will be required for each type for the alarm system to operate properly. Most practical alarm systems use both sensors, so ap-



4-7 Multiple normally closed sensors must be wired in series.



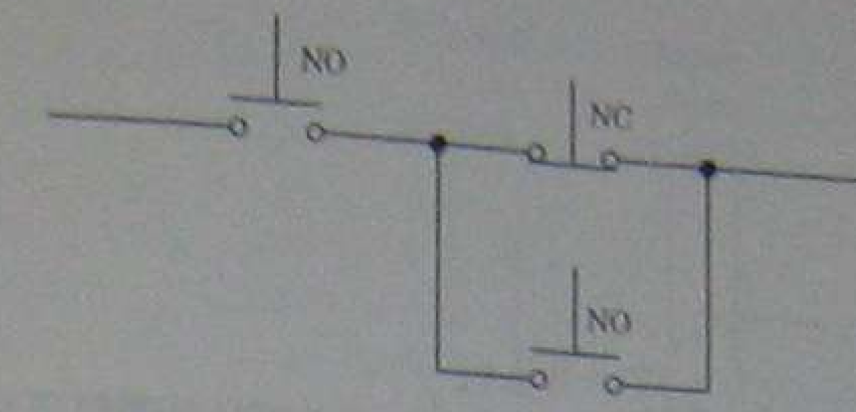
4-8 The central control box can be treated as an undefined functional black box for the time being.

propriate provisions must be made in the control center circuitry. You can learn the details of the control circuitry in this chapter. For now, just treat it as a black box, as in the simple system diagram of Fig. 4-8.

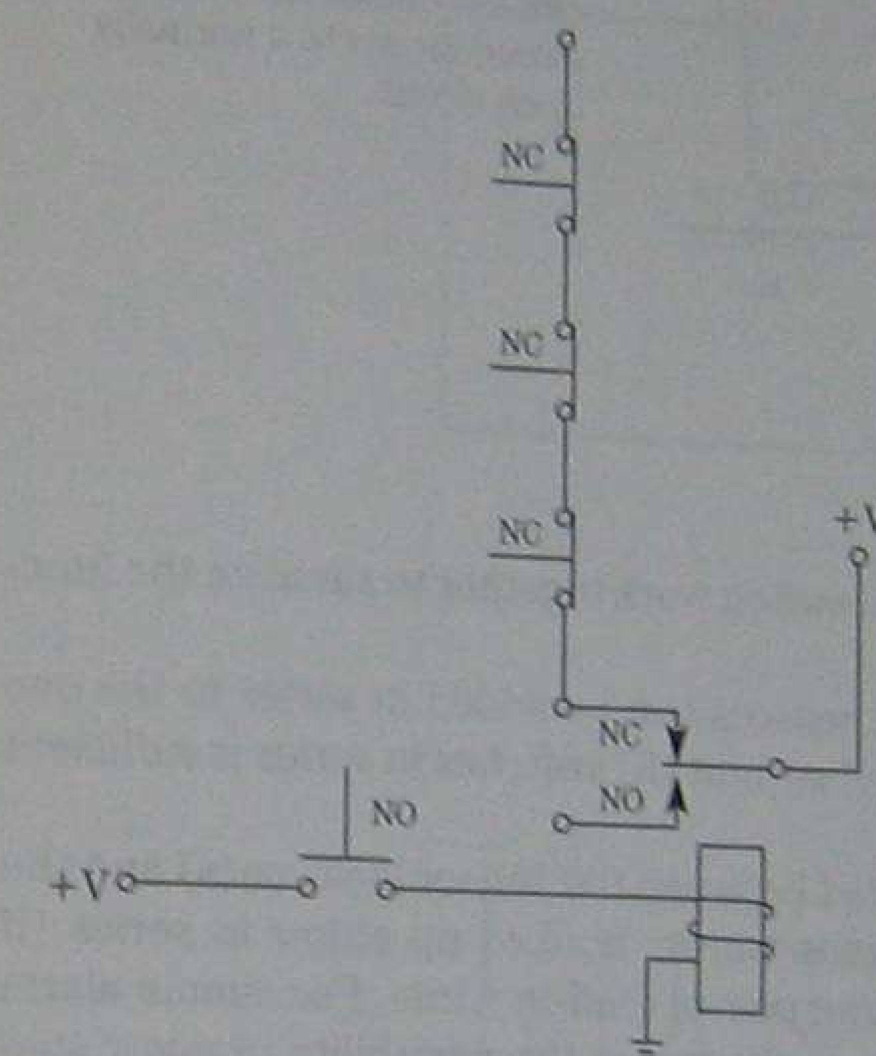
Normally open and normally closed switching devices cannot be used directly in the same circuit, either in series or in parallel. The circuits shown in Fig. 4-9 will not work. Try tracing the circuit path as each sensor is moved from its normal (inactivated) state and see why such a circuit is nonfunctional.

But in many practical alarm systems it would be very desirable to combine NO and NC sensors on a single pair of wires leading back to the control center. Actually it's not too difficult to do, although the required circuitry is necessarily a bit more complex than the nonfunctional circuits of Fig. 4-9. Figure 4-10 shows how to add a normally open device to a normally closed circuit. A simple relay is shown, but almost any form of electronic switching can be used. For example, the relay could be replaced with a suitable SCR or transistor switch or, in some digitally based systems, a digital gate. The switching device is really irrelevant for this discussion. The same general principles apply in any case.

Whatever electronic switching is used, the switch function must be normally closed. When no control voltage is applied to the electronic switch, the circuit is closed. Applying a control voltage activates the electronic switch, and opens the circuit. The electronic switch is connected in series with all the other NC sensors in the circuit, because it is to function in the same way. Usually, the normally open sensor on the control side of the electronic switch is open, of course, so no control voltage reaches the electronic switch to activate it. Its switch contacts remain closed. But if



4-9 Normally open and normally closed sensors cannot be used directly in the same circuit, either in series or in parallel. This circuit is not functional.

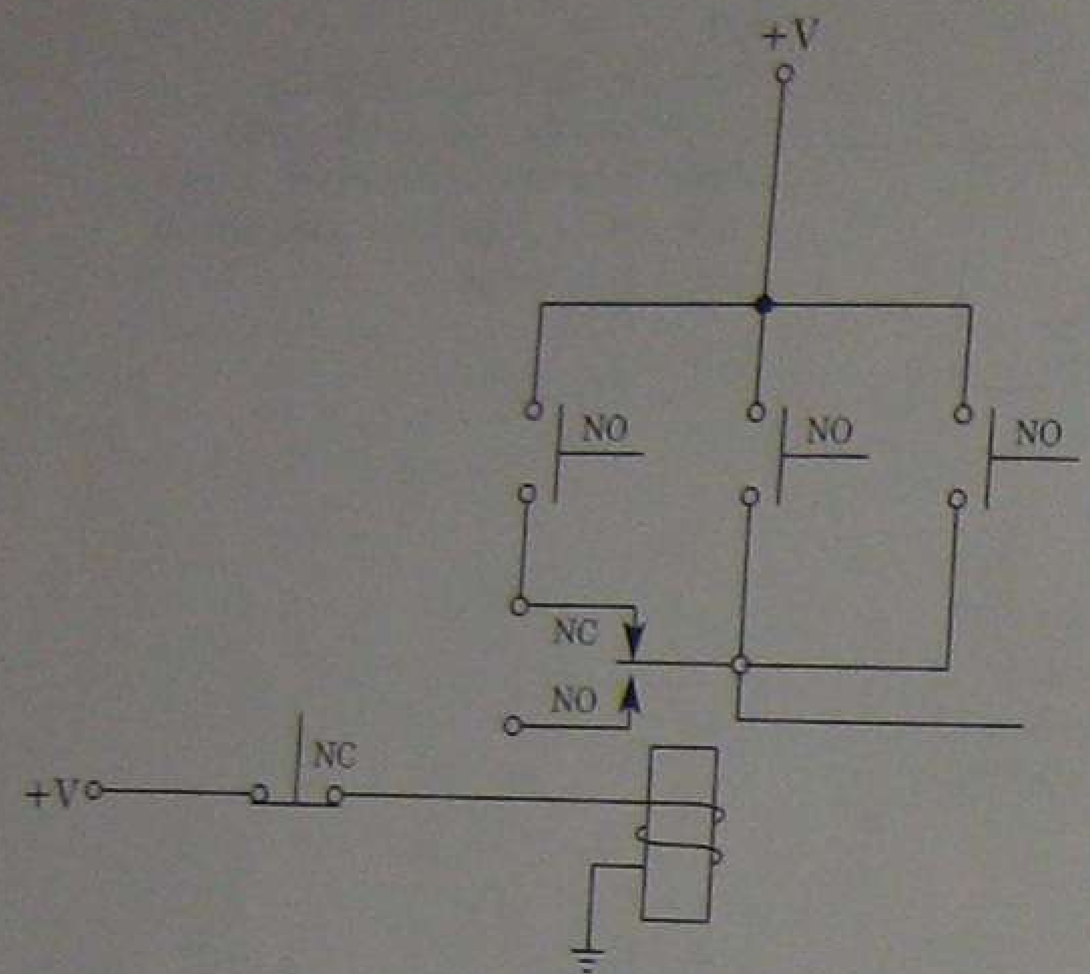


4-10 This circuit demonstrates one way to combine a normally open device to a normally closed circuit.

the NO sensor is tripped, closing its switch contacts, this completes the circuit to the relay coil (or other input to the electronic switch), activating the relay (electronic switch), causing its contacts to open. Just like opening a normally closed sensor, this triggers the alarm.

Additional normally open sensors can be placed in parallel with the one shown. Closing any one or more of several NO switching devices in parallel is sufficient to complete the circuit.

A normally closed sensor can be added to a normally open circuit in a very similar way, as shown in Fig. 4-11. Again the relay (or other electronic switch) has normally closed contacts, even though you might have expected to use a normally open electronic switch in this application. The NC electronic switch is wired in parallel with the other NO sensors, as if it were one of them. The control voltage operating this electronic switch must pass through the normally closed sensor. Usually, this device will be closed, of course, completing the control voltage circuit, so the electronic switch is held in its activated state—the switch contacts are open. If the NC sensor is tripped, it opens its internal contacts, breaking the circuit, so the control voltage is removed from the relay's coil (or input of the electronic switch). The relay or electronic switch is released from its active to its normal state, closing its contacts. In ef-



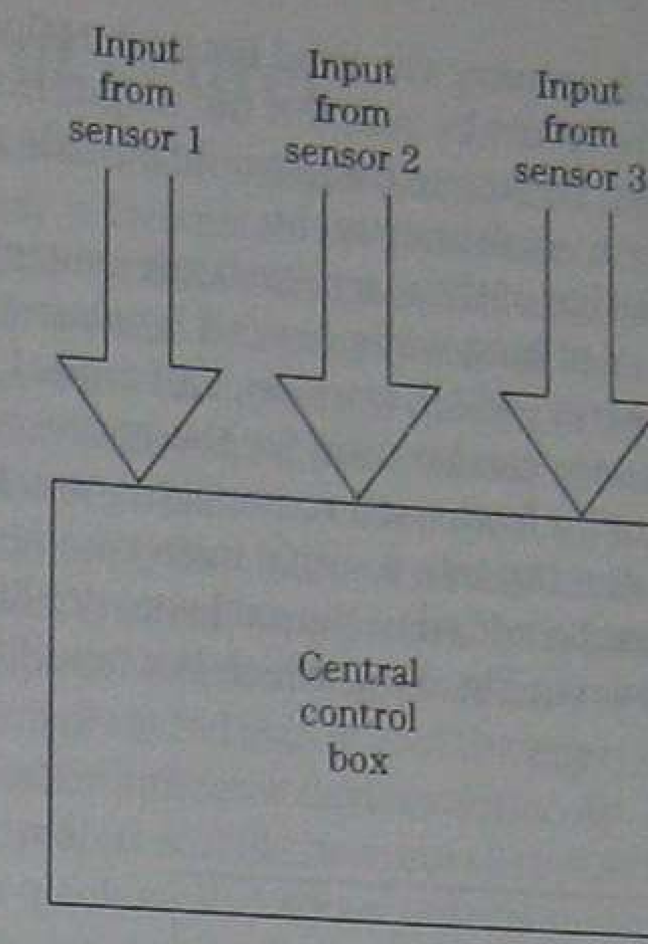
4-11 This circuit demonstrates one way to combine a normally closed sensor to a normally open circuit.

fect, the NC sensor and the NC electronic switch work together to simulate the functioning of a NO sensor.

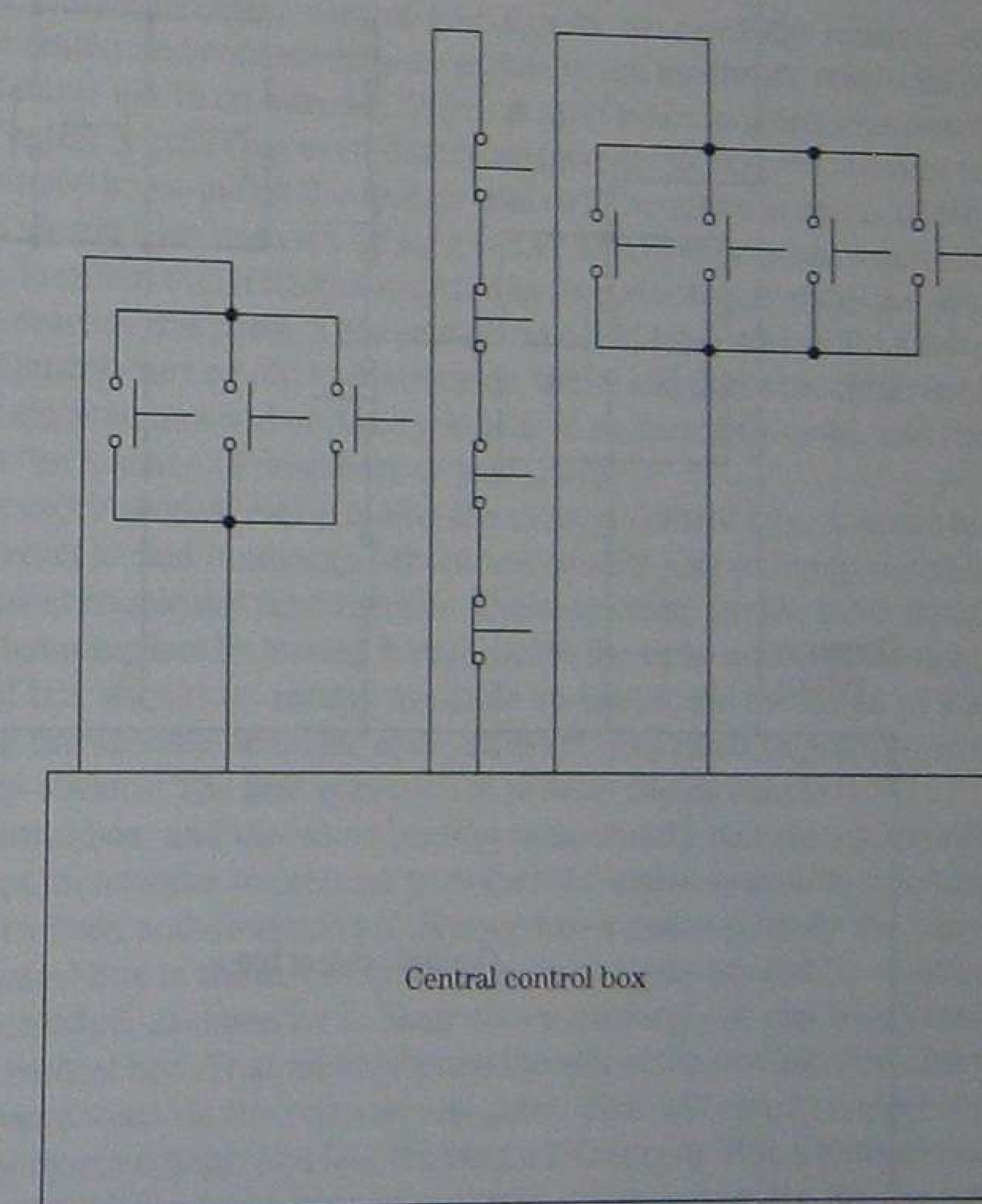
Of course, multiple normally closed sensors can be added in series to the one shown in the diagram. Opening any one of several NC switches in series is sufficient to break the circuit.

In principle, just two wires are needed between the sensor location(s) and the control center. Additional sensor locations can be hooked up either in series (if NC) or in parallel (if NO), using the same pair of lead-in wires. For simple alarm systems, this is well and good. However, it eliminates the possibility of many special features.

The security offered by an alarm system can be greatly increased by designing it to inform the user what area has been breached when the alarm is set off. This information is very important in a moderate to large house. Was there an intrusion detected in the kitchen, in the living room, or in one of the bedrooms? Generally the only way the control circuit can tell the difference is to have different independent sensor circuits. A simplified block diagram is shown in Fig. 4-12. For convenience, only one sensor is shown in each area, but additional sensors can be wired in series or parallel, as discussed in this chapter. At the expense of a few additional wires from the protected rooms to the control center, the alarm system can give more information. LEDs (or other indicator devices) can be mounted on the main control panel indicating which circuit (or circuits) has triggered the alarm. These indicators can even be arranged into a simplified map of the house, as shown in Fig. 4-13, for maximum ease of use. The homeowner can tell at a glance where the problem is. Separate circuits also can be used for intrusion and fire alarms. In fact, it can be helpful for the alarm system to produce a different sound for a fire than an intrusion, so everyone in the household can know immediately what action to take. Tell children to stay put or go to the parents room if there is a late night break-in. But tell them to go outside immediately if there is a fire.



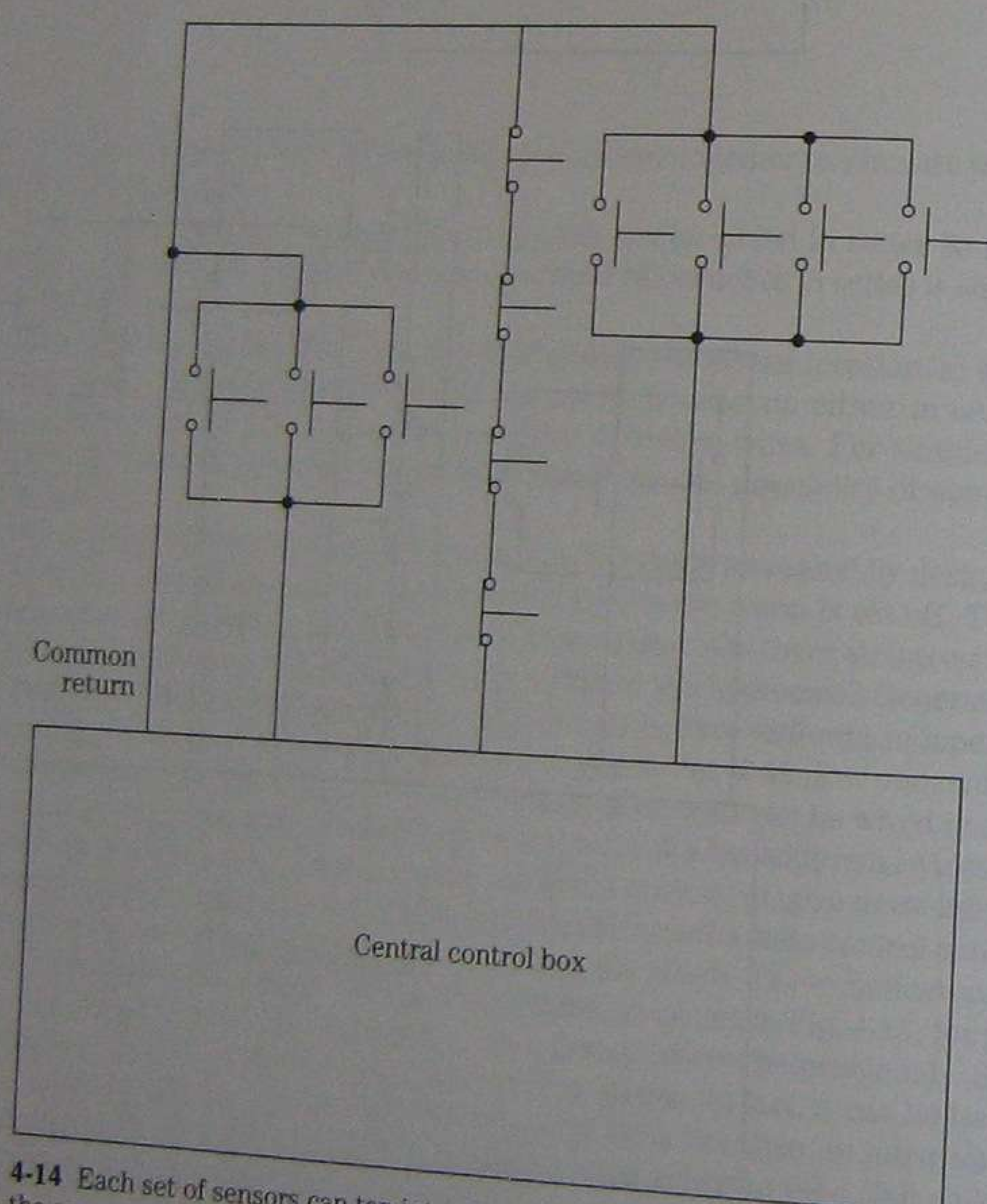
4-12 Generally the only way the control circuit can tell which sensor, or group of sensors, has been activated is to have different independent sensor circuits.



4-13 The sensor area indicators can even be arranged into a simplified map of the house.

There is some duplication of circuitry required for such refinements to a home alarm system, and additional wires must be run, but the long-term advantages make this well worthwhile in most cases. Of course there would be little point in such modifications in a security system for a small apartment.

Depending on the specific design of the alarm system's control circuitry, it might be possible to reduce the number of long wires needed by almost half. Each sensor or set of sensors requires two wires, which you can call *signal*, and *common*. In most systems, a single common wire can be used for the entire system. There is no need to run a separate common wire from each room all the way to the control center. Instead, each set of sensors can tap into a single main common wire as it passes the area. Only the signal wire must be added to the cable or wire bundle for each new section. This arrangement is shown in Fig. 4-14, which is a modification of Fig. 4-12.



4-14 Each set of sensors can tap into a single main common wire as it passes the area.

The control center

Certainly the portion of a home alarm system that can be expected to vary the most from design to design is the control center. In fact many manufacturers take great efforts to protect their individual designs in this area. If you are installing alarm equipment supplied by a specific company, you will be using their approach to system control centers, of course. If not, you will quickly find your own favorite control center.

There are so many different types of alarm system control center circuits available, that it would be impossible to cover them all here, or to give much general information that would apply in all or even most cases. Because this is not a book of do-it-yourself circuits, it seems inappropriate to go into specific detail in this area. For this discussion, treat the control center more or less as a black box. The switching data from the sensors is fed into it, and the appropriate control signals for the actual alarm and any other indicator devices come out. Don't concern yourself how the various signals are treated within the control center between the input and the output. Instead, take a quick look at some general principles of placement and installation that are likely to be applicable in many home installations.

A home alarm system's central control box should be centrally located, of course. It should be readily and conveniently accessible to the legitimate residents of the home, but preferably not to an intruder. There is little point in going overboard on protecting the central control box, even though an intruder is likely to attempt to interfere with or destroy it. Assuming the system was well thought out and properly installed, the alarm should have been set off long before an intruder could reach the central control box location. Still if it's too easy for an intruder to sabotage the system once he or she reaches this point, a genuine alarm could be mistaken for a false alarm that was legitimately turned off. In some cases, this could make the difference between whether help is summoned or not, especially if no one is at home, and the system depends on the reaction of neighbors or passers-by.

Similarly, don't worry about cleverly hiding the central control box. A smart intruder is almost certain to find it anyway—there are usually just so many possible hiding places, and most people will tend to make similar choices. On the other hand, there's no sense in tempting fate by leaving it right out in the open and in plain sight. The central control box should be readily available to legitimate members of the household, who will presumedly be under some stress if they need to get to it in a hurry, but not overly obvious. The best approach is to keep things simple.

The central control box, and the wires leading to it, should be reasonably well secured. Don't tempt an intruder to attempt to defeat the alarm system by yanking out the central control box and destroying it. Sensor wires and especially the wires leading from the control box to the actual alarm sounding device should be covered and not directly accessible. An intruder is likely to try yanking out any wires connected to a central control box. That might silence the alarm. Removing wires from normally closed sensors won't do the intruder any good. That will simply trigger the alarm (if it isn't already sounding), just like tripping a NC sensor. But a yanked-out wire will electrically "look" like an untripped normally open sensor. On the output end, pulling out the wires will prevent the necessary signal from reaching the alarm sounding device.

In most cases, the best practical protection for the system wiring is to enclose it in well-designed, sturdy conduit, which cannot be opened easily or quickly. The conduit should be securely fastened to the walls or other structural items as much as possible. Do not give an intruder direct access to any wires if it can possibly be avoided.

Mount the central control box securely with sturdy mounting screws. Use more screws than are really necessary to support the weight of the box. Yes, that means a bit more work during installation and if any future repairs are needed, but that is precisely the point. You don't want someone (like an intruder) to open or remove the control box quickly or easily. Perhaps you might even want to add a bit of melted wax over the screw heads. The screws can't be removed without scraping the wax away. The wax can be a nuisance if you ever have to service inside the control panel, but not a monumental one. It will be a much bigger nuisance for an intruder who is trying to disable the system under considerable time pressure. One or two "secret" hidden screws also can be a good idea. Placement of a few critical holding screws in locations that are not obvious will not be too big a hassle during possible future repairs, if you know where they are. But they can frustrate and slow down a desperate intruder. These tricks are scarcely guaranteed to keep someone else out. If the intruder is determined enough and has enough time, she or he will get past these obstacles. But they will surely slow an intruder down, perhaps enough for him or her to get caught in the act, or to give up and flee.

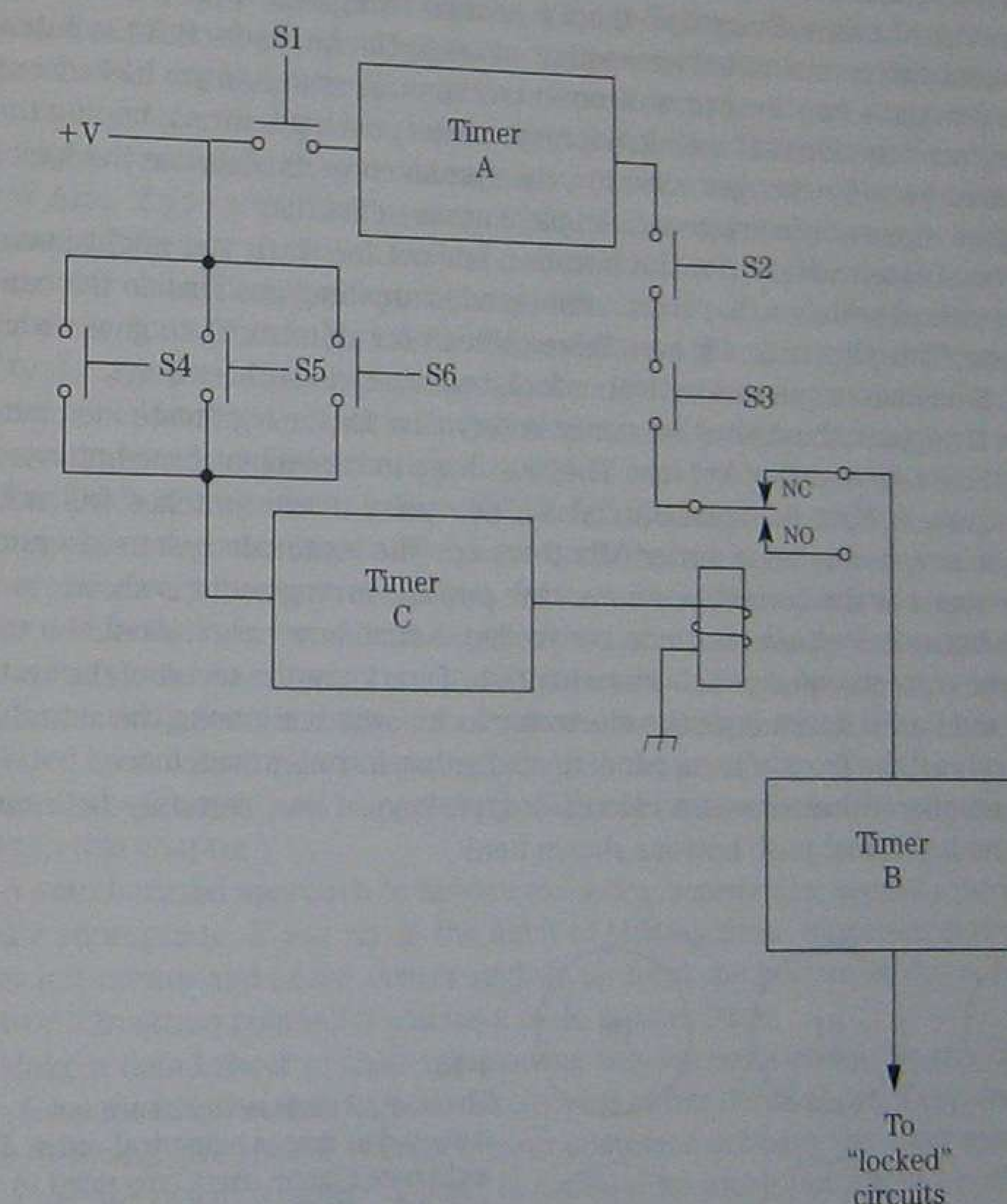
Even if an intruder doesn't actually damage or destroy the central control box, what is to stop the intruder from simply turning off the alarm system? Yes, the alarm has presumedly already sounded before anyone ever reaches the central control box, but if the intruder can turn it off promptly, neighbors or passers-by are likely to assume it was just a false alarm. Obviously, an effective home security system must include provisions to minimize such an occurrence. Rather than relying on physical security measures, such as hiding the central control box, it is generally more effective to use electronic security. A security switch of some sort can go a long way toward discouraging unauthorized operation of system functions.

There are three possible approaches to such a security switch. The first is simply a secret hidden switch that must be operated before any of the other system controls will function. This approach is inexpensive and simple, but probably not very effective as a security measure. There are just so many practical locations for such a hidden switch. Once an intruder has figured out that such a switch exists, which shouldn't take long at all, she or he probably won't have much trouble finding it, especially if the intruder happens to have any knowledge of electronics systems.

A little more security can be had with a locking key switch. This device is discussed in the section on arming and disarming the alarm system. In this application, a lock switch has two major disadvantages. It is likely to be something of an inconvenience to the legitimate system operator(s), especially under emergency conditions (a false alarm or a genuine intrusion), when nerves are likely to be jangled. The key must first be found before it can be used. Yet the key can't be kept anywhere too handy, or an intruder is likely to be able to find it. If the intruder gets hold of the key, it will obviously serve no purpose as a security device. In addition to being a potential convenience to the legitimate occupants of the house, it could be a major convenience for an intruder.

Probably the best approach to securing the central control box is to use an access code to enable any or all critical controls. Two or more switches must be depressed in a specific sequence. An error will lock out use of the control panel for some predetermined amount of time. Similar access codes were discussed earlier in the section on arming and disarming the alarm system. Actually, things can be kept somewhat simpler here than for the system arming switch at the main entrance. An intruder might try to quickly turn off the alarm if he comes across the system's central control box, but because the intruder is already in the house, he or she is not likely to want to spend a lot of time trying.

The access code can be entered via a calculator-type keypad, but the results can be as good if a half dozen or so push-button switches are used. A very simple, but surprisingly effective security circuit is shown in block diagram form in Fig. 4-15. There are three timer circuit sections and a handful of push-button switches, and



4-15 This circuit, using just three timer circuit sections and a handful of push-button switches, is a very simple but surprisingly effective security circuit.

that's about it. Any standard timer circuit can be used in this application. High precision wouldn't be of any advantage here. The simple and popular 555 timer *IC* (integrated circuit), for example, will do the job just fine.

In operation, to release the electronic lock, switch S1 must be pressed first, triggering timer A. This timer is set for a relatively short timing period of just a second or two. Before timer A times out, switches S2 and S3 must be simultaneously pressed to activate timer B, which activates the "locked" controls until it times out. A timing period of two or three minutes is appropriate for timer B.

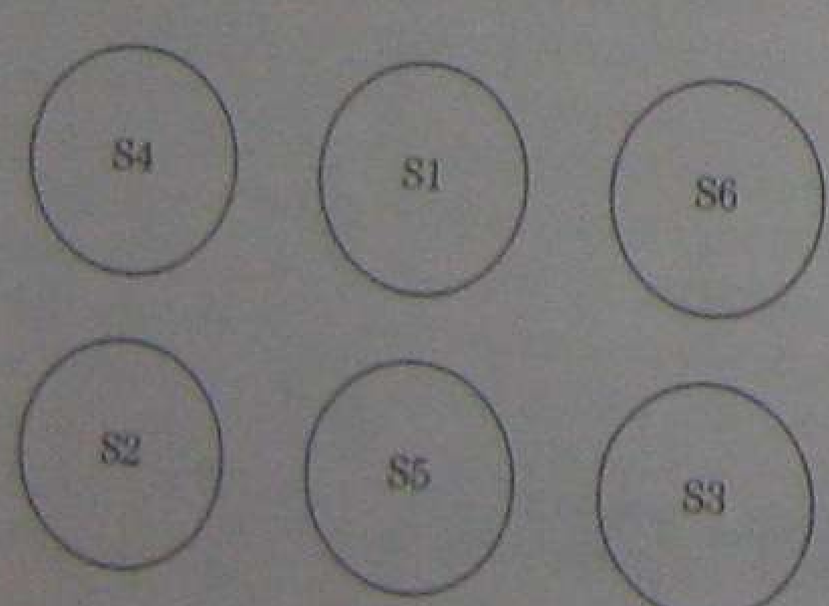
At any point in the sequence, pressing any of the other switches (S3 through S6) will activate timer C, locking out the correct switches until it times out. A good choice for the timing period of timer C is 20 to 30 seconds. More of these "booby-trap" dummy systems can easily be added in parallel, to make guessing the correct combination even more difficult. Because two switches have to be depressed at once, an intruder is even less likely to guess correctly—an intruder is more likely to try one switch at a time. Every time there is an incorrect guess, there is a waiting period of about half a minute before another attempt can be made. But the intruder doesn't even know how long to wait or when the code switches are locked out or when they are functional. If the intruder just keeps pushing buttons, hoping to get lucky, she or he will never get access to the system controls, because the lock-out timer will be repeatedly retriggered. Simple, but very effective.

To complicate matters (for the intruder, but not for you), you might even include a few dead switches that aren't connected to anything at all inside the central control box. This ploy makes it even more difficult for an intruder to guess what is going on. Some wrong guesses activate a lock-out timer, and others don't.

More important, the correct sequence is very easy for the legitimate members of the household to remember and use. They just have to remember three buttons in a simple sequence. First S1, then S2 and S3. Of course, these switches will not be mounted in simple numerical order. Mix them up. The legitimate system users only need to remember the correct positions. One possible arrangement is shown in Fig. 4-16. The buttons don't even have to be labelled. Notice how easy it would be to remember the correct sequence of buttons to press, if you know the secret of the system.

You could even intermingle the electronic lock's switches among the actual system controls on the front control panel to confuse an intruder even more.

The numbered buttons of a calculator-type keypad can certainly be used in place of the individual push buttons shown here.



4-16
The control code switches are not mounted in simple numerical order. The legitimate system users only need to remember the correct positions.

In most home alarm systems, the central control box is, by far the most complex section on the level of electronic circuitry. Even so, it still is relatively simple, at least on the conceptual level. It is just a signal switching multiplexer/demultiplexer. It accepts input signals and routes them to the appropriate output or outputs. In any electronic system, the electromechanical parts are far more likely to develop problems than the purely electronic circuitry. The central control panel will rarely develop problems. In almost all cases repair calls after installation has been completed (and all bugs and errors corrected) are with an external sensor or the interconnecting wires. Such problems are almost always mechanical. Common alarm system repairs are discussed in another chapter. For the purpose of this discussion, be concerned with preventing repairs before any problems arise and making them easy and convenient to deal with.

It is a very good idea to tag each wire into the control box. Make it easy to determine just what sensor or area it comes from. A color code would certainly be a good idea. The code eliminates the need for bulky tags that can be pulled off or smudged or otherwise made illegible. Because every system is unique, a standard all-purpose code might not be appropriate. Mount a card with an explanation of the color code inside the system's main control panel. Don't rely on memory. Someone else might someday have to service the system. Why make the job more difficult for them? Also, if you are in the business of alarm system installation, you are going to face many different situations, calling for individualized modifications in any generalized color code. There are just so many different colors available to choose from. A particular color will probably have to mean different things in different systems. Are you really going to remember all the specific details of such a variable color code if you are called back to work on an installation you did a year or more ago? If you don't have an on-site color code chart, you might as well not bother with a color code at all. The odds are against it being really helpful when it is needed. Certainly it is worthwhile to devise as generalized and standardized a color code as you can, but be prepared for very frequent exceptions. Include even the "standard" elements of the color code in the reference chart to permit someone else to understand the system, if necessary, and to allow future in the standard code. A brown wire might have meant one thing five years ago, but now its old meaning is obsolete and has been superseded by a different new meaning. Why risk the possibility of confusing yourself? Especially because it is so unnecessary. (There is more discussion of general color codes in this chapter.)

A standardized approach to hidden mounting screws (for security purposes) is usually appropriate. If you are in the habit of putting these disguised screws in the upper left corner and at the center slightly up from the bottom of the control box, you won't frustrate yourself if you have to do repairs later.

Make a detail sheet of hidden mounting screws, color codes, or any other features for a specific installation. Make two copies of this detail sheet. Keep one in your office files, and give the other copy to your customer, advising the customer to keep it in a secure place. A safety deposit box would be ideal, but might be overkill. A locked box in a closet should be sufficient to prevent an intruder from reading the "juicy details" of the alarm system. If you ever need to make repairs on the system, you can easily consult your office copy. The customer's copy is in case someone else must do future repairs for any reason. This act is not foolishly giving business to someone else. It is part of giving the customer a well thought-out, complete system. You might not be available for some reason when repairs are needed. Your installation company might go out of business (many companies do). On the other hand, your business might become too busy to handle the repair call when it comes in. You might move from the area. If your company is very small, an emergency repair situation might occur while you're on vacation. The customer might, for whatever reason, prefer to go to someone else. These are all fully legitimate reasons why someone else might need the detail sheet to do the repairs efficiently. Not giving the customer a copy of the detail sheet is, in a very real sense, cheating your customer.

It would be foolish and risky to give the customer the only copy. Some people are careless, and accidents and mistakes do happen. You don't want to be placed in the embarrassing position of having to repair your own installation blindly because the customer no longer has a copy of the detail sheet, and you didn't keep a copy in your files. Such an awkward situation is so easy to prevent.

Installing the output alarm device

On one level, it isn't appropriate to say any one portion of a home security system is more critical or important than the rest. After all, everything must work together as a system. The system, as a whole, will only be as good as its weakest element. However, given all that, it is still true that installing the output alarm device calls for extra care and planning. If the alarm can't sound, the rest of the system certainly isn't going to accomplish much. Even if the alarm does sound, it must be heard, or it isn't going to accomplish anything useful.

The important issues are the proper location and protection of the alarm output device. For the most part, assume the device is an audible alarm of some sort—a bell, a siren, or other sound-making circuit. Such an audible device will be the primary (if not only) output device for the vast majority of home alarm systems. Supplemental silent alarms also can be included in such a system, but they are more or less incidental. Alarm output devices that do not rely on sound include such things as indicator lights and autodialers to summon help from some other location.

An audible alarm should normally be used in any home alarm system, unless there are strong, special reasons to make an exception. An audible alarm serves so many purposes so easily. It can immediately alert any legitimate occupants of the house to an intrusion or other emergency condition. It can alert neighbors or passers-by that something is wrong, and the authorities should be notified or other help summoned. It also can let an intruder know that the odds of escaping with the goods are sharply reduced and fleeing is not the best plan. Audible alarms are usually effective in frightening off potential burglars, often before they get a chance to take anything (or at least before they can get much).

The choice of the sound of the alarm is for the most part a matter of personal preference. Usually one of four basic types of alarm sounds are used:

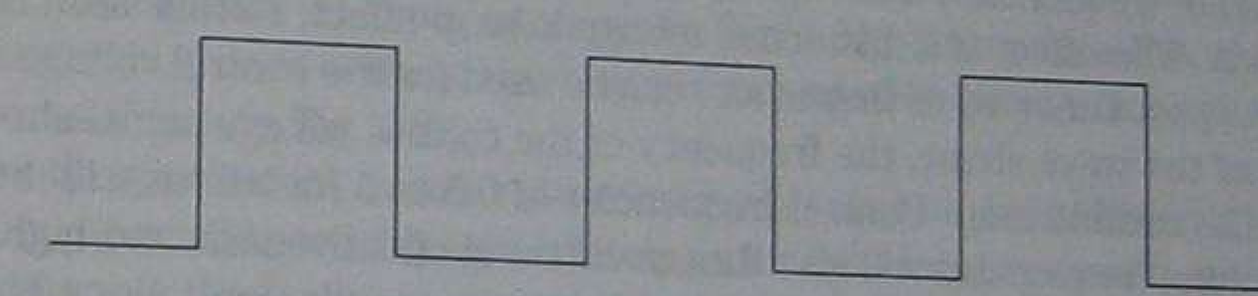
- Bell
- Buzzer

- Continuous-tone siren
- Multitone alarm or "whooper"

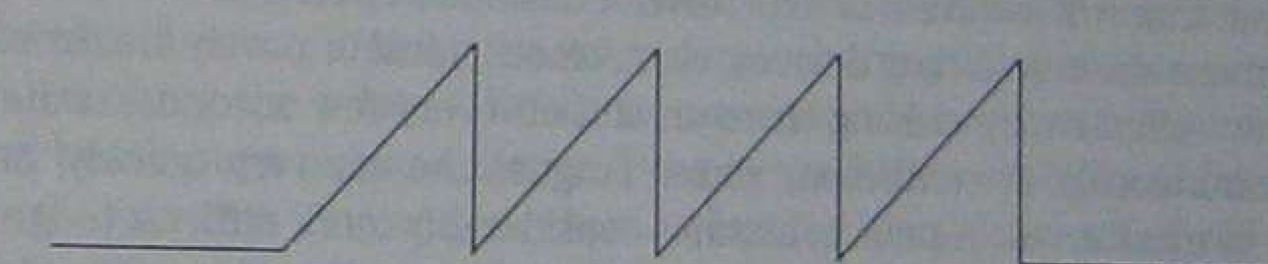
Bells and *buzzers* are electromechanical devices. When the appropriate electrical system is applied, a clapper strikes a bell, or a piece of metal is set into vibration and amplified to produce a harsh, well-carrying buzzing sound. Some sirens also are electromechanical in nature, but most modern siren devices are electronic oscillator circuits.

A *continuous-tone* siren is a straightforward oscillator circuit of one type or another. As long as it is fed a suitable supply voltage, it emits a tone through a speaker (or similar device). This tone is a constant tone with a single, specific frequency. For discussion, the wave shape doesn't really matter, although a harmonically rich wave shape such as a square wave (as shown in Fig. 4-17) or a sawtooth wave (Fig. 4-18) will carry farther and sound louder for a given amount of power consumption, than a pure sine wave (Fig. 4-19), which nominally has no harmonic content at all. The sound of an amplified sine wave becomes very piercing and irritating very quickly, so it is likely to bring complaints from the neighbors if the alarm ever sounds for more than a minute or so.

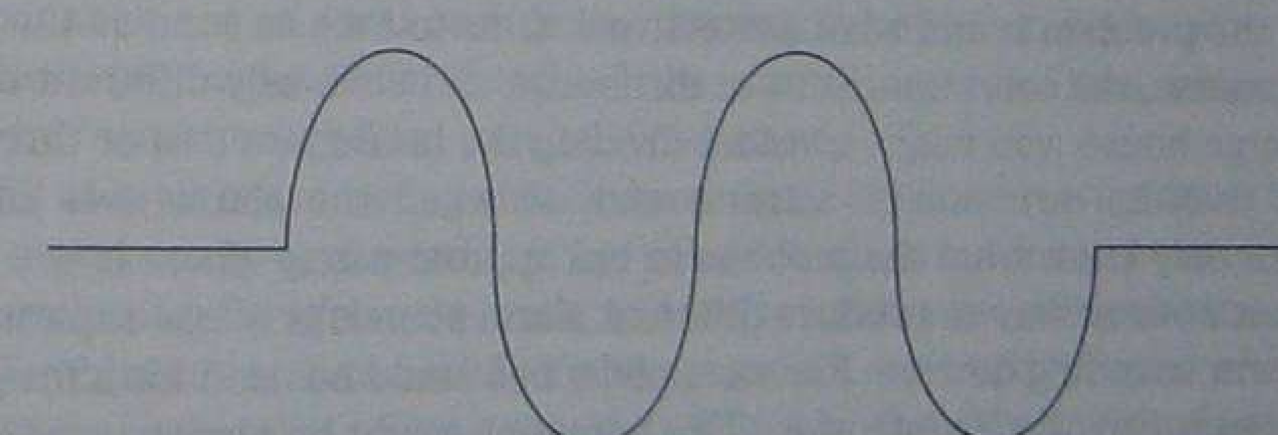
The siren tone can be emitted continuously, but it is usually more effective to pulse it on and off, as shown in Fig. 4-20. The pulsing makes the sound more distinctive and harder to ignore.



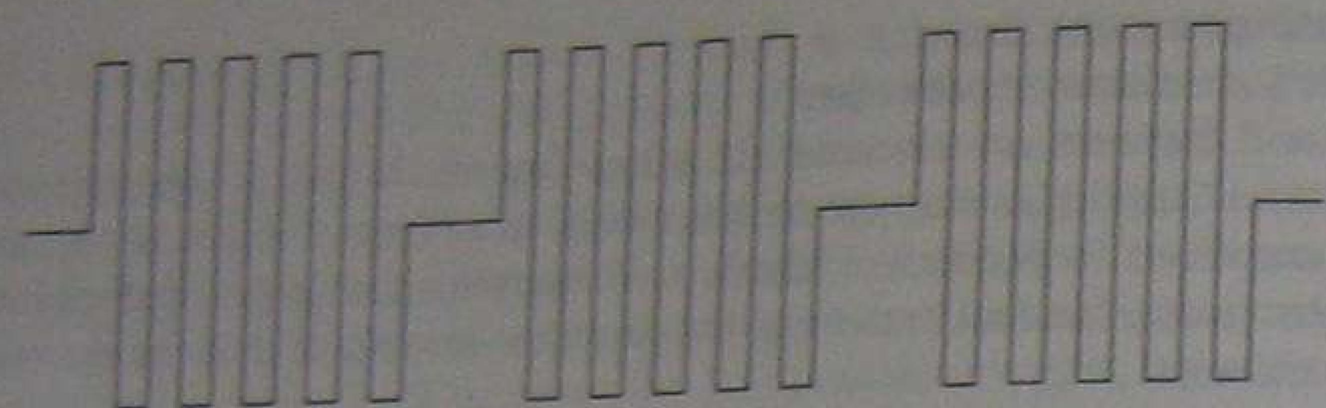
4-17 A square wave is a harmonically rich waveform.



4-18 Another common harmonically rich waveform is the sawtooth wave.



4-19 A sine wave is very pure harmonically and is therefore a weaker signal for alarm purposes.



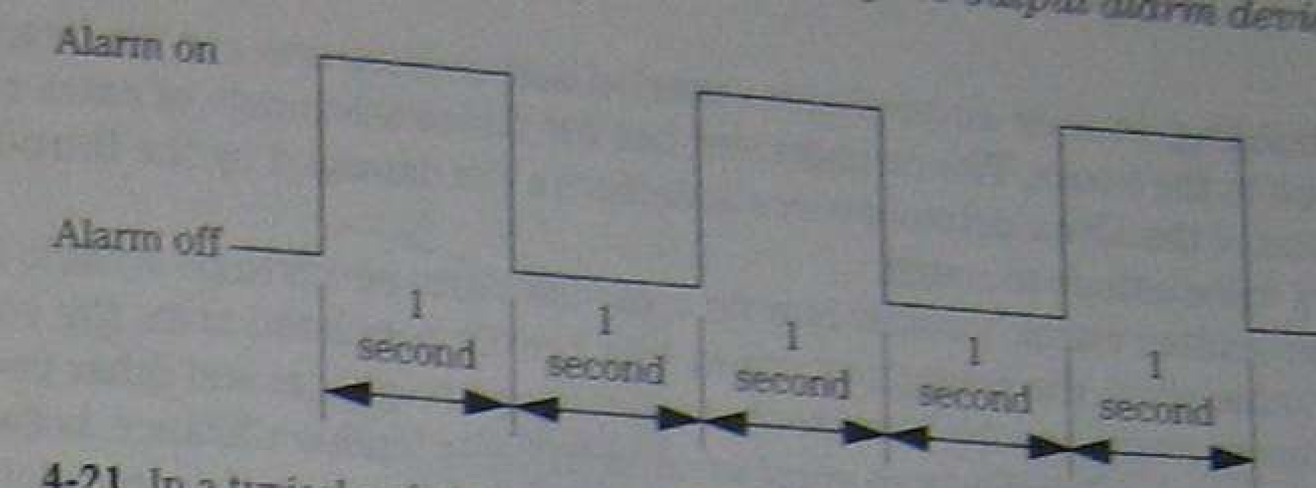
4-20 It is usually most effective to pulse an alarm tone on and off.

A *multitone* alarm, or *whooper* siren can be even more effective. By producing two or more frequencies in a rapid sequence, the alarm sound is more demanding of attention, and harder to ignore. There are several ways the multiple frequencies can be combined. Usually the main circuit will be some type of *VCO* (voltage-controlled oscillator). Changing the input voltage changes the output frequency. To get the multitone alarm effect, an ac waveform is the control voltage input. A square wave will switch back and forth between two discrete frequencies. The effect is similar to a British police car siren. Using a sawtooth wave as the control voltage input will cause the sound to smoothly glide from one extreme frequency to another, passing through all intermediate frequencies; then the signal will jump back to its original frequency and start over. The effect is a distinctive *whoop-whoop* effect, so this siren is often called a *whooper*. Other wave shapes also can be used for the control voltage signal. Regardless of the wave shape, the frequency of the control voltage signal should be well below the audible limit. Control frequencies of 0.5 to 5 *Hz* will usually be best. Lower switching frequencies will lose the ear-catching effectiveness, and higher frequencies will tend to blur the sound into a single, apparently continuous complex tone with a lot of harsh sidebands. In the later case, you might as well use a continuous tone siren that will involve less expensive and simpler circuitry.

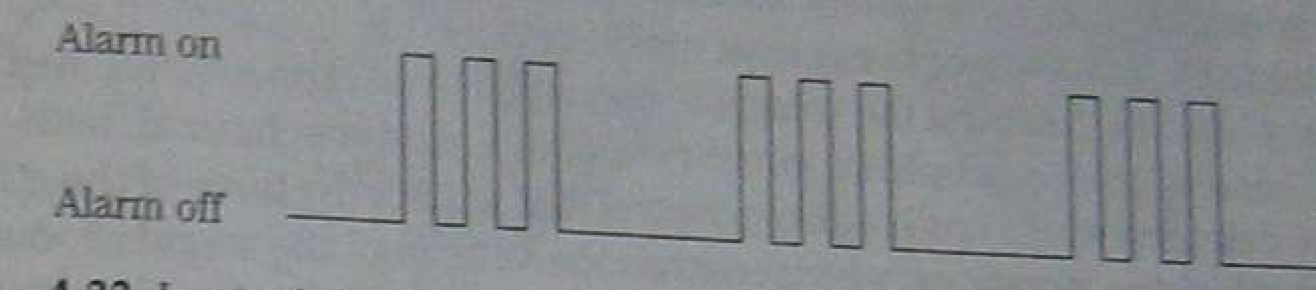
Any of these alarm sounding devices, electromechanical or purely electronic, can be made more effective by pulsing them on and off every few seconds, rather than sounding continuously. A continuous sound fatigues the ear very quickly, and the brain starts to mask it out. A pulsing alarm is considerably more difficult to ignore.

In complex alarm systems, it can be very helpful and perhaps even life-saving to use different alarm sounds for different purposes. For example, a fire might produce a different sound than an intrusion. The residents of the house will immediately know what the problem is and what protective actions to take as soon as the alarm sounds. Of course, the sounds must be as distinctive and obviously different as possible. In a large house, you might consider dividing the house into two or three sections, each with its own unique alarm sound, so when the alarm goes off, the residents not only know what the problem is, but approximately where it is.

The most obvious way to produce different alarm sounds is to use separate and differing alarm sounding devices. For example, a bell could be used for a fire, and a whooper siren is used for an intrusion. This approach might be obvious and logical, but it is a bit wasteful and unnecessarily complex. It will usually be easier and less expensive simply to design the control circuitry to produce different pulsing patterns. For example, if an intrusion is detected, the alarm might be turned on and off



4-21 In a typical coded alarm system, a detected intrusion can be indicated by the alarm being turned on and off at even one second intervals.



4-22 In a typical coded alarm system, a detected intrusion can be indicated by groups of three short bursts of tone, separated by about a second and a half of silence.

at even, one-second intervals, as shown in Fig. 4-21. If there is a fire, the alarm will be sounded in groups of three short bursts separated by about a second and a half of silence, as shown in Fig. 4-22.

Another important question to consider is just how loud should the alarm be. Most people would probably immediately go for the obvious answer—as loud as possible. After all, the louder an alarm is, the less likely it will be to be ignored or unnoticed. True enough, but only within certain limits. An alarm can be too loud. Excessively loud sounds can be annoying or even potentially harmful. Many areas have local ordinances limiting the volume of such things as alarms to avoid unnecessarily disturbing the peace. The alarm can certainly be loud enough to do its job without becoming a public nuisance. Bear in mind the possibility of false alarms, as well as the fact that if no one is at home when the alarm is set off, it will continue to sound for some time. Even with a shutoff timer (as discussed in this book), an excessively loud alarm can be a significant hardship on your neighbors. A deafeningly loud alarm sounding for 15 to 20 minutes can seem like hours, if not years. By all means check out all local ordinances thoroughly to determine at what point legal complications might set in if (when) the alarm is set off. Don't subject your customers to unnecessary fines for a too-loud alarm.

Will the alarm sounding device be mounted indoors or outdoors? An indoor alarm must usually be at a much lower volume than an outdoor mounted unit. Inside, the sound will reflect from the walls, and the reverberation will make the sound seem considerably louder than outside in the open air. If anyone is at home when the alarm is triggered, excessive volume can be painful and possibly disorienting. This sound level might be fine if the effects could be limited to the intruder, but legitimate members of the household will be equally affected by the noise level. For use inside the house, it's usually better to mount several small, low-volume alarm devices throughout the building, so their covered areas overlap and at least one can be heard at every point in the house. This arrangement has the added advantage of extra reliability. If one of the alarm output devices is defective (or damaged by the intruder), the others will continue to sound.

For an outdoor alarm, consider how far away the alarm needs to be audible if no one is at home when the emergency arises. In a heavily populated area, the sound doesn't have to reach very far, because there are several neighbors and other people close by. In a sparsely populated rural area, with considerable distance between neighboring homes, a much louder alarm will naturally be needed. Also consider the normal noise levels of the area. In an inner city district with considerable traffic or noisy factories or train tracks nearby, an alarm might have to be somewhat louder than normal to be obvious over the normal noise level.

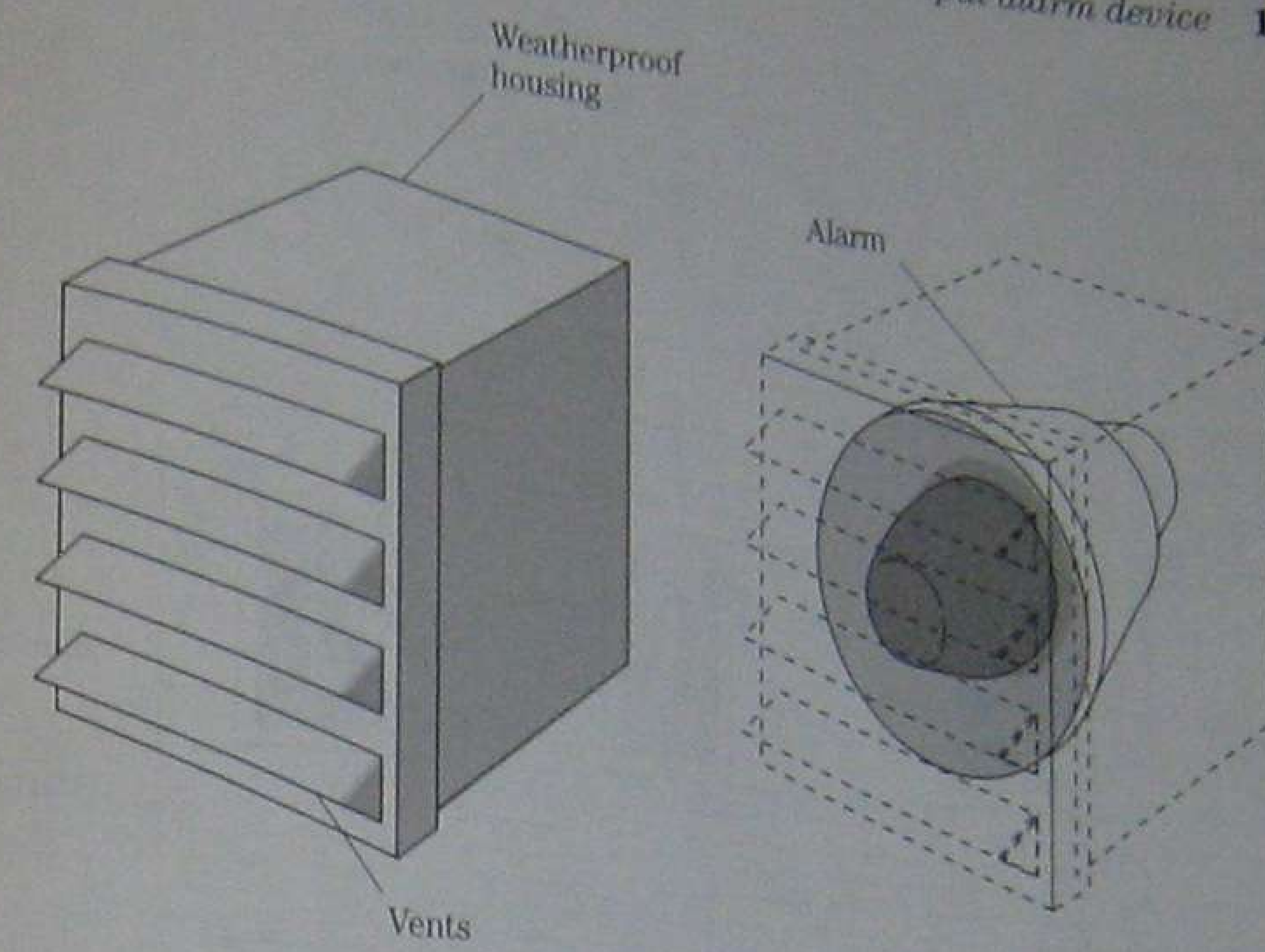
It is easy enough to control the volume of an amplified electronic siren. Just add a volume control to the amplifier circuitry. Some electromechanical bells and buzzers are designed with a crude volume control that adjusts the force of the striker or the strength of the vibrations, which controls the volume of the sound produced. In many of the devices, the sound level can be controlled somewhat by adjusting the voltage applied to the input/control terminals. Usually a higher voltage will produce a louder sound. In most cases the useful range will be limited, but at least you have some degree of control over the alarm volume. On some electromechanical devices, however, changing the input voltage will have little or no effect on the sound level. These units are essentially fixed volume devices. Once a size is selected, you're stuck with whatever volume it produces.

For electromechanical devices, the sound level is more or less directly related to the size of the unit. For example, a 12-inch alarm bell will be considerably louder than a similar 8-inch alarm bell. Buzzers are usually small and low in volume. They are best suited for indoor use. The sound might not be loud enough to carry outdoors. Of course, you can combine both indoor and outdoor sounding devices in any alarm system to maximize the protection.

Any outdoor alarm must be adequately protected from the weather. Reputable manufacturers will indicate if an electrical device is rated for outdoor use or not. An additional weatherproof housing never hurts, even if the device is designed for outdoor use. This idea is a good one in areas frequently subject to heavy rains or other rough weather. Of course, the weatherproof housing must be as acoustically transparent as possible. Make sure it does not significantly deaden the sound produced by the alarm. A grill with downward-facing slits, as shown in Fig. 4-23, will usually do a reasonably good job of keeping most rain, dust and other troublesome particles out of the mechanism, but permit the sound to pass through with no noticeable reduction in volume.

Some electronic sirens are built into a single unit, with an attached speaker or similar transducer. Others are separate circuits where the output is fed to an external speaker or horn. It is a good idea to mount the actual circuitry inside the building, if possible, with only the speaker, horn, or whatever mounted outside (with suitable weather protection).

In addition to weather protection, protect an external alarm against tampering. You don't want your alarm system to be disabled by vandals, or worse, by an intruder



4-23 To protect an outdoor speaker or siren, a grill with downward facing slits will usually keep out most rain, dust, and other troublesome particles.

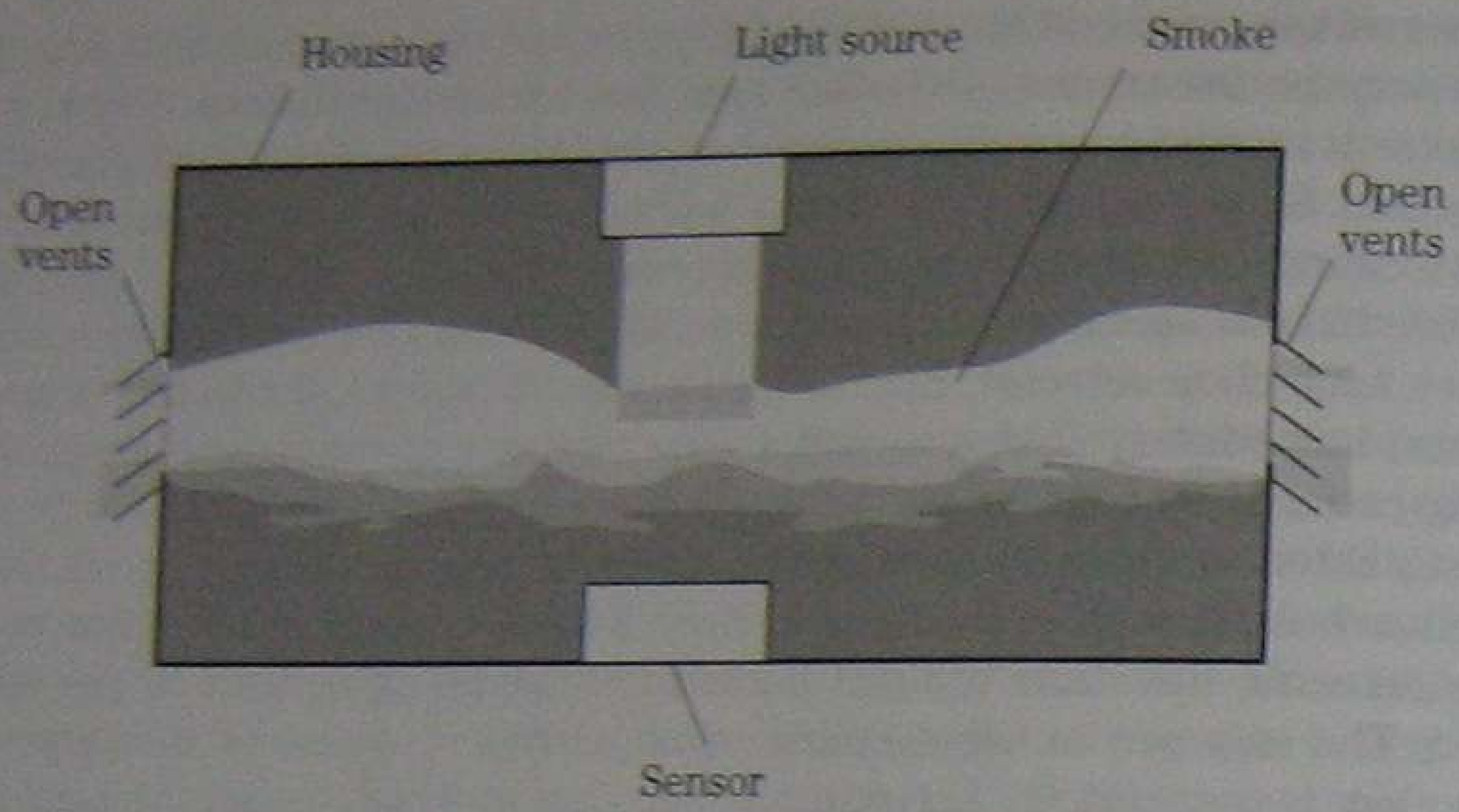
before he or she gets in and sets off the alarm. (Indoor alarm sounding devices also should be reasonably protected against tampering, but it is less critical here, and less solid protection is required.) All wires and especially connections must be enclosed in a sturdy housing. It should not be possible for anyone to cut the wires. The alarm-sounding device should be very securely mounted, and ideally enclosed in a locked cage or similar protective structure.

Mount outdoor alarm sounding devices physically as far off the ground as possible. Make them as inaccessible as possible. Obviously they won't be completely inaccessible, or how would you mount them? Do your best to discourage a potential intruder from trying to get at them. You might not be able to make it impossible, but you can make the task require a lot of time, and make the intruder risk attracting attention.

The area around the exterior alarm sounding devices should be well lit and as visible as possible from as many directions as possible.

For maximum protection, use multiple alarm sounding devices at different locations. An example is shown in Fig. 4-24. If they are all relatively inaccessible, it would take a very determined intruder to attempt to disable them all. It wouldn't hurt to mount one or more extra alarm sounding devices in less-obvious, less-visible places. Even if an intruder does tamper with the main alarm sounding devices, she or he might miss the hidden units. There is no guarantee, of course, but this little trick can help improve the odds.

There's no reason why you can't use a few intrusion sensors in the immediate area of each alarm sounding device. For example, opening the housing could set off



5-1 In an optical smoke detector, the smoke blocks the light from a source before the light reaches a photosensor.

sensor are placed in a semi-enclosed housing, as shown in Fig. 5-1, no object can get in to block the light from the source before the light reaches the photosensor. But air can get in easily, and that includes smoky air. The smoke will come between the light source and the photosensor, blocking off some of the light. The photosensor will respond to this reduction in the amount of light striking its sensing surface. The circuitry connected to the photosensor is calibrated to trigger the alarm when the detected light is slightly reduced, indicating the presence of smoke. Unfortunately, dust or other airborne particles also might set off an optically based smoke alarm.

Alternately, special electronic sensors can detect the change in the chemical composition of smoke-filled air. This approach is considerably more reliable, though more complex than the optical method, and it is used in one form or another in virtually all commercial smoke detectors now on the market. This method of smoke detection is rather complex and requires too much space to describe it adequately. Fortunately, there is little or no need for the practical alarm system technician to know the details of the inner workings of smoke detectors. These units are widely available commercially at low cost, and are self-contained. They are almost never cost effective to repair. It's almost always cheaper simply to replace a defective smoke detector with an entirely new unit. Therefore, the alarm system technician can reasonably treat a smoke detector as a black box. Either it works or it doesn't work, and how it's supposed to work doesn't really matter.

Although it is foolish and risky to consider one or two smoke detectors to be adequate protection against fire in any home, it would be equally foolish to leave these devices completely out of a home security system. In many areas, local ordinances require the installation of smoke detectors in homes, and even where they aren't legally required, they are very much a good idea. A smoke detector is so inexpensive compared to the home alarm system as a whole, that there is little or no reason for not using it. A smoke detector does provide excellent, if limited, protection. For certain types of fires (slow smoldering fires), there is no better way to detect them in their early, less destructive stages.

In a large house, use several smoke detectors. Remember, they are cheap. There's no need to scrimp. It's better to install too many smoke detectors than too few. The down side of installing too many smoke detectors in a home is a little added expense, typically ten to twenty dollars per smoke detector. An alarm system installer should be able to buy smoke detectors in quantity, lower the unit price even more. The down side of installing too few smoke detectors is the possibility of hundreds or thousands of dollars of property damage or serious injury, or even death of one or more members of the household in the event of a smoky fire. Which alternative seems like the more reasonable trade off?

In most homes, the most critical location(s) for smoke detector(s) is near any sleeping areas. Noxious fumes from smoke are most likely to have tragic results when everyone is asleep. A person who is awake is more likely to smell or hear something suspicious and investigate. Many people have died in their beds from extensive smoke inhalation, without ever waking up. A hall outside several bedrooms is a logical place to install a smoke detector. A more cautious approach is to install a smoke detector in each bedroom.

A garage or a basement also would be a good place to install an extra smoke detector. A slow smoldering fire could continue in such locations for some time, even during waking hours, without anyone noticing, because most people don't spend much time in these areas. A garage or basement also is the most likely place for possibly flammable materials to be stored, making a fire somewhat more likely to start there.

As stated, the very worst place to install a smoke detector is in or near the kitchen. A detector in the kitchen will accomplish little but numerous false alarms. At best, this would be extremely annoying, and possibly tragic if the smoke detector is disabled by having its battery removed to stop a false alarm and not replaced.

Whatever the location in the house, it is usually best to mount a smoke detector high up on a wall or on the ceiling. The high location will help prevent accidental damage from anyone bumping into it, or from too curious children. More importantly, a smoke detector will tend to function more reliably at a higher physical level. In the event of a fire, even the slowest burning smoldering fire, the smoke is going to be hot, at least hotter than the normal air in the area. Hot air, including smoke, tends to rise. The rising of hot air is why experts recommend crawling on your hands and knees if you ever have to escape from a major fire with the room filled with smoke. The safest, most breathable air will be down close to the floor.

Installing a smoke detector is not even remotely difficult. It's just a matter of mounting it in place. Most commercial smoke detectors are designed to be held by one or two standard screws. Other than that, the installer just has to make sure a fresh battery is correctly installed in the unit, and the installation of the smoke detector is complete.

Thermal sensors

Too many homes are currently protected against fire only by a smoke detector. Many well-meaning but short-sighted officials have irresponsibly led the public to believe this is adequate protection. It most definitely is not. Certainly a smoke detector by itself is better than nothing, but it can only protect against some types of fires. How can anyone guarantee they'll only have the "right" type of fire?

No, an adequate home security system must offer double-barrelled fire protection, incorporating both smoke detectors **and** thermal sensors. There is no rational excuse for making this an either/or choice. Use both to do the job right.

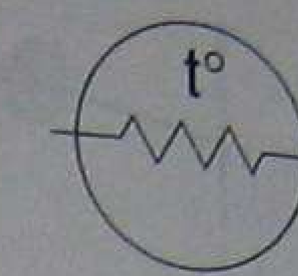
Commercially manufactured thermal-sensing fire alarms are not widely available now, unfortunately. But a wide variety of thermal sensors are commonly available, and they can easily be incorporated into an existing alarm system, pretty much like the sensors used for detecting intruders. Some thermal sensors will require some specialized support circuitry, usually in the form of a comparator circuit for a continuous-range type sensor, and others can be wired directly into the alarm system, just like any other switching sensor. The support circuitry, if required, rarely needs to be very complex or expensive.

A *thermal sensor* is generally any electronic device that produces some electrical response to a detected change in temperature. Of course, if you get too loose with this definition, almost any electronic component could qualify, if the temperature changes sufficiently. Most capacitors will vary their value in response to the ambient temperature. If a resistor is heated sufficiently, it also will change its value, perhaps permanently. Any semiconductor device is always heat sensitive to some degree, which is why heat sinks are frequently used to protect such components. A semiconductor component will change its performance characteristics in response to changes in temperature, and the delicate crystalline structure of the semiconductor can be easily damaged or destroyed by over heating. Of course, a sensor that is destroyed by the condition it is supposed to detect would hardly be practical or reliable.

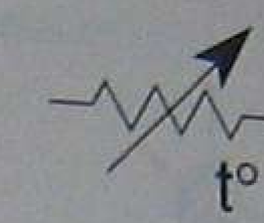
A practical thermal sensor offers a predictable and repeatable (that is, nondestructive) response to changes in the detected temperature. Of course, any electronic component or device will be damaged or destroyed by sufficient extremes of temperature, but a practical thermal sensor can stand up to much higher temperatures than most standard electronic components. The thermal sensor is unlikely to be damaged unless it is actually engulfed by the fire, in which case, the damage to the sensor is probably the least of your worries.

Thermal sensors are available as either continuous-range or switching devices. *Continuous-range* thermal sensors usually (but not always) work by varying their resistance in response to the sensed temperature. A device that changes its resistance proportionately with temperature is known as a *thermistor*. The word *thermistor* is a blending of *thermal* and *resistor*. There are many different devices that fit into the relatively broad heading of thermistor.

The standardized schematic symbol for a thermistor is shown in Fig. 5-2. Notice that this is basically just a slight variation on the standard schematic symbol for an ordinary resistor. The important element here is the letter t° for *temperature*, or *thermal*. The t° is the only part of the symbol that identifies the indicated component as a thermistor rather than some other type of resistor. Some technicians omit the circle, as it adds no information to the symbol. The circle is more eye catching than the small t, so it more clearly indicates that this component is something other than an ordinary resistor. A few schematics will add an arrow through the thermistor symbol as shown in Fig. 5-3 to indicate the variable resistance of the component, but



5-2
This is the standard schematic symbol for a thermistor.



5-3
A few schematics add an arrow through the thermistor symbol to indicate the variable resistance of the component.

this really isn't necessary, because the t° already implies the resistance varies with temperature.

Especially in hand-drawn schematics, neatness is vital. A sloppy t° could be mistaken for a +, indicating a positive value of some sort. The sloppy t° could cause unnecessary confusion very easily.

Thermistors can be divided into two broad subcategories, based on the way they function. Any thermistor must be either an *NTC* or a *PTC* type. *NTC* stands for *negative temperature coefficient*, which means the device resistance is inversely or negatively correlated to the sensed temperature. That is, increasing the temperature results in a corresponding decrease in the thermistor resistance, and vice versa.

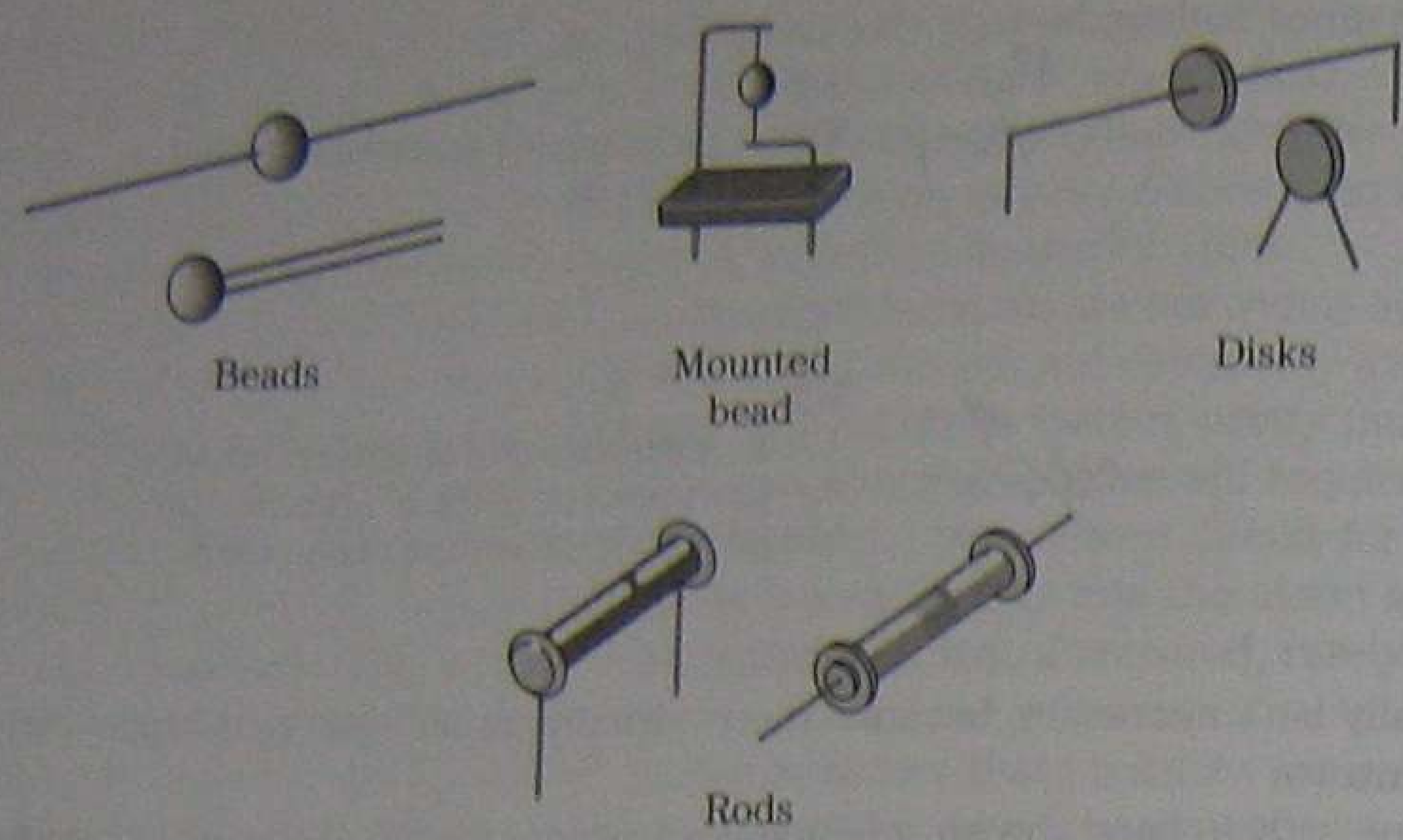
Not surprisingly, a PTC thermistor operates in just the opposite way. You've probably already guessed that *PTC* stands for *positive temperature coefficient*, which means the device resistance is directly or positively correlated to the sensed temperature. Therefore, increasing the temperature results in a corresponding increase in the thermistor resistance, and vice versa.

For a variety of reasons that needn't really be of concern, NTC thermistors are much more common in practical use than are PTC thermistors. For that reason, focus just on NTC devices. Everything said about NTC thermistors here also will apply to PTC thermistors if the resistance response is simply reversed.

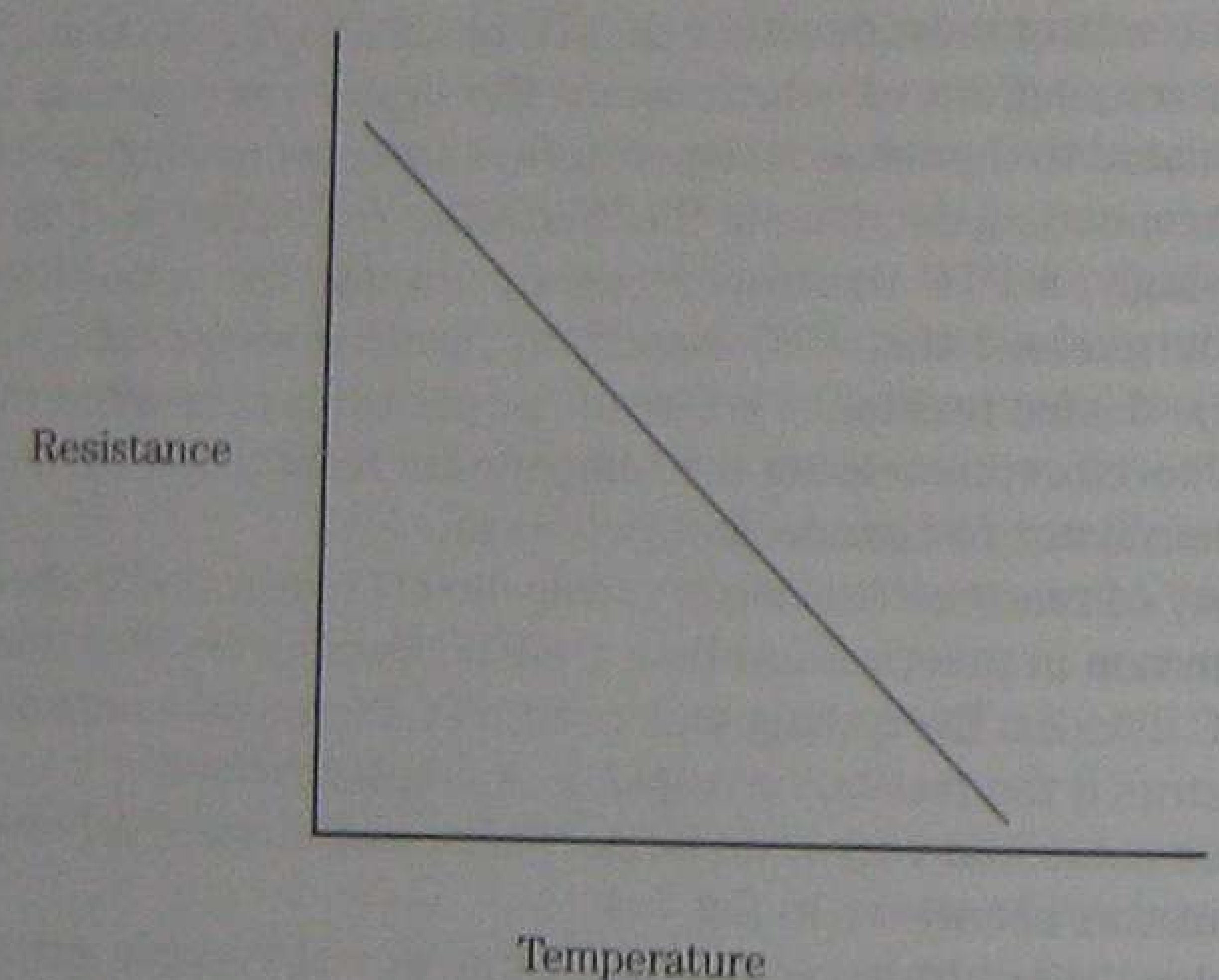
Thermistors come in a very wide range of shapes and sizes. A few typical body types for thermistors are shown in Fig. 5-4.

Most standard thermistors are formed from special ceramic materials, which function as semiconductors. Powdered metal oxides (particularly nickel oxides and manganese oxides) are often used to fabricate these components. In some cases, other oxides might be mixed in as well. The powdered oxides are mixed together with water and various electrically neutral binders, and the resulting material can be shaped as desired and fired into a solid ceramic. A coating of silver, or occasionally some other conductive metal, is placed over the ceramic center. Leads are added; then the assembly is enclosed in an insulating housing, usually made of epoxy, glass, or plastic.

An ideal thermistor would be perfectly linear over its entire range, as graphed in Fig. 5-5. Real-world components aren't nearly so perfect, of course. A typical resistance/temperature graph for a practical thermistor is shown in Fig. 5-6. The exact curve, and the placement and size of the linear portion depends on the design of the



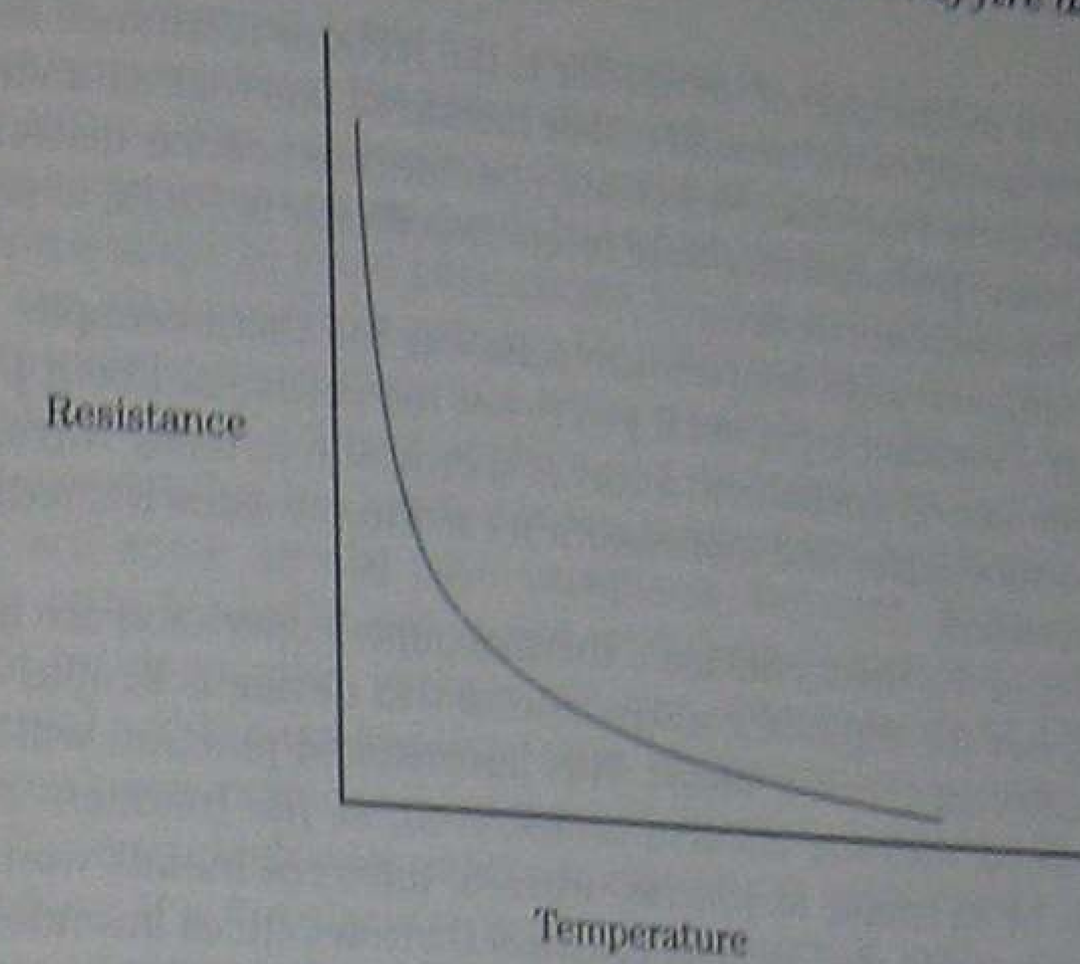
5-4 Thermistors come in a very wide range of shapes and sizes.



5-5 An ideal thermistor would be perfectly linear over its entire range.

thermistor used. In precision-measurement applications, a thermistor must be very carefully selected to be as linear as possible over the desired measurement range. For use in fire alarms, however, a thermistor is combined with a comparator circuit of some sort, and all that you are interested in is whether or not the sensed temperature is greater than or less than the preset trip point. Linearity is not generally a significant issue in this application.

In selecting a thermistor for use in a fire alarm system, the only really important specification is that the desired trip-point temperature is well within the rated oper-



5-6 This is a typical resistance/temperature graph for a practical thermistor.

ational range of the device. This requirement will rarely be a problem in home environments, when a temperature above about 150 to 200°F would almost certainly indicate trouble, and should trigger the alarm. This is still a fairly low temperature as far as most thermistors are concerned.

Most commercial thermistors are rated by their nominal resistance at 25° Celsius (about 77°F). This nominal resistance is just an approximation except for specialized (and expensive) high-precision devices. The higher this reference resistance is, the higher the effective temperature range of the thermistor will be (see the comparison chart of Table 5-1).

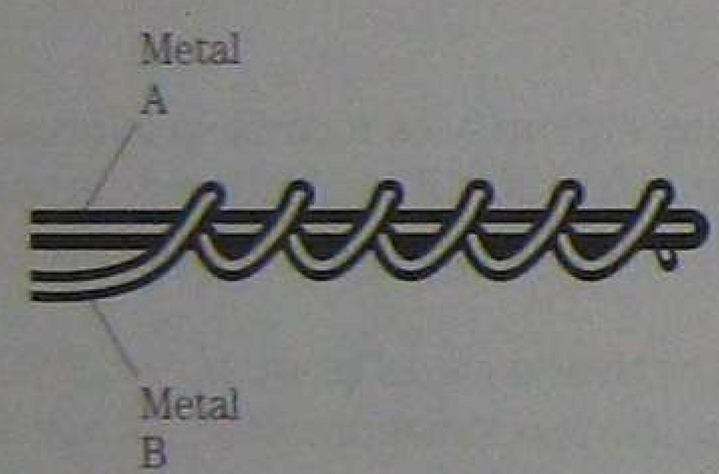
Table 5-1. Comparision of the temperature/resistance trip points for some typical thermistors

Temperature		Reference resistance at 25°C			
°C	°F	100	1 kΩ	10 kΩ	1 MΩ
–50	–58	2.32 kΩ	35.4 kΩ	441 kΩ	—
–30	–22	846	11.4 kΩ	135 kΩ	—
–10	14	354	4.23 kΩ	47.5 kΩ	—
10	50	166	1.79 kΩ	18.8 kΩ	2238 kΩ
30	86	85.4	834	8.19 kΩ	775 kΩ
50	122	47.5	425	3.89 kΩ	296 kΩ
70	158	28.3	233	1.99 kΩ	123 kΩ
90	194	17.8	136	1.08 kΩ	55.5 kΩ
110	230	—	—	624	26.8 kΩ
130	266	—	—	376	13.7 kΩ
150	302	—	—	237	7.48 kΩ

Closely related to this type of thermistor is the RTD, or resistance temperature device. An RTD is usually a wirewound coil or metalized film that exhibits a positive temperature coefficient response. Nickel and platinum are popular materials for use in RTDs. In fact, some technical literature refers specifically to PRTs, which are platinum resistance temperature devices.

Another continuous-range temperature sensor is the thermocouple. A thermocouple is not truly a resistive type, but if you're not too particular about precise definitions, it could be loosely considered a sort of thermistor. In many ways, the effect is the same. If thermocouples and thermistors are not in the same immediate family, they are at least cousins.

The intricacies of the theory behind a thermocouple's operation are a bit on the complicated side, but the physical construction of this device is simple—it's just a junction of two different types of metal. This mismatched junction will produce a voltage that increases with the ambient temperature at the junction. A practical thermocouple can be as simple as just two wires of different metals wound around each other, as shown in Fig. 5-7. In most practical thermocouples intended for long-term use, the junction will be welded together for maximum reliability.



5-7 A practical thermocouple can be as simple as just two wires of different metals wound around each other.

A working thermocouple can be made from almost any pair of dissimilar metals, but, not surprisingly, some combinations work considerably better than others, particularly in the areas of stability, linearity, and overall temperature range. Some examples, as recognized by NIST (National Institute of Standards and Technology—formerly the National Bureau of Standards) include:

- Chromel and alumel
- Chromel and constantan
- Copper and constantan
- Iron and constantan
- Nicrosil and nisil

Other effective thermocouples use various platinum alloys.

Thermocouples are more suitable to industrial and laboratory applications than home alarm systems, but they can certainly be used for home systems.

Thermal switches also are available, and they are more directly suited to alarm system applications. As the name suggests, a thermal switch is a switch that is activated when the temperature exceeds some specific preset level. For most common thermal switches, the temperature trip point is permanently set by the manufacturer of the device, and is not user adjustable. Some thermal switches are adjustable over

a limited range, however. A few can be adjusted for any of a moderately wide range of trip-point temperatures, but wide ranges are the exception rather than the rule.

For most fire alarm applications, the exact trip-point temperature isn't too critical. The trip-point temperature needs to be high enough above the normal expected ambient temperature to avoid false alarms, but low enough that the heat from a fire will set off the alarm before it gets too far out of control. Generally speaking, a reasonable trip-point temperature in a home would be in the 120 to 180°F range. It wouldn't take much of a fire to produce such temperatures, but it is highly unlikely that it will ever get that hot inside a home, unless something is very seriously wrong.

There are some special case exceptions, however. Even in air-conditioned homes, the attic is usually not cooled, and during summer months it can get extremely hot inside an attic. In some climates, a temperature of 130 to 160°F might not be unusual inside an uninsulated attic. Because attics are normally used for storage, and aren't generally occupied most of the time, they are a likely starting point for a fire. But such high normal attic temperatures could create some serious false alarm problems if a fire alarm thermal switch mounted in the attic has a trip-point temperature of about 140 or 150°F. It is supposed to be a fire alarm, not a hot sunny day alarm. The solution is obvious enough. Use a thermal switch with a higher trip-point temperature. Something between about 200 to 250°F should do nicely. Certainly you should avoid using a thermal switch with a trip point temperature much higher than 300°F. This is not a reasonable temperature that should be expected in a home under normal conditions. In certain heavy industrial settings, temperatures over 300°F might be only moderately warm, but you are concerned with home systems here, and people generally just don't live under such conditions.

Near a water heater is another place in the average home that reasonably calls for a thermal switch because of the likelihood of a fire starting there. A switch near a water heater requires a higher than normal trip-point temperature to avoid false alarms.

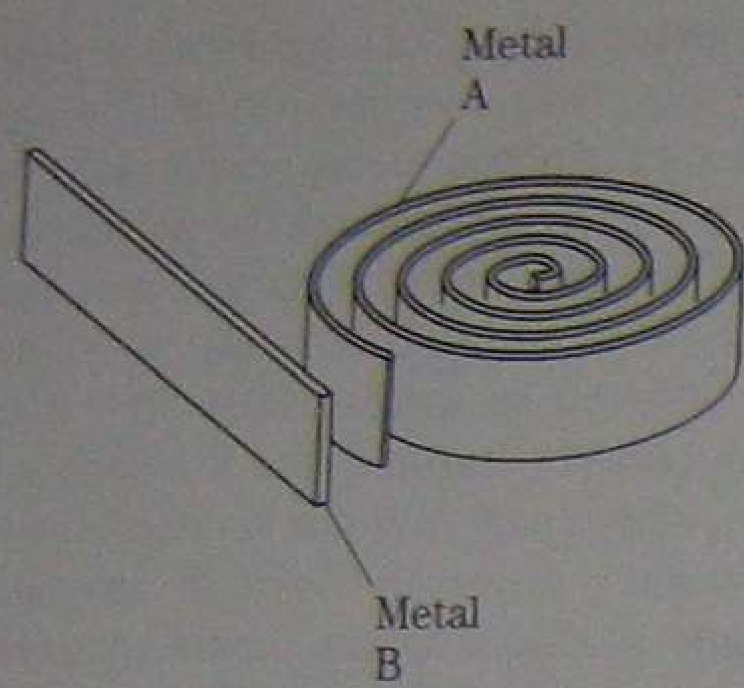
You also might consider mounting a moderately high temperature tripping thermal switch over the stove. Don't mount it too close, or ordinary cooking might set it off.

One of the simplest and most common types of thermal switch is similar in some ways to the thermocouple. This switch also is used in most electromechanical (as opposed to purely electronic) thermostats for household heating and cooling systems.

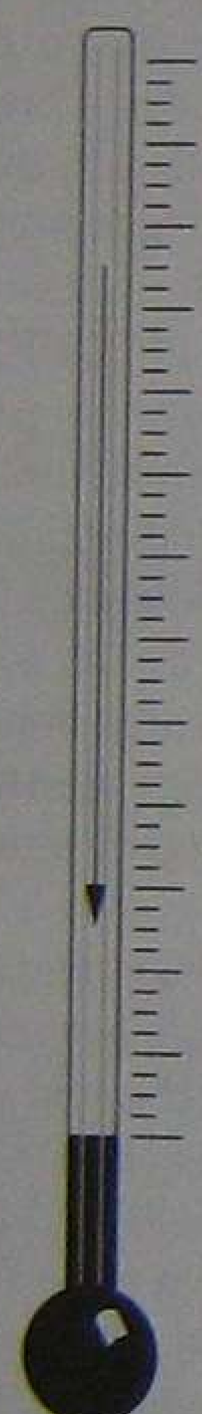
Once again, there are two dissimilar metals, but here they are normally close, but not quite touching. Usually the metal will be in the form of strips, rather than actual wires. In an adjustable thermostat, one (or sometimes both) of the metal strips will be coiled as shown in Fig. 5-8. Tightening or loosening the tension of the coiled strip will control the actual trip-point temperature.

This thermal switch is based on the principle that most materials, including metals, tend to expand as they are heated. Ordinarily, this expansion is so slight it goes unnoticed, but it is sufficient for electromechanical switching.

This expansion effect is most clearly demonstrated by the mercury inside an ordinary thermometer. Mercury is a metal with an extremely low melting point—so low, in fact, that mercury will only solidify at what to humans would be an abnormal and unbearably cold temperature. Generally, a liquid expands more readily for a given increase of temperature than a solid. At cold temperatures, the mercury con-



5-8
In an adjustable thermostat, one of the metal strips will be coiled so that tightening or loosening the tension of the coiled strip will control the trip-point temperature.



5-9
At cold temperatures, the mercury in a thermometer contracts and takes up less space in its sealed tube.

tracts, and takes up less space in its sealed tube. It only reaches up to a fairly low level on the scale, as shown in Fig. 5-9. When the temperature increases, the mercury expands. Because it is in a sealed tube, the only way it can expand is by moving upwards in the tube, filling more of it, up to a higher point on the scale, as shown in Fig. 5-10. A similar effect occurs with solid metals, but the differences are less obvious to the naked eye under most normal circumstances.

The two metal strips inside a thermostat or thermal switch are made of different types of metal because different materials naturally expand at somewhat different rates. If you have two strips of different metals expanding at differing rates, correct

5-10
At high temperatures, the mercury in a thermometer expands and takes up more space in its sealed tube.

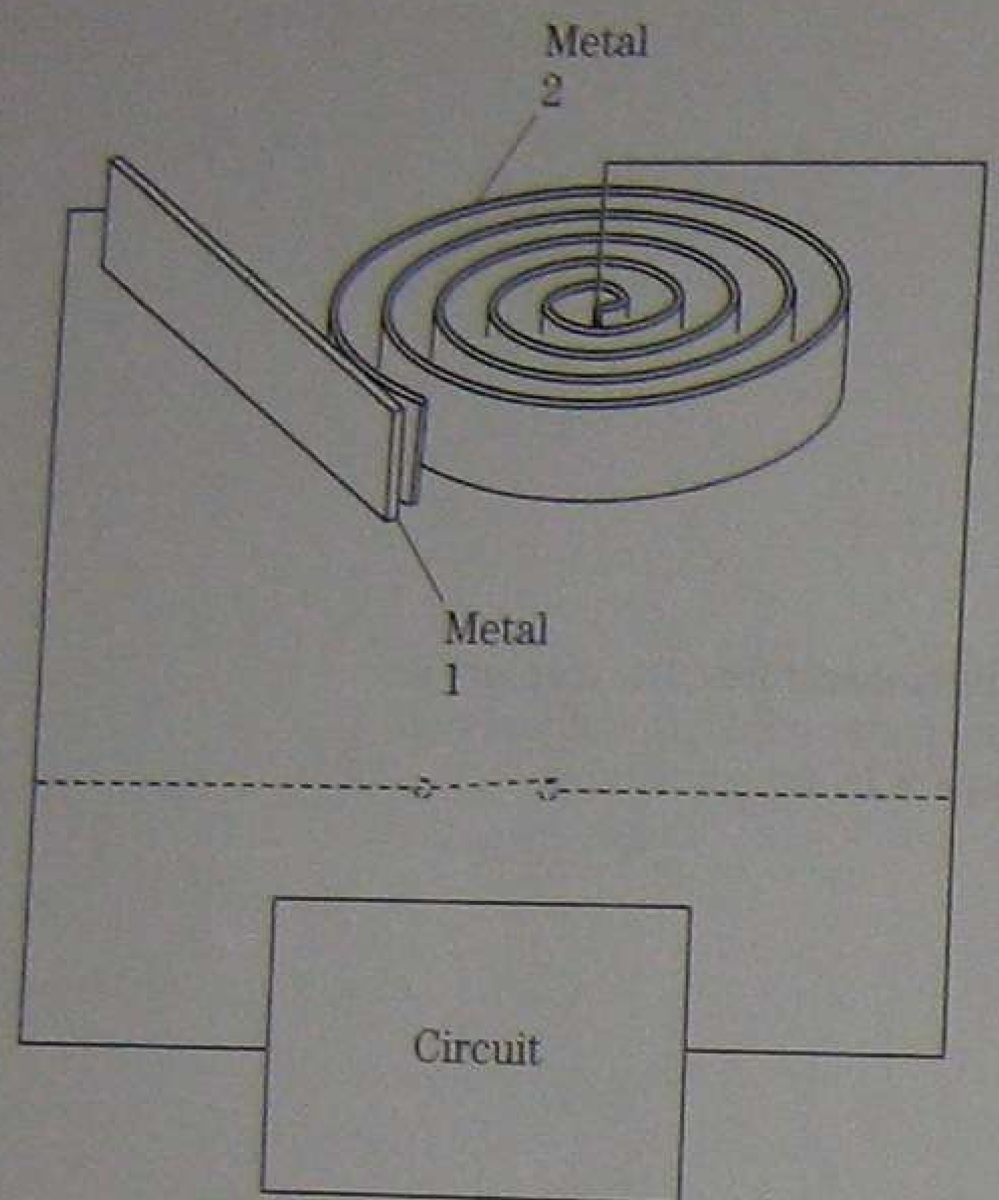
physical placement will cause the two metal strips to normally be separate, but to touch each other if the temperature exceeds a specific trip-point value, as shown in Fig. 5-11. If electrical terminals are connected to each of the metal strips, you have a simple, but effective temperature-activated normally open switch. If the temperature is below the trip point, the switch contacts (the dissimilar metal strips) will be open, but if the temperature exceeds this critical value, the switch contacts will be closed (the two metal strips touching).

Other types of thermal switches also are available, but are less common. Most still operate on some variation of the expansion with temperature principle, although in somewhat different ways.

Installing thermal sensors

A thermal switch or other temperature sensor can be installed in much the same way as the more standard sensors used for intrusion detection in a home alarm system. There are a couple of special points to keep in mind.

First, as with a smoke detector, it is usually best to mount a thermal sensor high on a wall or on a ceiling. This location will help prevent accidental damage from anyone bumping into it and from curious children. The most important reason for mounting a thermal sensor closer to the ceiling than the floor is that hot air rises and cold air falls. The thermal sensor's job is to watch out for abnormally increased tem-



5-11
When the trip-point temperature of a thermal switch is reached, the two strips of dissimilar metals touch each other, making electrical contact.

peratures, and this will be most detectable and obvious at higher positions. If there is a fire anywhere in the area, the temperature near the ceiling will soon get abnormally warm, but it might be some time before the increased heat is detectable near the floor level, especially if there are any cool drafts in the area.

Try to anticipate areas where fires are most likely to occur when choosing where to mount thermal sensors. Typically, a thermal sensor can cover a somewhat smaller area than a smoke detector, so you will probably need more of them. Certainly a thermal sensor should be placed near any potential fire or heat source, such as a water heater, a furnace vent, or a fireplace. But don't mount it too close, or the residents will be plagued with false alarms. Remember, it is the intended function of a water heater to get hot, and a furnace vent or a fireplace is supposed to send out some heat into the room. The thermal sensor must be selected and mounted to detect only **abnormal** amounts of heat, not the normal functioning of such common household features.

6
CHAPTER

Gas detectors

Dangerous gas leaks aren't too common in the average home, but they can occur and the results can be deadly. Some poisonous gases betray their presence with a distinctive smell, but some of the most poisonous gases are odorless, colorless, and tasteless. They can be silent, invisible killers. Even if the gas does have an odor, it might not be noticed until too late, unless someone is paying attention to the possibility of a gas leak. Under most circumstances, a strange odor is likely to go unnoticed unless it is strong, especially if there are other smells in the area that could mask that of the gas.

Gas leaks are relatively rare occurrences. When gas leaks happen, they are much more likely to have disastrous results than most other comparable accidents because many gases can do considerable damage, or even cause death, before their presence is detected. Often the presence of the poisonous gas is only detected after the fact, from its effects. Obviously it is more than desirable to detect a gas leak before an accident happens.

In addition to directly poisonous effects, many gases that might leak are highly flammable or even potentially explosive. Again, the leaking gas is all too often only discovered after the fact. The rubble in the aftermath of an explosion might reveal that gas must have been the culprit, but by then it's clearly too late for the information to help avert disaster.

In any house that uses a gas stove or gas heat, a potentially dangerous gas leak must be considered a real possibility. Even if there is no direct use of natural gas in the house, there might still be a risk. If any of the neighboring houses use natural gas, the odds are good that pipes carrying gas are buried in or near the property. If a gas main ruptures or leaks, anyone in the vicinity is at risk.

Many dangerous gases have nothing to do with ordinary home gas use (heating or cooking) but come from other sources. One of the deadliest common gases—carbon monoxide—can be found in any garage. Fumes from stored gasoline or alcohol also can be dangerous in high concentrations or where ventilation is poor. People who like to camp might keep a portable propane tank in the garage or basement, and this too can leak dangerously. There are numerous other possibilities, of course. It is foolish to assume any given home is safe from gas leaks without very carefully considering all the factors and variables.

Deoxidizing gases

Most of the potentially dangerous gases that are likely to show up in the home are the type known as *deoxidizing* gases. As the name suggests, a deoxidizing gas is one that tends to reduce the amount of available oxygen in the area. Of course, oxygen is vitally needed by your body. Oxygen deprivation that lasts more than a few seconds can cause permanent damage, if not death.

A deoxidizing gas is one that is relatively unstable and tends to bond chemically with any oxygen atoms it might encounter, even "stealing" them from other molecules with weaker bonds. The stolen oxygen atoms help stabilize the gas by changing its chemical composition.

An example of a deoxidizing gas, how it works, and why it so dangerous, is carbon monoxide. As you know, you breathe in oxygen from the surrounding atmosphere. When your body is through with the inhaled oxygen, the oxygen is combined with carbon atoms to form carbon dioxide, which you exhale. The prefix *di-* means *two*, so a carbon dioxide molecule consists of one carbon atom bonded to two oxygen atoms.

If there is just one oxygen atom to each carbon atom, the result is carbon monoxide, instead of carbon dioxide. (*Mono-* means *one*.) A carbon monoxide molecule has room for one more oxygen atom, and would be more stable with it. It will try to complete itself by latching on to the first oxygen atom it can.

Carbon dioxide is a fairly stable compound, and it acts as if it is functionally complete. It would be very difficult to force a carbon dioxide molecule to bond with a third oxygen atom, and even if such a bond could be made, it would be inherently very weak and unstable. The excess oxygen atom would drop off from the molecule at the earliest opportunity.

If you inhale carbon dioxide, it won't do you any good. You can't extract and reuse the oxygen atoms that have bonded to carbon atoms. But in itself, breathing in carbon dioxide is not harmful. That's a good thing, because you can't avoid breathing in quite a bit of carbon dioxide, no matter how hard you might try not to. Every time you exhale, you are adding more carbon dioxide to the nearby environment. Some of it will inevitably be drawn back into your lungs the next time you inhale. Ordinarily, this is no problem, and your body is well designed to cope with it. The only time you might have trouble with carbon dioxide is if you spend some time in a small enclosed area with poor or no airflow from the outside. As you exhale more and more carbon dioxide, the available oxygen in the area will be used up, and eventually you could run out of breathable oxygen. The problem here is not with the carbon dioxide, but with the local scarcity of usable oxygen.

There also might be problems breathing in areas with very high concentrations of carbon dioxide, even if the oxygen isn't really in short supply, but even in this case, the carbon dioxide isn't really acting as a poison or a problem in itself. Your lungs can

draw in just so much air at a time. If there are large amounts of carbon dioxide in the inhaled air, it's going to take up more room than normal, leaving less room for good oxygen. If the concentration of carbon dioxide is high enough, you might not be able to take in enough oxygen. Lack of oxygen is biologically dangerous, of course, but the carbon dioxide is really just acting as a neutral space filler, and isn't doing any active harm on its own.

With carbon monoxide, you have a very different situation, however. Carbon monoxide is functionally incomplete. You could say that a carbon monoxide molecule wants to become a carbon dioxide molecule, and will do anything it can to achieve this ambition.

What happens if you inhale some carbon monoxide molecules? They will grab any free oxygen molecules in the lungs, making them unavailable for biological purposes. If any carbon monoxide gets into your bloodstream, it will steal the oxygen atoms being carried by the red blood cells to various parts of the body, which will therefore not receive the oxygen they require for proper functioning. Even at relatively low concentrations, carbon monoxide can quickly take hold of most of the oxygen in the body, leaving it too little oxygen to carry on the essential biological functions. Particularly sensitive body parts, such as brain cells, will quickly start to die off due to oxygen deprivation. Within a matter of minutes, the entire body will die.

Because of its inherent deoxidizing characteristic, carbon monoxide, unlike carbon dioxide, acts as an actively poisonous gas. Because it is odorless, colorless, and tasteless, a person cannot detect it directly, until the harmful oxygen deprivation effects set in, and the presence of carbon monoxide (or some similar deoxidizing gas) can be deduced. By then it might already be too late.

Other common deoxidizing gases include methane, propane, and hydrogen, as well as fumes from gasoline or alcohol. Not all deoxidizing gases are equally powerful in their poisonous effects. It would take a significantly higher concentration of hydrogen (which occurs naturally in the atmosphere) or alcohol vapors to cause death than carbon monoxide. However, the effects can be just as deadly. It just takes more of certain deoxidizing gases than others to do the job.

The Taguchi gas sensor

Because potentially deadly deoxidizing gases are very difficult, if not impossible, to detect directly with your senses, an electronic alarm of some sort surely makes sense in areas at risk. A commonly used sensor device for detecting the presence of deoxidizing gases is the Taguchi gas sensor, often abbreviated as *TGS*. In much technical literature, references to unspecified gas detectors usually imply some form of the Taguchi gas sensor.

The Taguchi gas sensor is a semiconductor device made up of a combination of N-type metal oxides, such as tin, zinc, and ferric oxide. These materials respond electrically in the presence of a deoxidizing gas. As the concentration of the deoxidizing gas increases, the resistance of the sensing material decreases. This decreasing resistance can easily be electronically monitored to drive a meter or other continuous level indication device or circuit. Alternately, and more appropriately for discussion purposes, the varying resistance of a TGS can be used to control the input voltage to a comparator circuit of some sort. When the monitored resistance becomes lower than some preset calibration level (that is, when the detected concentration of the deoxidizing gas exceeds safe limits), the comparator circuit can trigger an alarm, alerting any occupants in the area to the dangerous condition.

The internal resistance of the Taguchi gas sensor is normally very high. In the presence of a deoxidizing gas, the resistance of the Taguchi gas sensor is proportionately reduced. The higher the gas concentration, the lower the resistance. The response of the Taguchi gas sensor is not instantaneous, because a chemical reaction is involved. It takes a few minutes for the sensor to stabilize to its normal high resistance state after power is first applied, or after a detected concentration of deoxidizing gas is removed. Typically a wait of about 5 to 10 minutes is required for the Taguchi gas sensor to clear and stabilize, before any further readings can be accurately made.

A wide variety of gas-sensing applications can be accommodated by the Taguchi gas sensor, thanks to its wide operational range and high sensitivity. This device can sense tiny concentrations of a deoxidizing gas, on the order of just a few *ppm* (parts per million), but it also can function reliably under very high concentration conditions, such as inside an automobile exhaust pipe for a pollution-emission control system.

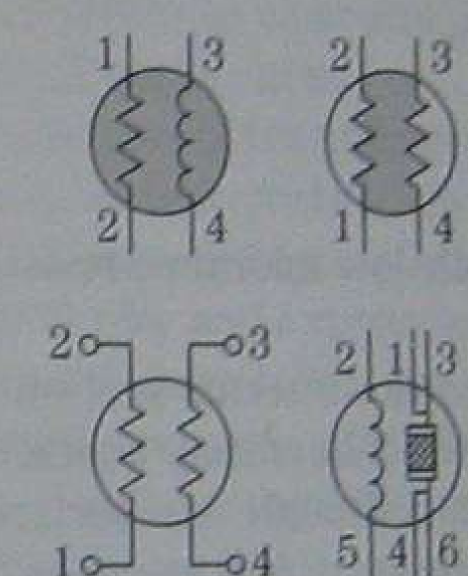
The power requirements for a Taguchi gas sensor also are conveniently low. A typical Taguchi gas sensor can be operated with about 1 V (volts), and will consume a little less than half an ampere or 500 mA (milliamperes). (Some units are specified for 1.2 V.) The current consumption is a bit high compared to many other semiconductor devices in use today, but it is still far from excessive. Undoubtedly improved Taguchi gas sensors designed to consume less current will eventually appear on the market.

Battery life for a Taguchi gas sensor will be only moderately good, but if ac power is used, the power consumption would be virtually negligible. The circuit would have to run about 2000 hours (almost three months) to use up one kilowatt hour—the smallest unit that can be indicated on a standard home power meter. In most areas it might add literally just a penny or two to the monthly electric bill. You could use rechargeable battery back-up power for a gas-detection alarm, but this would probably be unnecessary overkill in most home situations. A gas leak is highly unlikely to coincide with a power failure, so the temporary lack of gas protection if ac power in the home is cut off for some reason is unlikely to be a serious risk, unlike the case for an intruder alarm or fire alarm. The darkness and other effects of a loss of ac power would be a decided advantage to an intruder, and many burglars deliberately disrupt the power to homes they intend to rob before going in. The risk of intrusion can be considered somewhat higher than normal during a loss of ac power, so the intrusion detection alarm circuits are needed more than ever. An electrical fire can often interrupt ac power before it is detected by the fire alarm system. If the power outage is caused by a short circuit somewhere in the house, a failure in the fuse box, or a lightning strike, there is a fairly good chance a fire might be started from the same cause. Battery back-up is essential for fire and intrusion alarms, but this need doesn't really apply to extra alarm functions such as gas leak alarms or flooding alarms.

There have been several different designs for Taguchi gas sensors, but most commercially available devices of this type follow a common pattern. The standard Taguchi gas sensor has two electrically isolated sections—an input section and an output section. Although the input section cannot be interchanged with the output section, either section is bidirectional, and nonpolarized. Electrical current can flow through each section in either direction.

Most Taguchi gas sensors have 4 or 6 pins, and are designed to fit into a standard 7-pin miniature tube socket, making installation convenient. (One or three of the socket pins are left unused.)

Because the Taguchi gas sensor is not a commonly used electronic component, it has not yet been assigned a fully standardized schematic symbol. Most technical literature dealing with the Taguchi gas sensor uses similar symbols for this device, indicating its input and output sections and their resistive nature. Some typical schematic symbols that have been used to represent the Taguchi gas sensor are shown in Fig. 6-1.



6-1
These are some typical schematic symbols used to represent the Taguchi gas sensor.

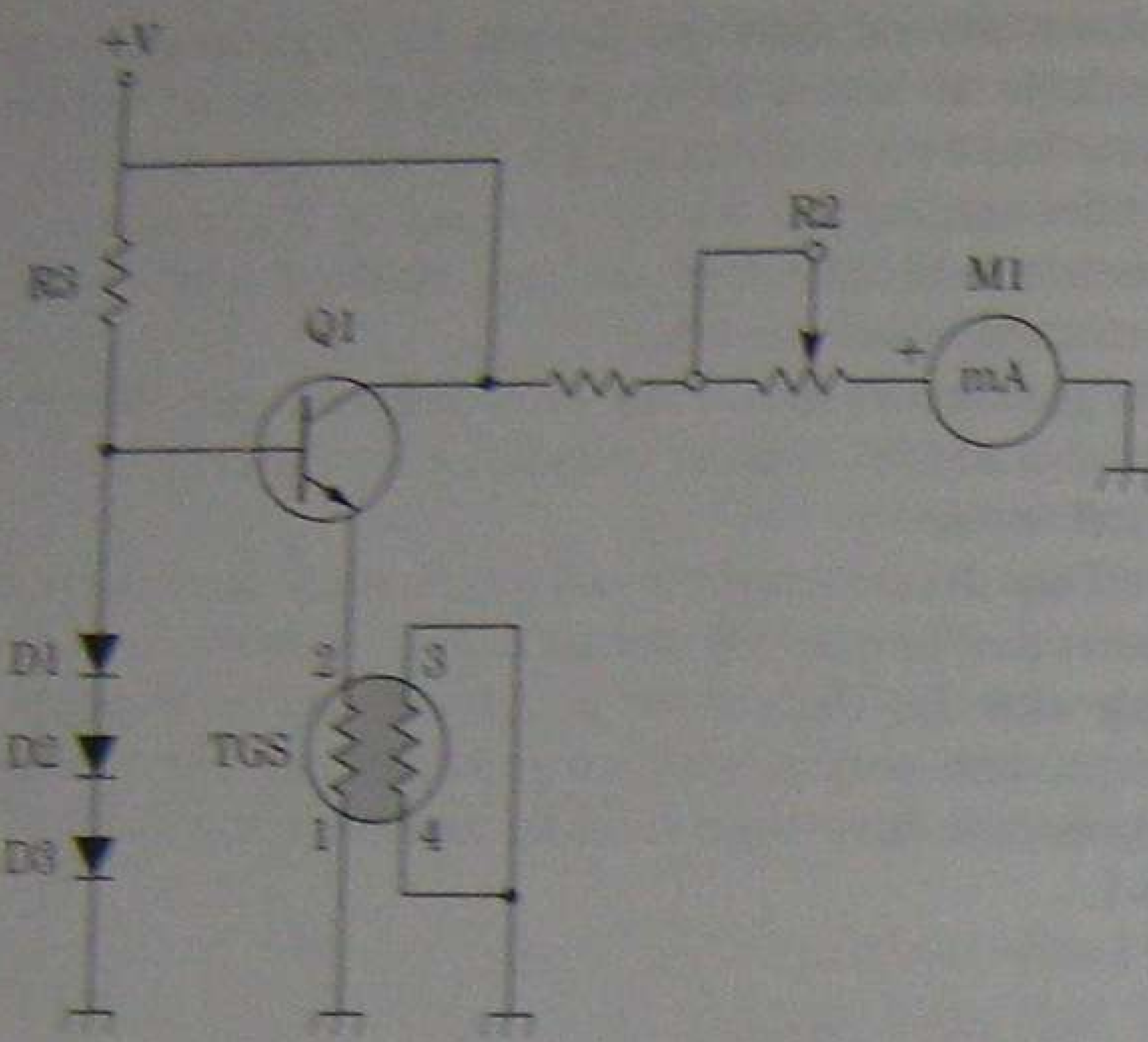
Response of the Taguchi gas sensor is reasonably linear, even over its wide operational range. This characteristic makes this device well suited for metering and measurement applications. Most gas meter circuits built around the Taguchi gas sensor use this device as part of a Wheatstone bridge network.

In an alarm system, you only need a simple yes/no type response, so the alarm can be activated when the detected concentration of deoxidizing gas exceeds a specific, preset level. Because the Taguchi gas sensor is primarily resistive in its response, the voltage drop across its output section can be used as the variable input of a comparator circuit. A fixed reference voltage that is equivalent to the desired critical trip point can be selected or adjusted to calibrate the sensor for almost any desired concentration level of deoxidizing gases in the monitored area.

The Taguchi gas sensor is singularly reliable, with an expected lifespan of at least several years.

Gas sensor circuits

A typical gas meter circuit is shown in Fig. 6-2. This device is a simple and direct circuit, with nothing complex or fancy. Despite its simplicity, it can be effective and



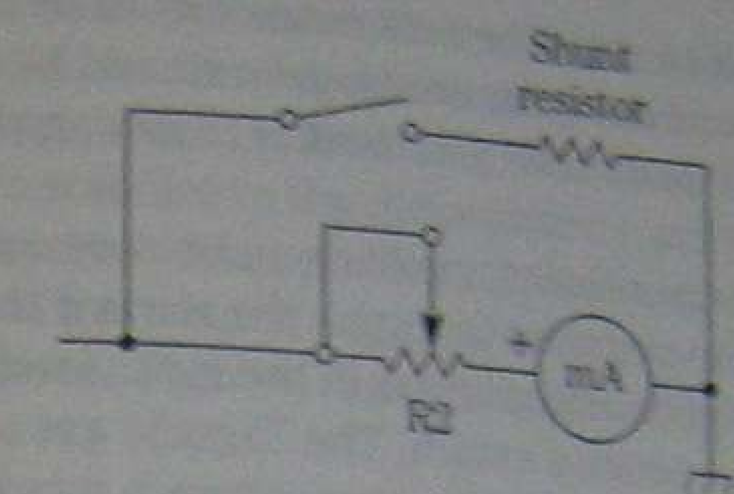
6-2 This is a fairly typical gas meter circuit.

accurate, if high precision components (especially low tolerance resistors) are used throughout the circuit.

In this circuit, only one of the Taguchi gas sensor internal sections is used. The nominal output section (between pins 3 and 4) is deliberately shorted out. Do not omit the connections to pins 3 and 4, however. Although this section of the TGS doesn't appear to be doing anything at all, it is necessary for the correct operation of the sensor. Fortunately, you don't need to go into the technical details of what goes within the Taguchi gas sensor. Treat it as a black box. In effect, the Taguchi gas sensor here functions as a simple two-lead resistor (between pins 1 and 2), whose resistance varies with the concentration of deoxidizing gas in the immediate vicinity. The higher the concentration of deoxidizing gas detected, the lower the resistance between pins 1 and 2 will be. (The resistance between pins 3 and 4 will be similarly lowered, of course, but that is of no practical consequence in this circuit.) Pins 1 and 2 are nonpolarized, which means they can be reversed without altering the operation of the circuit in any way.

Transistor Q1, resistor R3, and diodes D1 through D3 form a simple, but effective voltage regulator circuit. The combined voltage drop across the three series diodes less the voltage drop across the transistor base-emitter junction results in the approximately 1 V needed by the Taguchi gas sensor. The transistor also amplifies and buffers the proportional voltage from the Taguchi gas sensor to the milliammeter (M1). The range of the meter is set by resistors R1 and R2. Notice that R2 is actually a variable potentiometer, and it permits calibration of the circuit. A customized scale, calibrated in ppm, or any other convenient units can be made for the meter. Calibration of this unit is discussed in this chapter.

If the gas meter circuit is intended for frequent use in high concentrations of deoxidizing gases (for example, monitoring the output from an automobile exhaust



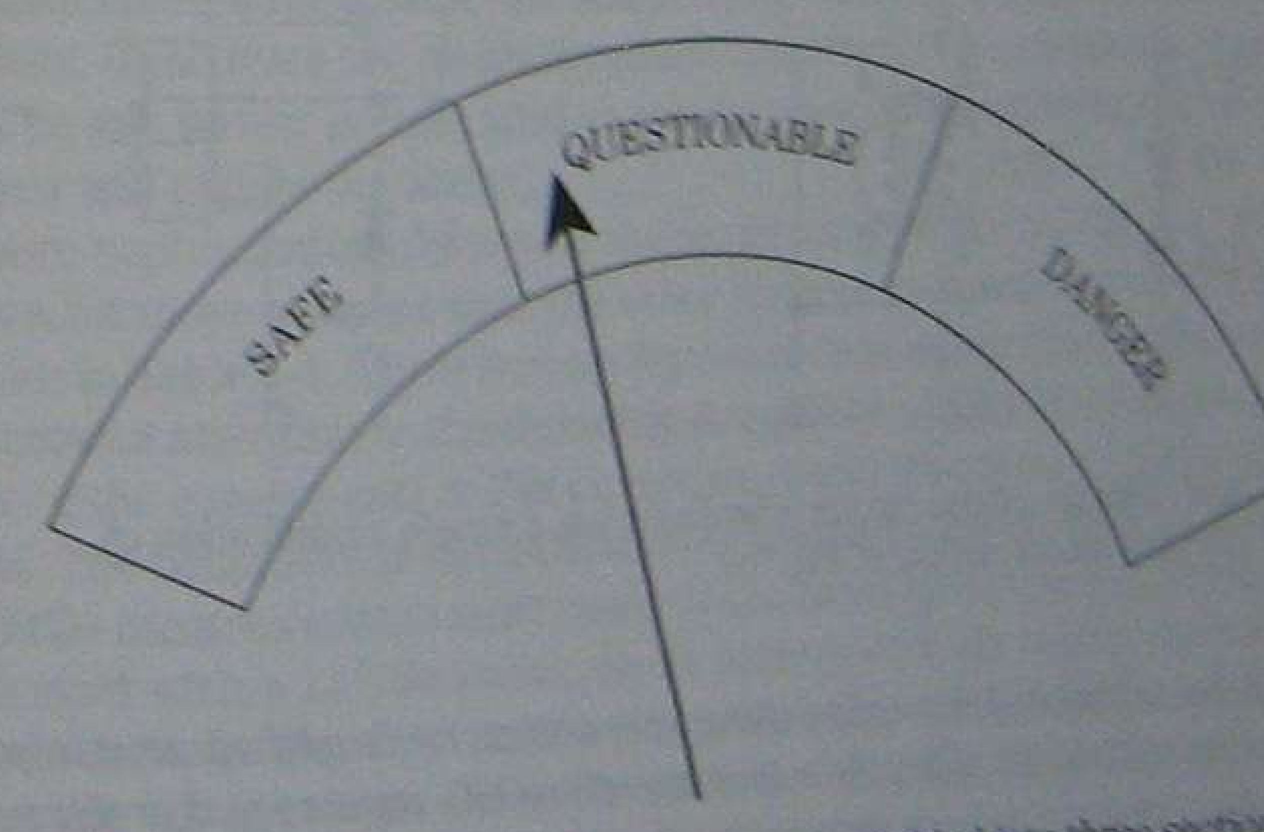
6-3 If the gas meter circuit of Fig. 6-5 is intended for frequent use in high concentrations of deoxidizing gases, desensitize the meter by placing a shunt resistor across it and R2.

pipe), desensitize the meter by placing a shunt resistor across it and R2, as shown in Fig. 6-3.

Because of the way the Taguchi gas sensor detects deoxidizing gases, there is some inherent time delay. When first applying power to this gas meter circuit, it is necessary to wait about 5 to 10 minutes before an accurate reading can be obtained. Similarly, if the Taguchi gas sensor is exposed to a high concentration of gas, it will take several minutes to clear and give accurate results after the deoxidizing gas has been removed from the area.

This circuit can potentially give very accurate results. Unfortunately, accurate calibration can be extremely tricky. For precise calibration, it is necessary to expose the Taguchi gas sensor to exactly known concentrations of deoxidizing gas. In addition to the difficulty and expense of getting precise quantities, there also is the danger of human exposure to the gas samples.

For a crude form of calibration, bring a drop of gasoline near the Taguchi gas sensor. Once the sensor and the circuit stabilize, adjust the meter for a full-scale rating via potentiometer R2. Because the unit is not calibrated to a known quantity, the scale should be marked off in convenient, but vague, units rather than direct ppm readings. A scale divided into three sections labelled SAFE, QUESTIONABLE, and DANGER, as shown in Fig. 6-4, is a practical choice. Keep in mind that the dividing points between these areas is vague and imprecise. Because you have to do some

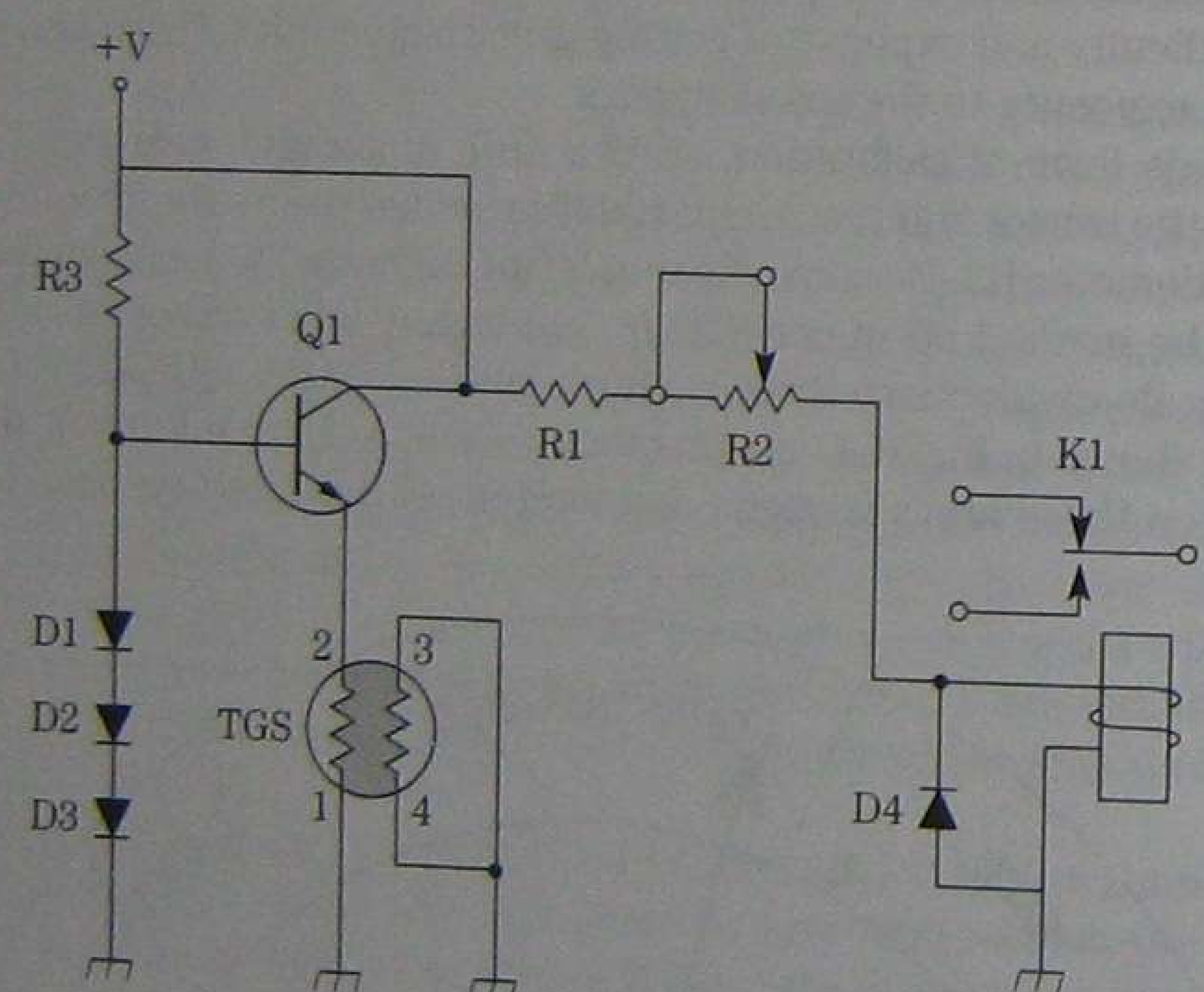


6-4 A convenient scale for a gas meter can be divided into three sections labelled as shown.

guesswork, it's best to err on the conservative side. The safe range should be rather narrow, at the low end of the meter scale, and the questionable area should be large. Begin the danger region at a slightly lower point than you think is truly dangerous. It's much better to be safe than sorry.

In home alarm systems, a calibrated measurement is unlikely to be necessary, or even desirable. You just want a simple yes/no response to trigger the alarm if there is any unusual increase in the concentration of deoxidizing gas in the monitored area. In essence, what you need is a type of gas-operated switch. The Taguchi gas sensor readily adapts to this application as well, and the calibration procedure is much simpler and more reliable.

The first gas alarm circuit, shown in Fig. 6-5, is basically just a simple modification of the gas meter circuit of Fig. 6-2. Instead of driving a meter, the output from the gas-detection circuitry is used as the input to a simple voltage comparator. The reference voltage, and therefore the sensitivity trip-point of the circuit is adjusted via potentiometer R2. Ordinarily, the output of the comparator is LOW, near ground potential. This LOW looks like an open switch to the central control box. When the deoxidizing gas concentration exceeds the preset limit, the comparator output goes HIGH, which the alarm system considers a closed switch. The circuit, in other words, functions as a NO (normally open) sensor in the alarm system.

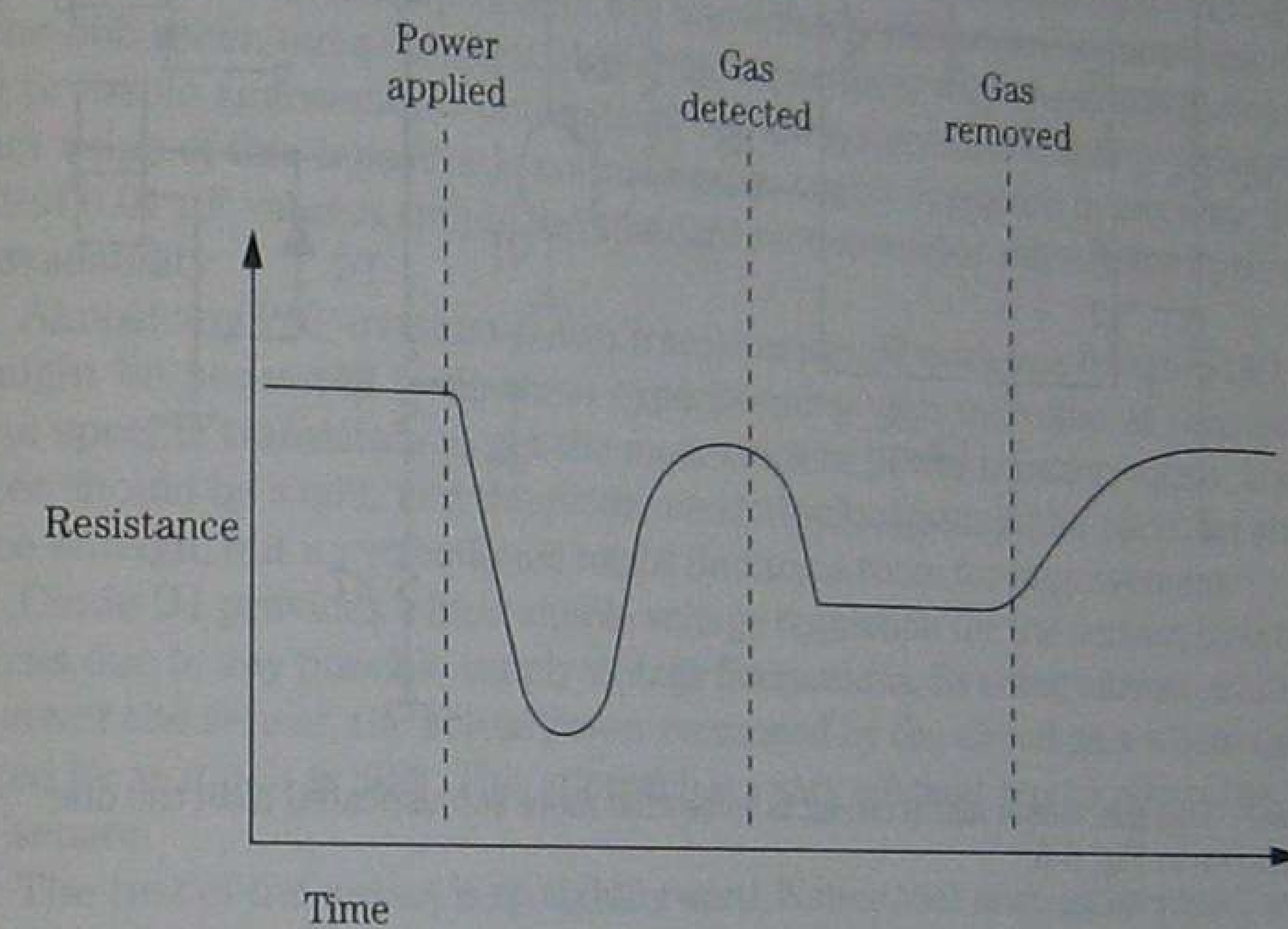


6-5 This gas alarm circuit is basically just a simple modification of the gas meter circuit of Fig. 6-2.

The output voltage of the comparator circuit can be amplified or attenuated, as appropriate, to match the signal levels of the other NO sensors in the alarm system.

Calibration of a gas sensor circuit like this is extremely simple, if you begin with the assumption that the normal air present when the device is installed is safe, but

any increase in the detected concentration of deoxidizing gases in the area indicates potential trouble. Adjust the calibration control (R2) for minimum sensitivity, before applying power to the circuit. Wait 5 or 10 minutes to give the Taguchi gas sensor time to stabilize to the atmospheric conditions and to get a meaningful reading. This waiting period is necessary because of the relatively slow response time of the Taguchi gas sensor. A typical resistance versus time graph for a Taguchi gas sensor is shown in Fig. 6-6, illustrating this principle.

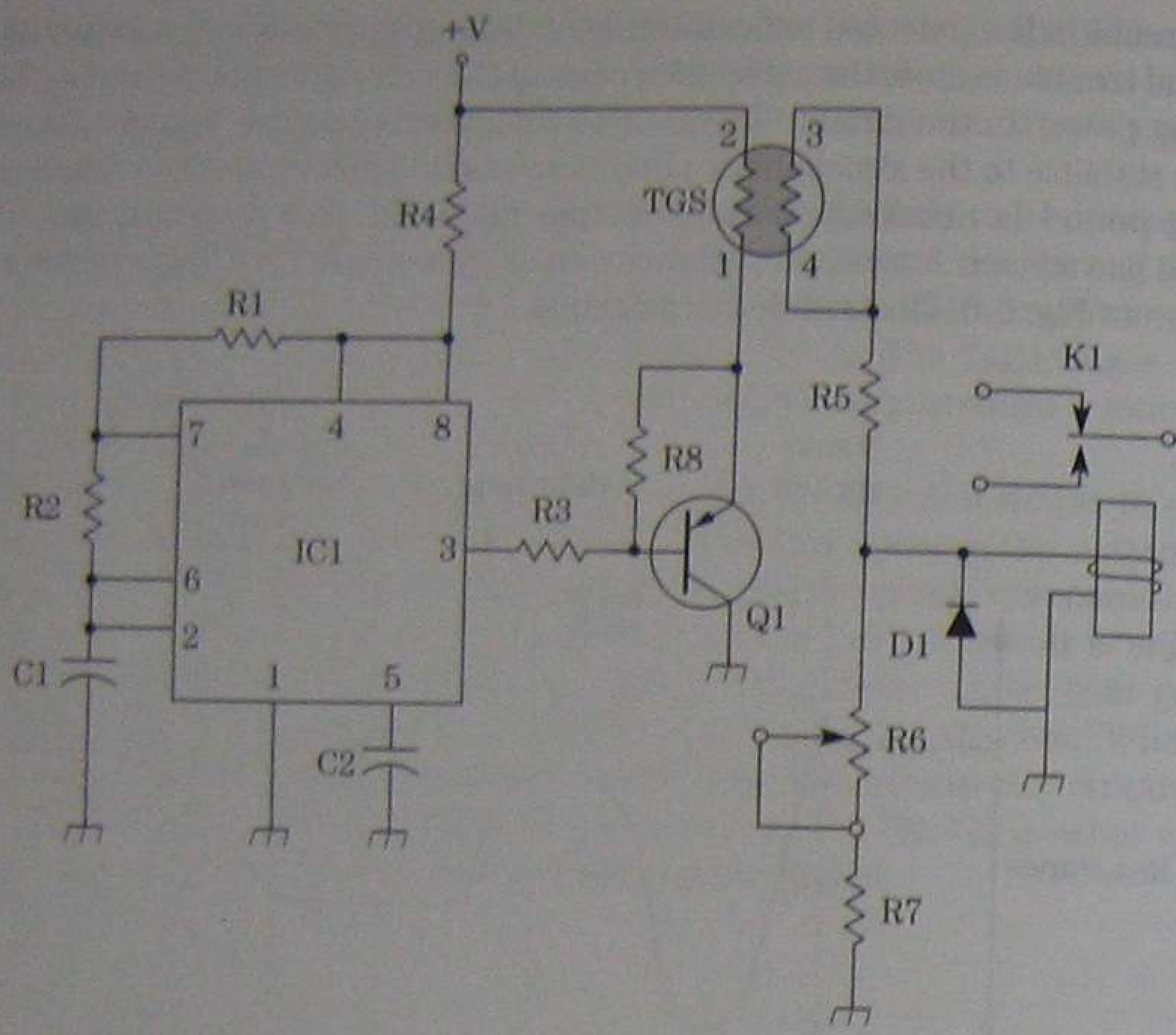


6-6 Typical resistance versus time graph for a Taguchi gas sensor.

Slowly increase the sensitivity until the alarm sounds. Stop increasing the sensitivity immediately and disable the alarm. Decrease the sensitivity control's setting just slightly. Reactivate the alarm to ensure that it won't go off again. That's all there is to it. The gas sensor is calibrated so any increase in deoxidizing gases in the monitored area will trigger the alarm.

A more sophisticated gas sensor alarm circuit is shown in Fig. 6-7. Because this circuit is a bit more complex than the other circuits presented here, a detailed parts list is given in Table 6-1. There is room for variation in most of the component values, but pay careful attention to the following description of circuit operation.

Most of the components in this circuit are devoted to power supply/conditioning functions. The basic sensor circuit could be powered directly by a 1.2 V source, but this is a little inconvenient in most cases. It can actually be more economical and efficient to start with a 12 Vdc (volts, direct current) supply voltage and use this circuit to reduce the power. Of course, a simple resistive voltage-divider string could be used, but the voltage drops across the resistors would necessarily consume more power than the sensor circuit, which is hardly an elegant or economical design approach.



6-7 This gas sensor alarm circuit is somewhat more sophisticated than the one shown in Fig. 6-5.

Table 6-1. Suggested parts list for the gas alarm circuit of Fig. 6-7

TGS	Taguchi gas sensor
IC1	555 timer
Q1	PNP transistor (Radio Shack RS2026 or similar)
D1	1N4001 diode or similar
C1	0.1 µF (microfarad) capacitor
C2	0.01 µF capacitor
K1	Relay
R1	120 kΩ (kilohm) ¼ W (watt) 5% resistor
R2	10 kΩ ¼ W 5% resistor
R3	270 Ω (ohm) ¼ W 5% resistor
R4	120 Ω ¼ W 5% resistor
R5	220 Ω ¼ W 5% resistor
R6	10 kΩ potentiometer
R7	1 kΩ ¼ W 5% resistor
R8	4.7 kΩ ¼ W 5% resistor

IC1 is a standard 555 timer chip, wired in its astable mode, to generate a series of narrow-width pulses, which switch the power transistor (Q1) on and off. The actual pulse width and frequency is determined by the values of resistors R1 and R2, and capacitor C1. There is room for considerable variation, but the component values suggested in the parts list have been selected to give about the maximum possible efficiency.

Capacitor C2 is included in the circuit simply to prevent any instability problems that could conceivably crop up from leaving the chip's unused control voltage input pin (pin 5) floating. Such problems are immediately rather rare in most practical use of the 555 timer, but a simple 0.01 µF disc capacitor is very cheap insurance against any probable aggravation from unusual but always possible stability problems. The exact value of this capacitor is not relevant to circuit operation in any way. The suggested 0.01 µF value is simply the standard recommended value, based primarily on its availability.

Almost any PNP medium-power transistor should work fine for Q1 in this circuit. It might be necessary to do some experimenting with the value of resistor R3 for some specific transistors to get the most efficient power transfer. Again, the differences should be slight, and the recommended value given in the parts list should be close enough, but a perfectionist might find some room for improvement.

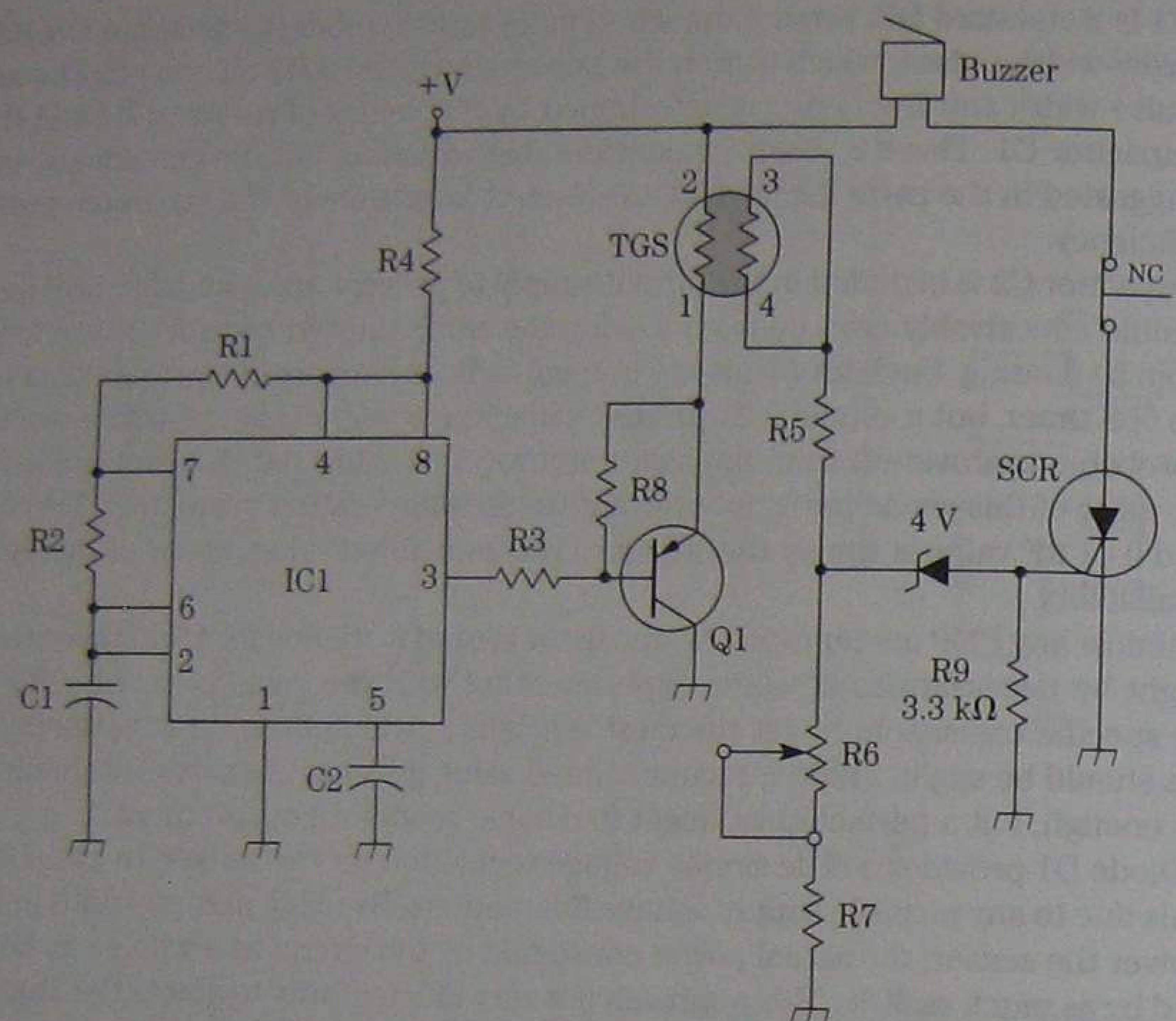
Diode D1 provides a little simple voltage regulation for the sensor, to avoid false signals due to any possible supply voltage fluctuations. By using narrow-width pulses to power the sensor, the actual power consumed by the circuit as a whole can be reduced by as much as 80%. This approach is a very efficient way to power the Taguchi gas sensor.

The rest of the circuit is straightforward. Notice that once again pins 3 and 4 are shorted together. Pins 1 and 2 are nonpolarized and interchangeable. (The same is true for pins 3 and 4, of course.)

The output section of the Taguchi gas sensor is part of a voltage divider string. The voltage fed through diode D2 to the relay coil will vary in accordance to the concentration of deoxidizing gas detected by the Taguchi gas sensor and the setting of sensitivity/calibration control R7. When a sufficient current passes through the coil relay, it will be activated. Either the NO or NC switch contacts can be used, to suit the rest of the alarm system.

In some applications, a purely local alarm indication might be appropriate. For this application, the output circuit of this gas sensor can be modified as shown in Fig. 6-8. Here the output control device is an appropriately rated SCR. A sufficient gate signal will turn on the SCR, sounding the alarm. If an SCR is used, a local reset switch must be used to permit the SCR to be turned off (by breaking the cathode-to-anode current flow). Breaking the flow is the only way to stop the alarm from sounding once it has been triggered. Let the Taguchi gas sensor restabilize five to ten minutes after clearing the air before reactivating the alarm, or you might get a quick false alarm indication. Once the Taguchi gas sensor has stabilized, later false alarms are reasonably unlikely.

The calibration procedure for this gas sensor circuit is much the same as for the previous example. Adjust the calibration control (R2) for minimum sensitivity, before applying power to the circuit. Wait 5 or 10 minutes to give the Taguchi gas sen-



6-8 This modification of the gas alarm circuit of Fig. 6-7 permits a completely locally controlled alarm.

sor time to stabilize to the atmospheric conditions and to get a meaningful reading. Now, slowly increase the sensitivity until the alarm sounds. Stop increasing the sensitivity immediately and disable the alarm. Decrease the sensitivity control setting just slightly. Reactivate the alarm to ensure that it won't go off again. That's all there is to it. The gas sensor is calibrated so any increase in deoxidizing gases in the monitored area will trigger the alarm.

The required and appropriate sensitivity for a gas sensor depends a lot on just what is expected in the protected area. Inside the house, near a gas stove or heater, for example, maximum sensitivity is called for. It is reasonable to consider any deoxidizing gas in the area to be too much. However, in a garage, it would be impossible to avoid all gasoline fumes, especially if there might be periods of poor ventilation. You certainly don't want the alarm to go off just because the garage door has been shut more than a couple of hours. Take such factors into consideration when you calibrate a gas sensor. By all means, the gas sensor should always be calibrated in the actual location where it is to be used to set the normal background level.

In areas where large concentrations of deoxidizing gases might be anticipated, even in the event of an accident, it might be a good idea to add a little automation to the system. In addition to sending an activation signal to the alarm system, the output of the gas sensor also can be used to automatically switch on a ventilation fan or air conditioner to clear the potentially dangerous gas from the area.

Because of the fairly slow response change time of the Taguchi gas sensor, it probably wouldn't be suitable for the gas sensor circuit to turn the automated ventilation fan back off on its own. You could use a timer to shut down the ventilation system after a preset time. Be generous in determining the timer duration. It's much better to let the ventilation fan to run too long than not long enough. Give it enough time to do its job and clear the air in the protected area adequately. For that matter, even if the ventilation fan or air conditioner required a manual switch to shut it down once automatically activated, no real harm would be done, except perhaps a little wasted power and wear and tear on the fan.