The 555 A Versatile Timer

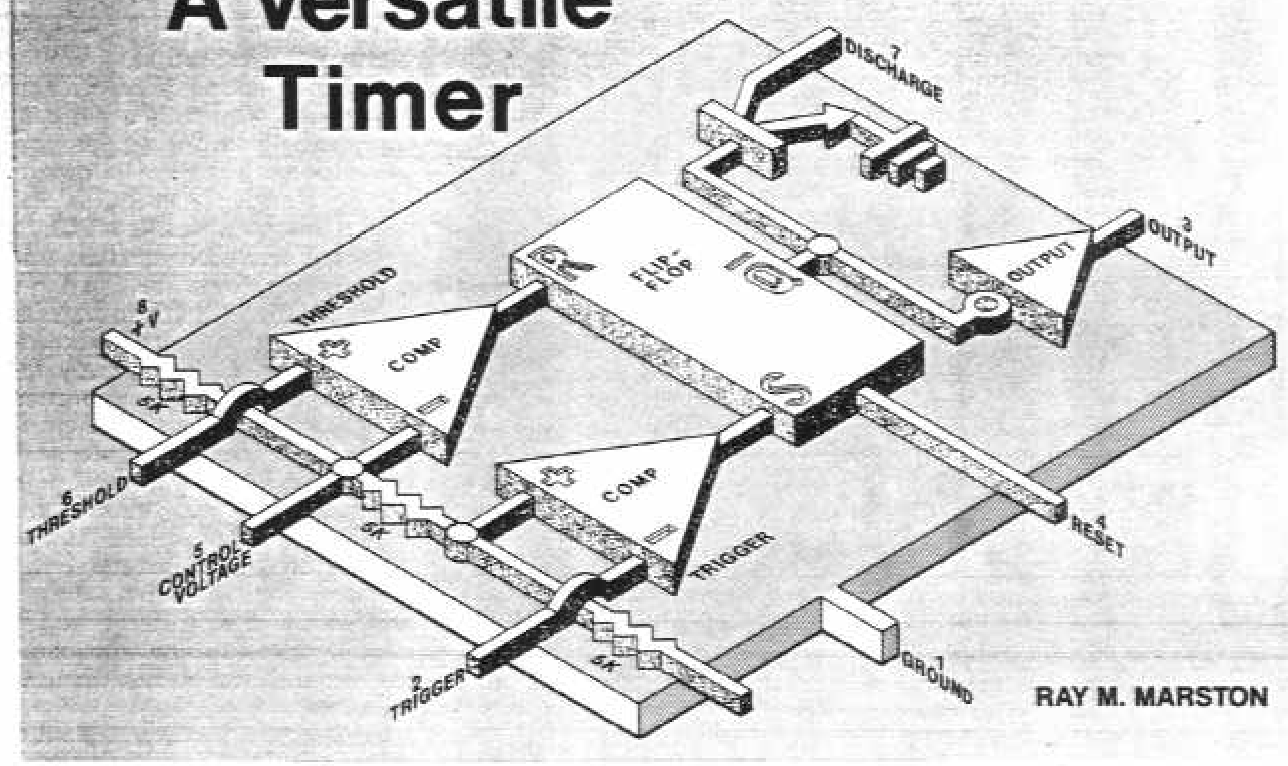

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FIG. 1—FUNCTIONAL BLOCKS OF THE 555 TIMER with its pinout identified.

Learn to use the 555 and 556 timer IC in practical circuits to obtain accurate time delays and square waves

IN ANY ASSOCIATION TEST FOR those who know integrated circuits, the three digits 555 will summon up the instant response "timer IC." It's the short form generic designation for progeny of the NE555, a popular monolithic timer/oscillator IC first introduced by Signetics many years ago. Still widely second-sourced because of its versatility, the 555 ranks as a standard "building block."

The 555 and its derivatives can be found in thousands of different circuits, and its possibilities for further applications appear limitless. Although classed as a linear IC, it is often used in digital or "quasi-digital" applications because its inputs and outputs are essentially square waves rather than sine or other complex waveforms. This article explains how the 555 works and shows you how to apply the IC in various practical control circuits.

A 555/556 overview

Figure 1 is a simplified block diagram of the 555 showing its principal functional blocks: threshold comparator, trigger comparator, R-S flip-flop, low-power complementary output stage, slave discharge transistor, and a voltage-reference potential divider. Both halves of a dual version of the 555 (two 555's on a single chip), the 556, have identical electrical characteristics. The 555/556 will run from 4.5 to 16 volts DC, although a typical supply will be +12 volts DC or less.

The outstanding features of the 555/556 include:

- Timing adjustable from microseconds to hours
- Duty cycle adjustable
- Ability of output to source (supply) or sink (dissipate) 200-milliampere current
- Output can drive TTL logic circuits
- Temperature stability exceeds 0.005%/°C
- Normally "on" and normally "off" output

The 555 and 556 were designed for precision timing applications, with the timing interval controlled by an external resistor and capacitor (RC) network. The devices contain voltage dividers consisting of three 5000-ohm resistors in series between the supply voltage and ground so that one-third of the supply voltage is developed across each resistor. The internal flip-flop circuit provides a definite "on" or "off" response. Its timing intervals are independent of the supply voltage.

The 555 has two basic operating modes: *monostable* (one-shot—a single pulse is emitted), and *astable* (a stream of output pulses is generated). In the monostable mode when functioning as timers, time is precisely controlled by the external RC network. In that mode the 555 produces output pulses with rise and fall times measured in microseconds.

In the astable mode, the 555 can be an oscillator. It can maintain an accurately controlled free-running frequency and duty cycle with only two external resistors and one capacitor. In either monostable or astable modes, timing accuracy is essentially independent of variations in supply voltage or ambient temperature. The device can be triggered and reset on falling waveforms.

Typical applications for the 555 include precision and sequential timing, pulse generation, pulse-width and pulse-position modulation, and linear ramp generation. Moreover, it can directly drive loads such as relays, solenoids, low-power lamps, and high-impedance speakers.

The 555 is packaged in plastic and metal DIP's and 8-pin metal cans for operation in the commercial temperature range of 0 °C to +70°C. Some plastic DIPs can operate in the −40°C to +85°C extended temperature range.

Alternate-sourced 555's can usually be identified by the inclusion of the numbers 55 or 555 in their designations. Examples include Harris' CA555, Motorola's MC1455, and National Semiconductors' LM555C. Other sources include Exar, Goldstar, Raytheon, Samsung, SGS-Thomson, and Sharp Electronics. CMOS versions of the 555, such as Texas Instruments' TLC555 are also available. In addition to their low power consumption compared to standard 555's, their outputs are compatible with CMOS as well as TTL.

Table 1 presents some basic electrical characteristics for the 555. The 556 is housed in a 14-pin DIP package but the block diagram of each circuit is identical to that of the 555 shown in Fig. 1. The 556 is also alternate-sourced by many of the same firms that offer the 555. Examples are Motorola's MC3556 and Texas Instruments' TLC7556.

How the 555 works.

Figure 2 is a representative circuit schematic for the 555. It contains 21 transistors, 4 diodes, and 15 resistors. The voltage divider consisting of three 5000-ohm resistors (shown in Fig. 1) appears to the right of Q10 in the trigger comparator. It applies one-third of the supply voltage to the non-inverting input terminal of the trigger comparator and two-thirds of the supply voltage to the inverting input of the IC's threshold comparator.

The output of the two comparators controls the R-S flip-flop, which in turn controls the states of the complementary output stage and the slave transistor Q6. The flip-flop's state can also be set by signals at RESET pin 4.

When organized as a monostable timer, the TRIGGER pin 2 is held high by external resistor R_T in series with the DC supply voltage. Under that condition, Q6 is saturated, shorting external timing capacitor C_D to ground, and OUTPUT pin 3 is driven low. Timer action is started by applying a negative-going trigger pulse to pin 2. As this pulse falls below one-third of the DC supply voltage, the output of the trigger comparator changes state. That causes the R-S flip-flop to switch, turning Q6 off, and driving OUTPUT pin 3 high.

As Q6 turns off, the short is removed from the external capacitor C_D. The capacitor charges through the external resistor R_D until the voltage across C_D rises to two-thirds of the supply voltage. Then the threshold comparator changes state and switches the R-S flip-flop back to its original state, turning Q6 "on" and rapidly discharging C_D. At the same time, OUTPUT pin 3 reverts to its low state. The *timing cycle* is then complete.

A characteristic of the 555 is that, once triggered, it cannot respond to additional triggering until the timing sequence is complete. However, the sequence can be aborted at any time by feeding a negative-going pulse to RESET pin 4.

The output pulse is a square wave whose duration (time delay) depends on the values of R and C. The formula for this is: t_D (time delay) = 1.1 (value of R × value of C)

Simply stated, time delay is directly proportional to the

TABLE 1—ELECTRICAL CHARACTERISTICS

Characteristics	Symbol	Min.	Typ.	Max.	Unit
DC Supply Voltage	V_{CC}	4.5	—	16	V
DC Supply Current (V+ = 5V)	I_{CC}	—	3	6	mA
(V+ = 5V)		—	10	15	mA
Power Dissipation		—	—	600	mW
Threshold Voltage	V_{th}	—	⅔	—	V
Trigger Voltage (V+ = 5V)	V_T	—	1.67	—	V
(V+ = 15V)		—	5	—	V
Reset Voltage	V_R	0.4	0.7	1.0	V
Reset Current	I_R	—	0.1	—	mA
Timing Error (Monostable)		—	1	—	%
Frequency Drift with Temperature		—	50	—	ppm/°C
Drift with Supply Voltage		—	0.1	—	%/V
Output Rise Time	t_r	—	100	—	ns
Output Fall Time	t_f	—	100	—	ns

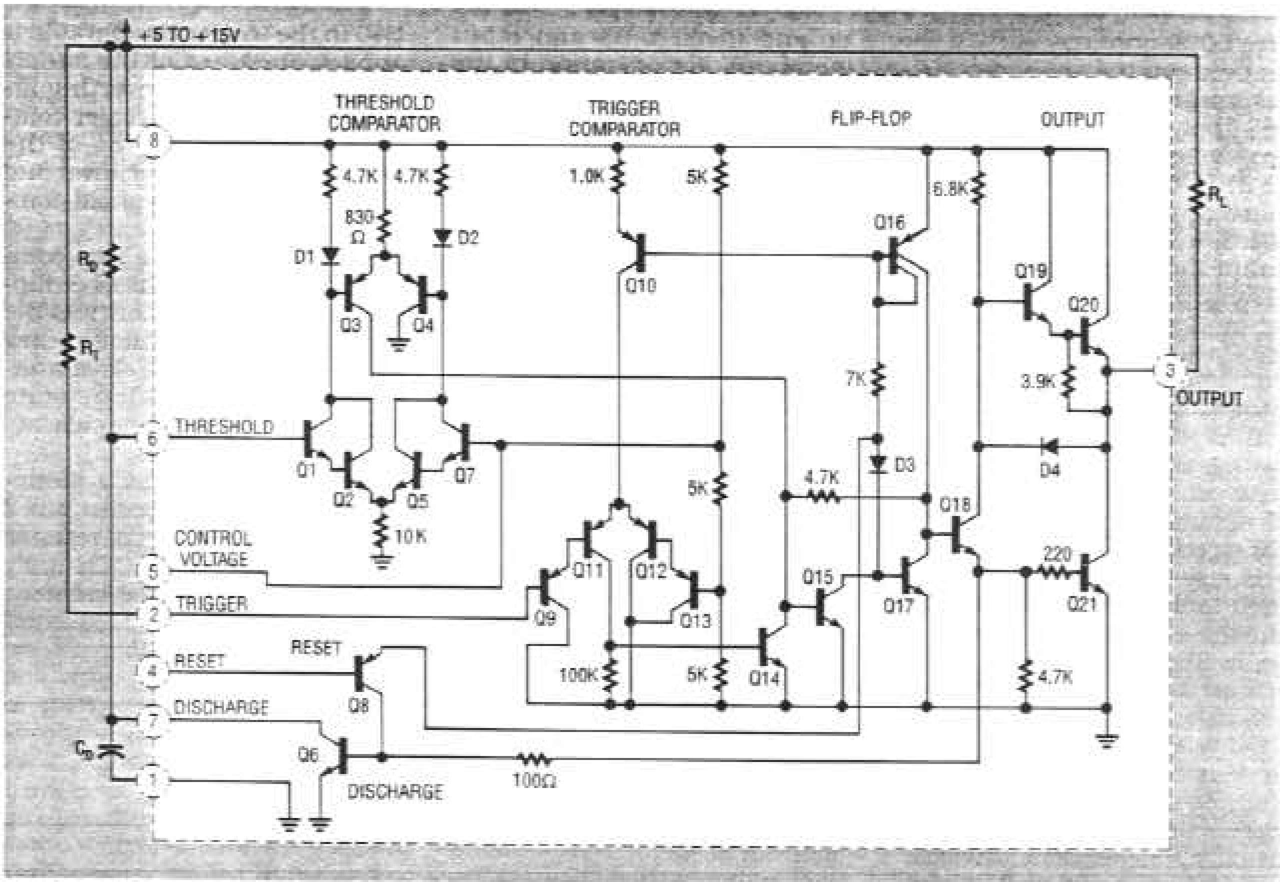

FIG. 2—REPRESENTATIVE CIRCUIT SCHEMATIC FOR A 555 timer with external resistive and capacitive components.

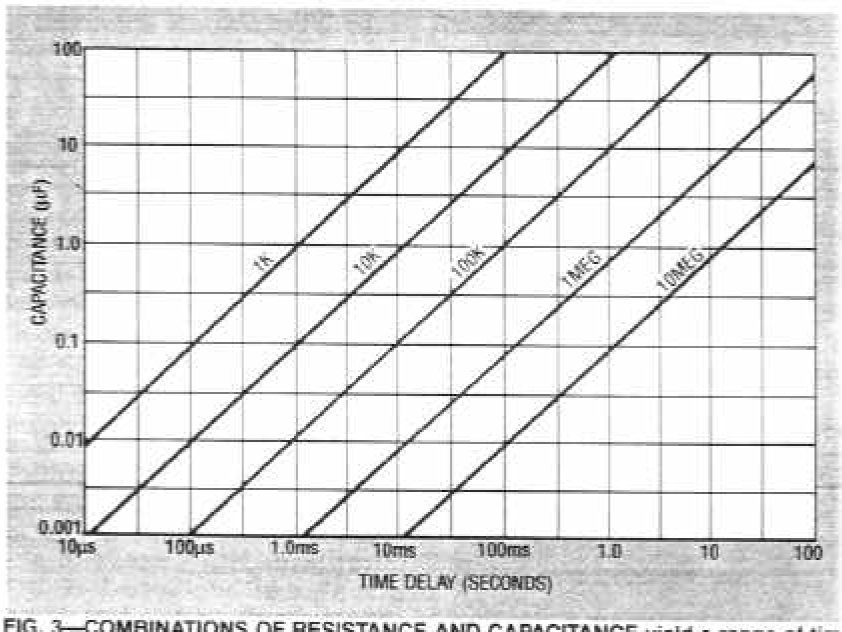

FIG. 3—COMBINATIONS OF RESISTANCE AND CAPACITANCE yield a range of time delays. The trigger pulse width must be less than the timing period.

product of R and C. Figure 3 is a plot of time delay vs. resistance and capacitance based upon the time-delay formula where t_D is in milliseconds. R is in thousands of ohms, and C is in microfarads. Figure 3 gives a family of time delay curves with variations in R_T and C_T. Delays from 10 microseconds to 100 seconds can be obtained by selecting suitable values of low-leakage capacitors from 0.001 µF to 100 µF and resistors from 1 thousand ohms to 10 megohms.

Figure 4-*a* is a simple fixed-period (approximately 50-second) manually-triggered time delay circuit, and Fig. 4-*b* shows the waveforms as they would appear on an oscilloscope. The sequence of events in Fig. 4-*b* is initiated by grounding TRIGGER pin 2 with momentary START switch S1. The CONTROL VOLTAGE pin 5 is decoupled by C2, and the output state can be determined by observing whether LED1 is illuminated or not. A square output pulse (whose fixed-period is determined by R1 and C1) appears at OUTPUT pin 3, while an exponential sawtooth (with the same period as the square wave) appears at DISCHARGE pin 7.

The fixed-period output of the circuit in Fig. 4 can vary from 1.1 to 120 seconds by making the changes shown in Fig. 5. Resistor R1 is replaced with a 10K fixed resistor and 1-megohm potentiometer R5 in series, as shown. A reset feature can be added by installing RESET switch S2, permitting

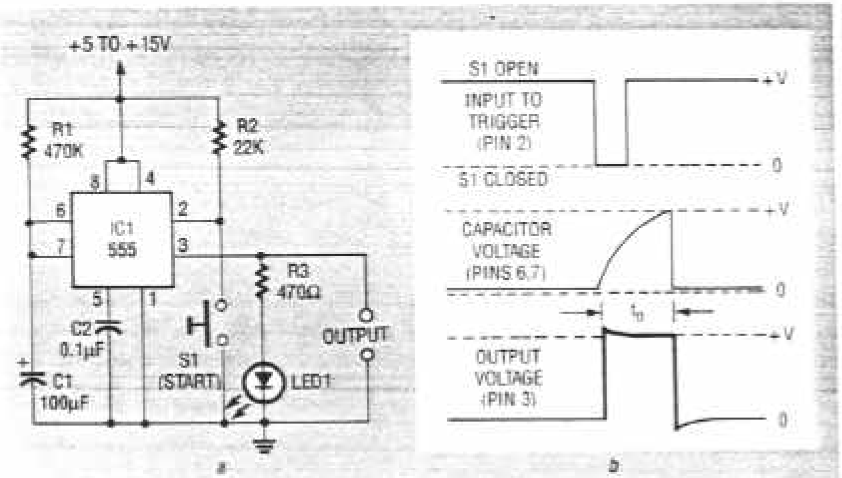

FIG. 4—FIXED-PERIOD TIMER produces a 50-second time delay (*a*). The waveforms at three pins are shown (*b* - *a*).

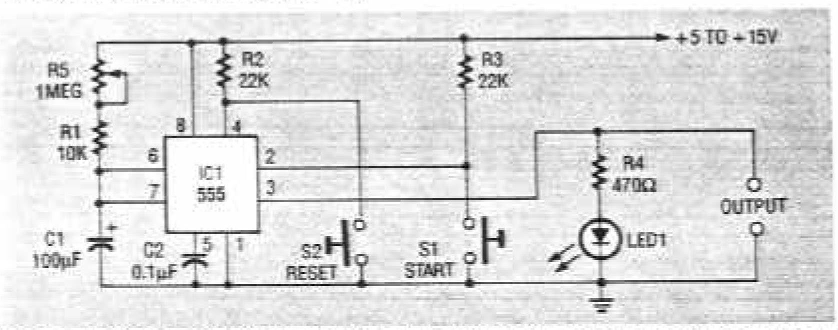

FIG. 5—VARIABLE-PERIOD TIMER CIRCUIT with reset capability produces time delays from 1.1 to 120 seconds.

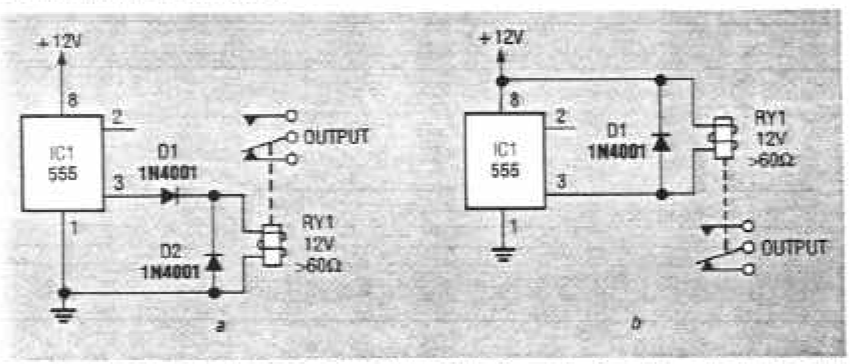

FIG. 6—ALTERNATE METHODS FOR ENERGIZING a relay from the output of a 555.

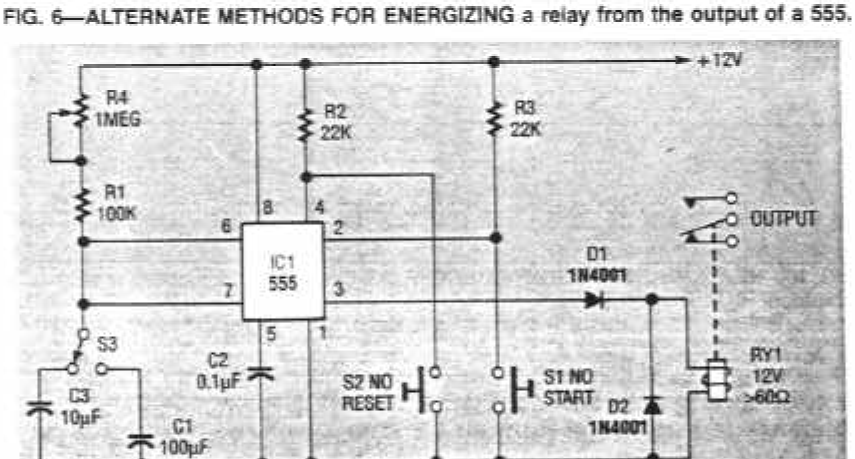

FIG. 7— TIMER WITH A RELAY OUTPUT provides time delays of 1.1 to 120 seconds.

premature termination of the timing period.

The 555 timer can drive non-inductive loads directly from pin 3 with currents as large as 200 milliamperes. However, if the circuit contains an inductive relay load, either of the schematics shown in Fig. 6 apply. In Fig. 6-a, the relay RY1 is normally off, but it goes on only when OUTPUT pin 3 goes high during the timing interval; in Fig. 6-*b*, RY1 is normally on, but it turns off during the timing interval. Diode D1 in both circuits protects the 555 against inductive-switching damage. The contacts of relay RY1 can control external circuits.

Figure 7 shows how a relay and a 555 can form a simple 1.1- to 120-second timer in two switch-selected decades. However, the general-purpose circuit has several drawbacks. First, it draws current continuously, even when the timer is off. Second, because of the wide tolerance variations in the electrolytic timing capacitors C1 and C2, potentiometer R4 needs two custom calibrated scales.

The schematic in Fig. 8 shows how to overcome these drawbacks. The RESET switch S2 and the set of relay contacts in parallel with the START switch S1, which are both normally open (N.O.) keep the circuit off so there is no current drain. The timing cycle is started by pressing momentary pushbutton switch S1, which connects power to the 555. At the instant of S1 closure, C3 is fully discharged. It therefore sends a start pulse to TRIGGER pin 2 through R4 and initiates a timing cycle.

As the timing cycle starts, RY1 is energized. The contacts in parallel with S1 close and keep the 555 powered even when S2 is released. At the end of the timing cycle RY1 is de-energized and its contacts re-open, disconnecting power from the 555.

The timing of the circuit in Fig. 8 is principally controlled by the values of resistor R1 and potentiometer R5, and either C1 or C2, which are switch-selected by S3-a. Note, however, that timing is also influenced by the setting of potentiometers R6 and R7. They are selected with switch S3-b and connected to CONTROL voltage pin 5 of the IC. Those potentiometers effectively shunt the internal voltage of the 555, thereby altering timing periods.

That feature allows the circuit to produce precise timing periods even when capacitors with loose-tolerance values are in the circuit. It also allows a single calibrated timing scale to cover the two switch-selected timing ranges.

To set up the Fig. 8 circuit, first set potentiometer R5 to its maximum value, set switch S3 to position 1 and push START button S1. Then adjust potentiometer R6 for a precise period of 10 seconds. Next, set 3 to position 2, push START switch S1, and adjust potentiometer R7 for a precise period of 100 seconds. With those adjustments complete, the timing scale can be calibrated over its full 100-second range.

Timers for car lights

Figure 9 is a circuit that automatically delays the turn-off of an automobile's headlights, permitting them to function as safety lights at night after the ignition switch is turned off. It is a useful circuit if you want your car's headlights to remain on for 50 seconds after you have parked, turned off the ignition, locked the doors, and walked away. The headlights will stay on long enough to illuminate your route until you can reach the safety of your home. The circuit does not interfere with normal headlight operation.

When the car's ignition switch S2 is turned "on," RY1 is energized (through diode D3) closing its contacts and connecting the 12-volt battery to the 555 and headlights switch S1. In this state the headlights operate normally. However, because both sides of capacitor C2 are connected to the positive supply, it is fully discharged.

When S2 is turned "off," the voltage across R3 goes to zero, de-energizing the relay. However, at that time C3 applies a

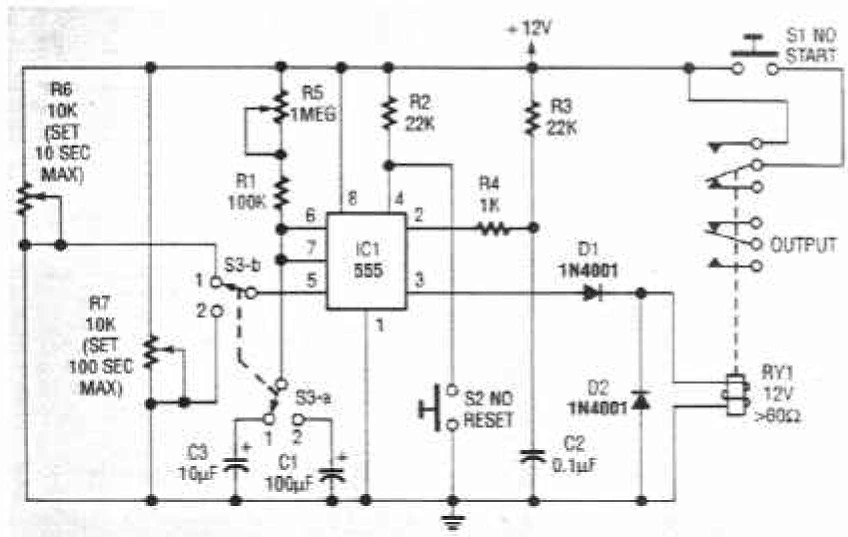

FIG. 8—PRECISION (COMPENSATED) TIMER with a relay output has two ranges: 0.9 to 10 seconds and 9 to 100 seconds.

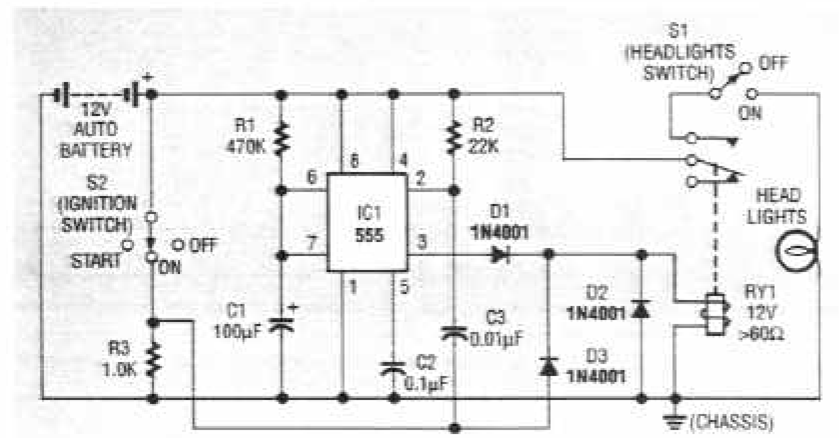

FIG. 9—HEADLIGHT TURNOFF CONTROL with automatic delay for automobiles.

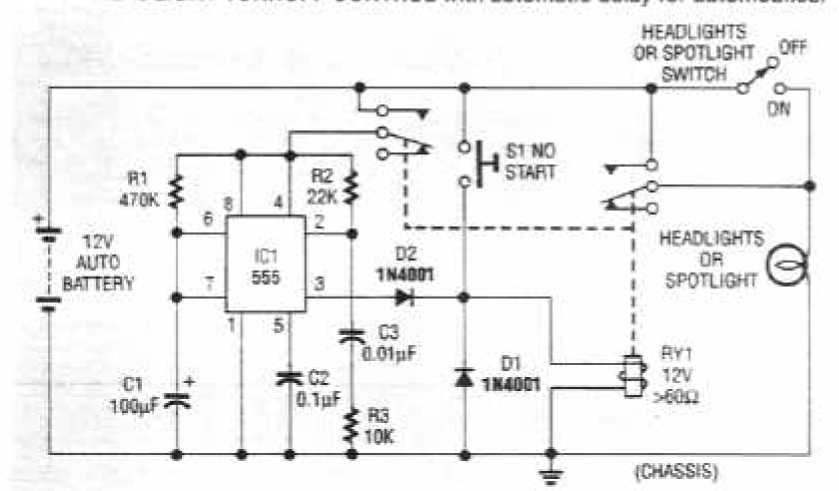

FIG. 10—HEADLIGHT/SPOTLIGHT TURNOFF CONTROL for automobiles is manually actuated.

negative-going trigger pulse to TRIGGER pin 2, initiating a 50-second timing cycle that applies current to the relay coil through D1.

Relay RY1's contacts remain closed for about 50 seconds after S2 is turned off, keeping the positive battery supply connected to S1 during this period. That keeps the headlights on if S1 is in its ON position. At the end of that 50-second time delay, RY1 de-energizes, its con-

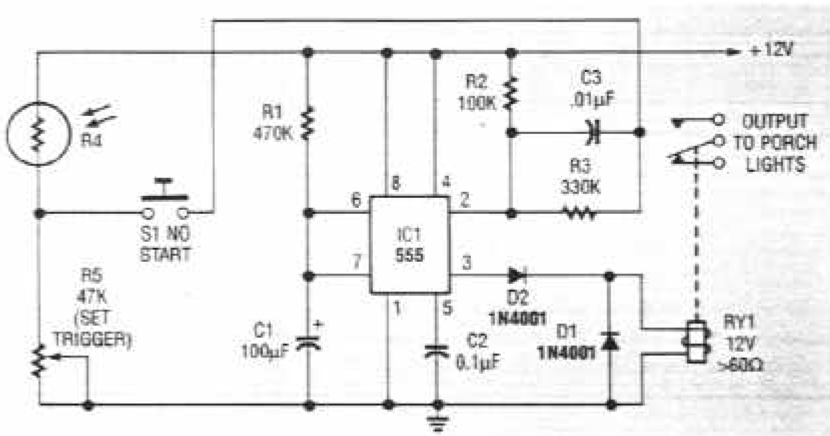

FIG. 11—PORCH LIGHT CONTROL AUTOMATICALLY turns on a light for a preset period only when triggered at night.

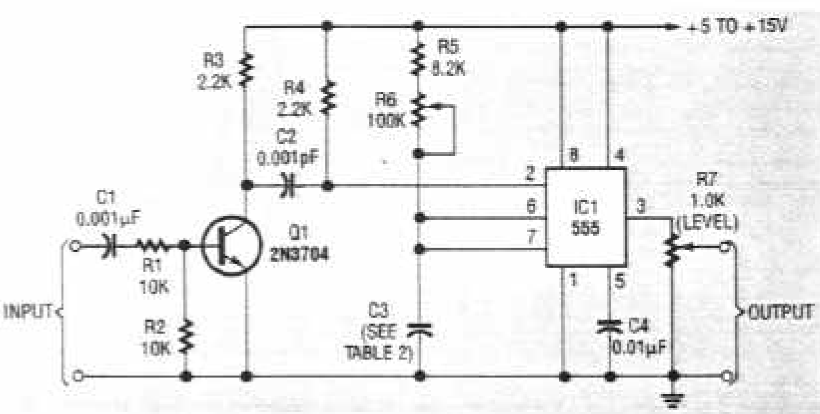

FIG. 12—ADD-ON PULSE GENERATOR can supplement a stand-alone pulse generator. It is triggered by rectangular input signals. Table 1 gives output pulse widths for various values of C3.

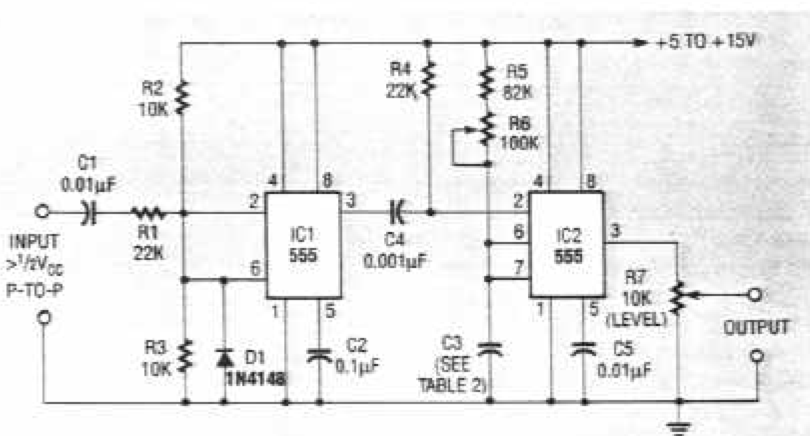

FIG. 13—MODIFIED ADD-ON PULSE GENERATOR can be triggered by any kind of input waveform including sine waves.

tacts open, and battery supply is disconnected from the 555 and S1.

The circuit in Fig. 9 is compatible with modern practice for powering the headlights switch S1 with ignition switch S2 so that headlights work only when the ignition switch is on. However, the circuit shown in Fig. 10 is applicable to older vehicles whose headlights or spotlight are independent of the ignition switch. The circuit illustrates a manual delayed turn-off light control.

That circuit works if the vehicle is parked with its lights off. They will be turned on for a preset 50-second period as soon as momentary pushbutton START switch S1 is pressed. When the delay period times out, the lights will be turned off again automatically.

The Fig. 10 circuit includes relay RY1 with two sets of normally-open contacts. The timing sequence is started with the momentary closure of pushbutton switch S1. Normally, both S1 and the relay contacts are open, so the timer circuit is not powered and the lights are off. Capacitor C3 is discharged under this condition.

When S1 is momentarily closed, RY1's coil is energized. That action closes its first set of contacts, applying power to the car's lights while also closing its second set of contacts, applying power to the 555. However, TRIGGER pin 2 of the IC is briefly grounded through C2, so a negative trigger pulse is fed to it, and a timing cycle is begun.

Consequently, OUTPUT pin 3 of the 555 switches high when the relay contacts close, locking the relay into its "on" state (regardless of the subsequent state of S1), keeping the lights on for 50 seconds. At the end of the timing cycle, pin 3 of the IC switches to its low state, de-energizing RY1. Then both sets of relay contacts open, disconnecting power from the 555 and the lights.

Automatic porch light

Figure 11 is an automatic control circuit for a porch light. It will turn a porch light on automatically for a preset 50-second period when its sensor detects the presence of a person. However, it performs that function only at night or under conditions of reduced visibility such as might occur during a storm. The circuit is activated with switch S1, which can be a microswitch triggered by a porch gate. It might also be a pressure-switch hidden under a porch mat and triggered by a person weighing perhaps 50 pounds or more.

Circuit operation depends on a negative-going pulse that falls below the internally controlled

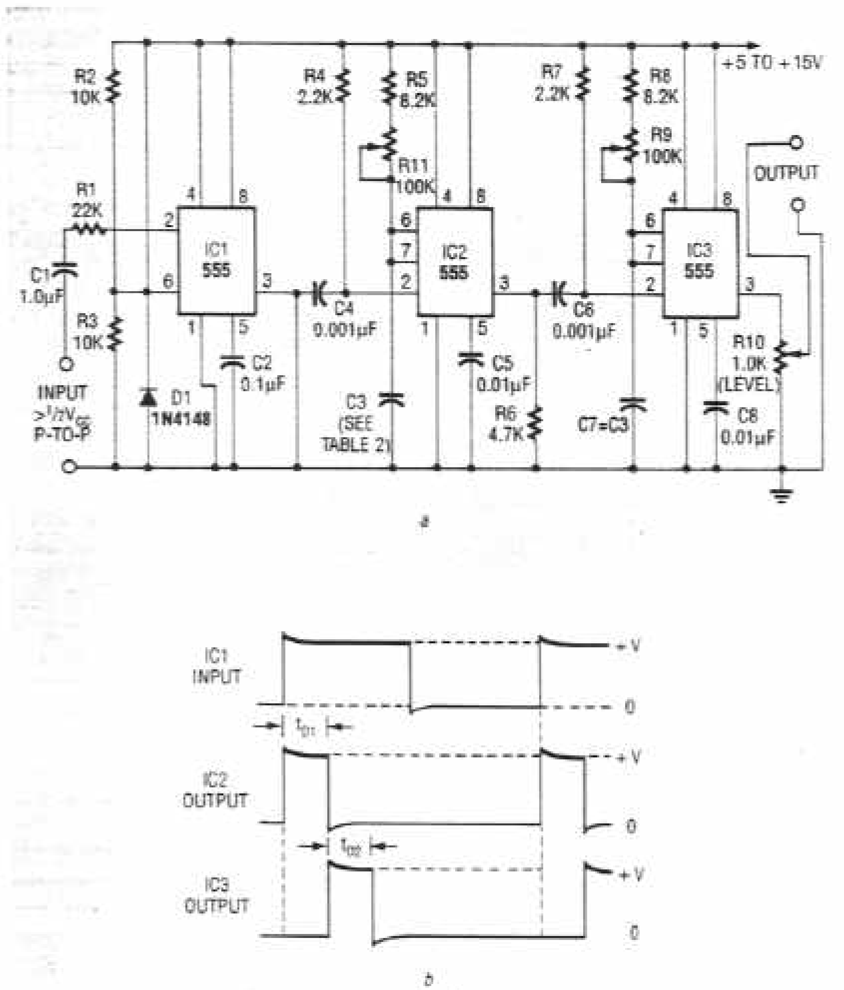

FIG. 14—ADD-ON DELAYED PULSE GENERATOR can be triggered by any input waveform (*a*). Waveforms at input to IC1 and those at the outputs of IC2 and IC3 based on different values of R and C (*b*).

one-third supply voltage being fed to TRIGGER pin 2 of the 555. If the trigger pulse does not fall below that value, the timing cycles cannot be initiated.

In Fig. 11, the photocell (resistor R4) and potentiometer R5 are in series as a light-dependent voltage divider. One side of S1 is connected to the junction between R4 and R5, and the other side is connected to pin 2 through a the network of C2 and R3. In normal daylight the photocell's resistance is low, so a high voltage appears at the junction of R4 and R5. As a result, closing S1 sends a voltage pulse to pin 2 whose value is too low to pull pin 2 below one-third of the supply voltage. Thus, the timer cannot be triggered with S1 under those conditions.

However, the photocell's resistance value increases at night or under reduced visibility, causing a low voltage to appear at the R4-R5 junction. Under that condition, closing S1 generates a voltage pulse that pulls pin 2 below the one-third supply voltage value, triggering the timer.

The cadmium-sulphide (CdS) photocell (resistor R4) should have a resistance of 1000 to 47,000 ohms under "dark" turn-on conditions. Potentiometer R5 can be adjusted to preset the minimum "dark" level for circuit triggering. The trigger signal is fed to pin 2 of the 555 through the C3 and R3, a network that shapes the trigger pulse and effectively isolates the DC component of the photocell-potentiometer network from pin 2.

Pulse generators

In all of the circuits presented so far, the 555 functions as a monostable (one-shot) pulse generator. Suitable trigger signals are fed to TRIGGER pin 2 and output pulses are taken from OUTPUT pin 3. The 555 can generate well formed output pulses with periods from 5 microseconds to hundreds of seconds. The maximum usable pulse repitition frequency is approximately 100 kHz.

The signal reaching TRIGGER pin 2 must be a carefully shaped negative-going pulse. Its amplitude must switch from an "off" value greater than two-thirds of the supply voltage to an "on" value less than one-third of the supply voltage. (Triggering actually occurs as pin 2 drops through the one-third supply voltage value.) Trigger pulse width must be greater than 100 nanoseconds but less than that of the desired output pulse. That condition assures trigger pulse removal by the time the monostable period times out.

Suitable trigger signals for the 555 in the monostable mode can be formed by converting the input signal to a good square wave that switches between the full positive supply voltage and ground. The square wave is then coupled to pin 2 with a resistor-capacitor differentiating network having a short time constant. That network converts the leading or trailing edges of the square wave into suitable trigger pulses.

TABLE 2—CAPACITOR VALUES FOR PULSE-WIDTHS

Capacitors C3 (Microfarads)	Pulse Width Range (Time in Seconds)
10.0	90 ms - 1.2
1.0	9 ms - 120 ms
0.1	900 μs - 12 ms
0.01	90 μs - 1.2 ms
0.001	9 μs - 120 μs

Figure 12 shows a timing circuit that accepts input signals already in the form of square waves or pulses. Transistor Q1 converts a rectangular input signal into a form that switches between the positive supply and ground. The output signal is

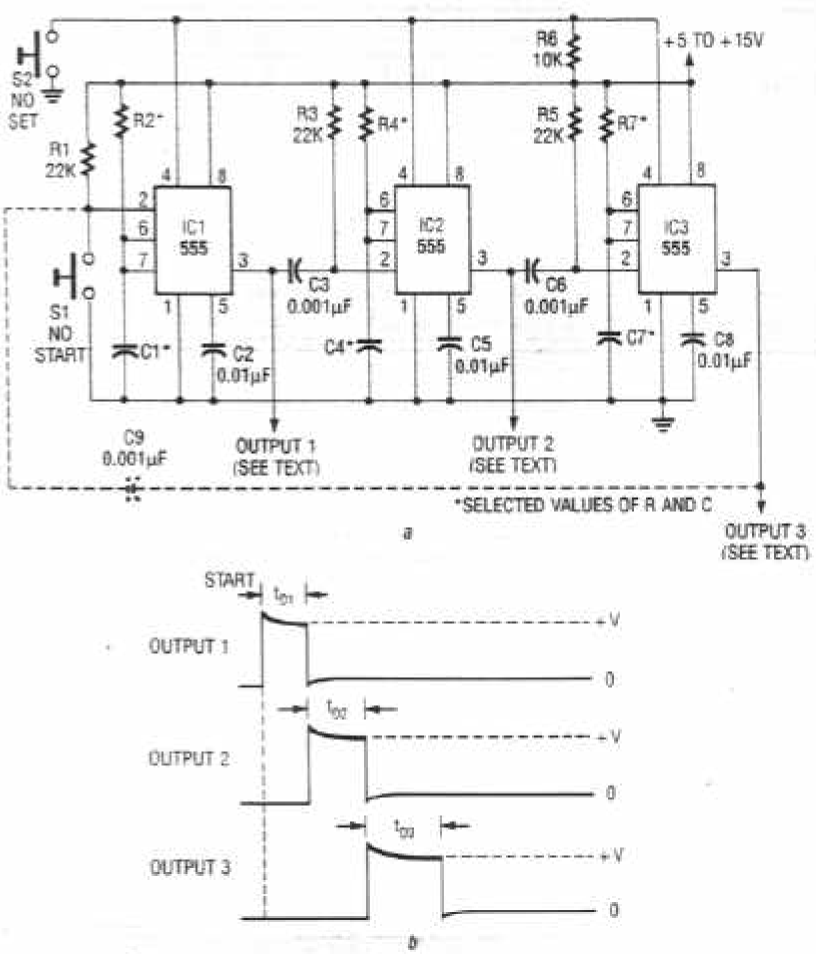

FIG. 15—THREE-STAGE SEQUENTIAL TIMER or pulse generator (*a*) and waveforms at three different output pins (*b*).

then fed to TRIGGER pin 2 through differentiating network C2-R4. The circuit can become an add-on pulse generator in combination with a separate square-wave or pulse generator. Variable-amplitude output pulses can be obtained from potentiometer R7.

The output pulse widths of the Fig. 12 circuit can be varied over more than a decade range with potentiometer R6, and they can be switched in overlapping decade ranges with the values of C3 listed in Table 2. With the component values shown, output pulse width is variable from 9 microseconds to 1.2 seconds. Capacitor C4 decouples CONTROL VOLTAGE pin 5 to improve circuit stability.

Figure 13 shows a modification of the circuit in Fig. 12 that can be triggered by any kind of input waveform, including sine waves. Here the first 555 (IC1) is configured as a Schmitt trigger to convert all input signals into square-wave output signals. Those square waves trigger the second 555 (IC2) in the monostable mode in the same way as described earlier. The circuit can also become an add-on pulse generator in combination with any kind of stand-alone waveform generator that produces output signals with peak-to-peak amplitudes greater than one-half the IC's supply voltage.

Figure 14-*a* shows how two monostable circuits can be connected in series to make a delayed-pulse generator. As in Fig. 13, the first 555 (IC1) is configured as a Schmitt trigger. The second 555 (IC2) controls time delay width, while the third 555 (IC3) determines the output pulse width.

As shown in Fig. 14-*b*, the output pulse at pin 3 of IC3 appears at a time interval after the initial application of the trigger signal. This time delay width T_{D1} is determined by the product of the value of capacitor C3 and the sum of the values of resistor R5 and potentiometer R6, in accordance with the time delay formula given earlier. Similarly, output pulse width t_{D2} is determined with the values of C7, and R8 and R9.

This circuit can become part of a stand-alone pulse delay generator by building it into a square-wave generator case. The square-wave generator will provide the initial trigger signals needed.

A number of monostable pulse generators can be placed in series to operate in sequential form. Figure 15-*a*, for example, shows a three-stage sequential generator circuit. It can control lamps or relays in a pre-programmed time sequence after pushbutton switch S1 is pressed to give the START command. Note that the RESET pins (pin 4) of all three 555's are shorted together and positively biased by R6. Those pins can be shorted to ground with SET switch S2. When power is applied, S1 should be closed, ensuring that none of the 555's in the circuit are falsely triggered.

Figure 14-*b* shows the waveforms from the output pins of all three 555's (IC1 to IC3). The time delay t_{D1} is determined by the values of C1 and R2, t_{D2} is determined by the value of C4 and R4 and t_{D3} is determined by the values of C7 and R7 when inserted in the time delay formula given earlier.

Finally, three or more monostable circuits can be connected with capacitor C9 (shown in a dashed connection line) between S1 and pin 3 of the third 555 (IC3). This loop feeds a signal back from the OUTPUT pin of IC3 to the input TRIGGER pin of IC1, permitting infinite repetition of pulse sequence. The circuit can drive LED's and digital logic. The circuit also has the reset capability provided by S2 that clears the circuit when power is first applied. R-E

THE 555: A VERSATILE OSCILLATOR

Learn how to build the 555 IC into oscillator circuits whose frequency you can change so they'll wail, warble, and honk.

RAY M. MARSTON

THIS ARTICLE LOOKS AT THE VERsatile 555 monolithic integrated timing circuit as an astable multivibrator, the flip-side of its capabilities as a monostable multivibrator in time-delay circuits. A recent article (September R-E, pg. 58) explored the role of the 555 in the monostable mode.

Now you'll find out how to build many different kinds of circuits with the 555 configured as a self-triggering oscillator. You will want to build the circuits that can generate a variety of square or rectangular waveforms, wail like a police car, imitate the jarring he-haw sound of European emergency vehicles, or reproduce the Klaxon alarm of the Star Treks' starship Enterprise.

The last article on the 555 as a monostable multivibrator included a functional block diagram and an electrical schematic of the chip. You might want to refer back to those figures if you want more detailed information about how the 555 is organized. Figure 1 is a pinout diagram of the 555 as packaged in the most common 8-pin DIP. It was pointed out in the last article that, although a mature device, the 555 remains one of the most popular IC's available today.

At least five major semiconductor firms in the U.S. and Japan make the 555. There is also a dual version, the 556, that has two identical 555's on a single chip. The device is usually packaged in a 14-pin DIP. A quad version, the 558, has four indentical 555's on a single chip, and it is packaged in a 16-pin DIP. The alternate source suppliers usually include the numerals 55, 56 or 58 in their own designations for those devices.

The 555 occupies a strange position in the universe of integrated circuits. Classed as a linear IC because it can be triggered either by linear or digital signals, its output is always digital—in the form of rectangular or square waves or pulses.

The 555 in a *monostable* multivibrator circuit (also called a timer, time delay, or one-shot) generates a fixed-length output pulse for each trigger pulse at its input. This can be demonstrated with the circuit in Fig. 2. By contrast, the 555 in an *astable* multivibrator circuit is shown in Fig. 3. It has no stable output states and no external trigger is necessary to start circuit oscillation; it is said to be self-triggering. This circuit configuration is also called an *oscillator*, *signal generator*, *pulse generator*, or a *rectangle-wave generator*.

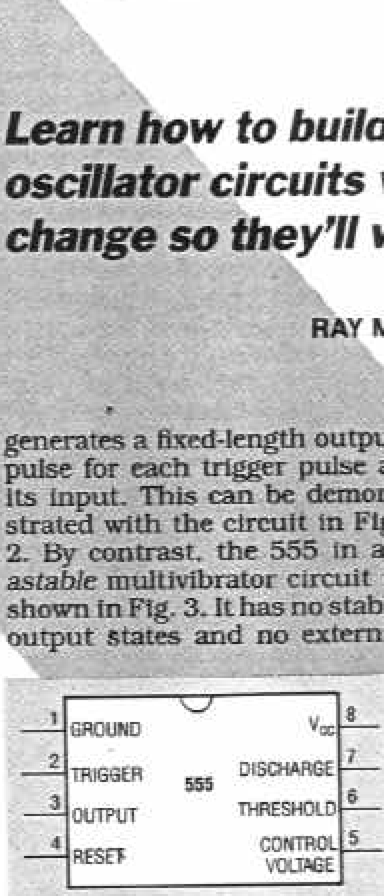

FIG. 1—PINOUT DIAGRAM OF THE 555.

As long as power is applied to the astable circuit, the output continually switches back and forth between the high and low states at a regular rate or frequency. The time in the high state (pulse width) and the time in the low state (space length) depend on the selection of external resistors and capacitors. Because of its relatively high output, the 555 in an astable circuit can drive LED's, speakers, and meters directly.

Astable operation

In the monostable multivibrator circuit in Fig. 2, OUTPUT pin 3, DISCHARGE pin 7, and THRESHOLD pin 6 are held low when the circuit is quiescent. A monostable timing period can be started by driving TRIGGER pin 2 low with pushbutton switch S1. That causes OUTPUT pin 3 to switch high, while DISCHARGE pin 7 is released and free to follow the voltage across C1. Voltage rises exponentially through R1 toward the supply

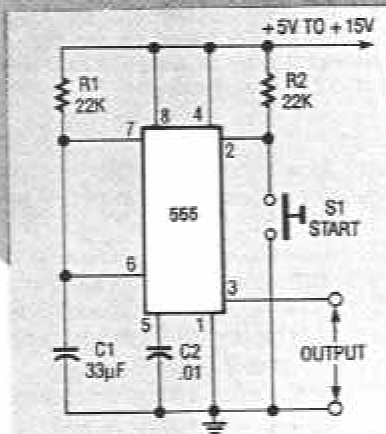

FIG. 2—MONOSTABLE MULTIVIBRATOR TIMING CIRCUIT based on the 555.

voltage. Eventually the voltage at pin 7 rises to two-thirds of the supply voltage, and monostable action ceases with pins 3, 6 and 7 grounded by the internal circuitry of the 555.

Examine the astable circuit shown in Fig. 3-a. In this circuit TRIGGER pin 2 is shorted to THRESHOLD pin 6, and timing resistor R2 is wired between pin 2 and DISCHARGE pin 7. When power is applied to the circuit, capacitor C1 charges exponentially (as it did in Fig. 1) through resistors R1 and R2 until the voltage on C1 reaches two-

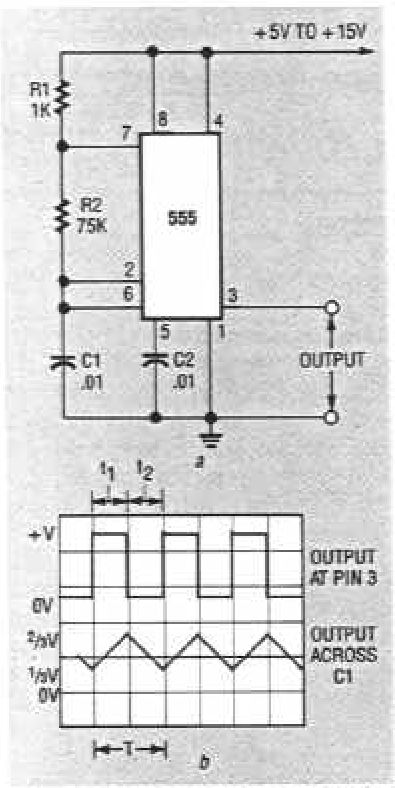

FIG. 3—A ONE-KILOHERTZ ASTABLE MULTIVIBRATOR based on the 555, *a*, and waveforms at output pin 3 and across C1 are shown in *b*.

thirds of the supply voltage. At that time, monostable action ceases and DISCHARGE pin 7 returns to its low state. Capacitor C1 then discharges exponentially into pin 7 through R2 until the voltage on C1 falls to one-third of the supply voltage, and TRIGGER pin 2 is activated.

At that time, a new monostable timing sequence is started and C1 recharges to two-thirds of the supply voltage through resistors R1 and R2. The whole sequence then repeats itself over and over with C1 alternately charging to two-thirds of the supply voltage through R1 and R2, and then discharging to one-third of that voltage through R2 only.

Notice that in Fig. 3-a, the value of R2 is very large with respect to the value of R1. It turns out that the oscillation frequency of the circuit is largely determined by the values of R2 and C2. Figure 3-b shows the nearly symmetrical square output waveform that appears between OUTPUT pin 3 and ground while a nearly linear triangle waveform is simultaneously generated across C1.

The graph of Fig. 4 shows the relationship between the free-running frequency of the circuit in Fig. 3-a and the capacitance values of C1 with the range of R2 values shown on the diagonal lines. In this graph the contribution of resistor R1 is neglected because it is a fraction of the R2 value.

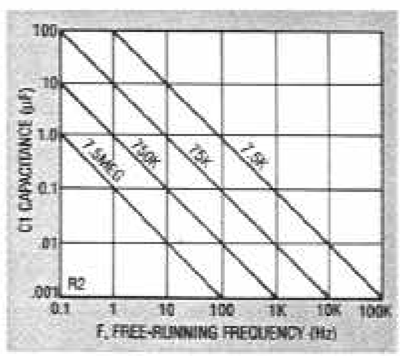

FIG. 4—THE FREE-RUNNING FREQUENCY OF OSCILLATOR in Fig. 3 as a function of capacitance values for C1 and the resistance value of R2 (when large with respect to R1).

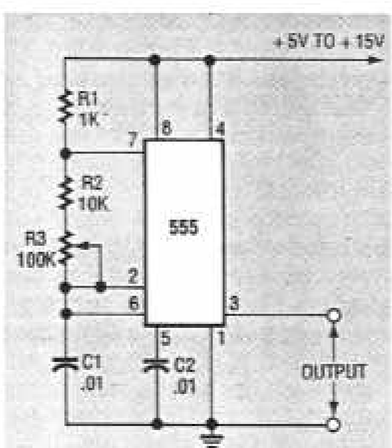

FIG. 5—THIS SQUARE-WAVE GENERATOR produces a variable frequency of 650 Hz to 7.2 kHz.

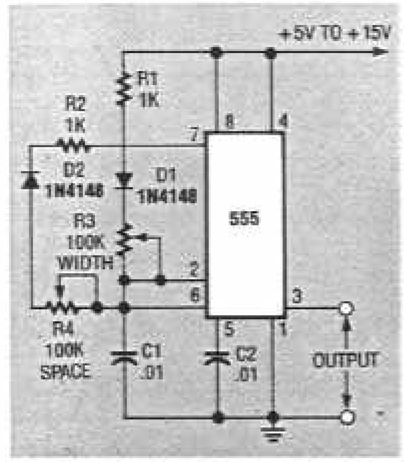

FIG. 6—AN STABLE MULTIVIBRATOR with independent pulse width and space periods variable from 7 to 750 microseconds.

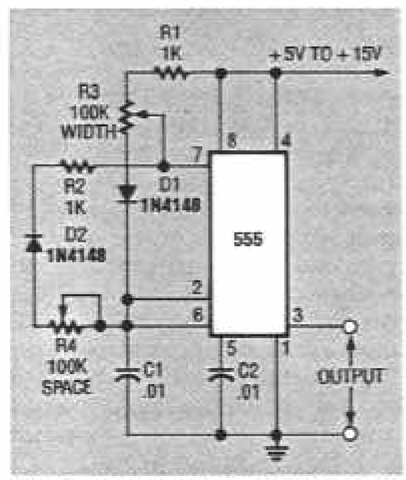

FIG. 7—ALTERNATE VERSION OF OSCILLATOR shown in Fig. 6.

The values of R1 and R2 can be varied from 1 kilohm up to tens of megohms. Resistor R1 can, however, have a significant effect on the total circuit current consumption because pin 7 is essentially grounded during half of the oscillation cycle. The duty cycle or pulse width-to-space ratio of the circuit can be preset at a nonsymmetrical value, if desired, by the choice of R1 and R2 values.

The high time (pulse width) and low time (space length) in this circuit must be calculated separately. The pulse width calculation includes the values for the timing capacitor C1 and both timing resistors R1 and R2. By contrast, the space length formula includes only the values of timing capacitor C1 and resistor R2.

Refer to Fig. 3-b. Pulse width (or time to charge capacitor C1 is:

$t_1 = 0.7\ C1\ (R1 + R2)$

Space length or time to discharge capacitor C1 is:

$t_2 = 0.7\ C1R2$

The total cycle time is:

$T = t_1 + t_2$

The ratio of pulse width to the total cycle time is the *duty cycle*. In a 555-based oscillator, the duty cycle is defined by the relative values of the two timing resistors R1 and R2:

Duty cycle = $R2/(R1 + 2R2)$

Frequency in hertz (Hz) is the reciprocal of total cycle time:

$F = 1/T$.

The circuit in Fig. 3-a can be modified in many different ways. Figure 5, for example, shows how it can be made into a variable-frequency square-wave generator by replacing R2 with a fixed resistor and potentiometer in series. The frequency can be varied over a range of about 650 Hz to 7.2 kHz with the values of the resistor and potentiometer R3 shown. If required, the frequency span can be further increased by switch-selecting alternative values of C1.

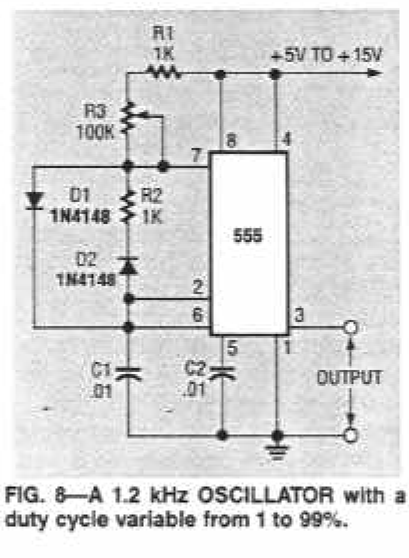

FIG. 8—A 1.2 kHz OSCILLATOR with a duty cycle variable from 1 to 99%.

Width-space control

The circuit in Fig. 3-a can generate a fixed-frequency output waveform with any desired pulse width-to-space length ratio by selecting the appropriate values for R1 and R2. In each operating cycle, C1 alternately charges through R1 and R2, and discharges only through R2. For example, if R1 and R2 have equal values, the circuit will generate a 2:1 width-to-space ratio.

The width-to-space periods can be independently controlled with either the Figs. 6 or 7. In Fig. 6, C1 alternately charges through R1, diode D1, and potentiometer R3, and it discharges through potentiometer R4, diode D2, and R2. In Fig. 7, C1 alternately charges through R1, potentiometer R3, and diode D1, and it discharges through potentiometer R4, diode D2, and R2. In both Fig. 6 and 7 circuits, R2 protects the 555 if potentiometer R4 is shorted.

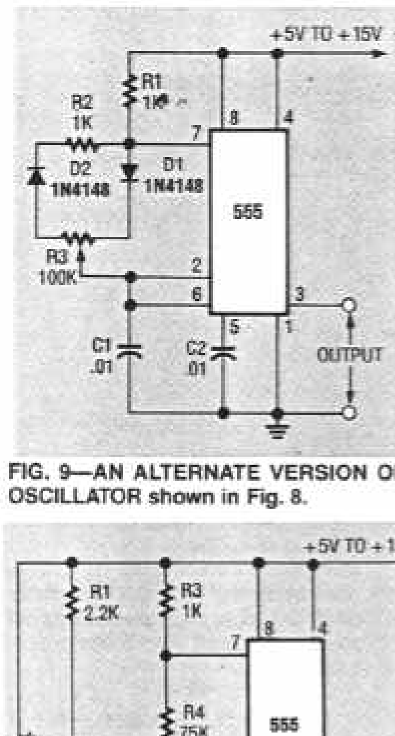

FIG. 9—AN ALTERNATE VERSION OF OSCILLATOR shown in Fig. 8.

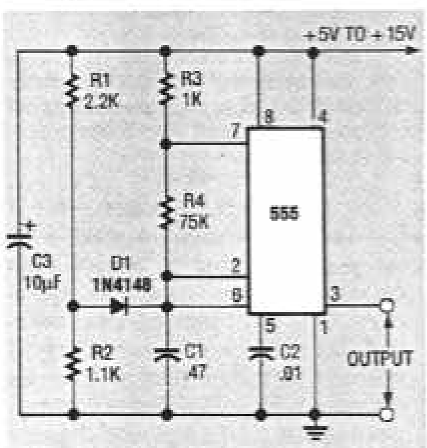

FIG. 10—A PRECISION LOW-FREQUENCY OSCILLATOR with a frequency of about 20 Hz.

In the circuits of Figs. 6 and 7, the width-to-space periods can be independently varied over about a 100:1 range, enabling the width-to-space ratio to be varied from 100:1 to 1:100. The oscillation frequency varies as the ratio is altered.

Figures 8 and 9 show alternate ways of connecting the 555 in the astable mode so that the width-to-space ratio can be varied without altering the oscillating frequency. In those circuits, the pulse width period automatically increases as the space length period decreases, and vice versa. Therefore, the total period of each operating cycle is constant. In those circuits, the feature of interest is the duty cycle. In Figs. 8 and 9, the duty cycle can be varied from 1% to 99% with potentiometer R3.

In the circuit of Fig. 8, C1 alternately charges through R1, the upper half of R3, and D1, and it discharges through D2, R2, and the lower half of potentiometer R3. In Fig. 9, C1 alternately charges through R1 and D1 and the right-hand half of potentiometer R3, and it discharges through the left-hand half potentiometer R3, D2, and

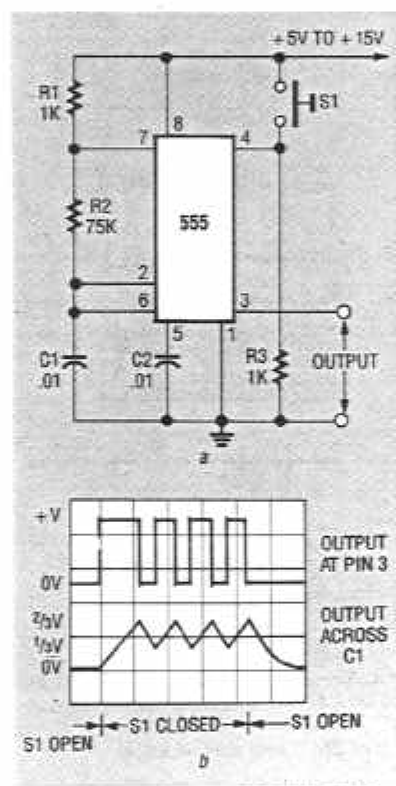

FIG. 11—GATED 1-kHz OSCILLATOR offering "press-to-turn-on" operation, *a*, CFHB and waveforms at output of pin 3 and across C1, *b*.

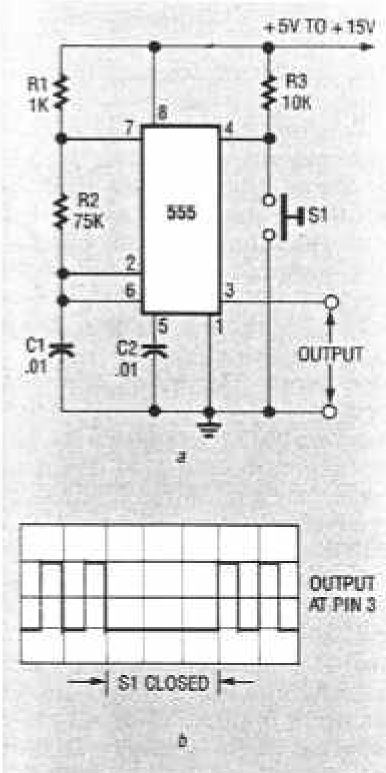

FIG. 12—GATED 1-kHz OSCILLATOR offering "press-to-turn-off" operation, *a*, and waveforms at output of pin 3 and across C1, *b*.

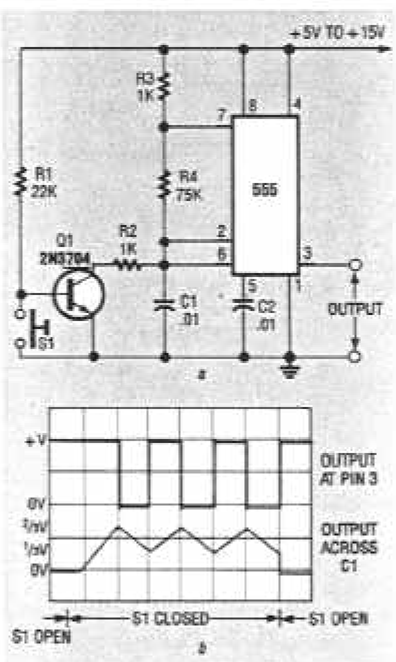

FIG. 13—ALTERNATIVE GATED 1-kHz OSCILLATOR offering "press-to-turn-on" operation, *a*, and waveforms at output of pin 3 and across C1, *b*.

R2. Both circuits oscillate at about 1.2 kHz with the value of C1 shown.

Precision astable circuit

In the description of astable multivibrator operation given earlier in this article, it was stated that in the first half cycle of oscillation timing capacitor C1 charges from zero volts to two-thirds of the supply voltage, but in all subsequent half-cycles it either discharges from two-thirds to one-third of the supply voltage or charges from one-third to two-thirds of that voltage. Consequently, the first half cycle of oscillation has a far longer period than all subsequent half cycles.

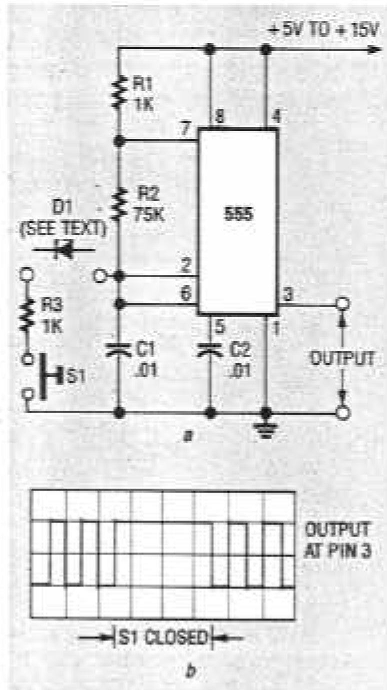

FIG. 14—ALTERNATIVE GATED 1-kHz OSCILLATOR offering "press-to-turn-off" operation, 1a and waveforms at output of pin 3, *b*.

In applications calling for a low-frequency clock signal, this large differential in period can cause a timing problem. However, this problem can be averted by adding an external voltage divider and diode as shown in Fig. 10. Those components bias C1 to a point slightly below one-third of the supply voltage (rather than zero volts) at the moment of switch-on. Here, R1 rapidly charges C1 to one-third of the supply voltage through D1 at switch-on, and all of the C1 charge is subsequently controlled by R3 and/or R4 only.

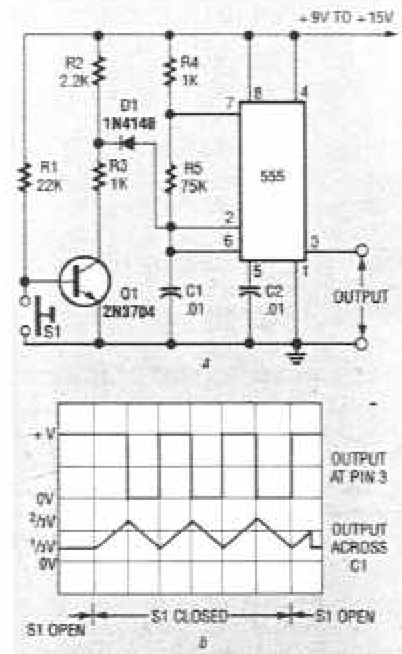

FIG. 15—PRECISION VERSION OF THE OSCILLATOR in Fig. 13, *a*, and waveforms at output of pin 3 and across C1, *b*.

Astable gating

The 555 in the astable multivibrator mode can be triggered ON and OFF in many different ways with either an electromechanical switch or an electronic signal. The most popular way to trigger the 555 is through RESET pin 4. Figures 11-a and 12-a show alternative ways of triggering the 555 with this pin and pushbutton switch S1.

The 555 is organized so that if pin 4 is biased above about 0.7 volts, the astable mode is enabled. But if it is biased below 0.7 volts by a current greater than 0.1 milliampere (by grounding pin 4 with a resistance less than 7 kilohms, for example) the astable mode is disabled, and the 555's output is biased low.

For example, the circuit in Fig. 11-a is normally turned off by R3, but it can be turned on by closing pushbutton switch S1, which biases pin 4 high. Figure 12-a shows an astable circuit that is normally on, but it can be turned off by closing pushbutton switch S1, which shorts pin 4 to ground. The circuits in Figs. 11 and 12 can also be triggered by applying suitable electronic signals directly to their

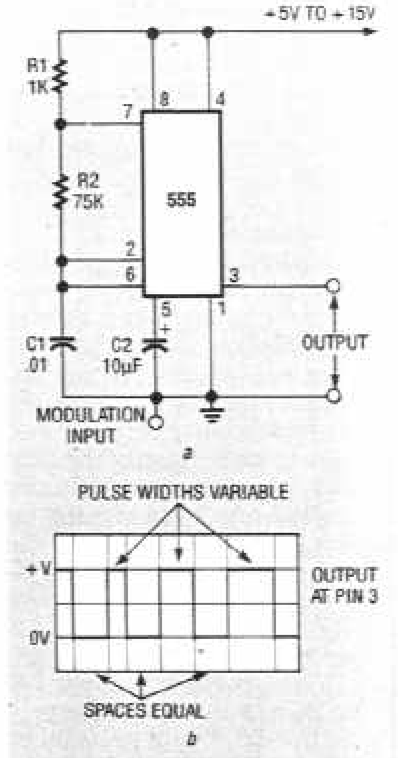

FIG. 16—CIRCUIT FOR APPLYING AC-COUPLED FM or PPM to a 555 configured as an oscillator, a, and waveforms at output of pin 3, b.

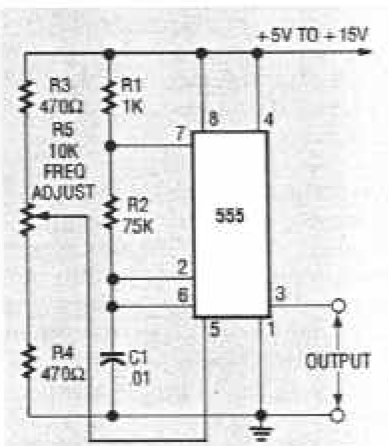

FIG: 17—CIRCUIT FOR APPLYING A DC-COUPLED FM or PPM to a 555 configured as an oscillator.

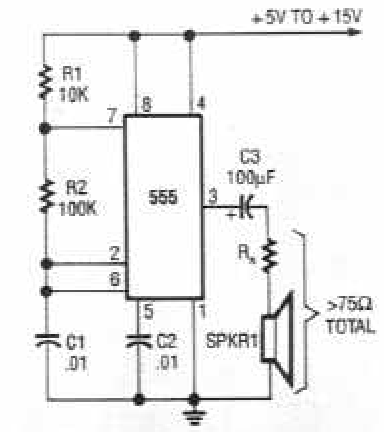

FIG. 18—CIRCUIT GENERATES 800-Hz MONOTONE ALARM that operates from 750-milliwatts.

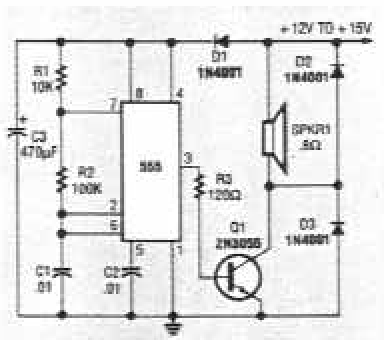

FIG. 19—CIRCUIT GENERATES 800-Hz MONOSTABLE ALARM.

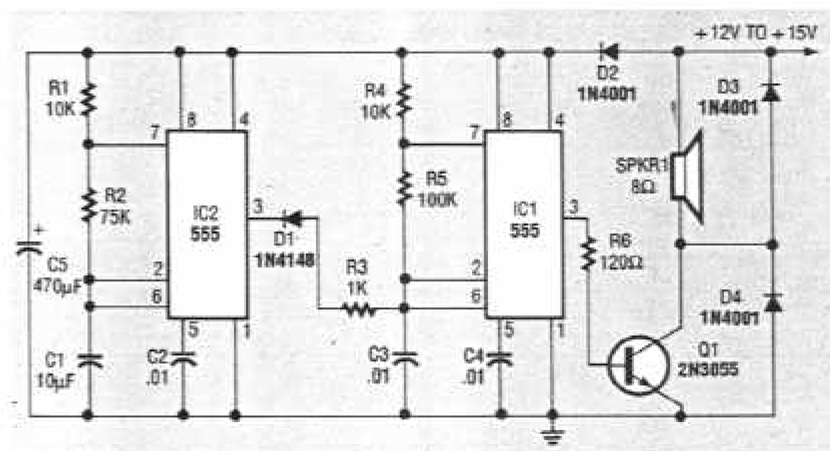

FIG. 20—CIRCUIT GENERATES 800-Hz PULSED-TONE ALARM.

RESET pins.

In Fig. 11-b, the precise circuit waveforms at OUTPUT pin 3 and across C1 are shown. It can be seen that the duration of the first half-cycle of oscillation is considerably longer than the succeeding half cycles because of the time for C1 to charge to two-thirds of the supply voltage. Also, note that when the astable mode is turned off, the C1 voltage decays slowly to zero; the output at OUTPUT pin 3 is zero volts in the OFF condition. The waveform characteristics of Fig. 12-a are similar as shown in Fig. 12-b.

Figure 13-a shows an alternative method for triggering the 555 in the astable mode. Here transistor Q1 is normally biased ON by R1, so it acts like a closed switch, which pulls the junction of C1 and R4 close to zero volts through R2 preventing oscillation. When pushbutton switch S1 is closed, Q1 is biased off, and the astable circuit is free to oscillate normally.

Refer to Fig. 13-b for the waveforms of the circuit in Fig. 13-a. When the astable response is triggered on, the first half cycle is again considerably longer than in succeeding half cycles, and that the voltage on C1 decays rapidly to nearly zero volts when the trigger is off. Also notice that OUTPUT pin 3 is high in the OFF state.

Figure 14 shows how the circuit in Fig. 13-a can be modified to give *press-to-turn-off* oscillation simply by replacing Q1 with a pushbutton switch. A digital signal can trigger this circuit if a diode is connected as shown in the diagram and the pushbutton S1 is deleted. With S1 removed, the circuit will be turned off when the input signal voltage is reduced below one-third of the supply voltage. The waveform is shown in Fig. 14-b.

Finally, to complete this look at triggering techniques, Fig. 15-a shows how the Fig. 13-a circuit can be modified so that the duration of its first half-cycle is almost equal to that of all succeeding half-cycles, thus giving precision operation. In the Fig. 15-a circuit, when pushbutton switch S1 is open, Q1 is saturated, so the voltage divider made up of R2 and R3 pulls the junction of R5 and C1 to slightly below one-third of the supply

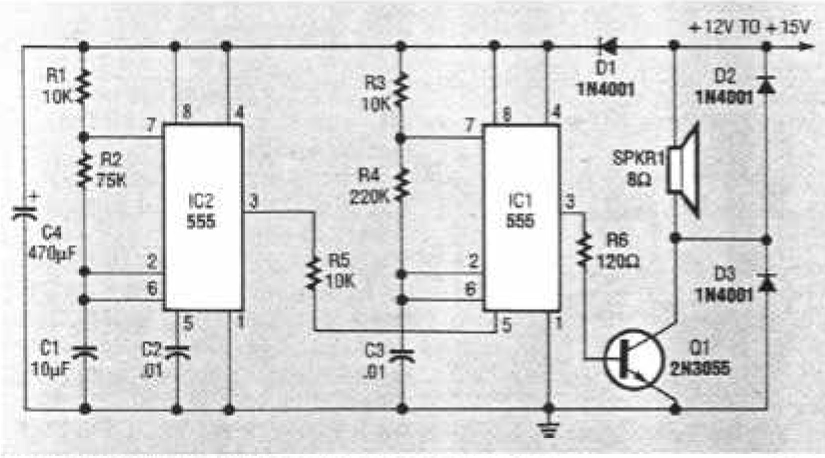

FIG. 21—CIRCUIT GENERATES WARBLE ALARM of European emergency vehicles.

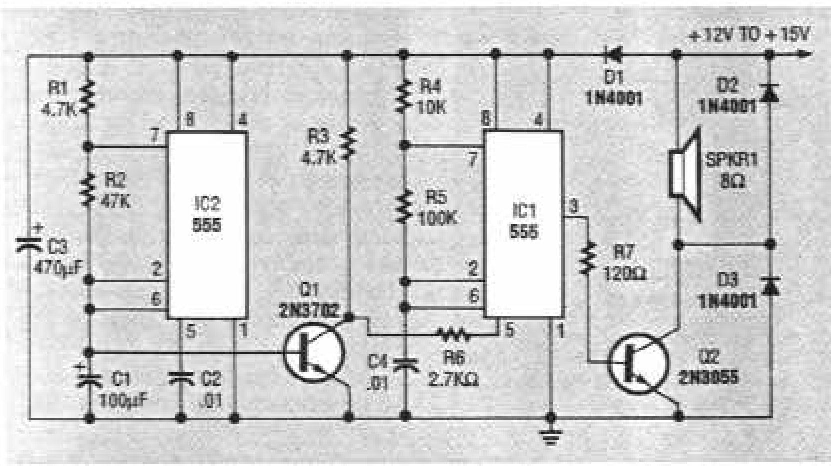

FIG. 22—CIRCUIT GENERATES SIREN WAIL of police cars.

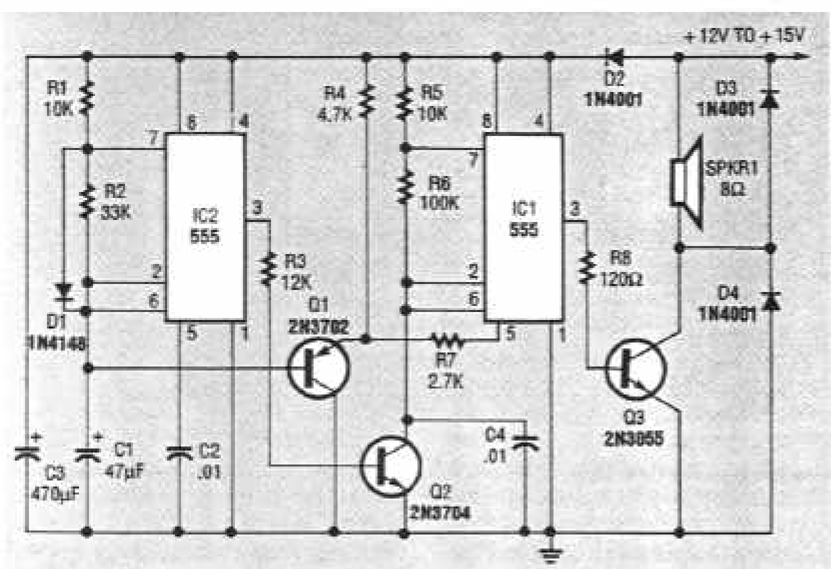

FIG. 23.—CIRCUIT GENERATES PENETRATING ALARM of Star Trek spaceship.

voltage through diode D1, thus turning the circuit off. When S1 is closed, Q1 turns off. D1 is reverse biased through R2, and the circuit is then free to oscillate normally.

Notice in Fig. 15-b that when S1 is first closed, C1 starts to charge from an initial value of almost a third of the supply voltage rather than from zero volts. Therefore, the duration of the initial half cycle is similar to that of all the succeeding half cycles.

Modulation techniques

All of the 555 astable circuits reviewed so far can be frequency or pulse-position modulated (FM or PPM) by feeding a suitable modulation signal to CONTROL VOLTAGE pin 5, which is connected to part of the internal voltage divider chain of the 555. The AC modulation signal is fed to pin 5 through a blocking capacitor, as in Fig. 16-a, or the DC modulation signal can be fed directly to pin 5, as shown in Fig. 17.

The voltage on pin 5 of the Fig. 15-a circuit alters the width of the pulses in each timing cycle of the 555, but it has almost no effect on the space duration. The signal at pin 5 changes the PPM pulse width position, affecting the total cycle period so it also influences the output frequency, as shown in Fig. 16-b. In so doing, pin 3 provides a frequency-modulated signal. Those characteristics of the 555 are useful for generating special waveforms.

Alarms and sirens

Some of the most popular applications for the 555 organized as an astable multivibrator are as waveform generators for loudspeakers. They can produce alarm and siren sounds. Figures 18 to 23 show different ways to create those sounds. All of the circuits in those figures are triggered by making or breaking their supply-voltage connections.

Figure 18 shows an 800-Hz monotone alarm-call generator circuit, which can be powered by any 5- to 15-volt DC supply. The speaker SPKR1 can have any impedance value. Note, however, that R_X must be wired in series with any speaker whose total impedances is less than 75 ohms. Select a resistor to give a total series resistance with the speaker of 75 ohms.

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VERSATILE OSCILLATOR

continued from page 74

That resistance value will keep the peak speaker currents within the 200-milliampere output limit of the 555. The output power of this alarm circuit depends on speaker impedance and supply voltage, but it can be as high as 750 milliwatts with a 75-ohm speaker and a 15-volt supply. Notice that C3 ia an electrolytic capacitor.

Figure 19 shows how the output power of the circuit in Fig. 18 can be boosted to several watts with buffer transistor Q1. The resulting high speaker output current can introduce a significant ripple voltage to the power source. Diode D1 and electrolytic capacitor C3 protect the 555 from the effects of that ripple. Diodes D2 and D3 clamp the inductive switching spikes from the speaker and protect Q1 against damage. The circuits in Figs. 20 to 23 have a similar output stages.

Figure 20 shows how a pair of 555's organized as astable multivibrators form an 800-Hz pulsed-tone alarm generator. In this circuit IC1 is wired as a 500-Hz alarm generator, and IC2 is wired as a 1-Hz oscillator that triggers IC1 on and off through diode D1 once per second, thus generating the pulse-tone alarm.

The circuit in Fig. 21 generates the penetrating two-tone "he-haw" sound of European emergency vehicles. Here, IC1 is also wired as an alarm generator, and IC2 is wired as a 1-Hz oscillator. But in this case the output of IC2 frequency modulates IC1 through resistor R5. The output frequency of IC1 alternates symmetrically between 500 Hz and 440 Hz in one-second alternating cycles.

Figure 22 shows a circuit that generates the wailing noise of a police siren. Here IC2 is wired as a low-frequency oscillator with a cycle period of about 6 seconds. The slowly varying *ramp* waveform of IC2, buffered by emitter follower transistor Q1, frequency modulates alarm generator IC1 through resistor R6. In this circuit IC1 has a natural center frequency of about 500 Hz. The alarm output signal starts at a low frequency, rises for three seconds to a high frequency, then decays over a period of three seconds to a low-frequency before repeating itself as long as power is applied.

Finally, the circuit in Fig. 23 generates an alarm that simulates the "Red Alert" that is often heard in the Star Trek TV series. The sound starts at a low frequency and rises to a high frequency in about 1.15 seconds, ceases for about 0.35 seconds, and then starts rising again from a low frequency. Here again, the sound pattern repeats as long as power is applied to the circuit.

The 555 labeled IC2 is wired as a non-symmetrical oscillator. Capacitor C1 alternately charges through R1 and diode D1, and discharges through R2. The result is a rapidly rising and slowly falling "sawtooth" waveform across C1. After buffering by Q1, this waveform frequency modulates pin 5 of IC1 through R7, causing the output frequency of IC1 to rise slowly during the decay part of the sawtooth waveform and to collapse rapidly during the rising part of the sawtooth waveform.

The rectangular waveform at pin 3 of IC2 turns IC1 off through common-emitter amplifier Q2 during the decay phase of the alarm. Therefore, only the rising parts of the sound pattern are heard which sound very much like the Star Trek Red Alert.

The outputs of most of the circuits in this article have been taken from *output* pin 3, but many of the figures haven shown triangular waveforms developed across the timing capacitor (e.g. Figs. 3b, 11b, 13b and 15b). There might be occasions when you will find those sawtooth (or ramp) waves useful. You can obtain a sawtooth by tapping the charge voltage across the timing capacitor. By charging the capacitor with a constant-current source instead of a simple resistance, the ramp can be made quite linear. R-E

RAY M. MARSTON

555 OSCILLATORS

Put the 555 time to work as a Schmitt trigger or as the heart of light and temperature alarms and drivers, a metronome, and a continuity checker.

TWO PREVIOUS ARTICLES (September, page 58 and October page 69) explained the operation of the popular and versatile industry-standard 555 timer IC as a monostable and astable multivibrator. They gave examples of its use in accurate time delay or oscillator circuits.

This third article starts by discussing the 555 as the key component in a Schmitt trigger circuit. It goes on to explain the role of the 555 in various astable multivibrator or oscillator circuits with many practical applications. Those circuits include light- and dark- as well as hot- and cold-actuated alarms. Other circuits are a code practice oscillator, a door buzzer, a continuity tester, a signal generator, and a metronome. Various light-actuator and relay-driver circuits are included.

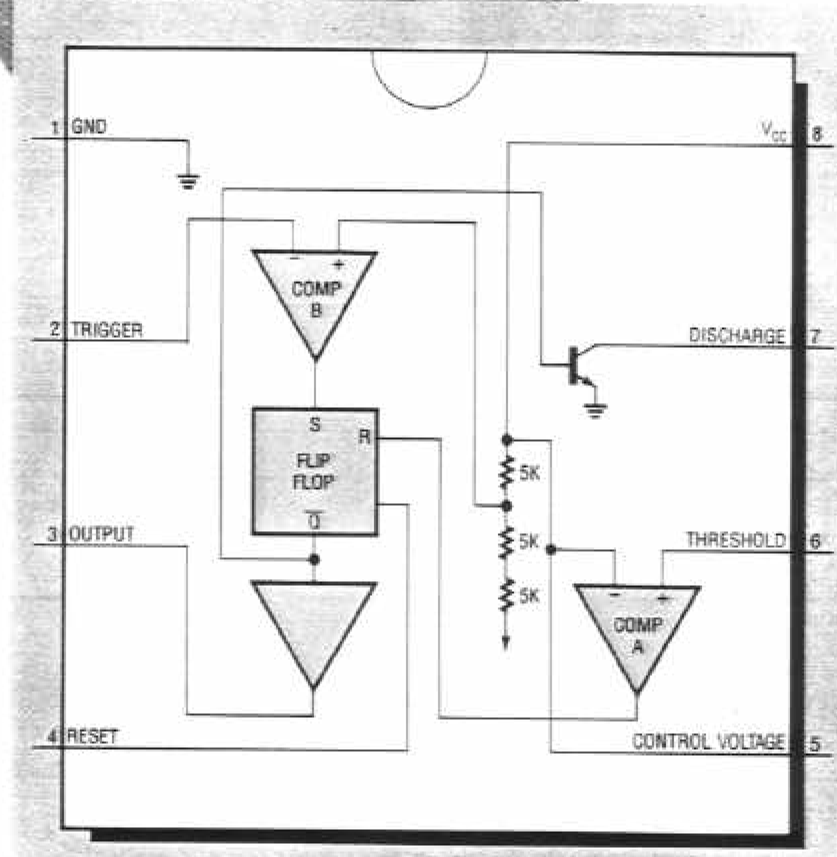

FIG. 1—PINOUT AND FUNCTIONAL BLOCK diagram of the 555 timer IC.

Schmitt trigger

Figure 1 is the pinout and functional block diagram for the 555 timer IC. In previous articles it was pointed out that for a 555 in the time-delay operation mode, timing can be precisely controlled by one external resistor and one capacitor. For astable operation as an oscillator, the free-running frequency and duty cycle can be accurately controlled with two external resistors and a single capacitor.

It is worth recalling that the 555 can be triggered and reset on falling waveforms, and the output circuit can source or sink up to 200 milliamperes, or drive TTL circuits. The 555's features include normally on and normally off outputs.

Figure 2-a illustrates the 555 IC as the active component in a Schmitt trigger circuit. Notice that the 555's TRIGGER pin 2 and THRESHOLD pin 6 are connected to form an input terminal. External input signals are applied directly at that point. The OUTPUT pin 3 becomes the output terminal.

Internal comparators A and B (see Fig. 1) are biased with an on-chip voltage divider. That divider biases comparator A at two-thirds of the supply voltage, and the non-inverting terminal of comparator B at one-third of the supply voltage. Comparator A drives the R input and comparator B drives the S input of the on-chip R-S flip-flop.

When the input voltage of the circuit in Fig. 2-a rises above two-thirds of the supply voltage, the 555 output switches to its low state. It remains there until the input voltage falls below one-third of the supply voltage. Then the output switches high and remains high until the input rises above the two-thirds supply level again.

The difference between those two trigger levels is called the *hysteresis* value. It is one-third of the supply in Fig. 2-a. That large hysteresis makes the circuit useful in signal conditioning where noise and ripple must be rejected, as shown in Fig. 2-b.

Figure 3 shows how the cir-

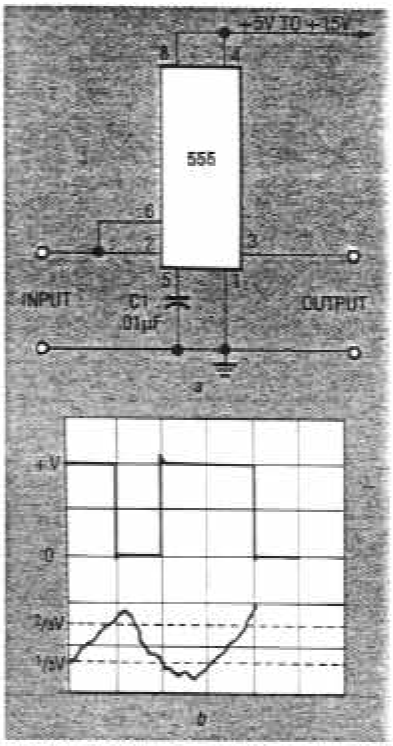

FIG. 2—A SCHMITT TRIGGER CIRCUIT formed with a 555 timer IC.

cuit in Fig. 2-a can be modified into a high-performance sine- to square-wave converter useful at input frequencies up to about 150 kHz. The voltage divider formed by R1 and R2 biases the input terminal (pins 2 and 6) of the 555 at its quiescent value of one-half the supply voltage (i.e., midway between the upper and lower trigger values).

The sine-wave input signal is superimposed on this point with capacitor C1. Square-wave output signals are taken from pin 3 of the IC. Resistor R3 is wired in series with the input terminal to ensure that the sine-wave signal is not distorted when the 555 switches.

Figure 4 shows how the Schmitt trigger circuit can be made into a dark-activated relay actuator by wiring the light-dependent voltage divider consisting of potentiomenter R1 and photocell R2 to the input terminal of the IC. The potentiometer and photocell resistance values are nearly equal at the middle of the light-activation range.

The inherently high input backlash or hysteresis of the Schmitt trigger limits the usefulness of this circuit to very specialized light-sensing applications. A more useful relay-driving, dark-activated switching circuit is shown in Fig. 5. It acts as a fast comparator rather than a true Schmitt trigger. The THRESHOLD pin 6 to internal comparator A of the 555 is tied permanently high by resistor R3, while the output of the light-sensing potentiometer R1 and photocell R2 voltage divider is applied to TRIGGER pin 2 of comparator B.

The photoresistive element for this circuit can be any cadmium-sulfide photocell whose resistance is between 470 ohms and 10 kilohms at the desired turn-on light level. The circuit in Fig. 5 can also function as a light- (rather than dark-) activated switch by exchanging the positions of the potentiometer and photocell, as shown in Fig. 6-a.

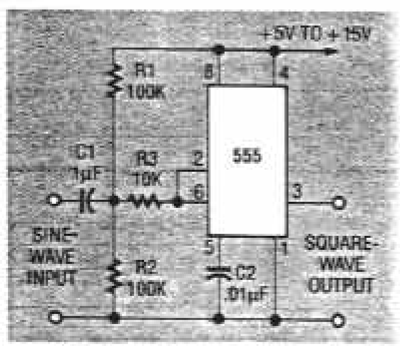

FIG. 3—A SCHMITT TRIGGER SINE- AND SQUARE- wave generator formed with a 555 IC.

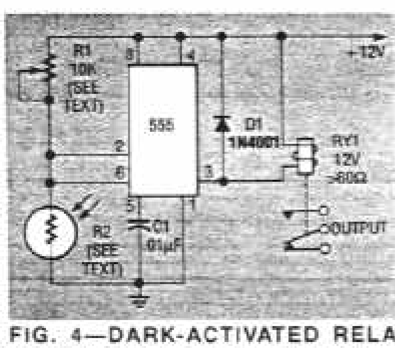

FIG. 4—DARK-ACTIVATED RELAY SWITCH BASED on the 555 has a lot of hysteresis.

The circuit can also function as a temperature-activated switch by substituting a thermistor with a negative temperature coefficient for the photocell, as shown in Figs. 6-b and 6-c. (A thermistor with a negative temperature coefficient decreases in resistance as temperature increases.) The thermistor for this application must have a resistance value between 470 ohms and 10 kilohms at the desired turn-on temperature. Thermistors are typically packaged as radial-leaded disks, and their resistance values are specified at 25° C.

Stable of oscillators

The 555 in the astable multivibrator or oscillator mode has three outstanding advantages over other kinds of oscillators:

- Excellent frequency stability with variations in supply voltage and temperature.
- Frequency variable over a wide range with a single potentiometer control.
- Low impedance output that can source or sink currents up to 200 milliamperes.

Figure 7 shows the 555 as the semiconductor IC in a Morse-code practice oscillator. The circuit is an oscillator with its frequency variable from 300 Hz to 3 kHz by adjusting tone control potentiometer R3. The sound volume of headphone Z1 can be varied with potentiometer R4, and the headphones can have any DC resistance from a few ohms up to a few megohms. The oscillator circuit draws no quiescent current until the normally-open Morse key connects the circuit to the 5- to 15-volt supply.

Figure 8 shows the 555 as the semiconductor device in a simple electronically actuated door buzzer. Pushbutton switch S1 connects the 555 to the 9-volt battery, and the output of the IC is coupled to speaker SPKR1 through capacitor C4. Capacitor C1 produces a low supply-line impedance, ensuring ade-

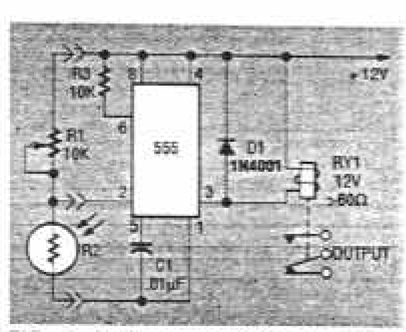

FIG. 5—MINIMUM-BACKLASH, DARK-ACTIVATED relay based on the 555.

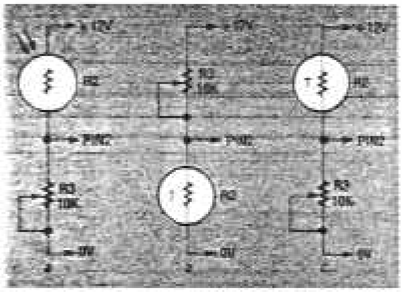

FIG. 6—ALTERNATIVE SENSOR CIRCUITS for Fig. 5 provide actuation by light (a), under-temperature (b), and over-temperature(c).

quate output drive current to the speaker when S1 is closed. The circuit generates a monotone buzzing sound set by potentiometer R2.

Figure 9 shows the 555 as the semiconductor component in a continuity tester that generates an audible tone only if the resistance between the test probes is less than a few ohms. The circuit's operation depends on an output tone that sounds only if the RESET (pin 4) is biased positive to about 600 millivolts or greater by sensitivity potentiometer R5. Pin 4 is normally pulled to ground by resistor R2, so no tone is heard.

For the buzzer in the circuit of Fig. 9 to sound, the two probe tips must touch, connecting R2 to the output of the reference generator formed by resistor R3 and Zener diode D1 through sensitivity potentiometer R5. Potentiometer R5 must be carefully adjusted so that a buzzing sound is barely audible. Consequently, if the resistance between the probe tips exceeds a few ohms when a continuity test is being made, the buzzing tone will not be heard. The circuit draws several milliamperes whenever S1 is closed, even if the probe tips are not touching.

Figure 10 shows the 555 functioning as a signal generator for testing both audio and radio-frequency circuits. The circuit oscillates at a frequency of a few hundred hertz when S1 is closed. Its square-wave output is very rich in harmonics, and those can be detected at frequencies up to tens of megahertz with a radio receiver. The signal level can be varied by adjusting potentiometer R3.

In Fig 11 the 555 is the active component of a metronome with a beat rate variable from 30 to 120 beats per minute. The beat rate can be set by adjusting potentiometer R3, and the beat level can be set by adjusting potentiometer R4. This circuit is a modified version of the stan-

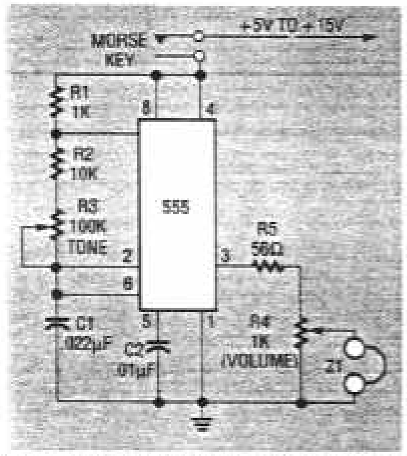

FIG. 7—CODE-PRACTICE OSCILLATOR with variable tone and volume.

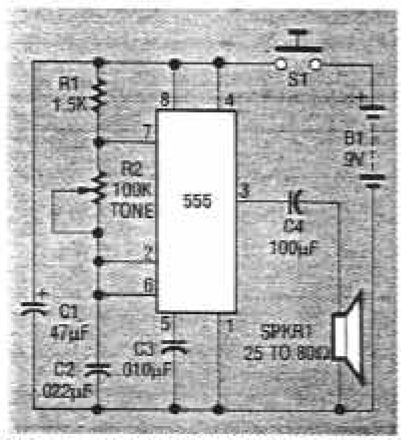

FIG. 8—ELECTRONIC DOOR BUZZER based on the 555.

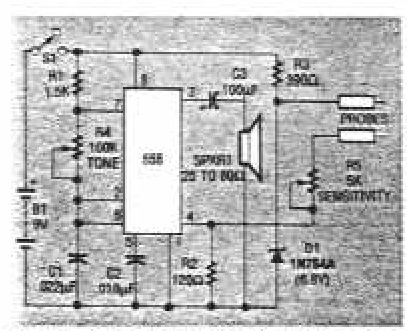

FIG. 9—CONTINUITY TESTER based on the 555.

dard astable multivibrator in which the main timing network is driven from OUTPUT pin 3 of the IC.

When the output switches high, C1 charges rapidly through diode D1 and resistor R1 in series to generate a beat pulse only a few milliseconds long. When the output switches low again, C1 discharges through potentiometer R3 and resistor R2 in series to provide an *off* period of up to two seconds (30 beats per minute). The output pulses are fed to speaker SPKR1 through level-control potentiometer R4 and buffer transistor Q1.

LED flashers and alarms.

Figures 12 to 14 show the 555 in LED flasher applications in which the LED's have equal *on* and *off* switching times. With the component values shown, each circuit flashes at a rate of about one flash per second.

The circuit in Fig 12 has a single-ended output. Either a single LED (or LED's in series) can be connected between the OUTPUT pin3 and GROUND pin 1 of the 555, and all LED's turn on and off together. Resistor R3 sets the *on* current of the LED's.

The circuit in Fig. 13 is similar to that of Fig. 12, but it has a double-ended output connection. The LED's above pin 3 are

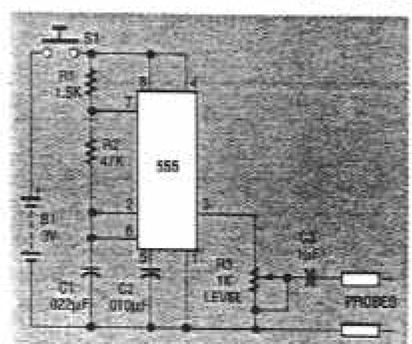

FIG. 10—SIGNAL GENERATOR based on the 555

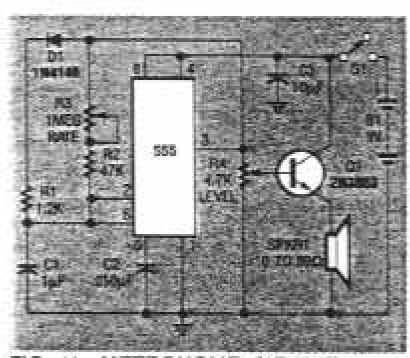

FIG. 11—METRONOME CIRCUIT based on the 555.

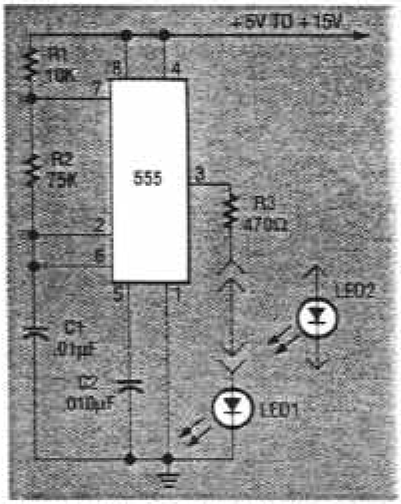

FIG. 12—LED FLASHER WITH SINGLE-ENDED output.

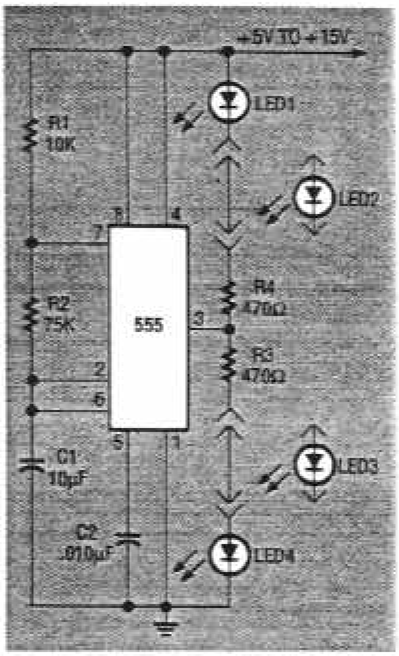

FIG. 13—LED FLASHER WITH DOUBLE-ENDED output.

on when the LED's below pin 3 are off, and vice versa. Resistor R3 sets the *on* currents of the lower LED's, and resistor R4 sets the *on* currents of the upper LED's.

Figure 14 shows how to modify the circuit in Fig. 12 for automatic dark-actuation. Resistors R3 and R4, photocell R1, and potentiometer R2 form a light-sensitive Wheatstone bridge that triggers the 555 through bridge balance-detector Q1 and the RESET pin 4 of the IC.

The oscillator is normally disabled by resistor R6, which pulls RESET pin 4 close to zero volts. The circuit oscillates only when pin 4 is pulled to a positive voltage greater than 600 millivolts. That can be achieved only by turning on Q1.

As one arm of the Wheatstone bridge, resistors R4 and R5 apply a fixed half-supply voltage to the emitter of Q1. The photocell and potentiometer form the other arm that applies a light-dependent voltage to the base of transistor Q1.

Under bright light, the photocell offers low resistance. As a result, the base-emitter junction of Q1 is reverse biased, and the circuit does not oscillate. By contrast, under dark conditions, the photocell resistance is high, so Q1 and the oscillator are biased on. Normally, potentiometer R2 is adjusted so the 555 is triggered at the desired dark level. The photocell should have a resistance between 470 ohms and 10 kilohms under this condition.

The precision gating method described can trigger a variety of 555 oscillator circuits to form useful audible alarms and relay drivers. By interchanging the photocell with the potentiometer, or replacing the photocell with a thermistor having a negative temperature coefficient, those circuits can be triggered by increases or decreases beyond preset values in either light or temperature. Figures 15 to 17 illustrate practical examples of such circuits.

Figure 15 shows an automatic heat- or light-actuated relay driver. The circuit works with any 12-volt relay having a coil resistance greater than about 60 ohms. When actuated, the circuit triggers the relay RY1 on and off about once per second.

A heat-or light-activated monotone alarm is shown in Fig. 16. When triggered, this circuit

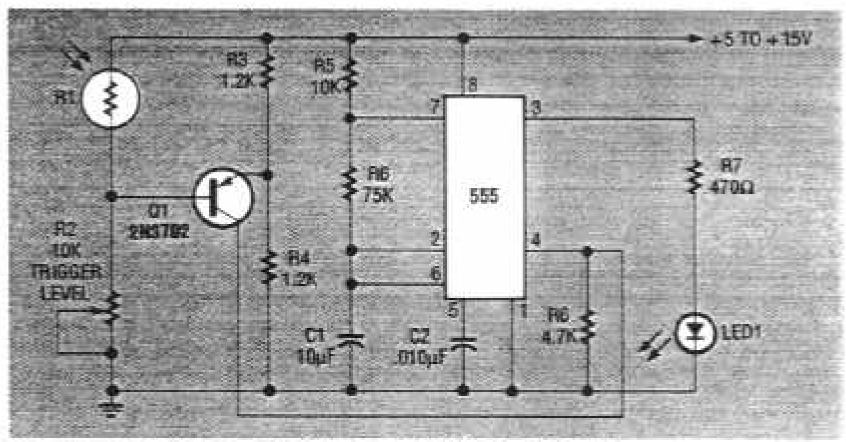

FIG. 14—AUTOMATIC (DARK-ACTUATED) LED FLASHER.

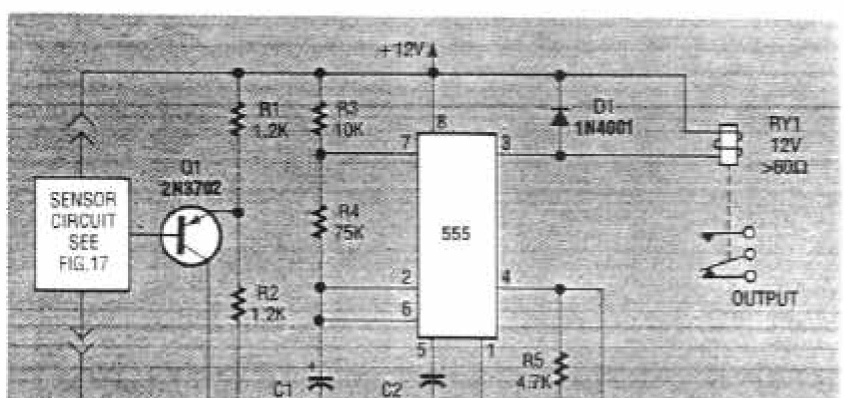

FIG. 15—HEAT- OR LIGHT-ACTUATED relay pulser

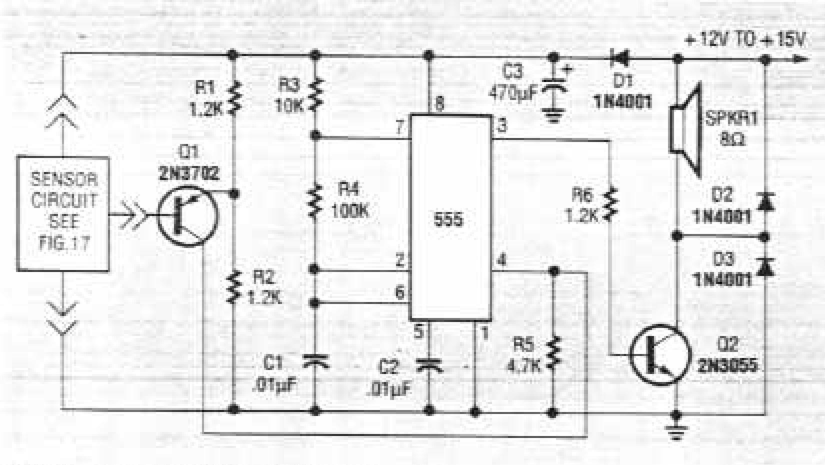

FIG. 16—HEAT- OR LIGHT-ACTUATED medium-power 800-Hz alarm.

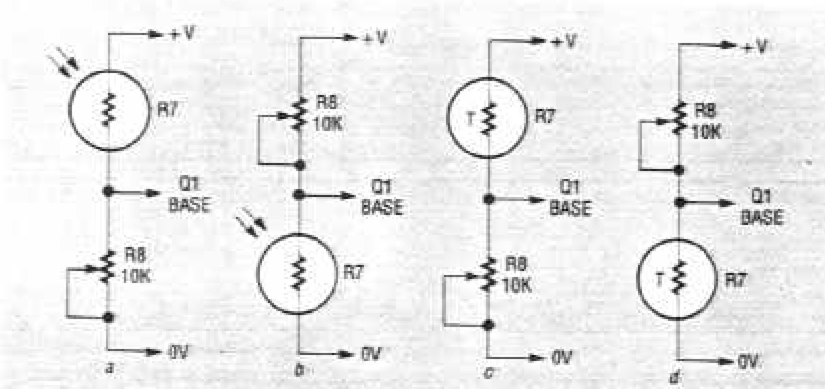

FIG. 17—ALTERNATIVE SENSOR CIRCUITS for Figs. 14 or 15 for actuation by darkness (a), light (b), under-temperature (c), or over-temperature (d).

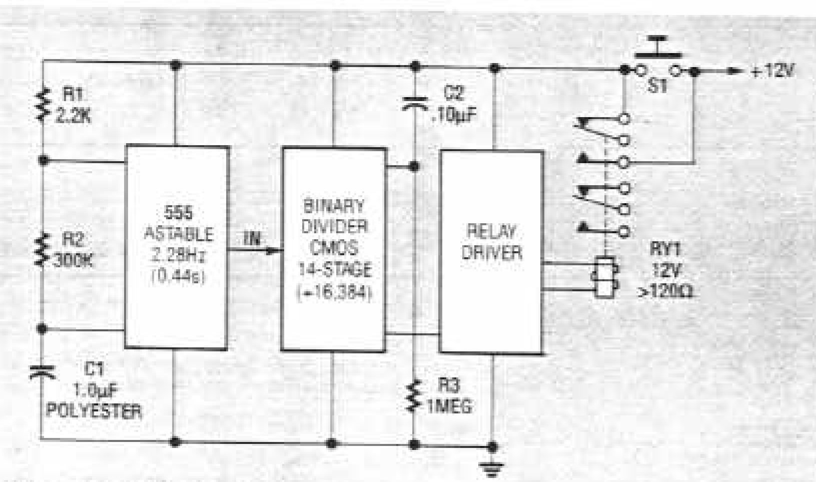

FIG. 18—A 60-MINUTE TIMER based on the 555.

generates a buzzing sound at about 800 Hz. Several watts of power are drawn from speaker SPKR1 through buffer transistor Q2. The resulting high speaker output current could transfer ripple voltage to the power supply so diode D1 and capacitor C3 protect the circuit from that interference. Diodes D2 and D3 clamp the inductive switching spikes of the speaker, protecting Q2 against damage.

Alternative sensor circuits that can automatically activate the circuits of either Figs. 15 or 16 are shown in Fig. 17. If light actuation is desired, the sensor should be a cadmium-sulfide photocell. If the circuit is to be triggered when light level *falls* to a preset value (dark actuation), the circuit of Fig 17-a should be used. If the circuit is to be triggered when the light intensity *rises* to a preset value (light actuation), the circuit of Fig 17-b should be used.

If you want temperature actuation, use a thermistor with a negative temperature coefficient as the sensor. For undertemperature operation, use the circuit of Fig. 17-c; for over-temperature operation, use the circuit of Fig. 17-d. Regardless of the kind of operation desired, the sensor element must have a resistance value between 470 ohms and 10 kilohms at the desired trigger level.

Long-period timers

A 555 can function as a superb manually-triggered relay-driving timer when it is connected in the monostable or pulse-generator mode. In practical applications, such a circuit will not generate accurate timing signals of more than a few minutes because they require an electrolytic capacitor with a high capacitance value. Electrolytic capacitors typically have wide tolerance values (−50 to +100%) and large and unpredictable leakage currents.

If the 555 is to be the active component in long-period timers, the external circuitry must include a capacitor other than an electrolytic. Figure 18 shows, as a block diagram, the principles behind a design for a 60-minute relay-driving timer. In this case, the 555 is organized in the astable mode. It has its output connected to the relay driver through a 14-stage binary divider IC. That configuration gives an overall division ratio of 16,384.

If the output of the 555 is set to zero at the start of an input count, the output will switch high upon receiving the 8192nd input pulse. The circuit will remain high until the 16,382nd pulse arrives. At that time, the output will switch low again, completing the normal operating sequence.

In Fig. 18, the timing sequence is initiated by closing S1, which connects the supply to the circuit, simultaneously

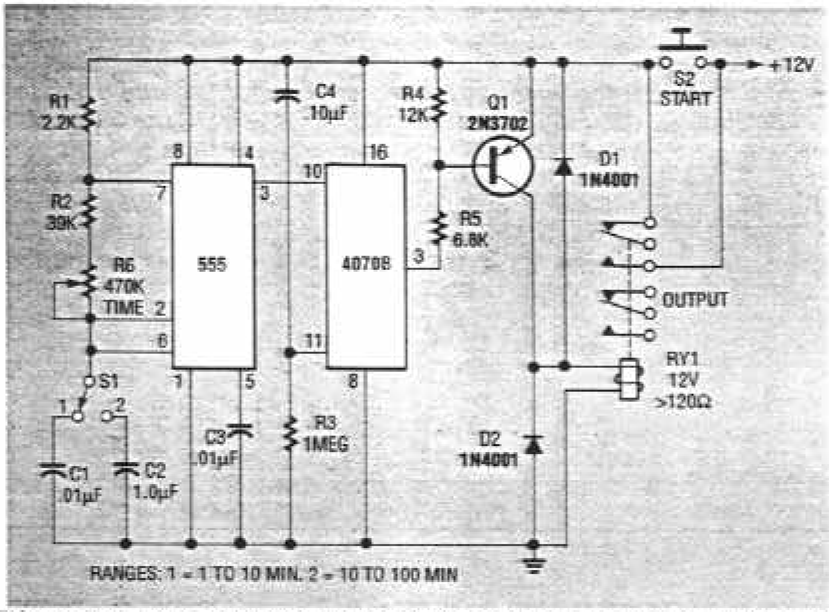

FIG. 19—TWO-RANGE RELAY OUTPUT TIMER providing 1 to 10 minute- and 10- to 100-minute intervals.

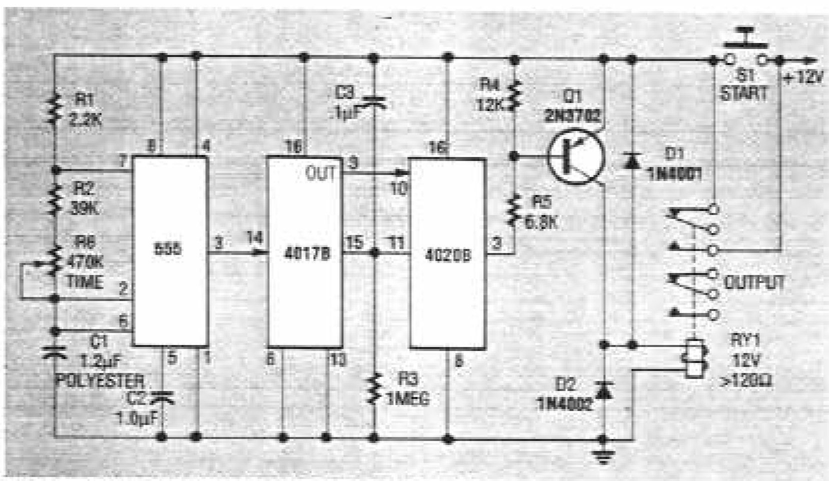

FIG. 20—EXTRA-LONG PERIOD RELAY OUTPUT TIMER provides 100-minute to 20-hour intervals.

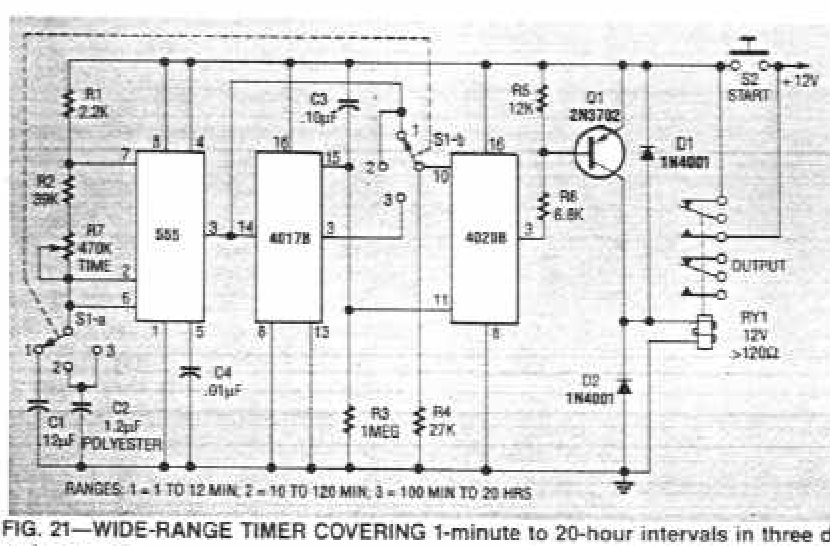

FIG. 21—WIDE-RANGE TIMER COVERING 1-minute to 20-hour intervals in three decade ranges.

triggering the oscillator and setting the counter to zero through capacitor C2 and resistor R3. That drives the counter output low and turns the relay on. The contacts of RY1 maintain the power supply connection once S1 is released.

This condition is maintained until the 8192nd oscillator pulse arrives at the input of the counter. Then the counter output switches high and turns the relay off. As the relay turns off, the contracts of RY1 open, disconnecting the supply from the circuit and completing the operating cycle.

In this circuit, the oscillator must operate with a cycling period that is 1/8192nd of the required timing period (0.44 second for this circuit). That can be achieved with a 1 microfarad polyester capacitor and a resistor of about 300 kilohms.

Figure 19 shows how the design in Fig. 18 is implemented to form a practical relay-output timer circuit useful for one to 100 minutes in two overlapping decade ranges. That circuit is powered from a 12-volt supply. The relay must have a coil resistance of 120 ohms or more.

Figure 20 illustrates how the time delay of the circuit in Fig. 19 can be extended by connecting an additional divider stage between the output of the 555 and the input of the relay-driving output state. In this circuit a divide-by-ten 4017B CMOS IC is connected between the output of the 555 and the 4020B 14-stage binary counter.

The arrangement in Fig. 20 gives an effective overall division ratio of 81,920, thus making delays from 100 minutes to 20 hours available from this single-range timer. Notice that both of the divider IC's are automatically reset by the series combination of capacitor C3 and resistor R3 when switch S1 is closed.

Figure 21 shows to modify the circuit in Fig. 20 to make a wide-range general-purpose timer that covers one minute to 20 hours in three decade-based ranges. The divide-by-ten stage is active only when switch S1-a is at position 3. R-E

Use the 555 to generate sawtooth waves, detect missing pulses, convert DC to AC, boost DC voltage and more.

THE VERSATILE 555

RAY M. MARSTON

THE POPULAR 555 TIMER IC HAS been the star of three previous **Electronics Now** articles (September 1992, page 58, October 1992, page 69 and November 1992, page 61.) Just when you thought that all possible applications for that versatile 555 had been exhausted—surprise! This article takes the 555 into new territory—a sawtooth generator, a "ramp" generator, a time-base generator, a frequency meter, and even a tachometer for your car.

But that's not all—there is a missing-pulse detector, and DC voltage doubler, tripler and quadrupler. There are also negative and high-voltage generators and a DC to AC inverter!

If you've been following the previous articles and (we hope) building some or all of the circuits presented in them, you'll be all set for the circuits presented here. Who said the microprocessor was the most versatile IC, anyway?

The last three articles on the 555 explained its basic operating principles. You would have learned (or refreshed your memory) about how to place external components so the timer functions either as a monostable or astable multivibrator. You might want to reread the introductory sections of those articles to brush up on the unusual features of the 555. A complete schematic of the circuitry contained in the 555 is given as Fig. 2 on page 64 of the September 1992 issue.

Figure 1 is another functional block diagram and pinout of the bipolar 555 with a different arrangement of functional blocks than the others given earlier, illustrating yet another manufacturer's preferred data book presentation. Neither diagrams nor data sheets on the 555 have been standardized.

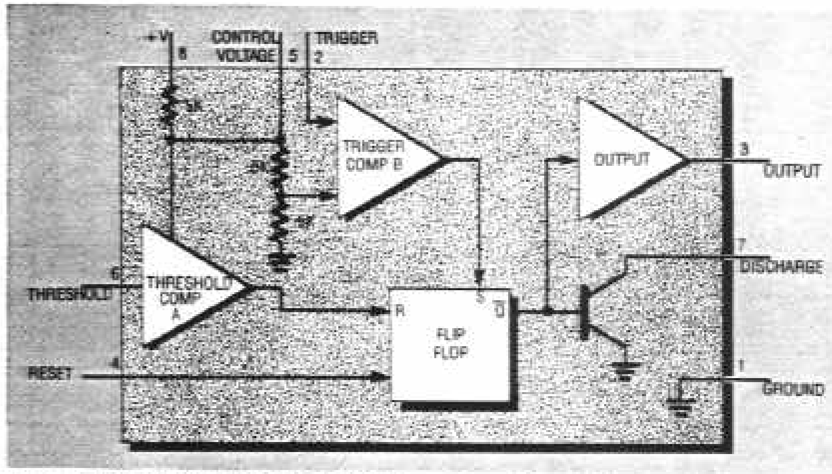

FIG. 1—FUNCTIONAL BLOCK DIAGRAM and pinout for the bipolar 555 timer IC.

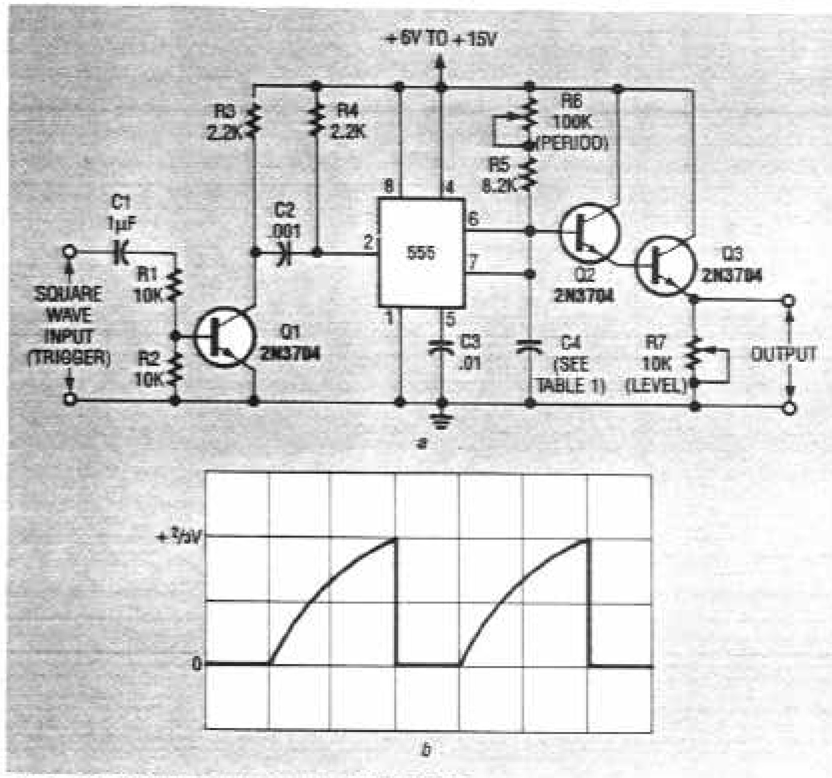

FIG. 2—TRIGGERED SAWTOOTH GENERATOR based on the 555, a, and typical output waveform, b.

Sawtooth-wave generators

The 555 with external components can become a triggered nonlinear (exponential) sawtooth waveform generator, as shown in the schematic Fig. 2-a. The circuit is a modified

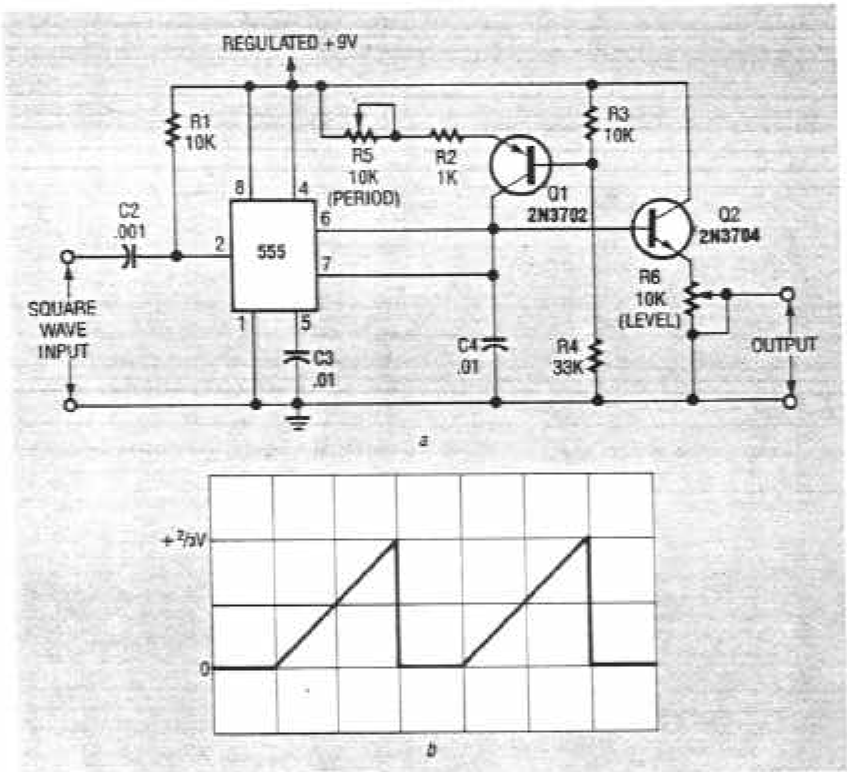

FIG. 3—LINEAR SAWTOOTH OR RAMP waveform generator based on the 555, a, and "ramp" waveform, b.

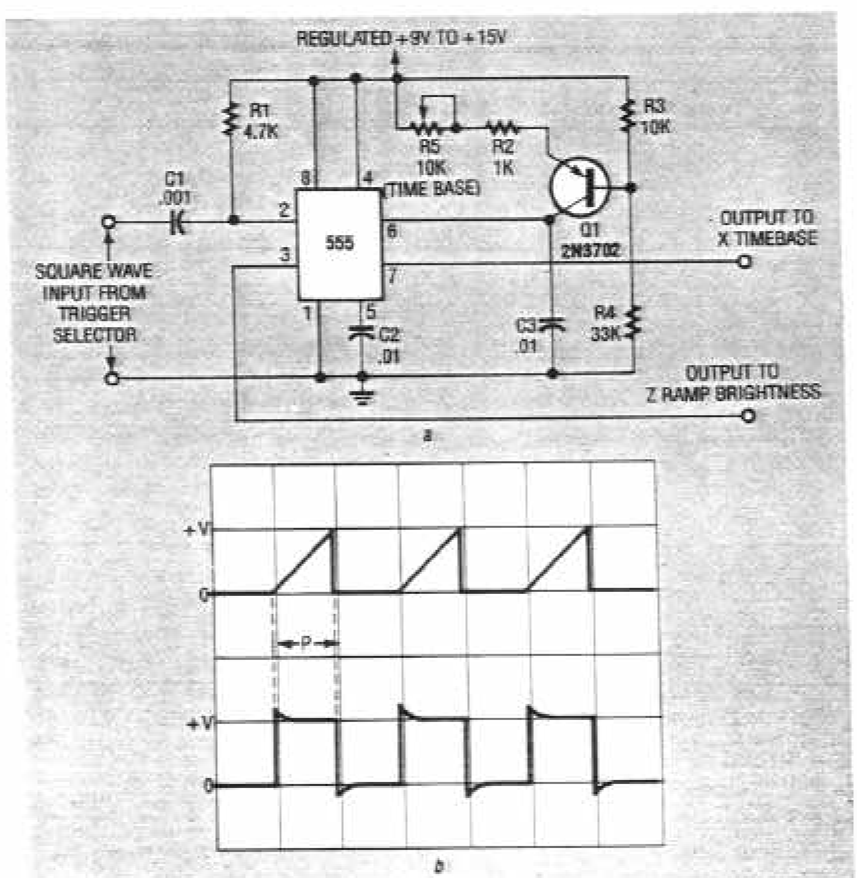

FIG. 4—OSCILLOSCOPE TIME-BASE GENERATOR circuit based on the 555, a, and ramp and ramp brightness pulse waveforms for an oscilloscope's X and Z axes.

monostable multivibrator that is triggered by an external square wave TRIGGER pin 2 obtained through capacitor C2 from the collector of transistor Q1. Note that OUTPUT pin 3 of the 555, used in most of the 555-based circuits presented earlier is unused here.

The voltage across C4 (the timing component) is normally zero, but whenever the circuit is triggered, C4 charges exponentially through resistor R5 and PERIOD potentiometer R6 to two-thirds of the supply voltage. At that time, the monostable period ends and the voltage across C4 drops abruptly to zero. The output sawtooth waveform (Fig. 2-b) is taken across capacitor C4 through buffer transistors Q2 and Q3 and LEVEL potentiometer R7.

The period of the sawtooth or width can be varied from 9 microseconds to 1.2 seconds with the capacitance values for C4 listed in Table 1. The circuit's maximum usable repetition frequency is approximately 100 kHz.

The generator must be triggered by rectangular input waveforms with short rise and fall times. Potentiometer R6 controls the sawtooth period over a decade, and potentiometer R7 controls the amplitude of the output waveform.

Figure 3-a shows a triggered linear sawtooth or *ramp* waveform generator. Capacitor C4 is charged by a constant-current generator that includes Q1. The output waveform (Fig. 3-b) is taken at the wiper of LEVEL potentiometer R6, which is coupled to the voltage across C4 through Q2. Note that the curved ramps of Fig. 2-b have been flattened.

When a capacitor is charged from a constant current source, its voltage rises at a predictable linear rate that can be expressed as:

Volts/second = amperes/farad

By introducing more practical values, alternative expressions for the rate of voltage rise are:

V/µs = A/µF, or

V/ms = mA/µF

Those formulas state that voltage rate-of-rise can be in-

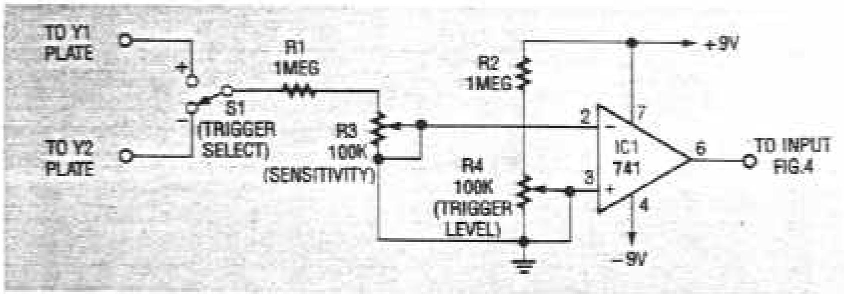

FIG. 5—TRIGGER SELECTION CIRCUIT for the Fig. 4 circuit

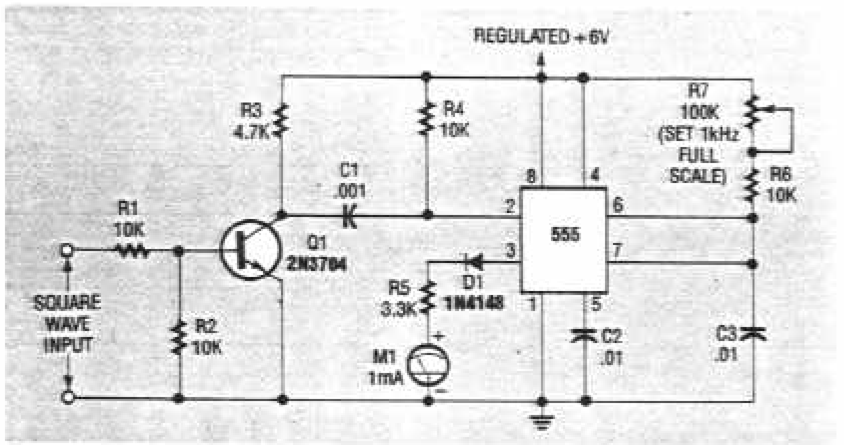

FIG. 6—A 1-kHz LINEAR-SCALE ANALOG FREQUENCY meter circuit based on the 555.

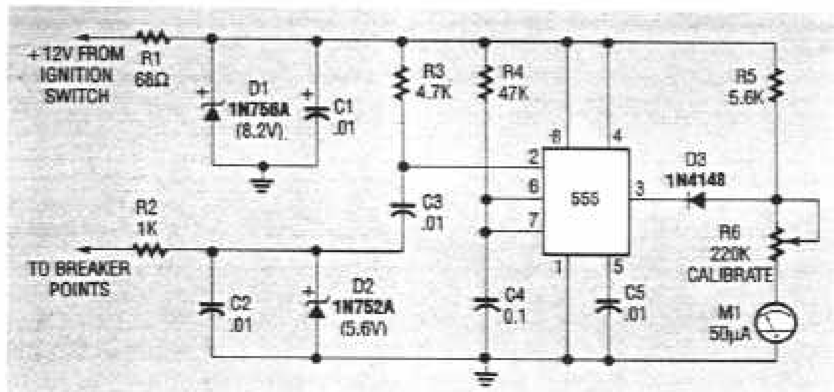

FIG. 7—VEHICULAR TACHOMETER CIRCUIT based on the 555.

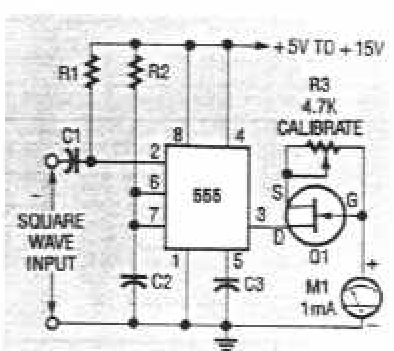

FIG. 8—ALTERNATIVE ANALOG TACHOMETER CIRCUIT to Fig. 6.

creased either by increasing the charging current or by decreasing the capacitance value.

The charging current in the Fig. 3-a circuit can be varied over the range of about 90 microamperes to 1 milliampere with PERIOD potentiometer R5, thus giving the 0.01 microfarad timing capacitor rates-of-rise of 9 volts per millisecond to 100 volts per millisecond.

Each one-shot or monostable cycle of the 555 ends when the voltage across C4 reaches two-thirds of the supply voltage. As shown in Fig. 3-a, the supply is 9 volts, so two-thirds of 9 volts is 6 volts, the amplitude of the ramp waveforms in Fig. 3-b. The sawtooth cycles of the circuit have periods variable from 666 microseconds (2/3 millisecond) to 60 microseconds (6/100 millisecond).

Periods can be increased beyond those values by increasing the value of C4, or reduced by reducing the value of C4. In this circuit, stable timing periods depend on a stable voltage source.

Fig. 4-a shows how the circuit in Fig. 3-a can be modified to become an oscilloscope timebase generator. It can be triggered by external square waves through a suitable trigger selector circuit. The *ramp* output waveform (top of Fig. 4-b is fed to the X plates of an oscilloscope with a suitable amplifier stage. The pulsed OUTPUT from pin 3 of the 555 (shown in the lower half of Fig. 4-b) is fed to the CRT's Z axis to trace the ramps with higher brightness.

The shortest useful ramp period that can be obtained from the circuit in Fig. 4-a (with a 0.001 microfarad capacitor C3) is about 5 microseconds. That value, when expanded to give full deflection on an oscilloscope with a ten-division graticule, yields a maximum timebase rate of 0.5 microsecond per division.

The timebase circuit of Fig. 4-a can synchronize signals at trigger frequencies up to about 150 KHz. At higher frequencies, the input signals must be divided by a single- or multi-decade frequency divider. With that approach, the timebase can be used to view input signals at megahertz frequencies.

Figure 5 illustrates a simple but versatile trigger selector circuit for the timebase generator in Fig. 4-a. Operational amplifier IC1 (a μA741) has a reference voltage fed to its non-inverting input pin 3 by TRIGGER LEVEL potentiometer R4. The signal voltage is then fed to IC1's inverting pin 2 through switch S1, resistor R1 and SENSITIVY potentiometer R3.

Switch S1 selects either in-phase or out-of-phase input signals from the Y-driving amplifier of the oscilloscope, permitting the selection of either the plus or minus trigger modes. The output of the circuit in Fig. 5 is coupled directly to the C1 input of Fig. 4.

Analog frequency meters

Figure 6 shows the 555 IC organized as a linear-scale analog frequency meter with a full-scale sensitivity of 1 kHz. The circuit's power is obtained from a regulated 6-volt supply, and its input signals can be pulses or square-wave signals with peak-to-peak amplitudes of 2 volts or greater. Transistor Q1 amplifies this input signal enough to trigger the 555. The output from pin 3 is fed to the 1-milliampere full-scale deflection moving-coil meter M1 through offset-canceling diode D1 and multiplier resistor R5.

Each time the monostable multivibrator is triggered, it generates a pulse with a fixed duration and amplitude. If each generated pulse has a peak amplitude of 6 volts and a period of 1 millisecond, and the multivibrator is triggered at an input frequency of 500 Hz, the pulse will be high (at 6 volts) for 500 milliseconds in each 1000 milliseconds. Moreover, the *mean* value of output voltage measured over this period is 500 milliseconds/1000 milliseconds × 6 volts = 3 volts or half of 6 volts.

Similarly, if the input frequency is 250 Hz, the pulse is high for 250 milliseconds in each 1000-millisecond period. Therefore, the mean output voltage equals 250 milliseconds/ 1000 milliseconds × 6 volts = 1.5 volts or one quarter of 6 volts. Thus, the circuit's mean value of output voltage, measured over a reasonable total number of pulses, is directly proportional to the repetition frequency of the monostable multivibrator.

Moving-coil meters give *mean* readings. In the circuit of Fig. 6 a 1-milliampere meter is connected in series with multiplier resistor R5, which sets meter's sensitivity at about 3.4 volts full-scale deflection. The meter is connected to give the mean output value of the multi-

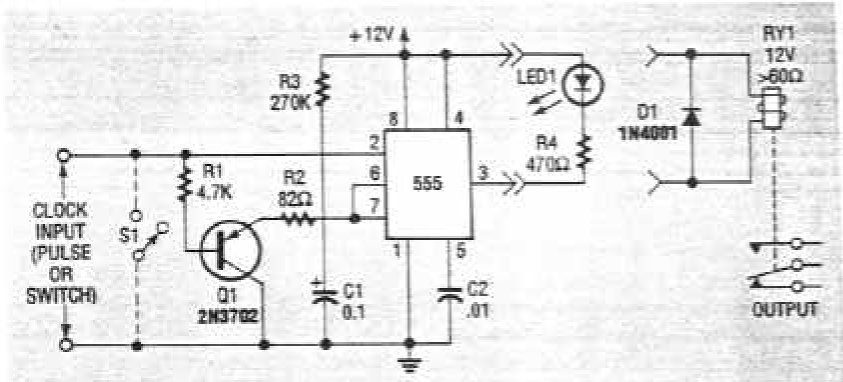

FIG. 9—MISSING-PULSE DETECTOR with LED or relay output.

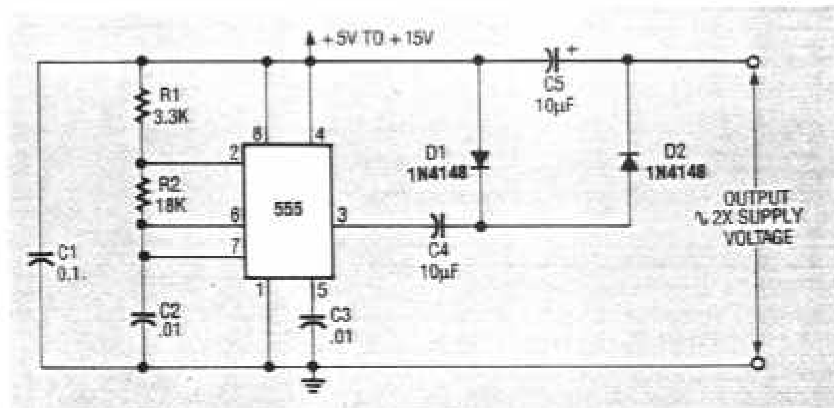

FIG. 10—DC VOLTAGE-DOUBLER based on the 555.

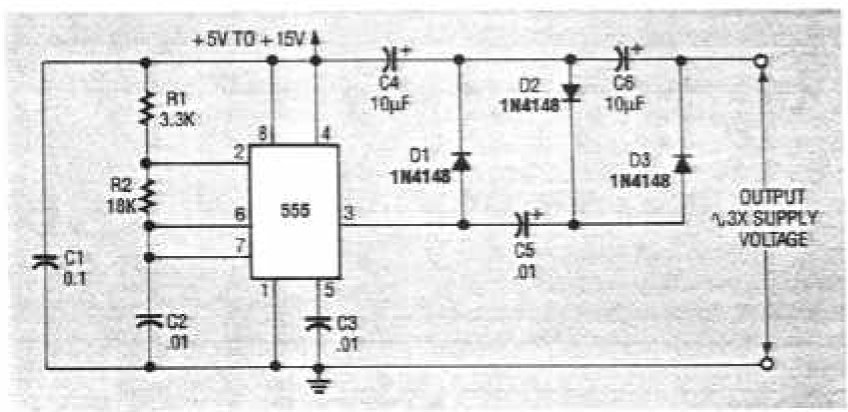

FIG. 11—DC VOLTAGE-TRIPLER based on the 555.

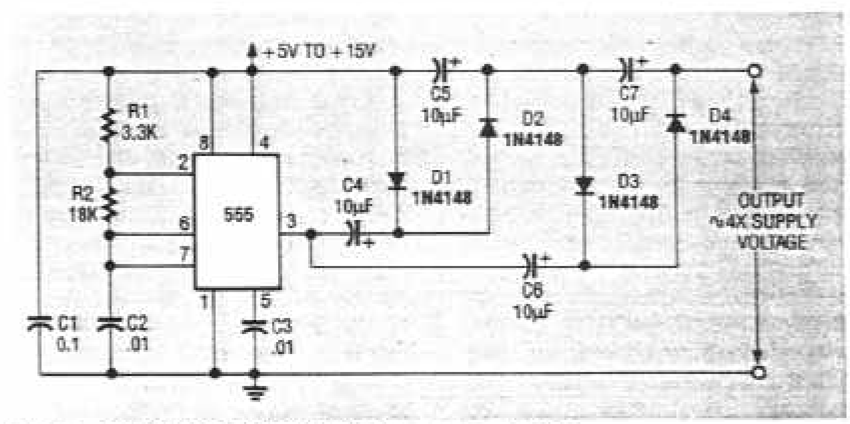

FIG. 12—DC VOLTAGE-QUADRUPLER based on the 555.

vibrator, and its reading is directly proportional to the input frequency.

With the component values shown, the circuit is organized to read full-scale deflection at 1 kHz. To set up the circuit initially, a 1-kHz square-wave signal is fed to its input, and full-scale-adjust potentiometer R7 (it controls pulse length) is set to give a full-scale reading on the meter.

The full-scale frequency of the circuit in Fig. 6 can be varied from about 100 Hz to 100 kHz by selecting the value of C3. The circuit can read frequencies up to tens of megahertz by introducing the input signals to the monostable multivibrator through either a single or multi-decade digital divider. The dividers can reduce the input frequencies to values that can be read on the meter.

Figure 7 shows how the circuit in Fig. 6 can be modified to become an analog tachometer or revolutions per minute (rpm) meter for motor vehicles. The circuit is powered by a regulated 8.2 volts derived from the vehicle's 12-volt battery with resistor R1, Zener diode D1, capacitor C1, and the ignition switch. The 555 is triggered by a signal from the vehicle's breaker points conditioned by the network of resistor R2, capacitor C2, and Zener diode D2.

The 50-microampere moving-coil meter M1, the rpm indicator, is activated from OUTPUT pin 3 of the 555 through diode D3. Current is applied to the meter through series-connected resistor R5 and CALIBRATE potentiometer R6 from the power supply when the 555's output is high. But current is dropped nearly to zero by diode D1 when the 555's output is low.

Both the circuits of Figures 6 and 7 are powered from regulated sources to ensure a constant pulse amplitude and provide accurate, repeatable readings from the meter. The meter is actually a current-indicating device, but it is connected as a voltage-reading meter with suitable *multiplying* resistors. They are R6 and R7 in Fig. 6 and R5 and R6 in Fig. 7.

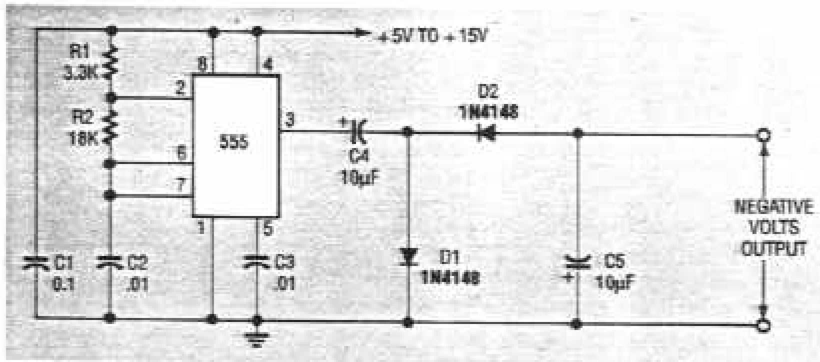

FIG. 13—DC NEGATIVE-VOLTAGE GENERATOR based on the 555.

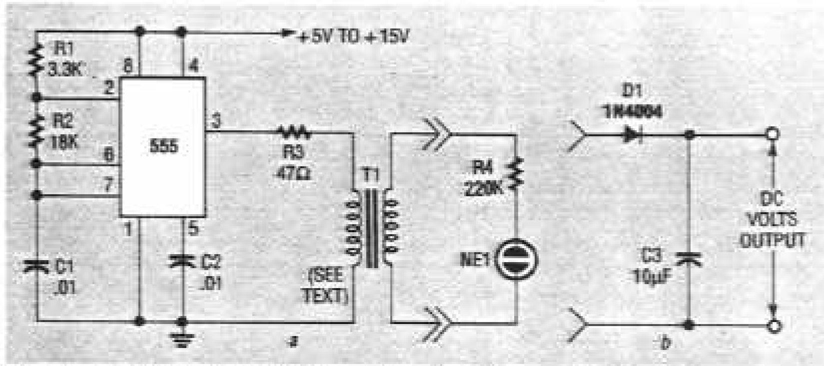

FIG. 14—NEON-LAMP DRIVER based on the 555, a, and DC-to-DC converter with rectifier and filter replacing lamp, b.

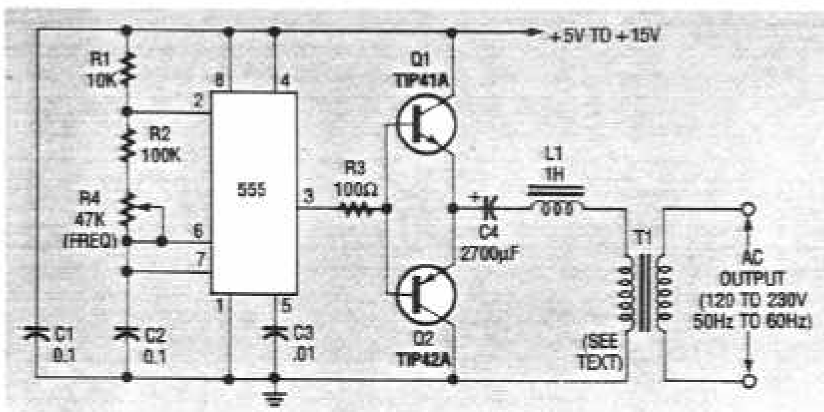

FIG. 15—DC-to-AC INVERTER based on the 555.

The diagram of Fig. 8 shows the outline schematic for an alternative analog frequency meter that requires neither a multiplier resistor nor a regulated power supply. In this circuit, OUTPUT pin 3 of the 555 is connected to the meter through JFET transistor Q1. Configued as a constant-current generator through potentiometer R3, it sends a fixed-amplitude pulse to the meter regardless of variations in the supply voltage.

Missing-pulse detector

Figure 9 illustrates how the 555 can become the key component in a *missing-pulse detector* that closes a relay or illuminates a LED if a normally expected event fails to occur. The 555 is connected as a monostable multivibrator except that Q1 is placed across timing capacitor C1, and its base is connected to TRIGGER pin 2 of the IC through R1.

A series of short pulse- or switch-derived clock input signals from the monitored event is sent to pin 2. The values of R3 and C1 were selected so that the natural monostable period of

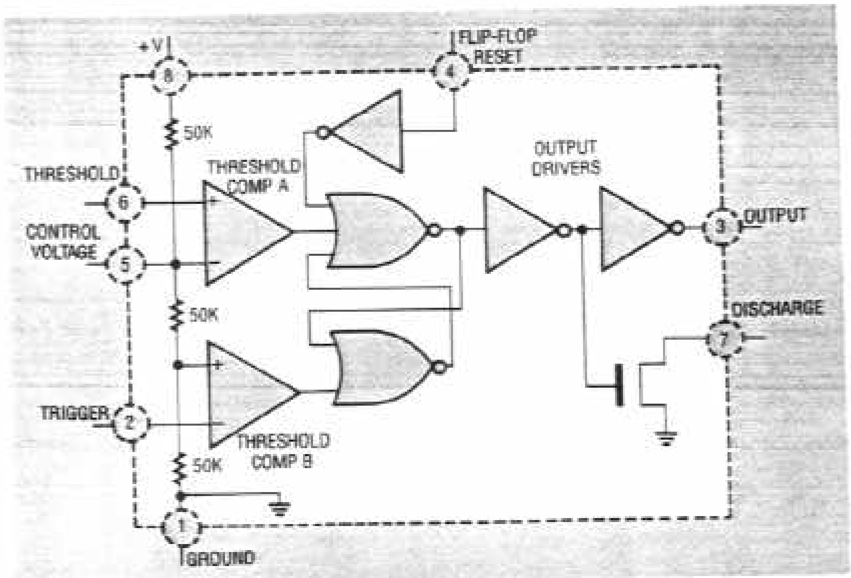

FIG. 16—FUNCTIONAL BLOCK DIAGRAM and pinout of the CMOS 7555.

the IC is slightly longer than the repetition period of the clock input signals.

Thus, each time a short clock pulse arrives, C1 is rapidly discharged through Q1, and simultaneously a one-shot timing period is initiated through TRIGGER pin 2 of the IC, forcing OUTPUT pin 3 high. Before each monostable period can terminate naturally, however, a new clock pulse arrives and starts a new timing period. Therefore OUTPUT pin 3 remains high as long as clock-input pulses continue to arrive within the preset time limits.

If a clock pulse is missing or its period exceeds the pre-set limits, the monostable period will end on its own. If that happens, pin 3 of the IC will go low and drive either the relay or LED "on." As a result, the circuit becomes a missing-pulse detector. It will produce a pulse output when an input pulse fails to occur within the timer delay.

Missing-pulse detectors like this can automatically warn of gaps or one or more missing pulses in a stream of pulses at the input. They are used in communications systems, continuity testers, and security systems. With the component values shown, the timer has a natural period of about 30 seconds. This period can be changed by changing R3 or C1 to satisfy specific needs.

Voltage converters.

The 555 IC can be instrumental in converting a DC voltage to a higher DC voltage, reversing the polarity of a DC voltage or converting it to an AC voltage. Figures 10 to 15 show variations of those circuits.

Figure 10, for example, shows how the 555 functions in a DC voltage doubler. The 555 is organized as a free-running astable multivibrator or square-wave generator that oscillates at about 3 kHz. (The oscillation frequency is set by the values of R1, R2 and C2.) The circuit's output is sent to the capacitor/diode voltage-doubler network made up of C4, D1, C5, and D2. That network produces a voltage that is about twice the supply voltage. Capacitor C1, across the supply, prevents the 3-kHz output of the 555 from being fed back to the IC, and C3 stabilizes the circuit.

The voltage-doubler circuit of Fig. 10 will operate from any DC supply offering from 5 to 15 volts. As a voltage doubler it can provide outputs from about 10 to 30 volts. Higher output voltages can be obtained by adding more multiplier stages to the circuit circuit. Figure 11 is the schematic for a DC-voltage tripler that can supply from 15 to 45 volts, and Fig. 12 is the schematic for a DC voltage quadrupler that supplies from 20 to 60 volts.

The DC negative-voltage generator is a particularly useful 555-based converter circuit. It supplies an output voltage that is almost equal in amplitude but opposite in polarity to that of the IC supply. This circuit can provide both positive and negative voltages for powering op-amps and other IC's with dual power requirements from a positive supply. The DC negative-voltage generator in Fig. 13, like that shown in Fig. 10, is a 3-kHz oscillator that drives a voltage-doubler output stage made up of C4, C5, D1, and D2.

Figures 14-a and 15 show DC to AC inverters that change input DC voltage to output AC voltage by means of transformer coupling. The AC voltage from these inverters needs no further conditioning, and it can be converted back into higher DC voltages with the addition of only a half-wave rectifier and a capacitor filter.

The inverter shown in Fig. 14-a can drive a neon lamp with its AC output. If the lamp and resistor R4 are replaced by the diode and capacitor filter as shown in Fig. 14-b, the AC output can be converted back to a low-current, high-voltage DC output. For example, with a 5- to 15-volt DC input, the inverter can produce an output of several hundred volts DC.

The 555 in Fig. 14-a is configured as a 4-kHz oscillator and its square-wave output from pin 3 is fed back to the input of audio transformer T1 through resistor R3. Transformer T1 has the necessary ratio of primary to secondary turns to produce the desired output voltage. For example, with a 10-volt supply and a 1:20 turns ratio on T1, the unloaded output of T1 will be 200 volts, peak.

The DC-to-AC inverter schematic of Fig. 15 produces an AC output at line frequency and voltage. The 555 is configured as a low-frequency oscillator, tunable over the frequency range of 50 to 60 Hz by FREQUENCY potentiometer R4. The 555 feeds its output (amplified by Q1 and Q2) to the input turns of transformer T1, a reverse-connected filament transformer with the necessary step-up turns ratio. Capacitor C4 and coil L1 filter the input to T1, assuring that it is effectively a sinewave.

A CMOS version of the 555

The standard bipolar 555 timer IC is still one of the most popular and versatile IC's today, but it has some drawbacks that were overcome by a CMOS version. For example, the 555 will not operate from voltages less than about 5 volts. Moreover, it typically draws 10 milliamperes of quiescent current when run from a 15-volt supply. This rather large current drain makes it unsatisfactory for most battery-powered circuits.

In addition to those shortcomings, the 555 produces a massive 400-milliampere current spike from the supply as its output is switched from one state to the other. A spike, lasting only a fraction of a microsecond, can cause lost bits in digital circuits near the 555 or powered from the same supply.

The CMOS version of the 555 timer, also able to operate in both monostable and astable modes, is known generically as the 7555. Figure 16 shows the functional block diagram and pinout of the 7555. This can be compared with the functional block diagram of Fig 1. Note that the pinout is identical.

Harris Semiconductor's version of the 7555, for example, is designated the ICM7555. In common with all other 7555's, it will run from a +2- to +18-volt DC supply. Notice that the resistors in its internal voltage divider are 50 K rather than the 5K of the 555. Other sources of the 7555 are Maxim (ICM7555) and Sanyo (LC7555).

Supply current to the 7555 is typically only 60 microamperes when run from an 18-volt supply. In addition, typical TRIGGER, THRESHOLD, and RESET currents are 20 picoamps, orders of magnitude lower than those of the bipolar 555. Those low currents permit the use of higher impedance timing elements for longer RC time constants. The 7555 can be organized to time out in periods from microseconds to hours.

Table 2 compares the characteristics of the 7555 to those of the 555. The 7555 permits:

- Lower supply current
- Wider supply voltage range
- Lower power dissipation
- Lower current spikes in output transitions
- Higher switching frequency performance

These improvements must be balanced against the higher cost of the 7555. The 7555 should be specified only if:

- It is to be used in a battery-powered circuit where power economy is critical
- Available power is 5 volts or less (too low for the 555)
- It is to be in digital circuitry whose signal output could be degraded by noise.

The 7556 is the dual CMOS counterpart of the bipolar 556. The 7555 can directly replace any 555 in all the circuits presented in this series. R-E