Circuit Design From Scratch

A hands-on approach to creating new circuits, including a practical car theft alarm you design.

By Jules H. Gilder

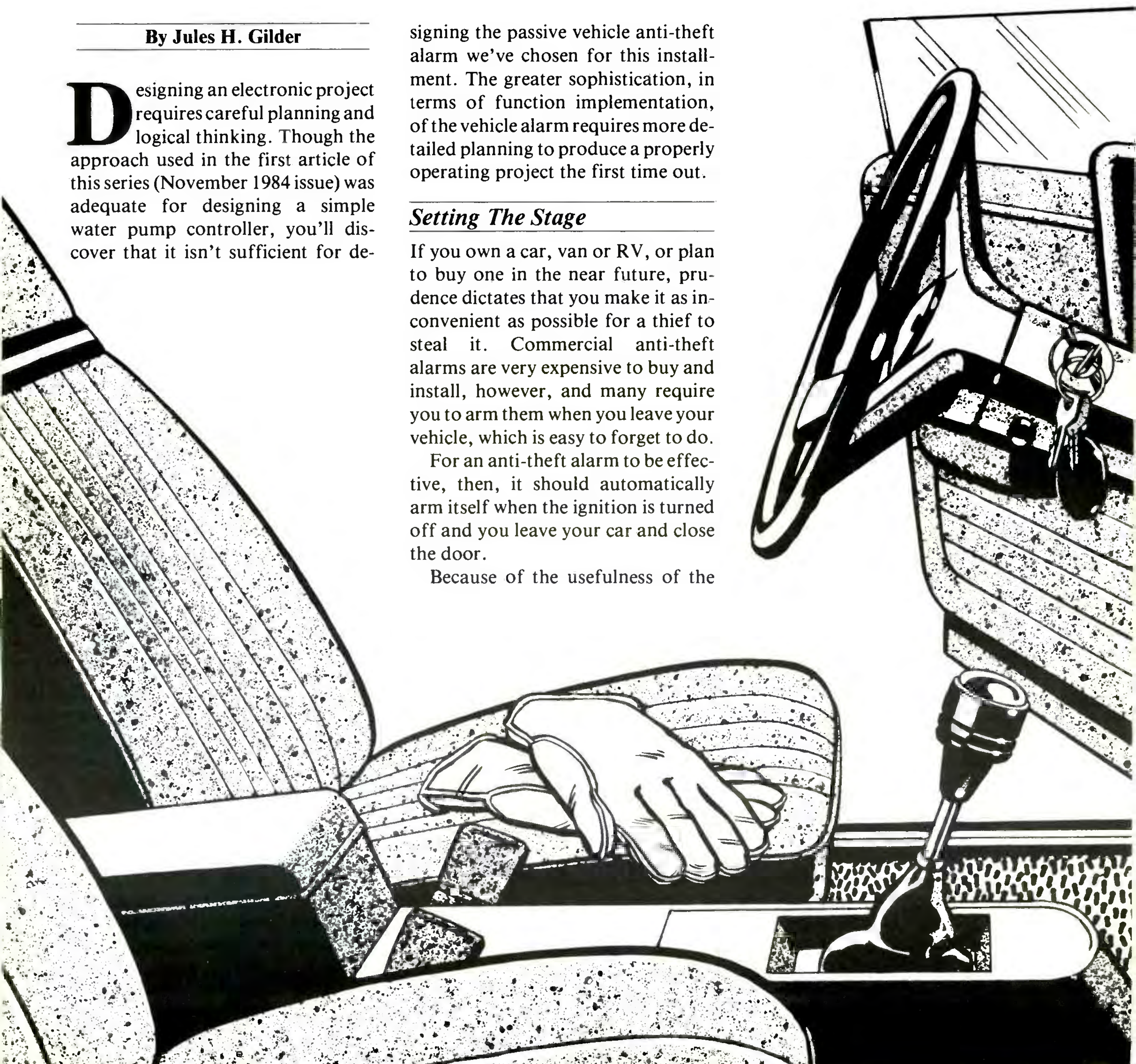
Designing an electronic project requires careful planning and logical thinking. Though the approach used in the first article of this series (November 1984 issue) was adequate for designing a simple water pump controller, you'll discover that it isn't sufficient for designing the passive vehicle anti-theft alarm we've chosen for this installment. The greater sophistication, in terms of function implementation, of the vehicle alarm requires more detailed planning to produce a properly operating project the first time out.

Setting The Stage

If you own a car, van or RV, or plan to buy one in the near future, prudence dictates that you make it as inconvenient as possible for a thief to steal it. Commercial anti-theft alarms are very expensive to buy and install, however, and many require you to arm them when you leave your vehicle, which is easy to forget to do.

For an anti-theft alarm to be effective, then, it should automatically arm itself when the ignition is turned off and you leave your car and close the door.

Because of the usefulness of the



passive alarm and the possibility of reducing car insurance cost, it has been chosen as our design project this time out. In the following pages, we'll show you how to design and build this alarm from scratch. Along the way, we'll develop word descriptions, logic truth tables, and the design equations that you'll use to implement the circuits needed to provide the full range of alarm functions.

Table 1. Power Controller Operating Conditions

	(A) reset switch	(B) door status	(C) current output	(D) ignition switch	(E) turn/keep power on
1	on	—	—	—	off
2	off	closed	off	off	off
3	off	open	off	off	on
4,6	off	open	on	off	on
5	off	closed	on	off	on
7	off	closed	off	on	off
8	off	open	off	on	off
9	off	open	on	on	on

(1) Define The Problem

No matter what anyone tells you, the most important step in the design process is deciding exactly what you want a circuit to do. Though this may sound obvious to you, just stating what you want may not be enough to get you started on the design. You must *fully* define what is to be done and when. I neglected to heed this when designing the project presented here, the result being that my first design failed to operate properly. That failure is the reason why you're reading this in the February 1985 issue of MODERN ELECTRONICS, instead of the December 1984 issue for which it was originally intended. So my advice is: Write down exactly what you expect your circuit to do *before* you do anything else.

Following this counsel, let's list the features that should be incorporated into our vehicle anti-theft alarm:

(1) Automatic arming 15 seconds after the engine is shut off and the door is opened. If the door is not opened (you don't leave the vehicle), the alarm is not armed.

(2) Once armed, any door that opens and turns on the dome (courtesy) light triggers the alarm.

(3) Once triggered, you have 15 seconds to close the door and either start the engine or turn the ignition switch to the accessory position to disarm the alarm. Otherwise, the alarm will sound and cannot be shut off until the door is closed (with the ignition on) or a RESET switch is closed (more about this later).

(4) The alarm is to sound the vehicles's horn intermittently for about 2 minutes. After this, it must shut off and rearm itself to be ready for the next intrusion. Additionally, you want a provision for causing the vehicle's headlights to flash on and off in step with the horn so that the vehicle can easily be located at night.

(5) The system should have either a hidden switch or a keyswitch that can be used to reset the alarm and also temporarily disable it when the vehicle is given to a parking-lot attendant.

(6) The system should work in cars that have door switches that connect to either chassis ground (the most common arrangement) or to the +12-volt line.

(2) Flesh Out Design Details

Unlike the previous project in the November 1984 issue, we cannot go directly from initial project description to logic design. We must first flesh out the details. From 1 above, we see that no system power switch is to be used. Instead, power is to be applied automatically once the ignition is turned off and the vehicle's door is opened. Thus, part of the alarm system is going to have to function as a power controller for the rest of the alarm system.

What the above means is that the power controller portion of the circuit must always be connected to the positive side of the battery, while the remainder of the circuit is to receive power only when the controller decides to deliver it. Since this portion of the system is the key to making this a passive alarm system, let's tackle it first and define its operation in detail.

To begin with, from 3 above, the system must be able to be switched off at any time with a RESET switch. The best place to implement the manual reset function is in the power controller, since without power, the rest of the system won't work. Hence, the power controller must know the state of the RESET switch. If it is on, the output provided by the controller will always be off. Conversely, if the RESET switch is off, sometimes the controller will be on and sometimes it will be off (more about this later).

Since the power controller is to be activated by the vehicle's door switch, it must also know whether or not the door is open. Next, the controller must be provided with information about the state of the ignition switch. From 1 above, the alarm is armed (powered by the controller) only if the ignition is off and the door has been opened.

There's one more factor that influences the decision to provide power from the output of the controller—whether or not the controller is currently providing power. For this, there must be some feedback on the status of the output signal.

Now that we know the factors that are going to control the arming of the alarm system, let's make a list of what is to happen and when:

(1)Whenever the RESET switch is

Table 2. Power Controller Truth Table

	(A) reset switch	(B) door status	(C) current output	(D) ignition switch	(E) turn/keep power on
1	1	—	—	—	0
2	0	1	0	0	0
3	0	0	0	0	1
4,6	0	0	1	0	1
5	0	1	1	0	1
7	0	1	0	1	0
8	0	0	0	1	0
9	0	0	1	1	1

on, no power is provided by the controller, no matter the status of the other signals. (The rest of the items on this list occur only if the RESET switch is off.)

(2) When the vehicle's ignition is first turned off and the door is still closed, power has not yet been applied to the alarm.

(3) Once the door is opened (with the ignition off), for a fraction of a second, the output is still off, but the controller is going to turn it on.

(4) After the initial fraction of a second, the ignition is still off and the door is open, but now the output status is on.

(5) As the vehicle is exited and the door is closed, with the ignition off, we want the controller to supply power to the rest of the circuit and continue to do so.

(6) Upon reopening the door, we want the system to be in the same condition as in 5 above.

(7) If we close the door and turn the ignition switch to on or "accessory" within about 16 seconds, the output is still on for a fraction of a second, but we want the system to turn if off.

(8) After the initial fraction of a second, the output of the controller turns off and remains off.

(9) To meet the conditions detailed in item 3 of our original list of features, we want the controller to continue to provide power with the door open, the alarm system armed (power provided by the controller), and the ignition on.

This list gives a complete word description of how the power controller portion of our passive alarm is going to work. It has been put into easier-to-understand form in Table 1. The line numbers in this table correspond to the numbered items on our latest list. From this summary, it's easy to produce the logic truth table that defines the action of the system.

To convert Table 1 into the logic truth table in Table 2, you simply substitute 1 for *on* and *closed* and 0 for *off* and *open*. The 1 was chosen to represent the door's closed condition because in most vehicles the switch is not grounded when the door is closed and the voltage on the circuit side of the switch is at + 12 volts.

Notice that in Tables 1 and 2 that one set of conditions is repeated (item 4, 6). When we use the information contained in these tables, it is necessary to use this set of conditions only once. Consequently, we'll simply refer to this row as row 4.

(3) Power Controller Equation

With the aid of a truth table, we can now write an equation that describes the task the power controller is to perform (column E). As you already know from the first installment of this series, we use only those rows of the truth table that contain a 1 in column E. In addition, if an element in a column is a 1, that element is represented as the letter that heads the column. If the element is a 0, it is represented as the letter that heads the column but with a bar over it.

Therefore, the first part of our equation would be represented by the term for row 3:

$$E = \bar{A}\bar{B}\bar{C}\bar{D}$$

because all elements in this row are 0. Continuing in the same manner for rows 4, 5 and 9, we obtain:

$$E = \bar{A}\bar{B}\bar{C}\bar{D} + \bar{A}\bar{B}C\bar{D} + \bar{A}BC\bar{D} + \bar{A}\bar{B}CD.$$

Since $\bar{A}$ is common to all terms, it can be factored out:

$$E = \bar{A}(\bar{B}\bar{C}\bar{D} + \bar{B}C\bar{D} + BC\bar{D} + \bar{B}CD).$$

Similarly, $\bar{D}$ can be factored out of the first three terms:

$$E = \bar{A}\,[\bar{D}\,(\bar{B}\bar{C} + \bar{B}C + BC) + \bar{B}CD].$$

Finally, factoring out $\bar{B}$ gives:

$$E = \bar{A}\,\{\bar{D}\,[\bar{B}\,(\bar{C} + C) + BC] + \bar{B}CD\}.$$

Now we're going to use one of the rules of Boolean algebra that states:

$$\bar{X} + X = 1 \text{ (rule 1).}$$

Using this rule, our equation becomes:

$$E = \bar{A}[\bar{D}(\bar{B} + BC) + \bar{B}CD].$$

A second rule of Boolean algebra states:

$$\bar{X} + XY = \bar{X} + Y \text{ (rule 2).}$$

Applying this to our equation, we get:

$$E = \bar{A}[\bar{D}(\bar{B} + C) + \bar{B}CD].$$

We can now expand the middle term of our equation and get:

$$E = \bar{A}(\bar{B}\bar{D} + C\bar{D} + \bar{B}CD).$$

If we now factor C out of the two terms in the equation, the result is:

$$E = \bar{A}[\bar{B}\bar{D} + C(\bar{D} + \bar{B}D)].$$

Once again, we can use rule 2 to simplify matters:

$$E = \bar{A}[\bar{B}\bar{D} + C(\bar{B} + \bar{D})]$$

$$E = \bar{A}(\bar{B}C + \bar{B}\bar{D} + C\bar{D}).$$

Factoring out the $\bar{D}$ term, we obtain:

$$E = \bar{A}[\bar{B}C + \bar{D}(\bar{B} + C)].$$

This is about as compact as the equation is going to get, however it is expressed in terms of OR gates (the addition) and AND gates (the multiplication). To minimize parts count, we'd like to try to express the whole equations in terms of NAND and AND gates. This can be done by using a third rule from Boolean algebra, which converts an OR term to a NAND term:

$X + Y = \overline{\overline{X}\,\overline{Y}}$ (rule 3).

By setting $X = \overline{B}$ and $Y = C$, we obtain:

$E = \overline{A}[\overline{D}(\overline{\overline{\overline{B}}\,\overline{C}}) + \overline{B}C]$ and

$E = \overline{A}[\overline{D}(\overline{B\,\overline{C}}) + \overline{B}C]$.

Applying rule 3 once more to the equation, we get:

$E = \overline{A}\,\overline{[\overline{\overline{D}(\overline{B\,\overline{C}})}\;\overline{\overline{B}C}]}$.

(4) Convert The Equation To A Circuit

Since the last equation uses only AND and NAND terms, we will stop here and use it to build our power controller circuit. A circuit that illustrates how the various input signals combine to produce the final output is shown in Fig. 1. Although any logic family could be used to implement this circuit, it is best for automotive applications to use low-power, high-noise-immunity CMOS devices.

(5) Design The Timers

From our original specifications, we know that three separate timing circuits are required, one each for exit delay, entrance delay, and amount of time the alarm sounds. The system must also have an oscillator to pulse beep the horn, which is used here as the alarm sounder.

It's possible to build the delay and oscillator circuits with ordinary NAND gates. However, if we use a special kind of gate, known as a Schmitt trigger, we can minimize the number of gates needed and simplify the circuit's design.

A Schmitt trigger provides a snap-action output in response to a slowly changing input. Snap action is made possible by the Schmitt trigger's *hysteresis,* which is a dead band throughout which no change in output occurs.

To understand what hysteresis is, refer to Fig. 2. Notice that voltage at the input can increase substantially without causing a change in output voltage. At a point known as the upper threshold voltage, however, the output suddenly and rapidly changes. When input voltage decreases, there's a similar situation during which no change in output occurs for quite a while as the input voltage drops below the threshold at which the device initially switched high. The voltage can continue to decrease in this dead band until a second voltage—the lower threshold voltage—is reached. Output voltage then rapidly drops.

The dead band and rapid switching make Schmitt triggers ideal for cleaning up noisy signals and for use in timing circuits. Except for these special characteristics, Schmitt-trigger gates are identical to other logic gates and can be used as replacements for them.

We're going to use two 4093 Schmitt-trigger NAND gates in our alarm. These quad 2-input NAND-gate ICs function similarly to the standard 4011 NAND gates used in the power controller. Some uses will be in timing circuits, others will be as ordinary logic gates.

Schmitt triggers can be used to produce two basic types of timers. One is a power-off timer whose output goes low for a specified period of time and then goes high and remains high for as long as power is applied (Fig. 3). The other is a power-on timer whose output goes high for a specified period of time and then goes low and remains low for as long as power is applied (Fig. 4).

The power-off timer in Fig. 3 con-

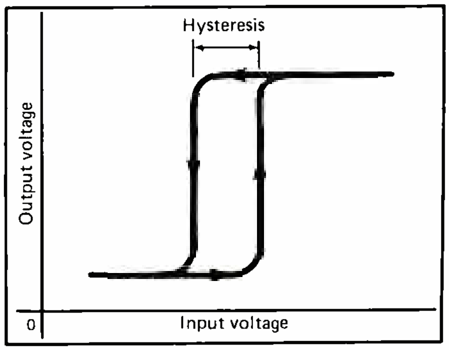


Fig. 2. By plotting input vs. output voltage of a Schmitt trigger, the upper and lower threshold points at which the device switches are obtained, as shown here.

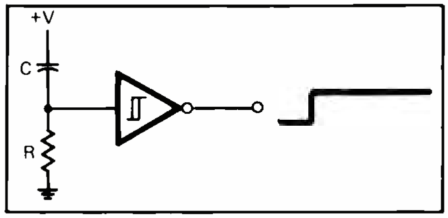


Fig. 3. The power-off timer uses only one gate, a resistor and a capacitor to produce an output that is low for a given period of time and then goes high and remains there.

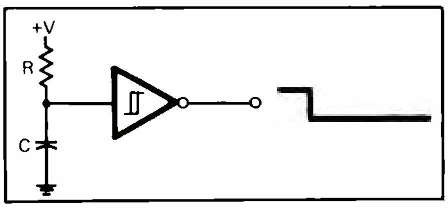
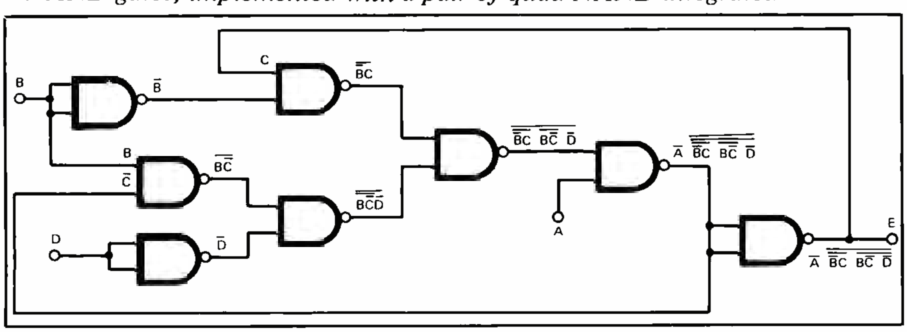


Fig. 4. The power-on timer provides an output voltage for a specified period of time and then goes low

Fig. 1. The power controller of the passive alarm is built around eight 2-input NAND gates, implemented with a pair of quad NAND integrated circuits.



sists of a single gate whose input has a resistor (*R*) to ground and a capacitor (*C*) connected to the positive voltage supply. When voltage is first applied to the circuit, a very rapid input change occurs for a fraction of a second as *C* charges. During this time, *C* appears as a short circuit to the changing voltage, applying a positive voltage to the input of the Schmitt-trigger gate.

Since the gate is an inverter, its output immediately goes low. After the first fraction of a second, the voltage applied to *C* is no longer changing (it's a constant dc voltage), so *C* blocks the flow of current.

In the meantime, the positive voltage that initially got through is decaying. When it drops below the low threshold point, the Schmitt trigger's output switches back to high and remains that way for as long as power is applied. The amount of time required for the voltage to drop to the low threshold point is calculated from the formula $T = 0.7RC$, where *T* is in seconds, *R* is in megohms, and *C* is in microfarads.

The Fig. 4 power-on circuit is very similar to the power-off circuit, except that the positions of *R* and *C* are reversed. In operation, the charge on *C* is initially zero and the output is high. As the charge builds up, it reaches the upper threshold point, causing the gate's output to switch low and remain low for as long as power is applied. The time constant formula for the delay in switching is $T = 1.05RC$.

The only other circuit that requires a Schmitt trigger to operate well is the astable multivibrator (oscillator) shown in Fig 5. It uses only one gate, one resistor, and one capacacitor, with resistor *R* providing the positive feedback required to sustain oscillation. When power is first applied to the circuit, *C* has no charge on it and the input is low, forcing the output high. As the output goes high, current flows back through *R* and starts to charge *C*. The voltage on *C* rises

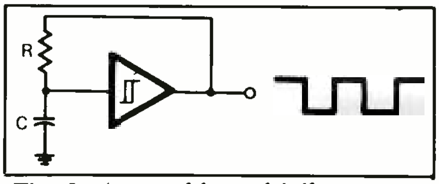


Fig. 5. An astable multivibrator can be formed with a single Schmitt trigger gate when a resistor is used to provide the positive feedback required to sustain oscillation.

exponentially until it is great enough to trigger the input with a logic high and force the output low.

Because *C* is still charging when the input to the gate is triggered, however, current begins to flow through *R* once again, this time in the opposite direction. Capacitor *C* now discharges exponentially until its charge drops below the low threshold point, causing the cycle to repeat itself. Frequency of oscillation is calculated from the formula $F_0 = [1/(1.4RC)]$, where F_0 is in Hz, *R* is in megohms, and *C* is in microfarads.

If a 2-input NAND gate (Fig. 6) is used instead of a simple inverter, the oscillator can be gated on and off. For example if the second input is connected to the positive supply, the circuit will oscillate as usual. However, if the input is set low, by connecting it to ground or the negative side of the power supply, the oscillator will cease to operate and its output will go high.

(6) Powering The Timers

We now need a circuit to control the power going to the timers that, in turn, controls how long the alarm sounds. We'll call this the timer power controller so as not to confuse it with the main system power controller. The timer power controller must know three things before it can determine that an alarm condition exists and the horn should be sounded. It must know if: the exist delay time has expired; a door has been opened; and the timer that controls how long the alarm is on has been activated.

Let's see how this circuit determines when to turn on the alarm horn:

(1) If the delay time has expired, the door is closed and the alarm is not active, it should remain inactive.

(2) If the exit delay time has passed, the alarm is not yet active and the door has been opened, the alarm should be activated.

(3) Once activated, the alarm should remain on while the door is open.

(4) Even after the door is closed and the alarm is armed, the alarm should remain on for a full 2 minutes.

(5) If the exit delay time has not expired, the door is closed and the alarm is not on, it should not be turned on.

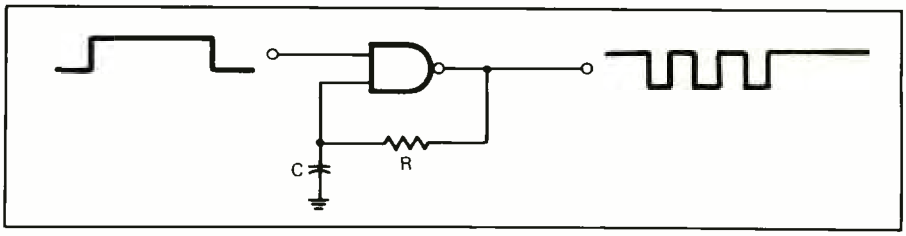
(6) Even if the door is opened while the exit delay is active and the alarm is off, the alarm should remain off.

(7) If the exit delay timer gets stuck in the active mode, the door is open and the alarm is already on, it should remain on.

(8) Even if the door is closed, as long as the alarm is already on, it should remain on.

The last two combinations of inputs could not normally occur in a

Fig. 6. If a 2-input NAND gate is used to build an astable multivibrator, the oscillator can be gated on by applying a positive voltage to the unused input.



properly operating system and can be ignored. They're included here as a safety factor should the exit delay timer get stuck in the active mode. Besides, it doesn't cost any more to implement, even if this capability is never needed.

A summary of the power timer controller's operation, in words, is shown in Table 3. Applying the same rules used for Table 2, this becomes the logic truth table shown in Table 4.

Table 3. Timer Power Controller Operation

	(B) door status	(F) exit delay	(G) alarm timer on	(H) turn or keep power on
1	closed	off	no	no
2	open	off	no	yes
3	open	off	yes	yes
4	closed	off	yes	yes
5	closed	on	no	no
6	open	on	no	no
7	closed	on	yes	yes
8	open	on	yes	yes

Table 4. Timer Power Controller Truth Table

	(B) door status	(F) exit delay	(G) alarm timer on	(H) turn or keep power on
1	1	0	0	0
2	0	0	0	1
3	0	0	1	1
4	1	0	1	1
5	1	1	0	0
6	0	1	0	0
7	1	1	1	1
8	0	1	1	1

(7) Equation For The Timer Power Controller

The next step is to convert Table 4 into an equation that, in its final form, can be implemented with only AND and NAND gates:

$$H = \bar{B}\bar{F}\bar{G} + \bar{B}\bar{F}G + B\bar{F}G + \bar{B}FG + BFG$$

$$H = \bar{F}(\bar{B}\bar{G} + \bar{B}G + BG) + FG(\bar{B} + B)$$

$$H = \bar{F}[\bar{B}(\bar{G} + G) + BG] + FG$$

$$H = \bar{F}(\bar{B} + BG) + FG$$

$$H = \bar{F}(\bar{B} + G) + FG$$

$$H = \bar{F}\bar{B} + \bar{F}G + FG$$

$$H = G(\bar{F} + F) + \bar{F}\bar{B}$$

$$H = G + \bar{F}\bar{B}$$

$$H = \overline{\bar{G}\,\overline{\bar{F}\bar{B}}}$$

The final equation allows the circuit in Fig. 7 to be implemented. To do this, however, we must have the inverse of both the B and F signals available. The first is available from the system power controller. By choosing the proper timer, in this case, the power-off timer, we can generate the inverse of F directly, without an extra gate.

As in the case with the system power controller, this circuit produces a positive output all the time power is to be applied to the timer circuits. Since neither power controller can directly supply the current required to power their respective circuits, the output of each is used to operate separate transistor switches that *can* provide the required power.

Since the output signal is high when power is required, a transistor that gets turned on by a positive voltage must be used. Hence, we use a general-purpose npn transistor, such as the 2N2222 specified. Of course, just about any other general-purpose npn switching transistor will do as well.

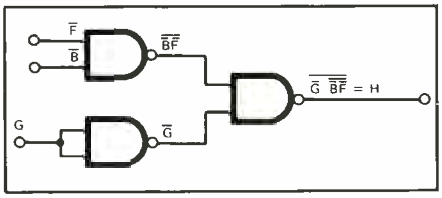


Fig. 7. The timer power controller is a lot simpler than the main power controller and requires only three gates to provide all of the proper signals.

(8) Finishing The Timed Alarm Section

The voltage that turns on the gated astable multivibrator that controls the beeping of the horn must be positive for the on and negative for the off conditions. Therefore, the timer used to control the duration of the alarm must be a power-on timer.

When multivibrator *IC4D* in Fig. 8 is not oscillating, its output is high. Since we want the relay (*K1*) that operates the horn to be off when the multivibrator is not oscillating, an inverter is used to correct the signal. This inverter (*IC5B*) also acts as a buffer for the oscillator. The signal is then fed to 2N2222 transistor *Q3*.

Although the alarm duration timer starts as soon as the door is opened, we want the beeping of the horn to be delayed for 15 seconds to permit you time to get into your vehicle, close the door, and turn on the ignition. A 15-second power-off timer controlling the input to the multivibrator is what is needed. This timer can be implemented by ANDing the signals of the 15-second power-off and 2-minute alarm timers. Since NAND gates are used, the output of a NAND gate must be followed by an inverter to obtain the AND function.

For the reset function, the signal applied to the circuit must be high when the switch (*S2*) is open and low when closed. This is most easily ac-

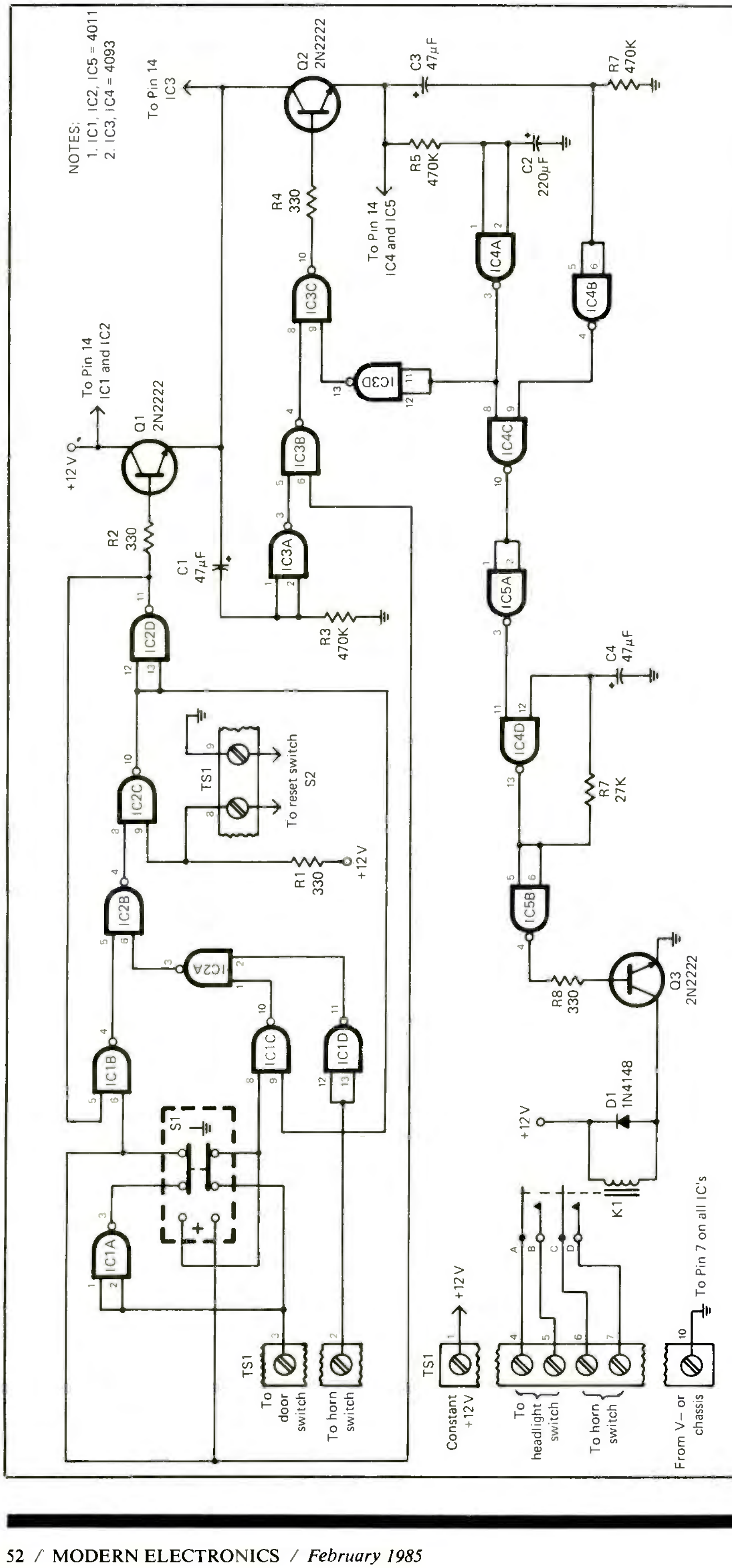


Fig. 8. This is the final schematic diagram of the entire passive alarm system.

PARTS LIST

Solid-state devices

D1—1N914 diode

IC1,IC2,IC5—4011 standard CMOS quad NAND gate

IC3, IC4—4093 Schmitt-trigger CMOS quad NAND gate

Q1, Q2, Q3—Npn switching transistor (2N2222 or similar)

Capacitors

C1, C3, C4—47-µF, 25-volt electrolytic

C2—220-µF, 25-volt electrolytic

Resistors (all ½-watt, 10%)

R1, R2, R4, R8—330 ohms

R3, R5, R6—470,000 ohms

R7—27,000 ohms

Miscellaneous

K1—12-volt dc spdt relay

S1—Dpdt switch

S2—Spst keyswitch or slide or toggle switch (see text)

TS1—8- or 10-lug screw-type terminal strip (see text)

Perforated board and solder posts or printed-circuit board; IC sockets; suitable enclosure; stranded hookup wire; spade lugs; electrical tape; machine hardware; solder; etc.

complished with the aid of pull-up resistor *R1*. When *S2* is open, virtually no voltage is dropped across *R1*. Thus, both ends of the resistor have a high voltage and the output of *IC2C* is high. When *S2* is closed, one end of *R1* is grounded and the input to *IC2C* drops to zero, as required. A single-pole, single-throw (spst) slide or toggle switch can be used here, but it would be prudent to use a more secure key-operated switch instead.

(9) Handling Both Types Of Door Switches

The alarm was designed with the assumption that the door switch in the vehicle shorts to ground when the door is open. Since in some vehicles the switch connects to the positive side of the electrical system when the door is opened, we include a provision that will accommodate either condition—hence the inclusion of *S1*

(Continued on page 82)

in Fig. 8. This cross-connected double-pole, double-throw (dpdt) switch has positions for both positive-voltage and ground switches.

Building The Project

Using Fig. 8, you're now ready to build your alarm. Assembly is simple and straightforward, requiring only standard construction techniques.

The project's electronics can be assembled on a piece of perforated board, using solder posts and IC sockets. However, if you're ambitious, you can design and fabricate your own printed-circuit board and use it instead.

Keep in mind that the CMOS ICs used in this project can be damaged by static electricity. So take proper precautions when handling them, and save installation of them in their sockets for last.

Though IC sockets aren't normally recommended for an automotive project (vibrations and other mechanical stresses cause ICs to work loose from their sockets), they are here to reduce to a minimum the possibility of static damage. You can guard against the possibility of the ICs working loose by applying a small daub of silicone adhesive to the bottom of their cases just before plugging them into their sockets. Don't overdo the adhesive, though, or you'll get it in the socket slots or on the IC pins.

You can use either an aluminum or a plastic box to house the project. Machine the box and mount screw-type terminal strip *TS1* and polarity selector *S1* (and RESET switch *S2* if you've decided against having remote control of this function) on the box. Then install the circuit board assembly in the box and connect and solder the free ends of the wires coming from it to the appropriate lugs on the terminal strip and polarity switch. Do *not* connect the various grounds on the circuit board to the case if you're using a metal box. The

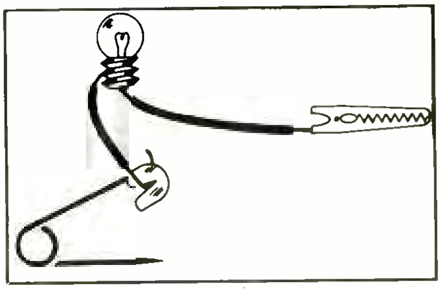


Fig. 9. Shown here are the connections that must be made between a screw-type terminal strip (TS1) and various points in the alarm circuit and vehicle's electrical system.

+12-volt and ground connections will be made via *TS1*.

Installing The Alarm

Remember that this is a *passive* alarm and, thus, doesn't require any action on your part to arm it. For maximum security, therefore, the box containing the electronics is best mounted where it won't easily be detected, preferably in a location that's inconvenient for even you to access. (You'll have to mount the box in a more accessible location if you've decided to mount the RESET switch on or in it.) Way up behind the dashboard or, if your vehicle has a deadbolt-type hood lock, on the firewall inside the engine compartment are good places.

If you use a relatively secure key-switch for the RESET switch, you can mount it in a location that isn't too obvious but where it's easy for you to get at in a hurry. A slide or toggle switch, however, must be located in a hidden part of your vehicle, where a thief isn't likely to find it in the 15 seconds before the alarm sounds. Hide all wiring inside panels, under carpeting, etc.

Before mounting the electronics package in its location, cut to length the 10 wires (eight if you've decided against using the flashing headlights option) that connect from *TS1* to the various points in your vehicle's electrical system. Install a spade lug on one end of each wire and trim away ½" of insulation from the other end, twist together the fine conductors, and lightly tin them with solder.

Connections to be made between the alarm's terminal strip screws and the various points in the vehicle's electrical system are detailed in Fig. 9. If you wish, you can reduce the number of wires needed by eliminating the connections to the headlights

Fig. 10. With this simple tester, you can safely determine which wires in a vehicle are connected to the positive side of the battery.

VEHICLE SIDE	TS1	CIRCUIT SIDE
Constant +12V point or + battery terminal	1	All +12V points in circuit
Any ignition – switched +12V point	2	IC1, Pins 12 and 13
Vehicle door switch	3	IC1, Pins 1 and 2
Wire in parallel with existing headlight switch	4	K1, contact A
	5	K1, contact B
Wire in parallel with existing horn switch	6	K1, contact C
	7	K1, contact D
From remote mounted reset switch (see text)	8	IC2, Pin 9
	9	Circuit ground
Vehicle chassis if negative ground; battery – terminal if positive ground	10	Circuit ground

and/or mount the RESET switch on the box.

The drawing shows one wire that connects to the car's door switch. Make sure you connect this wire to the appropriate wire on the door switch. If the door switch has only one wire, that's your wire. If there are two wires, however, you'll have to determine which is the correct one. To do this, you'll have to make the simple tester shown in Fig. 10. To use the tester, fasten the alligator clip to any convenient chassis ground point in your vehicle and, with the door closed, pierce first one and then the other door switch wire's insulation with the point of the pin and observe whether or not the tester's lamp lights. You'll know you've located the correct door switch wire when the tester's lamp is off with the vehicle door closed.

Having determined which door switch wire to use, carefully trim away a small portion of insulation (do not cut the wire) to expose the conductors. Wrap the free end of the door-switch wire coming from the alarm around the exposed conductors, solder the connection, and wrap with electrical tape. Reinstall the door switch.

Connect the remaining wires coming from the alarm box in the following sequence: ignition switch; chassis ground (under any screw head that provides a positive electrical connection to the vehicle's chassis) for a negative-ground system, or directly to the negative terminal of the battery in a positive-ground system; RESET switch, if mounted outside the alarm box; horn; headlights; and any part of the electrical system that has +12 volts at all times. The connections from the relay's contacts connect in parallel directly across your vehicle's headlights and horn switches.

Now you have a very practical design and should understand how to map out the general strategy to be used when creating a sophisticated digital electronics project. ME