Engineer's newsletter

555 turns 60 Hz into 60 clean square waves

You can use a 555 timer to isolate a system like a digital clock from line noise and transients as well as produce a clean square wave at line frequency, says Wistar Macomson of Boston, Mass. To lock the 555 into synchronism with the 60-hertz line frequency, you **select the RC network for oscillation at or near 60 Hz.** Then all you have to do is connect the timer as an astable multivibrator in accordance with the manufacturer's literature, except that you don't ground the control-voltage input, pin 5— you just leave it unconnected. A low-ripple power supply is unnecessary, adds Macomson, and a battery backup will also keep the 555 running, although then it may drift off 60 Hz.

IC timer circuit yields 50% duty cycle

by Frank N. Cicchiello
Geometric Data Corp., Wayne, Pa.

When a 555 timer is operated as an astable multivibrator, it normally produces a pulse-type digital output waveform that has a limited duty cycle. Circuit arrangements that allow the 555 to operate with a 50% duty cycle square-wave output may be rather complex, and many are unstable. However, the simple circuit shown here produces a stable square wave with a duty cycle of 50% ±1%. This circuit has no tendency toward hesitant starting or latch-up.

As a start, assume capacitor C_1 to be uncharged. When this is so, a zero-volt signal level is applied to the IC's internal comparator (as seen at pin 6) when power is first turned on. This, in turn, means that the digital output (pin 3), to which resistor R_1 is returned, is at V_{CC}. Therefore, C_1 charges exponentially toward V_{CC} through resistor R_1. When the voltage across capacitor C_1 reaches a value of 2/3 V_{CC}, as seen at pin 6, the IC's internal comparator triggers its internal flip-flop, causing the output (pin 3) to switch to 0 V or ground level.

Now capacitor C_1 discharges toward 0 V through resistor R_1 until the voltage V_{C1} drops to a level of ⅓ V_{CC}, as seen at pin 2, the IC's internal trigger circuit. At this point, the IC's internal flip-flop causes the digital output to switch back to the V_{CC} level, reestablishing the circuit's original conditions for charging C_1.

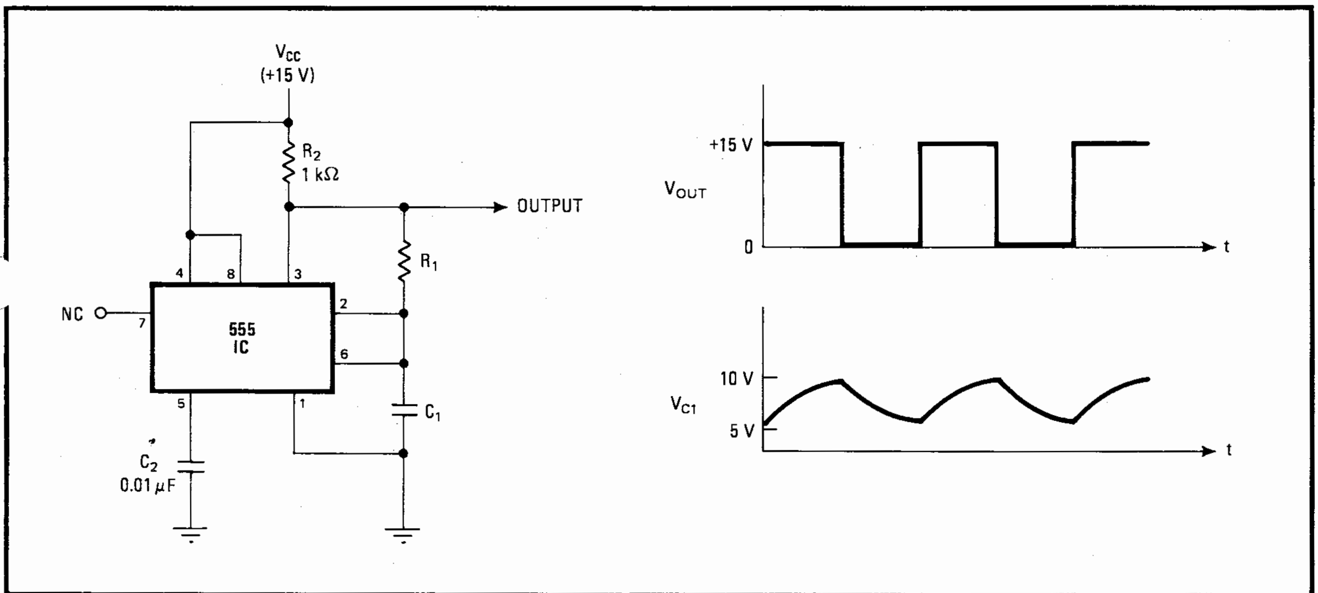
Connecting the trigger to the threshold inputs (pins 2 and 6) produces continued free-running or astable operation of the multivibrator, since these two circuits alternately control the IC's internal flip-flop/output circuit. It also means that the charging cycle need not start with 0 V across capacitor C_1 as previously explained, but may just as well begin its operation on the negative-going slope of C_1's waveform.

Resistor R_2 is a pull-up resistor, which ensures that the digital output voltage level at pin 3 closely approximates V_{CC}. Without it, the TTL-compatible output of the circuit may drop below this desired value. Capacitor C_2 is a bypass capacitor on the IC's unused voltage-control input. Circuit operation follows the formula:

$$t_1 = t_2 = 0.693\,R_1C_1$$
$$T = t_1 + t_2 = 1.386\,R_1C_1$$

so t_1 and t_2 are each equal to half of the period of the output, and T is the period.

The resistance of R_1 should be at least 10 times the value of R_2 but otherwise can be varied without upsetting the duty cycle. Transients occur in circuits that discharge C_1 rapidly, but they don't in this circuit. □



f (DESIGN) (kHz)	C_1 (μF)	R_1 (CALCULATED) (kΩ)	R_1 (ACTUAL) (kΩ)	f (ACTUAL) (kHz)
0.1	0.05	144.3	150	0.0962
1	0.01	72.2	75	0.962
5	0.01	14.4	15	4.81
50	0.001	14.4	15	45.3

All squared away. Free-running multivibrator built around 555 IC has 50% duty cycle because time constants for both charge and discharge are set by R_1C_1. Conventional discharge terminal (pin 7) is not connected in this arrangement. For values of supply voltage V_{CC} anywhere in the range from 5 to 15 volts, the actual output frequencies will not vary from those shown in table by more than 1%.

Microprocessor converts pot position to digits

by John M. Schulein
Aeronutronic Ford Corp., Palo Alto, Calif.

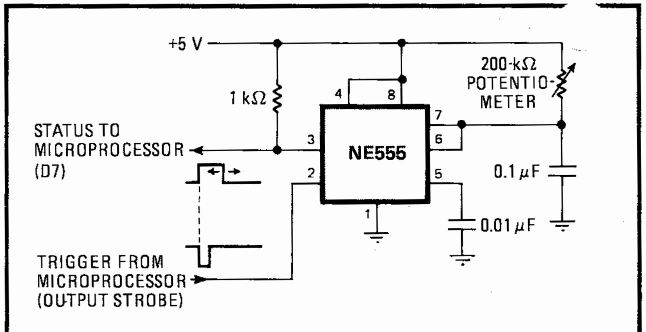
A few bytes of program in an 8008/8080 microprocessor, plus a 555 integrated-circuit timer, can convert the position of a potentiometer into a digital value. The arrangement is both economical and convenient when the position data is an input to a system already using the microprocessor, such as an industrial control system or a video game.

As the figure shows, a strobe pulse from the microprocessor triggers a 555 connected as a one-shot multivibrator. The output from the 555 stays high for a period of time that is proportional to the resistance of the pot. To measure this time period, the processor increments an internal register for as long as its input (D7) from the 555 remains high.

When data on the pot position is required, the microprocessor program calls up the POTPOS subroutine, which uses four flags, the accumulator, and the B register. In this subroutine, as the table shows, the processor:

1. Sets register B to 0.
2. Triggers the 555.
3. Increments register B.
4. Inputs the status of the 555 to bit D7 of the accumulator.
5. Sets a sign flag minus if status is high.
6. Jumps back to step 3 if flag is minus.
7. Returns to main program if flag is not minus.

Upon return to the main program, register B contains a number that measures the 555 output pulse duration and hence is a digital representation of the pot position.



PROGRAM SUBROUTINE

```
POTPOS:  MVI  B, Ø
         OUT  TRIGGER
CONT:    INR  B
         IN   STATUS
         ANA  A        (SETS SIGN FLAG)
         JM   CONT
         RET
```

NOTE: Register B contains the pot position on exit.

Where is the pot? Potentiometer position is digitized by one-shot multivibrator and subroutine for the 8008/8080 microprocessors. When program calls subroutine, processor triggers one-shot and measures output pulse duration (which is proportional to resistance of pot). Register B stores this value for use in computation of next step in a TV game, process control, etc.

When the hardware and software are used on an 8008 system with a 2.5-microsecond clock, the B register digital output varies from 2 to 65 Hex, i.e., has 100 different values, as the potentiometer is varied across its range. The values of the pot and the timing capacitor can be modified to suit the speed of the processor and the desired range of the digitized output. □

Triangular waves from 555 have adjustable symmetry

by Devlin M. Gualtieri
University of Pittsburgh, Pittsburgh, Pa.

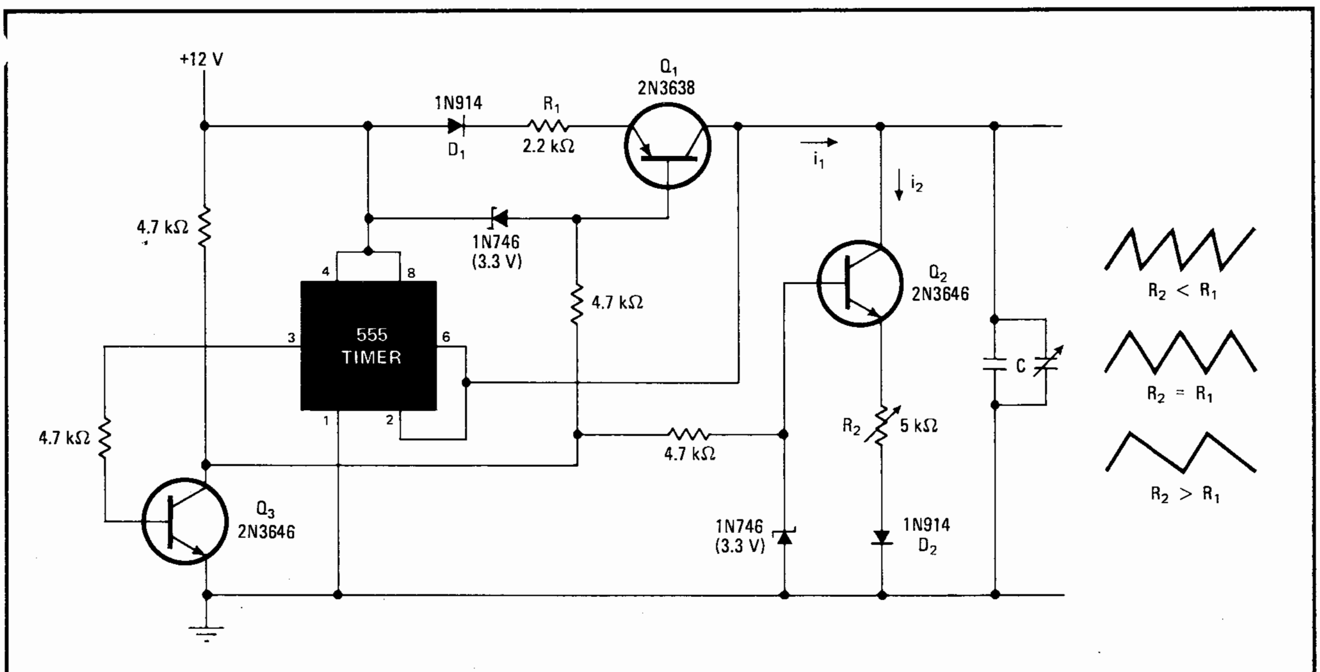
The fixed-frequency triangular waveform so often required in pulse-duration modulators or sweep generators too often turns out costly to implement. Though operational-amplifier circuits can develop a triangular wave by integration of a square wave, the tips of the triangle become blunt at frequencies above 10 kilohertz unless expensive devices with high slewing rates are used. Also, though single-package voltage-controlled oscillators provide triangular output, they are not cost-effective for fixed-frequency applications, and most have high current drain. However, an inexpensive 555 timer and some transistors can generate triangular waves at frequencies up to about 100 kHz.

The circuit shown generates a triangular waveform by alternately charging and discharging a capacitor. The transistors Q_1 and Q_2 with their zeners act as a switched-current source and a switched-current sink that are activated by Q_3. When Q_3 is on so that its collector is low, the Q_1 current source is switched on, and a current i_1 charges capacitor C. The linear voltage ramp that appears across C corresponds to the charging law $dV/dt = i_1/C$.

Voltage V across the capacitor increases until it reaches a level that is two thirds of the supply voltage, which is the upper trip point of the 555 timer. The voltage at pin 3 of the timer then goes low, turning off Q_3. Since the collector of Q_3 is thus made high, the Q_1 current source is deactivated, and the Q_2 current sink is switched on. The capacitor is discharged by i_2 until the lower trip point of the 555 timer is reached, at one third of the supply voltage. At this point the 555 changes state and the cycle repeats. Thus the output voltage varies from 4 V to 8 V if the supply is 12 V.

Q_1 and Q_2 may be any high-gain pnp and npn transistors, such as 2N3638 and 2N3646. Q_3 may be any npn switching transistor, such as 2N3646. The forward voltage drops of D_1 and D_2 ensure turn-off of Q_1 and Q_2. Resistor R_2 is a symmetry adjustment, controlling the discharge rate of C by varying i_2. For the values shown, the frequency in hertz of the symmetrical triangular wave form is roughly 75/C, where C is in microfarads; thus, C determines the frequency. □

Have you used a microprocessor to replace either hard-wired or mechanical logic in a circuit or made some other use of these versatile devices? Engineers who are just starting to design with microprocessors would be interested in learning about your experiences. We'll pay $50 for each microprocessor item published, as we do for all published Designer's Casebook ideas. Please send them to our Circuit Design Editor, summarizing the problem and how a microprocessor provides a novel solution.



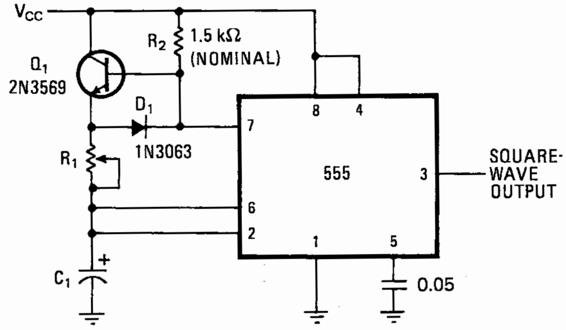
Ups and downs. Triangular waveform is generated across capacitor C by alternately charging and discharging through emitter-follower constant-current sources consisting of transistors Q_1 and Q_2 plus their zener diodes. Current sources are turned on and off by 555 timer.

Generator's duty cycle stays constant under load

by Arthur R. Klinger
School of Health Care Sciences, Sheppard AFB, Wichita Falls, Texas

In the 555 timer, configured as a square-wave generator, adding one transistor and a diode to the RC timing network permits the frequency to be varied over a wide range while maintaining a constant 50% duty cycle [see also *Electronics*, Sept. 19, p. 112].

In one simple configuration, a capacitor's charge and discharge currents flow through only one resistor. The high and low periods should be equal at any frequency, but, with heavy loads, the output may be offset by 1 volt or more from V_{cc} or ground. This varies the potentials across the RC network, creating quite large changes in duty cycle or frequency. Noise on the output lines can also cause erratic changes in the periods.



Workhorse. This configuration of the 555 timer can drive a heavy load without distorting its square-wave output, even over a very wide frequency range, unlike simpler hookups.

The circuit shown in the diagram removes the timing network from the output. While the timer's output is high, Q_1 is biased into saturation by R_2, so that charging current passes through Q_1 and R_1 to C. When the output goes low, the discharge switch (pin 7) cuts off Q_1 and discharges the capacitor through R_1 and D_1. With the same impedance in both paths, the high and low periods of the square wave are equal.

Q_1 should have a high β value so that R_2 can be large and still drive the transistor into saturation. With R_2 large, the IC's discharge transistor, which can sink 20 to 30 milliamperes, gets most of that current from the discharging capacitor and very little through R_2. The voltage drops in Q_1, D_1, and the internal discharge switch decrease the effective voltage across R_1, causing the actual periods to be slightly longer than those given by the astable and bistable formulas in the data sheets—0.69RC and 1.1RC, respectively. A high-conductance germanium or Schottky diode for D_1 would minimize these diode-voltage drops in D_1 and Q_1.

For precise square waves, the on characteristic of Q_1 should be the same as that of D_1 and the IC's internal pull-down switch. To optimize this balance, set the timing network to its highest frequency range, and adjust R^2 while monitoring the square wave output. Once adjusted at this frequency, an excellent square wave is maintained for all combinations of R_1 and C_1.

Since the usual current-limiting resistor is not needed, the minimum value of R_1 can be as little as a few hundred ohms. Such a small resistance carries large charge and discharge currents, leading to a frequency range twice as wide as the usual configuration provides. For example, if R_1 = 10 megohms, the frequency range can exceed 20,000 to 1 for a single choice of C. □

Timer ICs control life-test cycling

by Joseph E. Fleagle
St. Louis, Mo.

Life tests on electromechanical devices like solenoids and relays can be automated by a simple astable multivibrator that uses two 555 timers (or one 556 dual timer). The on and off times for the device under test are independently adjustable to any value between 10 milliseconds and 1 second for a wide range of testing rates and duty cycles. These times are adjusted by the settings of 10-turn potentiometers; the dial readings in milliseconds are accurate to within ±5%. Supply-voltage fluctuations have negligible effect on the timing.

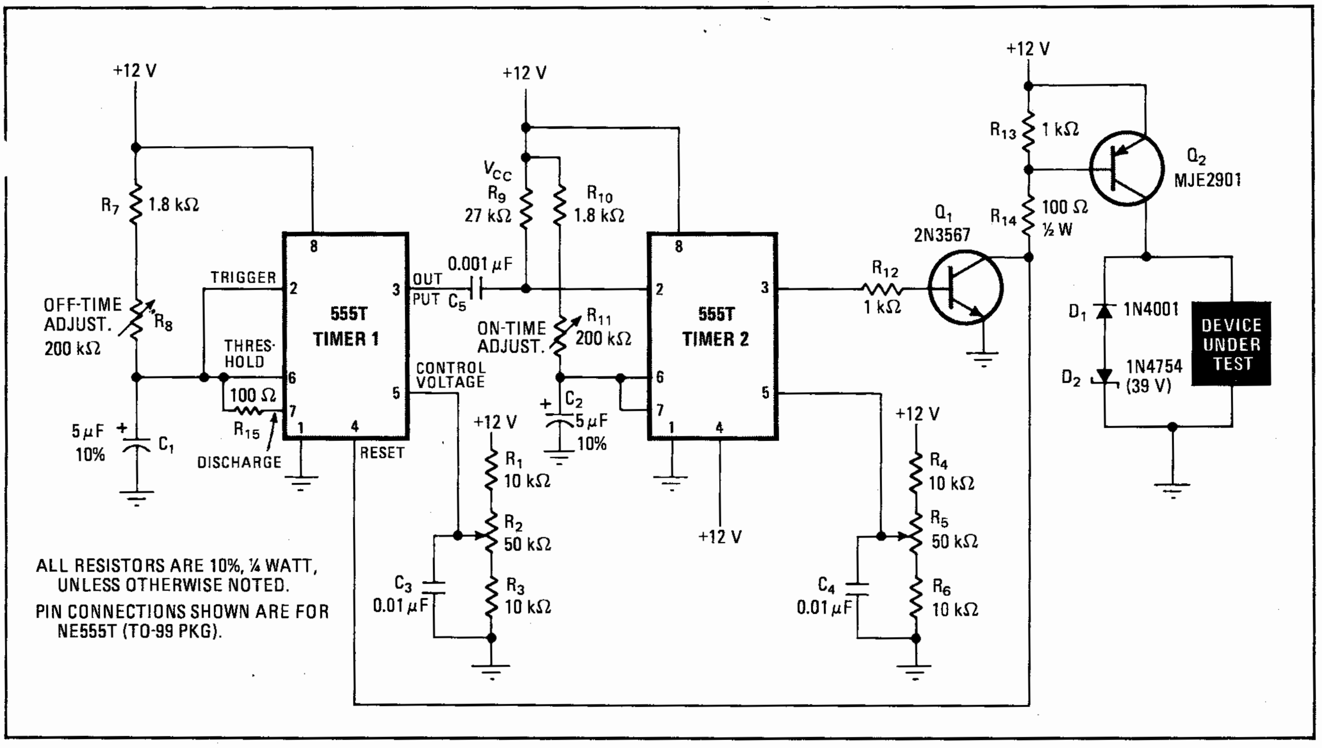
When power is initially applied to the circuit, timer 1 triggers immediately because the trigger terminal of timer 1 is low, since C_1 is uncharged, and the trigger terminal of timer 2 is high. Upon expiration of the output pulse from timer 1, the negative-going pulse triggers timer 2. The output from timer 2 turns on transistor Q_1, thus grounding the reset terminal of 1 to prevent retriggering until the output of 2 expires. When Q_1 goes on, it also turns on Q_2, which boosts the output current to 2 amperes. Diode D_1 and zener diode D_2 form a suppression network to protect Q_2 from destructive back voltages from inductive loads.

Adjustment for direct reading of the on and off times is straightforward. To set the off time, connect a scope to the output of timer 1 and adjust potentiometer R_8 for minimum resistance.

While holding the shaft of the pot so that it cannot rotate, set the dial to display the time measured on the scope; for example, if the scope shows the output-pulse duration is 10 milliseconds, adjust the dial to read 10. Then tighten the set screw. Next, adjust R_8 until the dial reads 999, and change R_2 until the pulse width is 999 milliseconds. These two adjustments interact slightly, so it may be necessary to repeat the steps once again.

The on time is calibrated in the same fashion, using potentiometers R_{11} and R_5. □

Engineer's Notebook is a regular feature in Electronics. We invite readers to submit original design shortcuts, calculation aids, measurement and test techniques, and other ideas for saving engineering time or cost. We'll pay $50 for each item published.



What a life. Device undergoing life test is cycled on and off by simple astable multivibrator that uses two 555 timers or one 556 dual timer. The on and off times, which are read directly from dials of potentiometers R_8 and R_{11}, can be set independently to any value from 10 milliseconds to 1 second. Diodes shunting device under test protect Q_2 against back voltages from inductive loads.

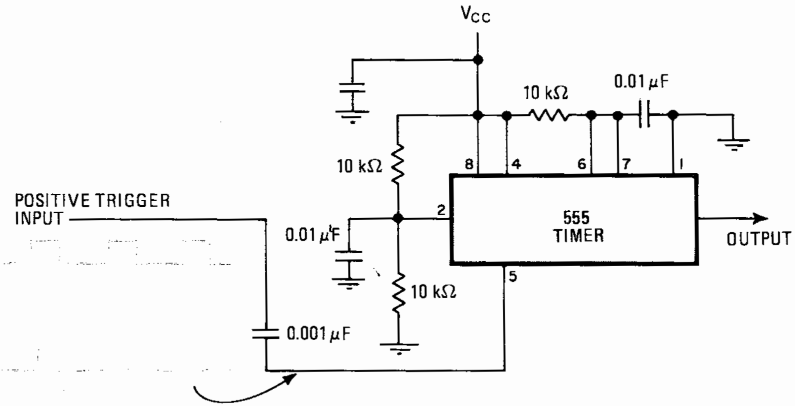
Positive pulse triggers 555 integrated-circuit timer

by Rudy Stefenel
San Jose, Calif.

Many applications require a circuit capable of producing timing intervals, and the most popular monolithic timer is the 555. Though versatile, this timer is limited by a negative-going trigger input. However, a careful study of the functional block diagram shows that pin 5, which is connected to the noninverting input of comparator 2 through a resistor, can be treated as a positive-going trigger input point. Thus pin 5 can now serve both as control voltage input for which it was originally inten by the 555 designers and as the positive trigger input.

Because the trigger pulse disappears by the time the timing capacitor is charged to the control voltage, the trigger input at pin 5 does not affect the control voltage. The sensitivity of pin 5 to trigger input is controlled by the voltage difference between it and pin 2. This is done by connecting pin 2 to a voltage divider network.

As shown in figure, the monostable multivibrator comprising the 555 timer is driven by the rising edge of the positive-going input trigger pulses. Pin 2 is connected to the center of the resistor network between supply and ground. In addition, a bypass capacitor is connected at pin 2 to make it insensitive to stray pulses coupled from nearby circuits. □



Trigger. The internal block diagram of IC timer 555 shows that pin 5 is connected to the noninverting input of the comparator 2 through a resistor and therefore can be used as a positive-trigger-input terminal. The monostable multivibrator consisting of timer 555 and its associated circuitry is driven by positive input pulses.

APPLICATIONS FOR THE IC "TIME MACHINE"

Some interesting circuits using the 555 timer-on-a-chip

BY WALTER G. JUNG
Contributing Editor

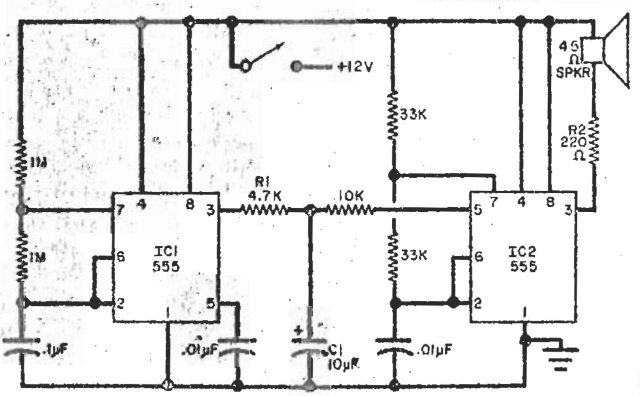
IN THE November 1973 issue of POPULAR ELECTRONICS ("The IC Time Machine," p 54), we discussed the basic operation of the 555 integrated circuit timer chip. Now that we understand the principles, let's see how some practical applications work.

Below, and on following pages, are five interesting and useful circuits that are easily built. Note the wide range of areas in which these circuits can be used.

Of course, the story of the IC "time machine" is by no means complete with these applications. We have barely scratched the surface with the circuits given here, but we hope that we have suggested some new ideas that will be useful in designing new projects.

In a case like this, the best approach to new circuit design is to understand fully the internal workings of the IC itself and know just what the inputs and outputs are at each pin. Then let the imagination go to work. The best way to do this is to make a "breadboard" and play with the IC, using different connections and varying the external components.

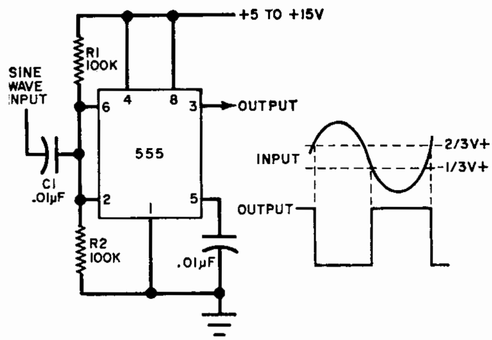
A WARBLE ALARM CIRCUIT



The warble alarm circuit shown on the opposite page uses two 555 IC's as an audio attention getter. The first 555, *IC1*, oscillates at a frequency slightly below 10 Hz. Its rectangular output is filtered by *R1C1* to produce a triangle wave, which in turn is used to frequency modulate *IC2*. The latter is operated at approximately 1 kHz and is modulated at a 5-Hz rate.

The output current of the 555 IC is sufficient to drive a small speaker and *R2* is used to prevent excessive loading, but the audible level of the tone produced is still quite noticeable. The exact frequency, rate, and deviation of the circuit can be easily modified to produce almost any type of warble sound desired. The on-off control is most efficiently achieved by interrupting the supply line so as to minimize standby power. The switch can be relay contacts or some other means of applying power when an alarm condition is sensed.

SCHMITT TRIGGER OR BISTABLE BUFFER



Aside from its basic use in timing functions, the 555 IC can be applied to advantage in other switching circuits. One example is the Schmitt trigger circuit shown here. In this circuit, the two comparator inputs (pins 2 and 6) are tied together and biased at half of the applied dc voltage through the voltage divider made up of *R1* and *R2*. Since the upper comparator (pin 6) will trip at ⅔ of the applied dc and the lower one at ⅓ of the applied voltage, the bias provided by resistors *R1* and *R2* is centered within the comparators' trip limits.

A sine-wave input of sufficient amplitude to exceed the reference levels causes the internal flip-flop to be set and reset. In this way, it creates a square wave at the output. As long as *R1* is equal in value to *R2*, the 555 will be automatically biased correctly for almost any supply voltage. Note that the output waveform (as shown in the diagram above) is 180 degrees out of phase with the applied input sine wave. Because of the 555's high output current capability, this circuit can be used to good purpose as a signal shaper/buffer circuit.

Such a circuit can also find application if you have a sine-wave-only audio generator and you would also like to have a simultaneous square-wave output. The major advantage of this circuit is that, unlike a conventional multivibrator type of squarer, which divides the incoming frequency in half to square it, the Schmitt trigger simply squares the input frequency without changing the frequency. A circuit of this type can easily be installed within almost any audio generator.

Inverting Bistable Buffer. By modifying the input time constant of the circuit shown above (reducing the value of input capacitor *C1* to 0.001 microfarad, for example) so that input pulses will be differentiated, the arrangement can also be used as either a bistable device or to invert pulse waveforms. In the latter case, the fast time constant of the combination of *C1* with *R1* and *R2* causes only the edges of the input pulse or rectangular waveform to be passed. These pulses set and reset the flip-flop; and a high-level, inverted output is the result.

(More on next page)

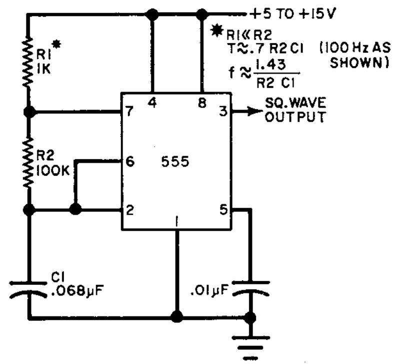
SQUARE-WAVE OSCILLATOR

A conventional astable circuit using a 555 IC does not normally produce a symmetrical output waveform. However, square waves can be obtained from a 555 by using the simple circuit shown here.

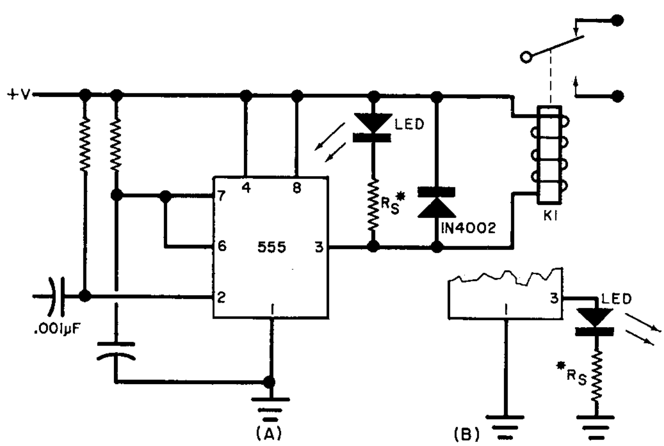
The assymetry of a conventional astable circuit is a result of the fact that the charging and discharging time constants are not equal. If the timing capacitor can be charged and discharged through the same (or equivalent) resistance value, the symmetry can be restored.

In the circuit shown here, capacitor *C1* is charged through *R1* and *R2* and it is discharged through *R2*. If *R1* is made very small in resistance compared to *R2*, then both time constants will be reduced so that they depend essentially on *R2* and *C1*.

The frequency of operation (*f*) of this circuit is approximately equal to 1.43 divided by the product of *R2* and *C1*. The frequency is of course independent of the supply voltage.



OUTPUT DRIVE CONSIDERATIONS



*SELECT FOR DESIRED LED CURRENT.. +5V USE 150Ω, +15V USE 680Ω

The 555 timer IC can provide up to 200 mA of output current in either its high or low state. However, this value should not be considered too strictly since some types of loads have a voltage limitation. If, for example, the 555 is used with a 5-volt supply to drive TTL logic, the output current is limited to much less than 200 mA because of the required input voltage for the following TTL stage. Since TTL output stages are normally specified for 0.4 volt at rated current, a more realistic maximum output current for the 555 is 5 mA, which is far less that the 200 mA specified.

Other types of loads, such as incandescent lamps, relays or light-emitting diodes are not as critical in terms or voltage and they can be driven by using the circuit shown above. Depending on the logic involved in the application, these types of loads can be connected from pin 3 to either +V or ground. In a timer such as that shown in (A) above, the output (pin 3) is normally at the ground potential and goes high during the timing interval. Therefore, a LED connected as shown at left will be on when pin 3 is low, and it will go off when pin 3 is high (during the timing cycle).

Since a 555 can operate over a wide dc supply range and a light-emitting diode requires about 1.6 volts, a series resistor (*Rs*) is used to drop the excess voltage and limit the LED current.

Relays can be driven as shown in this circuit by selecting a relay that is compatible with the applied dc. Of course, it will have to have the contact arrangement desired. Since the 555 has a healthy current output, the relay selected need not be particularly sensitive.

This permits relays rated at 12 volts and 100 mA to be used. The diode across the relay coil is used to prevent the back emf from damaging the IC chip. If the current demand is not too high, both an LED and a relay can be used at the same time.

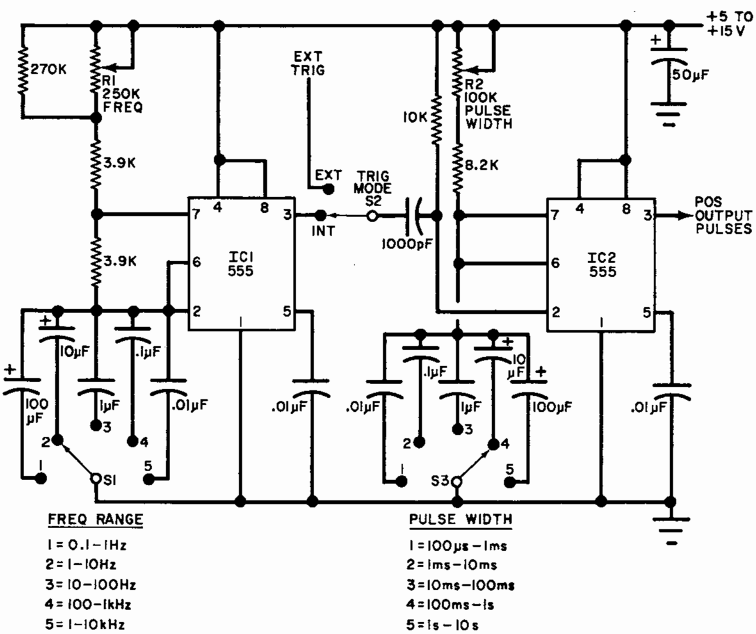
The connections shown at (B) are for the opposite type of logic where the LED is normally off and is pulsed on.

WIDE-RANGE PULSE GENERATOR

The most sophisticated of the 555 applications described here is the wide-range pulse generator, whose circuit is shown below.

This general-purpose pulse generator consists of an astable oscillator (*IC1*) whose output frequency can be varied over a 10:1 range by potentiometer *R1* (frequency control). Range selection is made by *S1*, with five ranges from 0.1 Hz to 10 kHz. Tantalum capacitors are used for the two lower ranges, while Mylar capacitors should be used for the upper ranges. The output of *IC1* feeds S2, which can be used to select either internal or external signals for *IC2*, a monostable circuit.

Integrated circuit *IC2* is a monostable generator whose output is a pulse with a width that can be varied over a range of 10 to 1 by changing *R2*. Switch S3 provides five ranges from 100 microseconds to 10 seconds. The output of the latter stage consists of positive-going pulses whose frequency (rate) and width can be set to almost any desired values. If the external mode of triggering IC2 is selected, almost any negative-going pulse can be applied to the external trigger input.



Bistable action of 555 varies with manufacturer

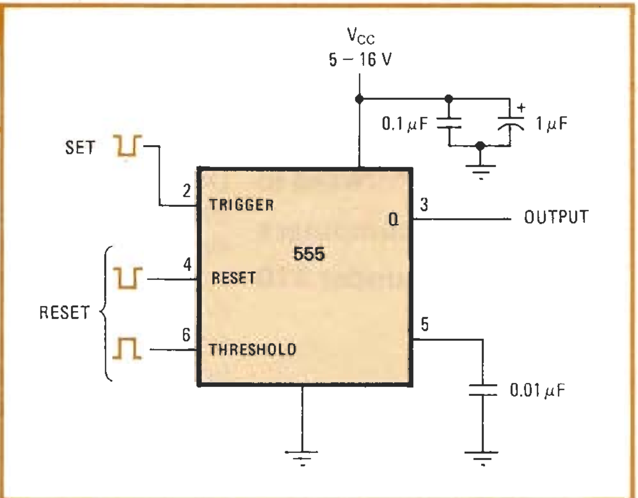
by Robert W. Bockstahler
General Dynamics Corp., Pomona, Calif.

The 555 integrated circuit, which has myriad uses as a timer and oscillator, can also function as a bistable flip-flop in such applications as TTL-compatible drivers for displays or latch elements for burglar alarms. This flip-flop operates from many different supply voltages, uses little power, and requires no external components other than bypass capacitors in noisy environments.

Pin 2 (the trigger pin of the 555) is an active-low SET function. Pin 4 (the reset of the 555) serves as an active-low RESET, and pin 6 (threshold) as an active-high RESET. Both the RESETs can be used, or just one, with the other connected in its inactive state. The table shows how the output responds to various input signals.

It is important to know the detailed characteristics of the particular 555 used as a bistable element because the circuitry differs from manufacturer to manufacturer, and certain functions, therefore, interact differently. The table points out, for example, that the threshold overrides the trigger on the LM555H, but the trigger overrides the threshold on the NE555V. □

INPUTS			OUTPUT	
PIN 4 (RESET) (ACTIVE-LOW)	PIN 6 (THRESHOLD) (ACTIVE-HIGH)	PIN 2 (TRIGGER) (ACTIVE-LOW)	NATIONAL LM555H	SIGNETICS NE555V
⊔	0	1	RESETS (↓)	RESETS (↓)
⊔	1	1	0	0
⊔	0	0	⊔	⊔
⊔	1	0	0	⊔
1	⊓	1	RESETS	RESETS
1	⊓	0	⊔	1
0	⊓	1	0	0
0	⊓	0	0	0
1	0	⊔	SETS (↑)	SETS (↑)
1	1	⊔	0	⊓
0	0	⊔	0	0
0	1	⊔	0	0



Bistable operation. A 555 timer can be used as a set/reset flip-flop, with pin 2 as the active-low SET input. Pin 4 can be used as active-low RESET input, with pin 6 inactive (i.e., low), or pin 6 can be used as active-high RESET input, with pin 4 inactive (high); in the latter case, an LM555H performs somewhat differently from an NE555V. Flip-flop operation with both pin 4 and pin 6 as control inputs is also possible; for example, pin 4 might be the RESET and pin 6 a power-on CLEAR.

High-impedance op amp extends 555 timer's range

by Ronald Zane
University of California, Los Angeles, Calif.

The period of oscillation of the 555 timer can be increased 20 times or more if the timing components are replaced by a feedback loop containing a transistor and a very-high-impedance input operational amplifier configured as an integrator. The circuit is an inexpensive way of generating timing periods of hours or days to control industrial processes, to turn on lights in the home for burglar protection, and for like applications.

As shown in the figure, resistor R_5 and capacitor C combine with the CA3140T op amp to make the integrator that controls the period of oscillation in the 555. The very low offset current of this op amp (typically 3 picoamperes but no greater than 30 pA) permits accurate integration of very low input currents (100 pA). Thus it ensures excellent control over the actual oscillation times.

The timer, operating in its astable-multivibrator mode, produces a change of state at pins 3 and 7 each time the input signal requirements are met at the threshold and trigger ports of the device. The output moves low when the input at the threshold terminal is greater than two thirds the supply voltage V_s. It stays low until the trigger input detects decay of the input signal's voltage to less than one third of V_s. Then the output assumes a high state.

Transistor Q_1 switches in accordance with pin 7 of the 555; point E_1 will be at ground when Q_1 is on, and at $V_s/2$ when Q_1 is off, because of the voltage divider made up of R_1 and R_2. The voltage at E_2, $V_s/4$, is determined by the divider made up of R_6 and R_7 (R_1, R_3, and R_4 in series hardly affect the calculation).

When Q_1 is on, the current through R_5 at the inverting input of the op amp is thus:

$$I = \frac{(V_s/2 - V_s/4)\,R_4}{R_5(R_3+R_4)} = \frac{V_s R_4}{4R_5(R_3+R_4)}$$

and when it is off, the current is:

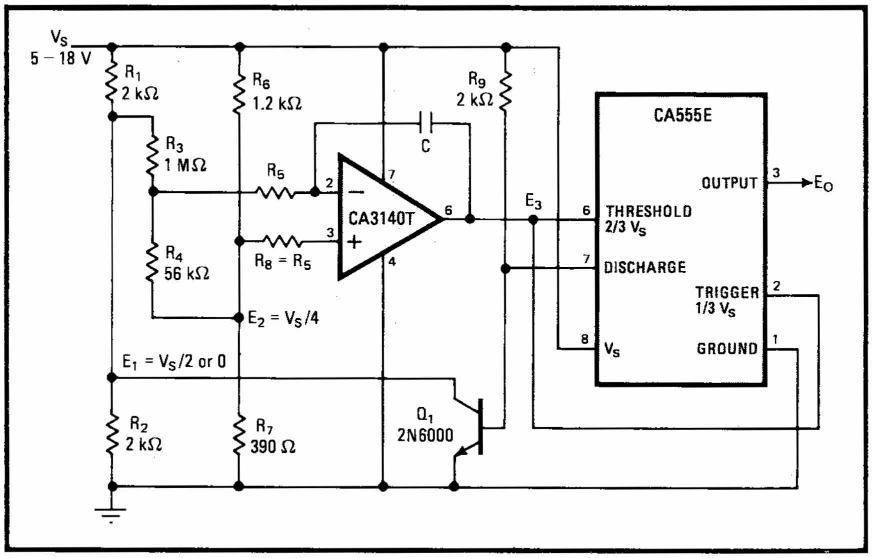
$$I = \frac{(0 - V_s/4)\,R_4}{R_5(R_3+R_4)} = \frac{-V_s R_4}{4R_5(R_3+R_4)}$$

The magnitudes of these currents are the same. The integrator then operates on this input current. Because its output is $E_3 = dV_s/dt = I/C$ by definition, and because E_3 switches between one third and two thirds of the supply voltage each cycle, the oscillator's period is:

$$t = \int_{1/3}^{2/3} \frac{C}{I}\,dV_s \frac{8(R_3+R_4)\,R_5C}{3R_4} = 50\,R_5C$$

The low offset current of the op amp allows R_5 to assume values in the hundreds of megohms. Even when R_5 equals 110 MΩ, the current through it is 1.8 nanoamperes, far exceeding the op amp's offset current.

If R_5 is 110 MΩ and C is 1 microfarad, the 555's period is 5,500 seconds. Since R_5 and C can be increased, periods of 10 hours or more may be realized with inexpensive components. If a 510-MΩ resistor and a 10-μF capacitor is used in the integrator, the oscillation period will be 70 hours. The bare 555, which may use a maximum timing resistance of 20 MΩ, coupled with a 10-μF capacitor for its timing capacitance, would have an oscillation time of only 280 seconds. □



Time-magnification. Oscillation frequency of a 555 may be lowered 20 times or more if a low-input-current, integrating op amp is used to replace timing components. One oscillation every few days is possible if a high-value capacitor, C, is used in integrator.

PERSONAL TIMING TESTER

BY J. R. DAVIES

HOW accurate is your sense of time? This little circuit, employing a 555 IC, tests your timing judgment by flashing a LED every 1.5 seconds (this interval can be changed). If you press a pushbutton at the right time, the LED will stay lit.

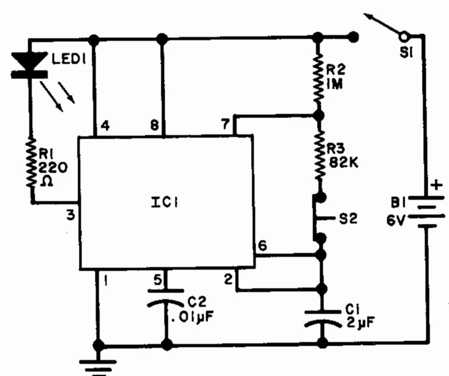
The LED is strobed on for 0.1 second. Since human reaction time is on the order of 0.3 second, you can't catch the LED once it is on. It is necessary to judge the time which has passed after the LED turns off before operating the test switch. A person with a good sense of timing should be able to "freeze" the LED on 20 to 40% of his attempts.

The circuit is basically an astable multivibrator built around a 555 timer IC. Switch *S1* is the master ON/OFF switch, and *S2* is the pushbutton reaction switch.

When not depressed, *S2* is closed and timing capacitor *C1* starts to charge up through resistors *R2* and *R3*. When the voltage across *C1* reaches two-thirds of the supply voltage, the 555 changes states allowing current to flow through *LED1*. When pin 3 goes high, no current flows through the LED.

Consequently, the LED glows only during the discharge interval. Since the capacitor charges through *R2* and *R3*, but discharges only through *R3*, the discharge time is much less than the charge time.

If *S2* is pushed at any time during the cycle, the charge and discharge paths are opened. The voltage across *C1* remains fixed, and the output remains in the same state as when *S2* was depressed. Thus, if the switch is opened while the LED is on, the LED will stay lit. Closing *S2* allows the cycle to resume at the point where it was interrupted. The circuit can be assembled on perforated board in a small utility box. Any LED which glows brightly with a forward current of 20 mA can be used for *LED1*. Capacitor *C1* should be a metalized film, Mylar, or polyester unit. If you can't find a close-tolerance capacitor with a large enough capacitance, parallel a number of smaller units to get 2 microfarads. Any 6-volt source, such as four "C" cells in series, can be used. ◈



PARTS LIST

B1—6-volt battery
C1—2-µF polyester capacitor (see text)
C2—0.01-µF capacitor
IC1—555 timer IC
LED1—20-mA LED (Texas Instruments TIL209 or equivalent)
R1—220-ohm, ¼-W, 10% resistor
R2—1-megohm, ¼-W, 10% resistor
R3—82,000-ohm, ¼-W, 10% resistor
S1—Spst miniature toggle switch
S2—Normally closed pushbutton switch
Misc.—Printed circuit or perforated board, suitable enclosure, mounting hardware, rubber feet (4), battery holder, hookup wire, solder, etc.

Timer IC paces analog divider

by Kamil Kraus
Plzen, Czechoslovakia

The quotient of two analog voltages, V_x/V_y, is required in many control and computation applications. This ratio can be produced by a circuit that consists of a voltage-to-frequency converter and an amplitude modulator, as shown in the accompanying diagram.

In the V-to-f converter, input voltage V_y drives a field-effect transistor through an operational amplifier. The FET operates as voltage-controlled resistor to determine the frequency of a 555-timer astable multivibrator. The resistance of the FET is given by:

$$R = V_p^2/[(1+R_1/R_2)I_sV_y - I_sV_p]$$

where V_p is the FET threshold and I_s is the drain current when V_y is zero.

In this mode of operation, the capacitor C charges and discharges between ⅓ and ⅔ of V_{CC}. Thus the output voltage of the timer varies from 5 to 10 volts if the supply is 15 V. The charge and discharge times and therefore the frequency are independent of the supply voltage.

Input voltage V_x is applied to the inverting input of op amp A_2, which acts as the amplitude modulator. When the output from the timer (pin 3 of the 555) goes high, transistor Q turns on and grounds the noninverting input of A_2, so that the output from A_2 is $-V_x$. When the timer output is low, transistor Q is off and the output from A_2 is $+V_x$.

The output from A_2 is therefore $-V_x$ during the charging time of the timer:

$$t_c = 0.693(R+R_B)C$$

and is $+V_x$ during the discharge time of the timer:

$$t_d = 0.693R_BC$$

The average value of the output voltage from A_2 over the period of the timer is given by:

$$\overline{V}_{out} = V_x(t_d - t_c)/(t_c+t_d)$$

Substitution of the expressions for the charge and discharge times, and use of the relation for R, yield:

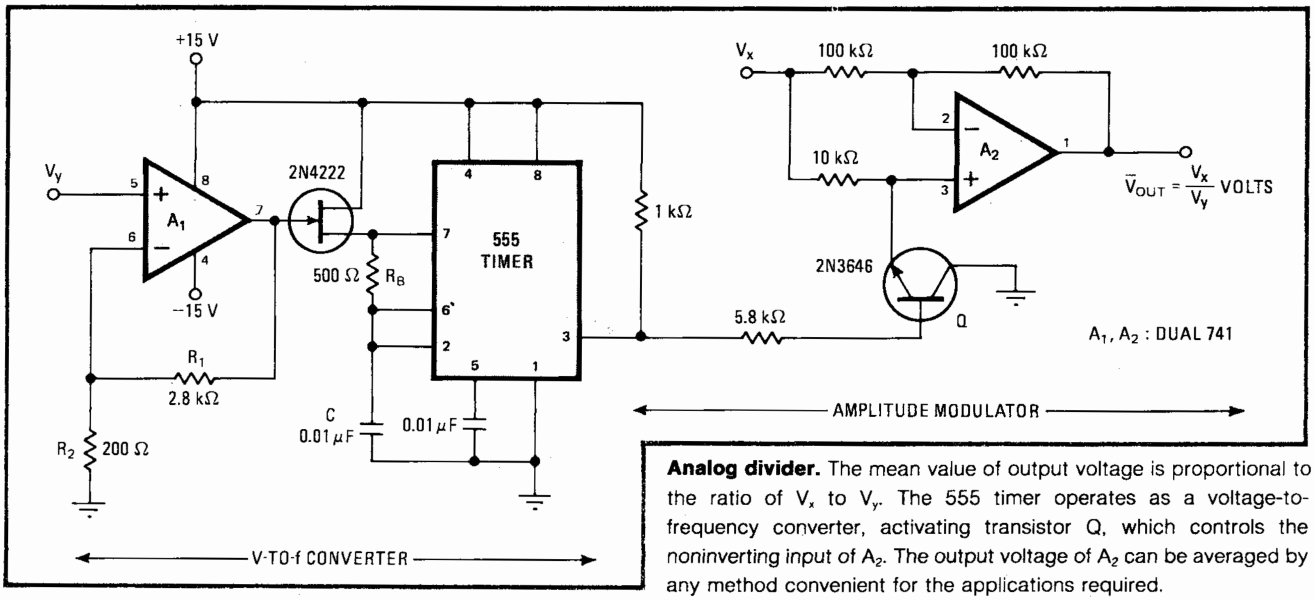
$$\overline{V}_{out} = -V_pV_x/(1+R_1/R_2)V_y$$

if R_B is made equal to $V_p/2I_s$. For the 2N4222 FET, V_p is 15 volts and I_s is 15 mA, so R_B is 500 Ω. The value of C is 0.01 microfarad, as recommended by the 555 manufacturer. If the value of R_1 is $14R_2$ as shown, the average output voltage, in volts, is:

$$\overline{V}_{out} = -V_x/V_y$$

Thus the mean value of the output voltage from A_2 is numerically equal to the ratio of input voltages V_x and V_y. These voltages can have any values in the range from 0 to +10 V; the average of the output can be realized with an RC across the output circuit, or read on a damped voltmeter, or whatever the application requires. □

Designer's casebook is a regular feature in Electronics. We invite readers to submit original and unpublished circuit ideas and solutions to design problems. Explain briefly but thoroughly the circuit's operating principle and purpose. We'll pay $50 for each item published.



Analog divider. The mean value of output voltage is proportional to the ratio of V_x to V_y. The 555 timer operates as a voltage-to-frequency converter, activating transistor Q, which controls the noninverting input of A_2. The output voltage of A_2 can be averaged by any method convenient for the applications required.

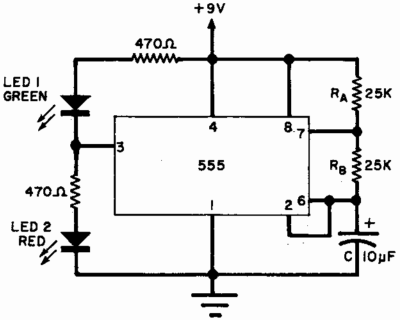


Fig. 5. A 555 RC relaxation oscillator that flashes LED's.

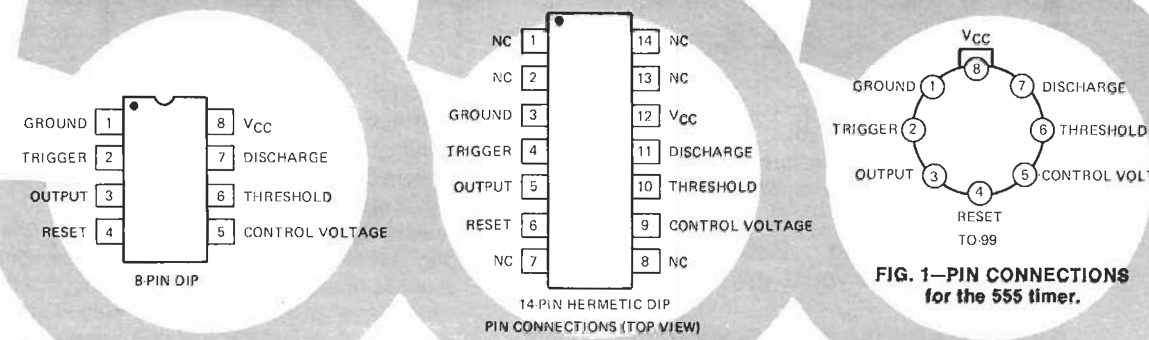


FIG. 1—PIN CONNECTIONS for the 555 timer.

555 TIMER IC APPLICATIONS

This series of articles will describe the operation of the 555 and present various applications including automotive, photographic and test equipment, among others.

by ROBERT F. SCOTT
TECHNICAL EDITOR

FOR SEVERAL YEARS, IT APPEARED THAT THE 709 op-amp would remain unsurpassed as the most useful and versatile integrated circuit; especially for electronics hobbyists. Now, it looks like that honor may have passed to the 555 family of timers.

Basically, the 555 timer is a highly stable integrated circuit capable of functioning as an accurate time-delay generator and as a free-running multivibrator. When used as an oscillator, the frequency and duty cycle are accurately controlled by two external resistors and a capacitor. This device originated with Signetics and is now available from such manufacturers as Exar, Motorola, National, RCA, Raytheon, Teledyne and Texas Instruments. The typical data sheet for this device lists the following features:

- Timing from microseconds to hours
- Monostable and astable operation
- Adjustable duty cycle
- Output compatible with CMOS, DTL and TTL (when used with a 5-volt supply)
- High-current output can sink or source 200 mA
- Trigger and reset inputs are logic compatible
- Output can be operated normally off

Applications listed include:

- Precision timing
- Time-delay generation
- Sequential timing
- Pulse generation
- Pulse shaping
- Pulse-position modulation
- Pulse-width modulation
- Clock generation
- Missing-pulse detection
- Appliance timing
- Frequency division
- Voltage-to-frequency conversion
- Linear sweep generation

We will examine the make-up and operation of the 555 family and then we will see how the various features and applications can be developed into practical circuits you can use in the home, car, lab and service bench.

The 555 is available in 8- and 14-pin DIP packages and in a circular TO-99 metal can with eight leads. The base connections are shown in Fig. 1. The device is available from most makers in at least two grades. The precision type generally maintains its essential characteristics over a range of −55° C to +125° C while the general-purpose type operates reliably only over a range of 0° C to 70° C. Type numbers for the precision and general-purpose types are as follows (the precision types are listed first): SE555/NE555 (Intersil and Signetics), RM555/RC555 (Raytheon), MC1555/MC14555 (Motorola), LM555/LM555C (National), SN52555/SN72555 (Texas Instruments) and CA555/CA555C (RCA).

(Many of the manufacturers listed also offer the 556 which is basically two 555's in a single package. Most dual timers have "556" in the type number. An exception is the D555—for dual 555—made by Teledyne. There are several quad timers available. Both dual and quad types may have specific limitations that do not apply to the 555. More about this later.

How the 555 operates

A functional block diagram of the 555 as a monostable timer is shown in Fig. 2 and the equivalent schematic of the IC is shown in Fig. 3. Timing is determined by external components R_T and C_T. The IC timer consists of a flip-flop, a high-current output stage, discharge and reset transistors and two comparators. (*A comparator is an op-amp that compares an input voltage to a reference voltage and indicates whether the input is higher or lower than the reference potential. When the input swings slightly above the reference value, the op-amp's output swings into saturation. At the instant that the input drops below the reference level, the op-amp's output swings into reverse saturation. The output changes state when the input rises above or drops below the reference voltage level by only a few hundred microvolts.*)

The reference voltages for the two comparators inside the 555 are developed across a voltage divider consisting of three 5K resistors. The threshold comparator is referenced at ⅔ V_{cc} and the trigger comparator is referenced at ⅓ V_{cc}. The two comparators control the flip-flop, which, in turn, controls the state of the output. When the timer is in the

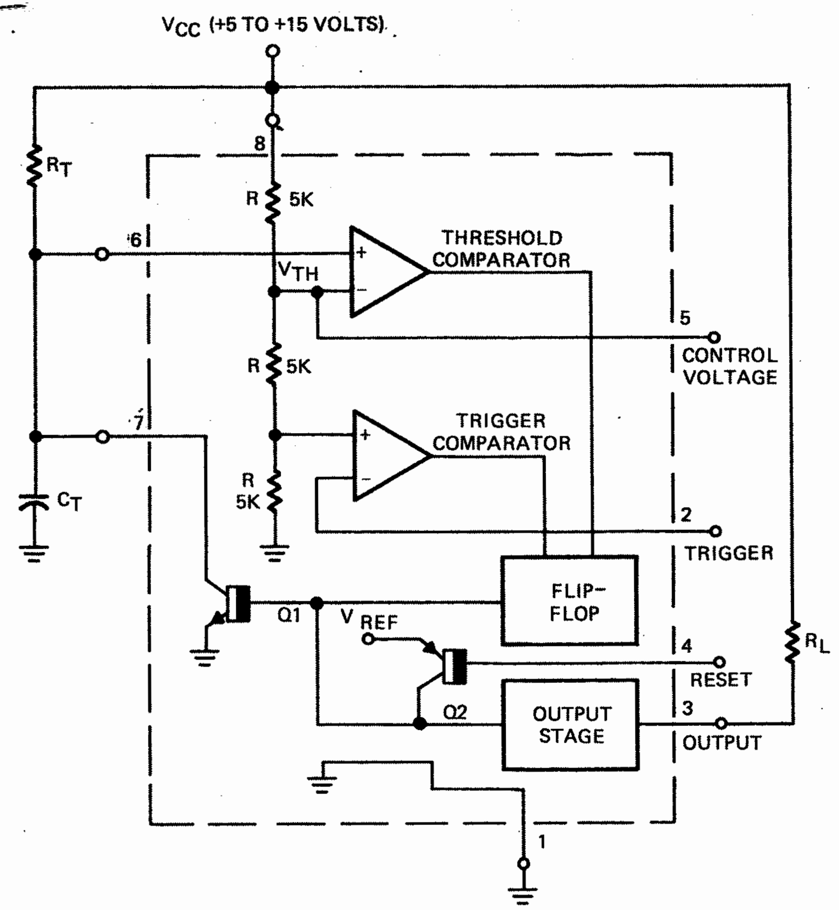


FIG. 2—FUNCTIONAL block diagram.

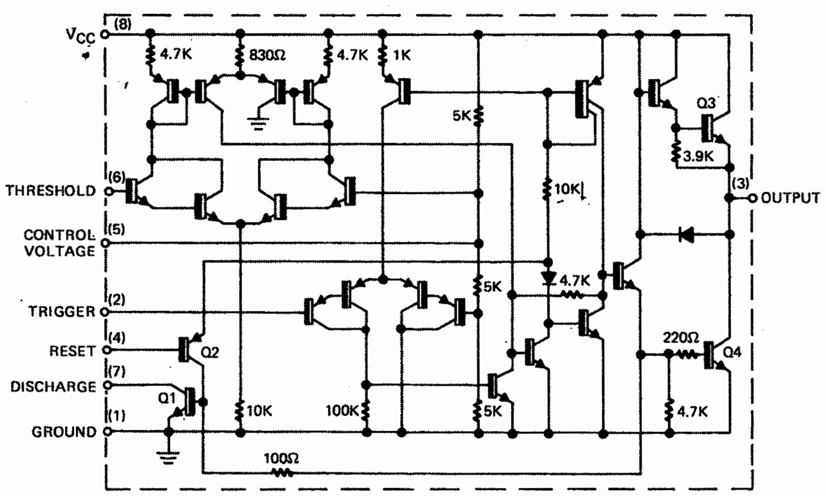


FIG. 3—555 TIMER schematic diagram.

quiescent state, internal transistor Q1 is conducting so it represents a short circuit across timing capacitor C_T. The level of the output terminal is low.

In most practical circuits, the voltage on pin 2 is held above the trigger point by a resistor connected to V_{cc}. When a negative-going trigger pulse on pin 2 causes the potential at this point to fall below ⅓ V_{cc}, the trigger comparator switches the flip-flop, cutting off Q1 and forcing the output level high to a value slightly below V_{cc}.

Capacitor C_T now starts to charge and the voltage across it rises exponentially until it reaches ⅔ V_{cc}. At this point the threshold comparator resets the flip-flop and the output returns to its low state—just slightly above ground. Transistor Q1 is turned on, discharging C_T so that it is ready for the next timing period. Once triggered, the circuit cannot respond to additional triggering until the timed interval has elapsed.

Figure 4 shows the waveforms associated with the 555 when operated as a monostable timer. The delay period—the time that the output is high—in *seconds* is $1.1 R_T C_T$, where R is in *ohms* and C is in *farads*. Figure 5 shows how delays running from 10 microseconds to 10 seconds can be obtained by selecting appropriate values of C_T and R_T in the range of .001 to 100 F and 1K to 10 megohms. In practice, R_T should not exceed 20 megohms. When you use an electrolytic capacitor for C_T, select a unit for low leakage. The time delay may have to be adjusted by varying the value of R_T to compensate for the very wide tolerance of electrolytics.

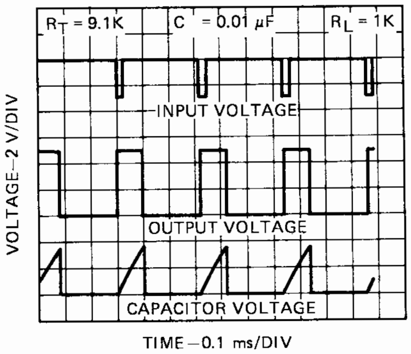


FIG. 4—555 TIMER WAVEFORMS when it is operated as a monostable.

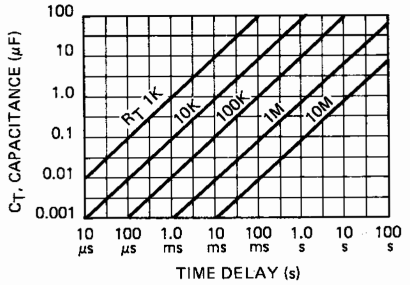


FIG. 5—DELAY TIMES for different values of capacitors and resistors.

Note that the 555, unlike most RC timers, provides a timed interval that is virtually independet of supply voltage V_{cc}. This is because the charge rate of C_T and the reference voltage to the threshold comparator are both directly proportional to the supply voltage. Operating voltage can range from 4.5 volts to a maximum of 18 volts for premium timers and 16 volts for general-purpose types.

Feeding the load

We have seen how the timed interval or delay is obtained. Now lets' see how we can use it. A look at the output circuit (Q3 and Q4 in Fig. 3) shows it to be a quasi-complementary transformerless arrangement similar to many audio output stages. Furthermore, we know that in this type of circuit, one side of the load goes to the emitter-collector junction of the output transistors and the other side of the load can be connected to *either* V_{cc} or to ground. The same applies to the load connected to the 555. Output pulses developed across load R_L can be obtained directly from pin 3.

When the load is connected to V_{cc}, a considerable amount of current flows through the load into terminal 3 when the output is low. Similiarly, when the output is high, the current through the load is quite small. Conditions are reversed when the load is returned to ground. In this case, output current through the load is maximum when the output potential is high and minimum when the output is low. The maximum current at terminal 3 is 200 mA when it is used as a current source or a current sink.

Driving a relay

A relay can be substituted for R_L in applications where the delay or timed interval is longer than 0.1 second. The relay should be a DC type with a coil operating at about V_{cc}, and not drawing more than 200 mA. Figure 6 shows a

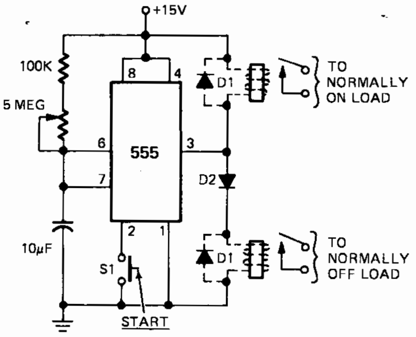


FIG. 6—RELAY TIMER showing two optional connections.

simple manual timer with the two optional connections for the relay. With the R/C values shown, the timing range is approximately 1 second to 1 minute.

You must be careful when connecting an inductive load such as a relay to the output of the 555 or any other solid-state device. When the current through an inductive load is interrupted, the collapsing magnetc field generates a high reverse emf (transient voltage) that can damage the device. The solution to this problem is to connect a diode (D1) across the relay coil so it conducts and absorbs the transient. Note that the diode must be connected so it is reverse biased in normal operation.

Diode D2 must be inserted in *series* with the relay coil when it is connected between the output terminal and ground. Otherwise, a negative voltage equal to one diode-junction drop will appear at pin 3 and cause the timer to latch up.

Triggering

We stated earlier that in most practical circuits, the trigger terminal is generally returned to V_{cc} through a resistor of about 22K. However, the simplest method of triggering a 555 is to *momentarily* ground the terminal. This is OK as long as the ground is removed before the end of the timed interval. Thus, if the device is used in a photo-timer application, as in Fig. 6, tapping pushbutton

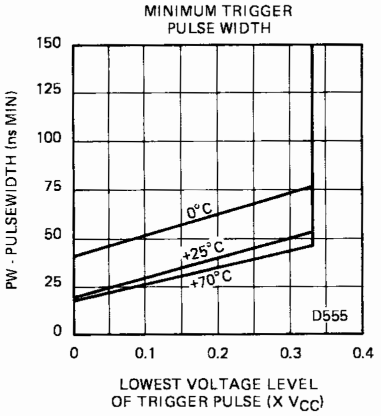


FIG. 7—TRIGGER PULSE WIDTH requirement varies with temperature and Vcc.

S1 is sufficient to trigger the circuit and start the timer.

In many applications, the 555 must be triggered by a pulse. The amplitude and minimum pulse width required for triggering are dependent on temperature and supply voltage. Generally, the current required for triggering is about 0.5 µA for a period of 0.1 µs. Triggering-voltage ranges from 1.67 volts when V_{cc} is 5 volts to 5 volts when V_{cc} is 15 volts. Figure 7 shows how trigger pulse width is related to temperature and V_{cc}.

The triggering circuit is quite sensitive and can be activated by simply touching the terminal with a finger or bringing your hand close to a length of wire fastened to pin 2. Thus, we have the makings of a crude capacitance relay.

Resetting

Once a timed cycle has been initiated by a negative-going pulse on pin 2, the circuit is immune to further triggering until the cycle has been completed. However, the timed cycle can be interrupted by grounding the reset terminal (pin 4) or applying a negative-going reset pulse to it. The reset pulse causes timing capacitor C1 to be discharged and the output to return to its quiescent low state. Reset voltage is typically 0.7 volt and reset current is 0.1 mA. When the reset terminal is not being used, it should be connected to V_{cc}.

The control terminal

The ⅔ V_{cc} point on the internal voltage divider is brought out to pin 5—the control terminal. The timing cycle can be modified by applying a DC control voltage to pin 5. This permits manual or electronic remote control of the timed interval.

The control terminal is seldom used when the timer is operated in the monostable mode and should be grounded through a 0.01-µF capacitor to prevent the timed interval from being affected by pickup of a stray AC or RF signal.

When the timer is operated as an oscillator in the astable mode, the generated signal can be frequency modulated or pulse-width modulated by applying a variable DC control voltage to pin 5. We'll have more on this in the next part of this series.

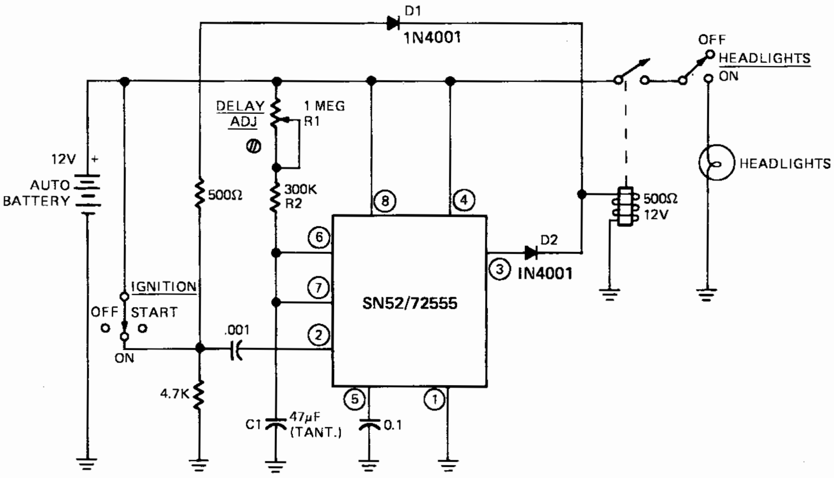


FIG. 8—AUTOMATIC HEADLIGHT turn-off circuit.

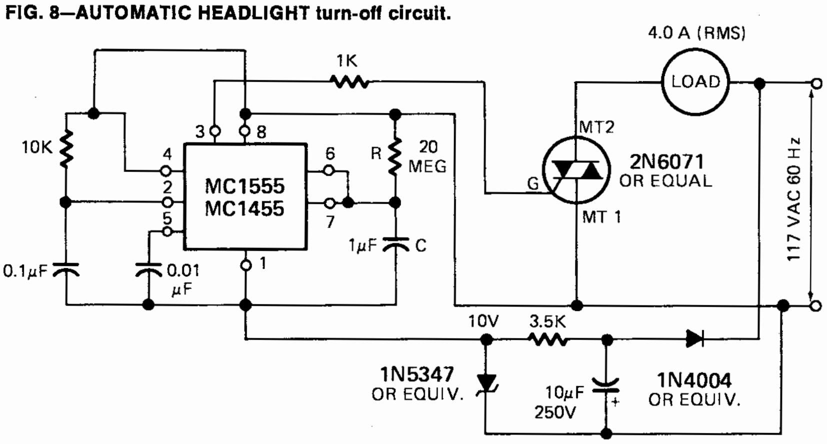


FIG. 9—555 TIMER used in a solid-state time-delay relay circuit.

Gadgets you can build

There is still quite a bit of practical technical information you will need to design your own circuits and to take full advantages of the potential of the 555-family. We hope to complete the technicalities in the next issue and get down to practical circuits you can use. In the meantime, here are a couple of circuits for you to try:

Automatic headlight turn-off—anyone who has stumbled around in a dark garage after leaving his car for the night will appreciate this automatic headlight shut-off switch (Fig. 8.) that was described in a Texas Instruments application note. It is to be installed in the car

(continued on page 102)

555 IC APPLICATIONS
(continued from page 42)

and used to automatically turn off the headlights a predetermined period after the ignition is switched off.

When the ignition is first switched on, battery voltage is fed to the relay coil through the 500-ohm resistor and diode D1. Switching off the ignition generates a negative-going pulse on pin 2 that triggers the timer. The output of the IC goes high to energize the relay and keep the headlights on long enough for you to leave the garage. With the values shown for R1, R2 and C1, the delay is adjustable from 10 seconds to 1 minute.

Timer with solid-state load control—(Fig. 9, from Motorola data sheet) uses a 555 timer to trigger a triac operating as a solid-state relay controlling a 4-ampere, 117-volt AC load. The 20-megohm resistor and 1-μF capacitor provide a 22-second delay in the application of power to the load.

A circuit of this type can be used in applications where two or more operations must be performed in a timed sequence. It might be used to delay the application of power to a fuel pump or gas valve in an industrial or domestic heating system until an exhaust fan has been running long enough to purge unburnt fuel. Or, perhaps it can be used to start the blower of an air conditioner before the compressor. Can you think of any applications for such a circuit?

R-E

Illegal Citizens band operator sentenced to year in jail

Ronald Eugene Evans, San Bernadino, CA, was fined $2,000 and sentenced to a year in prison by Judge Manuel Real of the U.S. District Court for the Central District of California last September, for operating a Citizens band transmitter without a proper license.

The conviction was the result of a month-long investigation by the FCC, responding to numerous complaints of television interference received from San Bernadino TV users. Besides operating without a license, Evans was found to be operating with an 800-watt linear amplifier, which put out 200 times as much power as is permitted.

Los Alamos judge has electronic as well as legal savvy

California physicist Paul VanderMaat answered a speeding charge with the defense that the ionized air that precedes a thunderstorm can affect a radar speed unit. He had been clocked—incorrectly, he said—by a police radar at 33 miles per hour in a 25-mile zone.

The judge, Raymond E. Hunter, agreed that ionization or static electricity accompanying an electric storm could result in a false radar reading, stating:

"Only in Los Alamos could a defendant use a principle of advanced physics and have a judge understand what he's talking about."

Hunter, who serves only part time as a Municipal Court judge, is, like VanderMaat, a theoretical physicist at Los Alamos Scientific Laboratory.

555 IC TIMER CIRCUITS

PART II *The 555 IC timer has a wide variety of applications. This month we will discuss various multivibrator circuits—how they work and how to control their output frequency.*

by ROBERT F. SCOTT
TECHNICAL EDITOR

LAST MONTH WE COVERED THE OPERATION of the 555 timer as a time-delay or pulse generator operating in a monostable mode. We noted that the time delay is controlled by one external resistor R_T and one external capacitor C_T and that the timed interval or delay (in seconds) is 1.1 ($R_T \times C_T$), where R_T is in *ohms* and C_T is in *farads* or where R_T is in *megohms* and C_T is in *microfarads*.

How long, how short?

The minimum length of the output pulse (time delay) is a function of the IC itself. First, the trigger pulse must be applied to the trigger terminal for at least ɔ0–100 nanoseconds (see Fig. 7, last month). The second, and major, factor contributing to the minimum delay is the time it takes the threshold comparator to react when the timing capacitor charge reaches ⅔ V_{cc}. Because of the variations in the internal construction of the IC and on temperature and other external influences, do not try for time delays or pulses shorter than about 5 µs.

The longer the timed period, the larger the values of C_T and R_T. The maximum practical value for R_T is 20 megohms. The maximum practical value of C_T is determined by the availability of low-leakage electrolytic capacitors. I have constructed an experimental 10-minute timer that operated quite reliably with a 3.9-megohm resistor and a 150-µF tantalum capacitor.

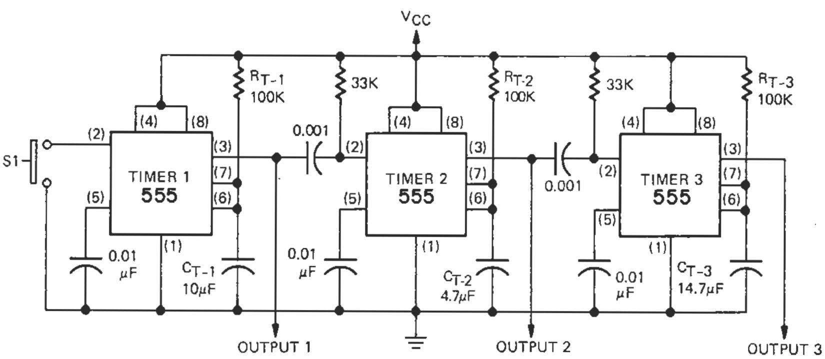
If you require a timer with exceptionally long intervals, resulting in unreasonable values for C_T and R_T, there are several methods that you can use. Perhaps the simplest is to use two or more timers in cascade—the output of the first triggers the second and so on. The resulting time delay is the sum of the multiple delays.

Figure 10 shows a sequential timer consisting of three 555's. It was designed for initiating three operations in sequence. For example, it can be used to apply power to cooling fans, then turn on the filaments in mercury-vapor rectifiers and then apply ˈate voltage to the rectifier plates. The ˌutput waveforms are shown in Fig. 11. In this case, the delays are in the order of seconds. For longer delays, of say 20 minutes, timers 1 and 2 could each be set for 10 minutes. Timer 3 could be adjusted to provide the required pulse width.

For even longer timed intervals— for example, in time-lapse photography we might want to operate a movie camera for 10 seconds every 8 hours—the 555 can be connected as a free-running oscillator feeding into a chain of counters that expand the time delay by the number of divide-by-2 stages. In the case of the 8-hour photography timer, we can connect the 555 as a 7.5-minute recycling timer (multivibrator) and feed its output into a six-stage divide-by-2 to multiply the delay by 64. The counter chain feeds a seconc 555 to expand the output pulse to the de sired 10 seconds.

Free-running oscillator

When the 555 is used in the astable o self-triggering mode to form an oscillato (Fig. 12), the timing resistance R_T is di vided into sections $R_{T\text{-}a}$ and $R_{T\text{-}b}$ with th discharge terminal (pin 7) connected tc the junction of the two resistors. The trig ger (pin 2) is connected to the threshol terminal (pin 6) to insure oscillation.



S1 CLOSES MOMENTARILY AT t = 0.

FIG. 10—SEQUENTIAL TIMER consisting of three 555's.

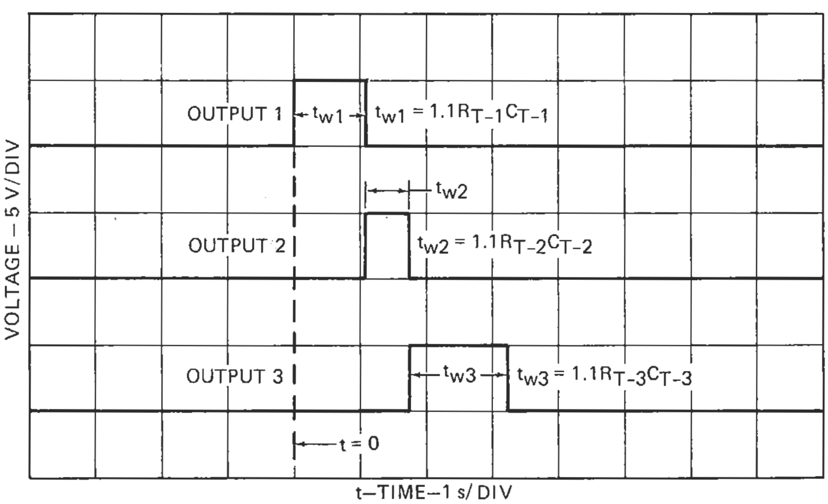


FIG. 11—OUTPUT WAVEFORMS of the sequential timer shown in Fig. 10.

When V_{cc} is first applied to the circuit (time = 0), capacitor C_T (Fig. 13) charges to ⅔ V_{cc} through $R_{T\text{-}a}$ and $R_{T\text{-}b}$ during time t1 and then discharge to ⅓ V_{cc} through $R_{T\text{-}b}$ during time t2. The delay cycle can be controlled by selecting values for $R_{T\text{-}a}$ and $R_{T\text{-}b}$ as the voltage on C_T swings between ⅔ V_{cc} and ⅓ V_{cc} as in Fig. 13.

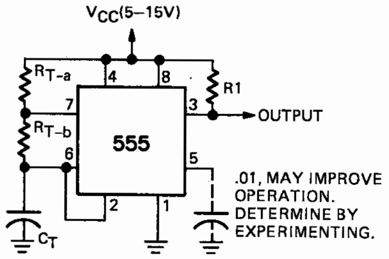


FIG. 12—ASTABLE MULTIVIBRATOR using a 555.

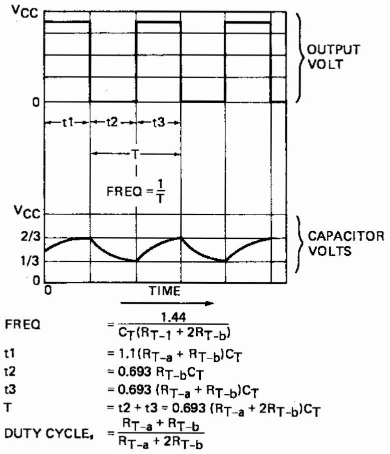


FIG. 13—OUTPUT WAVEFORM and capacitor voltage of the astable multivibrator.

As capacitor C_T starts charging toward ⅔ V_{cc}, the output goes high and remains so for period t1—in seconds equal to 0.693 ($R_{T\text{-}a}$ + $R_{T\text{-}b}$) C_T. The discharge period—the time that the output is low—is 0.693 ($R_{T\text{-}b}$) C_T. Frequency is the reciprocal of the total time period (T) or 1.44/($R_{T\text{-}a}$ + 2$R_{T\text{-}b}$) C_T. The free-running frequency of the multivibrator can be determined from Fig. 14 which relates frequency in *hertz* to C_T, $R_{T\text{-}a}$ and $R_{T\text{-}b}$. Note that if $R_{T\text{-}b}$ is greater than ½$R_{T\text{-}a}$, the circuit cannot oscillate because the voltage at pin 2 cannot drop to ⅓ V_{cc} so that the circuit can retrigger.

Duty cycle

The duty cycle depends on the values of $R_{T\text{-}a}$ and $R_{T\text{-}b}$ and is equal to ($R_{T\text{-}a}$ + $R_{T\text{-}b}$)/($R_{T\text{-}a}$ + 2$R_{T\text{-}b}$). It can be set from slightly above 50% to nearly 100%. The maximum duty cycle—the on-time divided by the total time is approximately 100%—is developed when $R_{T\text{-}a}$ is as small as possible while still sufficiently large to limit the current through the discharge transistor (Q1 in Fig. 3) to a level that does not exceed the value specified for the specific device.

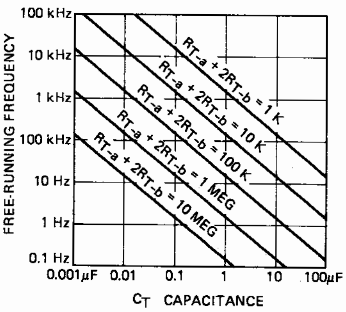


FIG. 14—FREQUENCY of the astable multivibrator can be determined from the graph.

For duty cycles less than 50%, a diode (D1 in Fig. 15) is connected between the discharge and threshold terminals. Capacitor C_T now charges only through $R_{T\text{-}a}$ ($R_{T\text{-}b}$ is shorted by diode conduction during the charge cycle) discharges through $R_{T\text{-}b}$ so the duty cycle is now $R_{T\text{-}a}$/($R_{T\text{-}a}$ + $R_{T\text{-}b}$) and can be varied from almost 0 to nearly 100%. Fig. 16 shows the waveforms as the duty cycle is decreased below 50%.

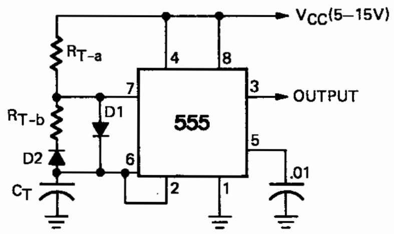


FIG. 15—DUTY CYCLES of less than 50% is achieved by this circuit.

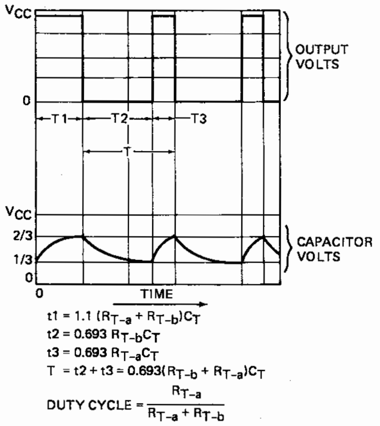


FIG. 16—OUTPUT WAVEFORM and capacitor voltage of astable when duty cycle is less than 50%.

The voltage drop across D1 will prevent the timing cycle from being *completely* independent of $R_{T\text{-}b}$. This can be prevented by installing D2 in series with $R_{T\text{-}b}$ as shown.

In some applications, we may need to vary the duty cycle of a multivibrator from about 0 to 100% while holding the frequency constant. In this case, replace $R_{T\text{-}a}$ and $R_{T\text{-}b}$ with a single linear-pot as in Fig. 17. Resistors R1 and R2—approximately 1,000 ohms each—are connected in series with the pot. R1 limits the maximum current through the discharge transistor. Resistor R2 establishes a minimum value for $R_{T\text{-}b}$ and to compensate for the addition of R1 to the network.

Variable-frequency square-wave generator

If $R_{T\text{-}a}$ and $R_{T\text{-}b}$ are varied simultaneously by equal amounts, we can then develop a variable-frequency square-wave generator as in Fig. 18. Resistors $R_{T\text{-}a}$ and $R_{T\text{-}b}$ should be kept at equal values so as to develop a good square wave with a duty cycle of approximately 50%. If $R_{T\text{-}a}$ and $R_{T\text{-}b}$ are both 500K and C_T is .036 µF, the frequency range of the oscillator will be from about 40 Hz to about 20 kHz. Use linear pots for the most constant duty-cycle throughout the tuning range.

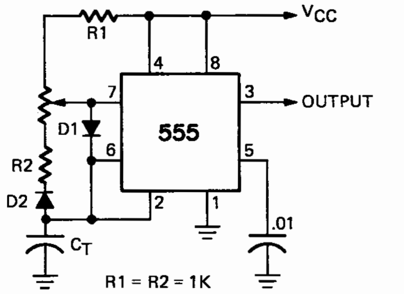


FIG. 17—ASTABLE MUTIVIBRATOR with duty cycle variable from 0 to 100% and frequency constant.

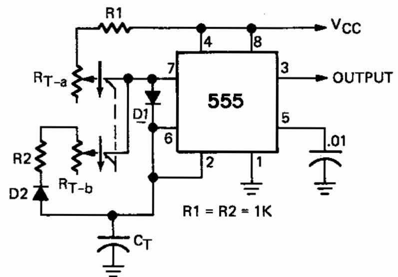


FIG. 18—SQUARE-WAVE GENERATOR with variable frequency and constant duty-cycle.

Selectable monostable/astable operation

You may want to use the 555 both as an astable oscillator and as a pulse generator operated by a signal applied to the trigger terminal. However, with the same values for $R_{T\text{-}a}$, $R_{T\text{-}b}$ and C_T, the time periods will be quite different for the two modes of operation.

In the monostable mode, the duration of the pulse is 1.1RC because C charges from 0 volts to ⅔ V_{cc}; while as an oscillator, the time period is 0.693RC because the charge on C varies between ⅓ V_{cc} and ⅔ V_{cc}. Figure 19 is a circuit (from *Radio Electronica*, Netherlands) showing how the 555 can be operated in both modes at the throw of a switch. A diode is connected between the output and control-

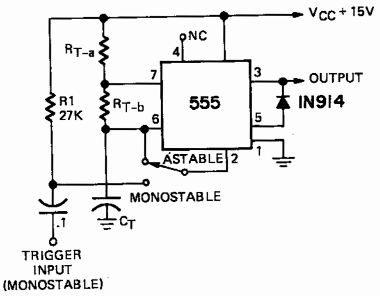


FIG. 19—ASTABLE OR MONOSTABLE operation can be selected by a switch.

volt voltage terminals, pins 3 and 5, respectively. With the diode in place, the reference voltage to comparator 1 (pin 5) is pulled down to approximately 0.9 volt when the output goes low. The fixed voltage on comparator 2 is now 0.45 volt so the timing capacitor must discharge almost to ground—to about 0.45 volt—before the circuit is retriggered by the voltage on trigger terminal pin 2. The periods of the monostable and astable modes are now equal to within about 5%.

The 555 family

In the months to come, we will give you lots of applications for your car, photo lab, home, as test instruments and many others. The 555-type of timer IC is available as a dual and as a quad device. You may want to adopt the device in some of the circuits that will follow or use in circuits that you develop as you become more familiar with the device. Before we get too far along, let me warn you of some pitfalls to watch out for.

The 556 is defined as a dual timing circuit containing two independent 555-type timers on a single monolithic chip. The pin configuration for the basic Signetics NE/SE556 dual timer is shown in Fig. 20-a. This same configuration is used in the XR-556 and many others. But, if you use the XR-2556 or the D555 by Teledyne, watch out: The pin connections are different as you'll see in Fig. 20-b.

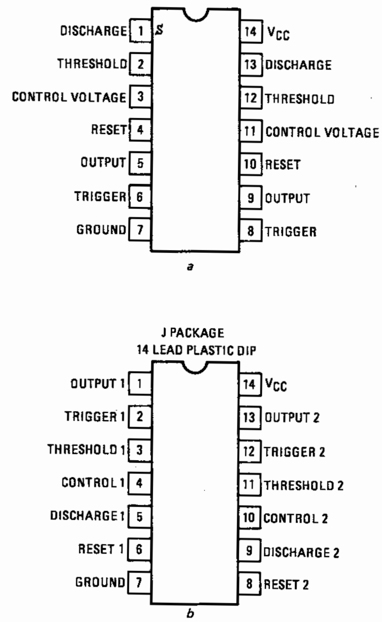


FIG. 20—PIN CONFIGURATION for Signetic's NE/SE556 and many others is shown in a. Exar's XR-2556 and Teledyne's D555 is shown in b.

Another thing to be careful of is the *output load*. The 555 can either sink or source up to 200 mA. Some duals—the Raytheon 556, XR-2556 and Teledyne D555, for example—can source or sink 200 mA while the Signetics 556 and XR-556 have a maximum current drive capability of only 150 mA per output. The 553's output *sinks* (consumes) 150 mA while the 554's output *sources* (supplies) 150 mA.

Quad timers such as the 553 have their threshold and discharge functions connected for use only in the monostable mode. If you want to use a quad timer as a free-running oscillator, the best bet is to use *two* sections with their output and trigger terminals cross-connected. A load can be connected in series with each trigger/output pair and V_{cc}. The time constants in the threshold circuit of each timer can be adjusted for frequency and duty cycle.

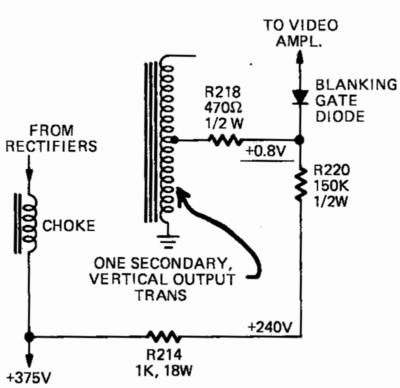
That's it for now. Next month, we'll give some really practical circuits that you will enjoy putting to work.

(To be continued)

BIG RESISTOR BLOWS

I replaced the horizontal output tube in this Zenith 20X1C38, and it promptly got red hot. Checking, I found the horizontal oscillator wasn't working, and that R214, 1000-ohms 18-watts, had blown out. Later, I discovered that R218 (470 ohms) and R220 (150K) were burnt up. These are in the blanking circuit. Replacing all of these and turning the set on (cautiously!), it worked. Question: why did that big resistor blow out?—W.B., Marietta, GA.

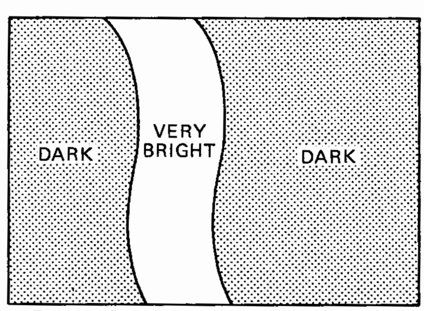
Honest answer; I don't know! However, I have replaced quite a few of these resistors in this chassis! If you use a 20–25 watt Brown Devil or similar type, it holds. There is no apparent reason, since in addition to the size, it is also mounted in a heat-sink clip on the chassis.



For a crystal-ball guess on the failure of the other two, I'd say that the 150K had arced internally and gone away down in value. The 470-ohm returns to ground through the heavy secondary winding of the vertical output transformer. So, it promptly overheated and went out too. Of course, in normal operation, the high resistance of R220, 150K, is enough to hold the current in this circuit to a very low value. "After the fact", there's no way of telling which one went out first.

WEIRD RASTER

I never saw anything like this before! All I can get on this G-E DC chassis portable is a weaving bright line about three inches wide (see diagram). If I turn the brightness full on, I can see a dim raster, but the vertical bar is much brighter. There's a hum in the sound, too. I've checked the horizontal output transformer, tubes, and so on, and the horizontal AFC. No luck. Give me a good place to start!—C.H., Allentown, PA.



I can give you a very *good* place to start. Check the filter capacitors! The best way to do this is with a scope. Look for *any kind* of *signal* on their terminals. Since this is a tube-type chassis, you can bridge them with good ones without trouble.

Whenever you see any kind of screwball symptom that you can find no logical explanation for, go to the filter capacitors and see if one of them is *open*. If so, this sets up a feedback loop through the DC power supply.

WHISTLE, CAR RADIO

This Bendix auto-radio, whistles! Sometimes it can be reduced by careful tuning, but it's usually audible. Shows up on all stations, even strong ones. Sounds lik a regenerative set!—W.F.

It is! This sounds very much like regeneration due to a feedback loop somewhere in the set, probably in the IF. Even though this is a battery powered set, it needs filter capacitors. Without these, your DC supply lines will allow a feedback loop to form. This causes the oscillation and whistling.

Check the chassis carefully for a --ɔd big electrolytic capacitor. This will probably be found open. If the DC supply capacitor is OK, check for a similar unit on the AVC line.

GREEN FLASH AT TURN-ON

When I turn this RCA CTC-24 on, I get a light, medium-green raster for about 8-12 minutes. Then a normal picture, purity and all, and it stays on until I turn it off and let it cool for a good while. Any ideas?—E.G.

Could be a heater-cathode short in the green gun, but this would also wipe out the video. I believe that it is a bad solder joint somewhere around the plate circuit of the G-Y diff-amp tube, or perhaps a dirty plate contact on that tube's socket. Look for the little pale blue 3-watt plate load resistors behind the color difference amplifier tubes and check the solder joints on the PC board. **R-E**

555-type timer used to shape square waves

For a low-cost square-wave shaper, try the 555-type IC timer—a suggestion from Joe R. Wild, a product engineer for the B.F. Goodrich Co. in Akron, Ohio. This device's comparator characteristics make it a fast-switching wave shaper ideal for optical circuits, or when you want to use the ac line frequency as a clock reference. **Any positive waveform can be squared up.**

Wiring the timer is easy. The signal to be squared is applied to the timer's threshold and trigger pins, which are tied together. The reset and V_{CC} pins are also tied together and then run to the supply voltage. The ground and output pins are the standard types. (Discharge and control-voltage pins are not used.) **—Laurence Altman**

EQUATION WRONG, VALUES RIGHT

In "Applications For the IC 'Time Machine'," there appears to be an error. In the SW oscillator circuit on page 74, the equation for the operating frequency was given as $1.43/(R_2C_1)$, which is incorrect. The correct equation is $F \approx 1.43/(2R_2C_1)$.

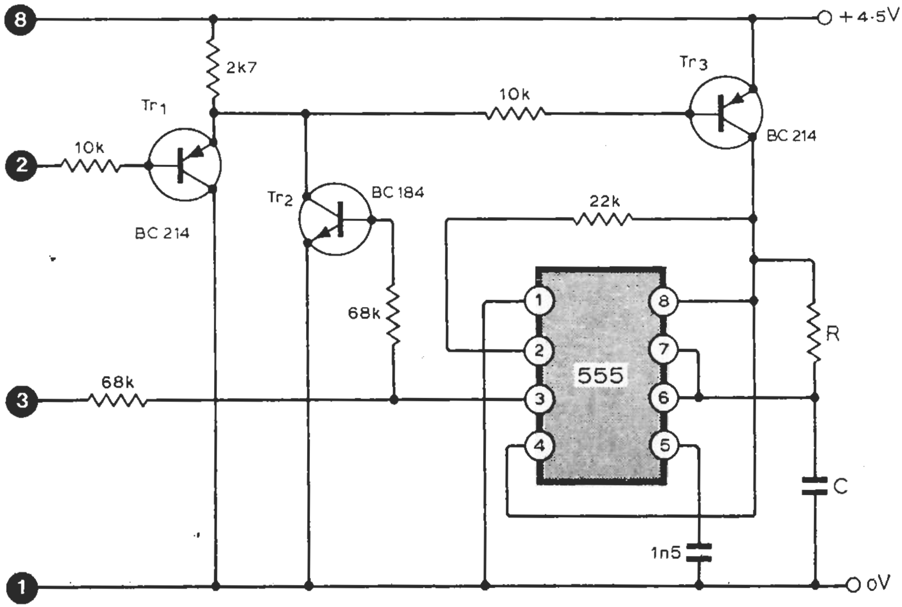
ALFRED GNAEDIG
Mexico City, Mexico

The author replies: "Asume t_1 to be the time during which the signal is at 'high' and t_2 the time during which it is at 'low.' Then, $t_1 = 0.7(R_1 + R_2)C_1$ and $t_2 = 0.7R_2C_1$. If $R_1 \ll R_2$, $t_1 = t_2 = 0.7R_2C_1$ and $T = t_1 + t_2 = 2(0.7R_2C_1)$. Therefore $f = 1/T = 1/0.7(2R_2C_1)$ or $1.43/(2R_2C_1)$ exactly as Mr. Gnaedig states. The f and T expressions on page 74 of the article are incorrect, but the values in the example are correct for 100 Hz as given."

Low current 555 timer

IN THE OFF STATE the supply current to a 555 timer is about 3mA. For battery powered circuits where this is too high the modified circuit shown can be used. This reduces the current to about 2µA although the on state current rises to about 3.5mA. Other properties of the timer remain practically unaltered. When the circuit is off, pin 2 is disconnected from ground so Tr_1 and Tr_3 are turned off. Because the 555 has no supply voltage Tr_2 is also off. When a negative trigger pulse is applied to pin 2, Tr_1 and Tr_3 are turned on and connect the timer to the supply rail. A positive pulse from pin 3 of the timer turns Tr_2 on which keeps Tr_3 on. After the delay period has elapsed the timer returns to the off state. Connections 4, 5, 6 and 7 of the i.c. are still used but pins 1, 2, 3 and 8 are replaced by the new connections.

Dr O. B. Hellman,
Turku,
Finland.



555 TIMER APPLICATIONS

DESCRIBED BY R. M. MARSTON

THE 555 TIMER is a highly versatile low-cost IC that is specifically designed for precision timing applications, but which can also be used in a variety of monostable multi-vibrator, astable multivibrator, and Schmitt trigger applications. The device was originally introduced by Signetics, but is now available under the '555' designation from many other manufacturers.

The 555 has many attractive features. It can operate from supply voltage in the range 4.5V to 16V. Its output can source (supply) or sink (absorb) any load current up to a maximum of 200mA, and so can directly drive loads such as relays, LED's, low-power lamps, and high impedance speakers. When used in the 'timing' mode, the IC can readily produce accurate timing periods that can be varied from a few microseconds to several hundred seconds via a single R-C network. Timing periods are virtually independent of actual supply rail voltage, have a temperature coefficient of only .005% per °C, can be started via a TRIGGER command signal, and can be aborted by a RESET command signal.

When used in the monostable mode, the IC produces output pulses with typical rise and fall times of a mere 100nS. It can be made to produce pulse-width modulated (PWM) pulses in this mode by feeding fixed frequency clock pulses to the TRIGGER terminal and, by feeding the modulation signal to the CONTROL VOLTAGE terminal.

When used in the astable mode both the frequency and the duty cycle of the waveform can be accurately controlled with two external resistors and one capacitor. The output signals can be subjected to frequency sweep control, frequency modulation (FM), or pulse-position modulation (PPM) by applying suitable modulation signals to the CONTROL VOLTAGE terminal of the IC.

THE 555: HOW IT WORKS

The 555 is available under a variety of specific type numbers but is generally referred to simply as a '555 timer.' The device is available in a number of packaging styles, including 8 and 14-pin dual-in-line (DIL) and 8-pin TO-99 types. Throughout this article all circuits are designed around the standard 8-pin DIL versions of the device.

Fig 1 shows the outline and pin notations of the standard 8-pin DIL version of the 555, and Fig 2 shows the functional block diagram of the same device (within the *double* lines), together with the connections for using it as a basic monostable generator. The following explanation of device operation assumes that the 555 is used in the monostable configuration shown in Fig 2.

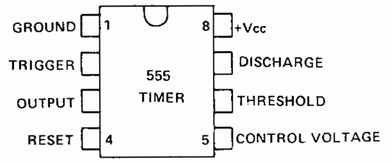


Fig. 1: Outline and pin notations of the standard 8-pin dil version of the 555 timer I.C.

The 555 houses 2 diodes, 15 resistors, and 23 transistors. These components are arranged in the form of one voltage-reference potential divider, two voltage-comparator op-amps, one R-S flip-flop, a low-power complementary output stage, and a slave transistor. The voltage-reference potential divider comprises three 5kΩ resistors in series, and is connected across the supply lines. Consequently, 2/3 V_{cc} appears at the junction of the upper two resistors of the potential divider, and is fed to one input terminal of the upper voltage-comparator op-amp and 1/3 V_{cc} appears at the junction of the two lower resistors of the potential divider, and is fed to one input terminal of the lower voltage-comparator op-amp. The outputs of the two comparators control the R-S flip-flop, which in turn controls the states of the complementary output stage and the slave transistor. The state of the flip-flop can also be influenced by signals applied to the pin 4 RESET terminal.

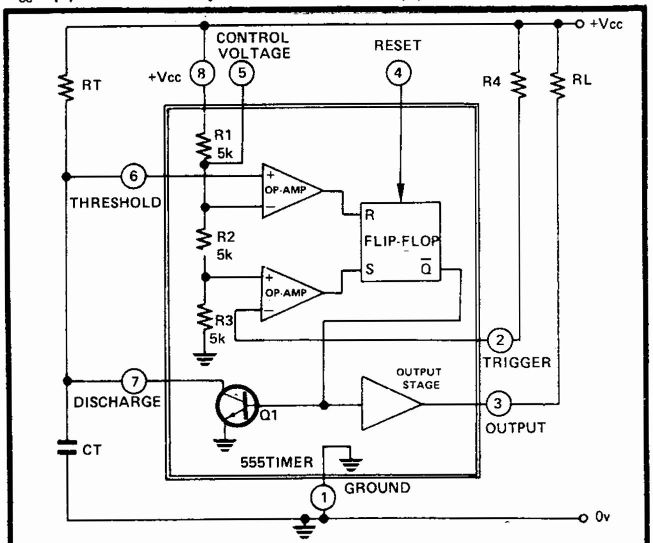


Fig. 2: Functional block diagram (within the square) of the 555 timer i.c., together with the connections for using the i.c. as a basic monostable generator or timer.

When the monostable or timing circuit of Fig 2 is in its quiescent state the pin 2 TRIGGER terminal of the chip is held high via R1. Under this condition Q1 is driven to saturation and forms a short circuit across external timing capacitor C_T, and the pin 3 output terminal of the IC is driven to the low state. The monostable action can be initiated by applying a negative-going trigger pulse to pin 2. As this pulse falls below the 1/3 V_{cc} reference value of the built-in potential divider the output of the lower voltage comparator op-amp changes state and causes the R-S flip-flop to switch over. As the flip-flop switches over it cuts off Q1 and drives the pin 3 output of the chip to the high state.

As Q1 cuts off it removes the short from timing capacitor C_T, so C_T starts to charge exponentially towards the supply rail voltage until eventually the voltage across C_T reaches 2/3 V_{cc}. At this point the upper voltage comparator op-amp changes state and switches the R-S flip-flop back to its original condition, so Q1 turns on, rapidly discharging C_T, and simultaneously the pin 3 output of the IC reverts to its low state. The monostable operating sequence is then complete. Note that, once triggered, the circuit cannot respond to additional triggering until the timing sequence is complete, but that the sequence can be aborted at any time by feeding a negative-going pulse to pin 4.

The delay time of the circuit, in which the pin 3 output is high, is given as

$$t = 1.1\ R_T\ C_T$$

where t = mS, R_T = kΩ, and C_T = μF. Fig 3 shows how delays from 10μS to 100 seconds can be obtained

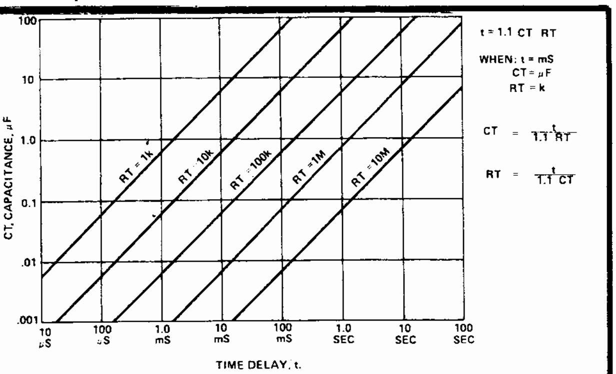


Fig. 3: 555 time delays for different values of resistance and capacitance.

by selecting suitable values of C_T and R_T in the range .001μF to 100μF and 1kΩ to 10MΩ. In practice, R_T should not be given a value less than 1kΩ or greater than 20MΩ, and capacitor C_T must always be a low-leakage component. Note that the timing period of the circuit is virtually independent of the supply voltage but that the period can be varied by applying a variable resistance or voltage between the ground and pin 5 CONTROL VOLTAGE terminals of the chip. This facility enables the periods to be externally modulated or compensated.

The pin 3 output terminal of the IC is normally low, but switches high during the active monostable sequence. The output can either source or sink currents up to a maximum of 200mA, so external loads can be connected between pin 3 and either the positive supply rail or the ground rail, depending on the type of load operation that is required. The output switching rise and fall times are typically about 100 nanoseconds. Having cleared up these points, let's now go on and look at some practical applications of the 555 timer I.C.

50 SECOND TIMER

This 50 second timer or pulse generator gives a direct voltage output at pin 3 which is normally low, but goes high for the duration of the timing period. Optional components R_4 and LED (shown dotted) give a visual indication of the timer action. The circuit works in the same basic way as already described, except that the timing action is initiated by momentarily shorting pin 2 to ground via START switch S_1. Note from the circuit waveforms that a fixed-period output pulse is available at pin 3 and an exponential sawtooth with an identical period is available at pin 7: The sawtooth waveform has a high output impedance.

The basic timer circuit of Fig 4 can be varied in a number of ways. The timing period can be made variable between approximately 1.1 seconds and 110 seconds by replacing R_1 with a 10kΩ fixed resistor and a 1MΩ variable resistor in series.

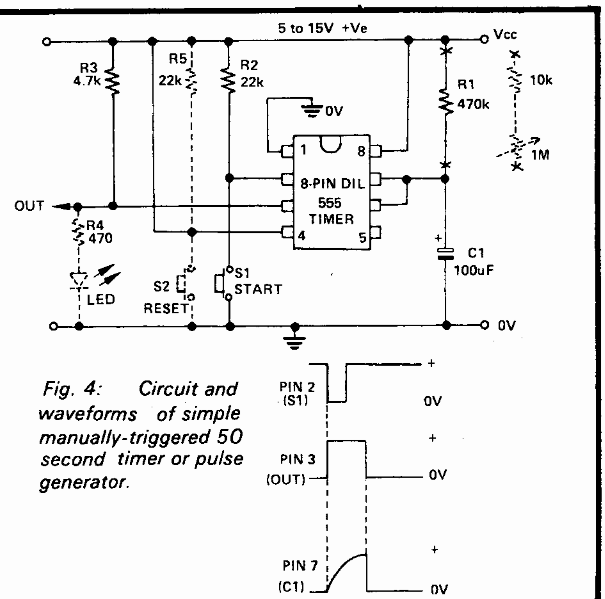


Fig. 4: Circuit and waveforms of simple manually-triggered 50 second timer or pulse generator.

The period can be further varied, if required, by switch-selecting decade values of timing capacitance. The dotted section shows how the circuit can be provided with a RESET facility, so that a timing period can be aborted at any time, by taking pin 4 to the positive supply rail via resistor R_5 and wiring RESET switch S_2 between pin 4 and ground.

The timing circuit of Fig 4 can be used to drive non-inductive loads at currents up to 200mA directly. They can be used to drive inductive relay loads by using the basic connections shown in Fig 5.

The Fig 5 circuit is designed to apply a connection to a normally-off external load for a pre-set period of 50 seconds when START switch S_1 is momentarily closed. The relay is normally off, but turns on for the 50 second period when the timing cycle is initiated. D_2 is wired in series with the relay coil to counteract the slight residual

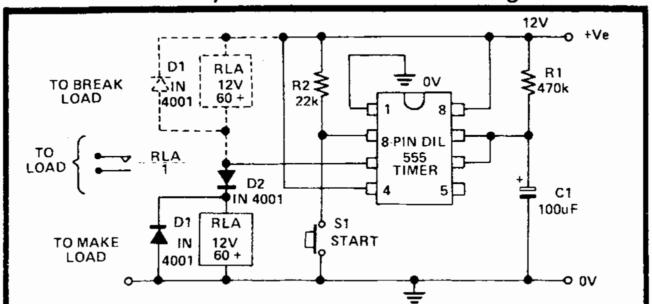


Fig. 5: Relay-output timer makes or breaks connection to load for pre-set period of 50 seconds when S, is momentarily operated.

voltage that appears at pin 3 of the IC under the OFF condition and thus ensure that the relay turns fully off. The dotted section shows how this circuit can be used to switch off a normally-on load.

Note in Fig 5 and all other relay-output circuits described here, that the relays used can be any 12 volt types that draw ON currents of less than 200mA, e.g., that have coil resistances greater than 60Ω.

The basic relay-driving timer circuit of Fig 5 can be adapted for use in a variety of useful applications. Some typical examples are shown in Figs 6 to 9.

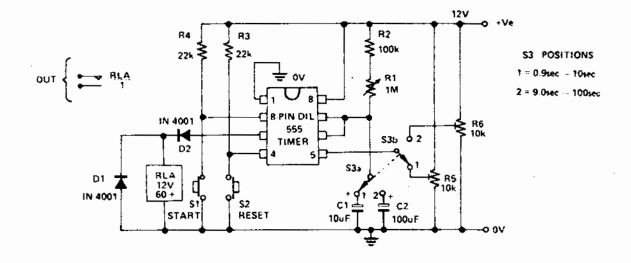


Fig. 6: Relay-output general-purpose timer covers 0.9 sec to 100 sec in two decade ranges.

Fig 6 shows the practical circuit of a relay-output general-purpose timer that covers 0.9 seconds to 100 seconds in two decade ranges: The circuit has a RESET facility provided via S_2, so that timing periods can be aborted part way through a cycle if necessary. A noteworthy feature of this circuit is that the maximum timing periods of each decade range of the timer can be precisely pre-set via R_5 or R_6, which effectively shunt the built-in potential divider of the 555 and thus influence the timing periods: This facility enables the circuit to give precise timing periods even when wide-tolerance timing capacitors are used.

To set up the Fig 6 circuit, first set R_1 to maximum value, set RANGE switch S_3 to position 1, activate START switch S_1, and adjust R_5 to give a timing period of precisely 10 seconds. Next, set S_3 to position 2, activate START switch S_1, and adjust R_6 to give a timing period of precisely 100 seconds. All adjustments are then complete, and the timer is ready for use.

DELAYED HEADLIGHT TURN-OFF

Fig 7 shows the practical circuit of an automatic delayed-turn-off headlight control system for automobiles. This facility enables the owner to use the car lights to illuminate his path for a pre-set time after parking as he leaves the garage or walks along a driveway, etc. The circuit does not interfere with normal headlight operation under actual driving conditions. It works as follows.

When the ignition switch is turned to the ON position current is fed to the coil of the relay via D_3 and the 12 volt supply rail, so the relay turns on and contacts RLA/1 close. As the contacts close they connect the 12 volt supply to the timer circuit and to the headlight switch. Thus, under this 'ignition on' condition the headlights operate in the normal way. Note that, since one side of C_2 is connected directly to the positive supply rail and the other side is taken to the positive rail via R_2, the capacitor is fully discharged under this condition.

The moment that the ignition switch is turned to the OFF position the D_3-derived current supply to the relay coil is broken, and simultaneously a negative-going trigger pulse is fed to pin 2 of the 555 as the C_2-R_3 junction drops to ground volts and C_2 charges up. Now, relays are inherently slow-acting devices, so contacts RLA/1 do not open instantaneously as the ignition switch is turned off. Conversely, the 555 is a very fast triggering device, and the instant that the trigger pulse is generated via the turn-off action of the ignition switch a timing cycle is initiated and current is fed to the relay coil via output pin 3 of the IC as it goes high. Thus the relay remains on for a pre-set period after the ignition switch is closed, and the positive supply rail remains connected to the headlight switch for the duration of this period. With the component values shown this period is roughly 50 seconds.

At the end of the 50 second timing period, pin 3 of the 555 switches to the low state and the relay turns off. As it does so, contacts RLA/1 open and remove the supply from the timer and the headlight switch, and the headlights turn off. The operating sequence is then complete.

Readers may care to note that the above system of operation is consistent with the practice adopted in many modern vehicles of feeding the headlight switch via the ignition switch, so that the headlights operate only when the ignition is turned on. On older types of vehicle, where headlight operation is independent of the ignition switch, a manually-triggered delayed-turn-off headlight or spotlight control facility can be obtained by using the circuit shown in Fig 8. The action of this circuit is such that, if the vehicle is parked with its lights off, they turn on for a pre-set 50 second period as soon as a push-button START switch is momentarily closed, and at the end of this period turn off again automatically.

The Fig 8 circuit uses a relay with two sets of normally-open relay contacts. The timing sequence is initiated by momentarily closing push-button switch S_1. Normally, both S_1 and the relay contacts are open, so zero power is fed to the timer circuit and the lights are off. C_2 is discharged under this condition.

When S_1 is momentarily closed power is fed directly to the relay coil, and the relay turns on. As the relay

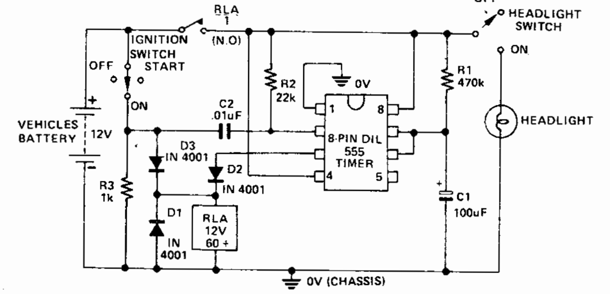


Fig. 7: Automatic delayed-turn-out headlight control system for automobiles.

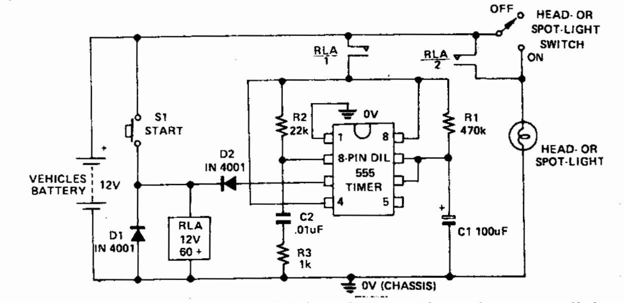


Fig. 8. Manually-triggered delayed-turn-off head- or spot-light control system for automobiles.

turns on contacts RLA/2 close and apply power to the vehicle lights and contacts RLA/1 close and apply power to the timer circuit, but pin 2 of the IC is briefly tied to ground via C_2 and R_3 at this moment, so a negative trigger pulse is immediately fed to pin 2 and a timing cycle is initiated. Consequently, pin 3 of the 555 switches high at the moment that the relay contacts close, and thus locks the relay into the ON condition irrespective of the subsequent state of START switch S_1, so the lights remain on for the duration of the 50 second timing cycle. At the end of the timing cycle pin 3 of the I.C. switches to the low state, so the relay turns off and contacts RLA/1 and RLA/2 open, disconnecting power from the timing circuit and the lights. The operating sequence is then complete.

PORCH LIGHT

Finally, to conclude this 'Timer Circuits' section of the 555 story, Fig 9 shows the circuit of a relay-output automatic porch light control unit that turns the porch lights on for a pre-set 50 second period only when suitably triggered at night time or under 'dark' conditions. The circuit is triggered via switch S_1, which may take the form of a microswitch activated by a porch gate or a pressure-pad switch activated by body weight and concealed under a porch mat or rug.

The operation of the Fig 9 circuit relies on the fact that for correct timer operation the negative-going trigger pulse that is fed to pin 2 of the IC must fall below the internally-controlled '1/3 V_{cc}' voltage value of the 555. If the trigger pulse does not fall below this value, timing cycles can not be initiated by the trigger signal.

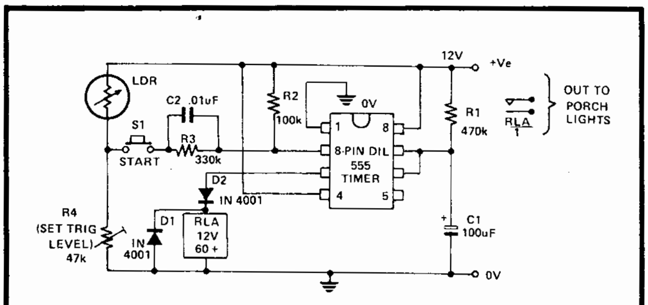


Fig. 9: Automatic porch light turns on for a pre-set period only when triggered at night.

In this design, light-dependent resistor LDR and preset resistor R_4 are wired in series as a light-dependent potential divider. One side of switch S_1 is taken to the output of this potential divider, and the other side of the switch is taken to pin 2 of the IC via the C_2-R_3 combination. Under bright or daylight conditions the LDR acts as a low resistance, so a high voltage appears at the output of the potential divider. Consequently, the act of closing S_1 causes a voltage pulse much higher than '1/3 V_{cc}' to be fed to pin 2 of the chip, so the timer is not triggered via S_1 under the 'daylight' condition.

Conversely, the LDR acts as a high resistance under dark or 'night' conditions, so a low voltage appears at the output of the potential divider. Consequently, the act of closing S_1 causes a voltage pulse much lower than '1/3 V_{cc}' to be fed to pin 2 of the IC, so the time circuit is triggered via S_1 under the 'night' condition.

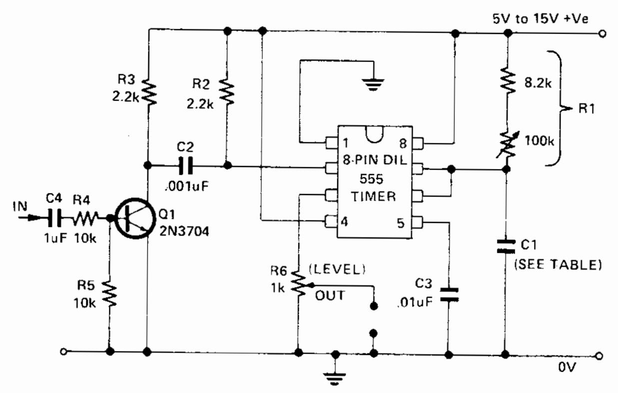
In practice, the LDR can be any cadmium-sulphide photocell that presents a resistance in the range 1kΩ to 100kΩ under the required minimum 'dark' turn-on condition, and R_4 can be adjusted to preset the minimum 'dark' level at which the circuit will trigger. Note that the trigger signal is fed to pin 2 of the IC via the C_2-R_3 combination, which act as a trigger signal conditioning network that effectively isolates the d.c. component of the LDR-R_4 potential divider from the trigger pin of the IC.

MONOSTABLE PULSE GENERATOR CIRCUITS

All the 555 timer circuits that we have looked at so far act essentially as monostable multivibrators or pulse generators. The 555 can be used as a conventional electronically-triggered monostable multivibrator or pulse generator by feeding suitable trigger signals to pin 2 and taking the pulse output signals from pin 3. The IC can be used to generate good output pulses with periods from 5μS to several hundred seconds. The maximum usable pulse repitition frequency is approximately 100kHz.

The trigger signal reaching pin 2 must be a carefully shaped negative-going pulse. Its amplitude must switch from an OFF value greater than 2/3 V_{cc} to an ON value less than 1/3 V_{cc} (triggering actually occurs as pin 2 drops through the 1/3 V_{cc} value). The pulse must have a width greater than 100nS but less than that of the desired output pulse, so that the trigger pulse is removed by the time the monostable period terminates.

One way of determining a suitable trigger signal for the 555 monostable circuit is to convert the input signal to a good square wave that switches between ground volts and the full positive supply rail voltage, and then couple this square wave to pin 2 of the IC via a simple short time-constant C-R differentiating network, which converts the leading or trailing edges of the square



C1 VALUE	PULSE WIDTH RANGE		
10uF	90mS	–	1.2sec.
1uF	9mS	–	120mS
0.1uF	0.9mS	–	12mS
.01uF	90uS	–	1.2mS
.001uF	9uS	–	120uS

Fig. 10a: Simple add-on pulse generator is triggered by rectangular input signals: circuit can be used at trigger frequencies up to 100kHz.

wave into suitable trigger pulses. Fig. 10a shows a practical circuit that uses this basic principle, but is intended for use only with input signals that are already of square or pulse form.

Here, transistor Q_1 converts the rectangular input signal into a signal that switches between the ground and positive voltage rails, and the resulting signal is fed to pin 2 via the C_2-R_2 differentiating network. The circuit can be used as an add-on pulse generator in conjunction with an existing square or pulse generator. Variable-amplitude output pulses are available from pin

3 via variable potential divider R6. The output pulse widths can be varied over more than a decade range via R_1, and can be switched in overlapping decade ranges by using the values of C1 listed in the table. With the component values shown the pulse width is fully variable from 9 μS to 1.2 seconds. Note that C3 is used to decouple the pin 5 CONTROL VOLTAGE terminal and improve the circuit stability.

Fig 10b shows how the above circuit can be modified so that it can be driven from any type of input waveform, including sine waves. Here, IC1 is connected as a simple Schmitt trigger, which converts all input signals into rectangular output signals, and these rectangular signals are used to drive the IC2 monostable circuit in the same way as described above. The Fig 10b circuit can thus be used as an add-on pulse generator in conjunction with an existing waveform generator of any type that produces output signals with peak-to-peak amplitudes greater than 1/2 V_{cc}.

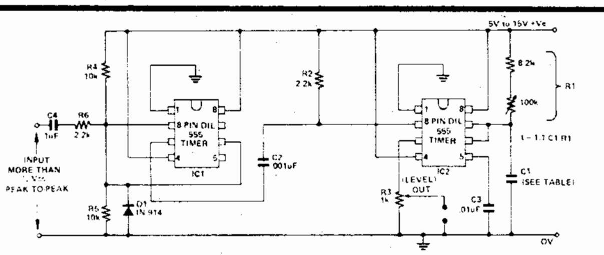


Fig. 10b: Improved add-on pulse generator is triggered by any input waveform.

Fig 11 shows how two basic monostable pulse generators can be connected in series to make a delayed pulse generator, in which IC1 is used as a Schmitt trigger and IC2 controls the delay width and IC3 determines the output pulse width: The final output pulse appears some delayed time after the initial application of the trigger signal. This circuit can be made into a self-contained instrument by building it into the same cabinet as a simple square wave generator, which can be used to provide the necessary drive signals.

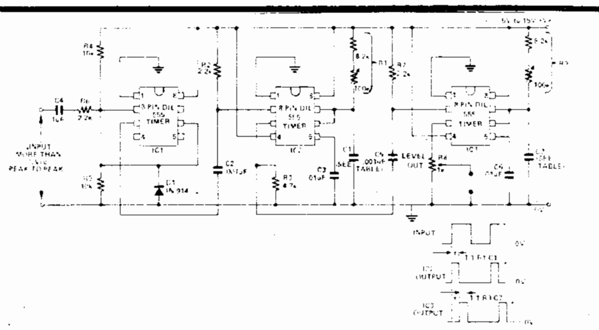


Fig. 11: Add-on delayed pulse generator is triggered by any input waveform. For C1 (and C7) values, see table in Fig. 10a.

Any number of basic monostable pulse generators can be wired in series to give a sequential form of operation. Fig 12 for example, shows the circuit and wave-forms of a 3-stage sequential generator, which can be used to operate lamps or relays, etc., in a pre-programmed time sequence once an initial START command is given via push-button switch S_1. Note that the pin 4 RESET terminal of all ICs are shorted together and positively biased via R7, and that these terminals can be shorted to ground via SET switch S2: This SET switch should be closed at the moment that power is first applied to the circuit, to ensure that none of the ICs are falsely triggered at this moment.

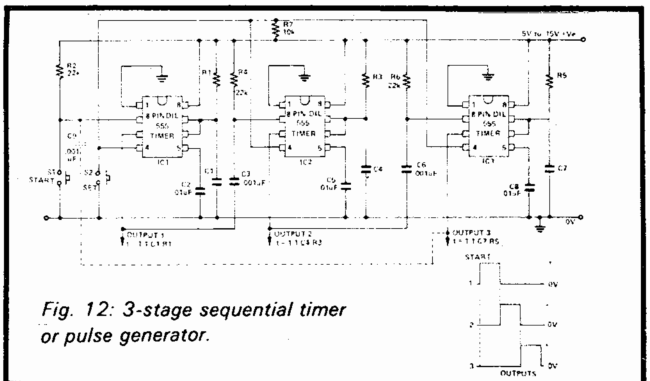


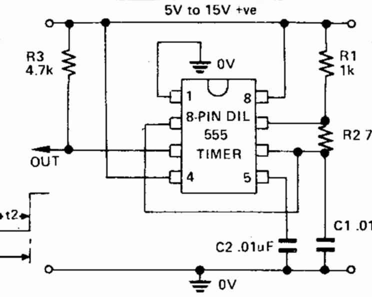
Fig. 12: 3-stage sequential timer or pulse generator.

Finally, three or more monostable circuits can be connected, via C9, in a continuous loop, with the output of the last monostable feeding back to the input of the first monostable, to form a 'chaser' circuit in which the sequential action repeats to infinity. This type of circuit can be used to drive lamp or LED displays, etc. Note that the circuit is again provided with the S_2 SET facility, so that the circuit can be emptied at the moment that power is first applied.

ASTABLE MULTIVIBRATOR CIRCUITS

Fig 13 shows the practical circuit of a basic 1 kHz astable multivibrator, together with the formulas that define the timing of the circuit. Note that TRIGGER pin 2 of the chip is shorted to the pin 6 THRESHOLD terminal, and that timing resistor R2 is wired between pin 6 and DISCHARGE pin 7.

When power is first applied to the circuit C1 starts to charge exponentially (in the normal monostable fashion) via the series R1-R2 combination, until eventually the C1 voltage rises to 2/3 V_{cc}. At this point the basic monostable action terminates and DISCHARGE pin 7 switches to the low state. C1 then starts to discharge exponentially into pin 7 via R_2, until eventually the C1 voltage falls to 1/3 V_{cc}, and TRIGGER pin 2 is activated. At this point a new monostable timing sequence is initiated, and C1 starts to recharge towards 2/3 V_{cc} via R1 and R2. The whole sequence then repeats add infinitum, with C1 alternately charging towards 2/3 V_{cc} via R1-R2 and discharging towards 1/3 V_{cc} via R2 only.



$t1 = 0.693(R1 + R2)C1$

$t2 = 0.693(R2)C1$

$T = 0.693(R1 + 2R2)C1$

$f = \frac{1.44}{(R1 + 2R2)C1}$

IF R2 IS GREATER THAN R1:

$t1 = 0.7\ R2\ C1$

$t2 = 0.7\ R2\ C1$

$T = 1.4\ R2\ C1$

$f = \frac{0.72}{R2\ C1}$

Fig. 13: Basic circuit of 1KHz astable multivibrator, with timing formulas.

Note in the above circuit that, if R2 is very large relative to R1, the operating frequency of the circuit is determined essentially by the R2 and C1 values, and that a virtually symmetrical output waveform is generated. The graph of Fig 14 shows the approximate relationship between frequency and the C1-R2 values under the above condition. In practice, the R1 and R2 values of the circuit can be varied from 1kΩ up to tens of megohms. Note, however, that R1 has a significant

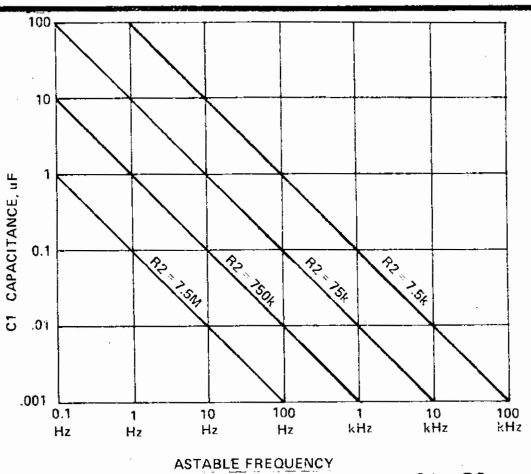


Fig. 14: Approximate relationship between C1, R2, and frequency when R2 is large relative to R1.

effect on the total current consumption of the circuit, since pin 7 of the IC is virtually grounded during half of the timing sequence. Also note that the duty cycle or mark/space ratio of the circuit can be pre-set at a non-symmetrical value, if required, by suitable choice of the R1 and R2 values.

The basic circuit of Fig 13 can be usefully modified in a number of ways. Fig 15, for example, shows how it can be made into a variable-frequency square wave

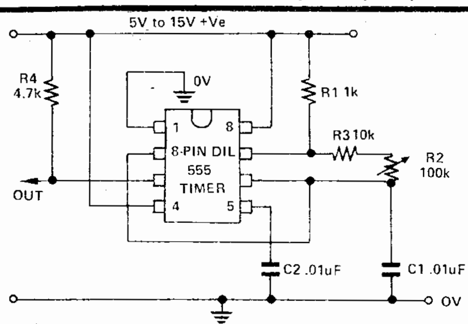


Fig. 15: Variable frequency square wave generator covers the range 650Hz-7.2kHz approximately.

generator by replacing R2 with a fixed and variable resistor in series. With the component values shown the frequency can be varied over the approximate range 650Hz-7.2kHz via R2.

Fig 16 shows how the circuit can be further modified

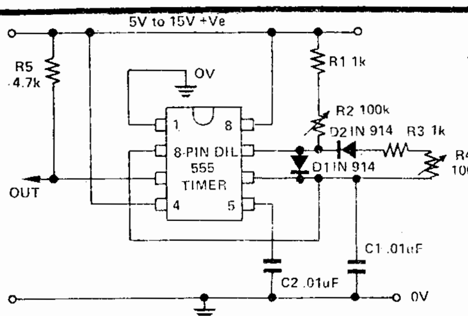


Fig. 16: Astable multi with mark and space periods independently variable over the approximate range 7.5µs to 750µs.

so that its MARK and SPACE periods are independently variable over the approximate range 7.5µS to 750µS. Here, timing capacitor C1 alternately charges via R1-R2-D1 and discharges via R3-R4-D2.

Fig 17 shows how the circuit can be additionally modified so that it acts as fixed-frequency square wave generator with a mark/space ratio or duty cycle that is fully variable from 1% to 99%. Here, C1 alternately

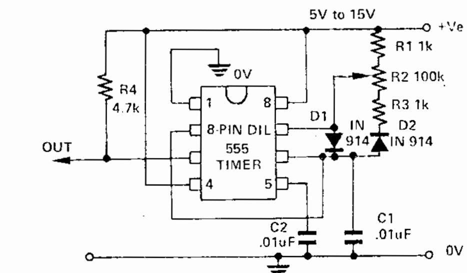


Fig. 17: Astable multi with duty cycle variable from 1 to 99% with frequency approximately constant at 1.2kHz.

charges via R1 and the top half of R2 and via D1, and discharges via D2-R3 and the lower half of R2. Note that the sum of the two timing periods is virtually constant, so the operating frequency is almost independent of the setting of R2.

GATING A 555 ASTABLE

The 555 astable circuit can be gated ON or OFF, via either a switch or an electronic signal, in a variety of ways. Figs 18 and 19 show two basic ways of gating the IC via a switch.

In Fig 18 the circuit is gated via the pin 4 RESET

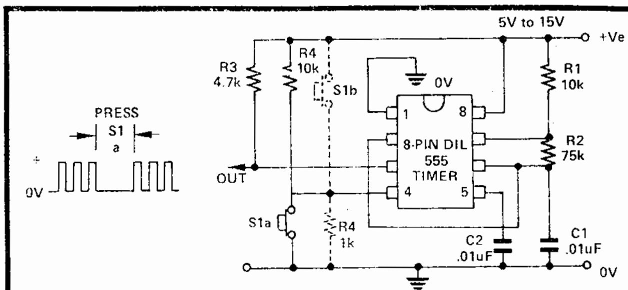


Fig. 18: Gated 1kHMZ astable with 'press to turn-off' or 'press to turn-on' operation.

terminal. The characteristic of this terminal is such that, if the terminal is biased significantly above a nominal value of 0.7 volts, the astable is enabled, but if the terminal is biased below 0.7 volts by a current greater than 0.1mA (by taking the terminal to ground via a resistance less than 7kΩ, for example) the astable is disabled and its output is grounded. Thus, the Fig 18 circuit is normally on but can be turned off by closing S1 and shorting pin 4 to ground, while the circuit shown in dotted lines is normally gated off via R_4 but can be turned on by closing S_2 and shorting pin 4 to the positive supply rail. These circuits can alternatively be gated by applying suitable electronic signals directly to pin 4.

The Fig 19a and 19b circuits are gated via the pin 2 TRIGGER and pin 6 THRESHOLD terminals. The characteristic here is such that the circuit functions as a normal astable only as long as pin 6 is free to swing up to 2/3 V_{cc} and pin 2 is not biased below 1/3 V_{cc}. If these pins are simultaneously driven below 1/3 V_{cc} the

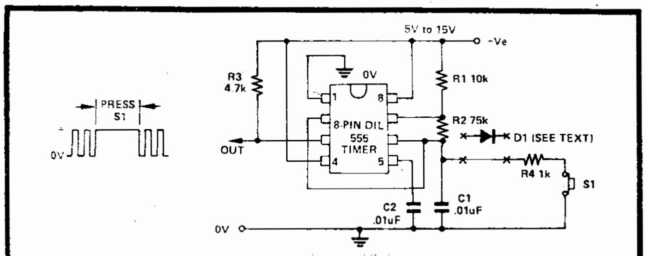


Fig. 19A: Alternative gated 1kHz astable with 'press to turn-off' operation.

astable action is immediately terminated and the output is driven to the high state. Thus, the Fig 19a circuit is normally on but turns off when S1 is closed. Note that an electronic signal can be used to gate the circuit by connecting a diode as indicated and eliminating S_1. In this case the circuit will gate off when the input signal voltage is reduced below 1/3 V_{cc}.

The Fig 19b circuit is connected so that it is normally gated off by saturated transistor Q1, but can be gated

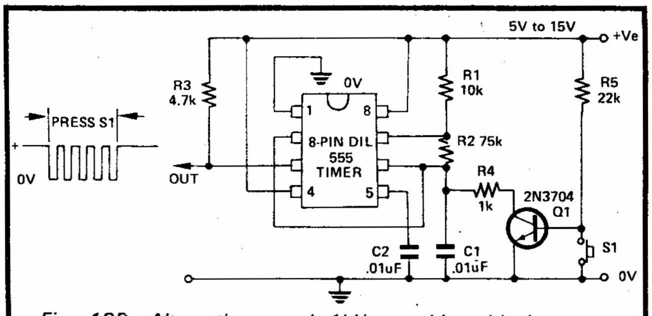


Fig. 19B: Alternative gated 1kHz astable with 'press to turn-off' operation.

on by closing S1 and thus turning the transistor off. This circuit can be gated electronically by eliminating R5 and S1 and applying a gating signal to the base of Q1 via a 10kΩ limiting resistor. In this case the astable turns off when the input signal is high, and turns on when the input signal is reduced below 0.7 volts or so.

All the 555 astable circuits that we have looked at can be subjected to frequency modulation (FM) or pulse-position modulation (PPM) by simply feeding a suitable modulation signal to pin 5. This modulation signal can take the form of an A.C. signal that is fed to pin 5 via a blocking capacitor, as in the case of Fig 20a or a D.C. signal that is fed directly to pin 5, as in the case of Fig 20b. The action of the chip is such that the voltage on pin 5 influences the width of the 'mark' pulses in each timing cycle, but has no influence on the 'space' pulses. Thus, since the signal on pin 5 influences the position of each 'mark' pulse in each timing cycle, this terminal provides pulse-position modulation (PPM), and, since the signal influences the total period of each cycle (and thus the frequency of the output signal), the terminal also provides frequency modulation (FM). These facilities are useful in special waveform generator applications, as is shown in the next section.

MISCELLANEOUS ASTABLE APPLICATIONS

The 555 astable multivibrator has three outstanding advantages over other types of astable circuit. First, its frequency can be varied over a wide range via a single resistive control. Second, its output has a low impedance and can source or sink current up to 200mA. Finally, its operating frequency can readily be modulated by applying a suitable signal to pin 5 of the IC. These features make the device exceptionally versatile, and it can be used in a vast range of practical applications of interest to both the amateur and professional user.

MORSE PRACTICE OSCILLATOR

Fig 21 shows how the 555 timer I.C. can be used as a morse-code practice oscillator. The circuit acts as a

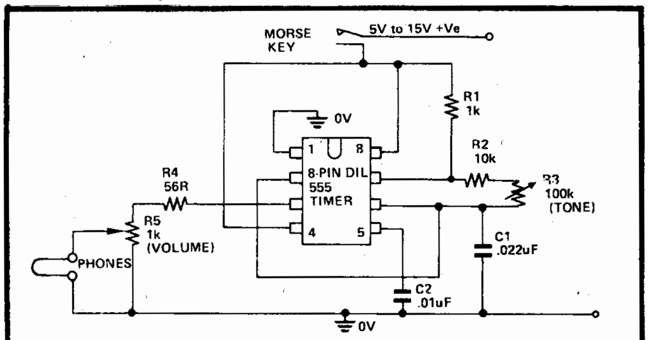


Fig. 21: Code-practice oscillator with variable tone (300Hz..3kHz) and variable volume.

normal astable, with frequency variable over the approximate range 300Hz — 3kHz via TONE control R3. The 'phone volume is variable via R5, and the 'phones can have any impedance from a few ohms up to megohms. The circuit draws zero quiescent current, since the normally-open morse key is used to connect the circuit to the positive supply rail, which can have any value in the range 5 volts to 15 volts.

Fig 22 shows how the 555 astable circuit can be used in LED flasher applications. This circuit operates at approximately 1 Hz, and has a single LED. The Fig 22 circuit has a single LED output; the dotted section shows how a second may be added, such that one LED is on while the other is off, and vice versa. Any types of LED's can be used in this circuit. Series resistors R_1 or

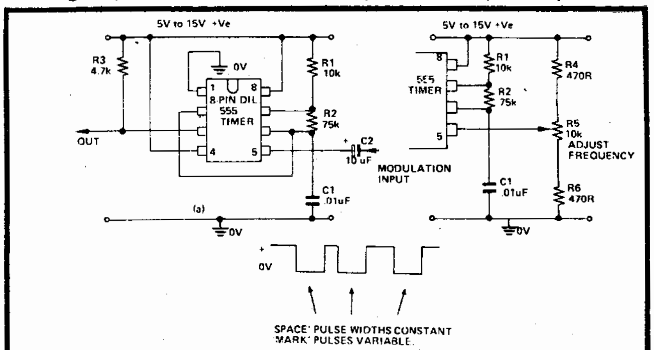


Fig. 20: Alternative ways of obtaining frequency or pulse-position modulation (FM or PPM) from the 555 astable circuit.

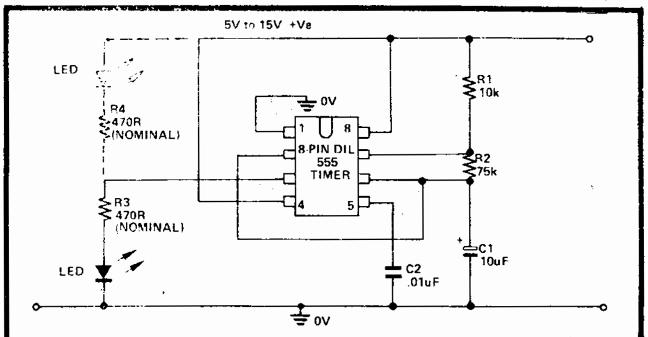


Fig. 22: Single and dual output led flashers give symetrical 1Hz outputs.

R_4 determines the ON current of each LED.

Fig 23 shows how the Fig 22 circuit can be modified to give automatic dark-activated operation. Here, R4 and R5 are wired as a fixed potential divider that sets $1/2\ V_{cc}$ on the emitter of Q1, LDR and R7 are wired as a light-sensitive potential divider that applies a variable voltage to the base of Q1, and the collector of Q1 is taken to RESET pin 4 of the IC, which is normally biased to ground via R6.

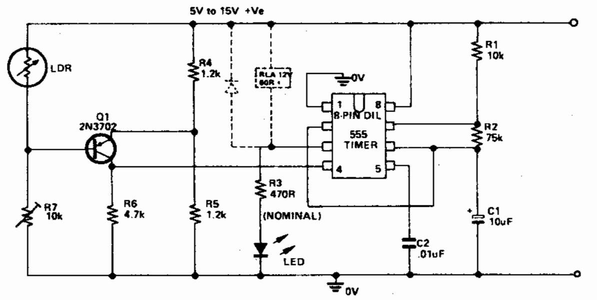


Fig. 23: Automatic (dark-activated) flasher.

In use R7 is adjusted so that the voltage to the base of Q1 is greater than $1/2\ V_{cc}$ under 'daylight' conditions, so Q1 is cut off, but under 'dark' conditions Q1 base is biased below $1/2\ V_{cc}$, so it is driven on. thus, under daylight conditions Q1 is cut off, so the 555 astable is disabled, with its output driven low, by 4.7kΩ resistor R6 which is wired between pin 4 and ground. Under 'dark' conditions, on the other hand, Q1 is biased on, so pin 4 is positively biased, and the astable operates normally and activates the LED.

The LDR used in the above circuit can be any cadmium-sulphide photocell that presents a resistance in the approximate range 470Ω to 10kΩ under the minimum 'dark' turn-on condition.

The dotted section shows how the 555 astable circuit can be used as a 12 volt relay pulser, which turns the relay on and off at a rate of one cycle per second. The relay can be any type with a coil resistance greater than 60Ω.

ALARM GENERATOR

Fig 24 shows the connections for making an 800Hz monotone alarm-call generator. The circuit can be used with any supply in the range 5 to 15 volts, and with any speaker impedance. Note, however, that R_x must be wired in series with speakers having impedance less than 75Ω, and must be chosen to give a total series impedance of at least 75Ω, to keep the peak speaker currents within the 200mA driving constraints of the 555. The available alarm output power of the circuit depends on the speaker impedance and supply voltage

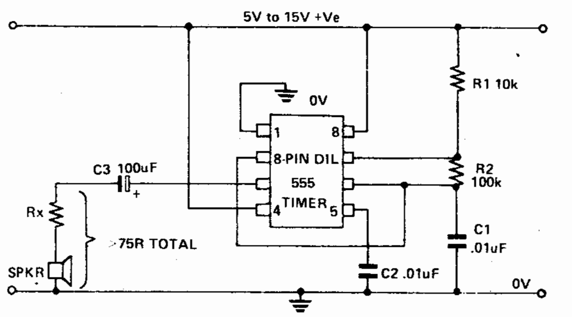


Fig. 24: 800Hz Monotone alarm call generator.

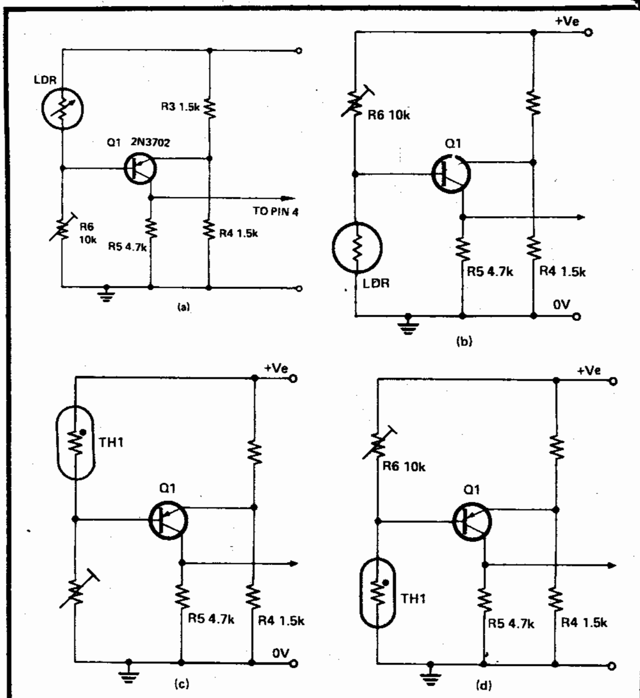


Fig. 24 a, b, c, d: Monotone alarm activated by dark (2), light (b), under-temperature (c), or over-temperature (d).

used, but may be as great as 750mW when a 75Ω speaker is used with a 15 volt supply.

The above circuit can be modified so that it is activated by darkness (a), by brightness (b), by an under-temperature (c), or by an over-temperature (d). Pin 4 is disconnected from the + Ve supply, and connected to the triggering circuit, which is designed around Q1. This works in the same way as already described for the automatic (dark-activated) LED flasher. The LDR used in the light-activated versions of this circuit can be any cadmium-sulphide photocells that present resistances in the approximate range 470Ω to 10kΩ at the desired turn-on levels. The thermistors used in the temperature-activated versions of the circuit can be any negative-termperature-coefficient types that present resistances in the same range at the required turn-on temperatures.

ALARMS AND SIRENS

The next 4 diagrams show a variety of useful alarm-call generator circuits. The Fig 25 circuit generates an 800Hz pulsed tone alarm call. Here, IC1 is wired as an 800Hz alarm generator, and IC2 is wired as a 1Hz astable which gates IC1 on and off via D1 once every second, thus causing a pulsed-tone output signal to be generated.

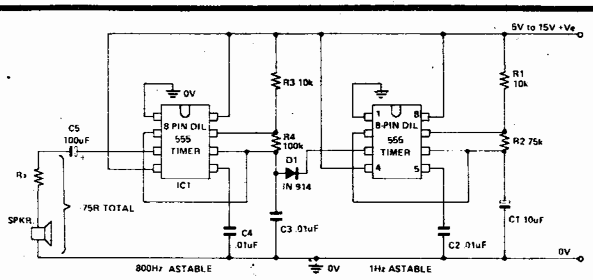


Fig. 25: Pulsed-tone (800Hz) alarm call generator.

The Fig 26 circuit generates a warble-tone alarm signal that simulates the sound of a British police siren. Here, IC1 is again wired as an alarm generator and IC2 is wired as a 1 Hz astable multivibrator, but in this case the output of IC2 is used to frequency modulate IC1 via R5. The action is such that the output frequency of IC1 alternates symmetrically between 500Hz and 440Hz, taking one second to complete each alternating cycle.

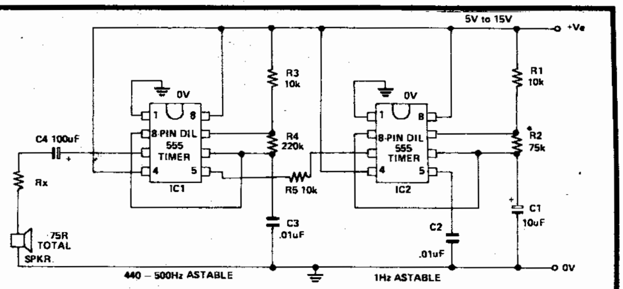


Fig. 26: Warble-tone alarm-call generator simulates British police siren.

The circuit of Fig 27 generates a 'wailing' alarm that simulates the sound of an American police siren. Here, IC2 is wired as a low frequency astable that has a cycling period of about 6 seconds. The slowly varying 'ramp waveform on C_1 of this chip is fed to pnp emitter follower Q1., and is then used to frequency modulate alarm generator IC1 via R6. IC1 has a natural centre frequency of about 800Hz. The circuit action is such that the alarm output signal starts at a low frequency, rises for 3 seconds to a high frequency, then falls over 3 seconds to a low frequency again, and so on add infinitum.

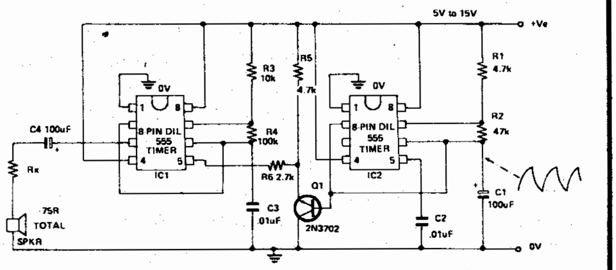


Fig 27: 'Wailing' alarm simulates American police siren.

Finally, to complete this quartet of alarm generator circuits, the Fig 28 circuit generates a siren alarm signal that is a simulation of the 'Red Alert' alarm used in the STAR TREK T.V. programme: This signal starts at a low frequency, rises for about 1.15 seconds to a high frequency, ceases for about 0.35 seconds, then starts

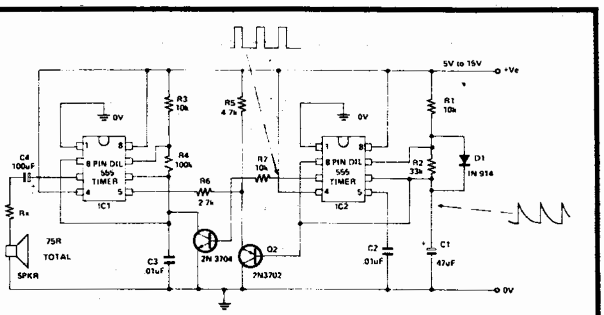


Fig. 28: 'Red alert' siren alarm simulates Star Trek alarm signal.

rising again from a low frequency, and so on add infinitum. The circuit action is as follows:

IC_2 is wired as a non-symmetrical astable multivibrator, in which C1 alternately charges via R1 and D1, and discharges via R2, thus giving a rapidly rising and slowly falling 'sawtooth' waveform across C1. This waveform is fed to pnp emitter follower Q1, and is thence used to frequency modulate pin 5 of IC1 via R6. Now, the frequency modulation action of pin 5 of the IC1 astable circuit is such that a rising voltage on pin 5 causes the astable frequency to fall, and vice versa; consequently the sawtooth modulation signal on pin 5 causes the astable frequency to rise slowly during the falling part of the sawtooth and collapse rapidly during the rising part of the sawtooth. The rectangular pin 3 output of IC_2 is used to gate IC1 off via npn common emitter amplifier Q2 during the collapsing part of the signal, so only the rising parts of the alarm signal are in fact heard, as in the case of the genuine STAR TREK 'Red Alert'.

MISCELLANEOUS APPLICATIONS

To complete the 555 story, this final section shows a miscellany of 555 applications, of varying degrees of usefulness. Fig 29 shows how a single 555 can be used as the basis of an event-failure alarm or a missing-pulse detector, which closes a relay or illuminates an LED if a normally recurrent event fails to take place.

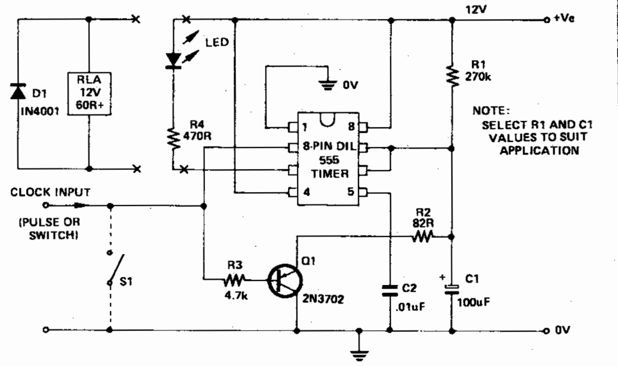


Fig. 29: Event-failure alarm or missing-pulse detector has relay or LED output.

The operating theory of the circuit is fairly simple. The 555 is wired as a normal monostable pulse generator, except that transistor Q1 is wired across timing capacitor C1 and has its base taken to TRIGGER pin 2 of the IC via R3: The TRIGGER pin is fed with a train of pulse- or switch-derived clock input signals from the monitored event, and the values of R1 and C1 are selected so that the monostable period of the IC is slightly longer than the repetition period of the clock input signal.

Thus, each time a clock pulse arrives, a monostable timing period is initiated via pin 2 of the IC, and C1 is discharged and the pin 3 output is driven high via transistor Q1. Before each monostable period can terminate, a new clock pulse arrives, and a new monostable period is initiated, so the pin 3 output terminal remains high so long as clock input pulses continue to arrive within the prescribed period limits. Should a clock pulse be missed, or the clock period exceed the pre-determined limits, however, the monostable period will be able to terminate normally, and pin 3 of the IC will go low and drive the relay or LED on. The circuit thus functions effectively as an event-failure alarm or missing-pulse detector. With the component values shown, the monostable has a natural period of about 30 seconds. This period can be varied via R1 and C4 to satisfy specific requirements.

Fig 30 shows how a couple of 555s can be used to make a pulse-width modulation (PWM) circuit. This circuit can be used for transmitting coded messages, or for applying variable power to a load at maximum efficiency.

Here, IC1 is wired as a 1kHz astable multivibrator, which is used to feed a continuous train of clock pulses

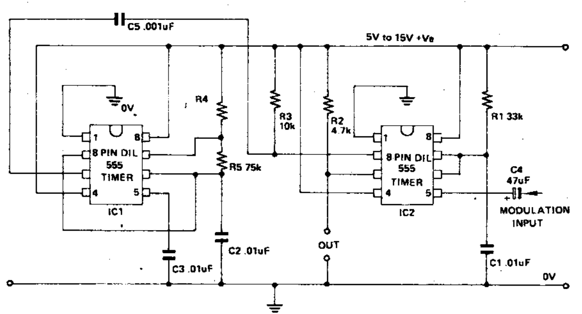


Fig. 30: Pulse-width modulation (PWM) circuit.

to the pin 2 TRIGGER terminal of IC2, which is wired as a normal monostable multivibrator or pulse generator and has a natural monostable period of approximately 0.36mS. The external modulation signal is fed to the pin 5 CONTROL VOLTAGE terminal of the monostable via C4, and determines the instantaneous widths of the generated pulses. Thus, the circuit generates a train of pulse-width modulated (PWM) pulses at a fixed repitition frequency of 1kHz.

SCOPE TIMEBASE

Fig 31 shows how a basic 555 monostable multivibrator can be modified so that it generates a

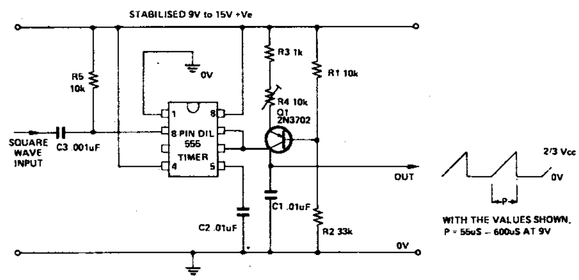


Fig. 31: Triggered linear-ramp generator can be used as the basis of an oscilloscope timebase.

linear ramp waveform of fixed duration each time it is triggered: This circuit can form the basis of an excellent oscilloscope time-base generator. The circuit works just like a normal monostable circuit, except that timing capacitor C1 is charged via constant-current generator Q1 during each timing cycle, thus causing a linear ramp voltage to be generated across C1.

When a capacitor is charged via a constant-current generator, the voltage across the capacitor rises linearly at a predictable rate that is determined by the magnitudes of the charging current and the capacitance. The relationship can be expressed as:

Volts-per-second = I/C, when I is expressed in Amps and C is expressed in Farads.

In this circuit the charging current can be varied over the approximate range 90μA to 1mA via R_4, thus giving rates of rise on the .01μF capacitor of 9V-per-mS to 100V-per-mS. Now, remembering that each monostable period of the 555 circuit terminates at the point when C1 voltage reaches 2/3 V_{cc}, and assuming that a 9V supply is used (giving a 2/3 V_{cc} value of 6V), it can be seen that the monostable cycles of the Fig 32 circuit have periods variable from 666μS to 60μS. Periods can be increased beyond these values by increasing the C1 value, or vice versa. Note when using this circuit that its supply rail must be stabilised if stable timing periods are to be obtained.

If the circuit of Fig 31 is to be used as the basis of an oscilloscope timebase, note that the input driving signal must first be converted to a good square wave, from which suitable trigger pulses can be derived via C3 and R5. The minimum useful ramp period that can be obtained from the circuit is about 5μS, which, when expanded to give full deflection on a ten-division 'scope screen, gives a maximum timebase speed of 0.5μS-per-division. Flyback beam-suppression signals can be derived from the pin 3 OUTPUT terminal of the IC.

The 'timebase' circuit gives superb signal synchronisation at trigger frequencies up to about 150kHz. If the timebase is to be used with input signal frequencies greater than this, the input signals should be divided down via a single- or multi-decade digital divider. Using this technique, the timebase can be used to view input signals up to many MHz.

Fig 32 shows how a 555 can be connected for use as a simple but effective Schmitt trigger or Sine/Square converter. The circuit acts as a good converter at input frequencies up to 150kHz or more. It works by changing its output state each time the pin 2 input signal swings from above the 2/3 V_{cc} level to

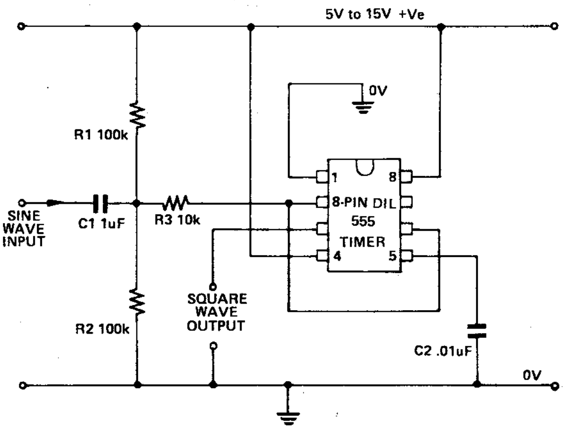


Fig. 32: 555 Schmitt trigger circuit acts as excellent sine/square converter up to about 150kHz.

below the 1/3 V_{cc} level, or vice versa. Resistor R3 is wired in series with pin 2 of the chip to ensure that the input signal is not adversely influenced by the transition action of the IC.

Fig 33 shows how the basic Schmitt circuit can be adapted to a dark-activated relay driving application by wiring light-dependent potential divider R1-LDR to the pin 2 input terminal of the IC. This circuit has an inherently high degree of input backlash, and is likely to be of value in only very specialised applications.

A far more useful relay-driving switching circuit is shown in Fig 35. This circuit has negligible input backlash, and can be used as either a light- or

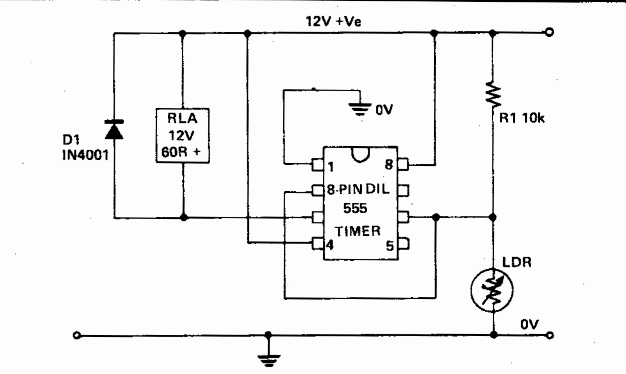


Fig. 33: Dark-activated relay switch has built-in backlash.

temperature-activated switch. In light-activated applications R1 is wired in series with a cadmium-sulphide photocell that presents a resistance in the approximate range 470Ω to 10kΩ at the required turn-on level. Dark-activated operation can be obtained by using the connections shown in Fig 34a or light-activated operation can be obtained by using the connections shown in Fig 34b.

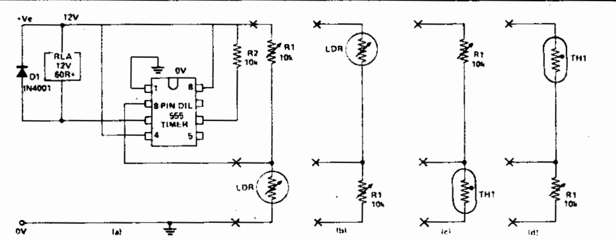


Fig. 34: Minimum-backlash relay switch can be activated by dark (a), light (b), under-temperature (c), or over-temperature (d).

For temperature-activated operation, R1 must be wired in series with a negative-temperature-coefficient thermistor. This thermistor must present a resistance in the range 470Ω to 10kΩ at the required turn-on level. Under-temperature operation can be obtained by using the connections shown in Fig 34c, or over-temperature operation can be obtained by using the connections shown in Fig 34d.

1kHz ANALOGUE FREQUENCY METER

This circuit needs a square-wave input driving signal with a peak-to-peak amplitude of 2 volts or greater. In this circuit the 555 is wired as a standard monostable multivibrator or pulse generator, and is powered from a regulated 6V supply. Transistor Q1 is used to amplify the square wave input signals to a level suitable for triggering the monostable stage, and the output of the monostable is fed to 1mA fsd meter M1 via multiplier resistor R5 and offset-cancelling diode D1. This meter gives a reading that is directly proportional to the frequency of the square wave input signals, and its operating theory is as follows:

Each time the monostable multivibrator is triggered it generates a pulse of fixed duration and fixed amplitude. If we assume that each generated pulse has a peak amplitude of 10V and a period of 1mS, and that the pulse generator is triggered at an input frequency of 500Hz, it can be seen that the pulse is high (at 10V) for 500mS in each 1000mS (one second) total period, and that the MEAN value of output voltage measured over this total period is 250mS/1000mS x 10V = 5V, or 50% of 10V. Similarly, if the input frequency is 250Hz the pulse is high for 250mS in each 1000mS total period, so the mean output voltage equals 250mS/1000mS x 10V= 2.5V, or 25% of 10V. Thus, the mean value of output voltage of the pulse generator, measured over a reasonable total number of pulses, is directly proportional to the repitition frequency of the generator.

Normal moving coil meters are 'mean' reading instruments, and in the Fig 35 circuit a 1mA f.s.d. moving coil meter is wired in series with voltage multiplier resistor R5, which sets the meter sensitivity at about 3.4V fsd, and is connected so that it reads the

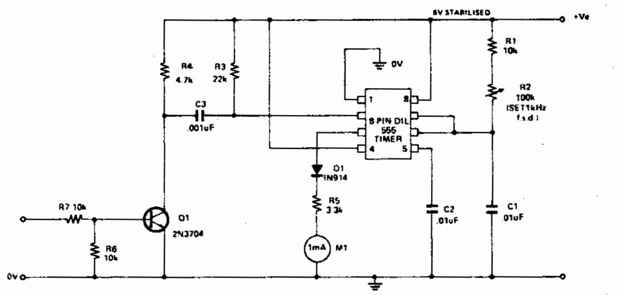
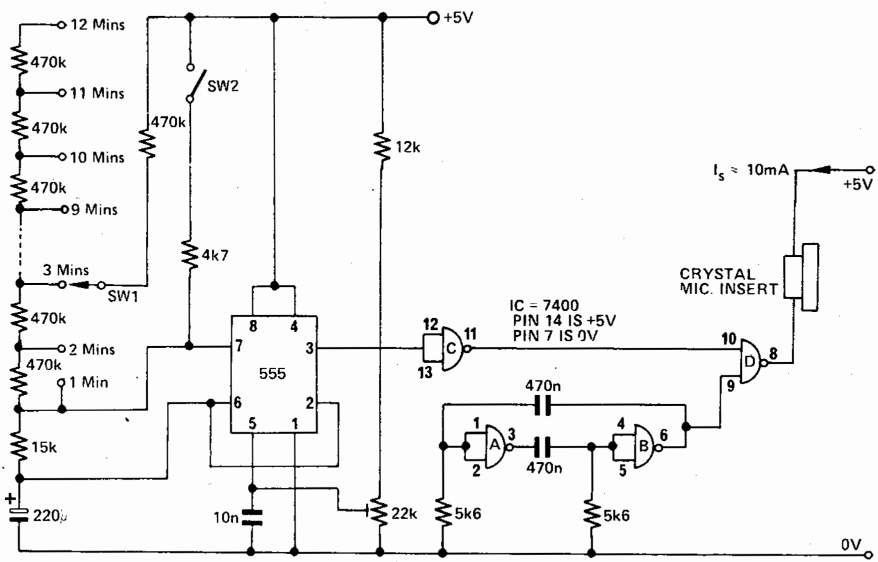


Fig. 35: Simple 1kHz linear-scale analogue frequency meter.

mean output voltage of the pulse generator. This meter thus gives a reading that is directly proportional to frequency, and the circuit thus acts as a linear-scale analogue frequency meter. With the component values shown the circuit is intended to read fsd at 1kHz. To set up the circuit initially, simply feed a 1kHz square wave signal to its input, and then adjust R2 (which controls the pulse lengths) to give full-scale reading on the meter; all adjustments are then complete.

The full-scale frequency of the above circuit can be varied from about 100Hz to about 100kHz by suitable choice of C1 value. The circuit can be used to read frequencies up to tens of MHz by feeding the input signals to the monostable circuit via a single- or multi-decade digital divider, thereby reducing the input frequencies to values that can be read by the monostable circuit. The circuit can form the basis of an excellent and inexpensive multi-range linear-scale analogue frequency meter. ●

tech-tips



1 - 12 MINUTE TIMER

The circuit is centred around the NE555V timer which provides a logic 0 level at pin 3 every 1 - 12 minutes, depending upon the position of the 12 way switch (SW1). SW2 is a push-button switch which synchronises the first pulse (originally a switch circuit was fitted to the reset pin, 4, but the first timing period was never the same as the subsequent periods). The variable 22k resistor allows a degree of fine adjustment for the timing period.

Gates A and B form a tone generator. Gate C inverts the output of the NE555V so that a logic '1' is fed to gate D at the end of each timing period. Thus a tone burst of a few seconds is produced by the transducer (any surplus crystal microphone insert should be suitable).

Monolithic timers form transducer-to-recorder interface

by T. George Barnett
Laindon, Essex, England

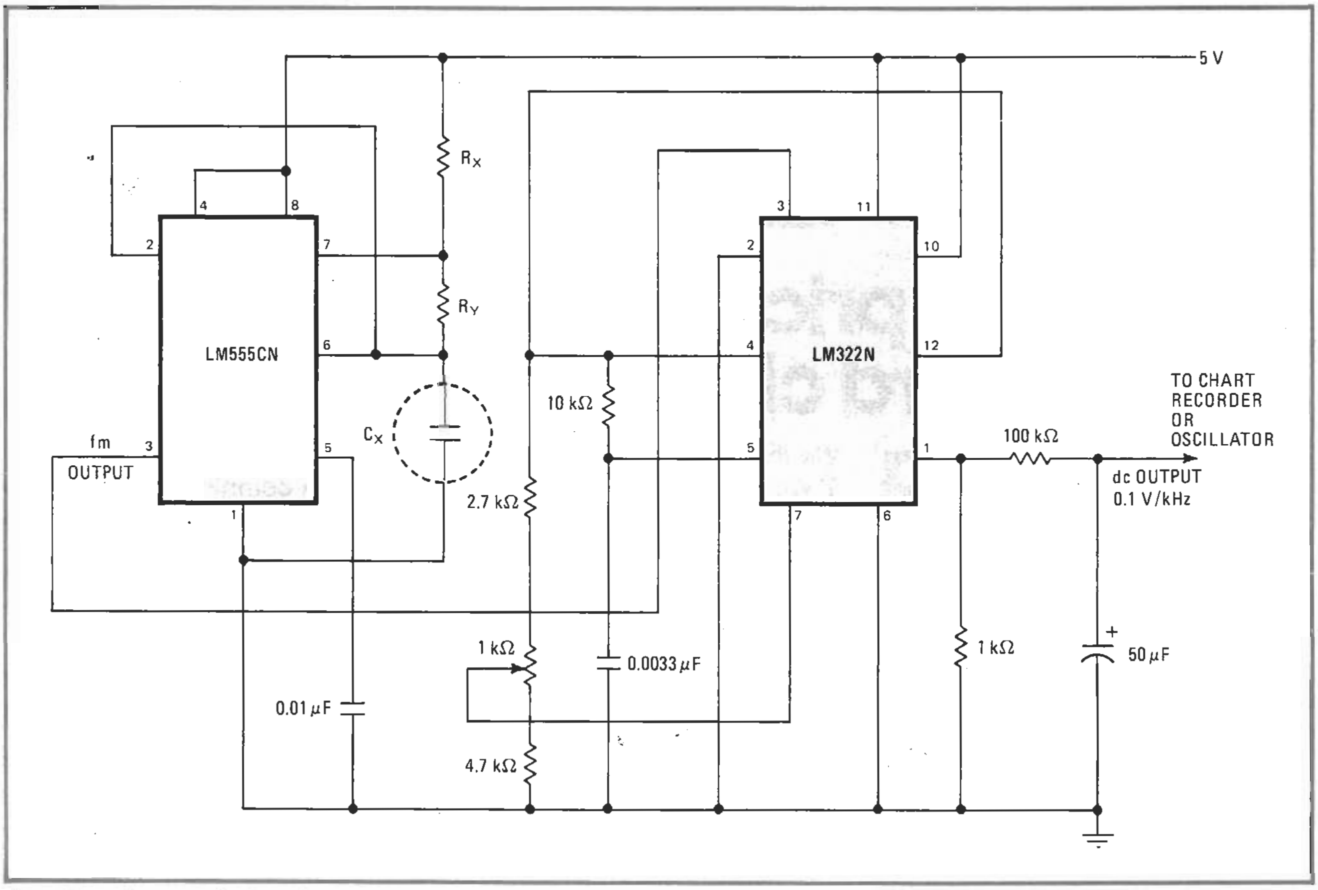
Capacitive transducers often require an expensive capacitance bridge to transform sensed capacitance variations into a voltage for presentation on a chart recorder or oscilloscope. A circuit using two monolithic timers can provide both a capacitance-to-voltage interface and a simple and accurate method for measuring the transducer capacitances.

As shown in the figure, the transducer serves as a capacitive frequency-determining element for the 555 timer. This makes it possible to measure transducer capacitances indirectly, while isolating the transducer from the scope or chart recorder to minimize the loading effect. The LM555CN timing device is connected in the astable mode, its free-running frequency set by R_x, R_y, and C_x. The transducer, typically in the range of 0.001 to 100 microfarads, is element C_x in the timing network.

As the transducer capacitance varies in response to the physical parameter being measured, the output frequency of the 555 varies linearly. The ratio of R_x to R_y sets the duty cycle, which depends on the frequency range desired.

The output of the 555 is presented to the LM322N timer. This circuit, wired as a monostable multivibrator, and combined with the one-pole resistance capacitance filter, forms a frequency-to-voltage converter. The dc output voltage varies linearly with the input frequency, and has a slope of 0.1 volt per kilohertz. The linearity is within 0.2% over the output voltage range of 0 to 1 v.

A 1-kilohm potentiometer connected to pin 7 of the 322 adjusts the output pulse width, serving to calibrate the system to a specified voltage at 10 kilohertz or some other frequency. To ensure linearity, the collector of the output transistor, pin 12, is fed to pin 4 (V_{REF}), so that the amplitude of the pulse at pin 1, the emitter of the output transistor, is constant. The period of the one-shot should be much less than the period of the astable multivibrator for best results. □



Transducer-to-recorder interface. Two timers determine transducer capacitance, perform capacitance-to-voltage conversion for chart recorder, while isolating transducer from output-circuit loading. Transducer placed in timing network of 555 astable multivibrator determines its frequency. LM322 one-shot, which should have a much shorter period than the multivibrator, transforms frequency into voltage.

An Electronic Timer for Less Than $5.00

BY PETE WALTON,* VE3FEZ

Do you have a TV set in your bedroom? Have you ever fallen asleep and left it on? Or even worse, just find yourself falling asleep and remember that you have to get up and turn the TV off. This versatile timer will turn the TV off from periods of three minutes after you have gone to sleep to periods up to about one hour. You can build this timer in one evening for a total cost of about $5.00 even if you have to buy all new components.

The circuit takes advantage of a new integrated circuit from the Signetics Company called the NE555. The NE555 is a very stable monlithic timing circuit in the form of an 8-pin dual-in-line package. It is currently selling for one dollar from most suppliers. The NE555 is capable of time delays from a few microseconds up to several hours. These delay periods are dependent on an external *RC* network consisting of one resistor and one capacitor.

Very basically the IC is made up of a voltage comparator circuit, one leg of which is connected to a reference voltage, which ur case is the power supply output voltage. The other leg of the voltage comparator is connected to the external *RC* network. When the capacitor has charged to a voltage equal to the reference voltage, the comparator will toggle a flip-flop connected to its output. The ON level of this flip flop is used to turn on a driver circuit which picks up our time delay relay. This a very basic description of a fairly complex IC. If you require a better explanation of the internal workings you can obtain one by writing to the Signetics people and requesting a data sheet.

The relay that I used was an IRC MR312 C with a coil resistance of 212 ohms. Almost any 12-volt relay will do the job as long as it does not draw more than the rated 200 ma limit from the output of the NE555. The *RC* network is a 100 mf capacitor in series with a five meg linear pot and a one meg resistor. These values, with the power supply that I used, gave time delays of 3 minutes at the low-resistance end of the pot and 58 minutes at the high-resistance end. You may have to experiment a little bit to get the exact time delay range that you require. This is due to possible differences in power supply voltage and components. You could even switch in different values of *R* and *C* with a rotary switch to give you several different time delay ranges.

The power supply consists of an old six volt filament transformer that was in the junk box, a full wave rectifier, and filter capacitor. Parts layout is not at all critical

[*Continued on page 82*]

*421 Lodor Street, Ancaster, Ontario, Canada.

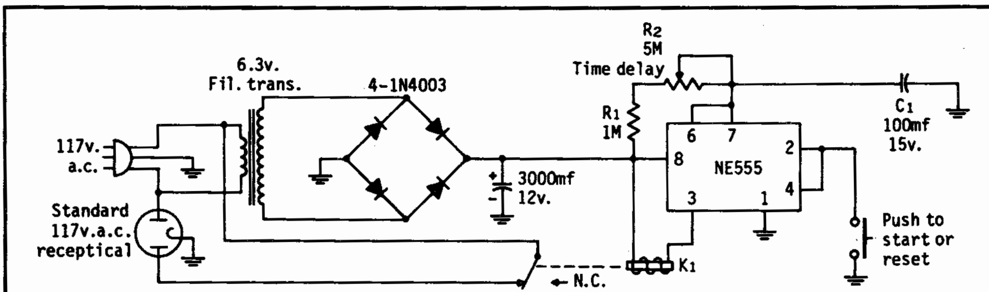


Fig. 1—Circuit of an inexpensive electronic timer adaptable to any number of simple timing applications around the home or shack. With the values shown for R_1, R_2, and C_1, the timers range is from 3 minutes to about one hour, using the power supply shown. Relay K_1 is any 12-volt-coil relay which draws 200 ma or less.

$5.00 Timer [*from page 42*]

and the whole unit can be kept very small. I built mine on a scrap piece of perf board abc vo inches wide by about three inches long. The completed circuit board is mounted in a standard Minibox using a three wire power cord for safety. On the front of the box is a standard 117-volt three-wire receptacle, the pot for setting the time delay period, and the push button to start the timer. The time delay pot was calibrated using an ordinary clock and a lot of patience. ■

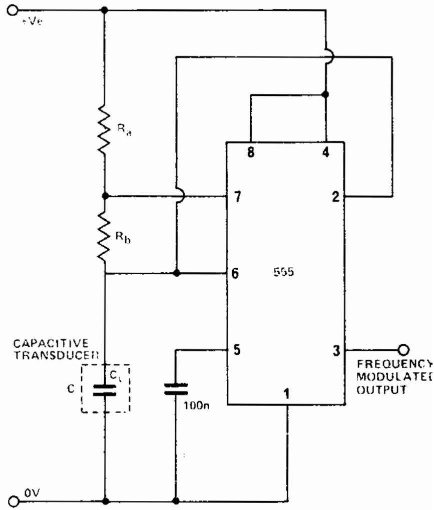
The Tape Recorder Controller in Tech-Tips October 1977 was incorrectly credited. It was in fact designed and submitted by P. B. Cordes of Bishop Auckland.

Low Cost Transducer Amplifier

T. Barnett

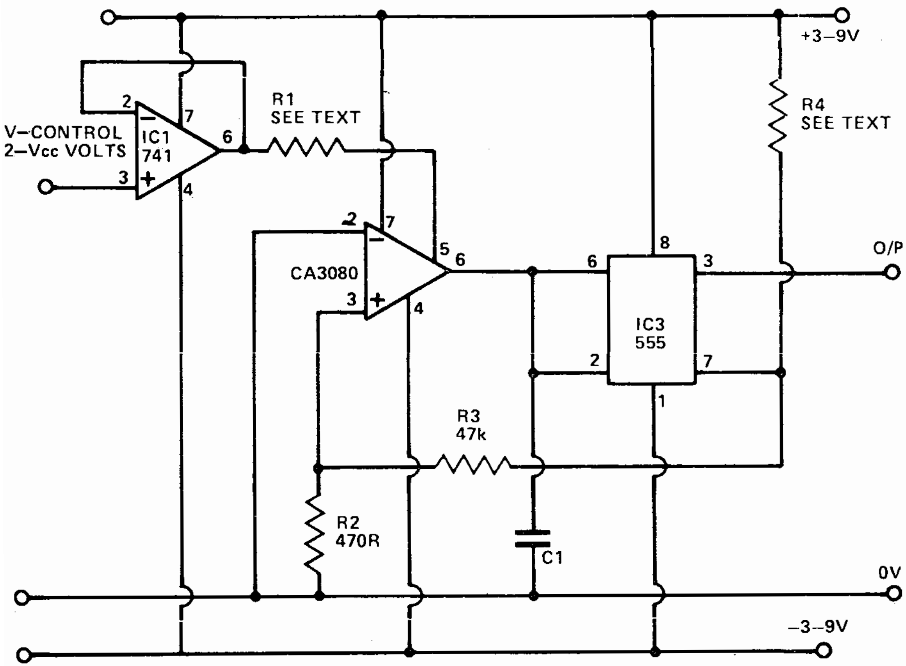
Capacitative tranducers are often used to measure displacement or pressure. The versatility of the low-cost 555 intergrated circuit timer can be utilis--ed with these types of tranducer to provide a frequency modulated output. This output, fed into a frequency-to-voltage converter, will give an analog output voltage proportional to the capacitance of the tranducer.

The 555 module is connected with the tranducer C_t substituted for the external timing capacitor. Precise setting of the duty cycle is obtained with resistors R_a and R_b and with pins 2 and 6 connected together, the device will trigger itself and thus free-run as a multivibrator. As the output will source or sink current up to 200 mA or drive TTL circuitry, it can be fed directly into most types of frequency-to-voltage converter.



555 Voltage Control

S Draper



This circuit was developed to provide a cheap, reliable and accurate voltage controlled oscillator. It uses readily available components and the control over mark-space ratio common to other 555 circuits is retained. Frequency-voltage response is linear over approximately one decade making the circuit useful in timing applications. Operation is as follows.

IC1 buffers the input voltage and produces the control current for IC2. IC2 is an operational transconductance amplifier and produces an output current multiplied by the differential input voltage. This output current is used to charge and discharge the capacitor C1 in the normal way. The equation for output high and output low times are given below:

$$\text{Output high time} = \frac{R1C1\ (47.5+R4)}{9024V\ \text{control}}$$

$$\text{Output low time} = \frac{R1C1}{192V\text{control}}$$

where all resistances are in kilohms and all capacitances are in microfarads.

Current consumption is a miserly 10mA from a 12V supply making the unit suitable for battery power.

N.B. — R1 should not be less than 18k

Tech-Tips is an ideas forum and as such is not aimed at the beginner; we regret that we cannot answer queries on these items. We do not build up or test these circuits prior to publication.

Two 555 timers build pulse-height discriminator

by R. Karni and T. Assis
I.A.E.C. Nuclear Research Center, Negev, Israel

When making pulse and noise measurements, it is sometimes necessary to count the number of transients or pulses of a given amplitude. By configuring two 555 timers as adjustable-threshold monostable multivibrators with the output of one inhibiting the other, the resulting pulse-amplitude discriminator generates a clean square-pulse output only when it receives an input pulse of predetermined magnitude.

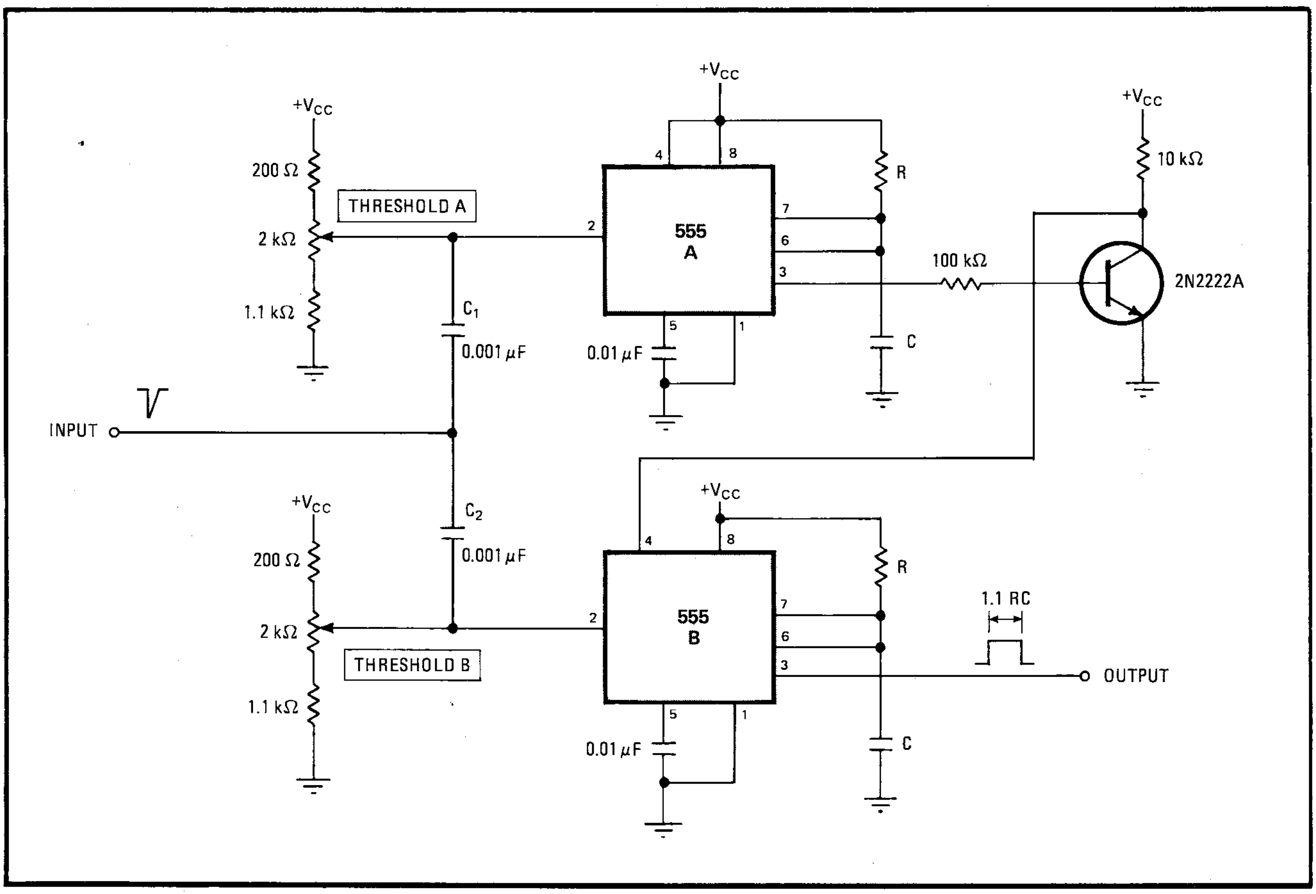
As shown in the figure, each 555 is connected as a basic monostable. In this configuration, a negative transition below a voltage level of $V_{CC}/3$ at the trigger input (pin 2) generates an output pulse at pin 3 of duration 1.1(RC). The voltage-dividing network at pin 2 permits an adjustable bias from $V_{CC}/3$ to almost V_{CC}. Therefore, since a V_{CC} of 15 v has been chosen, triggering can be made to occur on negative pulses from a minimum of nearly 0 volt on up to a maximum of almost 10 volts.

Both timers have trigger inputs biased in the same fashion, and both receive the same input pulse through decoupling capacitors C_1 and C_2. But the output of timer A is connected through an inverting buffer-transistor to the reset input (pin 4) of timer B; consequently, whenever monostable A is triggered, B is inhibited. It is this arrangement that permits the pulse discrimination.

If the threshold of timer A is set higher than that of B, only pulses having magnitudes between the two thresholds will produce a pulse at the output. Pulses of a magnitude less than the threshold of B will trigger neither monostable, and those of a magnitude greater than the threshold of A would trigger both—but the inhibiting action of A on B will allow no output pulse to be produced.

In using the discriminator, the control of B sets the threshold of the incoming pulse, while the control of A is set higher than B, to determine the "window" or the difference of the two thresholds.

With the components shown, and a 15-v supply, the pulse threshold is adjustable from 0 to about 10 v, and the window can be varied from a maximum of just under



Pulse-amplitude window. Two 555 timers, hooked up as monostables with differing thresholds, select pulses by height. Timer A inhibits B so that an output occurs only when pulse level is within window set by two controls. TTL output-pulse duration is 1.1(RC).

10 v (when the threshold of B is set to minimum), down to zero, when B is set to its maximum. If signals of greater amplitude are to be encountered, suitable dividers may be added to avoid transitions below ground at the pin-2 trigger inputs of the timers.

The output, which can drive up to 200 milliamperes of transistor-transistor-logic loads, may be connected to a counter or monitoring device. □

Compensating the 555 timer for capacitance variations

by Kenneth Lickel
Philips Medical Systems Inc., Shelton, Conn.

With the 555 timer, any error in the value of the external timing capacitor causes a corresponding error in the duration of the output pulse. If several fixed timing resistors are used to permit selection of various output pulse widths, it may be desirable to compensate for the capacitor variation instead of changing each timing resistor. The circuit below allows correction for capacitor tolerance variations up to ±12.5% by adjustment of a single variable resistor.

The output pulse width, t, is given by the time required for the timing capacitor to rise to the value of the control voltage, V_{CON}. That relationship can be shown by the equation:

$$V_{CON} = V_{CC}(1 - e^{-t/RC})$$

or

$$t = -RC\ln(1 - V_{CON}/V_{CC})$$

This equation shows that the pulse duration depends on the ratio of V_{CON} to supply voltage V_{CC} for given values of timing resistor R and timing capacitor C.

In the technique used to compensate for error in the timing-capacitor value, the ratio V_{CON}/V_{CC} is varied with an external resistance that shunts the 10-kilohm resistance inside the timer. As the circuit diagram shows, this external resistance consists of a 200-kilohm variable resistor R_A in series with a 17.8-kilohm fixed resistor R_B. The ratio V_{CON}/V_{CC} determined by the voltage-dividing network is:

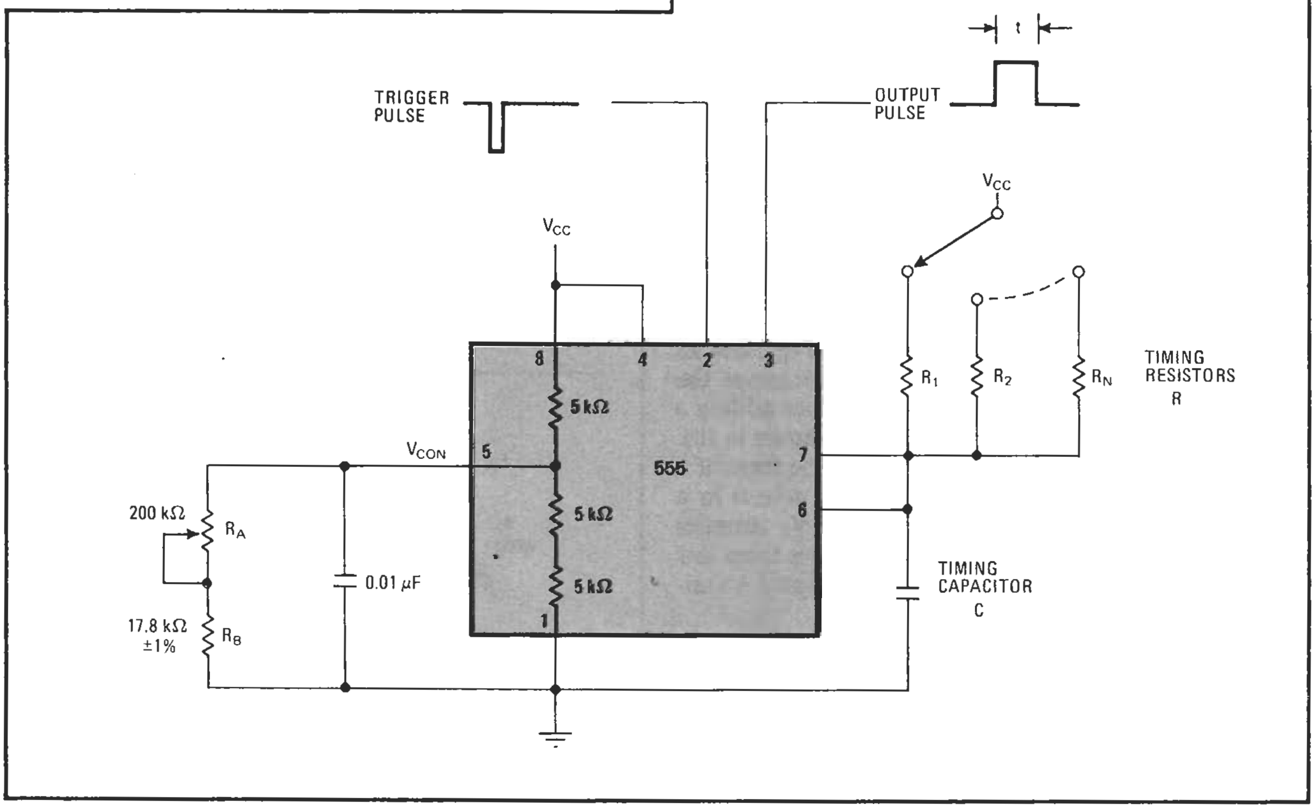
$$V_{CON}/V_{CC} = R_p/(R_p + 5\ k\Omega)$$

where

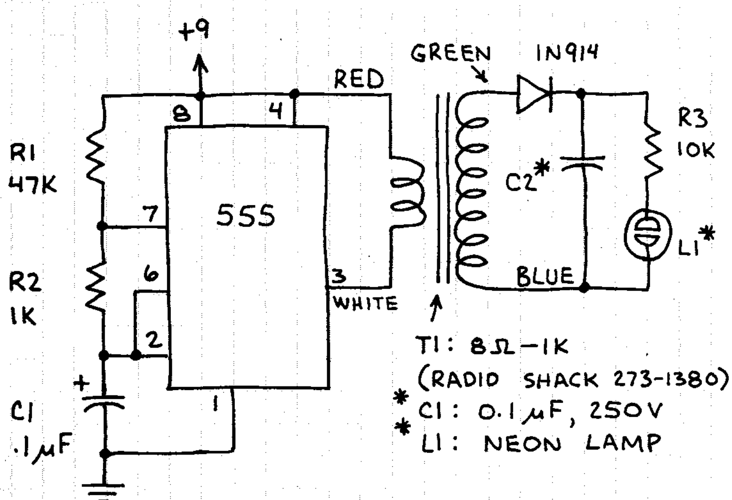
$$R_p = (10\ k\Omega)(R_A + R_B)/(10\ k\Omega + R_A + R_B)$$

If R_A is set at its minimum value (zero):

Timer. External variable resistance alters control voltage of 555 timer to compensate for variations in timing capacitor.

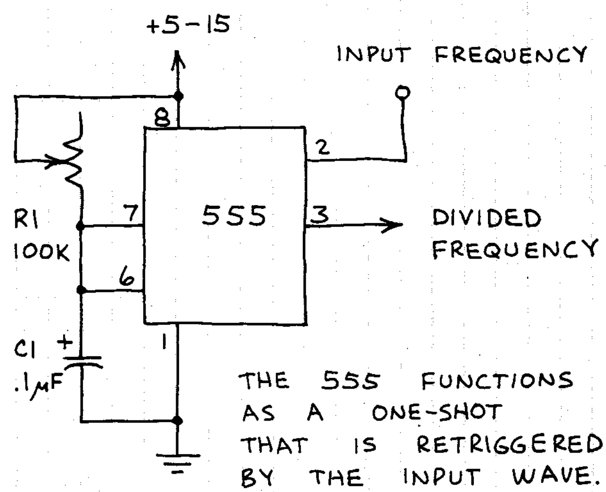


NEON LAMP POWER SOURCE



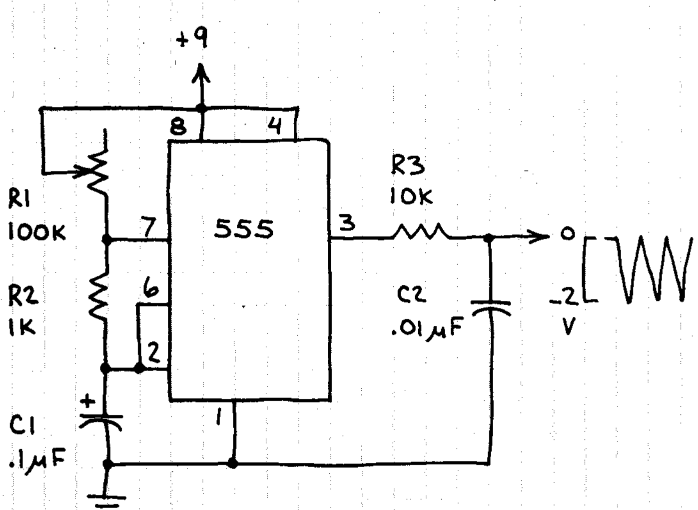
WORKS BEST WITH BETTER QUALITY NEON LAMPS. REDUCE R1 SLIGHTLY FOR MORE OUTPUT VOLTAGE.

FREQUENCY DIVIDER



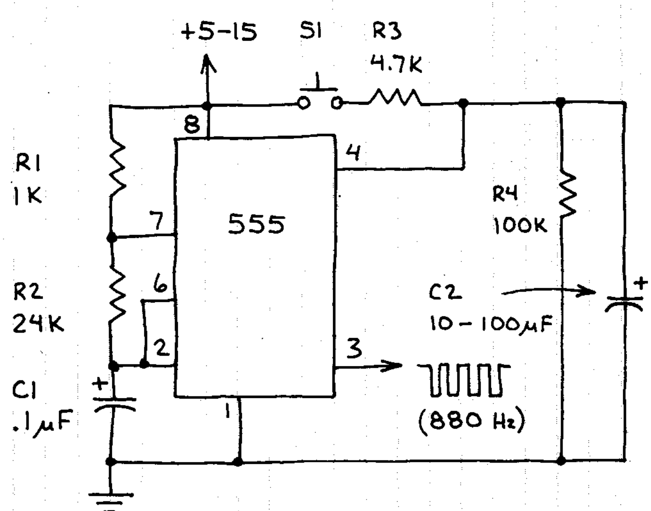
THE 555 FUNCTIONS AS A ONE-SHOT THAT IS RETRIGGERED BY THE INPUT WAVE. WAVES ARRIVING DURING THE TIMING CYCLE ARE IGNORED.

TRIANGLE WAVE GENERATOR



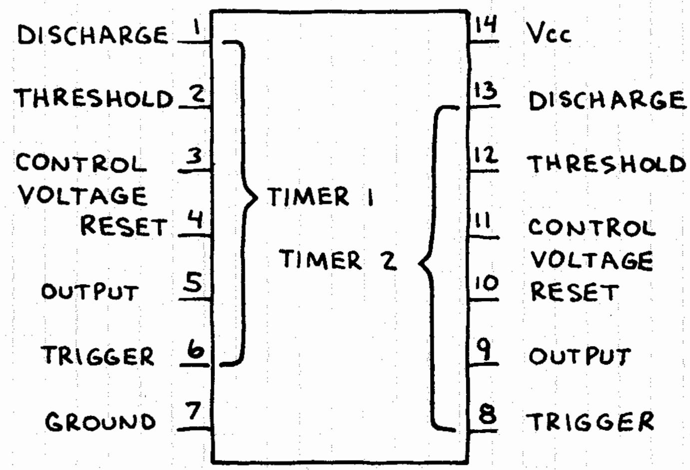
ADJUST R1 TO PROVIDE UP TO 10 KHz. OUTPUT FREQUENCY THIS HIGH PRODUCES CLOSELY SPACED TRIANGLE WAVES. THE WAVES ARE SEPARATED AT SLOWER FREQUENCIES (V‾V‾V‾).

ONE-SHOT TONE BURST



PRESS S1 AND STEADY OUTPUT FREQUENCY APPEARS AT PIN 3. RELEASE S1 AND OUTPUT FREQUENCY CONTINUES UNTIL C2 IS DISCHARGED BY R4. INCREASE C2 (OR R4) TO INCREASE LENGTH OF THE BURST. CHANGE FREQUENCY OF TONE BURST VIA R2 OR C1.

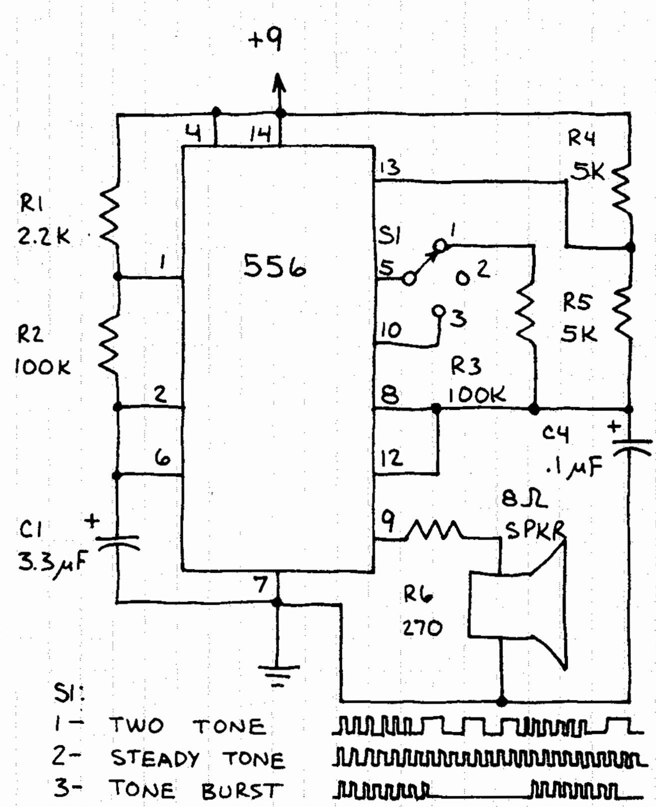
DUAL TIMER
556



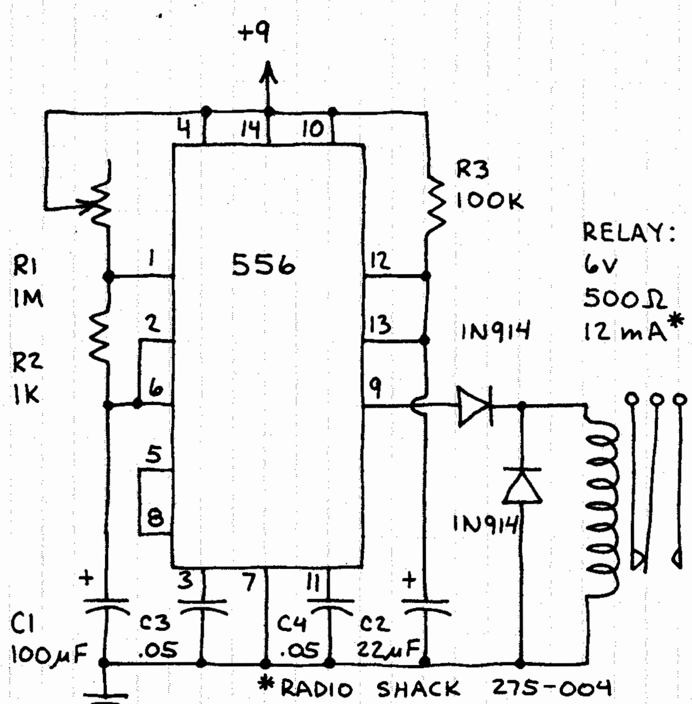
CONTAINS TWO INDEPENDENT TIMERS ON A SINGLE CHIP. BOTH TIMERS ARE IDENTICAL TO THE 555. ALL THE APPLICATION CIRCUITS CAN ALSO BE BUILT WITH TWO 555's. THIS PIN CROSS REFERENCE WILL SIMPLIFY SUBSTITUTING TWO 555's FOR A 556 OR HALF A 556 FOR A 555:

FUNCTION	555	556(1)	556(2)
GROUND	1	7	7
TRIGGER	2	6	8
OUTPUT	3	5	9
RESET	4	4	10
CONTROL V.	5	3	11
THRESHOLD	6	2	12
DISCHARGE	7	1	13
Vcc	8	14	14

3-STATE TONE SOURCE



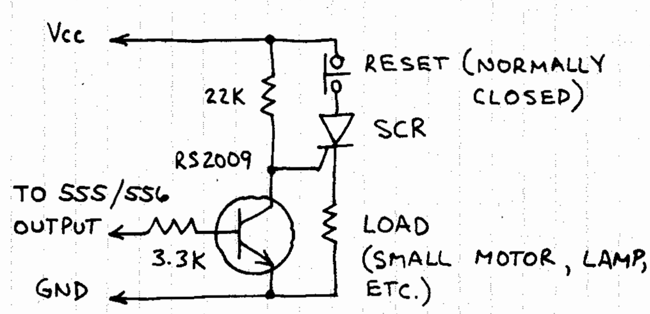
INTERVAL TIMER



*RADIO SHACK 275-004

TIMER 1 IS CONNECTED AS ASTABLE OSCILLATOR. TIMER 2 IS A ONE-SHOT RELAY DRIVER. 1 FIRES 2 ONCE EACH CYCLE. 2 PULLS RELAY IN FOR 3-5 SECONDS.

555/556 SCR OUTPUT

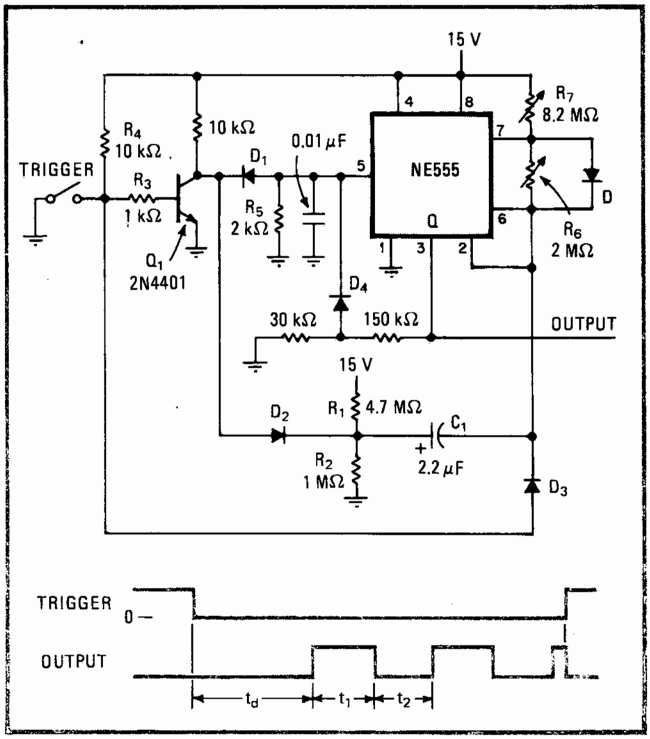


Timer's built-in delay circumvents false alarms

by Kamalakar D. Dighe
American Instrument Co., Silver Spring, Md.

A single 555 timer operating as an astable multivibrator can be used to set its own delay time before turning on, thereby circumventing the most annoying problem encountered with threshold-detector and industrial-alarm circuits—how to distinguish between an actual trigger signal and one that is generated by noise. With this circuit, a wide range of delay periods can be selected to negate the effects of noise spikes.

The circuit requires one transistor and several diodes to function, as shown in the figure. During the quiescent (no-trigger) condition, Q_1 is biased on, D_1 clamps pin 5 of the timer to the approximately 0.8 volt, and D_2 is back-biased. The R_1–R_2 voltage divider maintains the positive plate of capacitor C_1 at 2.5 v and the R_3–R_4 divider ensures that there is 1.5 v at the negative plate (D_3 is forward-biased). Thus the initial voltage across C_1 is 2.5 − 1.5 volts, or 1 v. Under these conditions, pin 6 is at a higher voltage (1.5 v) than the control voltage (V_c) at pin 5, and so the output of the timer at pin 3 is driven low, back-biasing D_4.



Sure-fire. Circuit can differentiate between real and noise-generated alarm signal by waiting a user-specified time before turning on. Frequency and duty cycle of astable multivibrator can be tailored for optimum response from loudspeaker or other audio-alarm monitor.

The delay period begins when the trigger or alarm input, represented by a switch, is grounded. Q_1 turns off, and the collector voltage climbs to 15 v, back-biasing D_1 and bringing pin 5 to 3.8 v (the voltage depends on R_5, which is in parallel with two 5-kilohm resistors internal to the 555).

Meanwhile, D_2 becomes forward-biased, with the result that approximately 14.5 v is applied at the positive plate of C_1, a step rise of approximately 12 v above the previous voltage. D_3 is now back-biased; the step voltage is therefore transferred to the negative plate of C_1, and pins 2 and 6 of the timer jump to 13.5 v.

Because the threshold voltage (13.5 v) is still larger than the control voltage (3.6 v), the output of the timer remains low. However, C_1 now starts to charge through R_6 and the discharge transistor within the timer. If the voltage at pins 2 and 6 reaches one half of the control voltage before the trigger input is removed, the output will move high. The time it takes the capacitor to charge to ½ V_c (that is, the delay time) is given by:

$$t_d = R_6 C_1 \ln \frac{V_m}{V_m - (V_f - V_i)}$$

where V_m is the maximum voltage, V_f is the final voltage on C_1, and V_i is the initial voltage across C_1. In this case, $V_m = 14.5$ v, $V_f = 14.5 - ½V_c = 12.7$ v, and $V_i = 1.0$ v. At the end of the delay period, the timer begins to oscillate at a frequency and duty cycle that can be set by the user.

When the timer's output is high, D_4 is forward-biased and the V_c voltage is clamped to approximately 2 v. C_1 is now discharging through R_7, and when the threshold voltage at pins 2 and 6 equals 2 v, the timer output moves low, reverse-biasing D_4 and restoring pin 5 to 3.6 v.

The time the output is high is given by:

$$t_1 = R_7 C_1 \ln(V_o/V_f)$$

where V_o is the initial on-state voltage of C_1 (14.5 − 1.8 = 12.7 v), and V_f is the final voltage on C_1 (14.5 − 2.0 = 12.5 v).

When the output moves low in the cycle, C_1 starts to charge through R_6. When the voltage at pins 2 and 6 drops from 2 to 1.8 v, the timer output goes high, the discharge cycle begins, and the cycle is repeated until the trigger signal is removed. The time the output is low is given by:

$$t_2 = R_6 C_1 \ln \left[\frac{V_m - (V_{f2} - V_i)}{V_m - (V_{f1} - V_i)}\right]$$

where V_{f1} = 14.5 − 1.8 = 12.7 v and V_{f2} = 14.5 − 2.0 = 12.5 v. □

Designer's casebook is a regular feature in *Electronics*. We invite readers to submit original and unpublished circuit ideas and solutions to design problems. Explain briefly but thoroughly the circuit's operating principle and purpose. We'll pay $50 for each item published.

555 IC TIMER CIRCUITS

The versatile 555 IC timer has many applications. Here are some interesting ones including pulse-width and pulse-position modulators

ROBERT F. SCOTT
TECHNICAL EDITOR

THIS IS THE THIRD IN A SERIES OF ARTICLES describing various applications of the 555 timer IC. In the article 555 Timer Applications (February 1976 issue), we saw how the device is used in the monostable mode as a time-delay generator and as a one-shot pulse generator. In March, we covered operation in the astable mode as a free-running oscillator generating pulses and squarewaves. We also threw in a few practical applications.

Monostable applications

Let's take another look at the basic monostable circuit (Fig. 1) and see how it can be

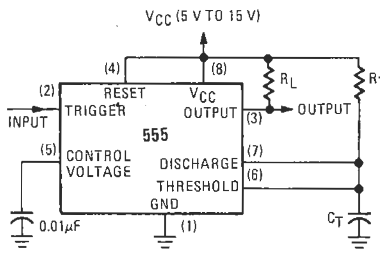


FIG. 1—THE 555 TIMER connected for monostable mode. Negative-going input pulse drives output high for interval equal to R_TC_T.

used for such applications as a heartbeat monitor, frequency divider, pulsewidth modulator and pulse-position modulator.

Recapping monostable operation: The output pulse is independent of the input waveform and is controlled by the time constant of R_TC_T. At the onset, C_T is held discharged by an internal transistor connected to the threshold control terminal. A negative-going pulse on the trigger terminal drives the output high and C_T begins to charge. When the voltage across C_T reaches the threshold level (in a time interval determined by R_TC_T), the output immediately returns to the "low" state.

Missing-pulse detector

When the 555 is connected as shown in Fig. 2-a, it can detect a missing pulse or an abnormally long period between two consecutive pulses in a train. Thus, it can be used to detect intermittent firing of a sparkplug in an internal combustion engine or to monitor the heartbeat of a sick patient.

When connected as shown and fed with a continuous train of pulses, the timing interval of the monostable is continuously being reset by each pulse in the evenly spaced chain as long as the pulse spacing is less than the timing interval. A decrease in pulse frequency or a missing pulse permits completion of the time-interval so the output level goes high—triggering an alarm or other device connected to the output terminal. Figure 2-b shows the waveform when the timer is used as a heartbeat monitor or missing-pulse detector.

A shaper must be inserted between the pickup transducer and the input to convert the heartbeat or sparkplug signal into a series of negative-going pulses.

Frequency divider

If the frequency of a pulse chain is known, it can be divided down as required by feeding it into a basic monostable circuit (Fig. 1) and adjusting the length of its timing interval. When the timing interval ($T = 1.1R_TC_T$) is longer than the *period* of the input trigger pulses, only those pulses that are more than $1.1R_TC_T$ apart will produce an output pulse. The operation of the divider is based on the fact that retriggering cannot occur during the timing cycle.

The output frequency f_o of the divider equals f_{in}/N, where N is the division factor. Figure 3 shows the circuit waveforms for a divide-by-five operation of the timer. The timing period of the circuit is set to approximately 4.5 times the period of the input pulse chain.

A second timer, or the second section of a dual device, can be used as a pulse shaper to adjust the duty cycle of the output waveform. Figure 4, from the Exar XR-2556 and Teledyne D555 data sheets, shows the device connected as a frequency divider and pulse shaper. The output of timer 1 is fed to timer 2 whose frequency is set to that of the output of timer 1. The duty cycle of the output waveform can be varied from 1% to 99% by varying R_{12}. Figure 5 shows the input and output waveforms associated with the frequency divider and pulse shaper shown in Fig. 4.

TYPICAL APPLICATION DATA

MISSING PULSE DETECTOR

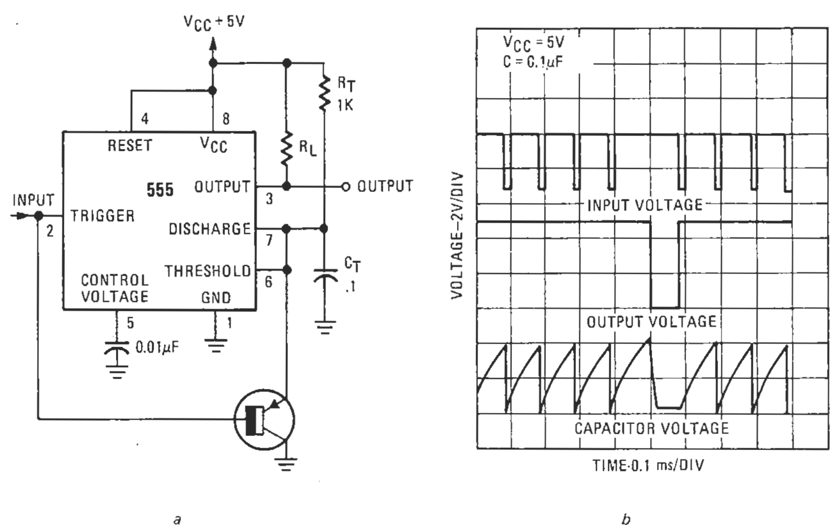


FIG. 2—MISSING-PULSE DETECTOR is shown at *a*. Waveforms at *b* shows how output goes low when there is a break in the input pulse chain.

Pulse-width modulation

When the monostable-connected timer (Fig. 1) is triggered by a continuous pulse chain, the charge time of capacitor C_T, and thus the duration of the output pulse, can be changed by varying the voltage on the control terminal. The waveforms in Fig. 6 show the operation of the pulse-width modulator.

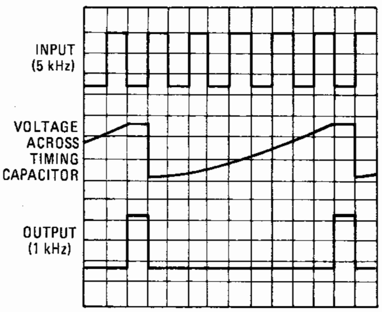


FIG. 3—PREQUENCY-DIVIDER WAVEFORMS from 555 set up to divide by five with 5-kHz input.

Pulse-position modulation

When the timer is operated in the astable mode, the instantaneous period or repetition rate of the output pulse can be varied by applying a modulation voltage to the control terminal. Figure 8 the timer as a pulse-position modulator and Fig. 9 shows the related waveforms. In this example, the timer operates as an oscillator whose output is modulated by a triangular signal. Note, however, that the modulating signal can have any desired shape and may be derived from another signal generator or from a pressure, temperature or humidity sensor.

Linear ramp generator

When the timer is operated so the timing capacitor C_T charges through a resistor, the voltage across it increases logarithmically. If we need a voltage that increases linearly with time, we can replace timing resistor R_T with a constant-current source and take the linearly increasing voltage from across C_T. In Fig. 10, a 2N2450, 2N4403 or similar transistor is connected as the constant-current source. Figure 11 shows the related waveforms.

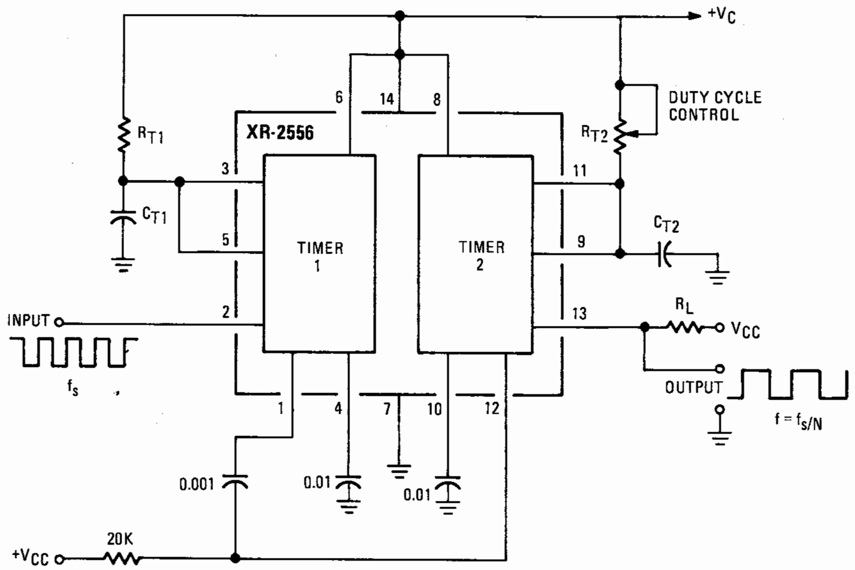


FIG. 4—FREQUENCY DIVIDER AND PULSE SHAPER. Timer 1 is frequency divider controlled by R_{T1} and C_{T1}. Timer 2 is a pulse shaper. The output duty cycle is set by R_{T2} and C_{T2}.

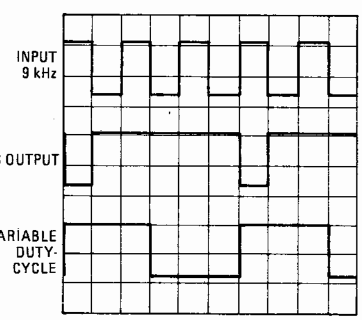


FIG. 5—WAVEFORMS associated with the divider and pulse shaper in Fig. 4.

(Note that in this application, the 0.010-μF decoupling capacitor must be disconnected from the control terminal. The modulation voltage can be direct coupled or fed through a suitable capacitor. Figure 7 shows how the voltage applied to the control terminal affects the pulse width or time delay of the signal developed at the output of the timer.

Another long-time timer

The last time around, we showed three timers connected in cascade to provide a time delay much longer than is practical with a single device. The overall delay is the sum of the delays in the three timers. Another method of achieving long delays is to use the scheme (Fig. 12) described in application notes supplied by most timer manufacturers. In this case, the two halves of a dual timer are connected in cascade with a type 8281 binary counter between them. The first timer is connected as an oscillator with a period of $1/f_o$. The 8281 counter provides selectable outputs (at times equal to 2, 4, 8 and 16 times the input) that are used to trigger the second half of the dual timer. The RC constants in the second timer are selected to give the desired output pulse length.

For your car

Figure 13 is a simple electronic tachometer described in Texas Instruments timer application note. It is operated by pulses generated as the car's distributor points open and

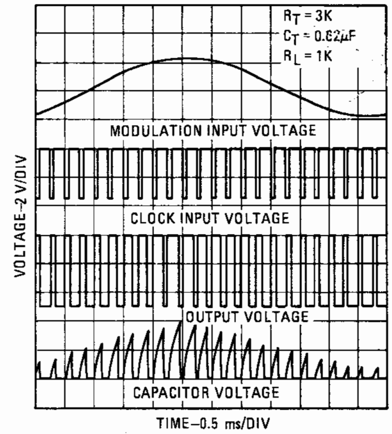


FIG. 6—OUTPUT PULSE WIDTH is determined by voltage on control terminal. Waveforms show circuit preformance with sinewave control.

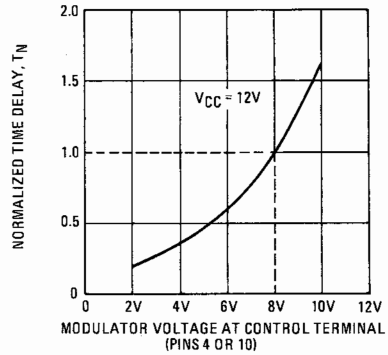


FIG. 7—HOW OUTPUT PULSE WIDTH or time delay varies with modulation voltage on control terminal.

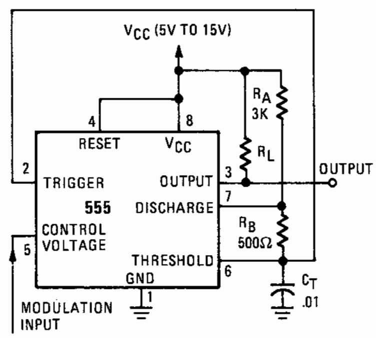


FIG. 8—ASTABLE OPERATION provides for pulse-position modulation when modulating signal voltage is applied to control terminal.

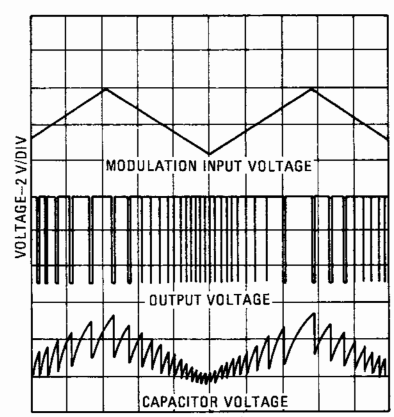


FIG. 9—PPM (PULSE-POSITION MODULATION) waveforms. Modulation voltage need not be symmetrical.

close. These pulses are shaped and clamped by the 1K input resistor and the 5-volt Zener diode. The processed pulses are then fed to the trigger input of the timer. The pulses on the trigger terminal cause the timer output to go "high" for a period equal to $1.1R_TC_T$. During this time, the 1N457 diode is back-biased and a current, determined by the setting of the 200K CALIBRATION control, flows through the meter. At the end of the delay period, the output terminal goes "low" (drops to around ground potential) and removes the blocking bias from the diode. The 1N457 now conducts, forming a low-impedance shunt around the meter.

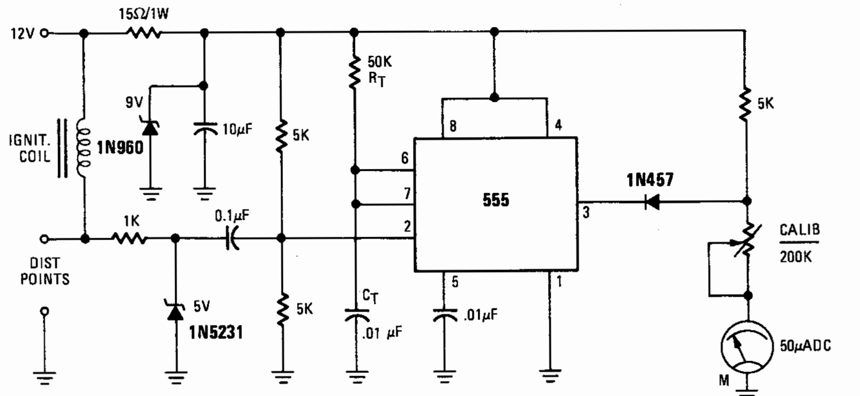


FIG. 13—ELECTRONIC TACHOMETER. Timer processes ignition pulses and controls current flowing through the meter movement.

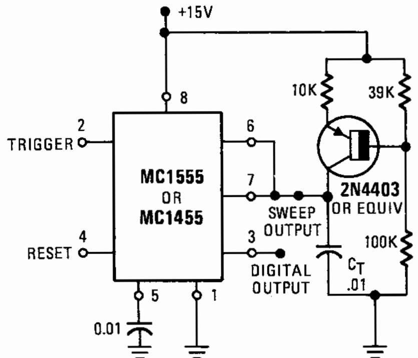


FIG. 10—LINEAR RAMP developed when timing capacitor charges through constant-current source.

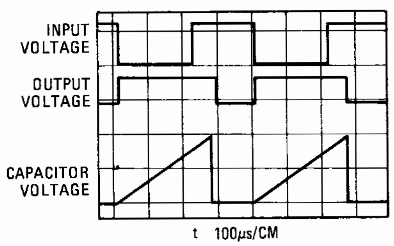


FIG. 11—WAVEFORMS developed in linear-ramp generator.

From this, we see that the meter is fed a train of current pulses. The meter interprets the ratio of the time that current flows through it to the time that it is removed as revolutions per minute. The best way to calibrate the tachometer is against another of known accuracy. Your local garage will probably have a portable tach or will have one built into their engine analyzer.

Non-timer applications

In previously described applications, the timer was used in both the monostable and astable modes for time delay or pulse generations. Another popular application is as a controlled flip-flop. All we need to do is to arrange for the voltage on the trigger terminal to swing from below one-third V_{cc} to a point above two-thirds V_{cc} under some varying outside influence as light, pressure, humidity or temperature. A control relay can be connected from the output terminal to ground or to V_{cc}, depending on the application.

Figure 14 shows how a 555-type timer and an LDR such as a CdS photocell can be used as a photosensitive relay in an intruder alarm or for switching on a light at sunset and off at sunrise. Under normal conditions, the light falling on the photoresistive (or photoconductive) cell causes its resistance to drop to a low value. The voltage on the trigger terminal is equal to one-third V_{cc}, or lower, keeping the relay de-energized. As daylight fades, or the light on the photocell is interrupted by an intruder, the photocell resistance rises and the relay is energized to actuate the alarm or turn on a lamp. The variable resistor is a SENSITIVITY control.

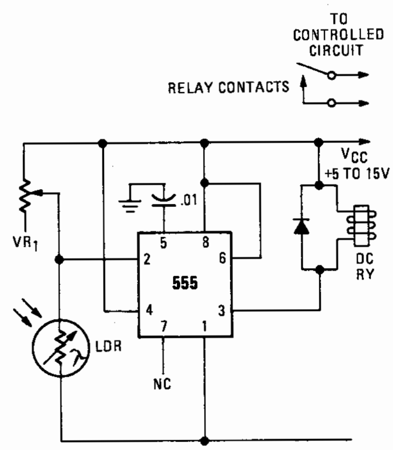


FIG. 14—TIMER CONTROLS RELAY in photo-electric applications. Circuit can be used to control lighting or detect intruders.

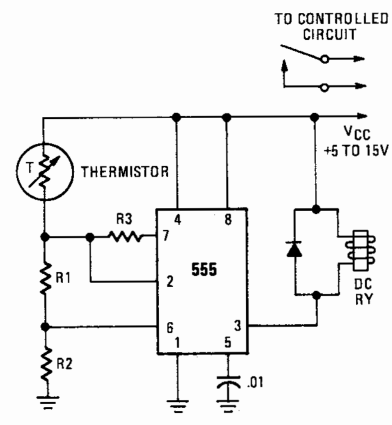


FIG. 15—ELECTRONIC THERMOSTAT can be based on this circuit. Performance depends on thermistor characteristics and on the resistive voltage divider.

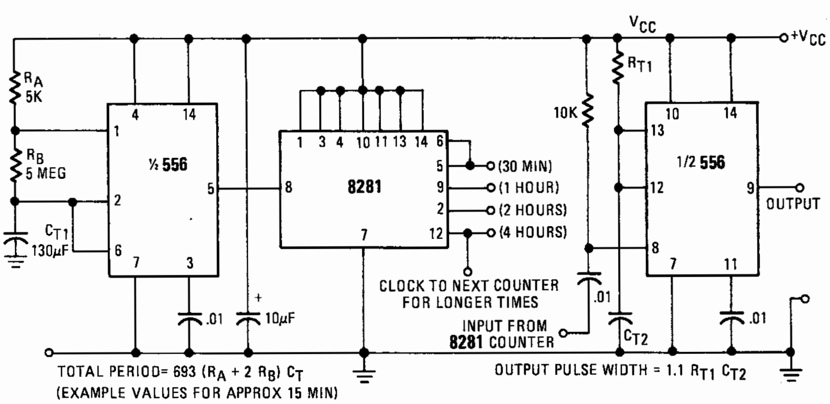


FIG. 12—DUAL TIMER and 8281 presettable binary counter teamed up for long time delays. The delay can be as much as sixteen times that set by the time-constant of the first timer.

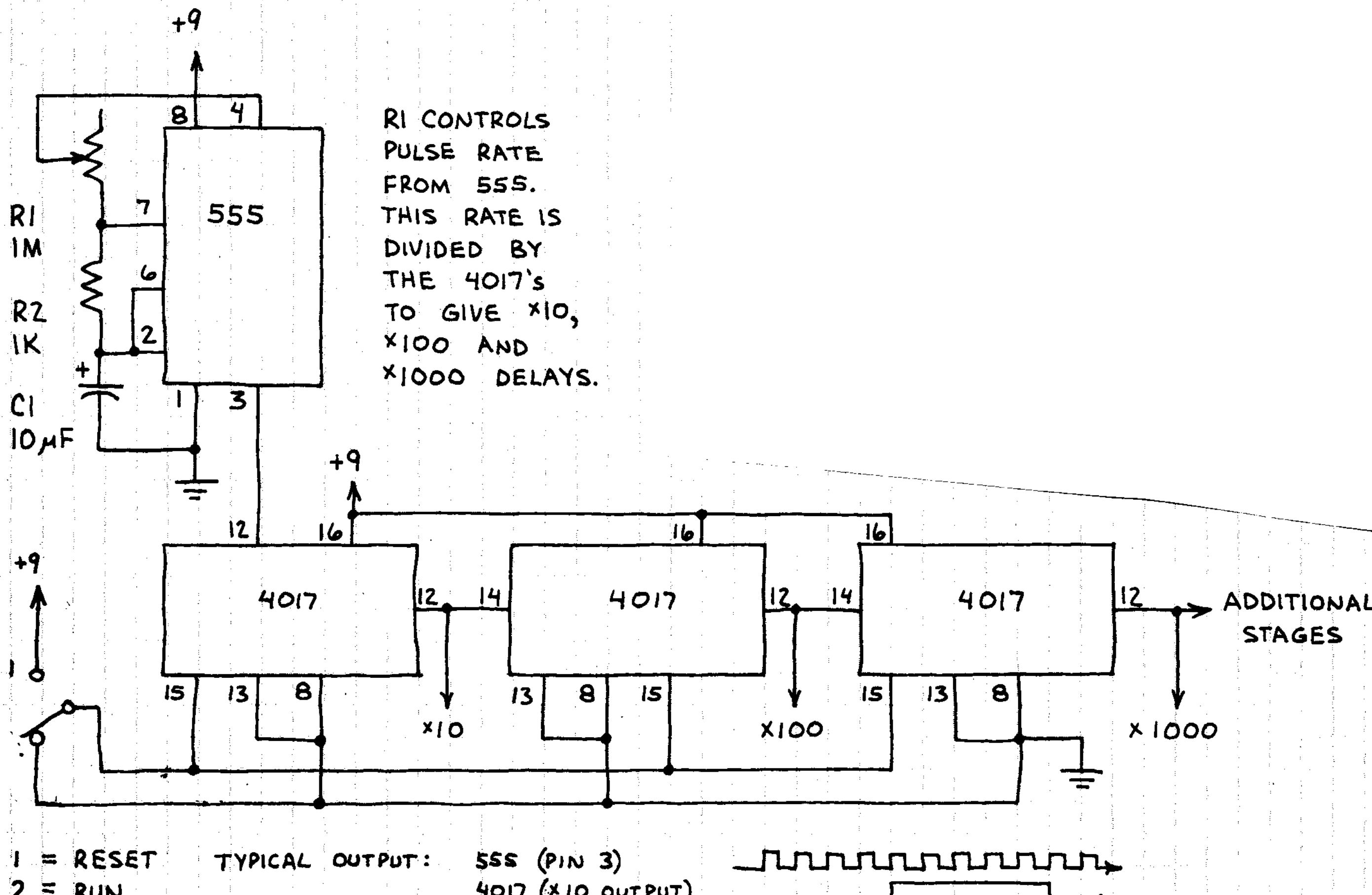
Another non-timer use of the 555 is as a thermostat or an interface between a thermistor and a power relay. An application of this type is shown in Fig. 15.

For example, it can be used to turn on a cooling or ventilator fan when the temperature reaches a certain level and turn it off when the temperature has dropped to a preset low level. Similarly, the circuit might be used to control a heater or oven or, with a lot of refinements, to control the temperature of photo processing chemicals and baths.

The on and off states of the controlled device are determined by the values of R1, R2 and R3 and on the resistance and temperature coefficients of the thermistor. **R-E**

TIMER (CONTINUED)
555

ULTRA-LONG TIME DELAY



Integrator improves 555 pulse-width modulator

by Larry Korba
Ottawa, Ont., Canada

In one method of providing linear pulse-width modulation with the 555 timer, a current source charges a timing capacitor, creating a ramp signal that drives the modulation input of the 555. Unfortunately, the circuit offers only a limited dynamic range of pulse widths and is highly sensitive to temperature. A better way is to use a resettable integrator as the timing element.

Charging with a constant current source (a) at best yields a 2:1 dynamic range for a supply of 5 volts—the linear operating range for voltage-to-pulse-width conversion is approximately 2.1 to 4.1 V, and the timing capacitor is totally discharged every timing cycle. Furthermore, the circuit requires temperature compensation to eliminate any timing fluctuation due to the temperature sensitivity of Q_1, since the base-emitter voltage varies at the relatively high rate of −5 millivolts per °C. And, to add to the circuit's woes, I_{cbo} varies with temperature as well.

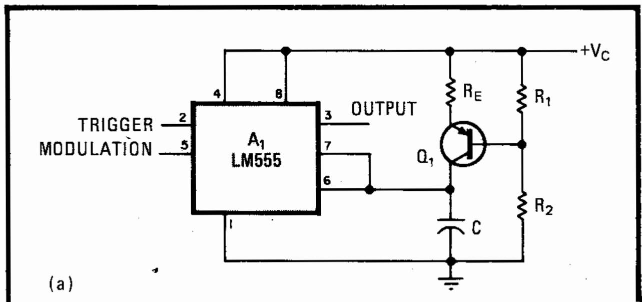
The resettable integrator (b) made up of A_2, Q_1, C, and R applies a trigger pulse to the 555, causing Q_1 to turn off. Integrator A_2 then ramps up until the voltage level at the modulation input of the timer equals that at pin 5. When that happens, Q_1 is turned on again, resetting the integrator and turning off the 555.

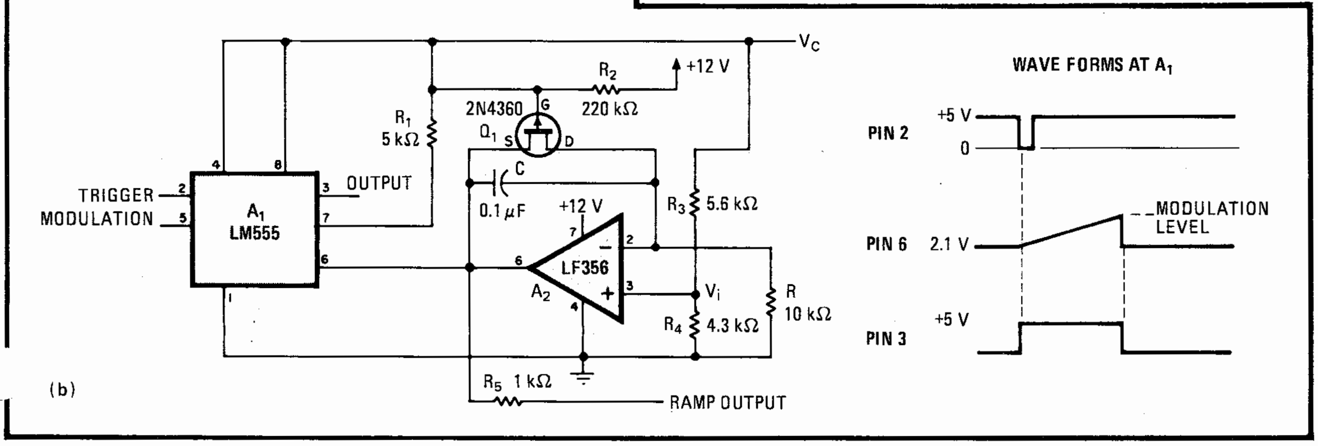
The voltage applied to the integrator, V_c, is set to 2.1 V. This makes the shortest linearly modulated pulse width equal to the trigger pulse width—2 microseconds. With the timing values shown, the maximum pulse width is 6 milliseconds, producing a dynamic range of more than 3,000:1 over the linear operating region.

The active components affecting the timing circuit are A_2, Q_1, A_1, and V_{cc}. Since the average temperature coefficient for the offset voltage of A_2 is a very low 5 microvolts/°C (affecting the timing by only 2.5 parts per million/°C), the circuit's almost negligible adverse temperature effects are largely due to the variation with temperature of the off current of Q_1, I_{dss}. I_{dss} doubles every 10°C; for the 2N4360, it is about 10 nanoamperes at room temperature.

It is important to note that for both circuits, the effects of V_{cc} and the 555 on timing stability are the same. As a bonus, however, the new circuit provides a linear ramp output that can be loaded fairly heavily without seriously affecting circuit timing. □

Engineer's notebook is a regular feature in *Electronics*. We invite readers to submit original design shortcuts, calculation aids, measurement and test techniques, and other ideas for saving engineering time or cost. We'll pay $75 for each item published.

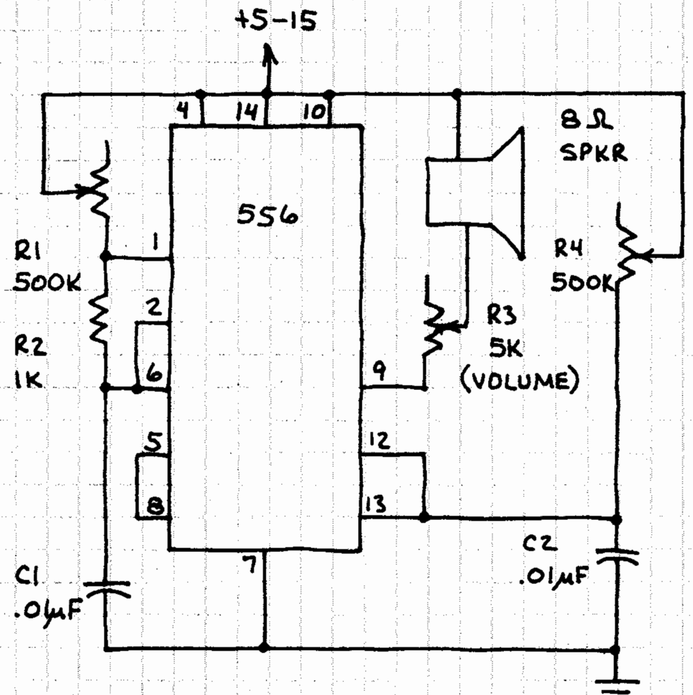




Old style, new style. In the most common method of linear pulse-width modulation using the 555 timer integrated circuit (a), the timing elements are current source Q_1 and capacitor C. The sensitivity of the pulse characteristics to circuit parameters leaves much to be desired. When a resettable integrator is used to time the modulator (b), circuit sensitivities are reduced greatly. As a bonus, pin 6 provides a ramp output with significant drive capability.

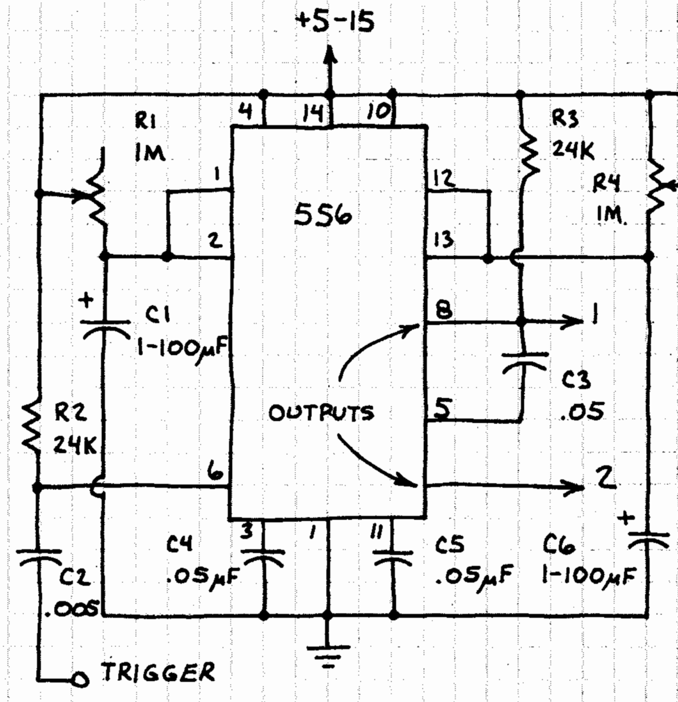
DUAL TIMER (CONTINUED)
556

SOUND SYNTHESIZER



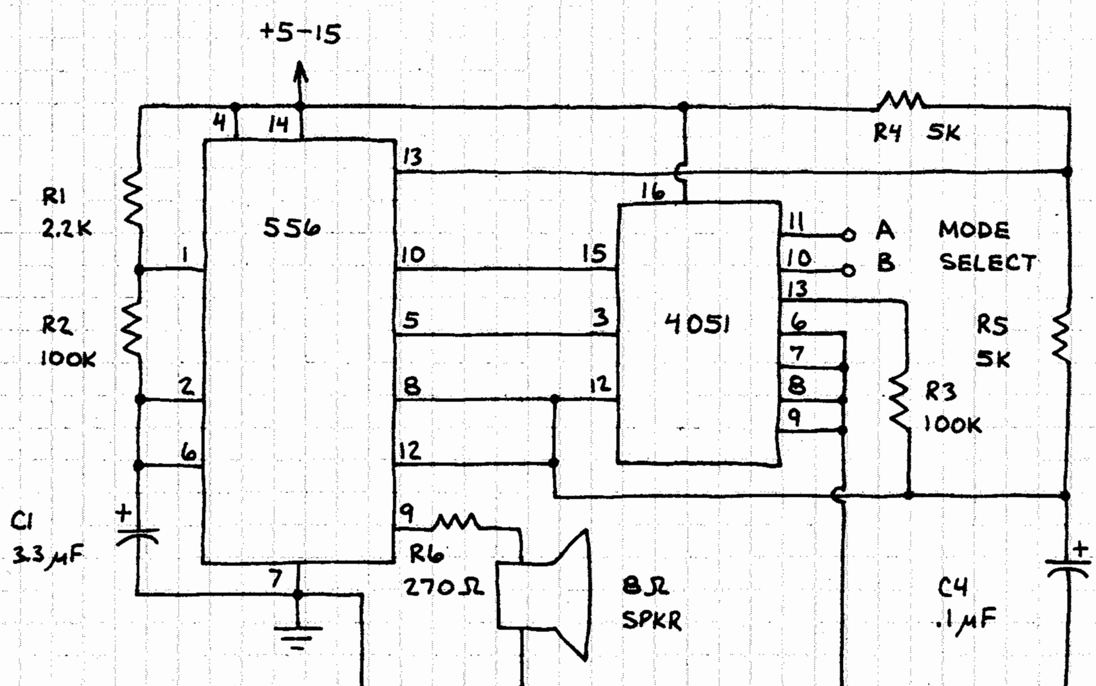
THIS CIRCUIT IS AN OSCILLATOR FOLLOWED BY A FREQUENCY DIVIDER. ADJUST R1 AND R4 FOR VERY UNUSUAL SOUND EFFECTS.

TWO-STAGE TIMER



BOTH TIMERS ARE IN ONE-SHOT MODE. GROUNDING THE TRIGGER INPUT INITIATES THE FIRST TIMER'S CYCLE TIME. THE SECOND TIMER'S CYCLE BEGINS AFTER THE FIRST IS COMPLETE.

PROGRAMMABLE 4-STATE TONE GENERATOR



MODE SELECT

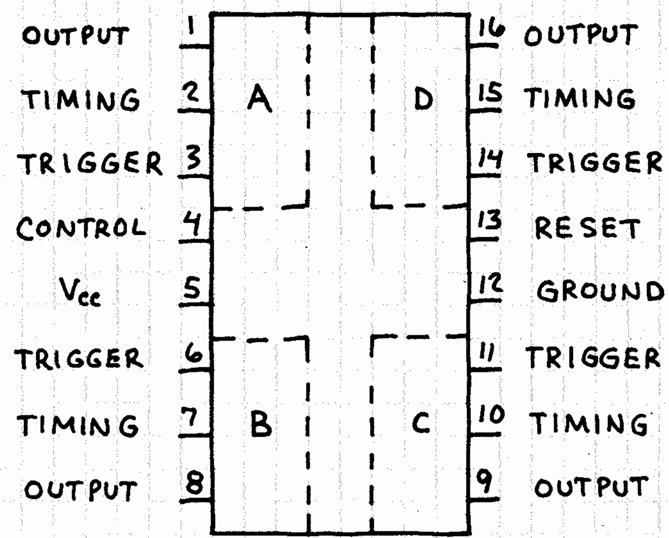
B A	OUTPUT
L L	TWO-TONE
L H	STEADY
H L	BURST
H H	METRONOME

L = GND
H = +5-15 (V_{DD})

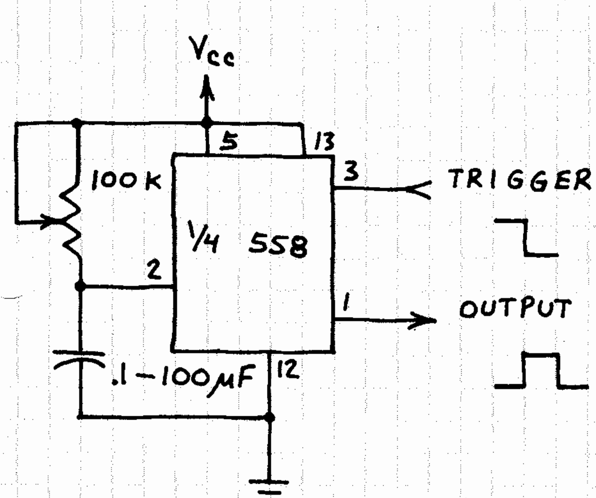
CHANGE C1 AND C4 TO ALTER THE OUTPUT TONES.

QUAD TIMER
558

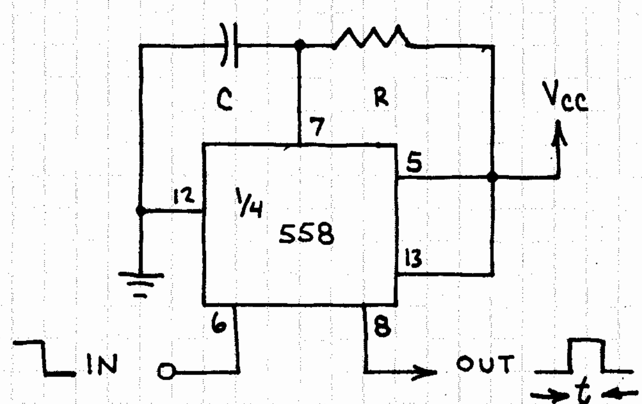
CONTAINS FOUR INDEPENDENT MONOSTABLE TIMERS. EACH TIMER IS SIMILAR TO PART OF A 555 TIMER. ASTABLE OPERATION POSSIBLE WITH ONE TIMER. V_{cc} = +4.5 TO 18 VOLTS. CONTROL AND RESET PINS ARE COMMON.



BASIC TIMER

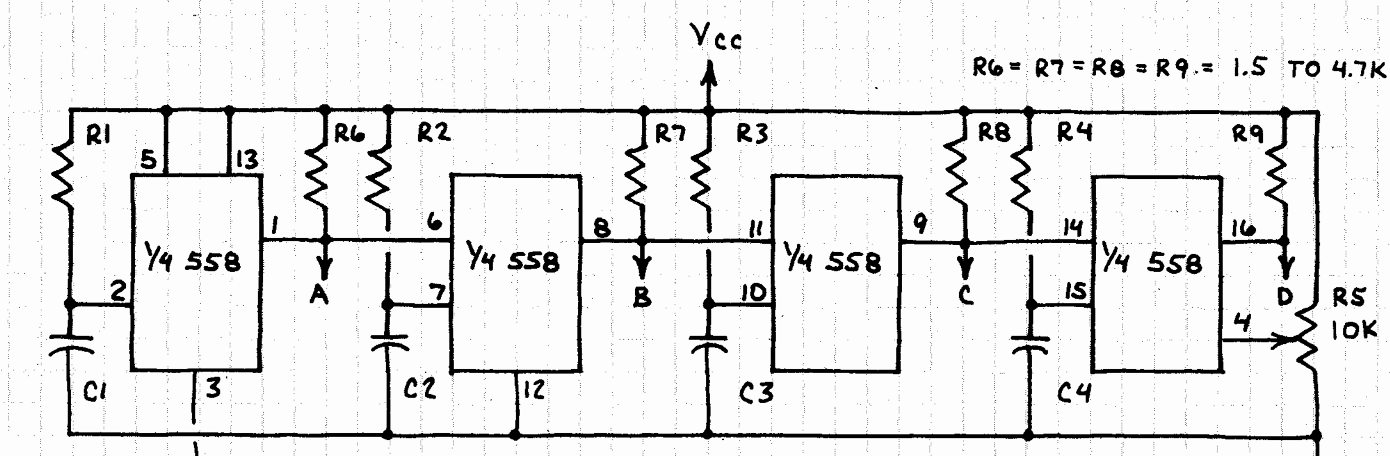


ONE-SHOT



$t = 1.1\,RC$

PROGRAMMABLE SEQUENCER



TRIGGER

OUTPUTS A, B, C, D GO HIGH, THEN LOW, SEQUENTIALLY. R1-R4 AND C1-C4 CONTROL DELAY PER STEP. R5 CONTROLS RATE.