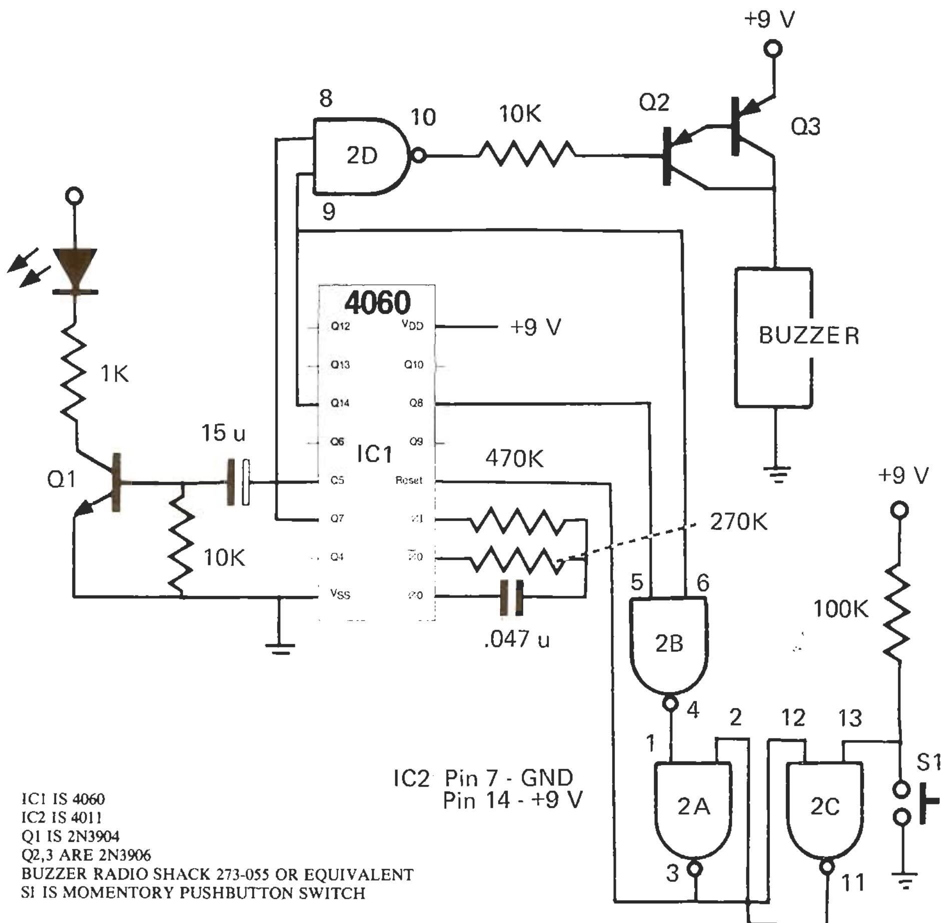
Low Power Timer with Automatic Shut-off

Ed Carew

This timer was designed to replace a 3 minute "hour glass" type timer used for the word game "Boggle". Advantages of the electronic timer are: simple design, automatic shut-off, LED activity indicator, low power and loud "buzz" at the end of timing interval.

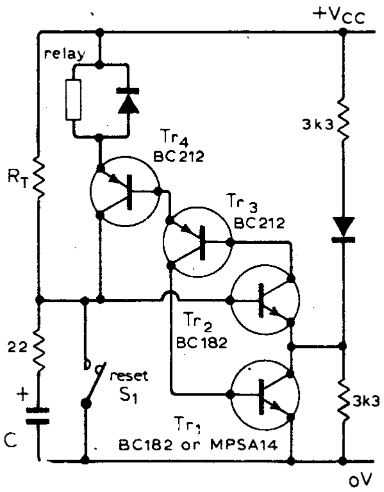
The CMOS 4060 is a counter oscillator which can produce long timing intervals with relatively small RC values. With values shown, the buzzer will activate for about 2 seconds at the end of a 3 minute interval. The LED flashes every 3/4 second for the 3 minute duration. Gates B1 and B2 form an R-S latch whch is set by depressing the push button switch, S1. This allows the 4060 reset pin to go low and the counter starts. At the end of the timing cycle (gated Q8 & Q14) the latch is reset and this resets the counter. With the counter reset, current consumption is so low that an on-off switch is not required. Battery life is determined mainly by the shelf life of the battery; my timer has the original battery after nearly two years.



One-shot timer circuit

The circuit shown is a four-transistor configuration which is similar in operation to the well-known 555 device but, since the normal state is all transistors on, the circuit has a high degree of impulse noise immunity — thereby avoiding the occurrence of spurious timing cycles which are sometimes troublesome in i.c. timing circuits.

In operation, the voltage on the timing capacitor C rises until Tr_2 begins to conduct which in turn causes Tr_3, Tr_4 and Tr_1 also to switch on. Regeneration in the circuit is caused by the interaction of Tr_2 and Tr_4, and the timing capacitor is discharged to about 0.6V by the operation of Tr_3 and Tr_1. The timing cycle is initiated either by the application of V_{cc} or by the opening of S_1. As in the 555, the timing period is V_{cc} independent as long as it is stable during the timing cycle.



J. L. Linsley Hood,
Taunton,
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Contributors to Circuit Ideas are urged to say what is new or improved about their circuit early in the item, preferably in the first sentence.

DELAY CIRCUIT

I recently put an alarm system in my house and, to avoid making holes in the walls, I used digital switches inside the door. I'd like some simple circuit to provide a 15-second delay from the normally open switches, so that I can get out of the house before the system is armed.—L. Holmquist, Whitman, MA.

Whenever you need any simple time-delay circuits, the first thing to consider is the 555. Although there are lots of ways to generate a time delay, if your requirements aren't in the nanosecond range, the 555 is the way to go.

Since the 555 was designed for general-purpose timing applications, it can be configured to perform a wide variety of different jobs. The schematic in Fig. 1 is the basic circuit arrangement for setting up the 555 to operate as a pulse generator. You haven't included enough details about your application for me to be sure about the values of the components to use, but the time-delay formula is simple enough for you to fill in the blanks yourself.

The time delay is almost exclusively dependent on the values of R and C, and won't be affected much at all by temperature or reasonable variations in the supply voltage. All those good things are inherent characteristics of the 555. The trigger input is normally high and the 555 output will be normally low. When the trigger is brought low momentarily, the 555 will start the RC delay and the output will go high. When the 555 times out, the output will go low again and stay there until it's retriggered by your digital switch.

The two important things to remember are that the 555 wants a low trigger and that it will put a high on the output for the delay time that's set by the resistor and the capacitor. You'll have to adapt that to your needs, because I don't know exactly what your setup is; but the 555 is so easy to use that you shouldn't have any trouble at all.

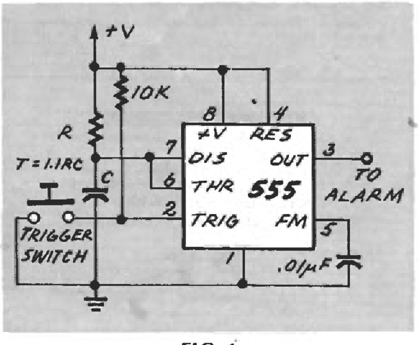


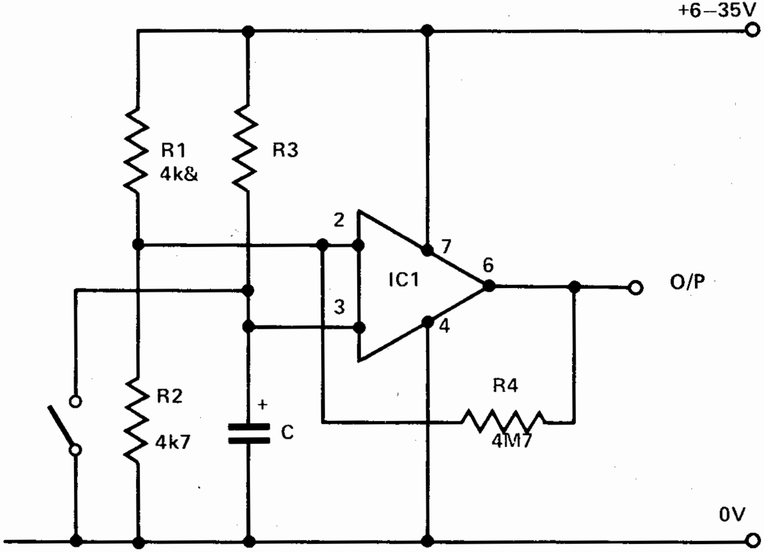
FIG. 1

741 TIMER

The circuit shows a very simple timer based on a 741 op amp.

R1 and R2 hold the inverting input at half supply voltage. R4 applies some feedback to increase the input impedance at pin 3, but its value is such that negligable damping of pin 2's voltage occurs. Pin 3, the non inverting input, is connected to the junction of R3 and C. After S1 is opened and C charges via R3. When the capacitor has charged up sufficiently for the potential at pin 3 to exceed that at pin 2 the output abruptly changes from 0V to positive line potential. If reverse polarity operation is required simply transpose R3 and C.

R3 and C can be any values and time delays from a fraction of a second to several hours can be obtained by judicious selection. The time delay is 0.7CR seconds where C is in Farads and R in ohms and hence is completly independent of supply voltage.



Time Delay Switch

T. Huffinley

IC1a is provided with resistive and capacitive feedback to form an integrator with initial conditions. IC1b is in an "open loop" mode so that its output is either high or low depending on its inputs, and changes state when the output of IC1a goes more negative than the voltage set at ZD2. When the output of IC1b goes positive the transistor Q1 biases hard on switching the SCR on. Diodes D1-D4 are to make the SCR conduct on both halves of the mains wave form.

The delay period is set by the components ZD1, ZD2, C, RV1, and R. If ZD1 is chosen to be 0V5 and ZD2 at 5V, then the maximum delay period is given by T=10.C.R.

$$RV1 = \frac{ZD2}{ZD1} \times R \leqslant 10.R$$

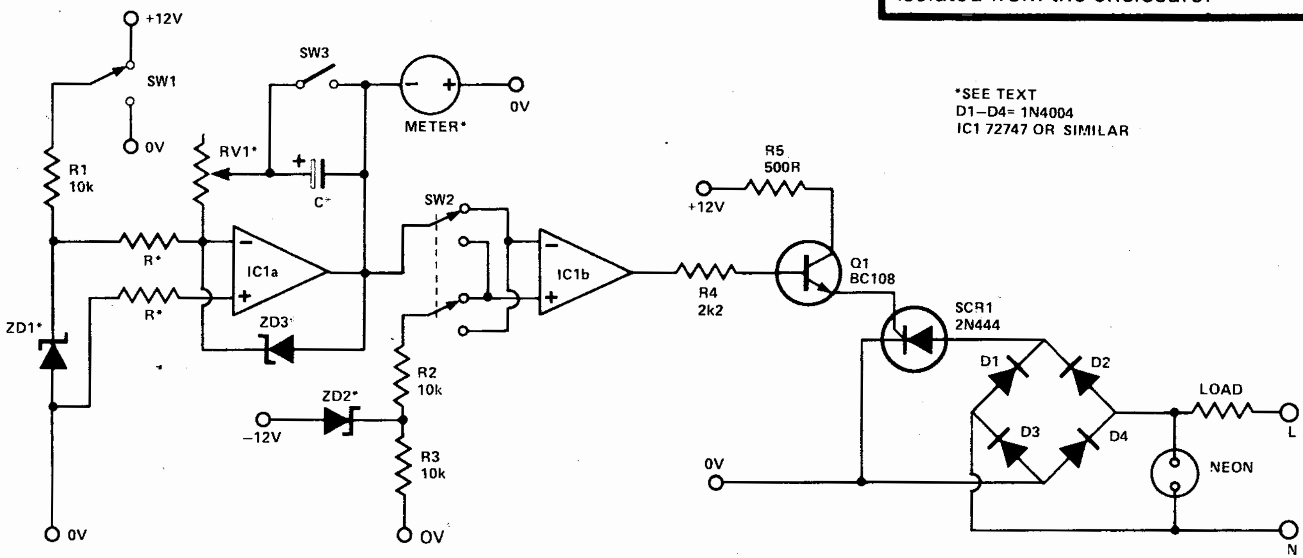
The meter is a voltmeter with a fsd equal to the value of ZD2. The switch then operates when the meter reaches fsd. The meter can therefore be calibrated to show remaining delay with 0V equal to T and fsd equal to zero.

SW2 changes round the inputs of the op-amp so that the output either swings from high to low, or, low to high. SW3 is to reset the time delay which it does by discharging the capacitor. ZD3 should be chosen to be a value slightly higher than ZD2, this is to stop the capacitor charging beyond a set limit and therefore overloading the meter. SW1 is the run-hold switch. When the switch is at +12 volts the integrator charges the capacitor. When the switch is set to 0V the charging of the capacitor is stopped until the switch is set back to 12 volts.

Q1 is a buffer to avoid loading on the IC and to trigger the SCR. The supply voltage should be 12-0-12 and does not need to be well smoothed as the zener diodes set the timing function.

Warning

The circuitry is not isolated from the mains and should therefore be isolated from the enclosure.



Precision timer

THIS circuit gives an audible tone lasting half a second at pre-selected times of 2, 4, 8, 16, 32 and 64 seconds. Two gates of the first i.c. are used as a square wave generator. A variable resistor of 500kΩ enables the generator to be set precisely against a known frequency. Where gates are being used as inverters the inputs are connected together. The square wave, via a spare inverter, clocks the binary counter which is advanced one count on the negative going transition of each input pulse. The six outputs of the counter go to the selector switch, the output of which is used to trigger a flip-flop on the positive going edge.

The flip-flop is used to reset the counter to zero and is set itself by the next positive going clocking pulse. Counting from zero then resumes at the next negative going clocking pulse. Two gates of the second i.c. are used as an audio frequency oscillator which drives a crystal earpiece through a spare inverter. The oscillator is normally off and is switched on for the half second that the counter is being reset.

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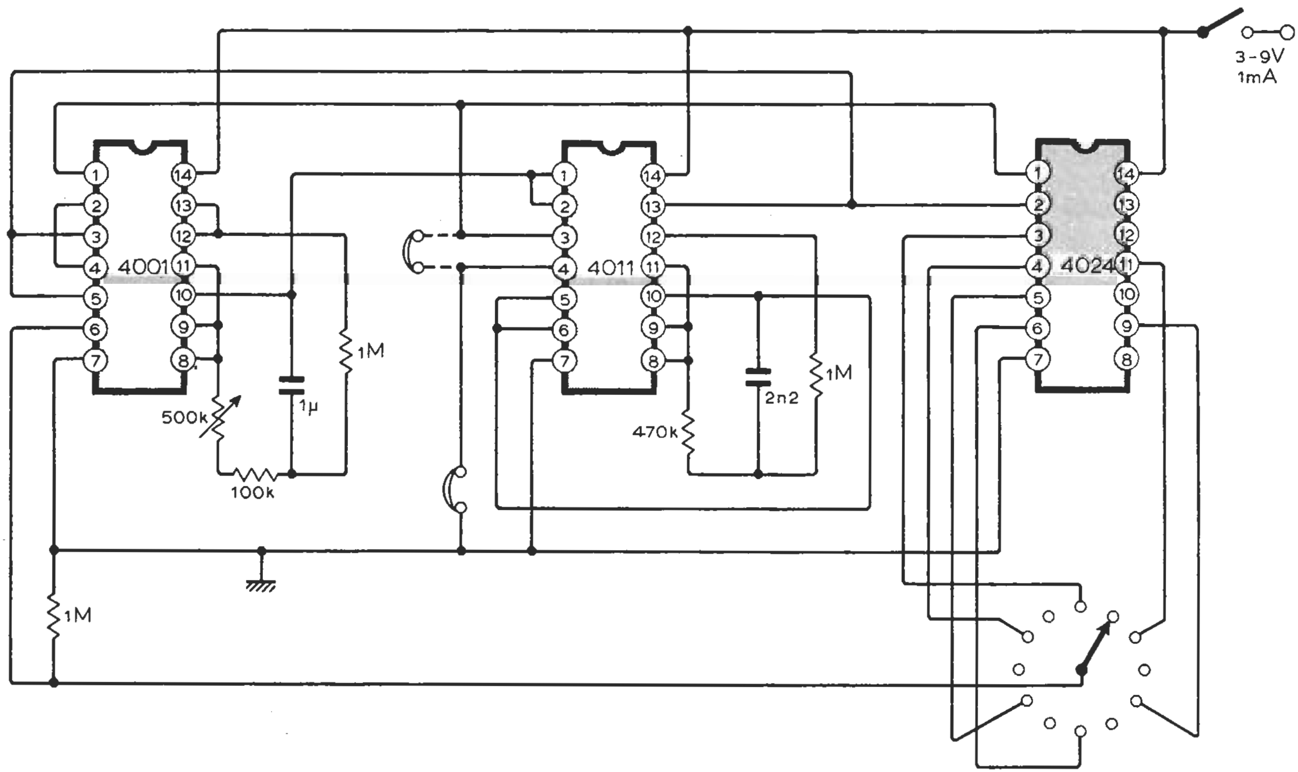


SHUT-OFF TIMER

For Battery-Powered Appliances

BY JEFFREY SANDLER

IT IS easy to attach a timer to a line-powered radio so that the power will be shut off after a certain time, should the listener fall asleep. It is not so easy with a battery-powered radio unless you build the simple circuit described here. With this simple add-on, you can fall asleep on the beach or in a hammock, secure in the knowledge that the radio will automatically shut down later to conserve the battery.

Circuit Operation. A schematic of the circuit is shown in Fig. 1. Resistor *R1* and capacitor *C1* provide a very long time constant. When *S1* is closed, *C1* is discharged and its low voltage is applied to the parallel high-impedance inputs of *IC1*. In this case the outputs of the NAND gates are high and the battery voltage is available at output 1.

When *S1* is opened, capacitor *C1* starts to charge slowly through *R1*. When the voltage across *C1* reaches about half that of the battery, the outputs of the NAND gates drop essentially to zero, effectively turning off output 1.

Transistor *Q1* is added to handle higher current loads. When output 1 is high, *Q1* is on and it supplies a higher current to output 2. The amount of current depends on the transistor used. Changing *R1* and *C1* changes the timing.

Construction. The circuit can be assembled on a small perforated board or a small pc board such as that shown in Fig. 2. You can make the board small enough to fit inside many transistor radios. The radio battery also supplies power to the timing circuit. However, the circuit draws so little current that it will not run the battery down when the radio is not in use. This low current demand is due to the use of CMOS logic and the high value of *R1*. Note that *C1* should have a very low leakage to maintain the charging interval.

The construction of *S1* is left up to the user. It can be a subminiature pushbutton switch, a pair of small bare leads that can be bridged with a fingertip or even a small mercury switch. If using the latter, simply momentarily tilt the radio on its side to "toggle" the timing circuit. If you elect to use your fingertip, you can vary the playing time by the length of time you keep your finger on the two leads. One to five seconds of contact time is usually enough to produce between five and 35 minutes of playing time.

The shut-down timer can be used to control almost any appliance if a separate battery is used for the timer and with output 2 driving a relay. The relay can then apply power through its own contacts to the appliance. ◇

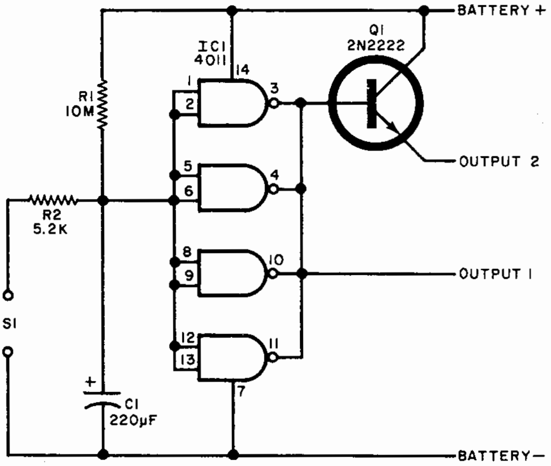


Fig. 1. Four parallel gates supply added power.

PARTS LIST

C1—220-μF low-leakage capacitor
IC1—4011 quad NAND gate (CMOS)
Q1—2N2222 or any low-leakage npn silicon transistor
R1—10-megohm, ⅛- or ¼-watt resistor
R2—5200-ohm, ⅛- or ¼-watt resistor
S1—See text

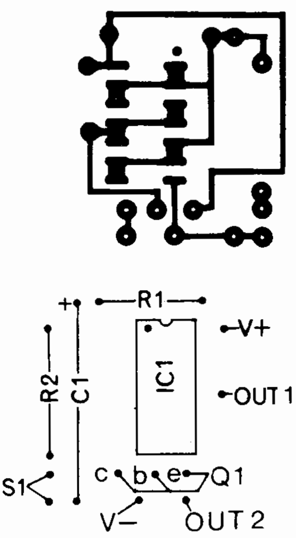
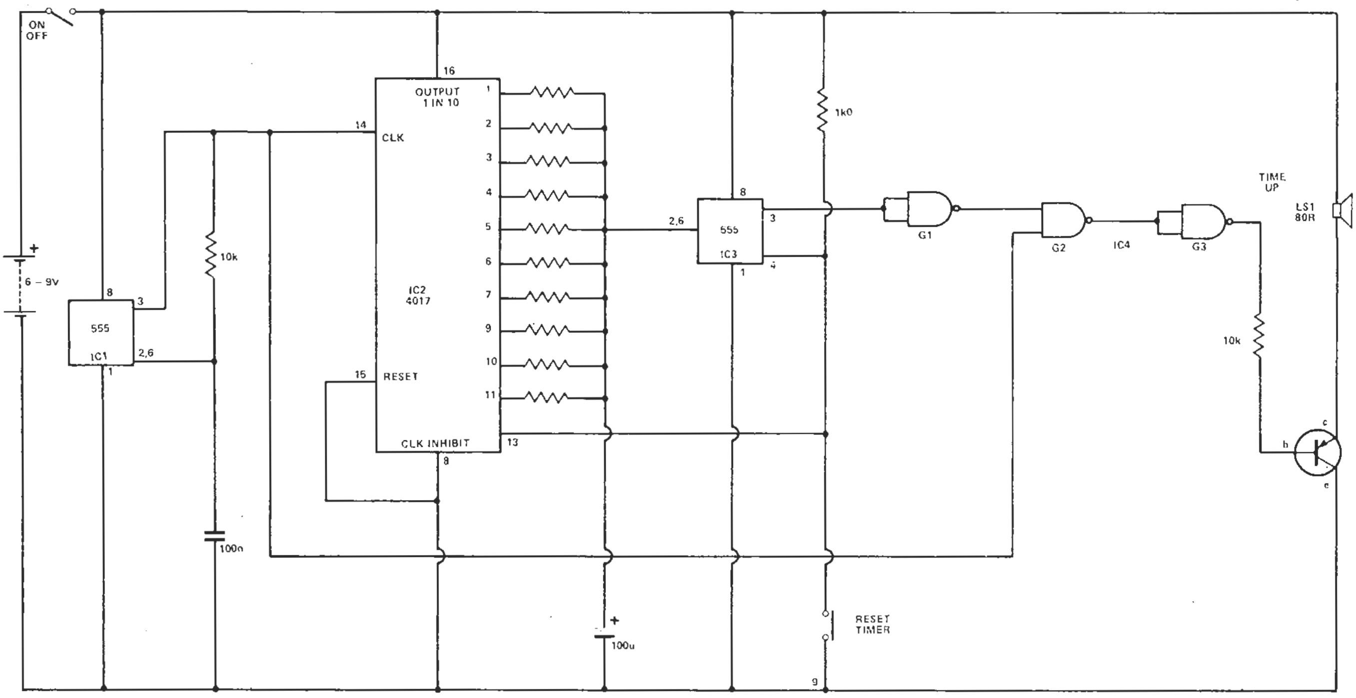


Fig. 2. Small pc board and component layout are shown.

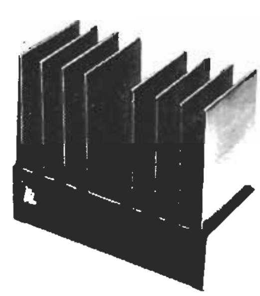


Random Delay Timer

This circuit is designed to add to the excitement of many board games. Players must make their moves within a random unknown time. The delays can be adjusted and the circuit uses only four ICs and a few passive components.

The 555 (IC1) provides a clock frequency for the 4017 and the 'time up' tone frequency. Normally the 4017 clock is inhibited as the clock inhibit pin 13 is high. However, when the 'reset timer' button is pushed, pin 13 is grounded and counting starts. The high output moves wildly between the outputs until the switch is released. Only one output will then be high, which one being entirely a matter of chance. The resistor connected to this high output determines the charging time of the capacitor. For the 100 u capacitor shown, 10 k should be allowed for each second of delay. When the capacitor has sufficiently charged up, IC3 switches off. This is inverted by G1 and appears high. The tone from IC1 is gated by this high signal to drive the loudspeaker via Q1.

Pressing the switch at any time clears the monostable and selects a random delay resistor. The delay resistors can be of any value selected by you. G1-3 are any NAND gates from a single 4011/7400. If the battery voltage is greater than 6 V a 4011 must be used.



Long Duration IC Timers That Really Work!

Programmed delays and intervals of many hours can be precisely timed by combining the short-term accuracy of the one-shot multivibrator with the precision of the binary counter. Here is how the setup operates.

JOSEPH J. CARR

ELECTRONIC TIMER CIRCUITS USUALLY CONSIST OF MONOSTABLE multivibrators (i.e., one-shots), and their periods are controlled by an R–C time constant. The 555 IC timer, for example, has an output duration of 1.1 RC. Most literature dealing with 555 applications claim that 10 megohms and 100 μF are the maximum values for R and C, respectively. However, at these maximum limits, *precision* components are difficult to obtain and, when available, tend to be expensive. Precision resistors in the 10-megohm range are relatively available, but capacitors with better than 5% tolerance in the above 1-μF range become increasingly difficult to obtain as the capacitance value goes up. In addition, many capacitors, even tantalum types, tend to be leaky; this deteriorates the precision of the R–C circuit. Also, most electrolytic capacitors are rated to be within −20% to +100% in the over 10-μF region.

Using the maximum values specified by 555 manufacturers produces an output period of $(1.1)\ (10^7)\ (10^{-4})\ =\ 1100$ seconds, or about 18 minutes. If you cascade several 555 devices so that the first device triggers the second and so forth, you can obtain long time delays between the occurrence of the trigger and the trailing edge of the last output pulse; these signals could be gated together to produce a long-duration timer using lower-value components of higher precision. However, even if six 555 IC's were connected in that manner, they would only produce a duration of not quite two hours.

A better alternative is to use a *countdown* technique in which a precision timebase oscillator drives a binary or BCD counter. If we build this circuit using TTL or CMOS IC's, the timer will accomplish our purpose, but still have a relatively high IC count.

The Exar Integrated Systems XR-2240, XR-2250 and XR-2260 timers (with counterparts being Intersil's 8240, 8250 and 8260, respectively) contain a timebase that is similar to the 555 timer, as well as a built-in binary or BCD counter.

Figure 1 is the block diagram of these IC's, and Fig. 2 shows the simplified internal circuitry for the XR-2240. The internal circuitry for the XR-2250 and XR-2260 is similar, except that the binary counter is BCD-coded, and the regulator output (pin 15) becomes an overflow output for the counter.

There are three basic sections in the timer IC: the timebase, the binary counter and the control logic (see Fig. 1). The timebase is an R–C multivibrator that produces output pulses with a duration equal to R × C. The counter in the XR-2240 is a straight 8-bit binary counter with outputs weighted in the standard 2^0, 2^1, 2^2, 2^3, 2^4, 2^5, 2^6 and 2^7 format to produce time weights of 1, 2, 4, 8, 16, 32, 64 and 128 times the timebase period.

The XR-2250 uses a BCD-weighting in which pins 1 to 4 form the least-significant digit (weighted 1, 2, 4 and 8), and pins 5 to 8 form the most-significant digit (weighted 10, 20, 40 and 80). The XR-2250 produces output times that are weighted 1 to

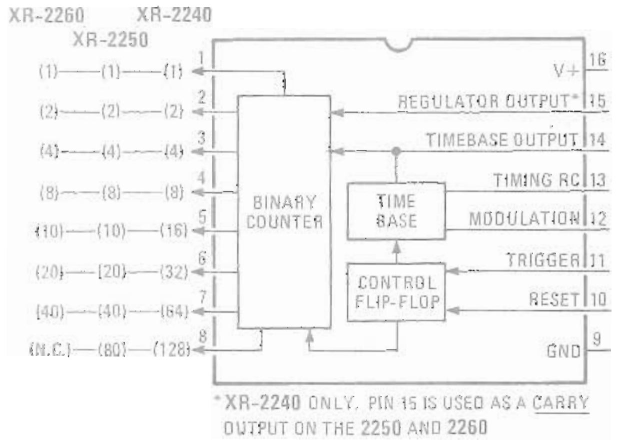


FIG. 1—TIMER IC PINOUT diagram for the XR-2240, XR-2250 and XR-2260. Numbers in parentheses are the binary weighted time durations.

99 times the timebase period.

The XR-2260 timer is similar to the XR-2250, except that the most-significant digit is limited to a maximum count of 5 (with a weighting of 50); output pin 8 on the XR-2260 is not used. This IC is designed for use in hours, seconds and minutes timers.

In all three IC timers, the timebase oscillator produces the pulses that are fed to the counter input, and the control flip-flop triggers the timebase and sets all counter outputs initially to 0.

The XR-2260 timebase, like the popular 555, consists of two voltage comparators, a flip-flop and two NPN transistors (see Fig. 2). This design allows an R–C timer to achieve better stability because there is less dependence upon temperature fluctuations and, especially, on changes in the power-supply voltage.

Transistor Q1 in the timebase is the discharge switch, which keeps capacitor C discharged whenever Q1 is turned on. Transistor Q2 is an open-collector output switch that drives the input of the binary counter. In normal operation, where the counter is driven by the internal timebase, the collector of Q2 (pin 14) is connected to the regulator output through a 20,000-ohm resistor.

The two voltage comparators are biased by voltage-divider network R1–R3. The noninverting (+) input of comparator 2 is biased to approximately 0.27+ (pin 16 is V+).

When a trigger pulse is applied to the control-logic section, the timebase flip-flop is placed in the SET condition, thereby turning off transistors Q1 and Q2. In this condition the timebase output terminal is forced high, and capacitor C starts charging through resistor R from the V+ voltage source. When the capacitor voltage reaches 0.27+, comparator 2 toggles, resetting the flip-flop and turning on Q1 and Q2. When Q1 is turned on, the capacitor is discharged rapidly. When Q2 is turned on, the timebase output terminal drops low. The length of time that the timebase output terminal remains high is the R–C time constant, or R × C (R is in ohms, C in *farads* for time in seconds).

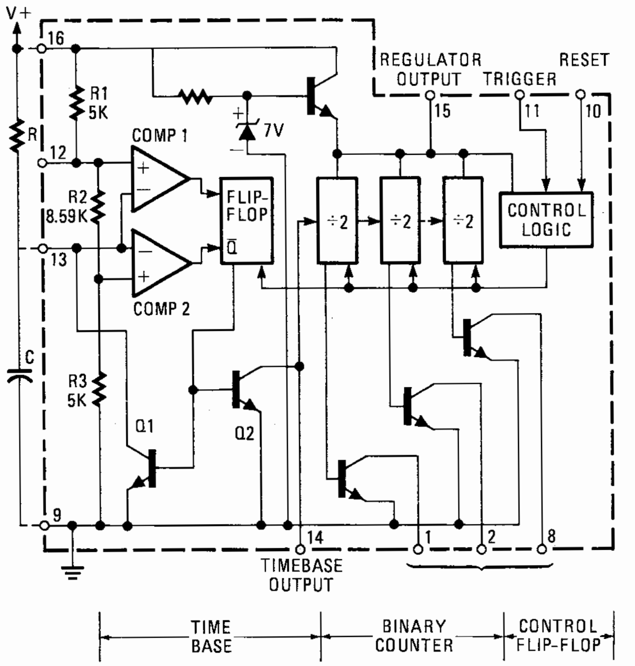


FIG. 2—XR-2240 IC contains a timebase circuit and a binary counter.

Each counter output is an open-collector NPN transistor capable of sinking a maximum of 5 mA, and must be connected to the V+ voltage through a pull-up resistor. Since the IC will operate with V+ supplies between 4.5 volts and 18 volts DC, the ***minimum*** value of the pull-up resistor is 900 ohms at the minimum supply voltage and 3600 ohms at the maximum supply voltage. A resistance of 10,000 ohms is typically specified.

The basic timing circuit is shown in Fig. 3-a. When a trigger pulse is received, the timebase begins producing pulses and the counter starts incrementing. It continues to increment until a positive-going reset pulse is applied to pin 10. Figure 4 shows the XR-2240 timing diagram for the first eight timebase pulses (only pins 1 to 4 are involved, pins 5 to 8 remain low until *after* the eighth timebase pulse).

If two or more outputs are wired together through a single pull-up resistor (a wired-OR configuration), then the output remains low for as long as any *single* output is low. This feature allows you to program the output period by connecting together the appropriate pins and selecting the timebase frequency. If only pin 1 is used, then the output duration is 1 × RC, and if all eight pins are wire-OR'ed together, then the output duration is 255 × RC.

If, for example, you wanted a 67-second timer, you could set the R–C time constant to 1 second (i.e., R = 1 megohm, C = 1 μF, or R = 10 megohms and C = 0.1 μF), and then wire-OR pins 1, 2 and 7 together to obtain weightings of 1, 2 and 64, respectively. The output duration will then be (1 + 2 + 64)RC, or 67RC. Since the R–C time constant is 1 second, the total output duration is 67 seconds. Any time duration between 1RC and 255RC can be programmed using the XR-2240, or between 1RC and 99RC using the XR-2250, or between 1RC and 59RC using the XR-2260.

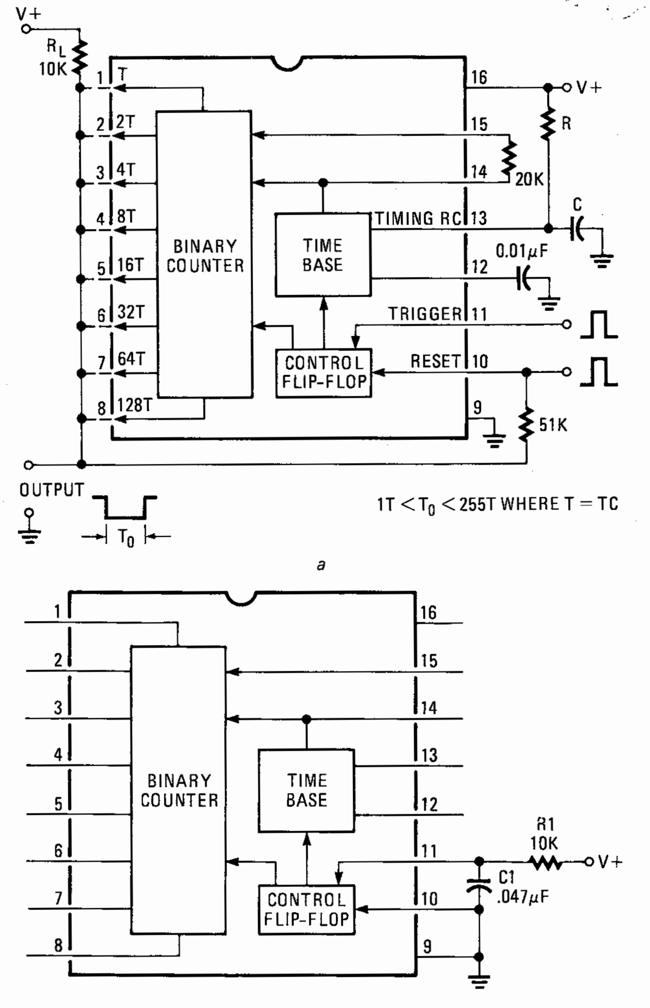


FIG. 3—EXTERNAL CIRCUITRY required for timer IC is shown in *a*. Timer starts counting after receiving trigger pulse. Modification shown in *b* is for free-running mode.

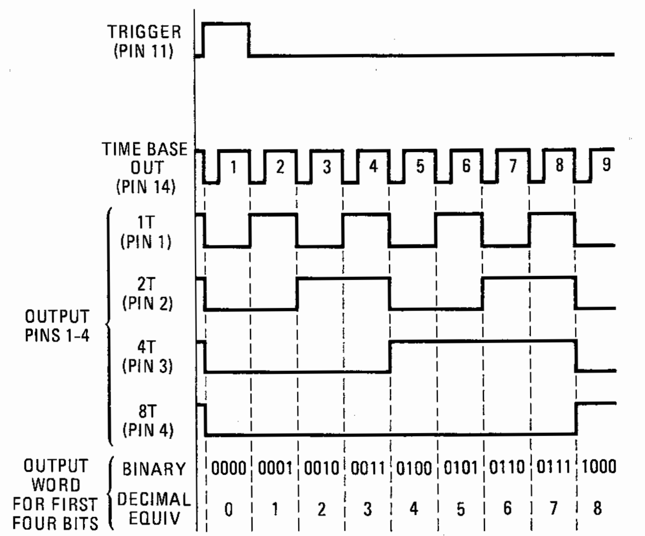


FIG. 4—TIMING DIAGRAM FOR XR-2240 for the first eight clock pulses after triggering.

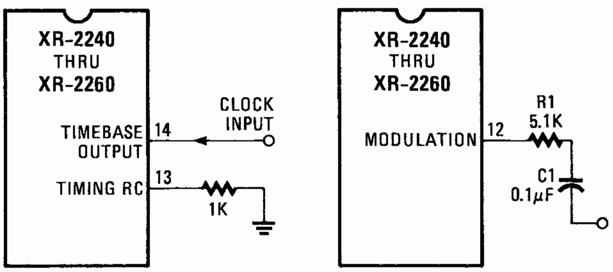
The circuit shown in Fig. 3-a is self-resetting because reset terminal pin 10 is connected to the output through a 51,000-ohm resistor. At the end of the output period, the output terminal snaps high, forming the positive-going reset pulse that shuts off the timebase oscillator.

The modification of the basic circuit shown in Fig. 3-b allows for continuous operation of the timebase. The trigger is tied permanently high, and the reset is grounded and therefore inhibited. You could also use this circuit in other applications besides simple timing procedures.

Precision in an R–C oscillator is often difficult to achieve because of changes in the power-supply voltage and thermal changes in the component values. The comparator timebase used in the Exar IC's and the 555 reduces the effects of power-supply changes because they operate on a fixed percentage of the V+ voltage, rather than being dependent upon the absolute voltage. The timebase can be partially freed of thermal effects by using precision (or at least metal-film) resistors and either silver mica, polycarbonate or polyethylene capacitors in the R–C network.

Figure 5 shows two alternate approaches to achieving greater precision. In Fig. 5-a, the internal timebase is disabled and an external clock is used instead. The external clock can be derived from the 60-Hz power line for moderate precision, or from a crystal oscillator/divider chain similar to the timebase used in a frequency counter for high-precision applications.

Figure 5-b shows an external reference being used to synchronize the internal R–C timebase oscillator. A series network consisting of a 5100-ohm resistor and a 0.1-μF capacitor is connected between the reference frequency source and the timer IC's modulation terminal, pin 12. The frequency source must have a pulse amplitude of at least 3 volts P-P and a duration between 0.3RC and 0.8RC. The repetition rate of the sync pulses can have a 12:1 ratio with the output pulses.



a b

FIG. 5—EXTERNAL TIMEBASE can be connected to timer IC as shown in *a*. Internal timebase can also be synchronized to an external source as shown in *b*.

Cascading timers

The output-pulse duration can be extended by cascading two or more timers. Because it is possible to wire-OR the outputs, this procedure is easier than in 555 circuits and results in longer durations-per-IC because of the countdown construction of each timer IC. Figure 6 shows two cascaded XR-2240 timers. In this scheme timer IC1 is the input section, therefore, its timebase oscillator is operating. The time period is set by R1 × C1. The 128 (R1 × C1) terminal (pin 8) forms the external timebase for IC2.

Both timer IC's have their respective trigger and reset terminals connected in-parallel. The IC2 outputs are OR'ed together through resistor R4, forming the timer output terminal. Feedback resistor R5 resets both IC1 and IC2 at the conclusion of the time period.

The total period generated by Fig. 6 is (2^{16}) (R1 × C1), or 65,536 (R1 × C1)! If the R1C1 time constant is set to 1 second, then the total period is 65,536 seconds, or more than 18 hours! Cascading allows you to use very short timebase periods to produce extremely long output durations. Of course, using short timebase periods means that the values used for R1 and C1 are small, which results in the use of more readily available precision stable components.

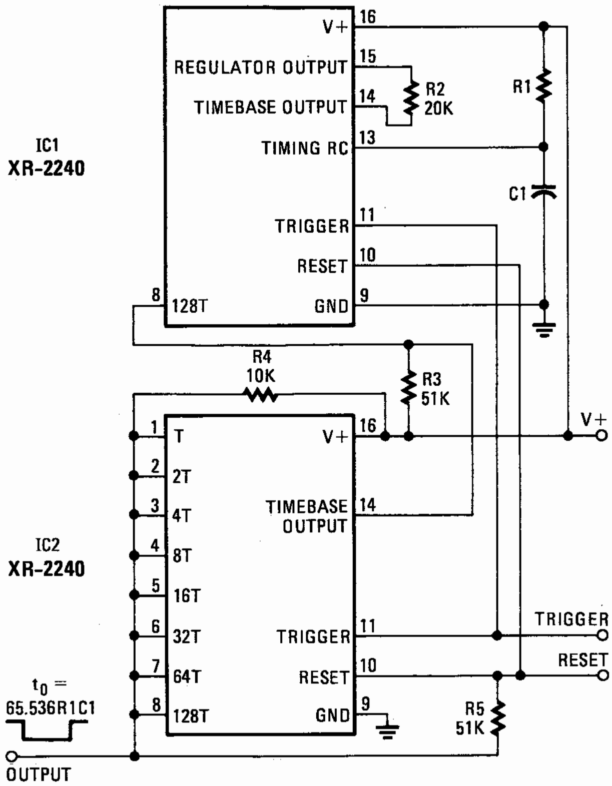


FIG. 6—EXTENDED DELAYS can be obtained by cascading two (or more) timer IC's together.

For example, let's design a simple 1-hour (3600-second) timer using the circuit shown in Fig. 6. The timebase period (i.e., R1 × C1) must be 3600/65,536, or 0.055 seconds. We must select a combination of R1 and C1 that will produce a 0.055-second time constant. The proper combination can be found by some pencil-and-paper trial and error calculation (thinking with a pencil saves hours of breadboarding and doesn't risk burning out IC's).

First, select a convenient value for C1. You could just as easily select a standard resistance, but it is easier to use a potentiometer to trim a fixed resistor to an oddball value than it is to use a variable capacitor to trim a standard-value capacitor to an oddball value. So, let's select 0.1 μF for C1.

Next, calculate the value of the resistance required from the equation R1C1 = 0.055. Since C1 is 0.1 μF (10^{-7} Farads), the formula becomes R1 = $0.055/10^{-7}$, or 5.5×10^5 ohms (550,000 ohms). If R1 is made from a standard 510K resistor and a 100K trimmer (a ten-turn type is preferred), then the timebase period can be adjusted to a precise 0.055 second. Make sure not to use carbon composition resistors (metal film is better) for R1 or unstable capacitors for C1.

Programmable timers

Figure 7 shows a timer that can be programmed using an external digital word. The basic circuit is the one shown in Fig. 3-a, except that the output terminals are connected to a pair of 7485 four-bit magnitude comparators.

The 7485 is composed of a set of TTL exclusive-OR gates connected to compare two 4-bit words and issue outputs indicating whether word A is greater than word B, word A equals word B, or word A is less than word B. Each IC has both magnitude inputs and outputs that allow several 7485 IC's to be cascaded. In this case, you must compare the 8-bit output of the counter with an 8-bit command from an outside source such as a microcomputer output port or a set of thumbwheel switches.

The timing diagram for Fig. 7 is shown in Fig. 8. Since word A programs the timer, the output durations are given in terms of the value of word A and the RC timebase period.

When the trigger pulse is received, word A has previously

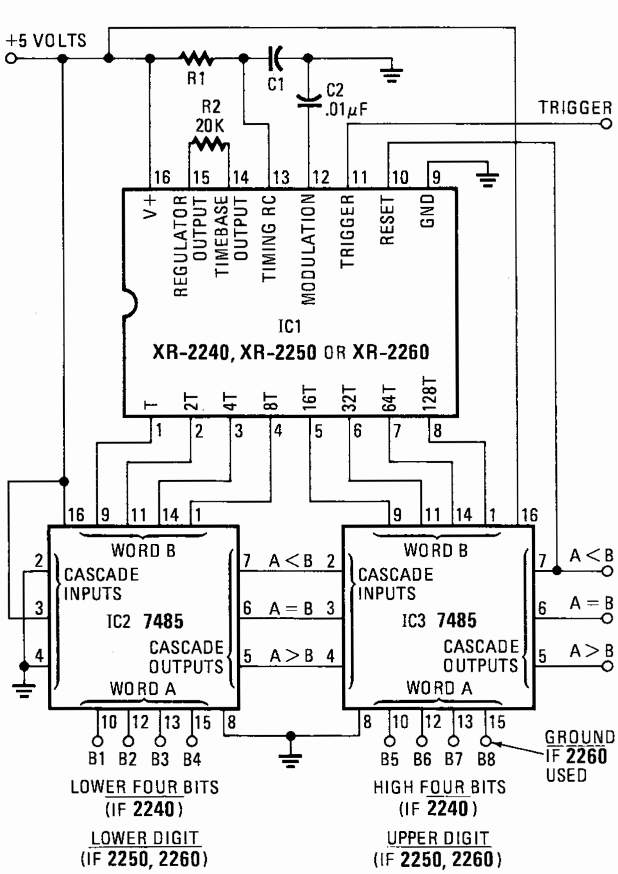


FIG. 7—PROGRAMMABLE DELAY TIMER can be obtained with the addition of two magnitude comparators.

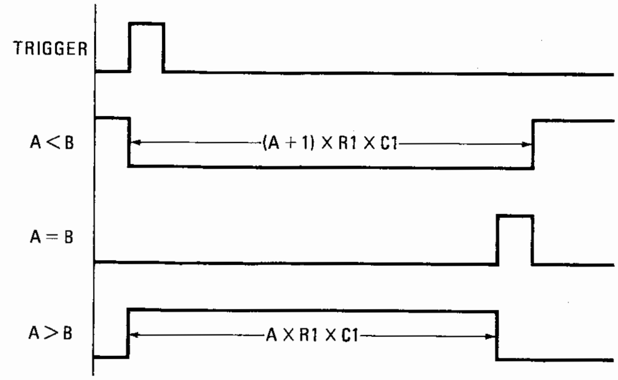


FIG. 8—TIMING DIAGRAM for the programmable delay timer.

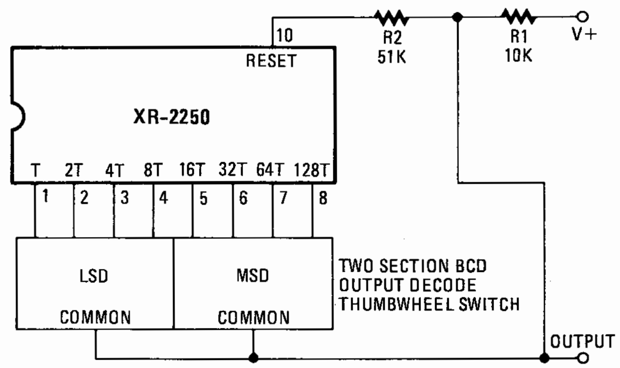


FIG. 9—PROGRAMMABLE DELAY TIMER using BCD thumbwheel switch.

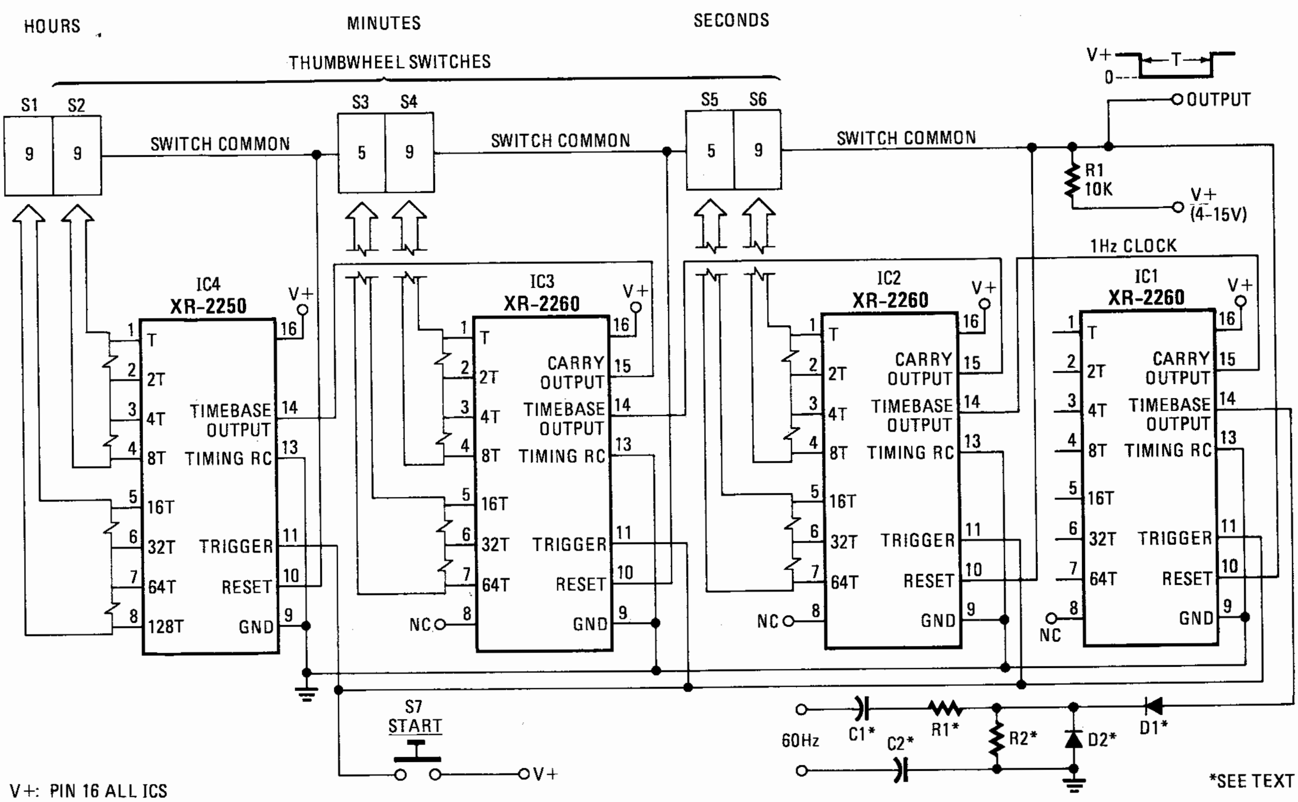


FIG. 10—100-HOUR PROGRAMMABLE TIMER uses BCD thumbwheel switches.

been set to some value between 00000000_2 (0_{10}) and 11111111_2 (255_{10}). All the timer outputs drop low, so word B is initially 00000000_2. At this time, word A is either greater than word B, or equal to it if word A is also 00000000_2. In the former case, the A>B output from IC3 is high and the other two outputs are low. When the counter has incremented so that word A and word B are equal, then the A = B output goes high for one clock period, after which word B is greater than word A, so the A<B output goes high. The timing durations are (A+1)R1C1 for A less than B, and AR1C1 for A greater than B. The A = B output produces a single pulse at time AR1C1.

Assume that the Fig. 7 circuit is programmed so that word A is 178_{10} (10110010_2), and that the R–C time constant is 5 seconds. What is the duration of the A>B pulse? The duration is A × R1 × C1, or (178) (5 seconds), or 890 seconds (about 14.8 minutes).

Thumbwheel switches with binary, BCD, or octal-output codes can be used to program these IC timers. Figure 9 shows a BCD thumbwheel switch that programs an XR-2250 timer. The BCD switches are connected to the output lines on the timer IC, and the switches are in turn connected to pull-up resistor R1. The switches provide a simple way to build circuits (such as that of Fig. 3-a) using convenient front-panel switches to change the output duration when desired.

Figure 10 shows the circuit of a precision 100-hour timer using the Exar XR-2250 and XR-2260 timer IC's. Four timers are in cascade and are programmed by thumbwheel switches.

Timer IC1 is used as a timebase to generate a 1-Hz clock from the 60-Hz AC power line. The values of C1, C2, R1 and R2 depend on the amplitude of the 60-Hz line used for the timebase.

The XR-2260 counts to 59, and on the 60th count generates a carry pulse on pin 15. This output pulse represents a frequency division of 60 for the XR-2260 and a division of 100 for the XR-2250.

As shown in Fig. 10, the *seconds* and *minutes* sections of the circuit are thumbwheel-programmed, cascaded XR-2260 IC's, while the *hours* section is a thumbwheel-programmed XR-2250 IC allowing a maximum of 99 hours. Both XR-2260 IC's use the carry-output pulse to drive the timebase input of the following stage.

The thumbwheel switches program the total duration of the output pulse, but some applications might require a continuous monitoring of the time that has *elapsed* since the trigger pulse started the counters. To do this, you can use an events counter or a clock IC that uses a 1-Hz input. Another alternative is to use an hours-minutes-seconds counter circuit with its reset terminal connected to the timer output. The timer output is active-low and so will allow counting during its time duration, but it will reset the counter when it goes high at the end of the time duration.

Precision is a word not ordinarily used in conjunction with the AC power-line frequency. Digital frequency counters and short-duration timers that use 60-Hz AC power lines as the timebase are often described as being only of moderate precision. The accuracy specification is usually given in terms of 1% or a little less as a result of small variations in the line frequency. The actual frequency varies above and below 60 Hz as the generator speed changes, but the average frequency is quite close to 60 Hz over a period of time. This timer, then, possesses good accuracy for long durations but only moderate accuracy for short time spans. Using a precision crystal-controlled 1-Hz or 60-Hz clock will insure that the accuracy remains the same over the *entire* range.

SWITCHING TRANSISTOR SHORTS

This Quasar TS-938 came in with no picture or sound. Found Q8 (power supply switching transistor) shorted. I replaced it and two days later it was back with Q8 shorted again. I need some help before I blow another one of those expensive transistors! With the replacement in, it worked fine. I could use some help.—H. Y., Baltimore, MD.

You sure could! This can be highly nonhabit forming. I ran across the same thing not very long ago. A friend used the same replacement transistor you did. We checked and found that this was a good transistor but had only a 700-volt peak-surge rating. The original transistor apparently had an 800-volt peak rating. We used a Sylvania ECG-165, which has a 1400-volt peak rating, and it is still working several months later. Always check the peak-voltage rating of this kind of transistor, and use a substitute with the highest rating you can find, of which there are several.

LOSS OF RASTER

This Zenith 19EC45 chassis loses the raster intermittently. I've checked everything I can think of, with no luck. Doesn't seem to damage anything! Where do I go from here?—D. L., Ridgefield, CT.

There is one problem we've run into in this and other Zeniths using the 9-90 horizontal module. Check resistor R808, 330 ohms. If this resistor is bad, it upsets the horizontal sweep. Replace it with a 1-watt resistor.

(Feedback: "That did it! Resistor R808 was almost open. The set is working fine now.")

TURN-ON SQUEAL

This Admiral M10 chassis "popped" at turn-on and finally quit. Resistor R818, in the horizontal driver collector, was open. Replacing this resistor brought the set back on. However, the horizontal oscillator/output would squeal at turn-on, now and then, and also at turn-off. All waveforms became normal after the unit stabilized, but fuse F1000 would blow after 5 to 8 hours of operation. After quite a bit of checking, I found electrolytic capacitor C811 (10 μF, 25 V) was intermittently opening up and allowing some kind of screwball feedback at turn-on and turn-off, and somehow making it blow that fuse.

Thanks to Leon Caldwell, Caldwell's TV, Mena, AR.

NO TINT CONTROL

Several things such as the IC, etc., were replaced in this Zenith 23DC14 chassis after a lightning hit. Now, I do have color and good tints, but no tint control at all. I don't get it.—L. C., Mena, AR.

This chassis uses a DC-voltage tint control, with presets in the color circuitry. Your tint-control DC voltage-supply circuit goes through the chromatic switch. Check for normal DC voltages and follow them through the switch.

(Feedback: "Right, the DC voltage on the tint control wouldn't vary at all. I found a burned-up 470-ohm resistor in the DC voltage-supply circuit. I also finally traced the DC supply voltage through the chromatic switch and found that *both* conductors going to the tint controls were completely blown. Two short pieces of wire fixed that!")

SCOPE PROBLEM

I've got all kinds of odd distortion in a Heath OM-2 scope. I've tried new tubes, with no luck. Do you have any bright ideas?—J. H., Chicago, IL.

Maybe not any *really* bright ideas, but, from my experience in working over old scopes, I recommend checking *all* the coupling capacitors in the vertical amplifier stages. While you're at it, check all the plate, grid and cathode resistors, too, and replace any that are off-value. Doing this fixes most of them.

I had a strange horizontal nonlinearity in an old scope. Replacing the coupling capacitors in the *vertical* amplifier stages cured it. I haven't explained that one yet, but it worked!

(Feedback: "That did it. Changed two 0.1-μF coupling capacitors and now the scope works fine!") **R-E**

Manufacturer's Circuits. A number of useful semiconductor switching and control circuits are described in a series of informative application bulletins published by the Unitrode Corporation (580 Pleasant St., Watertown, MA 02172). Entitled *New Design Idea*, the series is directed toward design engineers, but could be of real value to advanced experimenters and serious hobbyists. Selected from various issues, the interesting circuits illustrated in Figs. 3 and 4 are typical of those discussed in the bulletins.

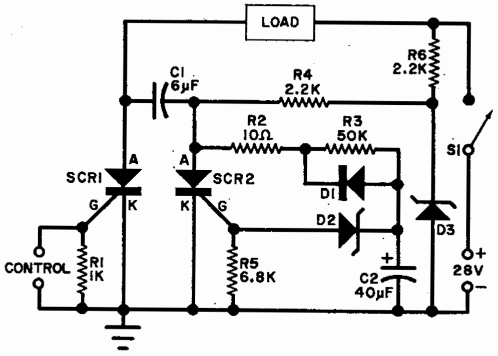


Fig. 3. Novel interval timer will provide three amperes for 1 sec. when toggled by control signal.

Suitable for use in programmers, automatic testing, temperature cycling, process control, and similar applications, the interval timer circuit given in Fig. 3 will supply up to 3 amperes for a period of 1 second when triggered by an external signal, switching off automatically and remaining off until retriggered by another pulse.

In operation, the timing cycle is initiated by applying a positive-going pulse to *SCR1*'s gate, switching this devise to a conducting state and supplying power to the load. At the same time, *SCR2* is switched "off" through *C1*'s commutating action, permitting timing capacitor *C2* to be charged slowly through *R2*, *R3* and *R4* by the constant voltage source established by zener diode *D3* in conjunction with series resistor *R6*. When *C2*'s increasing voltage exceeds series zener diode *D2*'s rating sufficiently to permit adequate conduction through *SCR2*'s gate, the latter device is switched "on," discharging both *C1* and *C2* (through *R2* and *D1*), *removing SCR1*'s anode voltage and, through *C1*'s commutation, switching the device back to a non-conducting state. With *SCR1* "off" and *C2* discharged, the load current is cut off and the circuit is ready for recycling.

Relatively few components are needed for circuit assembly. Silicon controlled rectifier *SCR1* is an SSPI type 3B3060 controlled switch and *SCR2* an SSPI type AA100; *D2*

(*Continued on page 87*)

COUNTDOWN TIMER QUERIES

(A number of readers questioned apparent discrepancies between the schematic diagrams and board layouts for the Digital Countdown Timer in the August and September 1976 issues. Most of the questions were among those included in letter below. Answers—supplied by author George R. Baumgras—appear in italics.—*Editor*)

The following errors were noted in the Digital Countdown Timer articles in the August and September issues:

1—IC8. Bottom layout shows pins 2 and 3 tied together but not on the schematic.

2—IC9 has the same function as IC8 but pins 2 and 3 are not tied together in the bottom layout. Is one of these wrong?

The 7490 and 7492 can be reset with either pin. Rather than leave an unused floating input to an active circuit, the two

continued on page 16

continued from page 14

inputs should be tied together. This is done during the circuit-board layout.

3—IC9. Bottom layout shows a wire going from pin 4 to pin 13 of IC10. Actually pin 4 is not connected to anything inside the IC. So why the hookup?

"No-function" pins are often used to simplify board layout but are not shown on the schematic. In this case, IC9 pin 4 should go across to IC9 pin 12.

4—The terminal of IC2-b that connects to IC9 pin 1 is not numbered.

Should be pin 6.

5—IC9. On the bottom layout, pin 4 goes to pin 13 of IC10. Since pin 4 is not used internally in IC9, I believe that the whole connection is wrong and pin 12 of IC9 should have been used. Is this correct?

The connection is correct as noted in question 3.

6—IC5, pin 3 goes to pin 2 of IC4 in the bottom layout. I think it should have been pin 2. Is this correct?

IC5 pins 2 and 3 go to IC4 pins 2 and 6. Also refer to question 1.

7—IC5. Pin 5 on the schematic is going to pin 13 of IC6. Pin 5 is the V_{cc} connection so this is not correct. I think it should have been pin 8, not pin 5.

Correct.

8—IC14 has pins 6 and 7 tied together on the bottom layout but not on the schematic?

9—IC16 has pins 2 and 3 tied together on the bottom layout but not on the schematic?

Refer to answer to questions 1 and 2.

10—IC 16. Pin 4 on the schematic goes to ground. Actually, it is not connected inside the IC. Is this necessary?

Should be IC16 pins 6 and 7.

11—IC17. Pins 6 and 7 tied together on bottom layout but not in the schematic?

Refer to answer to questions 1 and 2.

12—IC17. Pin 3 goes to ground on bottom layout but not in schematic?

Refer to answer to question 3. IC17 pin 3 connects to ground on the other side of the board.

13—IC15. R6 is marked 11K on the schematic and 1K in the parts list. Which is correct?

Should be 1K.

14—IC15. Pins 6 and 7 tied together to ground on bottom layout but not in the schematic. Which is correct?

IC15 pin 6 is not connected to pin 7. It goes to IC16 pins 1 and 14.

15—IC15. Pin 11 is tied to pins 1 and 2 on the schematic but pin 10 is tied to 1 and 2 on the bottom layout. Which is correct?

16—IC15. Pins 10 and 11 are tied together on the schematic but not on the bottom layout?

IC15 pin 11 connects to IC15 pins 1, 2 and 10. Add this connection to bottom layout.

17—IC4. Schematic shows pins 2 and 6 tied together and then to pin 2 of IC5. Bottom layout has the connection made to pin 3 of IC5. Which is correct?

Either is correct. Refer to answers to questions 1 and 2.

18—IC6. The resistor connected to pin 6 should be R27, not R20.

Correct. Should be R27, 3.3K.

19—Capacitor C4 is listed as 2.2 μF in the parts list and 22 μF on the schematic. Which is correct?

The correct value is 2.2 μF as in the parts list.

20—Top view of the control board. The EN and ADD labels are reversed on the left side of the board.

OK as shown.

21—On the alarm board we have three 1N4000 diodes. The outlines indicate axial-lead types. Actually, a 1N4000 is a 10-watt, stud-mount 7.5-volt Zener. Shouldn't these diodes be 1N4001's?

Yes. They should be 1N4001's or similar.

WILLIAM L. SCHREIBER
Fullerton, CA **R-E**

Rural fire departments using scanning monitors

The fire department of Wicasset, ME, recently purchased 11 scanning mon-

switching system in the world. The processor is also used in the No. 4 ESS for long-distance switching.

The new process-

minutes, seconds and tenths of seconds without the cumbersome conversions required with a decimal calculator. In the

Induction pickup drives elapsed-time indicators

by Edmund Osterland
Boonton Township, N.J.

Maintenance intervals for alternating-current machines like pumps, fans, and transformer-operated equipment can be monitored without hard-wiring to these units. By simple inductive pickup through the frame of a motor, for example, it is possible to operate such integrating modules as the Curtis Indachron, the Philips 49800 electrochemical elapsed-time indicator, or the Plessey E-cell device. These units function on microampere levels of current to record operating times of 100 to 10,000 hours, depending upon their specific dc input.

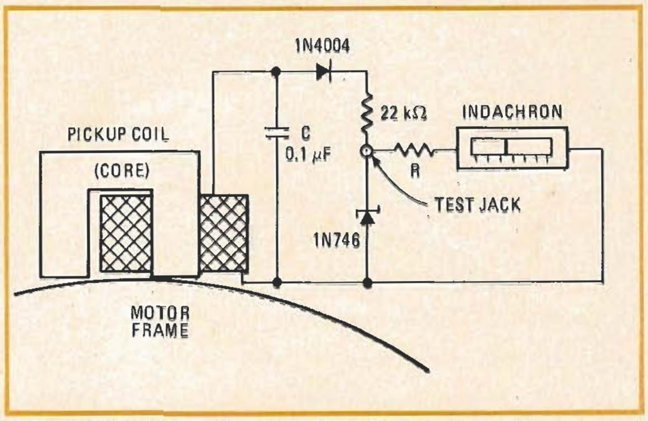
Figure 1 shows a pickup unit clamped (either mechanically or magnetically) to a motor frame. The location is not critical, but proper orientation can be aided by measuring the voltage at a test jack. Capacitor C in parallel with the pickup coil resonates the coil for maximum output voltage. The induced ac is rectified and applied through a current-limiting resistor to a zener diode. The zener diode regulates the rectified voltage input to the timing cell, and series resistor R determines the operating span.

A satisfactory pickup coil may be made from a small commercial choke such as the Stancor C-1003 by removing the strap mounting and the "I" portion, and sawing off one leg of the "E" laminations to provide a single-gap "U" configuration. This pickup delivers up to 10 volts ac when applied to the frames of ¼-horsepower to 1-hp motors and adjusted for optimum coupling.

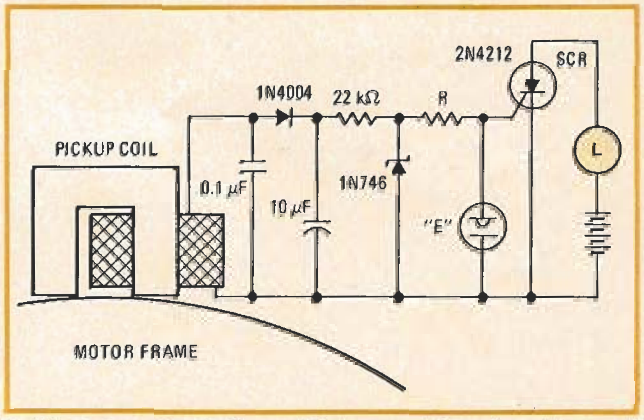
A resistor of 22 kilohms is shown in Fig. 1 followed by a zener diode (1N746) nominally rated at 3.3 v. However, in the low-current application described here, the regulated voltage drops below 2 v. In the event that the source voltage is insufficient for regulation by the zener, the system may still be used in the unregulated state by appropriate choice of calibrating resistor R. The table at left represents typical parameters for a circuit that uses a CP3 Indachron. Intermediate hourly spans may be observed on the calibrated scale of the Indachron unit.

If a signal is desired at the end of a prescribed time interval, a Plessey E-cell device can be used. Instead of having a scale readout, the E-cell abruptly increases in resistance at the expiration of its time cycle. In the circuit of Fig. 2, the bias change on the silicon controlled rectifier triggers an indicating light or a sound source such as the Mallory Sonalert, powered by the battery.

In addition to simplicity of connection, the pickups have the advantage of isolation in sealed systems such as, for example, cooling fluids in nuclear power plants or tightly sealed corrosive pumping systems. Also, it is possible to sample ON intervals of various machines without interrupting the power flow. □



1. Counts the hours. Operating time of ac equipment is measured by wireless pickup, rectification, and integration of total dc charge transfer. Zener diode sets dc voltage, and resistor R sets current level through current-integrating module such as the Indachron shown. Capacitor resonates pickup coil for maximum induced voltage, which can be monitored at jack.



2. Triggers a signal. The rectified current from the pickup coil depletes the working electrode of a Plessey E-cell device. When the electrode is completely depleted the device changes from a low impedance to high impedance, triggering the SCR to activate a battery-powered warning.

RESISTANCE VALUES FOR INTERVALOMETER USING CP3 INDACHRON		
TEST-POINT VOLTAGE	R (OHMS)	TIME SCALE (HOURS)
3.3	1.03 M	1,000
2.0	630 k	1,000
2.0	63 k	100
1.0	315 k	1,000

Silent timer warns of tape run-out

by Vernon R. Clark
Applied Automation Inc., Bartlesville, Okla.

At concerts and lectures especially, a cassette tape often runs out unnoticed. One solution is to install timing circuitry in the cassette-recorder case that will cause a light to flash when it's time to reverse or replace a cassette or to switch to another recorder. This silent warning system is also useful in duplicating cassette masters, where a preset recording time is important.

The alarm circuit operates from any voltage in the 5-to-15-volt range and can either be connected to the recorder bus or use its own battery. When the circuit is turned on, a light-emitting diode begins to blink once or twice per second, indicating that the circuit is functional and ready to start timing. When the start-timing button is pushed, the LED stops flashing and stays off for the duration of the timing period. At the end of the timing period, the LED begins to flash again, giving the signal to flip the tape.

The two main components of the circuit are a 14536 programable-timer integrated circuit and a 74C00 quad NAND gate IC. The timer contains an oscillator and a 24-stage counter. It counts pulses from the oscillator and, when some specified counter stage goes high, delivers a positive output pulse from the decode-out terminal (pin 13). Which of the counter stages triggers the output is specified by the voltages on pins 9, 10, 11, and 12. If these pins are high, high, low, and low, respectively (logic 1100), an output appears every time that stage 12 of the counter goes high. With all four pins high (logic 1111), output appears when stage 24 goes high.

Since this system was designed for a standard C90 cassette, which runs for 45 minutes a side, the timer is adjusted to provide a timing period of 44 minutes, or 2,640 seconds. Therefore the oscillator frequency is set at

$$f_{osc} = 2^{23}/2{,}640 = 3.2 \text{ kilohertz}$$

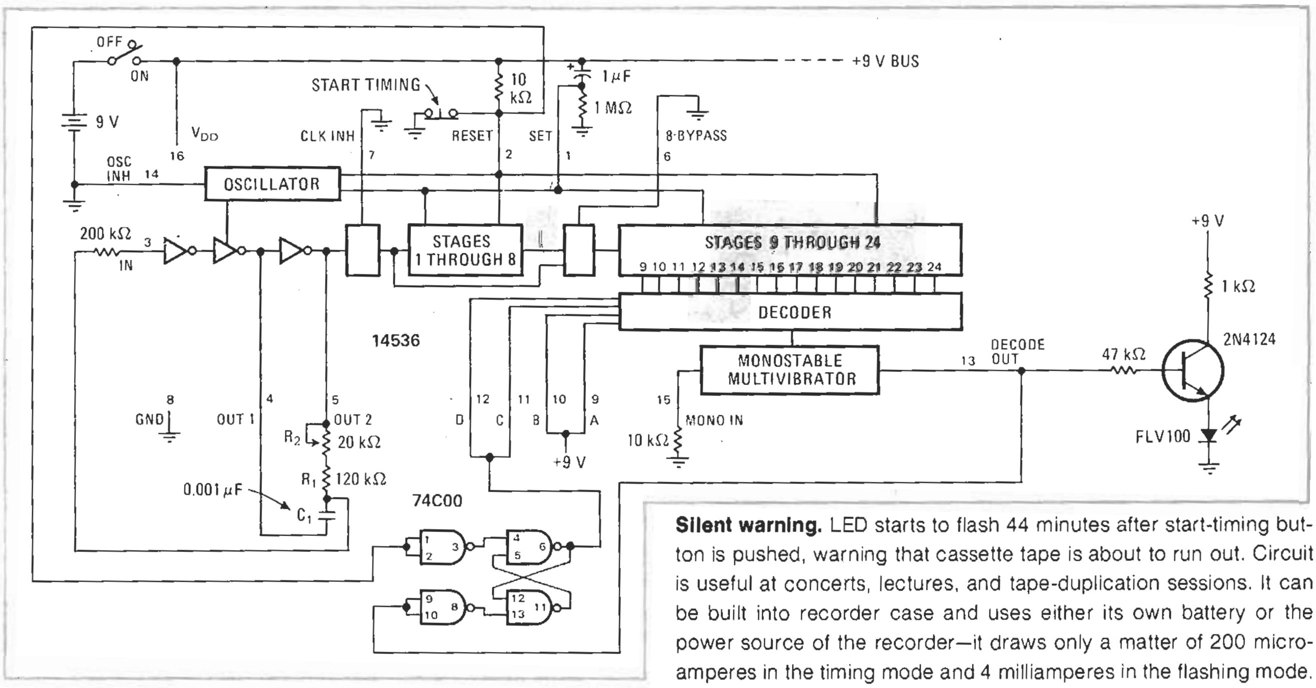
so that counting stage 24 will go high 44 minutes after the counter starts counting pulses from the oscillator (provided the decoder logic is 1111).

With this oscillator frequency, if the decoder terminals are set at logic 1100, stage 12 goes high after 2^{11} pulses, or

$$2^{11}/3.2 \text{ kHz} = 0.65 \text{ second}$$

The oscillation frequency is set by the time constant of C_1 and $(R_1 + R_2)$. A frequency meter is connected to pin 5, and R_2 is adjusted till the meter shows 3.2 kHz.

The circuit operates as follows: while the on-off switch is off, all pins are low. When the switch is turned on, pins 9 and 10 of the timer go high because they are wired to the positive-voltage bus. Therefore the decoder is programed with logic 1100, and the LED begins to flash every 0.65 second. When the start-timing button is pushed, the quad NAND circuit sets the decoder to logic 1111, so the LED stops flashing and the 44-minute count begins. After 44 minutes, the decode-out terminal (pin 13) goes high, resetting the decoder to 1100 so that the alarm signal flashes again. □

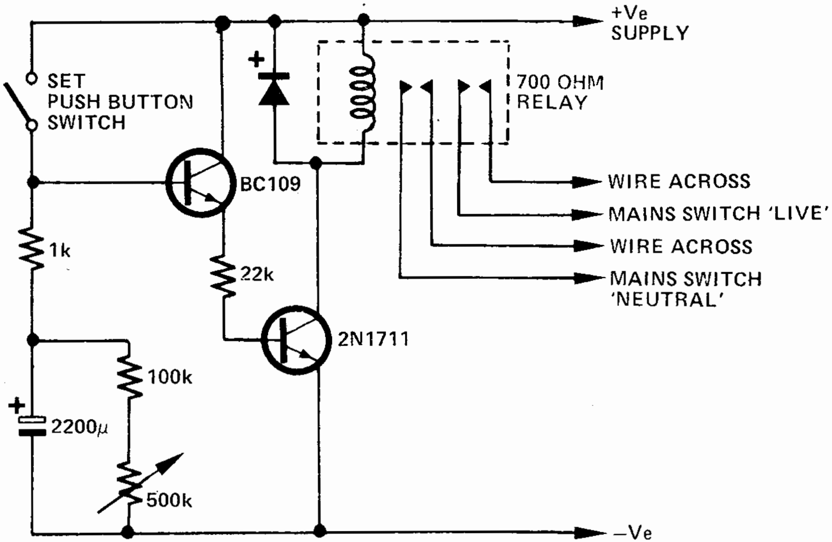


Silent warning. LED starts to flash 44 minutes after start-timing button is pushed, warning that cassette tape is about to run out. Circuit is useful at concerts, lectures, and tape-duplication sessions. It can be built into recorder case and uses either its own battery or the power source of the recorder—it draws only a matter of 200 microamperes in the timing mode and 4 milliamperes in the flashing mode.

tech-tips

Tech-Tips is an ideas forum and is not aimed at the beginner. We regret we cannot answer queries on these items.

ETI is prepared to consider circuits or ideas submitted by readers for this page. All items used will be paid for. Drawings should be as clear as possible and the text should preferably be typed. Circuits must not be subject to copyright. Items for consideration should be sent to ETI TECH-TIPS, Electronics Today International, 25-27 Oxford St., London W1R 1RF.



'SNOOZE' DELAY UNIT

When the Set switch is depressed the large electrolytic capacitor is charged via the limiting resistor (1k). This charge causes the BC109 to conduct which supplies enough base current to switch on the 2N1711 space and operate the relay. The relay contacts are wired in parallel with the mains switch so that if the mains switch is now turned off, the equipment will continue.

The supply voltage is taken from the equipment in which the unit is fitted and will determine the choice of relay. The maximum delay being 1.75 hours.

BUILD THE HI-FI/TV AUDIO-MINDER

- SHUTS A C POWER WHEN AUDIO ENDS
- ADJUSTABLE TIME DELAY
- CONVENTIONAL TIMER USE
- CONNECTS TO SPEAKER

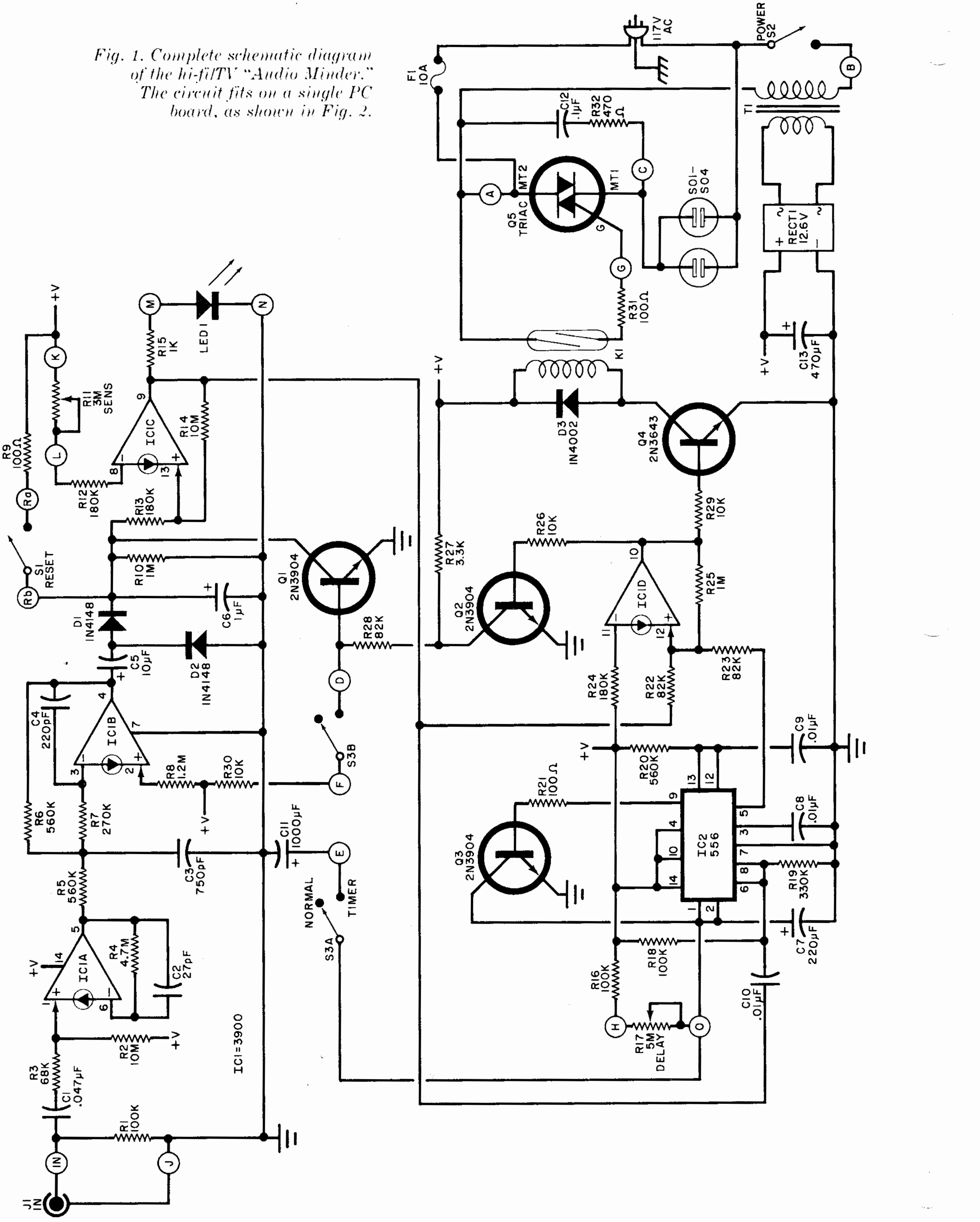
BY CURT KOBYLARZ

IF YOU EVER left an expensive stereo system or a TV receiver operating all night because you forgot to shut it off, take heart. Here is a low-cost, automatic shutoff controller for home entertainment equipment that does *not* require any internal circuit changes or connections. Shutoff is activated by the absence of an audio signal, not by a pre-set time interval, as with mechanical devices. Accordingly, the controller can be connected to speaker terminals or to a tape output monitor jack.

An adjustable delay system avoids premature shutoff, providing the user with enough time to change a record on a manual record player or a reel of tape on a recorder before the system is turned off. Shutoff time range is 50 seconds to 20 minutes after the signal level has dropped below a predetermined setting. At about 60,000 ohms impedance, the controller will not load most circuits. Noise filtering is provided to remove AM and FM interstation hiss to ensure against false shutoff triggering when using either of these signal sources.

Furthermore, the controller can be used as a standard non-audio timer for

Fig. 1. Complete schematic diagram of the hi-fi/TV "Audio Minder." The circuit fits on a single PC board, as shown in Fig. 2.



PARTS LIST

All capacitors disc or Mylar unless otherwise noted.
C1—0.047 μF capacitor
C2—27-pF capacitor
C3—750-pF capacitor
C4—220-pF capacitor
C5—10-μF, 15-volt electrolytic capacitor
C6—1-μF, 15-volt electrolytic capacitor
C7—220-μF, 15-volt electrolytic capacitor
C8,C9,C10—0.01-μF capacitor
C11—1000-μF, 15-volt electrolytic capacitor
C12—0.1-μF, 200-volt capacitor
C13—470-μF, 25-volt electrolytic capacitor
D1,D2—1N4148 diode
D3—1N4002 diode
F1—10-ampere fused and holder
IC1—LM3900 quad op-amp
IC2—556 dual timer
J1—Phono connector
K1—Reed relay, 500-ohm, 12-volt coil, normally open contacts
LED1—Any light-emitting diode
Q1,Q2,Q3—2N3904
Q4—2N3643
Q5—Triac, 20-A, 200 PIV
RECT1—Full-wave rectifier bridge
All resistors ¼-watt, 10% unless otherwise noted.
R1,R16,R18—100,000-ohm resistor
R2,R14—10-megohm resistor
R3—68,000-ohm resistor
R4—4.7-megohm resistor
R5,R6,R20—560,000-ohm resistor
R7—270,000-ohm resistor
R8—1.2-megohm resistor
R9—100-ohm resistor
R10,R25—1-megohm resistor
R11—3-megohm linear potentiometer ("Sensitivity")
R12,R13,R24—180,000-ohm resistor
R15—1000 ohm resistor
R17—5-megohm linear potentiometer ("Delay")
R19—330,000-ohm resistor
R21—100-ohm resistor
R22,R23R28—82,000-ohm resistor
R26,R29,R30—10,000-ohm resistor
R27—3300-ohm resistor
R31—100-ohm, ½-watt resistor
R32—470-ohm, ½-watt resistor
S1—Pushbutton switch, momentary contact, normally open ("Reset")
S2—Spst switch ("Power")
S3—Dpdt switch ("Normal/Timer")
SO1 to SO4—Ac power receptacle (sockets)
T1—Transformer: 12.6-volts, 300-mA, PC mount
Misc.: Suitable cabinet, heat-sink material, IC sockets (optional), strain relief, press-on type, mounting hardware, etc.
Following are available from WEI, 4921 N. Sheridan Rd., Peoria, Illinois 61614: complete kit (SO-1) includes all components, PC board, metal case, power cord, ac receptacles, etc. at $39.95; PC board (SO-2) at $6.00; metal case (SO-3) at $8.50. All orders postpaid to the Continental United States only. Illinois residents please add 5% sales tax. Allow four weeks for delivery.

any electrical appliance, TV receiver, etc. up to its rated 1200 watts. In this mode, the controller will turn power off at a pre-set time ranging from 10 minutes to two hours. The complete circuit is shown in Fig. 1.

How It Works. The selected audio input is applied via phono connector, *J1*, to the first amplifier and filter *IC1A* where it is amplified and filtered with roll-off occurring about 1.25 kHz at −6 dB per octave. The second stage, *IC1B*, is a two-pole filter whose cutoff frequency is approximately 1 kHz with unity gain. The two stages combined roll off is about 18 dB per octave to remove noise and filter out any high-frequency hiss if an FM or TV station goes off the air (if this is to be the audio source).

The filtered signal is rectified to a dc level by *D1*, *D2*, and *C6*, with *R10* "bleeding" the charge from capacitor *C6* when a signal is not present. *IC1C* is used as a comparator having fast "snap action" (positive feedback) so that when the rectified signal applied to the non-inverting (+) input exceeds the level set by the SENSITIVITY control, *R11*, the output switches off very rapidly. Note that the 3900 op amps used here are current devices rather than voltage devices represented by conventional op amps, therefore all voltages must be converted to currents. This will explain why high-value resistors are used in many places in this circuit.

When *IC1C* output is high (audio signal present), *LED1* is turned on and current-limited by *R15*. The *IC1C* output signal also turns on the OR gate formed by *IC1D* which, in turn, causes *Q4* to saturate and draw current through the coil of the reed relay, *K1*. With the reed relay contacts closed, gate power is applied to the triac, *Q5*, and power is present across the multiple power sockets, *SO1* through *SO4*. This turns on any equipment connected to these sockets.

When the input audio signal either disappears or falls below the pre-set SENSITIVITY threshold, comparator *IC1C* switches off very rapidly. This action also starts one of the timers in *IC2* whose output (pin 5) keeps the OR gate operating until the timer times out. Power remains on the four sockets. If another audio signal should appear within the time-out interval, the second timer within *IC2* will generate a 5-millisecond pulse which will turn on *Q3* and discharge the main timing capacitor *C7*. This resets *IC2* back to zero and ensures that the last audio signal is always the one that begins the time-out delay. Transistors *Q1* and *Q2* act as a "quench" circuit by grounding the comparator signal an instant before shutdown. This is necessary because some audio power amplifiers generate a "thump" when turned off and this may retrigger the timer and never allow system shutdown.

Reed relay *K1* is necessary for complete isolation between the circuit and the triac. Snubbers circuit *C12* and *R32* protect *Q5* from line transients and surges generated when inductive loads (such as the power transformers in high-wattage power amplifiers) are suddenly switched off. The triac should be heat-sinked.

The timer function is determined by the setting of NORMAL/TIMER switch *S3*, which disables the input circuit by turning on the "quench" transistor, *Q1*, and connecting a larger capacitor (*C11*) in parallel with the main timing capacitor *C7*. Potentiometer *R17* sets the timer delay in either case, although the range for NORMAL and TIMER positions of *S3* is different.

Construction. The circuit is easily assembled on a single PC board, as shown actual size in Fig. 2, which also shows the component installation. Connections to off-board components are made via the lettered pads on the foil pattern. Note that some resistors are mounted "end up."

The triac is mounted on a metal bracket, which acts as the heat sink, and mounted as selected within the cabinet. If a metal case is used, make sure that the triac is electrically isolated, but thermally bonded to the heat sink. Use at least 18-gauge wire between the triac, power outlet sockets, and the power line. A three-wire line cord is recommended with the ground (green) lead connected to the metal chassis. Almost any type of cabinet may be used.

The switches, *J1*, potentiometers, and *LED1* can be mounted on the front panel, while the four controlled sockets can be mounted on the rear apron. Although four controlled power outlets are used, more can be added provided that the triac can handle them.

Operation. The selected audio input signal can be taken from the tape monitor output of either channel (use a "Y" connector if necessary), or di-

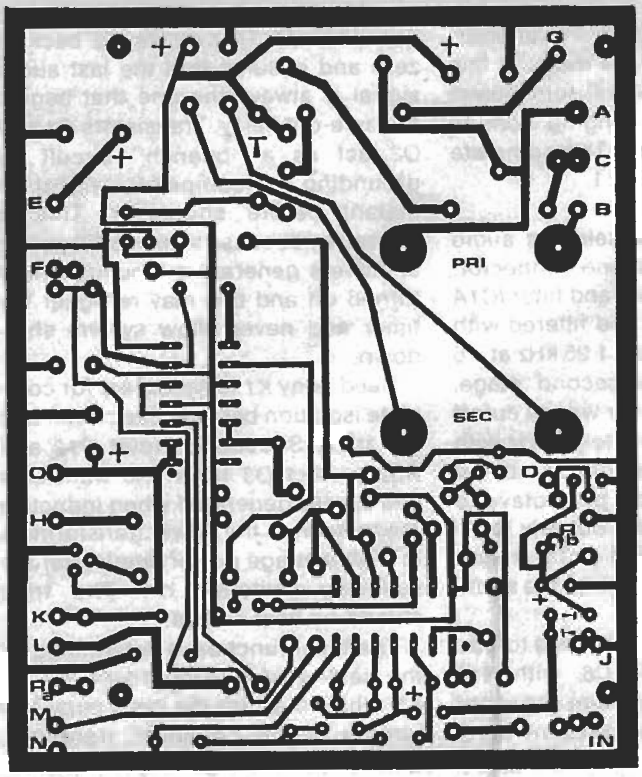
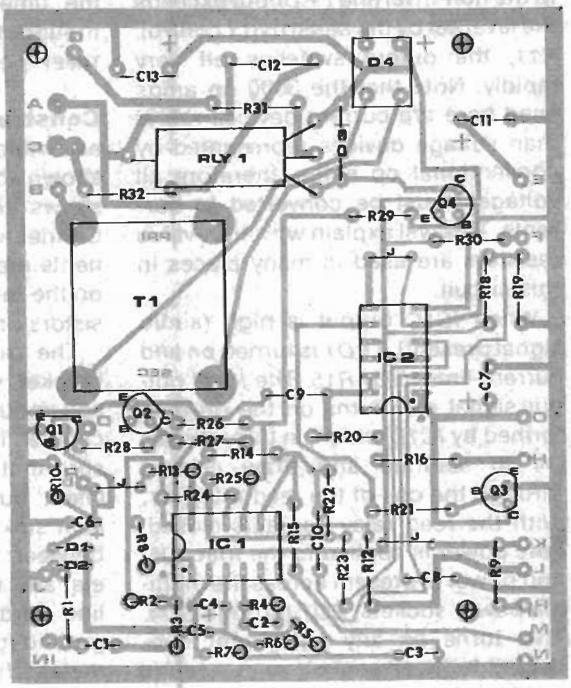


Fig. 2. The printed-circuit board's foil pattern is shown at left, while the flop side below illustrates component installation. Note that resistors installed on pads with a drawn circle are to be mounted end up.



rectly off the speaker terminals of either channel. The monitor output has the advantage of a constant level irrespective of volume control settings so the SENSITIVITY control need be set only once.

Connect the selected devices (tuner, amplifier, etc.) to the controlled sockets *SO1* through *SO4* and turn on their power switches. Connect the controller to the power line, place *S3* in the NORMAL position, and turn POWER switch *S2* on. Place both potentiometers in their mid positions, then depress RESET pushbutton *S1*. *LED1* should glow and the ac outlets should be energized. With no signal connected to *J1*, *LED1* will go out after *C6* discharges, but the delay timer will keep the outlets energized, until it times-out—determined by DELAY potentiometer *R17*.

Connect the selected signal source to *J1*, reset the controller, and adjust SENSITIVITY control *R11* until the LED remains on continuously. The DELAY potentiometer is adjusted as required. When the input signal is removed, the system should shut down after the delay period.

To shut down the system when an FM or TV station is used as the signal source and the station goes off the air, use the following setup procedure. Tune in the station and adjust the SENSITIVITY control until the LED just goes out, then bring it back until the LED remains on most of the time. Tune the receiver off-station for the hiss and observe that the LED goes out. The system is now adjusted so that it will automatically shut down after a station goes off the air for the night.

Use of the tape monitor output for the signal source is necessary when headphones are being used and the amplifier is disabled from the speakers. Since the input impedance of the controller is approximately 60,000 ohms it will not load the signal to the tape deck.

For use as a timer, place *S3* in the TIMER position, set the DELAY time as desired (10 minutes to 2 hours), and operate the RESET pushbutton *S1*. In this case, the input is not being monitored; the ac outlets will be deenergized only after the selected time interval has been reached. This mode is used to turn off any appliances or TV receiver automatically. ◈

STD TIMER

This compact unit calcultes the total cost of STD phone calls by counting the number of local-call charges appropriate to the called distance and duration of the call

SUBSCRIBER TRUNK DIALLING STD, is now the preferred method of making trunk phone calls within Britain. STD calls are easier and faster to make and can be cheaper than the old "charge per three-minute period" system. However, the method of charging for STD has a hidden trap which can result in phone bills being unexpectedly high.

The STD billing system works by charging a fixed amount (equal to the local-call charge) for each time unit used in making the call. The time allocated to each unit varies according to the distance. Thus if the call is only over a short distance and at night you may be charged one local call every 180 seconds, but if over a long distance and during the day the charge may be as much as one local call every eight seconds. The disadvantage of this method as far as the subscriber is concerned is that he loses track of time when talking — there are no pips to warn him.

The ETI 543 STD Timer operates by counting the number of local call periods used. Thus at the end of the call you simply multiply the number held in the counter by the local call charge to get at an accurate cost. Local-call charges are frequently reviewed, so the timer is designed to count the number of local-call charges only.

To use the timer simply check the phone book before making the call to determine the number of seconds per charge applicable, then set this time on the selector switch of the timer. Now dial the number and when the called party answers press the start button. The timer will switch on, "1" will be added to the display and the display will be incremented by "1" at the end of each time period (as selected). When the call is finished, you press the stop button and read the total units used. After about five seconds the timer will switch off automatically.

Note that although the power is still connected in the off-state the power consumption (in this state) is so low that battery drain doesn't affect battery life. In fact on the prototype the current drain was 2 x 10^{-10} amps! Yes, we actually measured it — guess how?

CONSTRUCTION

As the unit will be used on the phone table small size and neat appearance is necessary. We therefore built our unit into a zippy box which although looking neat does become a little crammed inside. For this reason it is important to use the printed circuit boards specified if all the electronics is to fit.

Commence construction by assembling components to the display board, ETI 543A, starting by installing the tinned-copper wire links as shown on the overlay diagram. Watch the orientation of the integrated circuits: the two 4511s have opposite orientations.

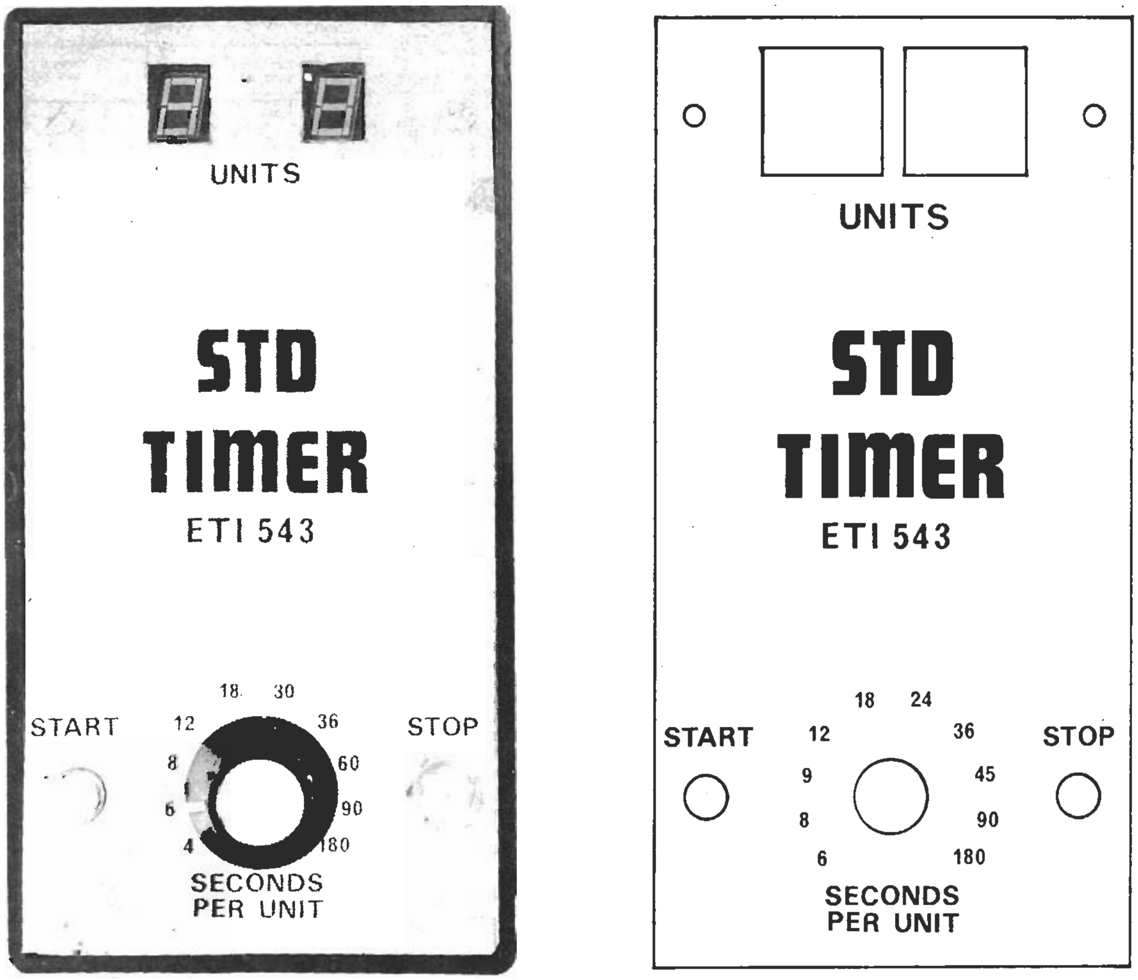
Now assemble the second board, again installing the links first. Do not mount R1 to R16 just yet. The rotary switch used for range selection must now be modified by removing the wafer, cutting the spacers in half and then reassembling (as shown in Fig. 2) on the printed-circuit board. The terminals of the switch should now be connected to the board by threading tinned-copper wire through the appropriate hole in the board (from the copperside) and through the terminal and then soldering to the terminal and the board. The resistors R1 to R16 may now be mounted into position and soldered, noting that they are mounted on-end — not flat.

Mount the two push-buttons to the front panel temporarily and then mount the completed second board and switch assembly to the front panel. Use spacing washers between the switch and the front panel. Connect the push-buttons to the board using tinned-copper wire and then remove the front panel.

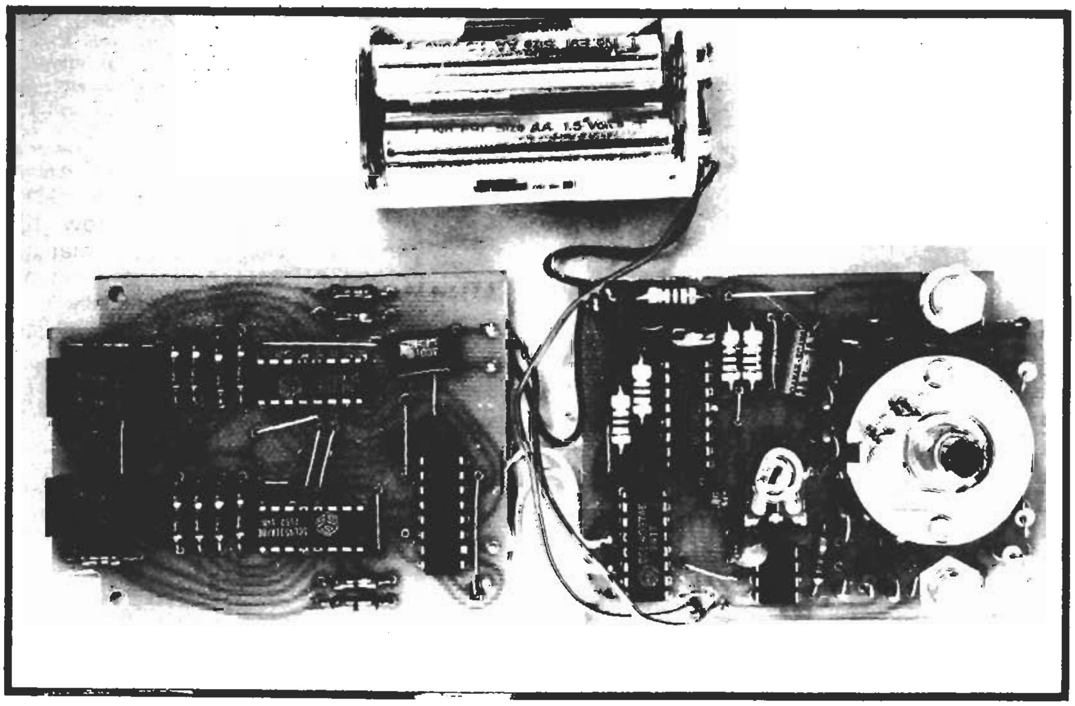
Now place the two boards end-to-end about 50 mm apart and wire them together as shown in Fig. 3. The 50 mm spacing ensures that when the boards are folded later the spacing will be OK. The battery holder may now be connected. However, note that there is insufficient room to allow a conventional battery power clip to be used. You have to solder the leads directly to the terminals.

Impedances around the switch are fairly high, and leakage through flux could affect timing accuracy.

So clean the copper side of the boards with turps or methylated spirits to remove excess flux. Insert the batteries in the holder and select the four second range. If the display is on press the stop button and after about five seconds the display should extinguish. Now press the start button and note that the display is "01" and should increment



Front panel for the timer. Full size



The two boards and battery assembly before being mounted in the case

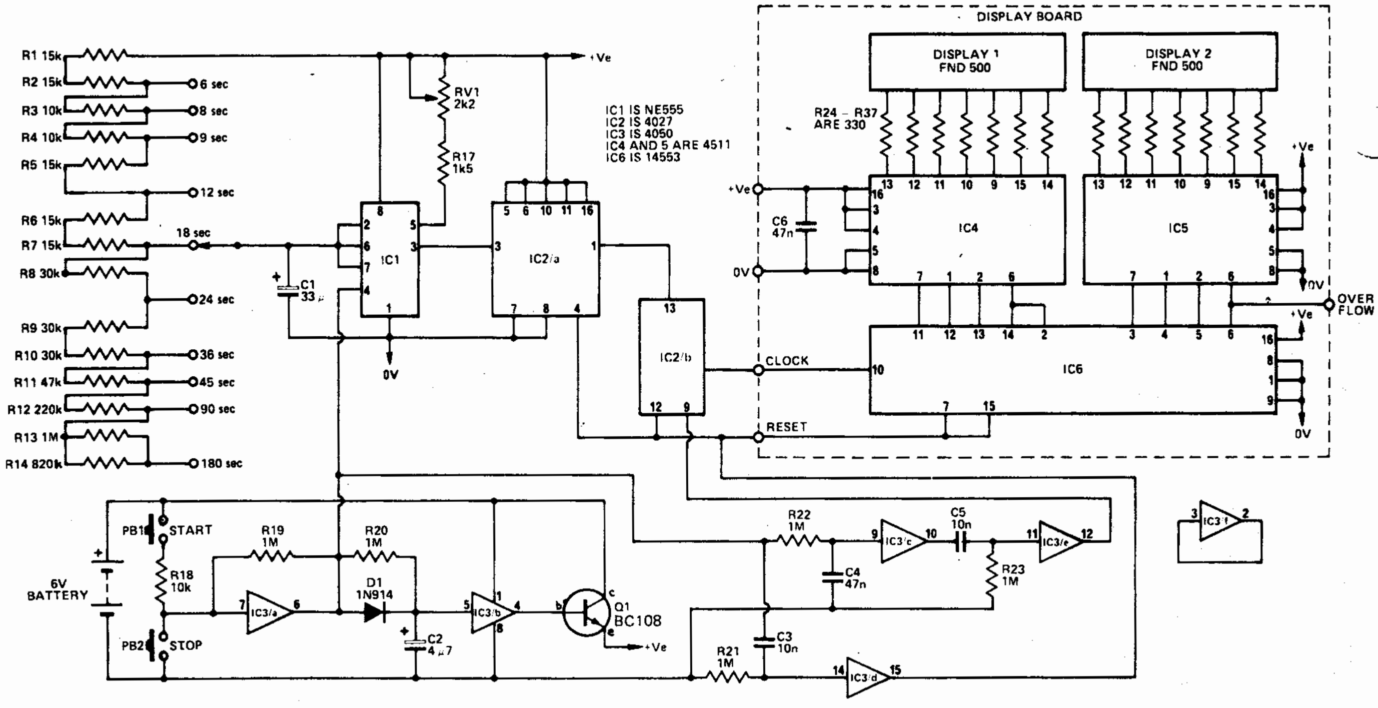


Fig.1 Circuit diagram of the STD timer unit

Specification

TIMING
Periods provided
6,8,9,12,18,24,36,45,90 and 180 seconds
Accuracy
first count −20%
successive counts ± 5%

DISPLAY
2 digit, seven-segment LED

POWER
Batteries
4 x pen cell (6V)
Battery drain
approx 50 mA in 'ON' state
" 1 μA in 'OFF' state

START AND STOP
by separate push buttons

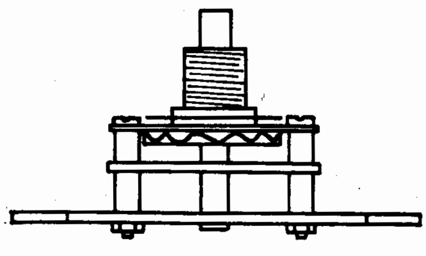


Fig.2 The switch must be disassembled, the spacers cut in halves and then reassembled to the PC board as shown in this diagram

How it works

The basic timing element is the familiar timing IC the 555. This is a convenient device as the timing may be altered by changing the value of a single resistor. The resistor in question is selected by switch SW1 to provide timing periods from one to 45 seconds in duration. As the timing of long intervals is difficult due to the leakage encountered in practical large-value capacitors, a divide by four stage is used to obtain the 6 to 180 second period required. To compensate for differences in the value of capacitor C1 a variable resistor is provided between 5 of the IC and the positive rail. Adjustment of this resistor varies the threshold voltage of the IC and thereby corrects the timing.

The first timing period of the 555 is about 50% longer than those following and to compensate for this the divider stage provides a by-three division, instead of the normal by-four division, on the first sequence. This is not, however, a problem: it can be an advantage. If a call is terminated just at the time the display changes the charge will be within the cheaper period.

The output of IC2 clocks the dual-decade counter IC6 which has a four-line BCD output code. This is decoded to seven-segment format by ICs four and five to drive the seven-segment LED displays. These decoders also have a store facility which is not used in this application. A link is therefore used to connect the store input to zero volta thus disabling it. The use of a link allows the store to be made available if the board is to be used for another application.

The timer is controlled by IC3 which is a hex (6) non-inverting buffer (if input is high, output is high etc). The cycle commences when pushbutton PB1 is pressed. This pulls pin 7 of IC3/1 high causing the output of the IC to go high (pin 6). IC3/1 latches in this state and stays there until the stop button is pressed — when the output goes low again. When the start button is pressed and the output of IC3/1 goes high the input of IC3/2 is also pulled high via diode D1 causing the output of IC3/2 to go high. This high turns on emitter-follower Q1 which then provides power to all circuits with the exception of IC3 which is permanently powered. The off-state current drain of IC3 on the prototype was measured at 200 nanoamps! Thus by using this technique the need to switch the unit on and off has been avoided as battery life in the OFF state will exceed the shelf-life of the battery.

When the 'start' push button is pressed the high at the output of IC3/1 is also fed to pin 4 of the 555 timer IC which starts to cycle at the rate selected by SW1. Pin 14 of IC3/4 also goes high until C3 is discharged by R21. This causes a 10 millisecond pulse to be generated at pin 15 of IC3/4 and this pulse is used to reset the display decade counter, IC6, and also IC2 at initial switch-on. In addition, after a 50 millisecond delay (due to R22 and C4) the output of IC3/3 goes high and this transition in conjunction with C5 and R23 produces another 10 millisecond pulse from IC3/5 which sets IC2/3 causing IC6 to be incremented by one.

When the stop button is pressed the 555 timer is disabled and the timing stops. However, due to the charge on C2, the power remains on for a further 5 to 10 seconds.

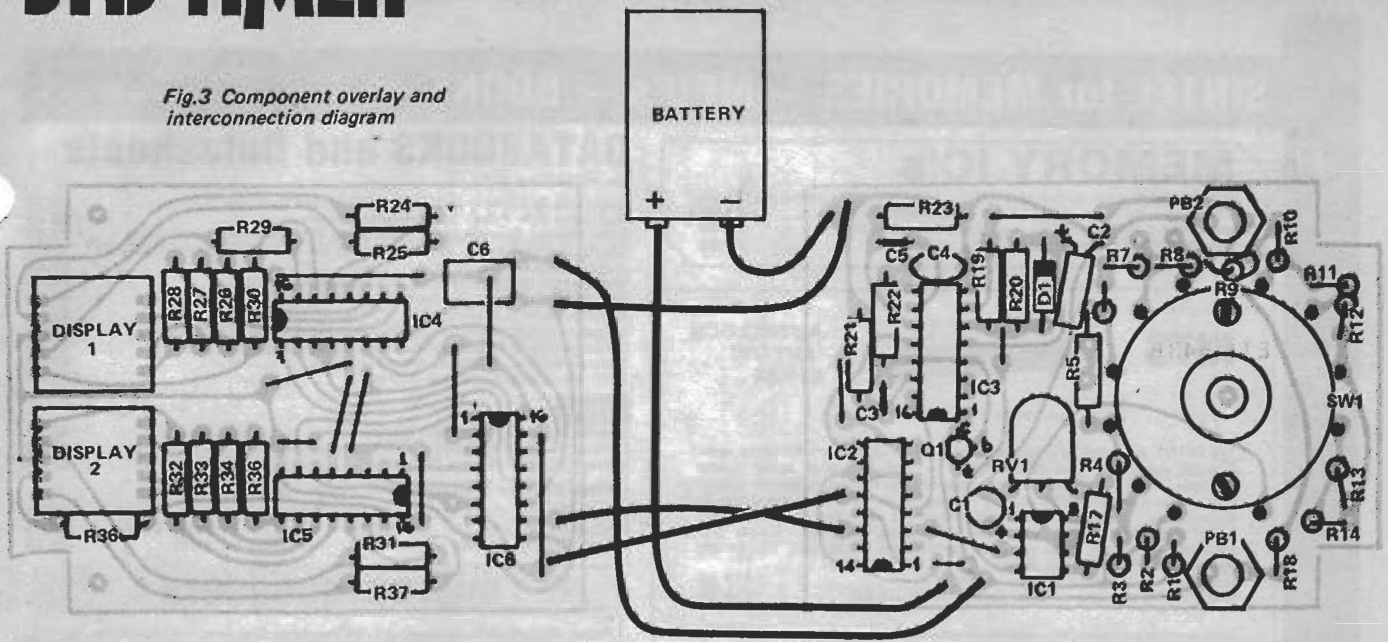


Fig.3 Component overlay and interconnection diagram

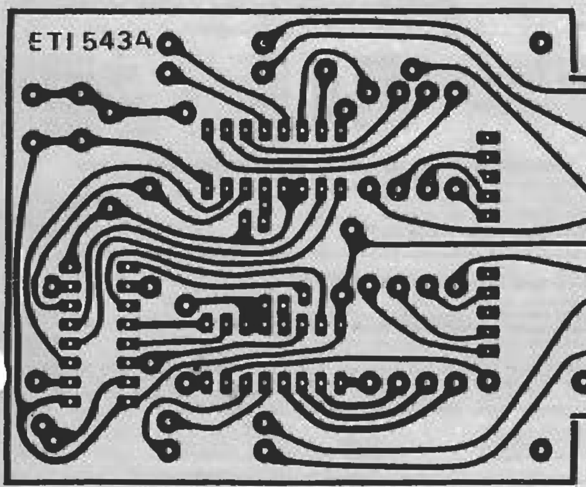


Fig.5 Printed circuit pattern for the display board. Full size 83 x 61mm

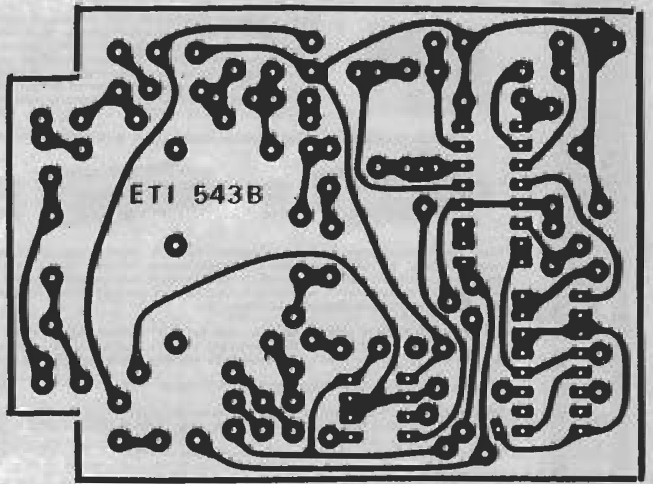


Fig.6 Printed circuit pattern for the timing board. Full size 83 x 61mm

Parts List

Resistors

R1,2	15 k	½W	5%
R3,4	10 k	"	"
R5-R7	15 k	"	"
R8-R10	30 k	"	"
R11	47 k	"	"
R12	220 k	"	"
R13	1 M	"	"
R14	820 k	"	"
R17	1 k5	"	"
R18	10k	"	"
R19-R23	1 M	"	"
R24-R37	330	"	"

Capacitor

C1	33 μ	10 V Tantalum
C2	4μ7	25 V electrolytic
C3	10 n	polyester
C4	47 n	"
C5	10 n	"
C6	47 n	"

Potentiometer

RV1 2k2 Trimpot (VTU)

Integrated Circuits

IC1	NE555	
IC2	4027 (CMOS)	
IC3	4050	"
IC4,5	4511	"
IC6	4518	"

Semiconductors

D1 IN914 or similar
Q1 BC108 or similar
Display 1,2 FND 500

Miscellaneous

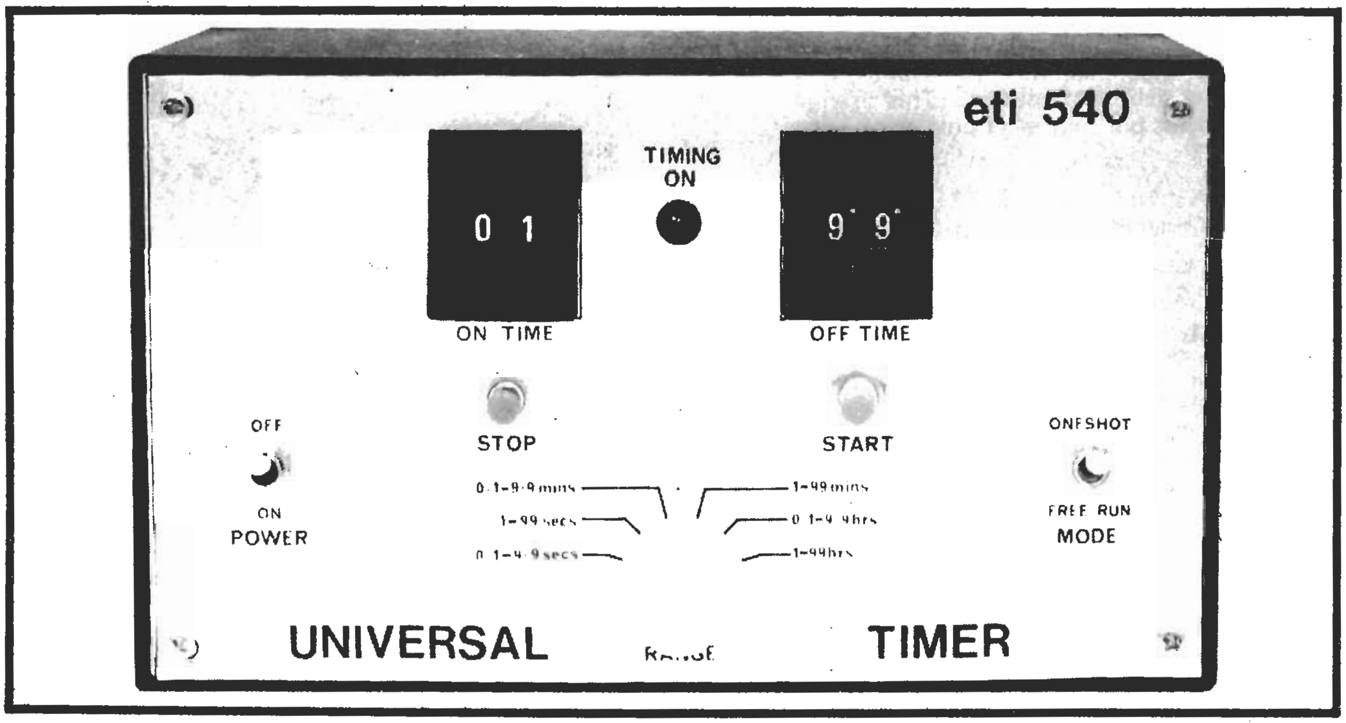
SW1 single pole 11 position switch
PB1,2 single make push buttons
PC Boards ETI 543A, ETI 543B
six pc board pins
plastic box
knob
4xAA size battery holder

by one every four seconds. Check the timing accuracy over a number of increments with a watch and adjust RV1 to obtain increments of exactly 4 seconds. Check the other ranges for accuracy and if greatly in error check and adjust the values of the appropriate resistors in the R1 to R16 chain.

Remove the batteries and mount the display board onto the front panel using 6 BA screws and spacers. If the box as specified is used the front panel will have to be cut to allow the displays to protrude through, thus allowing more room for the batteries. A quick assembly check will show how much extra room is required. Now mount the second board and the push buttons and mount the completed unit into the box.

That completes the unit; the only thing to do is to instruct the family how to use it and to persuade them to do so on every STD call. Best of luck. ●

UNIVERSAL TIMER



One tenth of a second to 99 hours. Both on and off times programmable. Manual or automatic operation, resettable at any time.

ETI project 540

THE TIMING OF EVENTS and processes is becoming an ever-increasing necessity particularly in applications involving automation.

Unfortunately most timers are either specifically made for a particular application — and difficult to adapt to others — or have restricted timing range, accuracy and facilities.

The ETI Universal Timer described in this project is free of most such constraints. It is extremely flexible, accurate and versatile. Its timing range is from 0.1 seconds to 99 hours. Both 'on' and 'off' times can be programmed (for example 12 hours on and 47 hours off). It can be manually started, stopped, or reset at any time, can be set for automatic cycling or for single cycle operation. It may be triggered by an external source (light, sound or pressure transducer, etc). Finally, as the unit is digital — the 50 Hz mains is used as the reference — timing accuracy is very high indeed, and a manual reset facility enables the timer to be synchronized with local time if so desired.

Clearly not all users will need all the facilities provided — so if the unit is required for a specific permanent use it is a simple matter just to leave out those ICs not required — several variations are described at the end of this project.

CONSTRUCTION

We strongly recommend that this unit be assembled using the printed circuit board shown.

Begin by fitting the links to the board as shown on the component overlay. Note that there are two points labelled 'a' and two points labelled 'b'. Link 'a' to 'a' and 'b' to 'b' using insulated hook-up wire routed on the copper side of the board.

Mount the resistors to the board followed by the diodes, transistors, capacitors and finally the ICs. Take particular care to ensure that all the polarized components are orientated correctly — especially the integrated circuits.

Wires should now be attached to the board for later connection to the front panel switches. We used rainbow cable for the connections to the thumb-wheel switches as this makes the wiring easier and also helps to keep the wiring tidy. Mount the printed-circuit board into the case and mount the power outlet socket. Assemble the switches to the front panel and then interconnect the printed-circuit board, front panel and power socket in accordance with the interconnection diagram.

Finally after wiring the 240 Vac

power circuitry insulate all 240 V terminals with tape to ensure that there is no risk of personal contact when fault finding is required at any later date.

CUSTOMIZING

The unit need not necessarily be built in its complete form and many different modifications are possible to lessen the cost of the unit when it is to be used for one particular application only. The modifications required for a number of specific applications are described.

Specific fixed time — delete selector switches SW3 to SW6, and replace by wiring links from the appropriate outputs of IC4 and IC5 to the inputs of IC6/1 and IC6/2 respectively. The range switch may also be omitted by installing a link between the appropriate output of IC1 to IC3 and pin 13 of IC4.

Single shot operation — connect both inputs of IC6/2 to ground and omit switches SW5 and SW6.

Timing 99 hours or less — omit IC3 and connect inputs of IC7/3 and IC7/4 to ground.

Timing 99 seconds or less — omit IC2, IC3 and IC7.

External triggering — simplest way is a relay contact in parallel with start or stop button.

The main consideration when making any changes is that the logic is CMOS and any unused inputs must be connected to ground or to +12 volts to prevent damage to the IC (which may overheat with unconnected inputs).

SPECIFICATION ETI 540

MODES

Freerun
On/off (note 1)
One shot
Manual override (note 2)

TIMING RANGE

0.1 seconds to 99 hours (note 3)

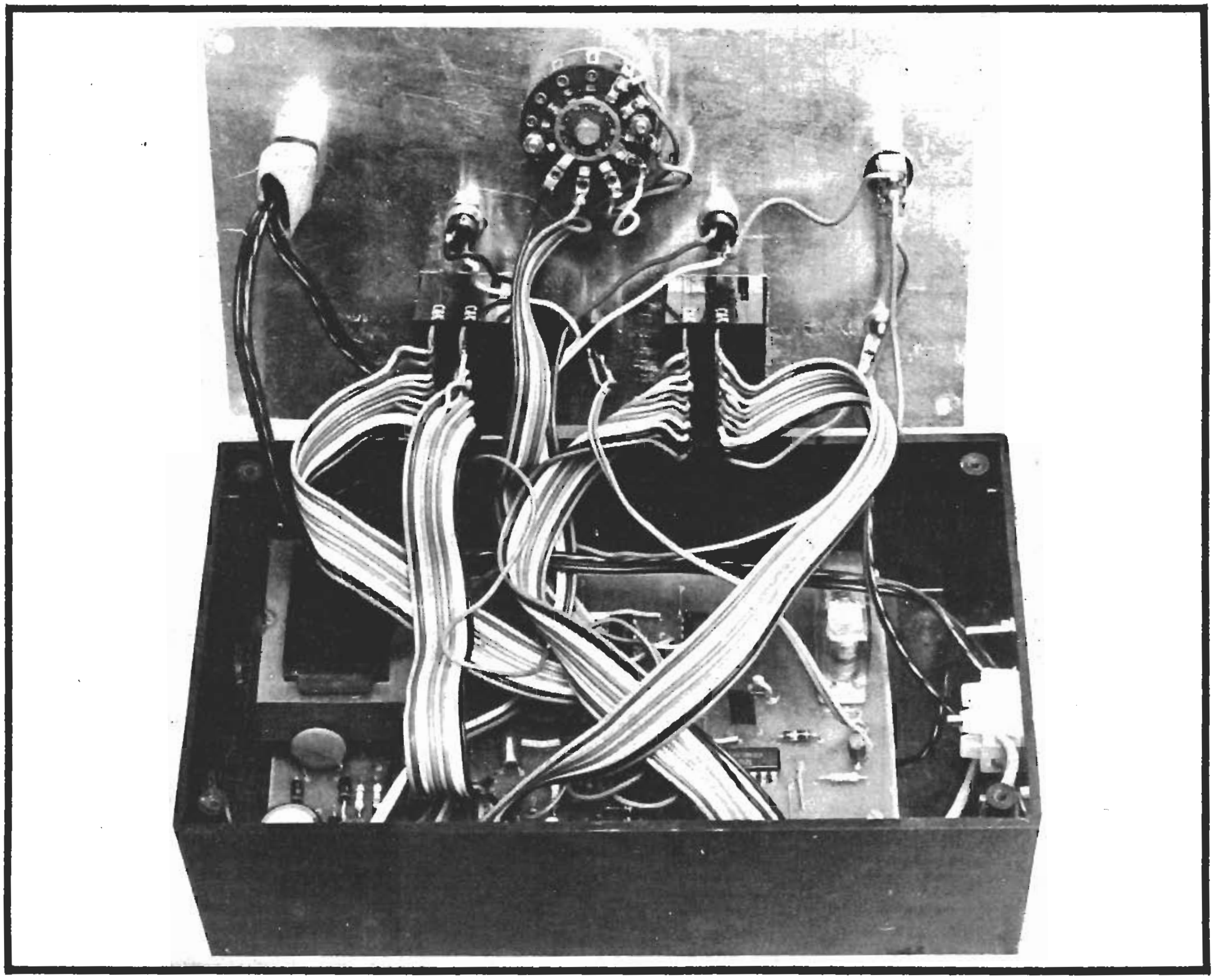
ACCURACY

Mains synchronized

OUTPUT

240 volts ac relay switched

Note 1. Both on and off times are variable independently.
Note 2. Unit may be stopped or started at any time. If the appropriate button is pressed whilst in the same mode the timing is recommenced.
Note 3. Timing is adjustable by a common coarse control which gives ranges having a full scale of 9.9 seconds, 9.9 minutes, 99 minutes, 9.9 hours and 99 hours. Each range is adjustable from 1 to 99 that is one second on and 99 seconds off is possible whereas one second on and two minutes off is not (different coarse range is required).



UNIVERSAL TIMER

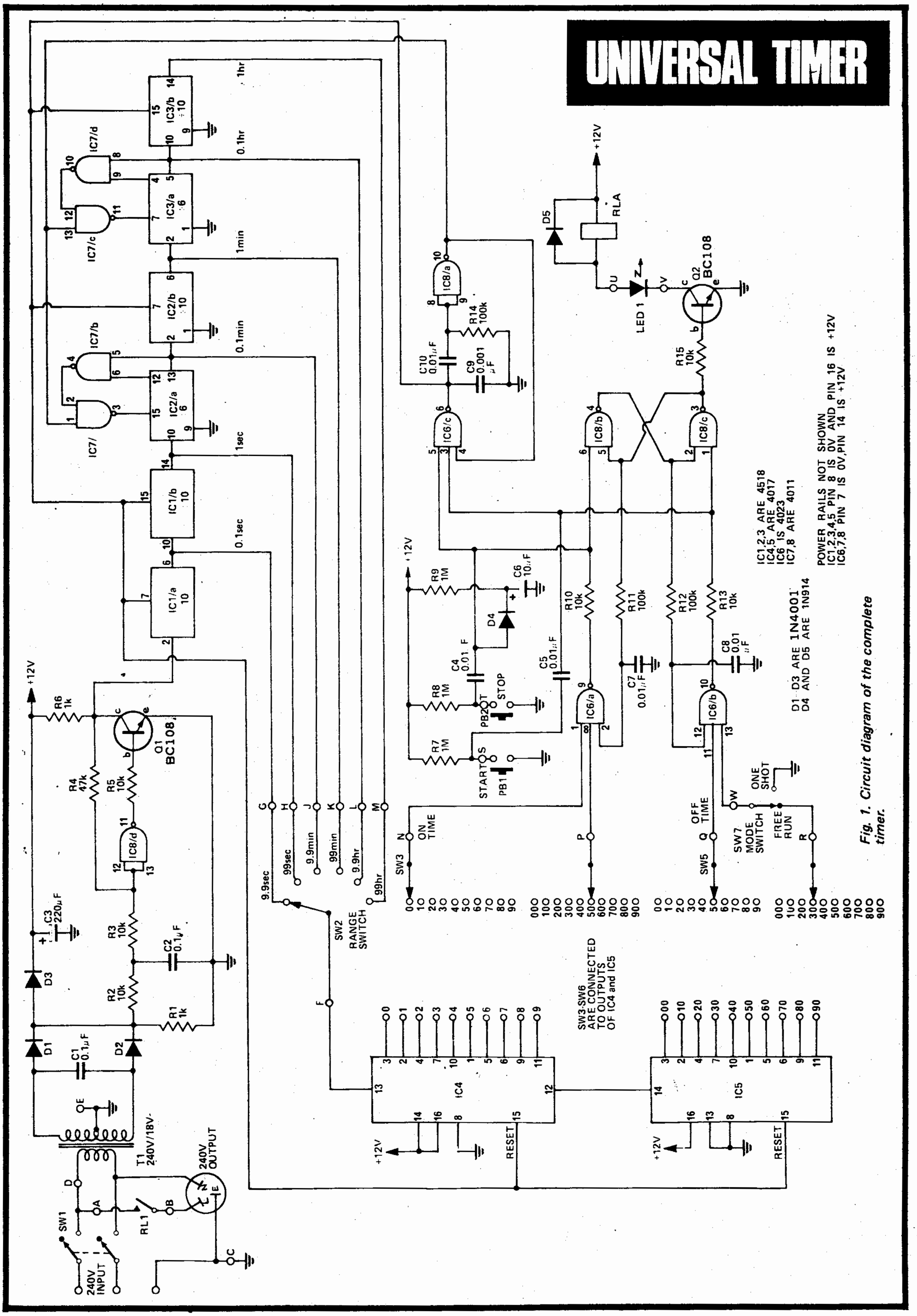


Fig. 1. Circuit diagram of the complete timer.

HOW IT WORKS — ETI 540

The 240 Vac is reduced to 12 Vdc by transformer T1 and diodes D1 to D3. Diode D3 isolates the smoothing capacitor C3 from the rectifiers and therefore 100 Hz ripple appears across R1. This waveform is used for the basic timing reference for the timer. To operate the counting ICs reliably a very fast rise-time waveform is required at the clock input. This is obtained by feeding the 100 Hz to a Schmitt formed by IC8/1 and Q1. Capacitor C2 is included to prevent the control tones superimposed on the mains for the control of hot-water services from upsetting the timing accuracy.

The 100 Hz from the Schmitt trigger is divided by 10 by IC1/1 to give a 10 Hz or 0.1 second output — the first required. Note that due to the low frequencies involved from now on the outputs will be referred to as time periods not as frequencies. A second divide by ten stage is used to give a one second output. A division by six is then performed by IC2/1 with IC7/1 and IC7/2 being used to decode the six count and reset the counter. This gives the one minute (or sixty second) period required. Further divisions of 10,6 and 10 are used to provide the six outputs required to select periods from 0.1 seconds to one hour.

One of these six outputs is selected by the range switch SW2 and is fed to a 4017 IC — the first of a pair of decade counters which have ten decoded outputs. The ten outputs of each IC go high in turn for one clock period each. As the two 4017 ICs are in series, a total division of 100 is obtainable. We have labelled the outputs of IC4 and IC5 as 0 to 9 and 00 to 90 respectively. IC4 is triggered by the clock enable as negative edge triggering is required. The second IC is clocked normally by the carry output from IC4.

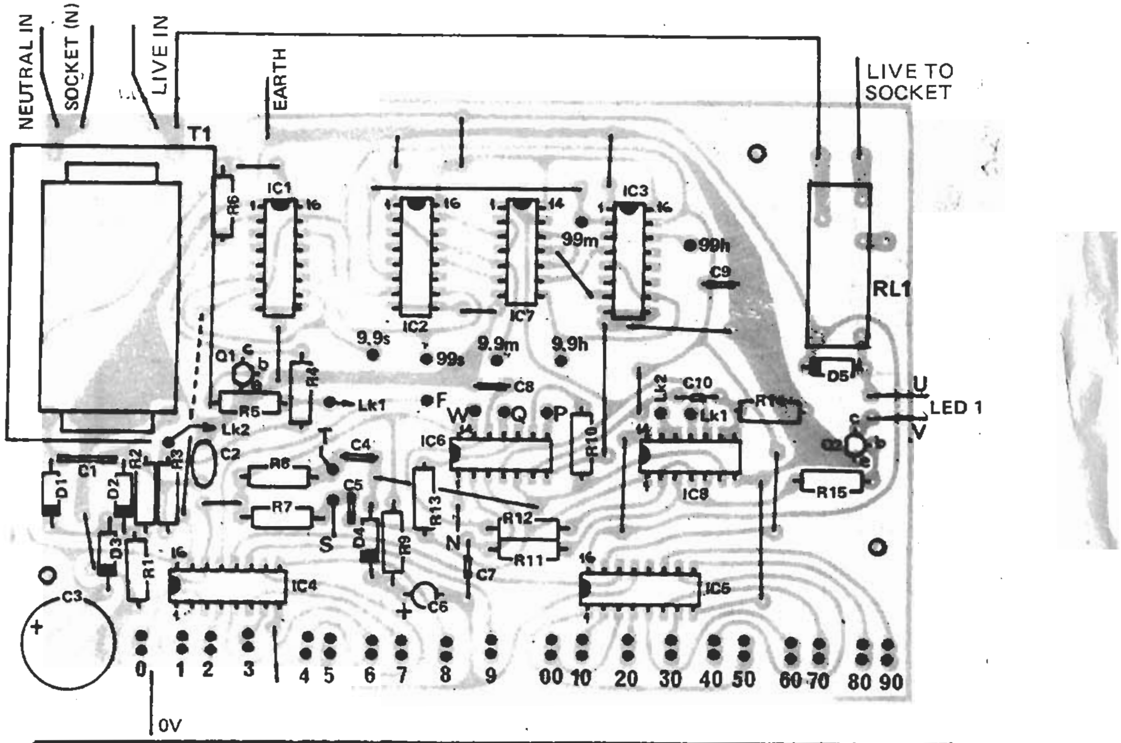
We pause at this point to go straight to the control output which is via a relay RL1, this in turn being controlled by the flip-flop made up of IC8/2 and IC8/3. This flip-flop can be controlled either manually by PB1 (manual on) and PB2 (manual off) or automatically by IC6/1 and IC6/2. To toggle the flip-flop automatically the output of either IC6/1 or IC6/2 must be low and for the output to be low the three inputs must all be high. This occurs only when the number selected by SW3 and SW4 (for IC6/1) and SW5 and SW6 (for IC6/2) is held by the counters IC4 and IC5 and the third input from the flip-flop is used to ensure that the off-time of the relay is controlled only by the off-time selector switches. A small time delay is incorporated in the signal back from the flip-flop to avoid the ambiguity that could arise with equal times.

If the output of either IC6/1 or IC6/2 goes low the monostable formed by IC6/3 and IC6/4 is triggered and its resultant output is used to reset all the counters to zero. This reset also occurs if either of the manual push buttons is pressed. The push buttons are coupled into the logic by capacitors so that only the initial part of the press actuates the logic and there is therefore no dependency on the length of time for which the button is pressed.

The sequence of events is as follows assuming that initially the switches are set for 25 seconds on and 14 seconds off.

On first switch-on C6 ensures that the flip-flop is toggled into the off state and also that the counters are all reset to zero. The control inputs from the flip-flop to IC6/1 and IC6/2 are low and high respectively. Therefore until the flip-flop changes state only IC6/2 can have the three high inputs necessary to provide a low at the output. Meanwhile the counters IC4 and IC5 are counting up at the rate of one count per second. After 14 seconds all three inputs to IC6/2 are high and the output goes low toggling the flip-flop. The monostable is then triggered and all counters are reset to zero. This removes the three high inputs to IC6/2 and the output goes high again. The pulse output of IC6/2 is very narrow and is about a microsecond long. As the flip-flop has now changed state the relay has been closed and IC6/1 has been enabled (control input to pin 2 now high). After 25 seconds all the inputs to IC6/1 are high and the same procedure as before resets the counters and changes the state of the flip-flop.

In the one-shot mode of operation one input of the off timer is grounded and **the off time procedure is effectively disabled. The only way that the timer can now start is for the** manual start button to **be pressed.**



PARTS LIST — ETI 540

Resistors

R1	—	1 k	½ W	5%
R2,3	—	10 k	"	"
R4	—	47 k	"	"
R5	—	10 k	"	"
R6	—	1 k	"	"
R7-R9	—	1 M	"	"
R10	—	10 k	"	"
R11.12	—	100 k	"	"
R13	—	10 k	"	"
R14	—	100 k	"	"
R15	—	10 k	"	"

Capacitors

C1	—	0.1 µF 50 V disc ceramic
C2	—	0.1 µF polyester
C3	—	220 µF 16 V electro
C4,5	—	0.01 µF polyester
C6	—	10 µF 16 V electro
C7,8	—	0.01 µF polyester
C9	—	0.001 µF "
C10	—	0.01 µF "

Diodes

D1-D3	—	1N4001 or similar
D4, 5	—	IN914 or similar
LED 1	—	TIL209 or similar

Transistors

Q1,Q2	—	BC108 or similar

Integrated Circuits

IC1-IC3	—	4518
IC4,5	—	4017
IC6	—	4023
IC7,8	—	4011

Transformer 240 V/18 V CT PL18/5 VA
pc Board ETI 540
Relay, single pole 280 Ω coil 240 V 5A contact

Switches

SW1	double pole toggle switch
SW2	single pole 6 position rotary
SW3-6	single pole 10 position *
SW7	single pole toggle
PB1,2	single pole "make" push buttons

* Thumbwheel switches — Doram 338—175

Case plastic 196 x 113 x 60 mm
power cord, plug and clamp
3 pin power outlet socket

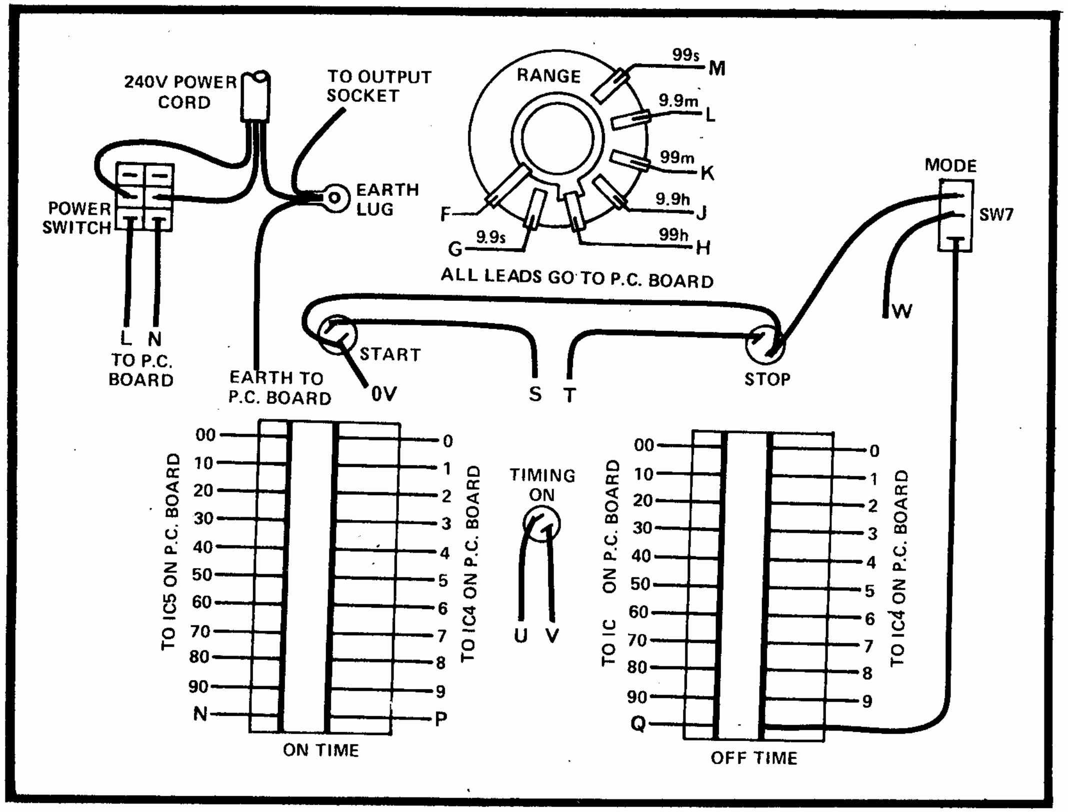


Fig. 3. Interconnection diagram.

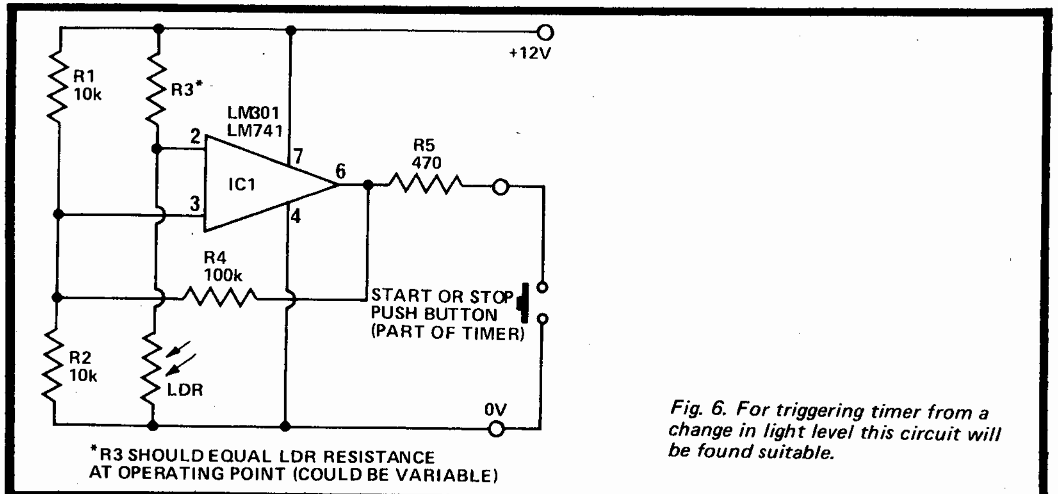


Fig. 6. For triggering timer from a change in light level this circuit will be found suitable.

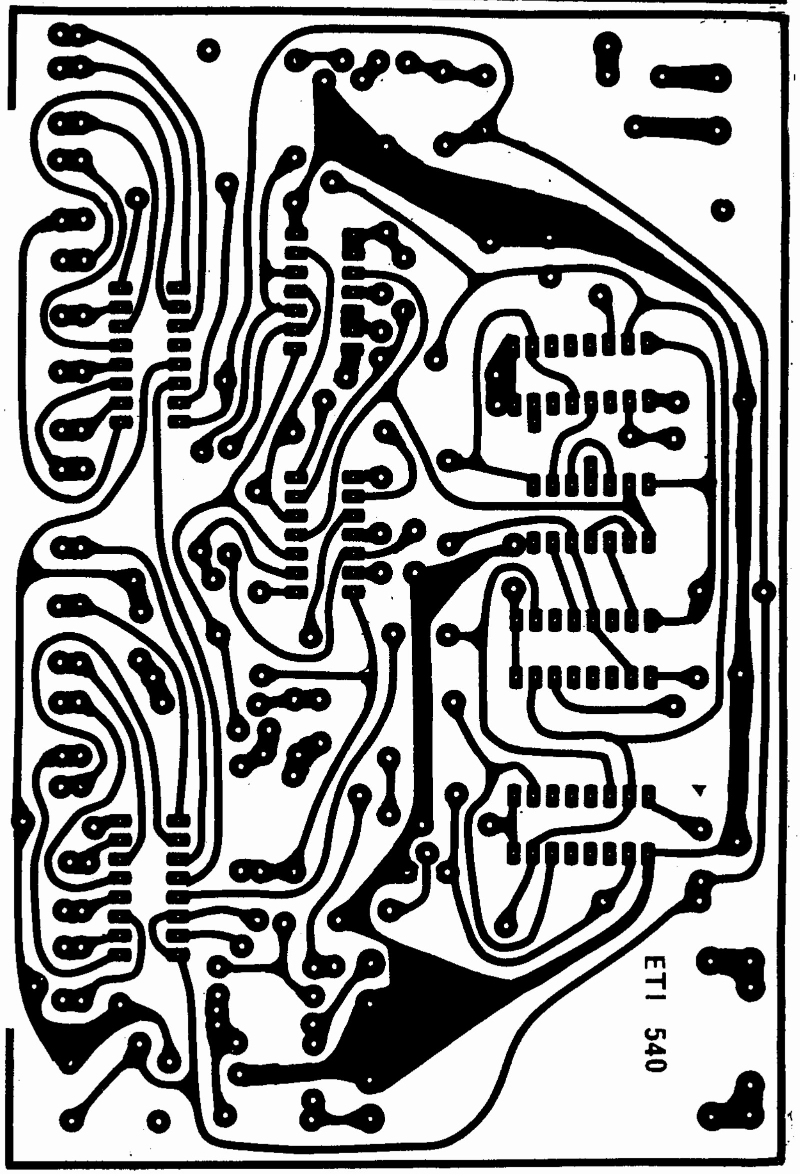
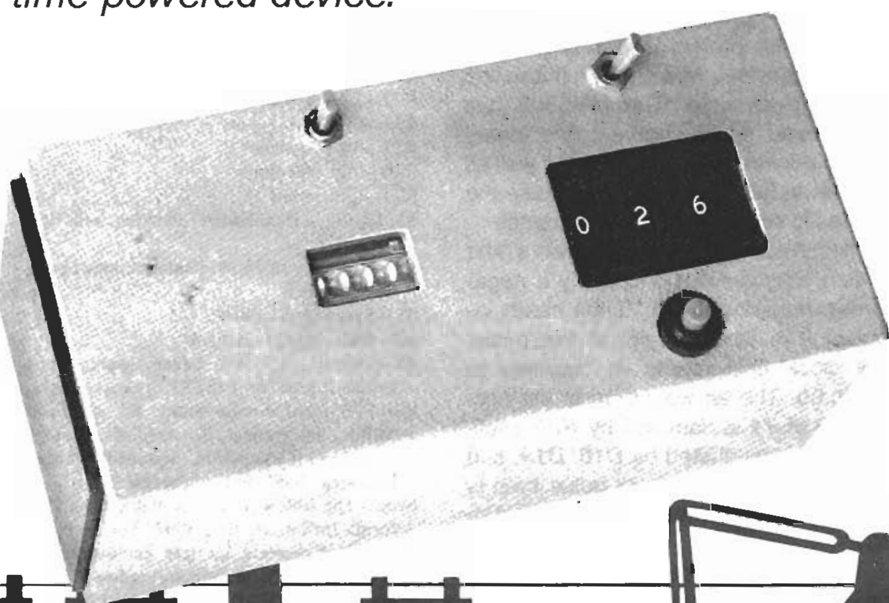


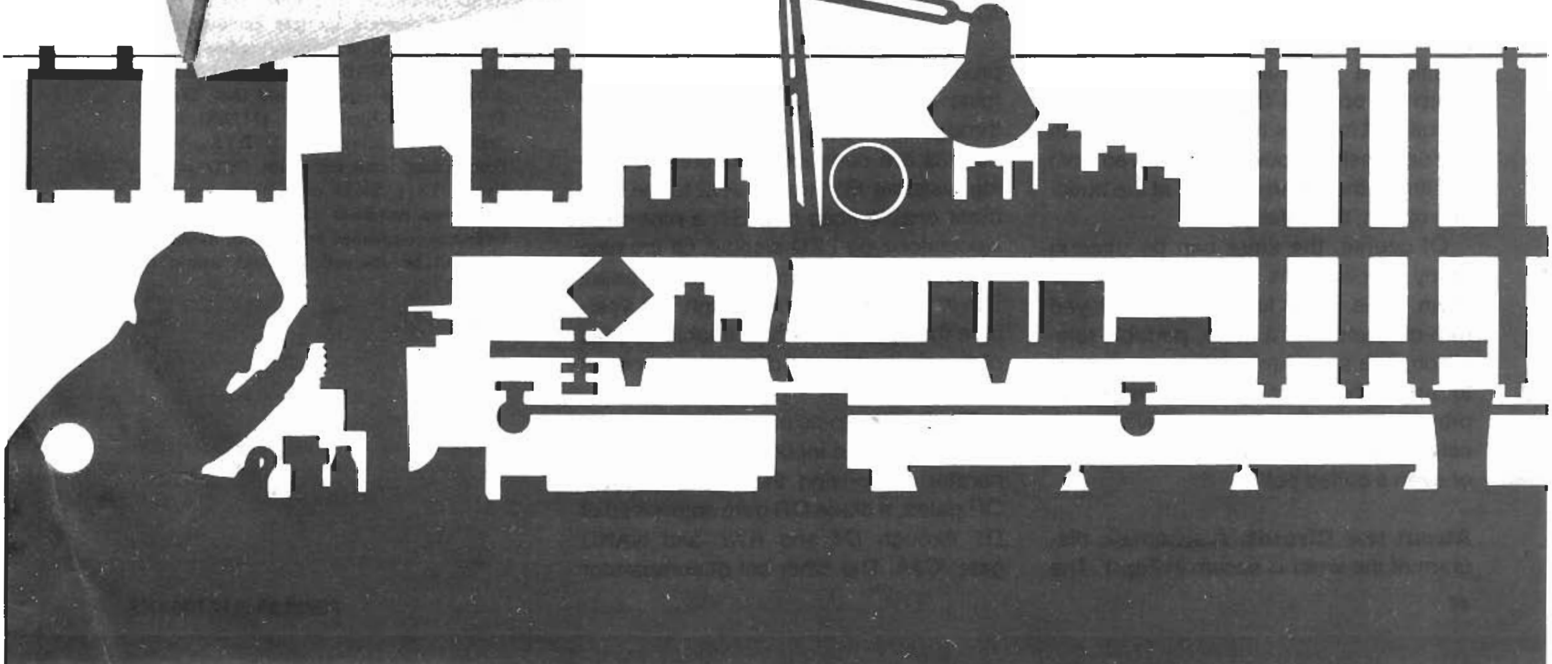
Fig. 4. Printed-Circuit board layout for the timer. Full size 153 x 100 mm.

BY MICHAEL S. ROBBINS

BUILD A DIGITAL DARKROOM TIMER

A solid-state precision interval timer to control an enlarger or other time-powered device.





A DARKROOM or other precision-application timer should possess the following attributes: accuracy; precise repeatability; provisions for setting the timing interval in minutes and seconds or hours and minutes; and a method of displaying elapsed time clearly in low ambient light levels. Most commercially available timers are electromechanical devices which fall short in one or more of the cited areas. The "Digital Darkroom Timer" described here, however, offers all of these features.

Its accuracy and precise repeatability are ensured by the use of a digital clock IC whose timebase is the 60-Hz ac line frequency. The timing interval is easily set by rotating three thumbwheel switches calibrated in minutes (0-9) and seconds (0-59). At the flip of a switch, the calibration is changed to hours (0-9) and minutes (0-59). A three-digit LED

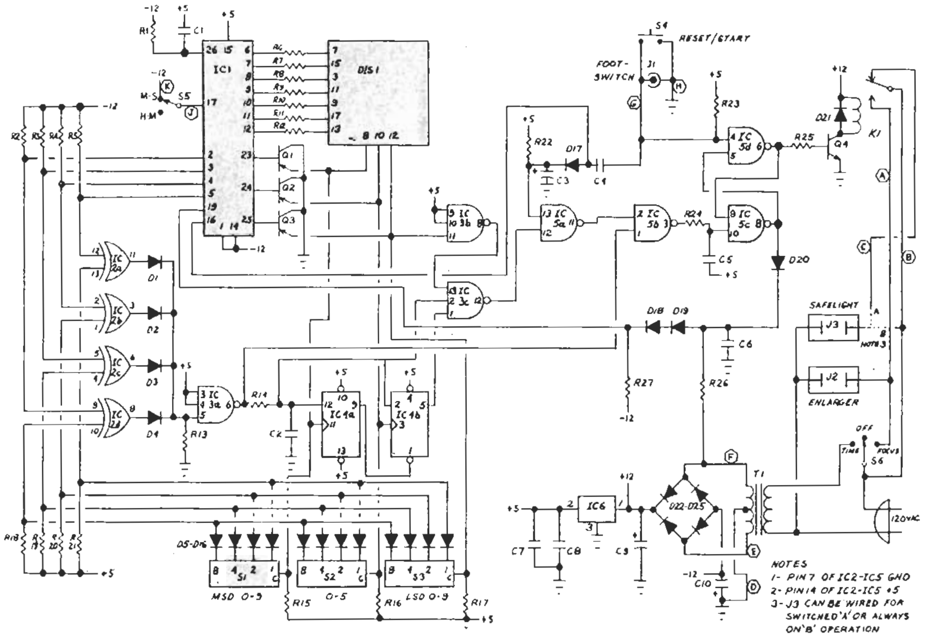


Fig. 1. Schematic diagram. PMOS clock chip IC1 counts 60-Hz pulses and produces seven-segment and BCD outputs.

display indicates elapsed time, and is useful when dodging or burning-in small areas of a print or when timing multiple-chemical processes. The display is rather small and not too bright, so it won't affect most black-and-white printing. (For film processing or work involving very sensitive paper, a deep red filter can be placed ovér the display.)

Two ac power sockets are mounted on the project enclosure, one for an enlarger and the other for a safe-light. The timer employs a three-position toggle switch labelled FOCUS/OFF/TIME. In the FOCUS position, the enlarger's power socket is energized. This allows the user to install a red filter under the enlarger lens and adjust the focus without exposing the photographic paper. In the TIME position, a panel-mounted pushbutton switch or optional footswitch resets the circuit and initiates the timing interval. In the OFF position, power is removed from the timer, the enlarger, and, at the builder's option, the safelight.

Of course, the timer can be used in many applications outside the darkroom. As is, it can function as a delayed turn-off switch for a radio, portable television, or a small lamp. When connected to an outboard relay or thyristor, the project can power a large television receiver, an audio system, home lighting, or even a coffee pot!

About the Circuit. A schematic diagram of the timer is shown in Fig. 1. The heart of the project is *IC1*, a National Semiconductor MM5309 full-function PMOS clock chip. The MM5309 has multiplexed seven-segment and binary coded decimal (BCD) outputs as well as a reset input. These features make the IC ideally suited for use in this project.

Momentarily closing RESET/START switch *S4* causes *C4* to apply a negative-going pulse to pin 16, the RESET input of *IC1*. Upon receipt of this pulse, the clock chip resets its counters to 00:00:00. The ac waveform at the secondary of *T1* is sampled by *R26*, rectified and level-shifted by *D18*, *D19*, and *R27*. The resulting 60-Hz pulse train is applied to pin 19, the timebase input of *IC1*.

The clock chip counts the pulses and produces multiplexed seven-segment (pins 6 through 12) and BCD (pins 2 through 5) outputs. The seven-segment outputs are connected via current-limiting resistors *R6* through *R12* to the segment enable lines of *DIS1*, a nine-digit, calculator-type LED display. Of the nine digits in the display only three are used. Driver transistors *Q1* through *Q3* interface the appropriate digit enable outputs of the clock chip and digit enable lines of the display.

The BCD outputs of the clock are routed to one set of inputs of a digital comparator comprising the four exclusive-OR gates, a diode OR gate composed of *D1* through *D4* and *R13*, and NAND gate *IC3A*. The other set of comparator

PARTS LIST

C1—0.005-µF disc ceramic
C2, C4, C5, C7, C8—0.1-µF disc ceramic
C3—5-µF, 12-volt electrolytic
C6—0.01-µF disc ceramic
C9—1000-µF, 16-volt electrolytic
C10—100-µF, 16-volt electrolytic
D1 through D20—1N914 signal diode
D21 through D25—1N4001 rectifier
DIS1—9-digit common-cathode calculator display (National Semiconductor No. NSN-198 or equivalent)
IC1—MM5309N PMOS digital clock chip (National Semiconductor)
IC2—SN7486 quad exclusive-OR gate
IC3—SN7410 triple three-input NAND gate
IC4—SN7474 dual D-type flip-flop
IC5—SN7400 quad 2-input NAND gate
IC6—LM340T-5.0 5-volt regulator
J1—RCA phono jack
J2, J3—Ac power socket
K1—Spdt 12-volt relay (Sigma No. 78RE1-12DC or equivalent)
Q1, Q2, Q3—2N3906 pnp transistor
Q4—2N3904 npn transistor
The following are ¼-watt, 5% tolerance carbon-composition or film resistors:
R1—330,000 ohms
R2 through R5—7500 ohms
R6 through R12—330 ohms
R13—680 ohms
R14—220 ohms
R15 through R21—4700 ohms
R22—22,000 ohms
R23, R24—1000 ohms
R25—10,000 ohms
R26—100,000 ohms
R27—1 megohm
S1, S2, S3—Thumbwheel switches with BCD outputs
S4—Normally open momentary contact push-button switch
S5—Spst toggle switch
S6—Spdt toggle switch
T1—18-volt, 150-mA center-tapped transformer (Triad No. F161XP or equivalent)
Misc.—Printed circuit board, IC sockets or Molex Soldercons, pc standoffs, suitable enclosure, hookup wire, line cord, strain relief, misc. hardware, solder, etc.
Note—The following are available from California Industrial, Box 3097, Torrance, CA 90503: Complete kit less enclosure (No. DTK), $34.95; aluminum/hardwood cabinet (No. DTCAB), $12.95; etched and drilled printed circuit board (No. DTPC), $7.95; 9-digit display (No. DTDIS), $1.39; Spdt 12-volt relay (No. DTRY5), $1.39; thumbwheel switches with BCD outputs (No. DTS1), $1.39 each (three required). California residents please add sales tax. Orders accompanied by check or money order will be shipped postpaid within the U.S.A.

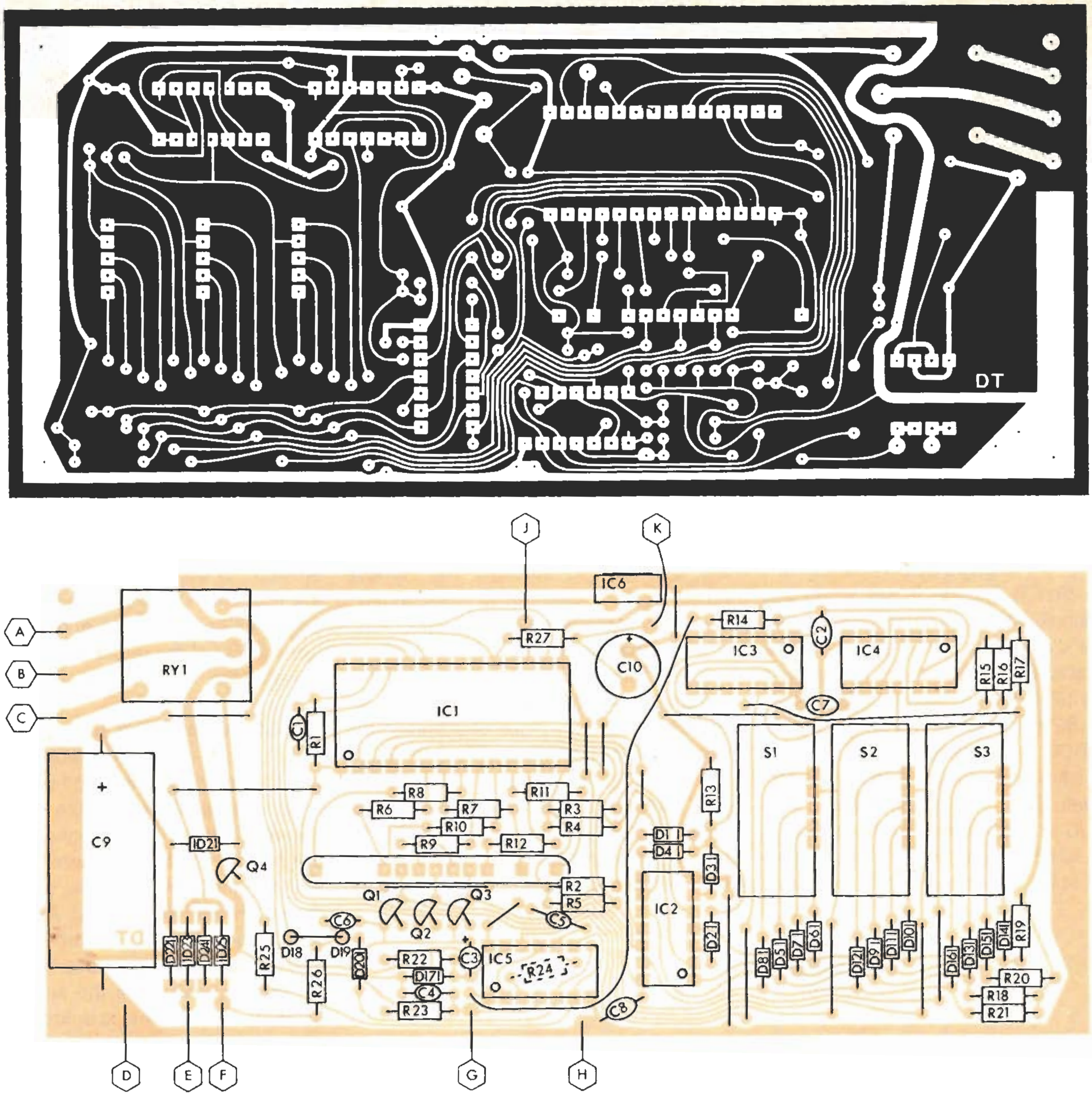
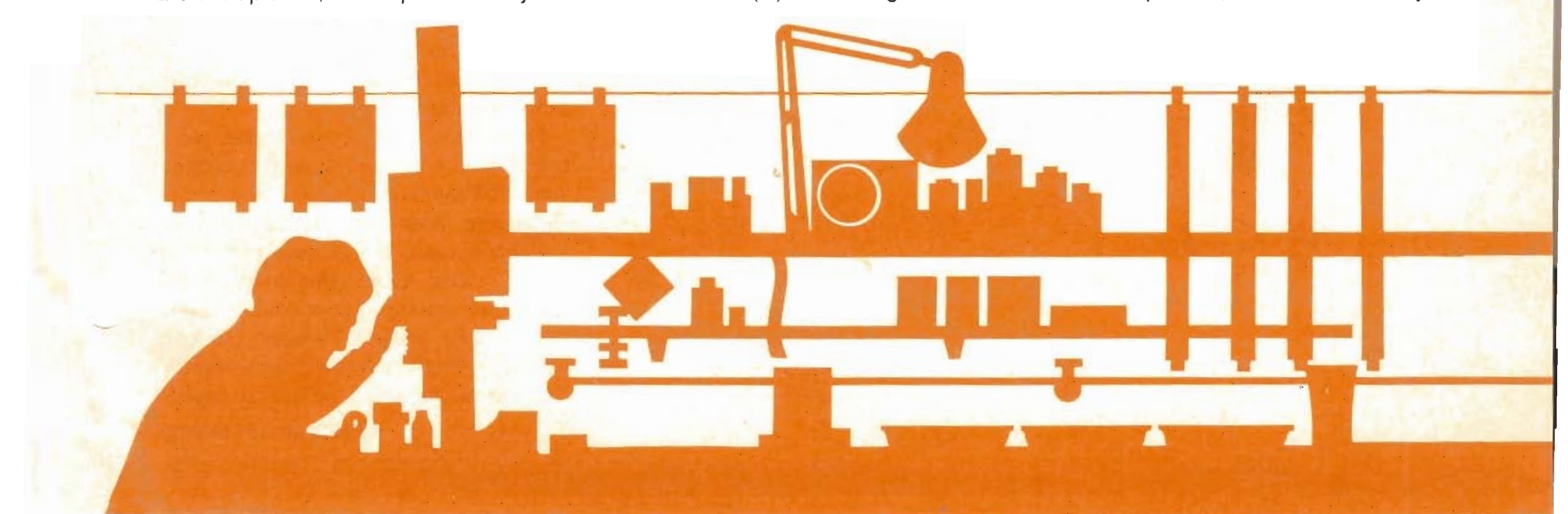


Fig. 2. Full-size etching and drilling (A) and parts placement (B) guides for a suitable printed circuit board.

inputs receives the BCD outputs of thumbwheel switches *S1*, *S2* and *S3*. Because the BCD outputs of the clock are multiplexed, those produced by the thumbwheel switches must be time-multiplexed in a synchronous manner.

This is accomplished by connecting the common (C) switch lugs to the display driver transistors *Q1*, *Q2*, and *Q3*. When, for example, the BCD equivalent of the first time digit is being applied to the comparator, *Q1* simultaneously acti-



vates the appropriate display digit and thumbwheel switch *S1*. Diodes *D5* through *D16* are used to isolate the BCD outputs of the inactive switches from those of the thumbwheel switch activated at any given instant.

The digital comparator generates an output pulse each time the BCD output of the clock chip matches that produced by the corresponding thumbwheel switch. Because all the BCD numbers produced by both the clock chip and the thumbwheel switches are not available simultaneously (again, due to multiplexing), some means of "remembering" the coincidence pulses is required. This function is performed by a memory or latch comprising two D-type flip-flops (*IC4A* and *IC4B*), several NAND gates, and an RS flip-flop formed by two cross-coupled NAND gates (*IC5C* and *IC5D*).

The first D flip-flop is set when the most significant BCD number generated by the clock chip is the same as that generated by *S1*. Similarly, the second flip-flip (*IC4B*) is set when the BCD output of *S2* matches the next-most significant BCD number generated by the clock chip—only if *IC4A* has already been set. This is so because the Q output of *IC4A* is connected to the CLEAR input of *IC4B*, whose PRESET input is tied to +5 volts. Therefore, the Q output of *IC4B* will be held low as long as that of *IC4A* is low.

If the least significant BCD number generated by the clock chip matches the BCD output of *S3* and the two D flip-flops have been set, the RS flip-flop formed by *IC5C* and *IC5D* will be set. Thus, when the elapsed time in BCD form equals the three BCD numbers generated by *S1*, *S2* and *S3*, the RS flip-flop changes state and deprives relay driver *Q4* of base current. The transistor then turns off and deenergizes the relay, removing line power from *J2*, the enlarger power socket. If the safelight power socket (*J3*) is connected using the "A" wiring (see schematic), power will be removed from it when the relay is energized. If *J3* is "B" wired, the relay will have no control over the flow of power to the socket. The safelight will remain powered no matter what position FOCUS/OFF/TIME switch *S6* is in, or whether *K1* is energized or not.

The RS flip-flop is also used to control the application of the 60-Hz timebase to the clock chip by means of a biased diode network (*D18*, *D19*, *D20* and *R27*). When the flip-flop is reset, 60-Hz pulses with high and low levels sufficient to drive the clock chip are applied to pin 19, the chip's timebase input. After the timing interval has elapsed, however, *IC5B* changes state and the dc level at the cathode of *D18* shifts so that the 60-Hz pulse train can no longer trigger *IC1*. The clock chip no longer counts and the display is frozen at a three-digit number which matches the setting of the thumbwheel switches. The setting of *S5* determines the range of the timer—either hours/minutes or minutes/seconds.

Transformer *T1*, diodes *D22* through *D25* and electrolytic capacitors *C9* and *C10* comprise a bipolar, full-wave power supply which produces ±12 volts dc. The relay requires +12 volts, and the clock chip's V_{DD} terminal −12 volts. A third supply voltage, +5 volts, is required by the TTL IC's. Also connected to +5 volts is the V_{SS} terminal of the PMOS clock chip. This allows the chip to drive the TTL IC's directly with no need for level shifting. Voltage regulator *IC6* derives the required +5 volts from the +12-volt supply. Capacitors *C7* and *C8* ensure the stability of the regulator IC and keep noise off the +5-volt line.

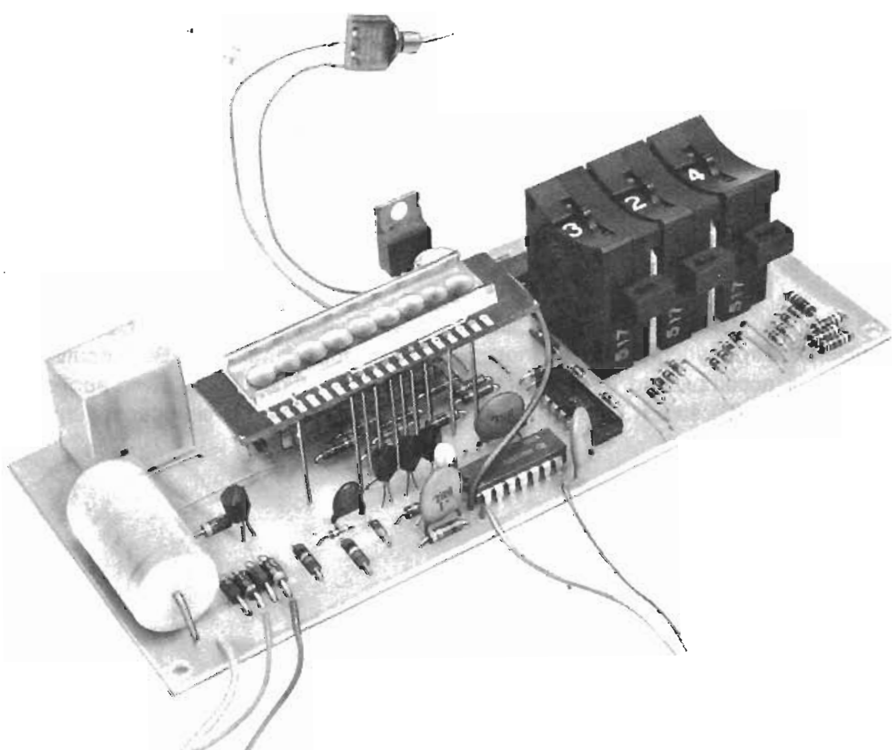


Fig. 3. Assembled timer removed from its enclosure shows how the display board mounts above main board. Cube at left rear is relay.

Construction. The use of a printed circuit board will simplify project assembly. Etching and drilling and parts placement guides for a suitable board are shown in Fig. 2. All components except the power transformer, switches *S4*, *S5* and *S6*, the power sockets and jack *J1* mount on the circuit board. Assembly is straightforward, but here are a few hints that will save you some time.

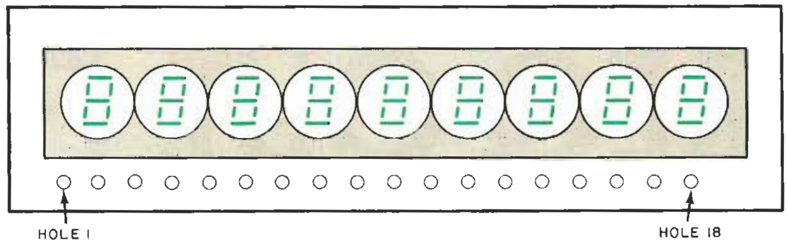
Begin by mounting the jumpers and fixed resistors on the pc board. Save the cut-off resistor leads to mount the display. Note the position of *R24* relative to that of *IC5*. If this IC is to be soldered directly to the board (which is not recommended) or mounted via a standard DIP socket, mount *R24* on the foil side of the board. However, if the IC is installed using Molex Soldercons, *R24* can be mounted on the component side. The resistor will sit in the "channel" formed by the Soldercons, which will also provide sufficient clearance between the bottom of the IC package and the top of the pc board to accommodate the body of the resistor.

Next, install the silicon diodes, using the minimum amount of heat consistent with the formation of good solder joints. Excessive heat can destroy delicate semiconductors like diodes, transistors and IC's. Also, avoid using too much solder when making a connection. Otherwise, solder bridges between adjacent foil areas might be formed inadvertently. Semiconductors and polarized capacitors must be installed with due regard to pin basing or polarity. Be sure that the diodes are installed so that their banded ends (cathodes) are positioned as shown in Fig. 2. Diodes *D18* and *D19* must be mounted vertically. Install *D18* so that its cathode is down (banded end nearest the board) and *D19* so that its cathode is up. Connect the two remaining leads together.

The capacitors can now be installed, paying close attention to the polarities of *C3*, *C9* and *C10*. The remaining capacitors can be installed either way as they have no polarity. Using sockets or Molex soldercons, mount the TTL IC's, but do not mount the clock chip yet. (That should be the last step of the assembly procedure.) Also, install the digit driver transistors oriented as shown in Fig. 2.

The switches and display can be connected to the pc board using Figs. 3 (photo) and 4 as guides. The layout and pinout details of the display are shown in Fig. 4. No connections are made to holes 1, 2, 4, 5, 6, 14, 16 and 18, the decimal point anode and the cathodes (digit enable lines) of the three left- and right-most digits of the display. Either straight pins or the clipped resistor leads can be used to support the display (see Fig. 3). The supporting leads or pins should first be soldered to the display pads and then, after properly positioning the display, soldered to the row of square pads on the main circuit board just above digit driver transistors *Q1*, *Q2* and *Q3*. Clip off any excess lead length.

Connections between the pc board and those components not mounted on it are denoted in Figs. 2 and 3 by letters enclosed by hexagons. For example, a length of hookup wire should be connected to pad *A* on the board (normally open contact of *K1*) and the FOCUS lug of *S6* and one side of *J2*. The safelight outlet, *J3*, can be wired so that it is not powered when the enlarger is (A) on or so



DISPLAY DETAILS

1-no connection	10-digit 5 cathode
2-digit 1 cathode	11-segment D anode
3-segment C anode	12-digit 6 cathode
4-digit 2 cathode	13-segment G anode
5-decimal point anode	14-digit 7 cathode
6-digit 3 cathode	15-segment B anode
7-segment A anode	16-digit 8 cathode
8-digit 4 cathode	17-segment F anode
9-segment E anode	18-digit 9 cathode

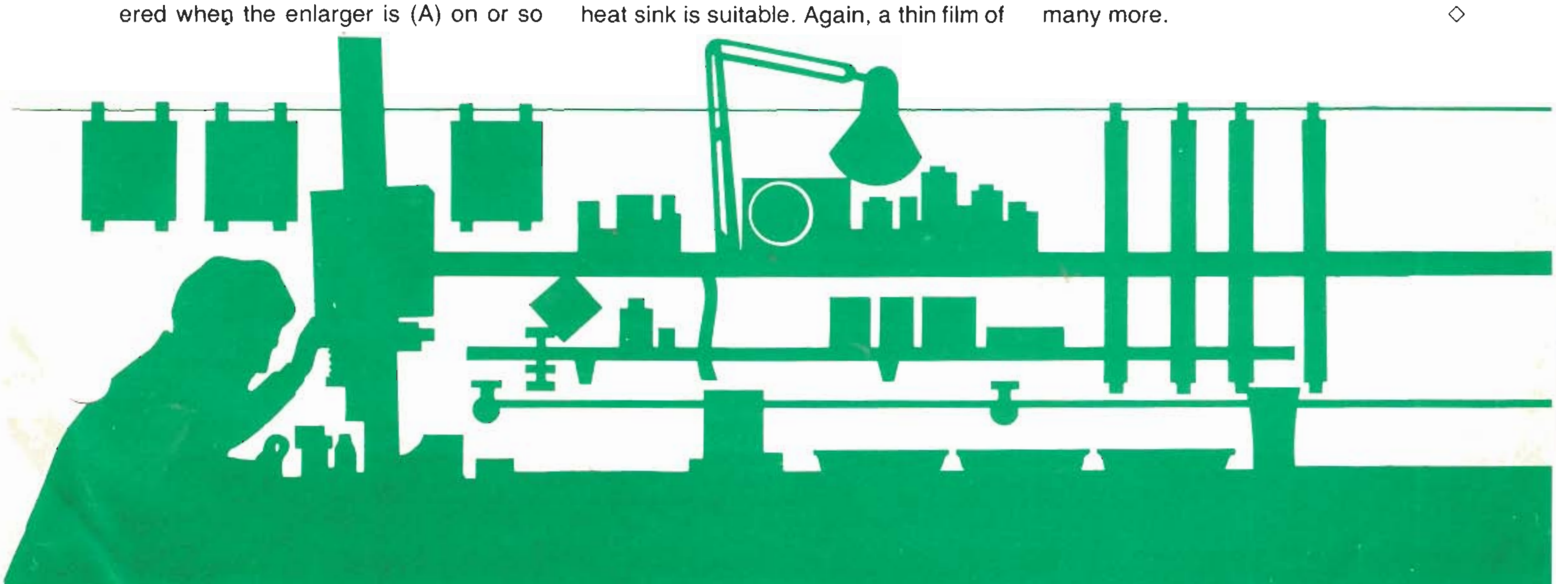
Fig. 4. No connections are made to holes 1, 2, 4, 5, 6, 14, 16, and 18 on display board.

that it remains powered (B). Jack *J1* is included to accommodate a footswitch. As shown in the schematic, the footswitch can be used to reset and start the timer. Alternatively, the "hot" side of *J1* can be connected to the collector of *Q4* for footswitch control of the relay—a great convenience for those who do a lot of dodging.

A heat sink must be provided for *IC6*, the 5-volt regulator. If the timer is housed in an aluminum enclosure, the tab of the IC can be fastened to it. A mica insulating washer is not required, but a small amount of silicone thermal compound should be spread on the back of the tab. This will improve the transfer of heat from the IC package to the project enclosure. If the timer is in a nonmetallic enclosure, a bolt-on heat sink should be used. Either a homebrew heat sink formed by bending aluminum stock or a preformed commercial heat sink is suitable. Again, a thin film of silicone thermal compound should be smeared on the back of the IC's tab before it is secured to the heat sink.

Using the Timer. The project should be used as you would a mechanical timer, except that the timing interval is selected by three detented switches rather than by rotating one large knob. Having preset the timing interval, you should load and focus the enlarger, place *S6* in the TIME position, and start the timer by closing *S4* or the footswitch connected to *J1*.

Although the project has been designed with the darkroom in mind, it has many nonphotographic applications in the home, shop, lab or classroom. To name just a few, the project can be used to time chemical experiments, as a quiz timer, or as a delayed turn-off switch for a television receiver or audio system. Without a doubt, you'll be able to think of many more. ◇

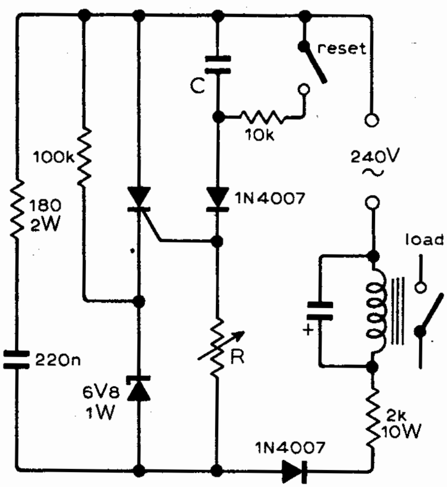


Economic timer

Many electronic timers require excessively high values of capacitance and resistance when used for long delays. If extreme accuracy is not required, this circuit overcomes the problem. When the mains voltage is applied capacitor C is initially discharged. The rising edge of the rectified sine wave causes a voltage across R which supplies a charging current to capacitor C. When the voltage across R reaches the thyristor trigger voltage it turns on and stops the harging of C. The relay is turned on and load current flows. On the next rising edge, triggering occurs at a higher voltage i.e. later in the cycle because there is a residual charge on C. Therefore, each successive mains cycle increases the charge on C. The circuit remains turned off when the voltage on C reaches the peak supply voltage.

The 180Ω resistor and 220nF capacitor supplies the initial current pulse to ensure a fast turn on of the thyristor. Using a low leakage capacitor for C the delay times shown in the table were obtained. Timing is stable to within 10% if the zener diode and thyristor are mounted together on a h[illegible]ink, and best results are obtained with low values of R and high values of C. Full wave rectification of the supply may be used to halve the delay times. In certain applications, where retriggering may occur due to voltage surges, a clipping circuit can be used on the supply. Certain thyristors, which have an internal resistor from gate to cathode, are unsuitable in this circuit.

G. J. Thompson,
Codnor,
Derbys.



C(μF)	0·01	0·1	1·0
R(Ω)	time (min-sec)		
10k	—	0–15	2–43
22k	—	0–35	5–51
47k	0–04	1–09	11–47
100k	0–09	2–10	23–25
220k	0–15	3–54	46–50
470k	0–27	7–39	98
1M	0–45	13–51	220

How to get nearly 100% duty-cycle range out of the 555 timer

⁊ 555 timer finds wide use in switching regulators, signal gene... rs, anu pulse-width modulators when it's wired as a variable-pulse-width generator. But you can get even broader duty-cycle variation from this circuit with a simple modification, says Glenn T. Darilek, a senior research engineer at Southwest Research Institute in San Antonio, Texas. As a bonus, the modification is likely to narrow the control-voltage range, too.

Instead of the timing resistor in the conventional configuration, **just use a high-value resistor in parallel with a series-connected low-value resistor and zener diode** (with its cathode facing the supply). According to Darilek, a 47-kilohm resistor shunted by a 1-kilohm resistor and a 4.7-volt zener extends the duty-cycle range from between 8% and 90% to near 0% and 100%, while decreasing the control-voltage range from between 0 and 9 v to 3.5 and 7.5 v. The only limitation on how narrow (or wide) the output pulse may be, he notes, is the timer's rise and fall times, which are typically 100 nanoseconds each.

programmable timer/controller

The circuit described here is a versatile timer/controller, capable of switching 4 separate outputs on or off at 4 pre-programmed times every day. The circuit is ideally suited for the control of domestic appliances such as cookers, central heating, intruder alarms (to be switched on at night) etc., or can be used as a straightforward 24 hour 'radio-snooze-alarm' clock. Almost all the work is performed by a single IC, so that the circuit is both compact and relatively inexpensive.

Table 1.

* 24 hour real-time clock with 4-digit display
* 4 control outputs
* programmable set point times with repeat 24 hours
* valid day programming to skip certain days if desired
* manual mode to verify programming
* each output can switch up to 400 mA

The heart of the circuit is formed by the MM57160 standard timer and controller (STAC) chip from National Semiconductor. This IC is designed for use in timing applications where up to 4 separate outputs are required to operate at up to 4 user-programmed times. Thanks to direct display drive capability and on-chip keyboard scan facility, very little in the way of external hardware is required to provide a complete timer/controller system. The main features of the IC are summarised in table 1. An interesting facility is the provision of valid day programming, which allows control outputs to be inhibited on certain days (weekends, for instance).

Circuit design

The circuit diagram of the timer/controller is shown in figure 1. Timing is derived from the 50 Hz mains frequency at the secondary of the transformer and shaped by N1, N2 and N3. Mains transients are suppressed by the interference filter R1/C1. During the positive half cycle of the 50 Hz input signal C2 is rapidly discharged by N1. The capacitor takes much longer to charge up again, however, since this can only occur via R3, which is roughly 1000 times greater than R2.

The condition of each of the four outputs of the timer/controller chip (IC1) is indicated by a LED. Each output has a current capability of 20 mA but buffers are included to increase the maximum load current to 400 mA. It must be remembered that the use of the buffers inverts the output levels i.e. if the control output is low (0V) then the buffer output will be high (equal to + supply). This should be borne in mind when programming the system.

A stabilised power supply is provided, using a 78L08 regulator IC. Components R7 and C3 are included to ensure that the timer is reset upon switch-on. Initial conditions are: (real time) clock to 00 : 00; all set point times to 00 : 00 and all outputs off; all days valid; and the IC in the real time clock mode.

Programming

Programming is carried out using push button switches having up to three different functions and these are summarised in table 2.

Set point times (switching times) are loaded as follows:

- The DATA ENTRY switch is momentarily depressed to take the system from the real time clock mode to the data entry mode, whereupon one of the set point times is displayed and its outputs status indicated on the decimal points of the display. If the data entry mode is selected immediately after power-up, the display will show 00 : 00, with the decimal points off.
- To examine the next set point, the ADVANCE SET POINT switch is depressed. The four set point values are stored in a revolving stack, so that four advances will cause the stack to roll round to the original value.
- Set point times are loaded or altered using the SET HOURS and SET MINUTES switches. When depressed, these switches increment the hours displays from 0-23 and the minutes displays from 0-59 at a rate of one per second.
- Next, the SET STATUS switch is used to program the output(s) to be activated at the set point times. When the SET STATUS switch is initially depressed the first decimal point is turned on, signifying that output 1 will be activated at this time.
- If this is the only output to be activated, the ADVANCE SET POINT switch can be depressed to go on to the next set point.
- If, however, output 2, 3 or 4 is to be activated, the SET STATUS switch should be pressed again to advance to the subsequent outputs. Each advance turns off the previous decimal point (and output).
- If more than one output is to be activated, e.g. 2 *and* 4, the HOLD STATUS switch is used to hold number 2 decimal point on before the SET STATUS switch advances through 3 to number 4. Thus using the SET STATUS and HOLD STATUS switches it is possible to program any combina-

Figure 1. Complete circuit diagram of the timer/controller. If desired, the output buffers N4 . . . N7 may be omitted.

tion of outputs to be activated at each set point.

- If an error is made during programming, operating the SET STATUS switch from position 4 will clear all data (including that set by HOLD STATUS), whereupon the correct information can be re-entered.
- The programmed information can be verified by using the MANUAL switch, which, when depressed in the data entry mode, transfers the decimal point status to the outputs, activating the appropriate relay, solenoid, etc. The system is returned to the real-time clock mode by depressing the DATA ENTRY switch a second time.
- To examine and alter the valid day information, the DAY MODE key is depressed, whereupon the current day is displayed in the left-most display digit and the validity of the day in the right-most digit. A valid day is signified by '1', an invalid day by '0'. When depressed in the day mode, the SET DAY switch advances to the next day. The validity information can be altered by the SET STATUS switch. To return to the real-time clock mode the DAY MODE switch is pressed a second time.
- With the aid of the HOLD STATUS/DEMO switch it is possible to rapidly cycle through the entire programmed sequence. When this switch is pressed in the real-time clock mode, the clock advances at a rate of one hour per second, i.e. a 24 hour day can be verified in 24 seconds, whilst a 7-day week requires less than 3 minutes to check.
- To set the real-time clock to the cor-

1

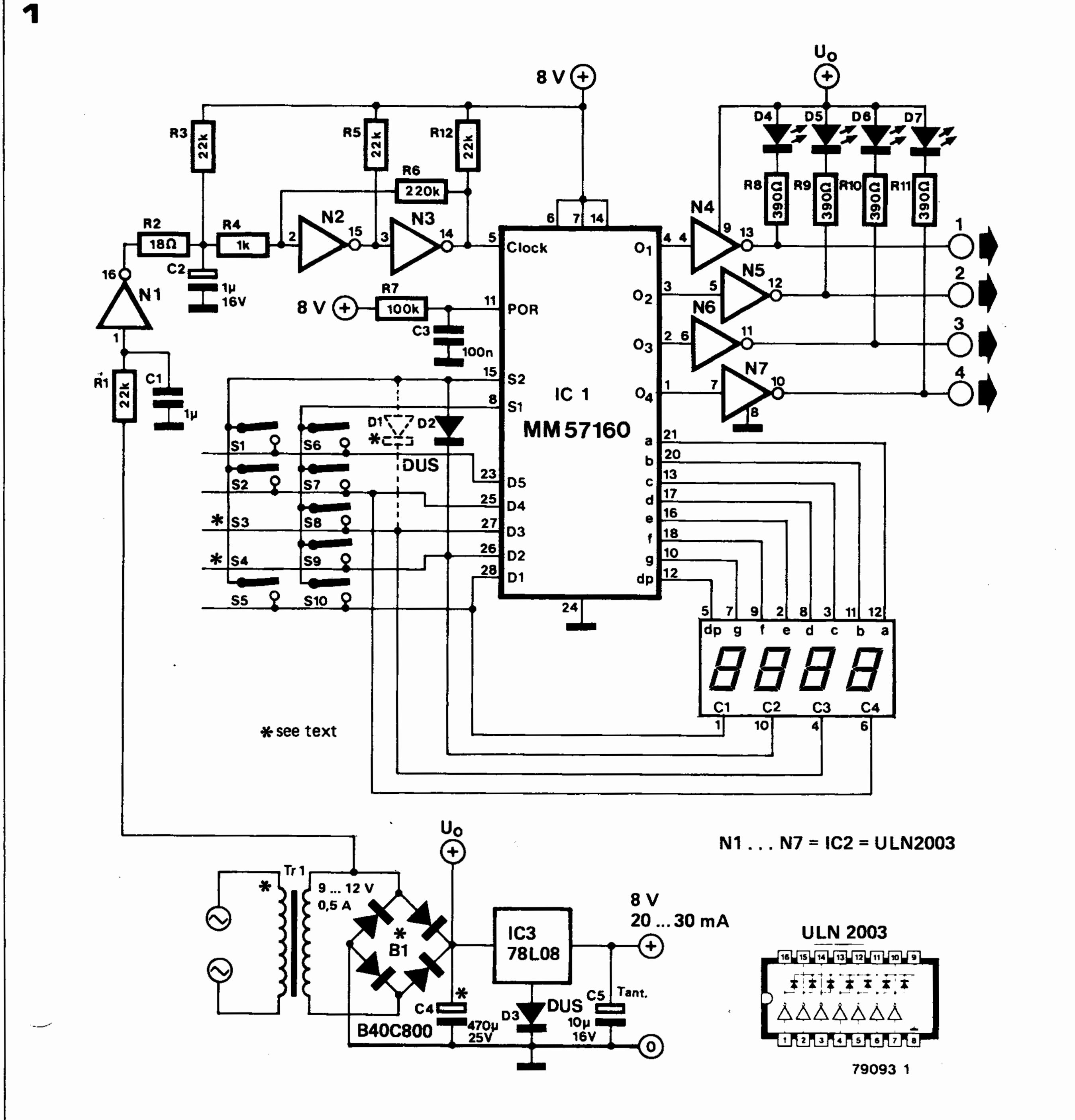
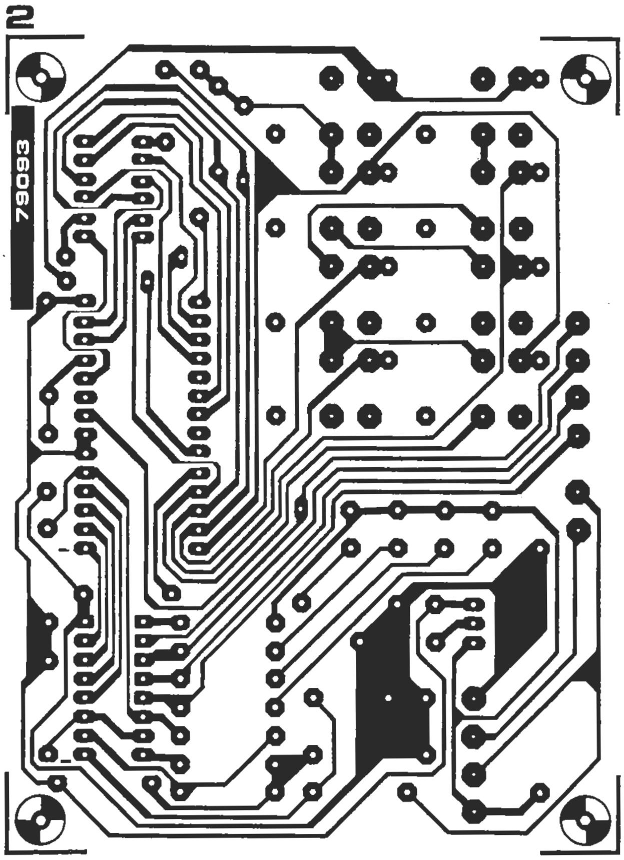


Table 2.

KEY NO.	KEY SWITCH NAME	FUNCTION		
		REAL-TIME CLOCK MODE	DATA ENTRY MODE	DAY MODE
1	MANUAL/ REMOTE TRANS-DUCER	Remote transducer input; forces output 1 ON, outputs 2–4 OFF until next valid set point after switch is off	Manual verification mode; allows data to be transferred to outputs 1–4	(None)
2	HOLD STATUS/ DEMO	Allows rapid demonstration of sequence by advancing clock at rate of 1 hr/sec	Holds output N ON while programming advances to output N + 1, N = 1–4	(None)
5	DATA ENTRY	Places unit in the data entry mode	RETURNS UNIT TO THE REAL-TIME CLOCK MODE	(None)
6	ADVANCE SET POINT/ RESET TIME	Resets time of day to 00.00 without changing set points but resets all days to valid	Advances display to the next set point so that it may be verified or altered	(None)
7	DAY MODE	Places unit in the day mode	(None)	RETURNS UNIT TO THE REAL-TIME CLOCK
8	SET STATUS	(None)	Controls programming of outputs; resets output N to "0" (unless preceded by HOLD key) and advances to output N + 1	Alternate action key; changes day from valid ("1") to invalid ("0") and vice-versa
9	SET MINUTES	Advances minutes display of real-time clock	Advances minutes display of selected set point	(None)
10	SET HOURS/ SET DAY	Advances hours display of real-time clock	Advances hours display of selected set point	Advances display to next day—must be set to current day before returning to real-time clock mode

2



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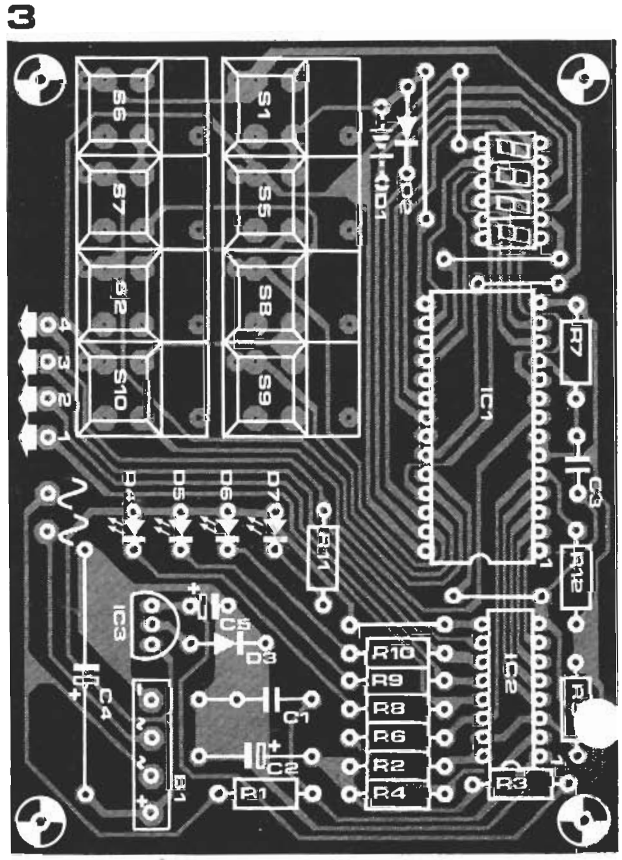


Parts list

Resistors:
R1, R3, R5, R12 = 22 k
R2 = 18 Ω
R4 = 1 k
R6 = 220 k
R7 = 100 k
R8, R9, R10, R11 = 390 Ω

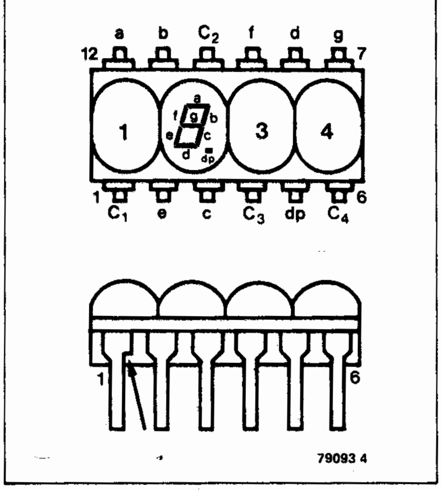
Capacitors:
C1 = 1 µ(Siemens)
C2 = 1 µ/16 V
C3 = 100 n
C4 = 470 µ/25 V*
C5 = 10 µ/16 V, tantalum

Semiconductors:
D1*, D2, D3 = DUS
D4 ... D7 = LED
IC1 = MM57160 (National)
IC2 = ULN 2003 (Sprague), XR 2203 (Exar), MC 1413 (Motorola) R.S. No. 307-109.
IC3 = 78L08

Miscellaneous:
S1, S2, S5 ... S10 = Digitast pushbutton switch
HP 5082-7414 display or equivalent
Tr1 = transformer, 9 V*
B1 = bridge rectifier, B40C800*

* see text

4



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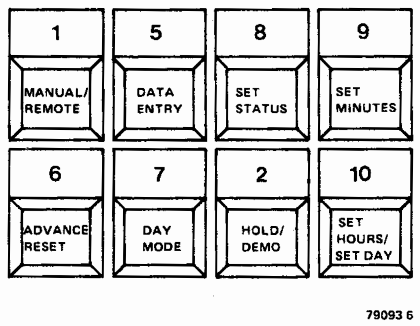


Figure 2. Track pattern of the printed circuit board for the timer/controller (EPS 79093). As can be seen there are a considerable number of connections to the displays and to the keyboard. The use of a printed circuit board reduces the amount of work and increases the reliability of the circuit.

Figure 3. Component overlay of the printed circuit board. Diode D1, (see text) is shown in dotted lines. If a different type of display is used, then it may not fit on the board, in which case separate connections will be necessary.

Figure 4. Pin-out of the HP 5082-7414. The segments are indicated by the small letters, whilst C1, C2 etc. stand for the cathode of the first display, second display, and so on.

Figure 5. Layout of the keyboard.

rect time the SET HOURS and SET MINUTES switches are used. The clock time can be reset to zero by pressing the ADVANCE SET POINT switch in the real-time clock mode. The set point times remain unaffected by this operation, however it should be noted that it also resets the valid day information (i.e. all days are valid).

- Finally, the MANUAL/REMOTE TRANSDUCER switch provides a facility for external inputs. When pressed in the real-time clock mode, the programmed data is ignored, and output 1 is switched on whilst outputs 2 . . . 4 are turned off. On valid days this condition is maintained until the next set point time. On non-valid days all outputs are turned off as soon as the switch is opened.

Construction

For ease of construction a printed circuit board (figures 2 and 3) is available from the Elektor print service. Since the display is made entirely of plastic it may be unwise to solder it directly to the board but it can be mounted in an IC socket.
The pin-out details for the display are given in figure 4 for those readers who may already possess a suitable type. It is often possible to pick up second-hand calculators and to extract the displays from them, thereby saving money. The only condition is that the display must be common cathode. If the pin-out of the display is not known, it is possible to determine it by using a multimeter switched to a resistance range and checking each of the pins in turn to see which segment they light up. Use a discrete LED first to check that the meter is set to the right range.
Like the Beatles, some readers may have an application for an 8-day week cycle. This facility can be selected by wiring a switch in series with diode D1, or D1 can be mounted directly on the printed circuit board. Similarly diode D2, if removed from the board will enable the timer to be used with a 60 Hz mains frequency supply.
The choice of transformer, bridge rectifier and smoothing capacitor is determined by the maximum current consumption of the circuit, which in this case is 4 x 400 mA = 1.6 A. However, if the load current of each output is known to be less than the maximum, it is a simple matter to calculate the desired transformer current rating.
As a rule of thumb the value of the electrolytic can be calculated on the basis of 2000 µF per amp. The values shown in the circuit diagram for the power supply components are sufficient to drive several relays (12 V/20 to 50 mA). The relays, like the LEDs and their resistors, can be connected to the unstabilised supply (positive end of C4).
One should check to ensure that the stabilised supply is satisfactory. With a voltage between 8 and 9.5 V trouble-free operation should be guaranteed. There is in fact no need for the supply voltage to exceed 8 V, and if one measures a voltage of more than 8.6 V, diode D3 can safely be omitted. However if for some reason the voltage regulator provides less than 8 V, the diode must be included.
Upon switch-on the displays should show '0000'. If this is not the case then pin 11 of IC1 should be grounded providing an additional reset pulse. If the display still refuses to reset then there is a fault in the circuit (defective IC, bad solder joint, etc.).
It may at first sight appear that programming the timer is rather a complicated process. However with a little practice it is possible to enter and check (using the DEMO and MANUAL switches) a program extremely quickly. The following sample program should help to familiarise prospective users with program entry and operation.

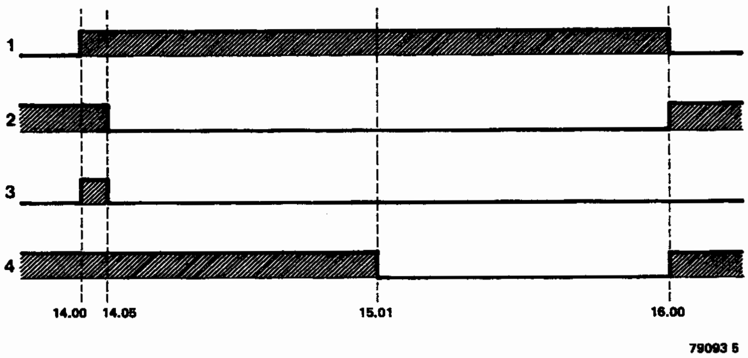
To illustrate how the timer/controller can be programmed, assume that it is required to perform the following operations:

1. Output 1 should turn on at 14.00 and turn off at 16.00 each valid day.
2. Output 2 should turn off at 14.05 and turn back on at 16.00 each valid day.
3. Output 3 should turn on at 14.00 and turn off at 14.05.
4. Output 4 should turn off at 15.01 and turn on again at 16.00.
5. Valid days are Monday to Friday inclusive. Saturday and Sunday are invalid days.
6. The current day is Monday, the time is 13.00.

From the above information we can construct the following 'truth table'.

time	01	02	03	04
14.00	1	1	1	1
14.05	1	0	0	1
15.01	1	0	0	0
16.00	0	1	0	1

The states of each output are illustrated in the timing diagram.
To load the above program into the chip memory the following sequence of key strokes is used.

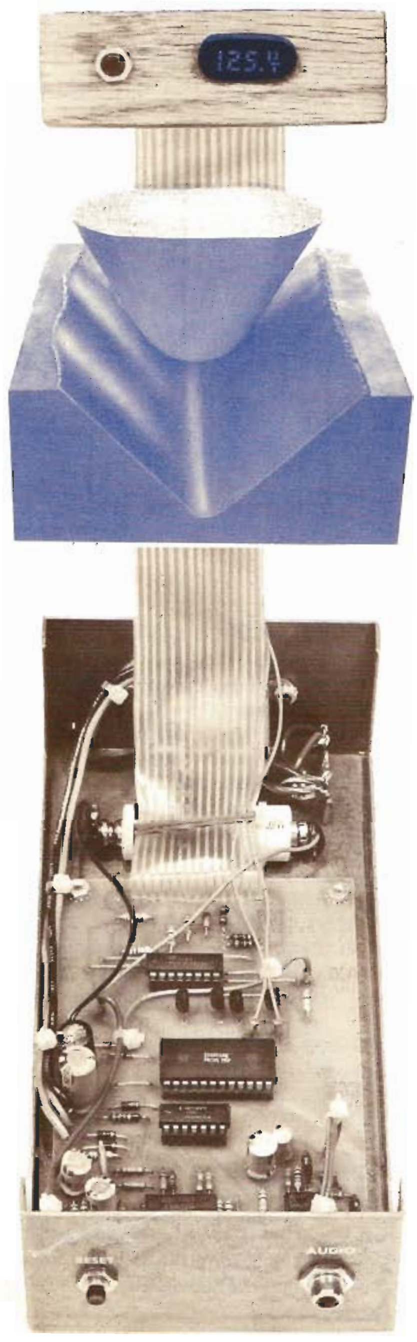


This timing diagram illustrates the changes in output states at the four set point times.

SWITCH DEPRESSED	DISPLAY	REMARKS
DATA ENTRY	0000	Initial display
SET HOURS	1400	Switch is depressed until first set point time is displayed.
SET STATUS	1.400	Set point 1 at 14.00 (2 p.m.), output 1 ON
HOLD STATUS	1.400	Hold output 1 ON
SET STATUS	1.4.00	Output 2 ON
HOLD STATUS	1.4.00	Hold output 2 ON
SET STATUS	1.4.0.0	Output 3 ON
HOLD STATUS	1.4.0.0	Hold output 3 ON
SET STATUS	1.4.0.0.	Output 4 ON
ADVANCE SET POINT	0000	All the above status information is stored in memory, and at 14.00 hours all four control outputs will be turned on.
SET HOURS	1400	Switch is depressed until second set point time (hours) is displayed.
SET MINUTES	1405	Switch is depressed until correct set point time (minutes) is displayed.
SET STATUS	1.405	Set point 2 at 14.05 hours (2.05 p.m.), output 1 ON
HOLD STATUS	1.405	Hold output 1 ON
HOLD STATUS	1.4.05	Output 2 ON
SET STATUS	1.40.5	Output 2 OFF, output 3 ON (second decimal point is extinguished, third decimal point turns on)
SET STATUS	1.405.	Output 3 OFF, output 4 ON
ADVANCE SET POINT	0000	The status information for the second set point is stored.
SET HOURS	1500	Switch is depressed until third set point time (hours) is displayed.
SET MINUTES	1501	Third set point time (minutes) is displayed
SET STATUS	1.501	Set point 3 at 15.01 hours (3.01 p.m.), output 1 ON. No other output is required so the next step is simply to store this status information.
ADVANCE SET POINT	0000	The status information for the third set point is stored.
SET HOURS	1600	Switch is depressed until fourth set point time is displayed.
SET STATUS	1.600	Set point 4 at 16.00 hours (4.00 p.m.), output 1 ON
SET STATUS	16.00	Output 1 OFF, output 2 ON
HOLD STATUS	16.00	Hold output 2 ON
SET STATUS	16.0.0	Output 3 ON
SET STATUS	16.00.	Output 3 OFF, output 4 ON. Output 2 and 4 are now programmed to turn on at the fourth set point. All that remains is to transfer this status information to memory.
DATA ENTRY	0000	Current status information stored in memory, return to real-time clock mode. It would also have been possible to press the ADVANCE SET POINT switch, in which case the first set point and status would have appeared (i.e. 1.4.0.0.)
DAY MODE	1 1	The timer is now programmed with valid day information. The first digit indicates the day, the second digit represents status information
SET DAY	2 1	Also valid day
SET DAY	3 1	Also valid day
SET DAY	4 1	Also valid day
SET DAY	5 1	Also valid day
SET DAY	6 1	A non-valid day, therefore . . .
SET STATUS	6 0	
SET DAY	7 1	This should also be a non-valid day, so . . .
SET STATUS	7 0	
SET DAY	1 1	Return to current day
DAY MODE	0000	Return to real-time clock mode.

The program can be checked by pressing the DEMO switch. As soon as this switch is depressed the clock will advance at a rate of 1 hour per second, lighting up the output LEDs in accordance with the program. Remember, however that because of the buffers the LEDs will indicate the inverse of the chip output states. Final' the clock can be set to the correct curr time using the SET HOURS switch.

HOW MANY HOURS ARE ON YOUR PHONO STYLUS?



BY DENNIS BOHN

ALMOST every hi-fi phono stylus is made from the hardest substance known to man—diamond. Even a diamond stylus, however, will become appreciably worn after a given number of hours of use. Keeping track of the number of playing hours a stylus has accumulated—and thus indirectly the degree to which it has become worn—is important for two reasons. Using a worn phono stylus dramatically reduces playback fidelity and can cause catastrophic, permanent physical damage to the grooves of a vinyl recording.

Presented here is a simple, inexpensive project that logs the number of hours a stylus has been used. This information is displayed at the push of a button on a four-digit, seven-segment LED readout to the nearest tenth of an hour. The [illegible] construction cost of this project—[illegible]0 or less—makes it an ideal solution to the problem of monitoring stylus use. With it, you will eliminate both the risk of using the same stylus too long and the needless expense of replacing it too soon.

About the Project. One principal design goal was to produce a circuit that would provide as accurate a count of actual stylus *playing time* as possible. This immediately ruled out the use of any scheme involving the sensing of the amount of time that the turntable was simply on. What was required was a method of determining the amount of time that the cartridge would actually be generating an audio output for subsequent processing by the phono preamp. This is the approach that was taken in the project described here.

The project is shown schematically in Fig. 1. Because there is no easy access to the output of the phono-preamp stage (apart from the fact that most equipment warrantees would be voided by any such tampering), the stylus timer begins with its own RIAA phono preamplifier. The audio output of one of the cartridge's channels is tapped at the stereo system's phono-preamp input by means of a Y connector/adapter and a short patch cord. Sensing the input signal of only one audio channel was deem ficient for the accuracy required. It is highly unlikely that long periods of time will exist in which there is a total absence of signal in one channel of a typical stereo disc.

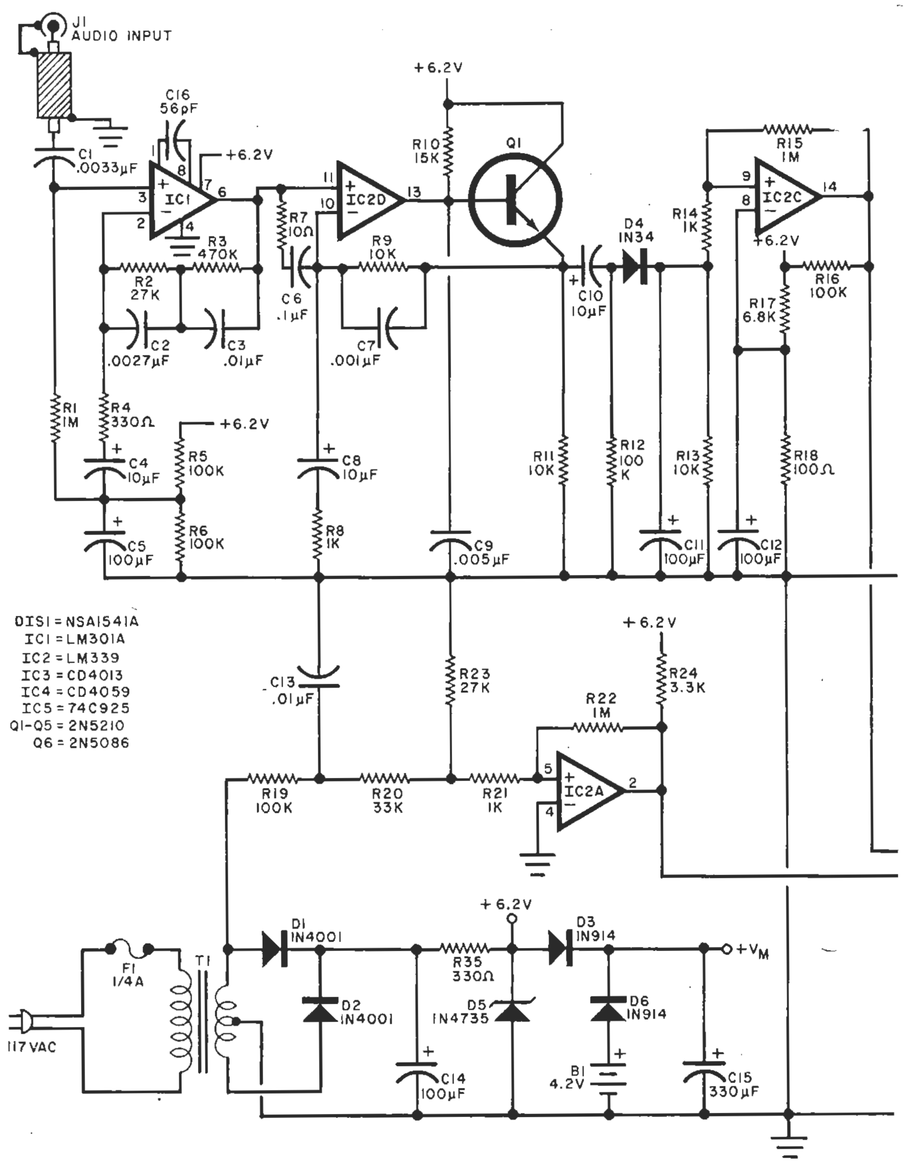
The output of the phono cartridge is applied to AUDIO INPUT jack *J1*. One megohm of resistance (*R1*) and 20 pF or less of parasitic shunt capacitance comprise the input impedance of the project. This means that there is no additional, significant loading of the cartridge. Therefore, the stylus timer's input network does not appreciably alter the loading and hence sonic performance of the phono cartridge.

Operational amplifier *IC1* boosts the level of the input signal and, with the help of *R2*, *R3*, *C2* and *C3*, provides RIAA playback equalization. Because the op amp is powered by a single-ended supply, dc level-shifting of the input signal (performed by *C5*, *R5* and *R6*) and capacitive input coupling (furnished by *C1*) are required. Output signals from *IC1* are directly coupled to the noninverting input of *IC2D*, which is one-fourth of an LM339 quad comparator. This stage is operated in linear fashion as an op amp with transistor *Q1* inside the overall feedback loop. Resistors *R10* and *R11* determine the bias of *Q1*. Resistor *R7* and capacitors *C6*, *C7* and *C9* furnish frequency compensation to ensure stability.

The 20 dB of gain provided by *IC2D* and the 40 dB of gain supplied by *IC1* (at 1 kHz) boost the input signal to the level required by the half-wave rectifying and averaging network *D4*, *C11*, and *R13*. The amplified input signal is converted into a positive dc voltage appearing across capacitor *C11*, which charges rapidly and discharges slowly through *R13*.

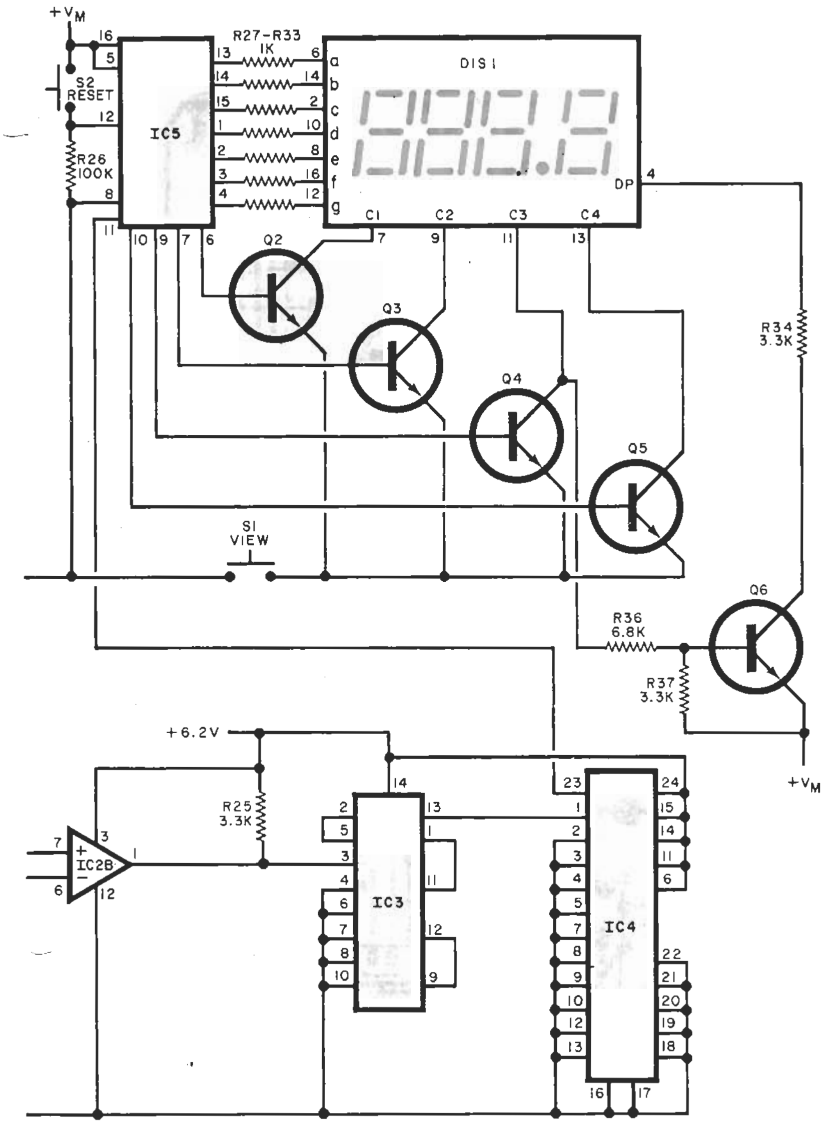
Comparator *IC2C* accepts the dc voltage appearing across *C11* and compares it with the reference of approximately 100 mV generated by *R17*, *R18* and *C12*. Resistors *R14* and *R15* provide hysteresis to stabilize the comparator. The output of this comparator is applied to the noninverting input of comparator *IC2B*, while the inverting input receives a shaped timebase signal derived from the ac power line. Transformer *T1* supplies a low-voltage 60-Hz sine wave to low-pass filter *R19C13*, whose output is attenuated by voltage divider *R20R23*. The attenuated sine wave, converted into a square wave with a dc offset by *IC2A*, is applied to the inverting input of comparator *IC2B*.

This comparator passes timebase pulses when audio from the cartridge drives the output of *IC2C* high. Timebase pulses then reach the CLOCK input of the first section of dual D flip-flop *IC3*. The mismatch between pull-up re-



PARTS LIST

B1—4.2-V mercury battery (Mallory TR-133 or equivalent)
C1—0.0033-µF Mylar capacitor
C2—0.0027-µF Mylar capacitor
C3—0.01-µF Mylar capacitor
C4, C8, C10—10-µF, 6.3-V tantalum capacitor
C5, C11, C12—100-µF, 10-V, radial-lead electrolytic
C6—0.1-µF disc ceramic capacitor
C7—0.001-µF Mylar capacitor
C9—0.005-µF disc ceramic capacitor
C13—0.01-µF disc ceramic capacitor
C14—100-µF, 35-V, radial-lead electrolytic
C15—330-µF, 6.3-V tantalum capacitor (see text)
C16—56-pF disc ceramic capacitor
D1, D2—1N4001 rectifier
D3, D6—1N914 signal diode
D4—1N34 germanium signal diode
D5—1N4735 6.2-V zener diode
DIS1—Four-digit, common-cathode LED display (NSA1541A or equivalent)
IC1—LM301A operational amplifier
IC2—LM339 quad comparator
IC3—CD4013 dual D flip-flop
IC4—CD4059 programmable divide-by-N counter
IC5—MM74C925 four-decade counter with multiplexed four-digit, seven-segment output drivers
J1—Insulated phono jack
Q1 through Q5—2N5210 or equivalent npn silicon transistor
Q6—2N5086 or equivalent pnp silicon transistor
The following, unless otherwise specified, are ¼-watt, 10% tolerance, fixed carbon-composition resistors.
R1, R15, R22—1 MΩ
R2, R23—27 kΩ
R3—470 kΩ
R4—330 Ω
R5, R6, R12, R16, R19, R26—100 kΩ
R7—10 Ω
R8, R14, R21, R27 through R33—1 kΩ
R9, R11, R13—10 kΩ
R10—15 kΩ
R17, R36—6.8 kΩ
R18—100 Ω
R20—33 kΩ
R24, R25, R34, R36, R37—3.3 kΩ
R35—330 Ω, ½ W



S1, S2—Normally open, momentary-contact pushbutton switch
T1—24-volt center-tapped, 40-mA step-down transformer
Misc.—Printed circuit board, IC sockets or Molex Soldercons, battery holder, fuse holder, suitable enclosure, Y phono-connector/adapter, shielded cable, phono plugs, hookup wire, line cord and strain relief, suitable hardware, solder, etc.

Note—The following is available from TOLECO Systems, Box 401, Kingston, WA 98346: kit of parts consisting of all required integrated circuits, common-cathode LED display, and etched, drilled and plated glass-epoxy printed-circuit board, No. ST-1, for $29.95, plus $2.00 postage and handling in U.S., $4.00, foreign. Also available separately is the etched, drilled and pla' glass-epoxy printed-circuit bc No. ST-2, for $8.95, postpaid in U.S. Washington state residents, add 5.3% sales tax. No COD or foreign-currency orders. The project as designed is suitable for use only in those areas whose power-line frequency is 60 Hz.

Fig. 1. The audio input is obtained from one channel of the cartridge output to the phone preamp. It is then amplified and rectified and compared to a reference to create timed pulses and drive the digital display.

sistors *R16* and *R24* holds the output of *IC2B* low in the absence of a signal from the cartridge.

The timebase signal from *IC2B* passes to dual D flip-flop *IC3*, which functions as a divide-by-4 counter. A 15-Hz pulse train appears at the Q output of the second flip-flop in *IC3* (pin 13) when *IC2B* allows the clock signal to pass. This pulse train is applied to the input of *IC4*, which is programmed to divide the input frequency by 5400. The resulting output pulse train has a period of 6 minutes or 0.1 hour and appears at pin 23 of *IC4* to clock four-decade counter *IC5*.

This chip contains not only counting stages but also seven-segment decoders and multiplexed display drivers. The outputs of *IC5* drive not only the seven segment lines of *DIS1* but transistors *Q2* through *Q6* as well. The latter drive the digit and decimal-point cathode lines of the display. Their emitters are connected together and to one side of pushbutton VIEW switch *S1*, the other side of which is grounded. No current flows through the LED display until the VIEW switch is closed. The elapsed stylus playing time is indicated in hundreds, tens, units, and tenths of an hour up to 999.9 hours. When 999.9 hours have been tallied, counter *IC5* resets to 000.0. The user can manually clear the counter by closing RESET pushbutton switch *S2*. Resistor *R26* is the pull-down component for switch *S2*.

A simple single-ended, full-wave supply satisfies the project's power requirements. There is no power on/off switch; line power should be applied continuously so that the information stored in *IC5* is not lost. One simple way to do this is to plug its line cord into the audio preamplifier's or receiver's unswitched power socket. Mercury battery *B1* and steering diodes *D3* and *D6* ensure that the count stored in *IC5* is not lost during power failures and during times when it is necessary to unplug the timer from the power line. Current drain of *IC5* is low, making battery life at least as long as that of the stylus. It is good practice to replace the battery each time the stylus is replaced. Capacitor *C15* is optional and supplies power when both ac and battery power are lost.

Construction. The high impedances and gains of the early stages of the signal-processing chain make the use of a carefully designed printed-circuit board almost a necessity. An etching and drilling guide and component layout are shown in Fig. 2. To keep construction cost low, a single-sided pc board using several jumper wires was used. As long as the jumpers are as short as possible and are installed neatly, they need [illegible] be insulated.

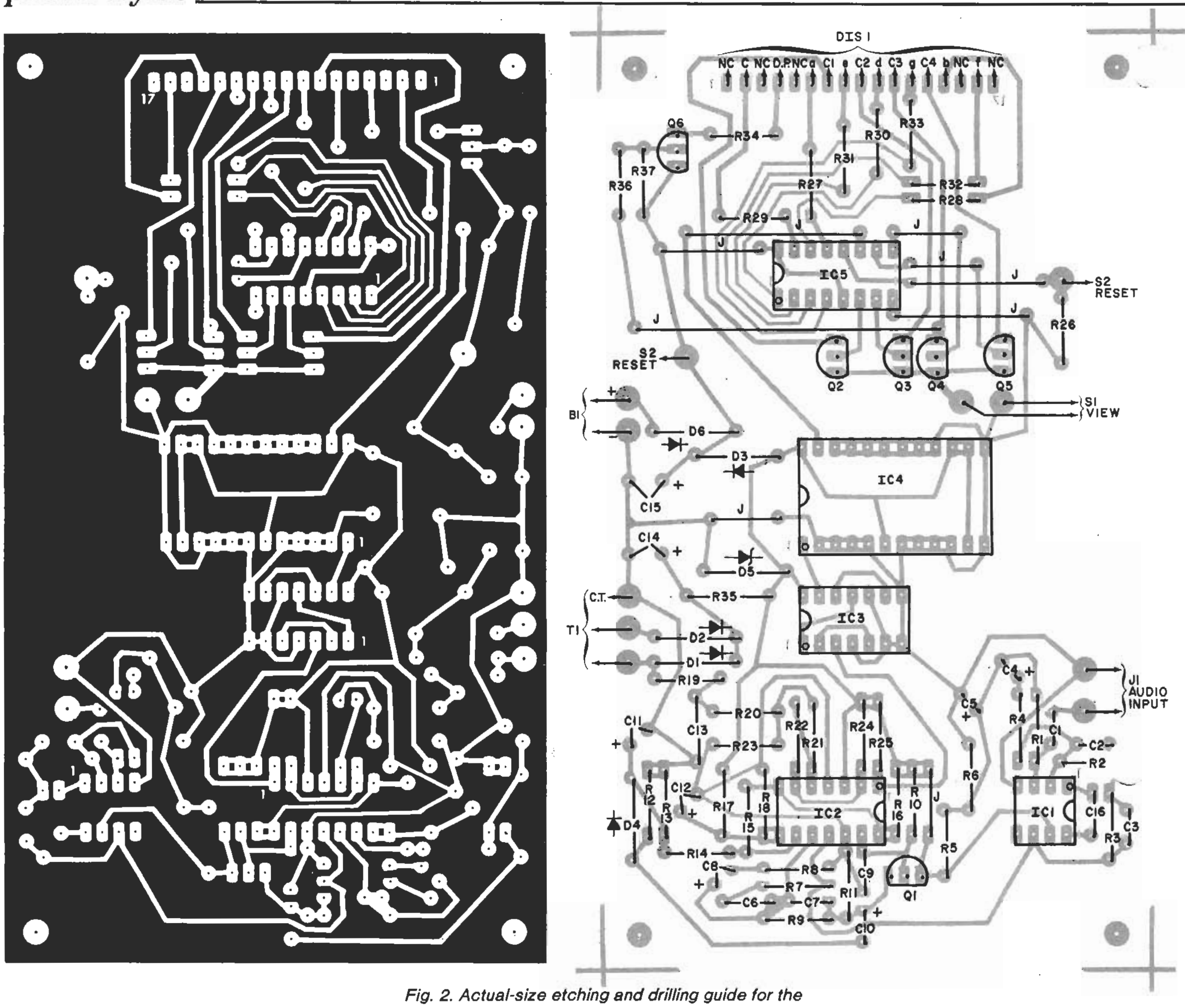


Fig. 2. Actual-size etching and drilling guide for the printed circuit board is above left, component layout at right.

After the jumpers are in place, install the resistors, and then the diodes—in the correct polarity. Molex Soldercons or IC sockets should be mounted on the board after the diodes, and then the capacitors should be installed. (The polarities of electrolytic capacitors must be observed.) Finally, the transistors should be installed. Using a small-tipped, low-wattage soldering iron and small-diameter (No. 22 AWG or similar), 60/40 rosin-core solder, make all necessary connections.

When all pc components have been mounted on the board, use suitable lengths of shielded cable and hook-up wire to connect the appropriate foil pads to those components that are not mounted on the board. Connect the shield of the cable running between input jack *J1* and the input foil pads at both ends. However, use an insulated phono jack to prevent a ground loop from arising. A suitable length of multiconductor ribbon cable can be used between the pc board and the display.

The author's prototype is housed in an aluminum utility box that encloses everything except the LED display and the VIEW switch. These were mounted on a small piece of oak and interconnected with the boxed section by a length of multiconductor ribbon cable. This arrangement permitted the placement of the utility box behind the audio preamplifier and the attachment of the oak display board to the rear of the turntable. The RESET switch was mounted *inside* the enclosure to prevent accidental switch closure and loss of count.

The display used by the author is a four-digit calculator-type readout selected for small size and low current demand. However, almost any type of LED display can be used, so long as it is of common-cathode design and is compatible with multiplexing. Discrete-digit LED readouts can be used in this application if all pins corresponding to the same display segment (a, b, c, etc.) are connected together to the appropriate outputs of *IC5*. Any available display color is acceptable. However, the use of a LED readout other than the one specified might require a change in value of current-limiting resistors *R27* through *R33*. Increasing the resistances will result in diminished display current and brightness. Decreasing them will cause more current to flow and more light to be radiated by the display segments. The output drivers of *IC5* can source a maximum of 30 mA, so the low [illegible]nit of resistance for *R27* through *R3*[illegible]approximately 100 ohms.

Transformer *T1* as specified is a 24-volt center-tapped component with a rated secondary current of 40 mA. The author's prototype has an actual current demand of approximately 32 mA in either the STANDBY (*S1* open) or VIEW closed) mode. In the latter, the flow of display current causes a decrease in current flow through zener diode *D5*. This is why the overall current demand remains constant whether the readout is glowing or not. If a display requiring more current is used, *T1* will have to be a component that can deliver more secondary current.

In any event, to minimize hum pickup and possible false time counts, the transformer should be positioned as far away from the input stage as possible. Its leads should be routed along the opposite side of the pc board from the input cable or, even better, at the opposite side of the board and at right angles to the input cable.

Installation and Use. For initial checkout, plug the line cord into an ac power socket and depress the VIEW pushbutton switch. The display should read 000.0. If it indicates some other number, momentarily close the RESET switch and verify that the display returns to 000.0 when the VIEW switch is closed again.

Next, position the project near your turntable and preamplifier in such a way that the LED display can easily be seen. Make sure that the audio system is turned off. Then disconnect one of the signal cables running from the turntable to the PHONO input jacks of the system's preamplifier. Either the right- or left-channel output of the turntable can be used. Connect a suitable Y adapter to the unoccupied preamplifier PHONO input jack and plug the floating output cable from the turntable into one of the adapter's two phono jacks. Finally, connect one end of a patch cord to the remaining Y-adapter phono jack, and the other end of the patch cord to the project's audio input jack (*J1*).

Turn the stereo system on and play a record for slightly more than six minutes, verifying that the display reads 000.1 hour when the VIEW switch is closed. If it does, return the tonearm to its rest position and unplug the project's line cord from the power socket. Wait a few minutes and reconnect the project to the ac power source. Depress the VIEW pushbutton switch once more. A readout of 000.1 hour on the LED display confirms that the battery-powered memory-backup circuit is working.

Finally, apply ac power to the stylus timer and to the audio system. Place the preamplifier's mode selector switch in its PHONO position, leaving the tonearm in its rest position. At the end of an hour, depress the VIEW pushbutton switch. If the display still reads an elapsed time of 000.1 hour, the project is not falsely counting the 60-Hz power-line frequency. If a false count is indicated, reroute any ac line cords passing near the project's audio input jack. Also, check the audio cable's shield and the connections between the shield and the phono jacks. Grounding the metal enclosure to the audio system ground at one point only will also help keep 60-Hz ac out of the high-gain stages of the timer. Repeat the test procedure to ensure that the false-count problem has been solved.

Knowing the playing time of the stylus to the nearest hour or even ten hours is sufficient for replacement purposes. Contact the manufacturer of your cartridge for his recommended stylus-replacement interval. If this information is not available, check spherical styli after about 200 hours, elliptical styli after 500 hours, and Shibata and similar types after 900 hours. Use a stylus-replacement microscope for making visual inspections. If in doubt about replacement, consult a dealer. ◇

CIRCLE NO. 56 ON FREE INFORMATION CARD

On/off timer maintains precision over wide range

by Alfred C. Pinchak, *Cleveland Metropolitan General Hospital, Department of Anesthesiology, Cleveland, Ohio*

This circuit improves in several ways upon available designs for timers whose on and off periods are selectable. Specifically, it provides more precise control of those periods, a wider range over which the time base can be set, and a more flexible range that the supply potentials may assume. The circuit, which is implemented mostly in complementary-MOS, draws a maximum of 20 milliamperes at 5 volts, including relay power.

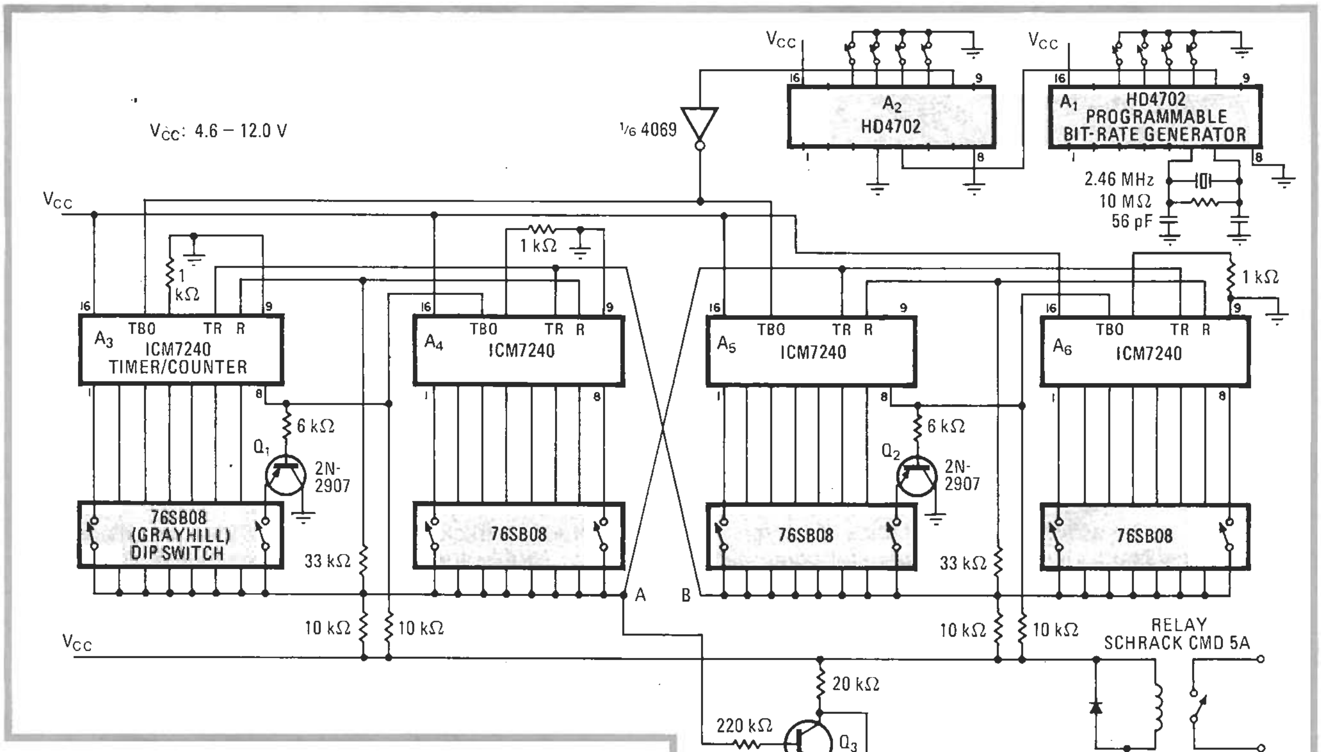
As shown, the HD4702 bit-rate generators, A_1 and A_2, provide a crystal-controlled clock signal for the ICM7240 timer-counter chips, A_3–A_6. Clock periods of from approximately 100 microseconds to 4 seconds are ordered by A_1 and A_2. The timer-counter outputs are wire-ORed together and are weighted in a binary fashion, with each position increasing in a 1, 2, 4, . . . 32,768 sequence. Thus by adjusting each dip switch appropriately, the on and off periods of the output signal can be independently set over the range $T_c < T_{on} < 65{,}536T_c$, where T_c is the clock period and $T_{on} = T_{off}$.

A_3 and A_4 form a one-shot that determines the off (low) period. Similarly, one-shot pair A_5–A_6 sets the on (high) period. Because the output of each one-shot (points A and B) are tied back to its own reset terminal and also to the trigger port of the other one-shot pair, the output at A is inverted with respect to B.

The 4702 time-base generators provide a direct clock signal for A_3 and A_5, with A_4 and A_6 driven by pins 8 of A_3 and A_5, respectively. A_3 and A_5, through transistors Q_1 and Q_2, also are part of the wired-OR network. Thus, all portions of each timer chip can be utilized to set the high and low periods. This feature is in contrast to previously published designs that cascade 2240 timers but restrict the T_{off} time to an integral multiple of $128T_c$.

Unfortunately, because of the wired-OR arrangement, the amplitude of the output signals at points A and B does not increase proportionally with supply voltage. In order to increase the effective range of the supply voltage, Q_3 is added to provide a level-shifting function. This extends the maximum supply voltage range from approximately 5.5 to 12 V.

The minimum supply voltage for an electronic output is approximately 3.8 V. However, the actual minimum voltage in cases where a relay is used will depend on the particular relay chosen. In this case, the minimum supply voltage was about 4.6 V. □



Improved. Timer, generating clock intervals ranging from 100 μs to 70 hours, allows for individual setting of on and off times in 100-μs-to-4-second steps over entire range. Level-shifting transistor, Q_3, ensures that output amplitude of wired-OR network is proportional to supply voltage. Device draws a maximum of 20 mA at 5 V.

BY DOUG FARRAR

CMOS logic allows more effective control of time and prevents track-change interruptions

8-Track Timer Simplifies Recording

THE 8-Track Timer (8TT) described here is the perfect companion to an 8-track tape deck. Its primary feature is a digital elapsed-time indicator that eliminates guesswork—and track changes in the middle of a song. In essence, the 8TT provides a visual indication of the amount of time used to record on one track and then tells you how much of that time you have used as you continue to record on each succeeding track. Thus, you'll always know exactly how much time remains before an end-of-track or end-of-tape occurs, and will be able to plan your recording sessions accordingly.

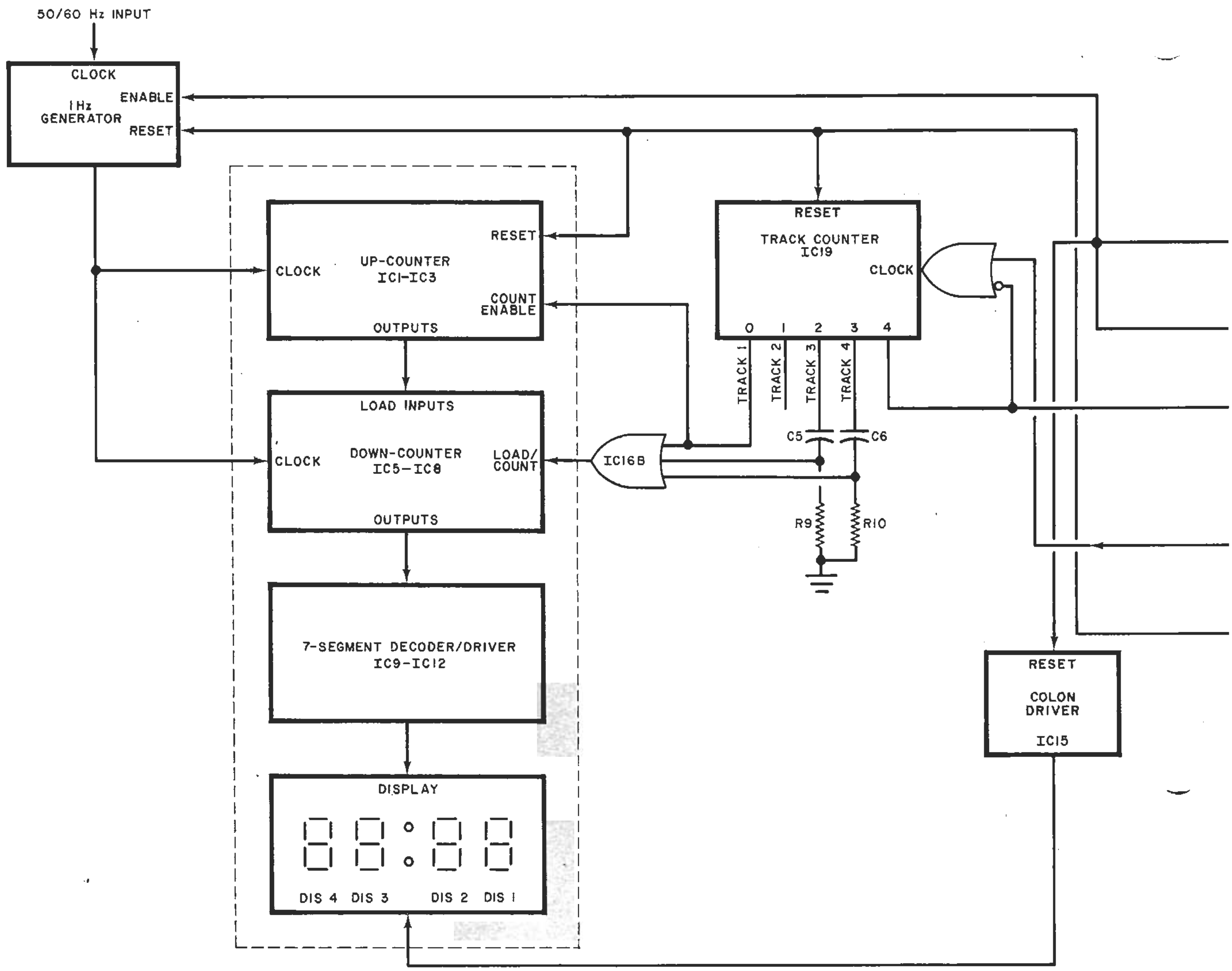
The project also offers the following:

- a PAUSE control;
- automatic shutoff after four "tracks" (that is, track pairs) have played;
- a CLEAR TAPE function that shuts the deck off after any change-of-track.

The last-mentioned function prepares the cartridge inserted in the deck for a recording session. If you don't want the 8TT to control the tape deck, simply remove line power from the project. Normal operation can then be resumed.

About the Circuit. The block diagram of the 8TT is shown in Fig. 1 and its schematic diagram in Fig. 2. A glance at the block diagram reveals five major functional sections: a 1-Hz pulse-train generator; an elapsed-time counter and display; a track counter; a motor flip-flop and controller; and a "logic" circuit.

The 1-Hz generator accepts a low-level signal derived from the ac power line and divides its frequency by either 50 or 60. The position of a jumper on the project's main printed circuit board determines which divisor is selected. This choice is of course governed by the line frequency of the commercial power source (50 or 60 Hz). The resulting train of 1-Hz pulses is employed as a time-



base for the elapsed-time counter.

CMOS up- and down-counter IC's perform the actual timing of the 8-track cartridge. The up-counter is enabled during the interval that track 1 is being used. It serves double-duty by counting the tape cartridge's start-of-track to end-of-track playing (or recording) time and by acting as a latch, storing this information for the rest of the recording session.

The outputs of the up-counter are connected to the parallel-load inputs of the down-counter. When the down-counter is placed in its asynchronous, parallel-load mode, its outputs follow the information presented to its parallel inputs. Removing the parallel-load command causes the counter to commence counting down from the last binary number to which the outputs followed the parallel inputs. The down-counter can thus be ordered to either pass the binary number generated by the up-counter directly to the display decoder/driver or

PARTS LIST

C1 through C12—0.1-µF disc ceramic
C13—500-µF, 25-volt electrolytic
D1 through D5—1N4001
F1—1-ampere fast-blow fuse
DIS1 through DIS4—FND70 or similar common-cathode LED display
IC1,IC3,IC14—4518 dual decade counter
IC2—4019 quad 2-input multiplexer
IC4,IC13,IC18—4001 quad 2-input NOR gate
IC5 through IC8—4510 decade counter
IC9 through IC12—4511 BCD-to-seven-segment decoder/driver
IC15—555 timer
IC16—4072 dual 4-input OR gate
IC17—4002 dual 4-input NOR gate
IC19—4017 decade counter/divider with 10 decoded outputs
IC20—7805 5-volt regulator
K1—12-volt relay with 250-ohm coil and 3-ampere spdt contacts
LED1,LED2—Light emitting diode
OC1—MCT-2 optoelectronic coupler
Q1—MPSA13 npn Darlington
The following are ¼-watt, 5% tolerance carbon-composition fixed resistors.
R1,R2,R3—1000 ohms
R4 through R7, R9 through R12, R48—10,000 ohms
R8,R13,R14,R15—100,000 ohms
R16—1 megohm
R17—330,000 ohms
R18—3.3 megohms
R19 through R46—220 ohms
R47-150 ohms
S1—1-pole, 5-position nonshorting rotary switch
S2—Spst toggle switch
T1—12.6-volt, 1-ampere transformer.
Misc.—Suitable enclosure, display bezel, 4-conductor chassis-mount female connectors, 4-conductor male connectors, printed circuit board, standoffs, line cord, etc.

Note—An etched, drilled and silk-screened printed circuit board is available for $15 postpaid (in U.S.) from Noveltronics, Box 4044, Mountain View, CA 94022. California residents add sales tax. Foreign orders: write for prices. Allow 2 weeks for checks to clear.

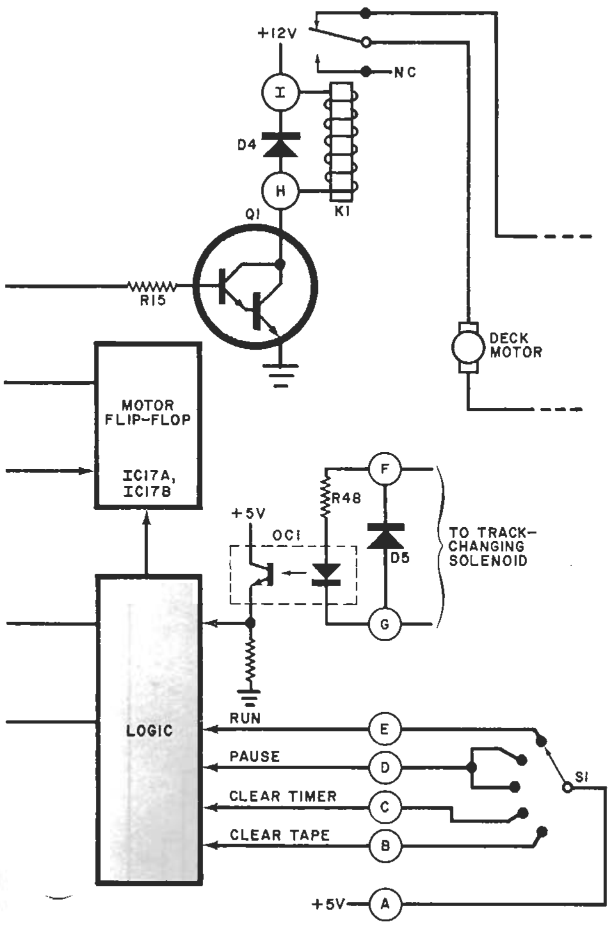


Fig. 1. Five major functional sections of the 8TT are shown in block diagram. The motor flip-flop is actually two cross-coupled NOR gates.

briefly sample the up-converter's output lines and then count down.

The first operation is performed during the time track 1 is being used and the second during the intervals associated with tracks 2, 3, and 4. The binary information present at the output of the down-counter is applied to a BCD-to-seven-segment decoder/driver network for the common-cathode LED displays.

The display's colon driver is a 555 astable multivibrator (*IC15*) that oscillates at a 2-Hz rate. The astable can be gated off by grounding its RESET input (pin 4). This happens whenever the deck is running normally and causes the display's colon to glow steadily. When the motor is shut off, the 555 indicates that fact by pulsing the display colon.

Every 8-track cartridge contains a short section of metallic tape. This tape trips a solenoid to move the deck's tape head through its four track positions. The voltage pulse generated when the solenoid is activated is sensed via optoisolator *OC1* and applied to the track counter's CLOCK input. In this way, the deck's mechanical track position is sensed by the 8TT.

Track counter *IC19* controls the operation of the up- and down-counters. During the track 1 interval, *IC19* enables the up-counter and places the down-counter in its parallel-load mode by way of OR gate *IC16B*. At the end of track 1, the track counter prevents the up-counter from incrementing further and enables the down-counter. At the start of tracks 3 and 4, a pulse generated by either *R9C5* or *R10C6*, respectively, is applied to the down-counter by way of *IC16B*. This loads the up-counter's latched value into the down-counter which then decrements toward zero.

Because each track should take an equal amount of playing time, the display will read 0:00 (or close to it) at the ends of tracks 2, 3, and 4. At the end of track 4, the track counter inhibits further timing and sets the motor flip-flop, stopping the deck motor.

The motor flip-flop is controlled by the logic section. Setting the flip-flop disables the 1-Hz generator, allows the display colon driver to oscillate, and energizes relay *K1*, which is mounted inside the tape deck. The relay's normally closed contacts are wired in series with one of the deck motor's power leads, so that setting the flip-flop removes power from the deck's motor.

The position of rotary switch *S1* determines the 8TT's operating mode. Setting it to its CLEAR TIMER position resets the up-counter and the track counter, and sets the motor flip-flop. This readies the 8TT for the start of a recording session. Placing *S1* in the PAUSE position sets the motor flip-flop, but switching it to the RUN position resets the motor flip-flop. With the switch in the RUN position, recording proceeds as previously described. Placing *S1* in its CLEAR TAPE position initially resets the motor flip-flop and allows the tape to run. At the first change of tracks, the 8TT sets the flip-flop. This stops the deck, leaving the cartridge "cleared" for recording.

Readily available CMOS IC's comprise almost all of the 8TT circuit. A regulated 5-volt and unregulated 12-volt supply is used as the power source. The 12-volt ac waveform developed across the transformer secondary is conditioned to a level compatible with the CMOS logic circuit before being applied to the input of the 1-Hz generator.

Construction. Almost all of the 8TT circuit fits on a single pc board whose etching and drilling and parts placement guides are shown in Figs. 3 and 4. An unusual feature of the board is the "wireless" connection between the logic and display sections. After the board has been fabricated as a single unit, it is cut along the indicated line. The two sections are then soldered together along the cut line to form a right angle. The resulting structure is rigid. The logic board is mounted parallel to the bottom of the project enclosure using spacers as shown in Fig. 5. This automatically positions the display board vertically.

Before soldering the two boards together at a right angle, mount and solder all components and jumpers on each board. Note that *C13*, the elec-

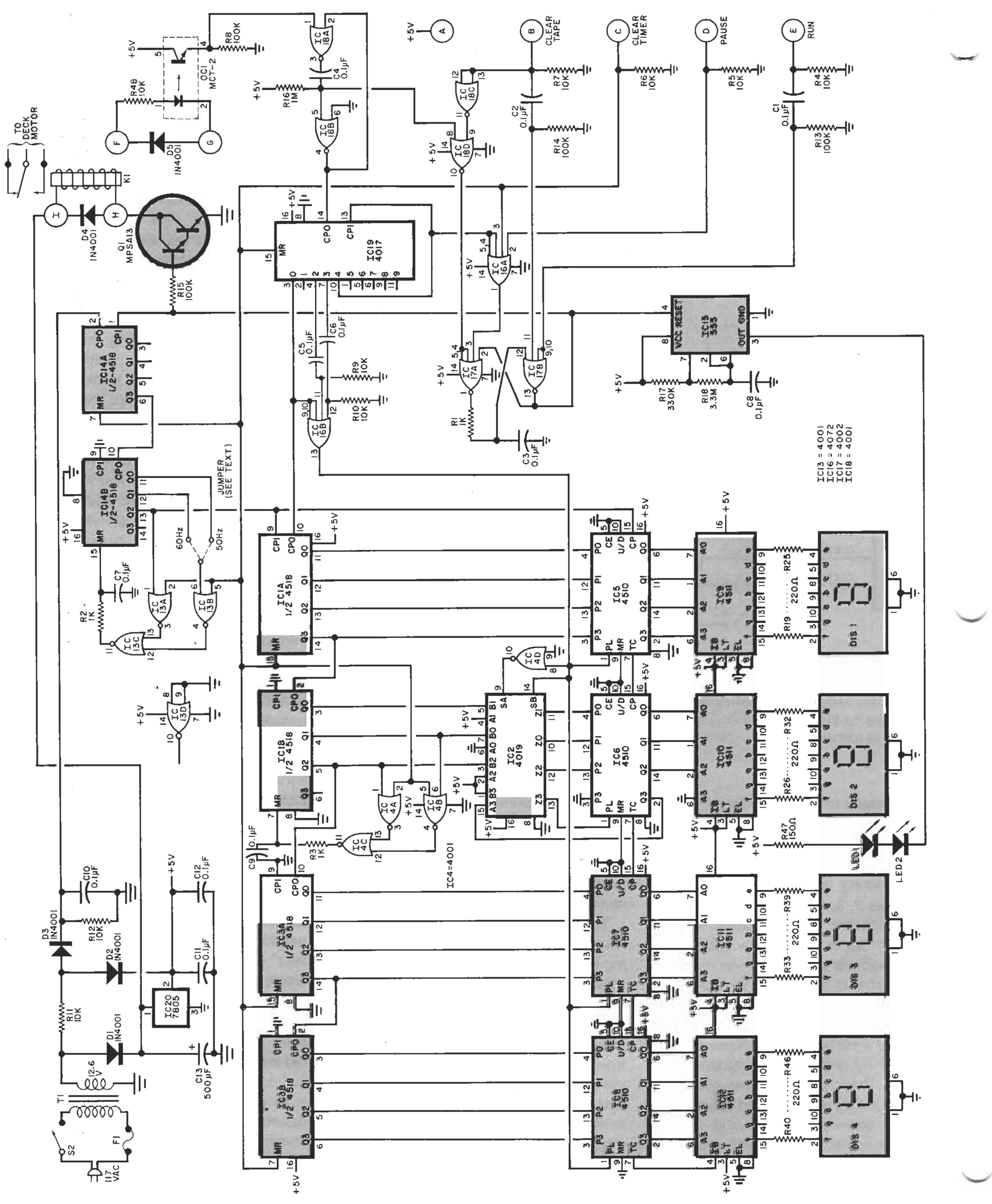


Fig. 2. Schematic diagram of 8TT. CMOS logic is used throughout.

'rolytic filter capacitor in the power supply, is located on the display board, but is mounted on the foil side. This allows the vertical display board to fit flush with the front panel of the project enclosure. If the line frequency of the available power source is 60 Hz, use a jumper to connect pin 12 of *IC14B* to pin 6 of *IC13B*. If a 50-Hz ac source is used, the jumper should interconnect pin 11 of *IC14B* and pin 6 of *IC13B*.

Mount the logic board on spacers at least 2" high so that power transformer *T1* can be mounted directly beneath it. The regulator IC (*IC20*) should be mounted directly to the project enclosure to provide heat sinking. Be sure to add a thin layer of silicone heat-sink compound to improve thermal transfer between the IC package and project enclosure. A 1" × 2½" (2.5- × 6.4-cm) rectangular hole should be cut into the project enclosure's front panel for the digital display. To increase the legibility of the display, affix a red filter to the back side of the front panel using epoxy or similar adhesive.

The tape deck to be controlled must be slightly altered (see Fig. 6). Mount relay *K1* inside the deck enclosure at a convenient location. Cut one of the power leads running to the motor. Connect one end of the severed lead to the normally closed contacts of the relay and connect the other end to the relay's pole. The coil leads will be connected to a jack to be described shortly.

Now locate the track-changing solenoid. When a track change occurs, dc voltage will be momentarily applied across the solenoid. The polarity of this applied voltage must be determined. This is most easily accomplished by means of an oscilloscope or voltmeter. With the meter or scope probes connected across the solenoid, depress the deck's program or track change pushbutton and note the meter's (or scope trace's) deflection. Compare this with the polarity of the probes and determine which side of the solenoid becomes positive with respect to the other. Mark this lead with a small flag of vinyl tape.

Make a hole on the tape deck's rear apron large enough to accommodate a chassis-mount, 4-conductor female connector. Install this connector and solder the leads from the track-changing solenoid and relay coil to the connector lugs. An identical connector should be in-

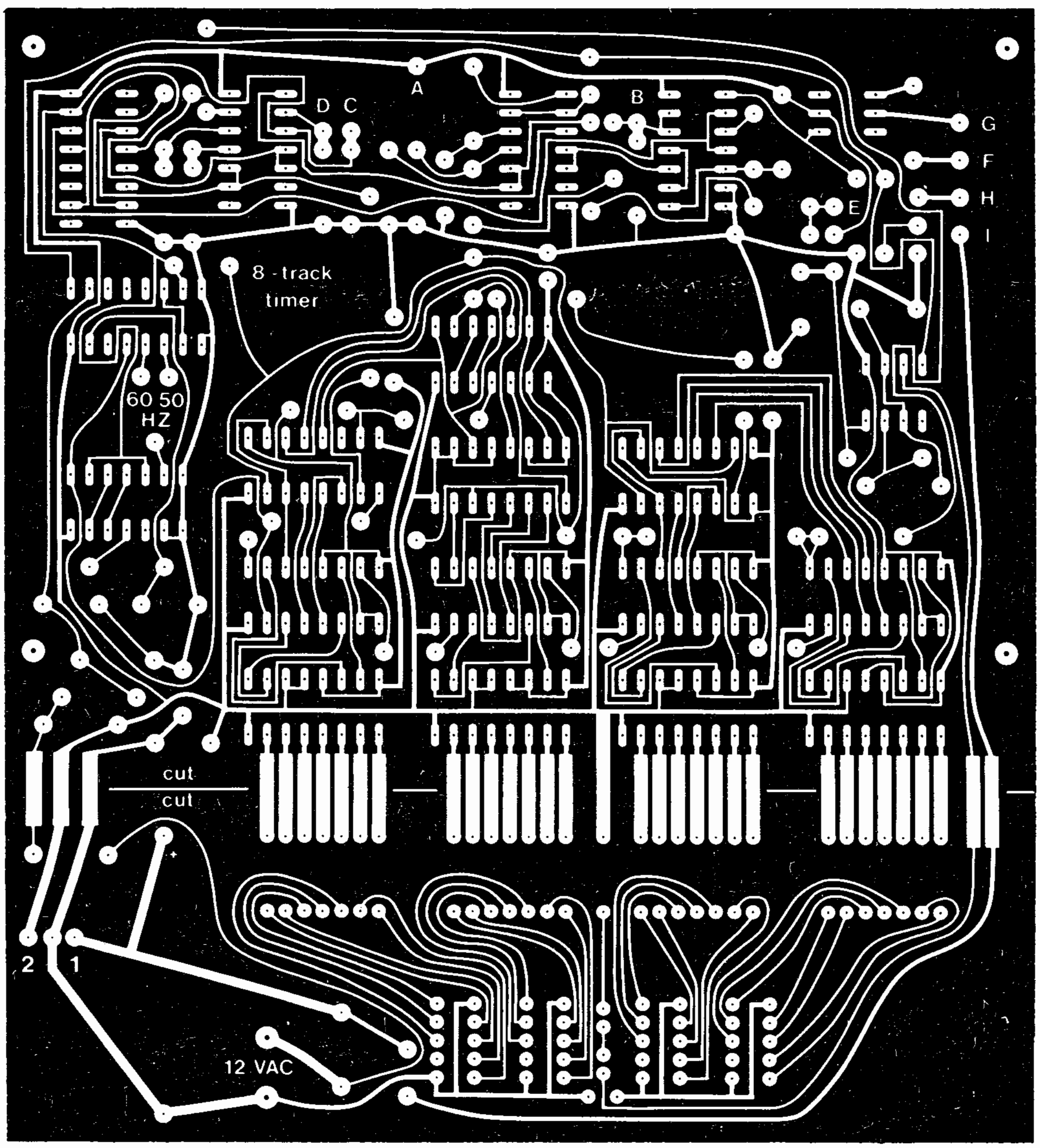


Fig. 3. Actual-size foil pattern for the 8TT's single pc board.

stalled on the rear apron of the 8TT enclosure and appropriate leads from the pc board soldered to it. Be sure that the connections to this second jack match those made to the first. The circled-letter markers on the schematic correspond to the designated foil pads on the project's printed circuit board.

For convenience, protective diodes *D4* and *D5* can be soldered to the lugs of one of the female connectors—either the one mounted on the rear apron of the project enclosure or that installed on the rear apron of the 8-track tape deck. Prepare a 4-conductor cable of a length sufficient to interconnect the project and tape deck. Solder the cable conductors to the lugs of male connectors compatible with the rear-apron female connectors. Take care to solder each conductor to the identically corresponding lug on each connector.

Flexible hook-up wire should be used to interconnect the main circuit board and rotary switch *S1*, the rear-apron connector, and the off-board power supply components. Rotary switch *S1* should be wired so that there are two adjacent PAUSE positions between the RUN and CLEAR TIMER positions. This minimizes the possibility of inadvertently entering the CLEAR TIMER mode (which would erase the information stored in the 8TT latch) when a switch to the RUN position was actually intended.

Testing and Use. Interconnect the 8TT and tape deck with the 4-conductor cable that you have prepared. Insert a tape cartridge into the deck and apply power to both the 8TT and the deck. Then place rotary switch *S1* in its CLEAR TIMER position. If all is well, the deck motor will stop turning, the display will read 0:00 and the display colon will blink on and off at a 2-Hz rate. Switching to the PAUSE position will cause no change. Placing the 8TT in its RUN mode, however, will cause the deck motor to start running and the display to function as an elapsed-time indicator. The display colon will glow steadily.

After approximately one minute of running time, make a mental note of the interval indicated by the display and depress the tape deck's track change pushbutton switch. The elapsed time indicated by the display will begin to decrement toward 0:00. Depressing the track-change pushbutton twice more will initiate the same count-down sequence, starting each time at the first track's running interval.

If you find that track counter *IC19* has trouble following the track state, decrease the value of *R48*. This will allow more current to flow through the LED in optoelectronic coupler *OC1* and provide stronger pulsing of the internal phototransistor. If the problem persists, doublecheck the wiring associated with the optocoupler and the solenoid to ensure that the voltage applied across the LED is of the correct polarity.

Depress the track-change pushbutton switch one more time. The 8TT will interpret this to mean that the tape has ended and will turn off the deck motor, cease timing, and cause the display colon to blink on and off. Any further depression of the track-change pushbutton will be ignored by the 8TT.

Once these operations have been verified, place rotary switch *S1* in its CLEAR TAPE position. The deck motor will then begin to run but will be shut off at the first change of tracks. Place *S1* in its CLEAR TIMER position and then in its PAUSE position. Prepare the cartridge for recording as required by your deck and you're ready to go.

Employ the 8TT's PAUSE mode when you want to stop recording momentarily. By keeping an eye on the 8TT's display, you will be able to interleave the program material neatly between the track-change interruptions.

If you want to use your tape deck without the assistance of the 8TT, simply remove power from the project by opening toggle switch *S2*. Although the deck has been modified in that the 4-conductor female connector and relay *K1* have been installed inside it, the deck is unaltered electrically. This means that the deck will function normally with the 4-conductor umbilical cable disconnected. Practically speaking, you can even leave the

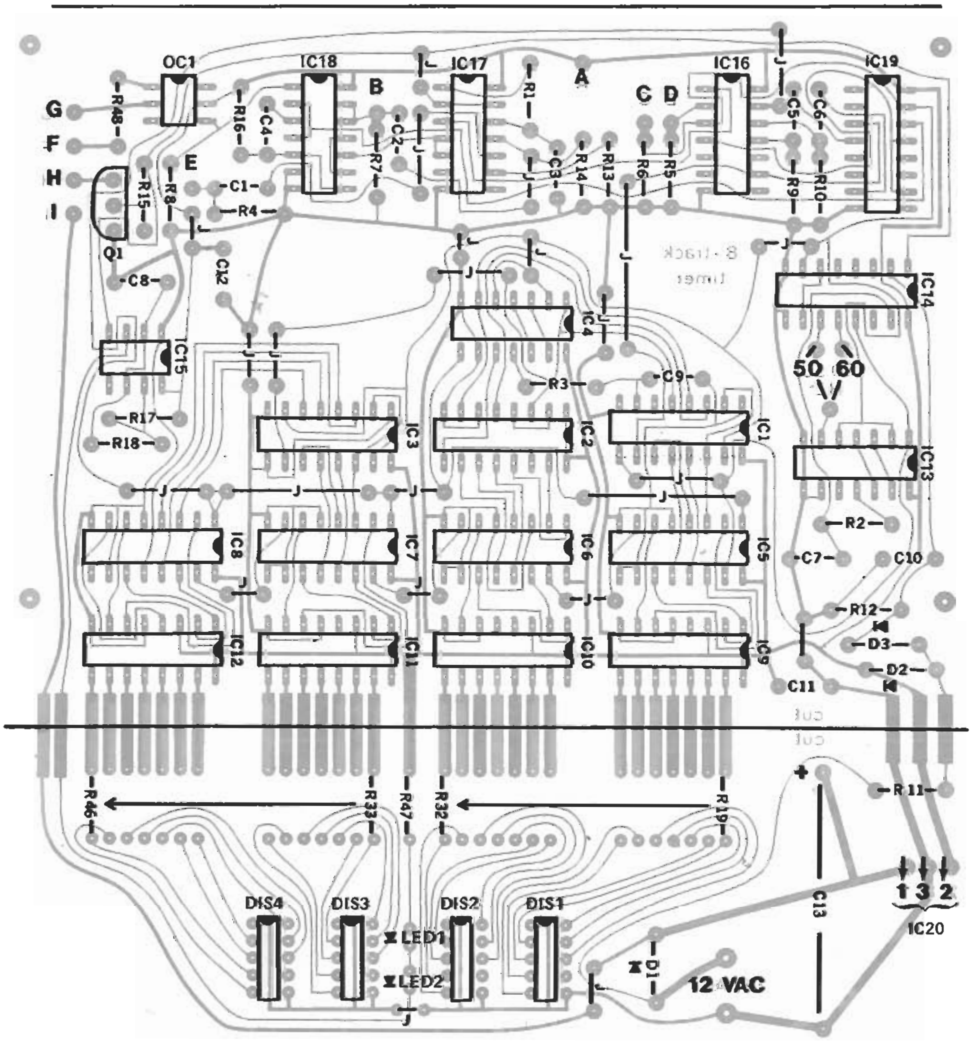


Fig. 4. Component placement guide for the 8-Track Timer.

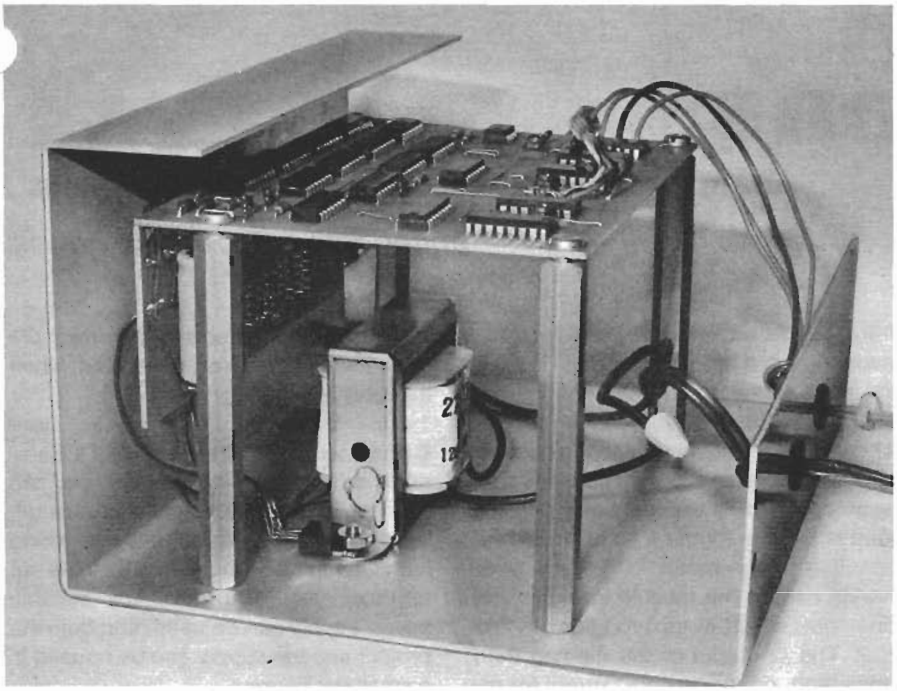
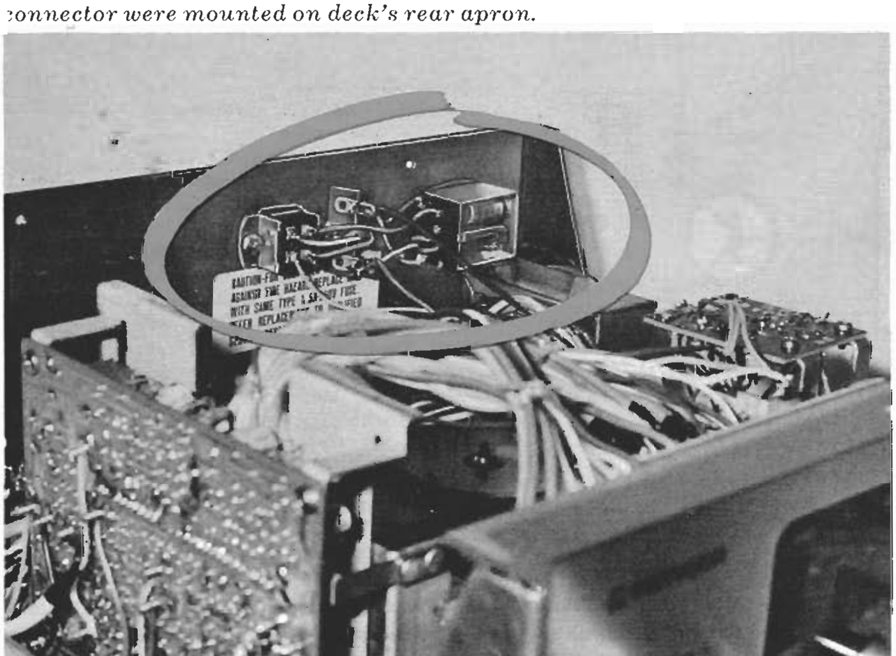


Fig. 5. Interior view of author's prototype reveals printed circuit board mounting details.

Fig. 6. View of tape deck shows how relay and connector were mounted on deck's rear apron.

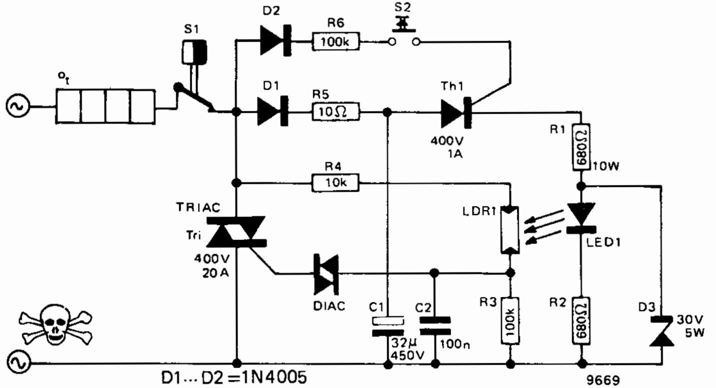


cable connected to both units. As long as the 8TT's power switch is in its OFF position, the deck will behave as if the 8TT were not connected to it. Also, because the interface between the deck and timer consists of a relay and opto-electronic coupler, there is no possibility that hum will be introduced into the deck by the 8TT.

One word of warning: fluctuations in tape speed, caused either by worn components in the deck's transport or by a binding tape cartridge will make the indications given by the 8TT misleading (if not useless). For best results, make sure your tape deck is in good working order and that the cartridges you use are in good condition. ◇

38

one-shot for immersion heater



Immersion heaters, which are used to heat water during the summer months when the central heating system is shut down, consume considerable amounts of power if left on continuously, even when the hot water tank is well-lagged. It is quite easy to switch on the immersion heater and forget about it, particularly if the switch is in some out-of-the-way place such as the airing cupboard. The circuit described here provides one-shot operation of the immersion heater, so that water can be heated as required. When the one-shot function is initiated the immersion heater will heat the water to the temperature determined by the tank thermostat and will then shut down. The heater will not operate again, even when the thermostat closes, until the one-shot button is again pressed.

Operation of the circuit is very simple. When the circuit is off C1 is charged via the immersion heater element, the thermostat and D1 to 320 V. When S2 is pressed the thyristor Th1 is triggered, and current flows through LED1. The initial surge current flowing through the LED is limited by R1 and D3. The LED is optically coupled to LDR1, so the resistance of the LDR falls and the Triac Tri is triggered every half cycle. The immersion heater current flows through Tri. Since the triac triggers at a point on the AC waveform corresponding to the diac breakdown voltage, this is the maximum voltage that appears across the triac before it triggers, so the voltage on C1 falls to about 20-30V. This gives a steady state current through the LED of about 20 mA.

When the thermostat opens no further current can flow into C1, so it discharges rapidly, Th1 turns off and the LED is extinguished. The resistance of LDR1 becomes very high, so the triac can no longer trigger, even when the thermostat closes again. The circuit will not operate again until Th1 is triggered by closing S2.

Note. Suitable LDRs that will withstand 240 V AC are made by Heimann and are available in U.K. from Guest Distribution.

add-on timer for snooze-alarm-radio-clock

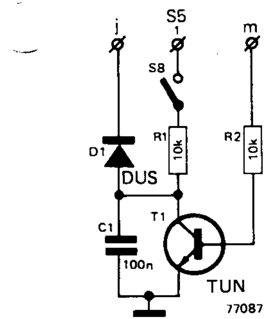
P.C.M. Verhoosel

This circuit will enable the digital clock published in Elektor No. 20 to be used as an interval timer that will switch on an appliance at a particular time and switch it off after a preset interval.

The circuit requires only three connections to the existing clock circuit, to points j, m and position 1 of S5, as shown. In addition, S6 must be replaced by a single-pole change-over switch with centre off position, for reasons which will become apparent.

The circuit functions as follows: when the clock is to be used as an interval timer S6 is set in the centre off position (this prevents the alarm output from activating the buzzer or the relay) and S7 is open. To set the interval timer, the start time is set (with S8 open) by turning S5 to position 3 and using S1 and S2 to set the desired alarm (start) time. S5 is then returned to position 1, S8 is closed and S1 and S2 are used to set the 'radio delay' time (max. 59 minutes), which is used as the interval time.

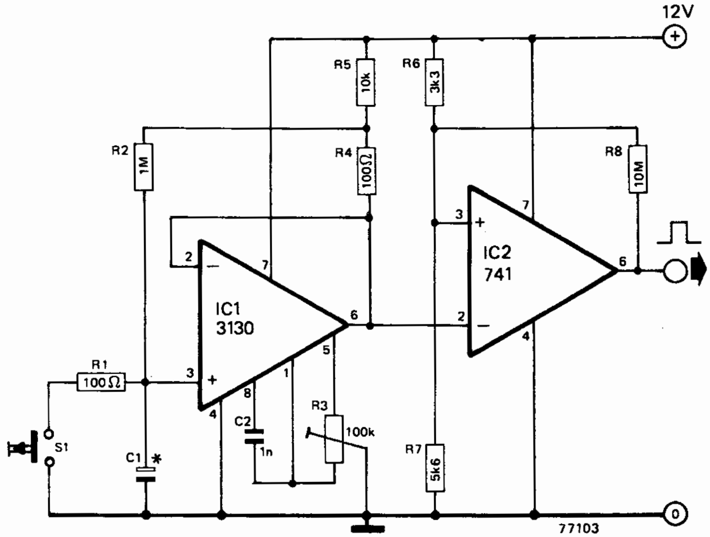
Until the desired start time is reached, 'alarm output' m will be low, T1 will be turned off and input j will be held high via D1 and R1, so the clock will display the selected interval time. When the start time is reached the alarm output will go high, turning on T1. The radio relay output will go high, energising the relay, and the 'radio delay' timer will start to run. At the end of the selected interval the 'radio delay' output will go low and the relay will drop out.



During the timing interval the clock will revert to normal time display, but the state of the interval timer can be examined by briefly setting S5 to position 4. The one disadvantage of this system is that it is not possible to read the actual time from the clock during the time the relay is not actuated, as opening S8 to revert to normal time display will also cause the relay to pull in. However, assuming that the interval timer is to be used while one is out of the house, this is not a great disadvantage.

To avoid cutting an extra hole in the clock case for S8 an alternative would be to replace S5 with a six-way switch. The sixth position of this would be connected to the top end of R1 in place of S8 and could then be labelled 'interval timer'.

long interval timer



*see text

The drawback of most analogue timers (monostable circuits) is that, in order to obtain reasonably long intervals, the RC time constant must be correspondingly large. This invariably means resistor values in excess of 1 MΩ, which can give timing errors due to stray leakage resistance in the circuit, or large electrolytic capacitors, which again can introduce timing errors due to their leakage resistance.

The circuit given here achieves timing intervals up to 100 times longer than those obtainable with standard circuits. It does this by reducing the charging current of the capacitor by a factor of 100, thus increasing the charging time, without the need for high value charging resistors.

The circuit operates as follows: when the start/reset button is pressed C1 is discharged and the output of IC1, which is connected as a voltage follower, is at zero volts. The inverting input of comparator IC2 is at a lower potential than the non-inverting input, so the output of IC2 goes high.

The voltage across R4 is approximately 120 mV, so C1 charges through R2 at a current of around 120 nA, which is 100 times lower than could be achieved if R2 were connected direct to positive supply.

Of course, if C1 were charged from a constant 120 mV it would quickly reach this voltage and would cease to charge. However, the bottom end of R4 is returned to the output of IC1, and as the voltage across C1 rises so does the output voltage and hence the charging voltage applied to R2.

When the output voltage has risen to about 7.5 volts it will exceed the voltage set on the non-inverting input of IC2 by R6 and R7, and the output of IC2 will go low. A small amount of positive feedback provided by R8 prevents any noise present on the output of IC1 from being amplified by IC2 as it passes through the trigger point, as this could otherwise give rise to spurious output pulses.

The timing interval is given by the equation:

$$T = R_2 C_1 \left(1 + \frac{R_5}{R_4} + \frac{R_5}{R_2}\right) \ln\left(1 + \frac{R_7}{R_6}\right)$$

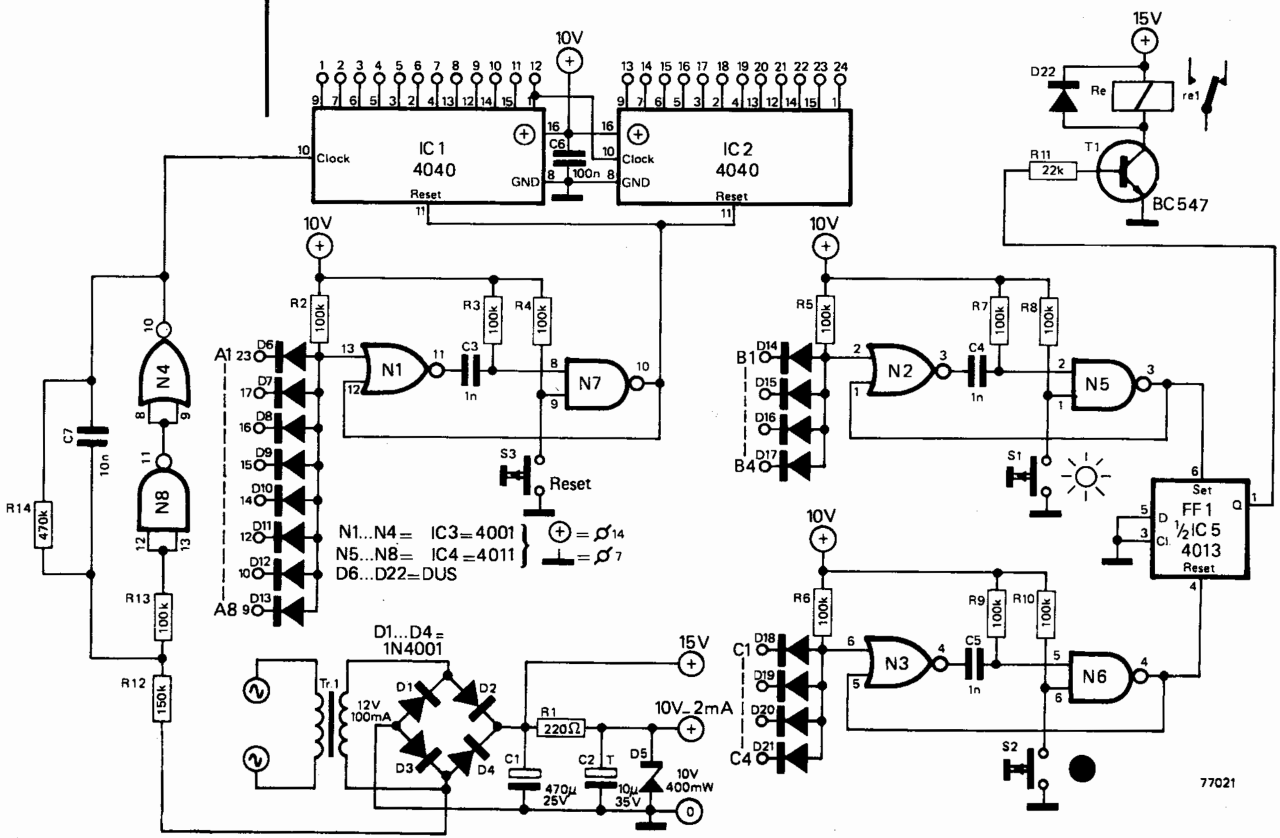
This may seem a little complicated, but with the component values given the interval is 100 · C1, where C1 is in *microfarads*, e.g. if C1 is 1 μ the interval is 100 seconds. It is evident from the equation that the timing interval can be varied linearly by replacing R2 with a 1 M potentiometer, or logarithmically by replacing R6 and R7 with, say, a 10 k potentiometer.

6

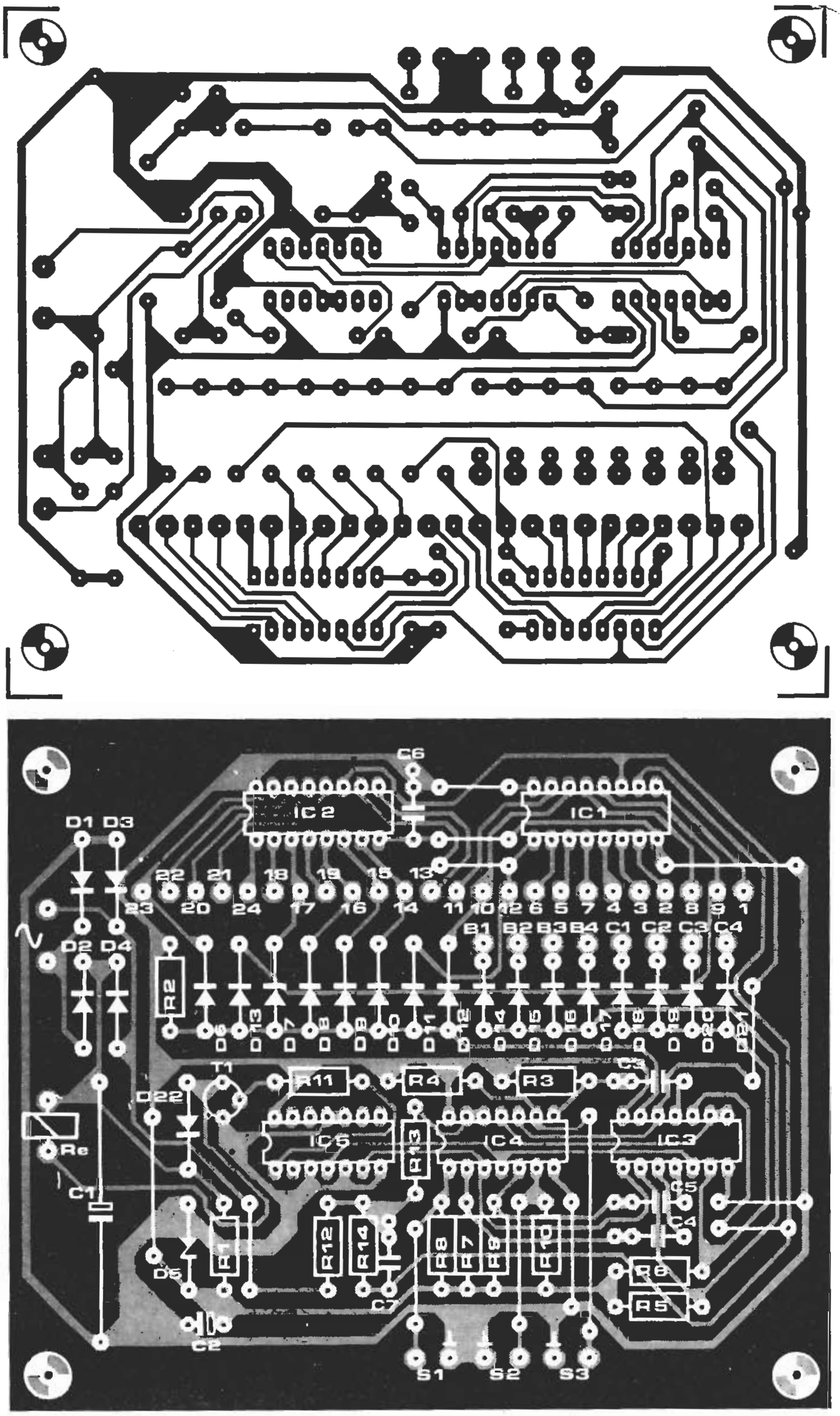
multi-purpose time switch

Using two CMOS counters it is a simple matter to construct a versatile time switch. The total cycle time of the switch can be set between zero and 93.2 hours, and the time switch can be made to switch equipment on and off at any time during this cycle.

The reference frequency for the timer is the 50 Hz mains frequency. Two 4040 counters are connected in cascade and count the 50 Hz pulses. Each of these ICs is a 12-bit counter, so the maximum time that the counters will count to is 0.02×2^{24} seconds, where 0.02 seconds is the period of the mains waveform. This is equal to 93.206 hours. If a shorter cycle time is required it is necessary that the counters be reset when the required count is reached. As an example suppose that the desired cycle time is 24 hours. The counter must therefore count up to $24 \times 60 \times 60 \times 50 = 4320000$, which in binary is 10000011110101100000000. Where a 1 occurs in this number the corresponding counter output is connected to one of the inputs of the diode AND gate D6 to D13. When the desired count is reached these outputs will all be high simultaneously and monostable N1/N7 will be triggered, giving

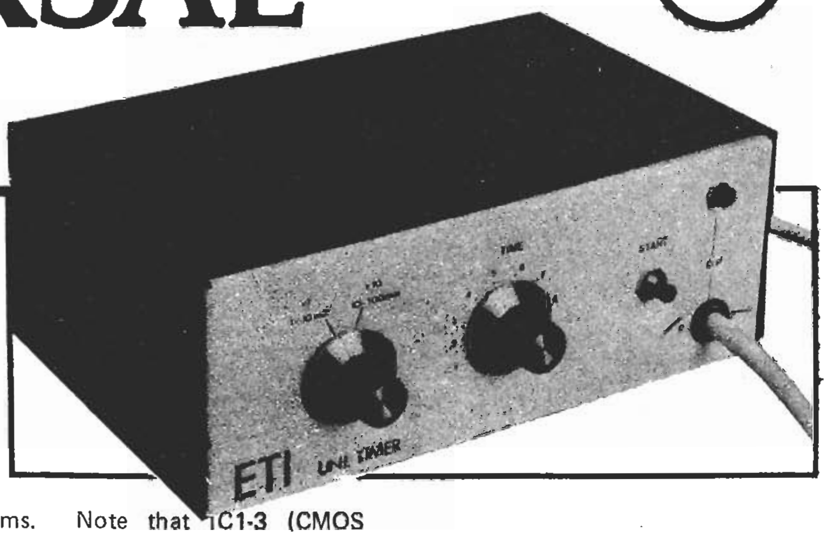


19



the counter a reset pulse.
A manual reset button is also provided. Any other desired cycle time up to the previously mentioned maximum may also be accommodated, but obviously some counts will require more or less diodes in the AND gate.
The switch-on and switch-off times of the equipment to be controlled are also determined in the same manner. The binary equivalents of the on and off times are calculated and the appropriate counter outputs are connected to AND gate inputs B1 to B4 for switch-on and C1 to C4 for switch-off. At switch-on monostable N2/N5 is triggered, which sets flip-flop FF1, turning on T1 to activate the relay. At switch-off monostable N3/N6 is triggered, which resets FF1. Manual controls are also provided. If several circuits are to be controlled with different switch-on and switch-off times then N2, N3, N5, N6, FF1 and T1 may be duplicated.
The one disadvantage of this circuit is that initially it must be reset at the time that the timing cycle is required to start, i.e. there is no time-setting facility, so in the event of a power failure it would be necessary to wait until the correct start time before resetting the circuit. For this reason it is best to make the start of the timing sequence occur at a convenient moment, such as in the morning or early evening.
To make the clock input of the counter less susceptible to interference pulses on the mains waveform it may be a good idea to precede it by a Schmitt-trigger using two CMOS NAND gates as described elsewhere in this issue.

UNIVERSAL TIMER



Our two-range (1-10 and 10-100 min) timer has excellent stability and produces a 30 second pulsed alarm sound at the end of each timing period. The unit is line powered, can switch 15 A loads and can give either make or break timing operation.

MOST analogue (pot controlled) long-period timers published in electronics magazines use a 555 one-shot IC and a large electrolytic capacitor as their main timing elements. Unfortunately, conventional electrolytic capacitors have very wide tolerances (typically −50% to +100%) and suffer from relatively large and unpredictable leakage currents. Consequently, these simple circuits cannot be relied upon to ~ive accurate or repeatable timing _eriods or to give periods significantly exceeding 15 minutes or so.

Our ETI Universal Timer gets away from the conventional design approach, with its inherent disadvantages, by using an astable clock generator and a divide-by-8192 CMOS counter as its main timing elements, the astable period being controlled by a pot and a highly stable polyester capacitor. Consequently, our timer has excellent accuracy and stability and can fully span the 1 min to 100 mins timing range in two switch-selected decade ranges.

Our timer has a few other unusual features. It is line powered and has a relay-switched power output socket that can be used to feed juice to external loads (heaters, lamps, etc.); the relay can switch currents of up to 15A and a mode switch enables the timer to give either make or break timing operations of the external loads.

Timing operations are initiated by a push-button start switch and a pulsed-tone alarm sounds for 30 seconds to give an audible warning on the completion of each timing cycle. The unit has a variety of practical uses in the home, workshop, darkroom, etc.

onstruction

Most of the circuitry (with the exception of T1, the relay, the switches and pot) is mounted on a single PCB, the construction of which should present few problems. Note that IC1-3 (CMOS types) should be mounted in suitable sockets and voltage regulator IC4 needs to be fitted with a small heat-sink.

When construction is complete, fit the PCB in a suitable case, together with the power transformer and the heavy-duty relay (which MUST be fitted in the specified socket) and proceed with the interwiring. Take special care over the interwiring of the relay contacts and SW2 and the 120V connections. Finally, drill a small hole (roughly 4 mm) in the top of the case, bond the acoustic transducer below it and connect it to the rest of the circuitry.

Testing

When the unit is complete, give it a functional test as follows. First, plug the unit in and check that its neon indicator illuminates when SW2 is set to TIMED BREAK position and turns off when SW2 is set to TIMED MAKE. Now set RV1 to its minimum position, set SW1 to the '1-10 min' range and firmly operate PB1. Check that the neon immediately changes state, indicating that the relay has turned on and the timing period has begun; also check that the relay turns off again at the end of the timing period (roughly one minute) and that the acoustic alarm operates and generates a pulsed-tone signal for roughly 30 seconds when the timing period is complete.

Calibration

Once the unit is functioning correctly, you can proceed with the scale calibration. The obvious (and very time consuming) way to do this is to check the timing periods obtained by varying RV1 against a stop watch, by trial and error, until suitable RV1 calibration points are found.

PARTS LIST

Resistors all ¼ W 5%	
R1	2k2
R2,10	39k
R3,9	1M0
R4	6k8
R5	4k7
R6	470R
R7	27k
R8	2M2
R11	47k
Potentiometer	
RV1	470k Linear
Capacitors	
C1,3,9	100n polycarbonate
C2	1u0 polycarbonate
C4	47u 25 V axial electrolytic
C5	10u 63 V electrolytic PCB type
C6	220n polycarbonate
C7	10n polycarbonate
C8	1000u 25 V axial electrolytic
Semiconductors	
IC1	ICM7555
IC2	CD4020B
IC3	CD4011B
IC4	78M12 or 7812
Q1	2N5087
BR1	50 V, 1 A bridge rectifier
D1	1N4148
D2,3	1N4001
Miscellaneous	
SW1	1 pole rotary switch
SW2	DPDT toggle 15 A 240 V
PB1	momentary push button
Tx1	transducer
RLA	12 V coil resistance > 100R, 3 pole changeover, contacts rated at 120 V, 20 A and 11 pin relay base 25 A rated
T1	12 V, 6 VA

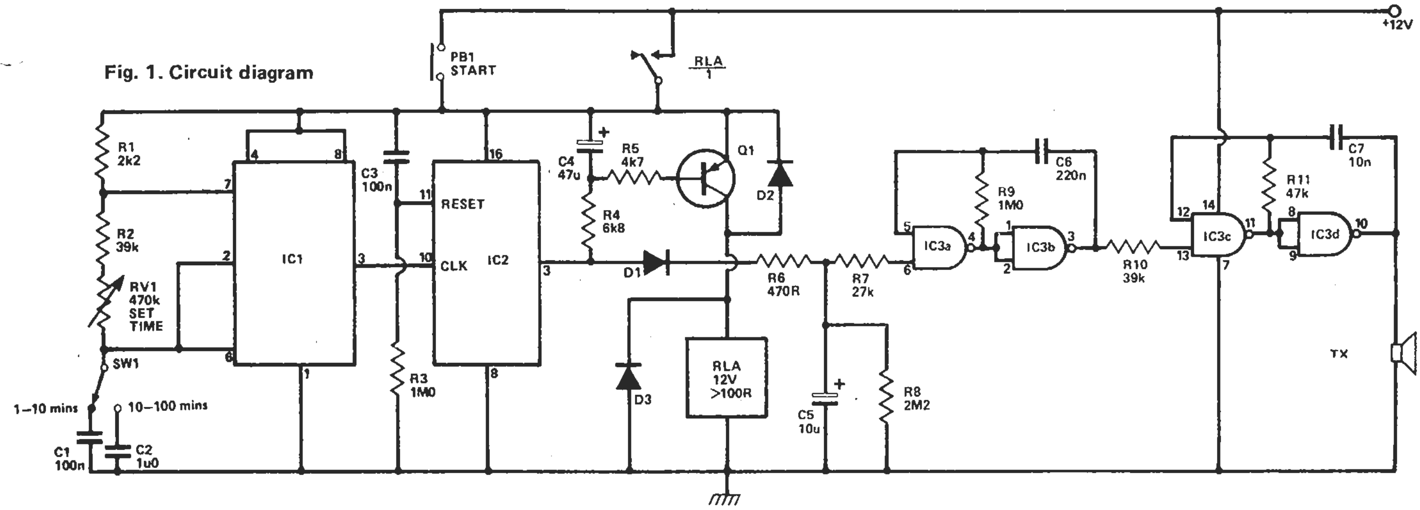


Fig. 1. Circuit diagram

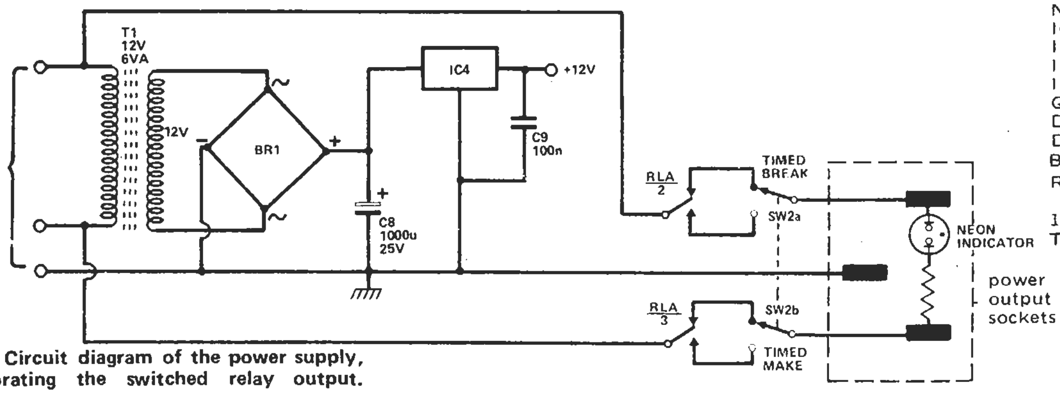


Fig. 2. Circuit diagram of the power supply, incorporating the switched relay output.

Note:
IC1 is ICM7555
IC2 is CD4020B
IC3 is CD4011B
IC4 is 78M12
Q1 is 2N5087
D1 is 1N4148
D2, D3 are 1N4001
BR1 is 50B, 1A BRIDGE
RLA is 12V relay, coil resistance 100R min. : 3 set of heavy — duty 120V, 20A changeover contacts
Txaccoustic transducer

Alternatively

If you have access to a reasonably accurate scope, a far easier way to calibrate the timing scale is to directly measure the period of the IC1 clock waveform, noting that a period of 7.32 mS corresponds to a timing period of precisely one minute. Thus, 1 min = 7.32 mS, 5 mins = 36.6 mS, 10 mins = 73.2 mS, etc.

The upper timing range of SW1 is approximately a decade up on the lower range, so a single calibration scale can serve for both ranges. The tracking accuracy of the two ranges depends on the relative accuracies of C1 and C2 and will typically be within 10% if good polyester components are used. If you want precise tracking you can achieve it by replacing C2 with a 820nF polyester capacitor and then padding its value up by trial and error, until precise coincidence of the '5 min' and '50 min' points is obtained on the two range scales. ●

PROBLEMS? NEED PCBs? Before you write to us, please refer to 'Component Notations' and 'PCB Suppliers' in the Table Of Contents. If you still have problems, please address your letters to 'ETI Query', care of this magazine. A stamped, self addressed envelope will ensure fastest reply. Sorry, we cannot answer queries by telephone.

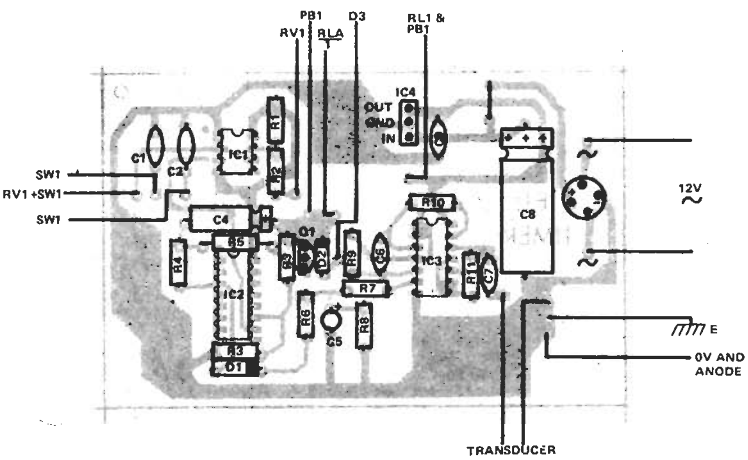
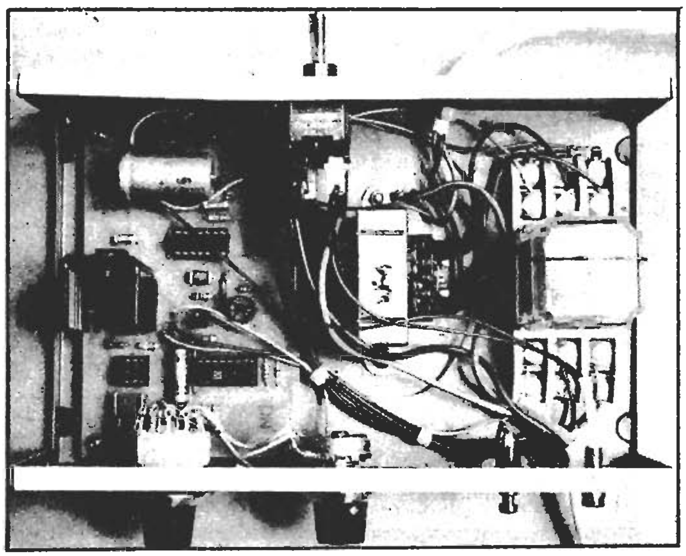


Fig. 3. Component overlay

Construction is fairly straightforward. IC4 needs a small heatsink and CMOS ICs 1-3 should be mounted in sockets.



The circuit comprises four main blocks, these being an astable clock generator (IC1), a multi-stage binary divider (IC2), a relay driver (Q1) and a gated alarm-call generator (IC3), all powered from a 12 V regulated line provided by IC4.

The clock generator is designed around IC1, a CMOS version of the 555 timer. The chip is wired in the astable mode and generates clock signals with periods variable over the 7.3 mS to 732 mS range via RV1 and SW1. The output of IC1 is used to clock the multi-stage CMOS binary counter designed around IC2, which is effectively wired in the 'divide-by-8192' mode; the output (pin 3) of this counter is normally low but goes high on the arrival of the 8192nd clock pulse.

The output of IC2 is used to drive relay RLA on via Q1 and to gate on the alarm-call generator (IC3) via the D1-R6-C5-R8-R7 network. This generator comprises a fast astable (IC3c-IC3d) and a slow astable (IC3a-IC3b). The slow astable is gated on by a momentary high output from IC2 and then gates the fast astable on and off at a rate of about 2 Hz.

The alarm-call generator part of the circuit is permanently connected to the 12 V supply lines, but the IC1-IC2-Q1 parts of the circuit are only connected to the supply rails when PB1 or relay contacts RLA/1 are closed. The complete circuit functions as follows.

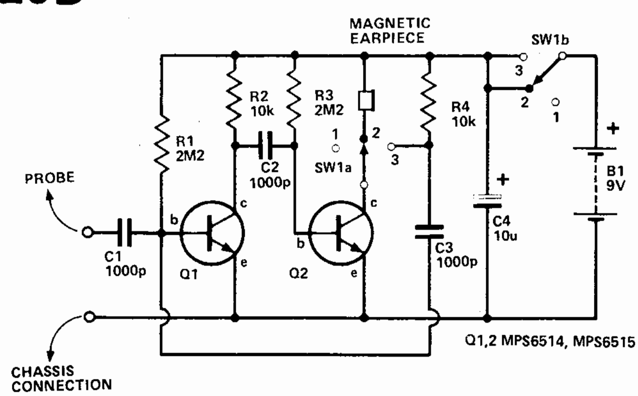
Timing operations are initiated by momentarily closing PB1, thereby connecting the supply to the IC1-IC2-Q1 circuitry. As PB1 is closed, a reset pulse is fed to pin 11 of IC2 via C3 and causes the counter's registers to set to zero, driving the output of IC2 low. As IC2's output goes low it drives Q1 and the relay on via R4-R5, thereby causing contacts RLA/1 to close and maintain the supply to the circuitry once PB1 is released.

As soon as PB1 is closed, IC1 starts to oscillate and generate clock pulses, which are then counted by IC2. On the arrival of the 8192nd clock pulse the output of IC2 switches high, turning Q1 and the relay off and causing contacts RLA/1 to open and break the supply connections to IC1-IC2-Q1. The timing sequence is then complete.

C4 imposes a slight turn-off delay on Q1, so that the output of IC2 remains high for 100 mS or so before the relay turns off. This brief high period is sufficient for the IC2 output to fully charge C5 via D1 and R6, thereby activating the IC3 alarm-call generator, which produces an audible pulsed-tone signal in the PB-2720 transducer. Once the relay has turned off, the charge on C5 slowly leaks away via R8 until, after about 30 seconds insufficient charge remains to gate IC3a on, at which point the alarm-call generator turns off. The entire operating sequence is then complete.

Designer Circuits

SIGNAL INJECTOR - TRACER



There are two extremely useful pieces of test gear for both the serviceman and the amateur constructor. These are a signal source and a signal tracer.

Faced with a transistor radio that doesn't work, what do you do? It is important that a logical approach is taken and although this may sound obvious, it is very, very easy to become diverted.

First check that the battery is not flat (for this accounts for about 50% of so called faults) and then check that a good contact is being made on the cut-out switch of the earpiece socket if one is fitted. Always check these first but assuming there is still no joy what do you do?

The volume control is easily located, contacts can generally be made to it quickly and it is an excellent place to start.

If you inject a signal of the slider of the volume control and it is heard at a decent level from the loudspeaker you can be fairly sure that nothing is wrong with the amplifier. If nothing is heard there is obviously something wrong and the field is immediately narrowed.

Assuming that the audio stage is working you can then inject and IF signal at the collector of the mixer stage — the same rules apply as before.

Alternatively you can take the signal detect' approach. If instead of injecting a signal at the voume control you can listen at the same point to establish that the radio isd is working satisfactorily up to a certain point.

The above is a super concise lesson in fault finding but it does illustrate the tremendous use that a signal injector and a signal tracer can be put to.

The project described here is for a combined device — it can inject signals at RF IF and audio and can detect signals at the same frequencies assuming that they are high enough in level. The simplicity of circuit may lead you to doubt this claim but it does do all this.

The function switch, SW1, has

No. 1 Off position
No. 2 Trace Position
No. 3 Inject Position

Position 1 merely disconnects the supply and the device is of course inoperative. As shown the function switch is in position 2 and in the trace mode.

One of the contacts is the common line and should be wired using a crocodile clip to the chassis of the equipment being investigated. The other connection is the probe.

This goes via DC blocking capacitor C1 whose working voltage should be high — if a 500 V working component is used the circuit can be used on valved equipment working at high voltages.

The signal is fed to Q1 which is arranged as a common emitter amplifier but which is biased nearly to cut-off which creates deliberate distortion at the same time as amplifying the signal. Distortion in such a manner leads to the detection of RF signals and so whatever the frequency fed in, assuming it is modulated, and audio output will be heard. The collector load of Q1 is R2 and the output of this stage is fed to a further one of similar design, but the collector load here is represented by a high impedance magnetic earpiece in which the signals are heard.

On inject, SW1 is in position 3 and the output of Q2 is coupled to R4, acting as the collector load and also to C3 which feeds back to the base of Q1. The circuit, which was previously an amplifier, now becomes a multivibrator producing a square wave signal at approximately 1kHz and this is fed, again via C1, to the probe.

A square wave can be described as a fundamental frequency plus all its harmonics and so in addition to 1kHz there is an output at 2kHz, 3kHz etc., going right up into the RF range. In fact, these are still a useable output at 30MHz.

Holding the probe near the aerial will produce an output from a working radio as the injector is working as a very low power transmitter and an output at 1kHz will be heard from the loudspeaker.

High gain transistors are needed in order to hear really low signal sources and high frequency types are needed to handle the upper harmonics.

Note that only high impedance magnetic earpieces are suitable, though 2000 ohms headphones can be used instead.

Once completed and used the signal injector/tracer will be fo[illegible] to be almost indispensable an[illegible] this reason it is worthwhile buil[illegible] the circuit carefully and neatly into a small chassis.

PROJECT OF THE MONTH

By Forrest M. Mims

A Simple, Low Cost Timer

FOR simple timer applications, transistor circuits are as good as more complicated and expensive IC designs. Figure 1, for example, shows a simple timer made from only three components—a field-effect transistor (FET), a timing capacitor and a discharge resistor. A LED, protected by a current-limiting resistor, indicates when a timing cycle is complete.

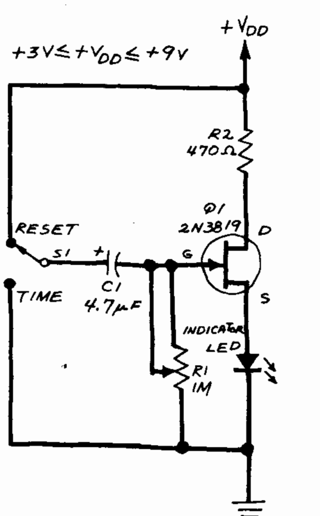


Fig. 1. Ultra-simple FET timer circuit.

The FET is responsible for the simplicity of this circuit. Its very high input impedance places a negligible load on *C1* during a timing cycle. By contrast, a bipolar transistor would quickly discharge the capacitor and prematurely end the timing cycle. In effect, the FET serves as a high-impedance buffer between timing capacitor *C1* and the output LED, which provides the timing indication.

When the circuit is connected to a single-ended positive supply, *C1* is charged to $+V_{DD}$ by momentarily placing *S1* in its RESET position. A timing cycle is initiated by placing the switch in its TIME position. This causes *Q1* to turn off and extinguish the LED. At the same time, *C1* begins to discharge through *R1*.

When the voltage across *C1* decreases to approximately 0.6 volt, the FET conducts, and the LED glows to indicate completion of the timing cycle. A new timing cycle can be initiated by momentarily toggling *S1* to its RESET position. Figure 2 is a plot of the voltage across *C1* during a typical timing cycle.

When I used a 4.7-μF miniature aluminum electrolytic capacitor as *C1*, I could obtain a maximum time delay of approximately 10 seconds. Shorter delays can be achieved by adjusting *R1* so that its effective resistance is decreased. Longer delays are available by using a component with more capacitance and less leakage for *C1*. Tantalum capacitors are well suited to such applications. Substituting a higher resistance potentiometer for *R1* can also give longer delays.

Adding a Relay. Figure 3 shows a more practical, expanded version of the basic timer of Fig. 1. Here each of three (or more) separate capacitors can be switched into the circuit to provide different time delays without any adjustment of *R1*. Of course, *R1* can also be adjusted if desired.

The most important addition to the circuit shown in Fig. 3 is *K1*, the output relay. Normally, *R2* keeps *Q2* conducting, which in turn energizes the relay coil. When a timing cycle is complete, however, *Q1* grounds the base of *Q2*, cutting off the bipolar transistor. This causes the relay to drop out. Diode *D1* absorbs any high-voltage inductive kick which might be generated during the keying of the relay coil.

With this circuit, delays of ten minutes or more are possible if quality capacitors are selected. Low-leakage capacitors are a *must* for time delays of this magnitude. ◇

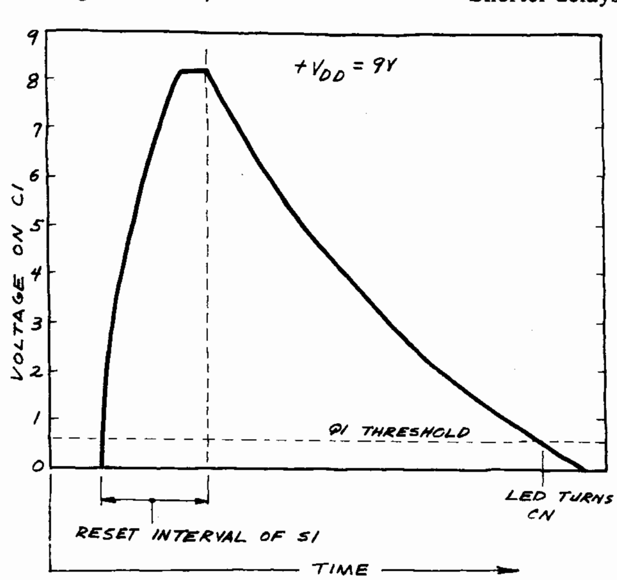


Fig. 2. Voltage on C1 during a timing cycle.

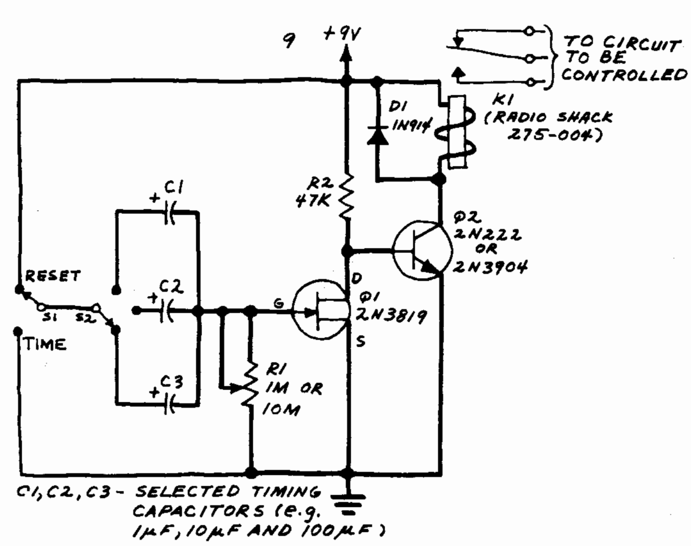


Fig. 3. A variable-delay FET timer.

Current mirror linearizes remote-controlled timer

by George Hughes and S. A. Hawley
Eye Research Institute, Boston, Mass.

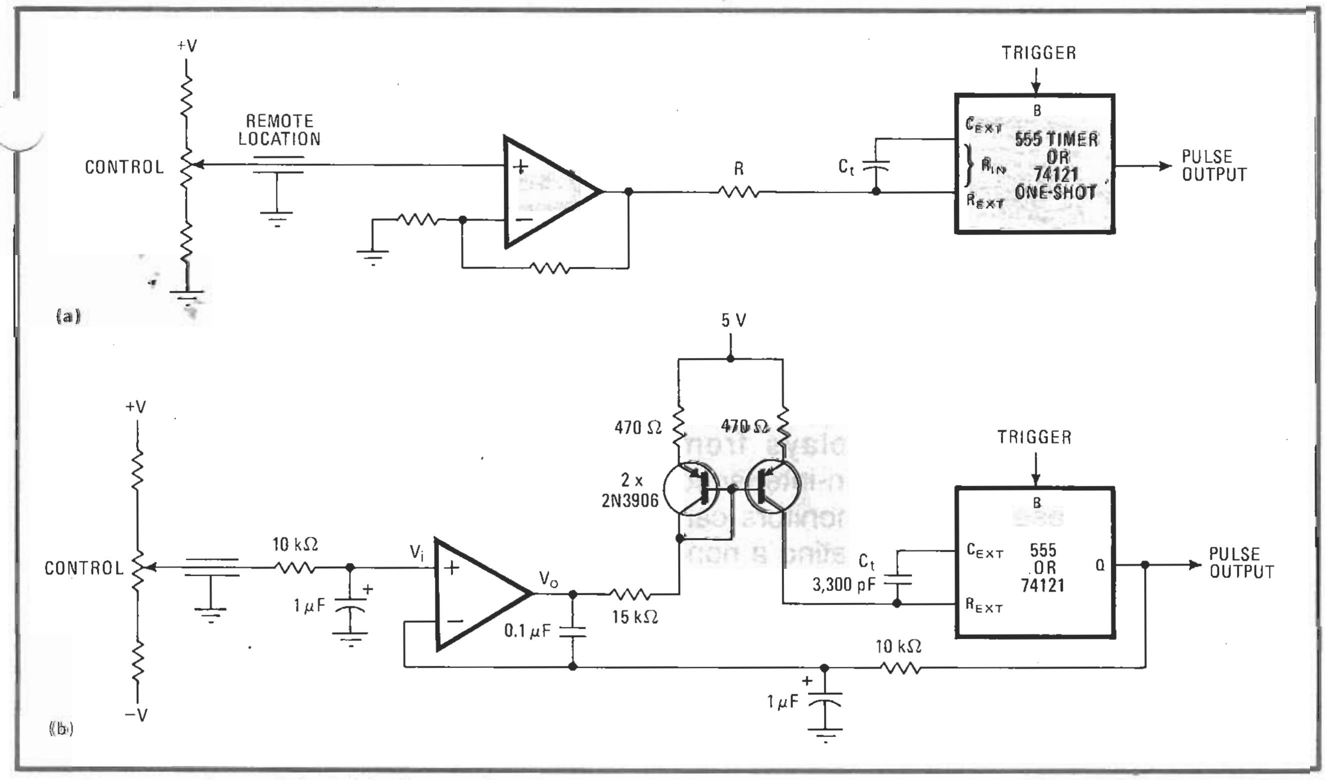
Although setting the pulse duration of timers of the 555 variety by remote means is most conveniently done with a single control such as a potentiometer, often there is an undesired nonlinear relationship between wiper-arm setting and output width because of the simple methods employed to achieve control. Adding a current mirror and feedback loop to the basic circuit solves the problem of linearity with little additional complexity or cost.

In general, any current passing through the pot's wiper should be minimized and the pot placed as close as possible to the circuit's interfacing operational amplifier, especially in remote-control applications, where the effects of stray coupling from various processing circuits can be considerable. A typical configuration is shown in (a). In this type of circuit, however, difficulties arise because the op amp's output voltage supplies charging currents to the one-shot's timing capacitor through a fixed resistor. As a result, the pulse capacitor width will be inversely proportional to the current driving C_T and will not be a linear function of the wiper-arm position.

Adding the current mirror and the feedback loop to the circuit, as shown in (b), overcomes this drawback. Here, the mirror's charging current is made a constant whose magnitude is proportional to only the voltage at the amp's noninverting input, V_i, and hence to the potentiometer's setting. In the feedback loop, the average value of the timer's output is compared with a voltage that represents the wiper-arm position, where current injected into timing capacitor C_T is such that the difference is kept small by the virtual-ground properties of the op amp. The average value of the timer's output is itself a linear representation of pulse duration, so that overall linear control is maintained.

This circuit will function with any TTL timer. Parts values are not critical and can be varied to suit a wide range of triggering rates and pulse durations. Substitution of matched dual transistors or packaged current mirrors is recommended to improve the circuit's temperature stability. □

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 $75 for each item published.



Current correspondence. A typical single-control pot arrangement for setting the on-time of a one-shot (a) has a nonlinear relationship of duration to wiper position because the current-driving capacitor, C_T, is proportional to $V_i(R+R_{IN})$. Adding a current mirror and feedback loop to the circuit (b) linearizes the relationship by generating a constant current set by V_i. The values shown are for $8 < T_{out} < 50$ μs.

BUILD THE TIME-ON RECORDER

Tells you at a glance how long an appliance or TV receiver has been operating

BY DANIEL M. FLYNN

WITH the cost of electricity constantly rising, you might want to check how many hours an appliance or the TV set has been on during the day. An ideal way to do this is with the Time-On Recorder described in this article. Unlike many mechanical timers, which you have to stop and start yourself, this recorder is triggered on and off by the appliance itself.

The recorder is a relatively simple device to build. It has a single clock chip which performs all timing functions. This chip, an *MM5309*, has a 24-hour LED display format. The chip times only when an appliance plugged into the recorder is turned on. A circuit in the recorder senses that the appliance is on and "enables" the clock chip. The recorder displays a continuously changing time until the appliance is shut off. At this point, the clock chip is disabled but it holds the time count. The displayed time remains unchanged until the appliance is turned on again, at which point the clock continues timing. This is how the recorder displays the cumulative "time on" of the appliance for the entire day.

Circuit Operation. To use the Time-On Recorder, an appliance must be plugged into socket *SO1* of the recorder and the recorder plugged into an ac outlet. When the appliance is in use, its current flows through fuse *F1* and the triac (Fig. 1). Fuse *F1* protects the triac and also disconnects the circuit from the line in the event the primary of *T2* becomes shorted. The triac is held on constantly by resistor *R1* as long as current is flowing through the device. The drop across the triac is approximately 2 volts, which remains relatively constant despite changing current. Most of this voltage is across *R2*, but a portion excites the 8-ohm winding of *T1*. The 1000-ohm, center-tapped secondary of *T1* produces an ac voltage that is rectified by *D1* and *D2*, filtered by *C1*, and applied through current limiter *R3* to the base of *Q6* an npn transistor. Fuse *F2* protects *T1* in the event the triac should open while a load current is flowing. If this happened, the entire current would be forced to flow through *T1* causing a great deal of damage.

When there is no load, *Q6* receives no base current and is off. Under this condition, pin 19 of the clock chip is brought up nearly equal to V_{SS} through resistors *R4* and *R5*. Pin 19 of the clock chip is the 50/60-Hz input. (See Fig. 2 for the pin-out configuration of the clock chip.) When it is held at V_{SS} the clock's time will not change. If a load is present and drawing current, transistor *Q6* receives a base current which forces it on. With *Q6* on, pin 19 of the clock chip is grounded. This condition allows the

clocking pulses produced from the 60-Hz line to pass through diode *D3*. These pulses cause the clock's time to advance. As soon as the load is turned off, *Q6* turns off, and the clock stops timing.

The clock chip, an *MM5309*, has multiplexed, 7-segment outputs which are used to directly drive a five-digit numeric, monolithic display. The digit-enable outputs of the clock chip are used to drive pnp transistors *Q1* through *Q5*. These transistors in turn drive the individual digits. Tens of hours and minutes and units of hours, minutes, and seconds are displayed. Units of seconds are displayed so the user can verify, at a glance, if the circuit is timing. Components *R7* and *C4*, connected to pin 26 of the clock chip, provide an RC network for the internal multiplex oscillator. Together, *R7* and *C4* determine the rate at which the display is multiplexed.

The dc supply voltage is provided by *IC2*, a full-wave bridge rectifier, and capacitor C2. The latter not only filters the voltage from *IC2* but, more importantly, it raises the average dc voltage from 11 volts to 17 volts, which is a functional voltage level for the *MM5309*. The *MM5309* does not require a voltage regulator.

Switch *S1* is connected to pin 16 of the clock chip and is used to reset the clock to all zeros. Normally pin 16 is tied high internally allowing the clock to time. Depressing *S1* shorts pin 16 to ground performing the reset function. Switch *S2* is optional and can be replaced with a jumper wire if the builder prefers to see units of seconds displayed all the time. (I found displaying units of seconds confusing without also displaying tens of seconds when trying to interpret the display.) Switch *S2* is depressed by the user to see if the clock is timing and then released.

Pin 14 of the *MM5309* is tied low so the timer will time correctly with a 60-Hz clock signal on pin 19. Pin 27, the 4/6 digit select, is tied low to enable the units and tens of seconds outputs (pins 21 and 20) along with the minutes and hour outputs. Lastly, pin 13, the 12/24 hour select, is left disconnected (the pin is pulled high internally) so the timer will time to 24 hours before recycling.

Construction. Building of the time-on recorder is not complicated. A printed-circuit board such as the one shown in Fig. 3 greatly simplifies wiring. However, the circuit is simple enough that it can be hard-wired on perfboard if desired. The mounting of all components except *F1*, *R1*, *SO1*, the triac, and the switches on the board helps reduce the amount of off-board wiring. Figure 4 shows component placement for the pc board. Take care in inserting ICs in case the leads must be bent to match holes.

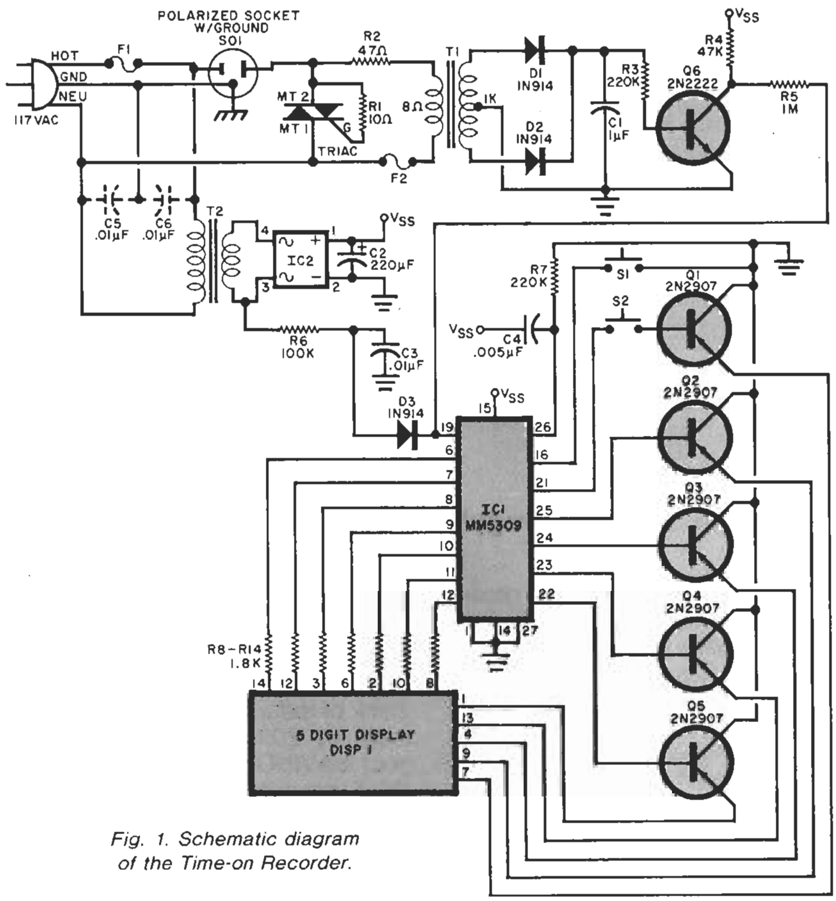


Fig. 1. Schematic diagram of the Time-on Recorder.

PARTS LIST

C1—1-μF, nonpolarized electrolytic
C2—220-μF, 35-V electrolytic
C3—0.01-μF, 50-V, ceramic-disc capacitor
C4—0.005-μF, 50-V, ceramic-disc capacitor
C5, C6—0.01-μF, 400-V, ceramic-disc capacitor
D1,D2,D3—1N914 signal diode
DISP1—5-digit, 7-segment, common-cathode display (H-P 5082-7415 or equivalent)
F1—6 1/4-A, 3AG, slow-blow fuse
F2—1/4-A, 3AG, fast-acting fuse
IC1—MM5309 PMOS clock chip (see note)
IC2—Full-wave bridge rectifier (Radio Shack 276-1161 or equiv.)
Q1 through Q5—2N2907 pnp transistor
Q6—2N2222 npn transistor
R1—10-Ω, 1/2-W, 10% tolerance carbon-composition resistor
R2—47-Ω, 1/2-W, 10% tolerance carbon-composition resistor
The following resistors are 1/4-W, 5% tolerance carbon-composition resistors:
R3, R7—220 kΩ
R4—47 kΩ
R5—1 MΩ
R6—100 kΩ
R8 through R14—1.8 kΩ
S01—Polarized ac socket with ground
S1, S2—Normally open, momentary-contact, pushbutton switch
T1—Miniature audio-output transformer (Radio Shack 273-1380 or equiv.)
T2—12.6-V, 300-mA transformer
Triac—400-V, 6-A (Radio Shack 276-1000 or equivalent)
Misc.—Suitable enclosure, circuit board, standoffs, line cord, strain relief, IC sockets (one 28-pin, one right-angle 14-pin), panel-mounted fuse holder, pc-mounted fuse holder, mounting hardware, terminal strip, solder, etc.
Note—The MM5309 clock chip is available from Jameco Electronics, 1355 Shoreway Rd., Belmont, CA 94002.

The line cord coming into the unit should be three-conductor and of 16- or 18-gauge wire. The line cord should be properly relieved for strain at the point of entry to the cabinet. Care must be taken when connecting the internal 115-V wiring. On a polarized, grounded, electrical socket, one side of the outlet is smaller than the other. This side is the "hot" side. The larger of the two blade holes is the neutral. The hot side of the line should be brought in and taken to the end tab of the panel-mounted fuse holder of *F1*. The side tab of the fuse holder is connected to the gold-colored terminal screw of *SO1*, the ac socket. The silver-colored terminal is connected to

Pin Connections
MM5309

Pin	Function	
1	V_{DD}	
2	$\overline{BCD\ 8}$	BCD Outputs
3	$\overline{BCD\ 4}$	
4	$\overline{BCD\ 2}$	
5	$\overline{BCD\ 1}$	
6	A	7-segment Outputs
7	B	
8	C	
9	D	
10	E	
11	F	
12	G	
13	12/24-hour select	
14	50/60-Hz select	
15	V_{SS}	
16	Reset	
17	Slow set	
18	Fast set	
19	50/60-Hz input	
20	S10	Digit enable outputs
21	S1	
22	H10	
23	H1	
24	M10	
25	M1	
26	MUX timing	
27	4/6-digit select	
28	Output enable	

Five-digit numeric display

Pin	Function
1	Cathode 1
2	Anode E
3	Anode C
4	Cathode 3
5	Anode DP
6	Anode D
7	Cathode 5
8	Anode G
9	Cathode 4
10	Anode F
11	N/C
12	Anode B
13	Cathode 2
14	Anode A

Fig. 2. Pin connections of the two integrated circuits.

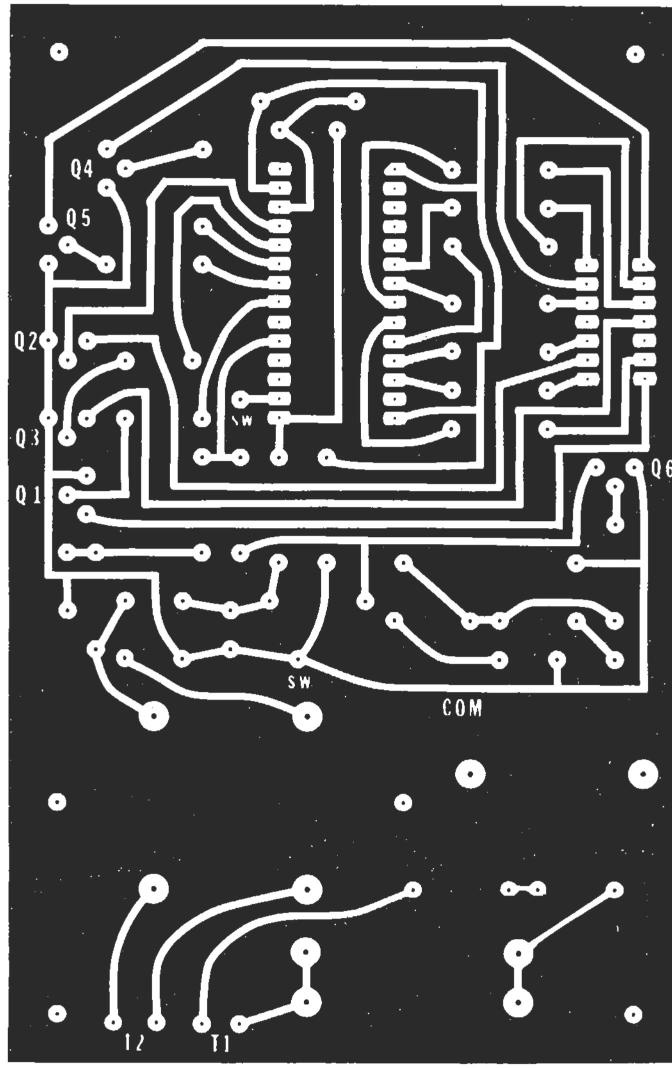


Fig. 3. Exact-size foil pattern for a printed-circuit board for the project.

the triac's *MT2* terminal. Then, as shown in the schematic, the triac's *MT1* terminal is connected to the neutral. The ground wire of the line should be electrically fastened to the metal chassis enclosure (if one is used) and to the grounding screw of *SO1*. All of the wiring just mentioned should be 16- or 18-gauge stranded wire. (Solid wire of this gauge is difficult to work with in the chassis box.) Other ac wiring is not as critical sizewise (24 gauge will work fine), but care should be taken to follow the schematic closely.

The time-on recorder pictured in Fig. 5 was assembled in a 3½ x 9 x 6″, 20-gauge, aluminum cabinet such as Radio Shack's part number 270-261. Whichever cabinet is chosen, it should be of easily machinable material since square holes are required for the outlet and the display. If the display is mounted on the board, it should be located at a side and mounted with a 14-pin right angle socket. This way the board can be mounted flat and positioned on standoffs so the display appears in the cabinet front.

The triac must be heat sinked. The metal chassis itself functions well as a heat sink if the triac is mounted with a nylon bolt on a mylar spacer. The triac can be connected to a terminal strip for all the connections to it. Also recommended is that the clock chip be mounted in a socket, with the chip placed in the socket only after all wiring is complete.

Using the Time-On Recorder. To use the recorder, plug it in and reset the clock so the display shows all zeros. Then plug an appliance into the recorder's socket. Turn the appliance

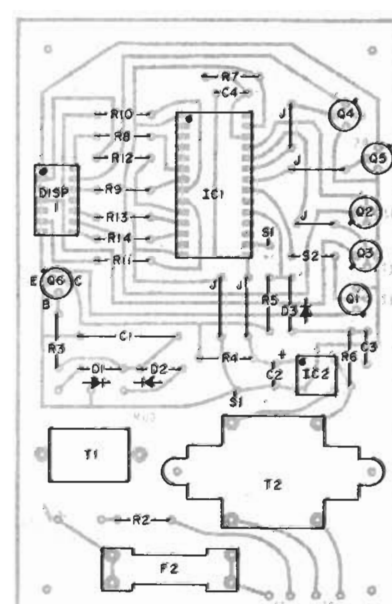


Fig. 4. Component layout for the board shown in Fig. 3.

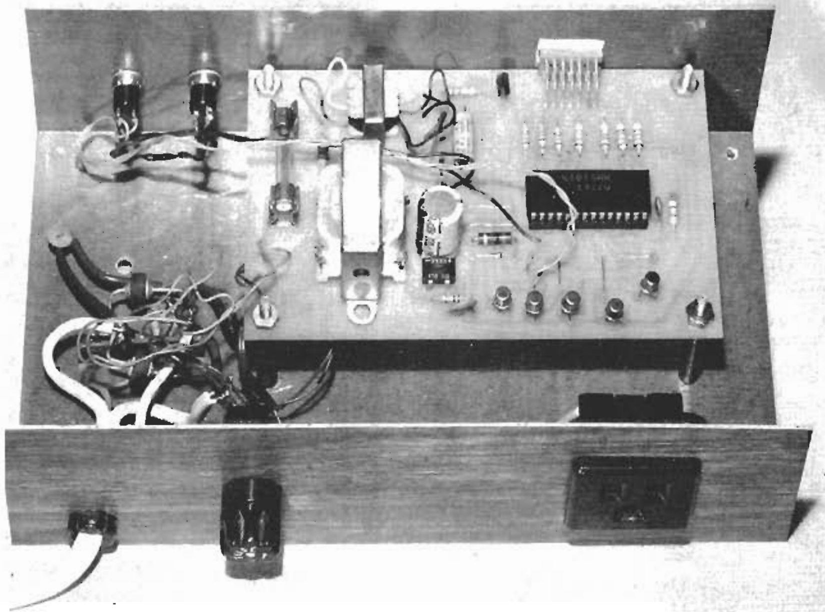


Photo of the internal arrangement of the author's prototype.

on and verify that the recorder starts timing. To find the cumulative time-on for a period longer than a day, note the recorder's display daily and then reset the recorder. At the end of the time period, add the results for each day. (The maximum display is 24 hours before the clock resets itself to zero.)

Please note that the recorder's maximum load is 720 watts (i.e., a load requiring no more than 6 amperes).

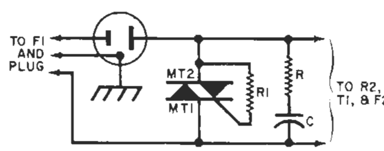


Fig. 5. An RC shunt on the triac improves operation with inductive loads.

Some loads, such as a dehumidifier may be rated at 5 A but when first turned on will draw in excess of 6 A. This will cause fuse *F1* to blow. In this case, the time-on recorder cannot be used. Also, if the ac line has noise spikes on it (from appliances such as a dehumidifier) the recorder may be accidentally reset and lose its count. To remedy this add capacitors *C5* and *C6* as shown in the schematic. These components may also be needed if the load is a fan. These capacitors short the noise spikes on the ac line to ground. Note also that there is a minimum load requirement to start the recorder timing. A load as small as 10 watts will activate the recorder, while a load of 7½ watts will not.

Although the recorder can be used to tell you how much television the family is watching or the like, it can also tell you how much the television is costing you to use. To find the cost, take the total time in hours, multiply it by the power rating of the load in kilowatts and then multiply by the cost of a kilowatt-hour in your area.

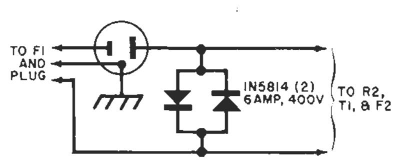
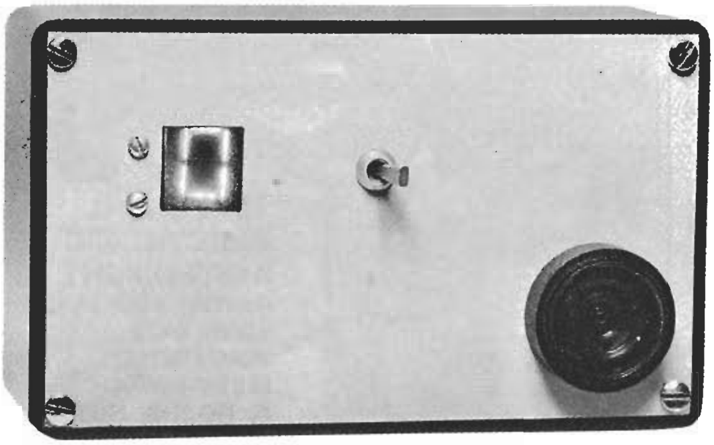


Fig. 6. Two diodes can be used to replace the triac if desired.

Going Further. The circuit shown in Fig. 1 uses a triac to produce the signal that enables the clock chip. The triac was selected because of its easy availability. It does, however, restrict the types of loads that can be timed. That is, the triac will prevent large inductive loads such as fans and other motors from starting.

If you want to avoid this, the circuit can be changed. Shunting the triac with a series RC circuit as in Fig. 5 would eliminate the problem mentioned with inductive loads. This solution, however, requires two additional components and creates the problem of finding the values of the two components. Therefore, the circuit shown in Fig. 6 is preferable. If the diodes are available, use the circuit to replace the part of the original circuit which uses the triac. No other change in the circuit is necessary.

If one of the diodes in Fig. 6 fails, fuse *F2* will blow to protect *T1*. In this case, the bad diode and *F2* will have to be replaced before the circuit will operate. This type of circuit failure should be kept in mind if *F2* blows but there are no wiring errors present. ◇



THE EXECUTIVE DIGITAL TEMPER COUNTDOWNER

Counts and displays for ten seconds—followed by an audible "blow-your-top" signal

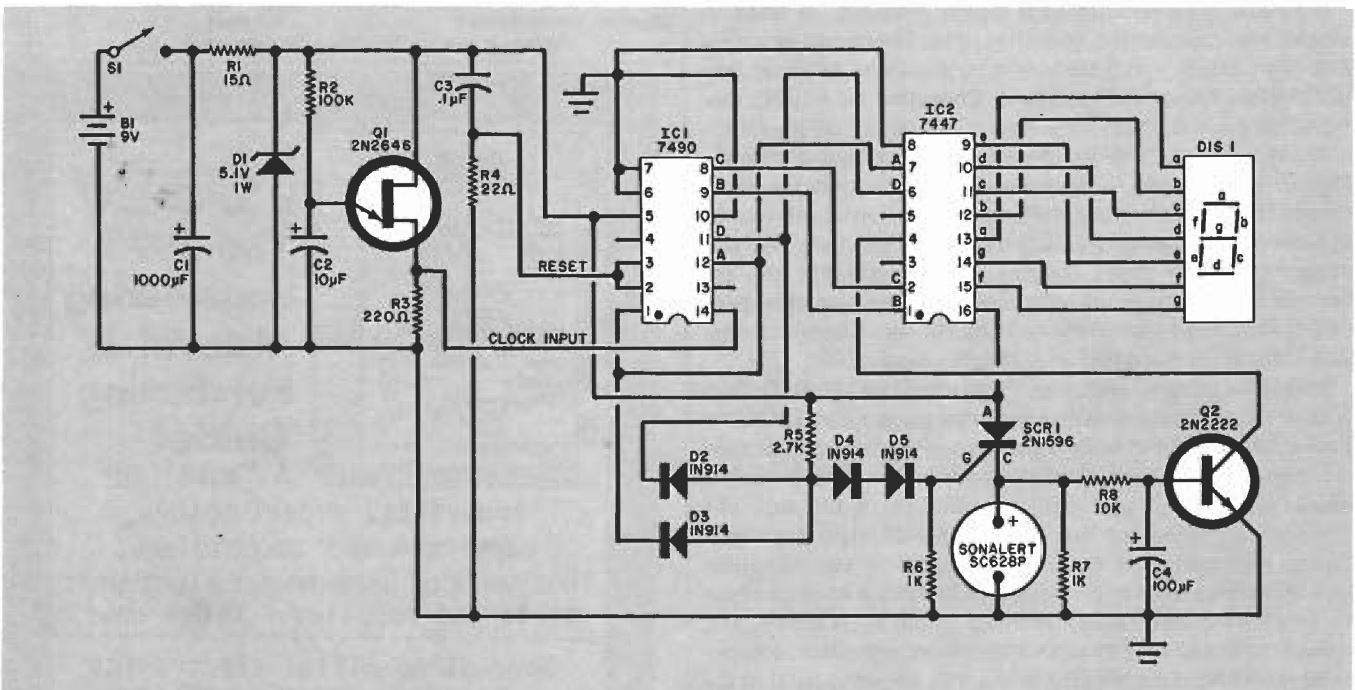
BY ROBERT D. PASCOE

"COUNT to ten before you blow your top" is familiar advice to help avoid losing one's temper. Here's a novel temper controller—a perfect gift for the executive who has everything—that does the counting for you.

Activating the temper timer starts the visual display of ten numerals (0 to 9), followed by an audible sound that means "*now* you can blow your top."

About the Circuit. The temper timer is a clock, whose pulse rate is 1 Hz; a decade counter and seven-segment display; and a Sonalert beeper. The schematic is shown below.

When switch *S1* is closed, power is supplied to the temper timer. Resistor *R4* and capacitor *C3* form a differentiator which is connected to the reset



PARTS LIST

B1—Six C or D cells in series (see text)
C1—1000-μF, 25-volt electrolytic capacitor
C2—10-μF, 25-volt electrolytic capacitor
C3—0.1-μF, 50-volt disc capacitor
C4—100-μF, 25-volt electrolytic capacitor
D1—5.1-V, 1-W zener diode (Motorola HEP Z0406)
D2, D3, D4, D5—1N914 diode
DIS1—Numitron (2000 series) or other 7447-compatible seven-segment display
IC1—7490 integrated circuit
IC2—7447 integrated circuit
Q1—2N2646 unijunction transistor (Motorola HEP 310)
Q2—2N2222 transistor (Motorola HEP 736)
R1—15-ohm, 1-watt resistor
R2—100,000-ohm, ½-watt resistor
R3—220-ohm, ½-watt resistor
R4—22-ohm, ½-watt resistor
R5—2700-ohm, ½-watt resistor
R6, R7—1000-ohm, ½-watt resistor
R8—10,000-ohm, ½-watt resistor
S1—Spst switch
SCR1—2N1596 silicon controlled rectifier (Motorola HEP R1102)
1—Mallory No. SC628P Sonalert®
Misc—Suitable plastic enclosure, battery holder, machine hardware, hookup wire, pc board or perforated board, solder, etc.

terminal of the decade counter. This arrangement insures that the counter starts at zero every time the sequence is initiated.

The UJT timing oscillator, *Q1*, generates one pulse per second which is fed to the clock input of the counter *(IC1)*. The outputs of the 7490 up-counter are introduced into the inputs of the BCD-to-seven-segment decoder, *IC2*. A 7447 chip is used for this function. The outputs of *IC2* are connected to the display. A Numitron (2000 series) was used in this project, but any seven-segment display compatible with the 7447 decoder can be substituted.

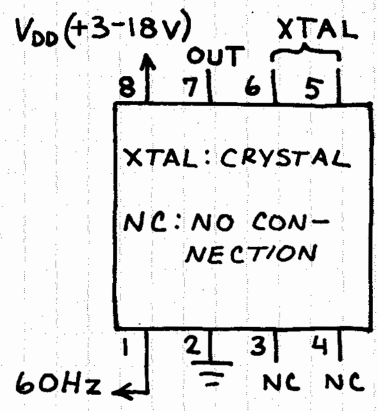
A diode AND gate, composed of *D2, D3,* and *R5,* controls the beeper and display-off sequence. When a 9 appears at the output of the 7447, the ouput of the AND gate goes high, and *SCR1* is triggered. Once *SCR1* is on, the Sonalert is activated, and audible beeps are emitted until the power switch is opened. The output of the gate also is connected to an inverter (*Q2*). When the output of the inverter goes low, the display is turned off. This is done to reduce power consumption. A small delay is introduced by *C4* to allow the last digit (9) of the count to appear on the display.

Any 5-volt supply capable of delivering 250 mA to the temper timer is suitable. For portability, six C or D cells can be used in the zener-regulated supply shown in the schematic. If longer battery life is desired, alkaline cells should be used.

Construction. The placement of components is not critical. Parts may be mounted on perforated board or a pc board. Leads should be run from the board to the display, rather than soldering the display directly to the board. This will afford a large degree of flexibility in mounting the board and display in an enclosure. The author used a plastic box (6¼" × 3" × 2") with an aluminum cover panel. A ¾" square hole was cut out of the panel for the display, and a bracket made from scrap aluminum was used to hold the Numitron securely.

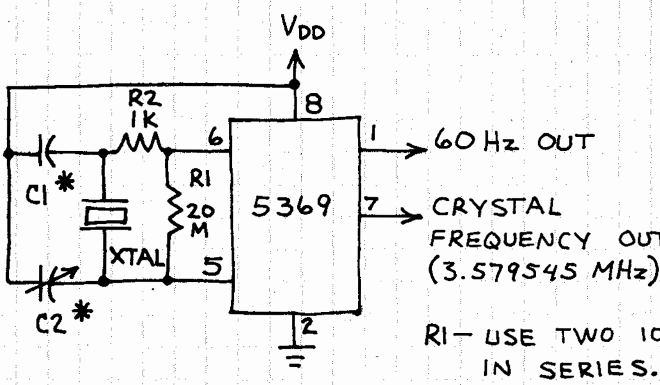
Operation. The device may be used any place and any time that your temper flares up. It is a good conversation piece for the home or office, and correct use of the temper timer, in conjunction with self-restraint, may well keep some conversations going that otherwise would have led to blows. ◈

60-Hz TIMEBASE
MM5369 (276-1769)



PROVIDES PRECISE 60 Hz SQUARE WAVE WHEN USED WITH 3.579545 MHz COLOR TV CRYSTAL. USE FOR MOST DO-IT-YOURSELF TIMERS, CLOCKS, CONTROLLERS, FUNCTION GENERATORS. INSTALL IN SMALL CABINET FOR WORKBENCH PRECISION CLOCK.

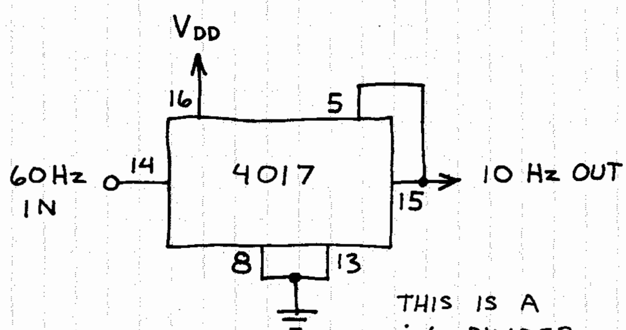
60-Hz TIMEBASE



R1 – USE TWO 10M IN SERIES.

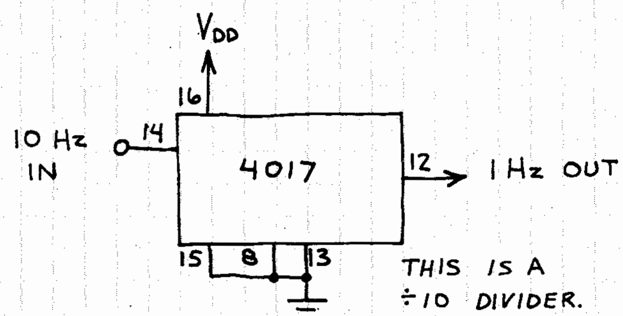
*
MOTOROLA SPECIFIES THAT C1 = 30 pF AND C2 = 6.36 pF. OK TO USE SIX 4.7 pF CAPACITORS IN PARALLEL OR 47 pF CAPACITOR FOR C1. TRY TUNABLE CAPACITOR (e.g. 5–50 pF) FOR C2. TO TUNE, CONNECT FREQUENCY METER TO PIN 7. TUNE C2 UNTIL FREQUENCY IS 3,579,545 Hz. ACCURACY FAIRLY GOOD EVEN IF YOU DON'T TUNE C2.

10-Hz TIMEBASE



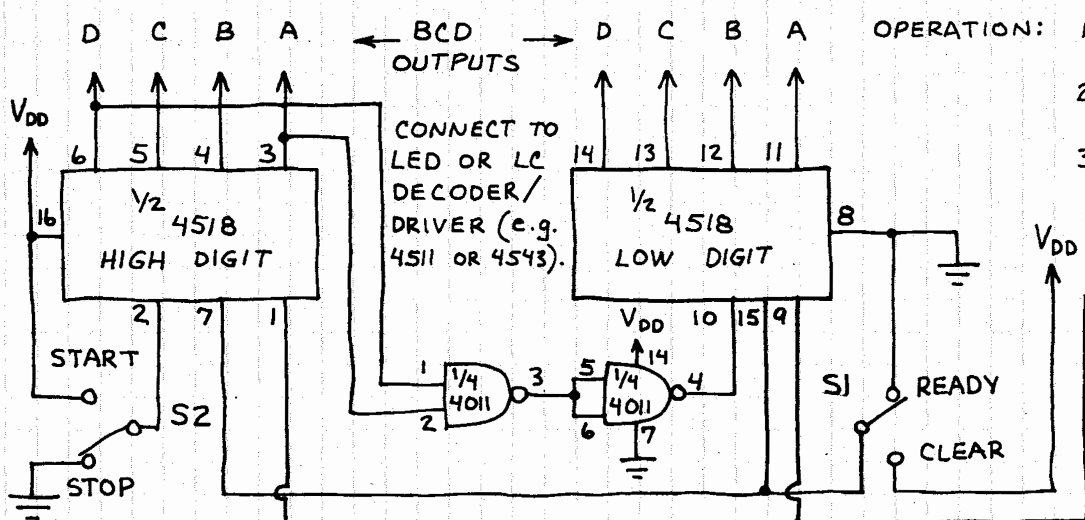
THIS IS A ÷6 DIVIDER.

1-Hz TIMEBASE



THIS IS A ÷10 DIVIDER.

DIGITAL STOPWATCH



OPERATION:
1. TOGGLE S1 FROM CLEAR TO READY.
2. SWITCH S2 FROM STOP TO START.
3. SWITCH S2 FROM START TO STOP.

1 Hz = 00–99 SEC

10 Hz = 0.0–9.9 SEC

OK TO ADD MORE STAGES.

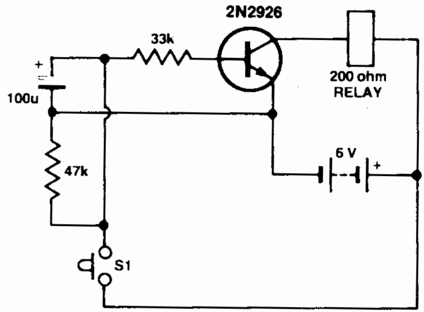
Simple Timer

vid Hughs

This simple little timer features a minimum of components, most of which can be found in any well-stocked hobbyist's junkbox, and you can fudge a variety of delays by trial and error substitution of components.

It works as follows. When you press S1 (an ordinary pushbutton) the 100u electrolytic capacitor rapidly charges up. When it gets to about 0.7 V the transistor will be forward biased and collector current will flow, in turn operating the relay. When you release S1, the capacitor will begin to discharge via the 33k resistor and the base of the transistor. When the voltage across the capacitor gets down to half a volt or so the transistor base will no longer be forward biased, collector current will cease and the relay will drop out. The capacitor will continue to discharge via the 47k resistor.

With the values shown, the relay will remain operated for about eight seconds or so. It is advisable to use either a tantalum or a low leakage (RBLL) electrolytic capacitor.



You can fudge things a little to obtain increased times by simply increasing the value of the electrolytic capacitor. Decreasing the value will shorten the period.

You can get quite long times with lower values of capacitance by substituting a Darlington pair for the 2N2926. In this case you can increase the two resistor values into the megohm range.

C-MOS ICs make precise digital timer

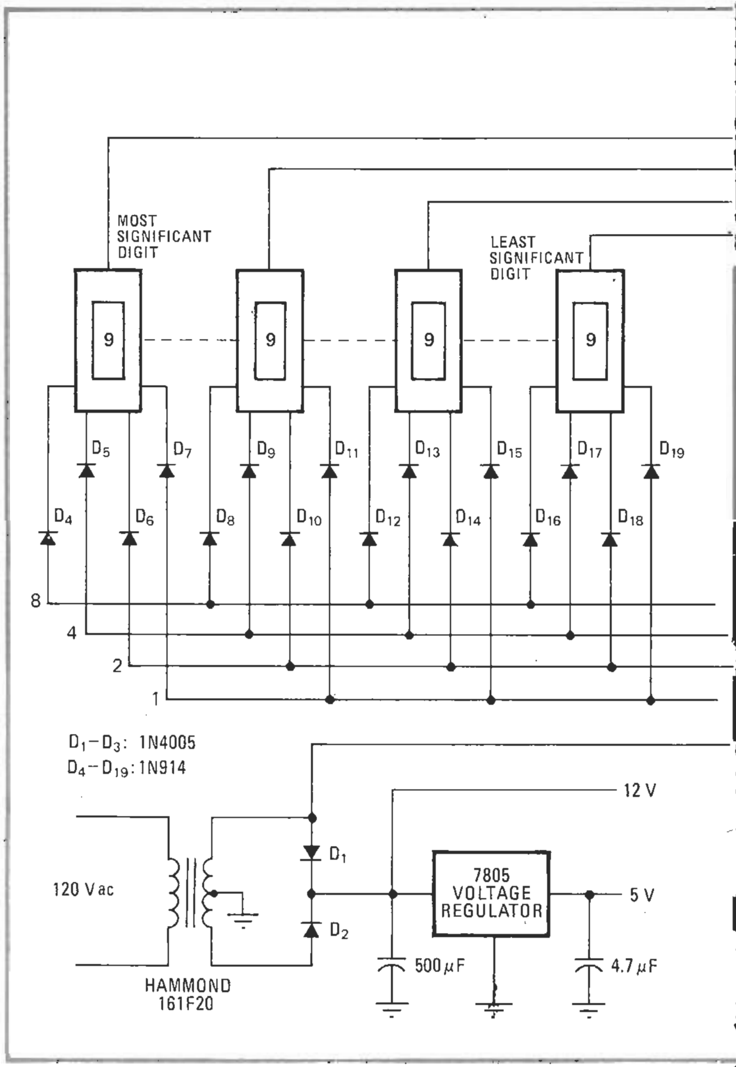
by Otto Neumann
Square D Canada, Waterloo, Ont., Canada

This digital timer (see figure) uses readily available complementary-MOS integrated circuits for low power consumption. It is simple and precise, and its timing sequences are set with four thumbwheel switches. Adding more frequency dividers to the clock input can extend the range from seconds to minutes to hours.

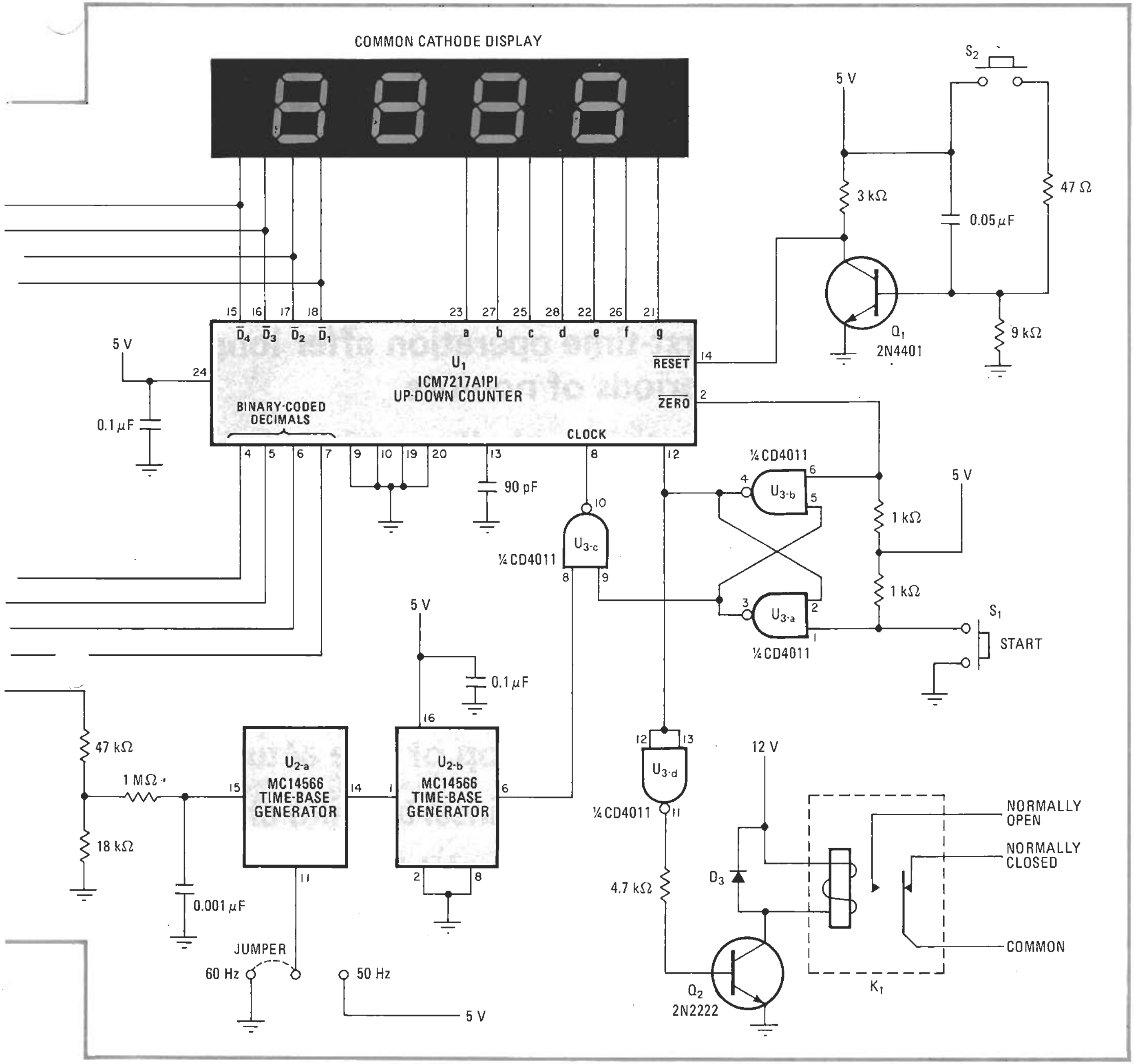
When the jumper on pin 11 of $U_{2\text{-a}}$ is tapped, the input frequency of 60 or 50 hertz is applied to $U_{2\text{-a}}$, which divides it by 6 or 5, respectively. $U_{2\text{-b}}$ further divides it by 10 to provide a pulse every second to the input of $U_{3\text{-c}}$. The timer starts counting down as soon as start switch S_1 is pressed. When counter U_1 reaches 0000, the low output on its pin 2 resets the flip-flop comprising $U_{3\text{-a}}$ and $U_{3\text{-b}}$, whose output in turn energizes relay K_1. The counter now reads the thumbwheel setting and shows it on the display.

When the counter starts counting, any changes in the thumbwheel setting will not affect the selected time because the counter is already loaded. Only after reset push button S_2 is pressed does the counter stop counting and return to the new setting. Transistor Q_1 and its components protect the reset input, which is susceptible to noise. Diodes D_4–D_{19} prevent crosstalk between the thumbwheel switches connected in parallel.

The internal oscillator frequency is 10 kilohertz and the scan cycle time is 400 microseconds when no capacitor is connected to pin 13 of U_1. The frequency can be reduced to 1 kHz by connecting a 90-picofarad capacitor from pin 13 to ground, causing the scan cycle time to increase. The common cathode display can be changed to a common-anode version by replacing U_1 with ICM7217IJI and reversing each of the D_4–D_{19} diodes. ☐



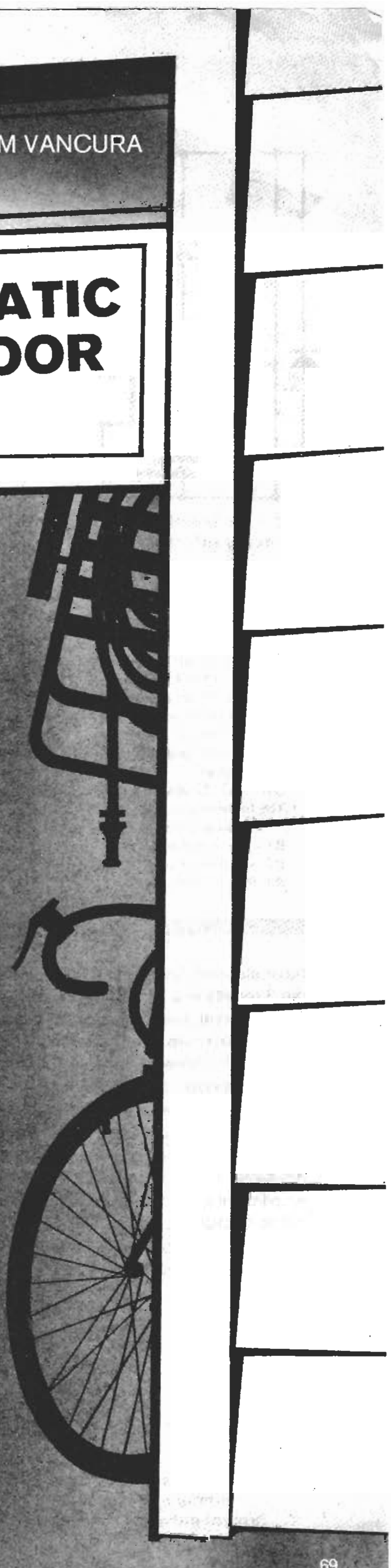
Timer. This digital timer uses C-MOS integrated circuits U_1 through U_3 to lower circuit power consumption. Frequency divider U_2 reduces the input frequency to 1 hertz, which is gated with flip-flop output to clock counter U_1. Thumbwheel switches set the desired time in seconds for the timer, which is initiated by pressing switch S_1.


COMMON CATHODE DISPLAY
U1
ICM7217AIPI
UP-DOWN COUNTER
BINARY-CODED DECIMALS
CLOCK
RESET
ZERO
5 V
0.1 µF
90 pF
3 kΩ
0.05 µF
47 Ω
9 kΩ
S2
Q1
2N4401
¼ CD4011
U3-a
U3-b
U3-c
U3-d
1 kΩ
S1
START
U2-a
MC14566
TIME-BASE GENERATOR
U2-b
MC14566
TIME-BASE GENERATOR
47 kΩ
1 MΩ
18 kΩ
0.001 µF
JUMPER
60 Hz
50 Hz
12 V
4.7 kΩ
D3
Q2
2N2222
K1
NORMALLY OPEN
NORMALLY CLOSED
COMMON

BY WILLIAM VANCURA

Simple circuit triggers electronic system to close garage door after selected time period.

AN AUTOMATIC GARAGE-DOOR CLOSER



THE STANDARD electrically powered radio-controlled garage-door opener has a drawback. It can be falsely triggered by a CB or amateur radio transmitter or other actuating signal, or the user can forget to send a signal command to close the door. In either case, an open garage door could invite thieves to remove valuable equipment—bicycles, lawn mowers, etc. The "Auto Closer" described here overcomes this problem. It automatically commands the system to close the door after a preselected time interval, providing improved security and convenience. The automatic function can be disabled by the user, too, in the event that it is desirable to keep the garage door open.

About the Circuit. The Auto Closer is shown schematically in Fig. 1. Switch *S1* is the door-position sense switch; it remains open as long as the garage door is closed. The open switch prevents the Auto Closer circuit from drawing current from the power supply and keeps it isolated from the rest of the door opener circuit. When the sense switch closes as the door opens, 24 volts ac from the main opener power supply is applied to the Auto Closer. Diode *D5* rectifies the ac into pulsating dc which is filtered by *C1* and *R3*. Zener diode *D1* provides +15 volts regulated for *IC1*, a CMOS 4020 14-stage binary counter.

When power is first applied to the Auto Closer, *R1* and *C2* momentarily keep pin 11 of *IC1* high, ensuring that the counter is reset as the timing cycle begins. A 60-Hz signal from the opener power supply is coupled by *R2* to the counter's CLOCK input. This clocking signal is peak limited by diodes *D2* and *D3*, thereby protecting the counter IC from excessive input levels. The outputs of the twelfth, thirteenth and fourteenth counter stages are available at pins 1, 2, and 3, respectively. When the counter is clocked by a 60-Hz signal, the periods of the square waves at these three outputs are 68 seconds (pin 1), 136 seconds (pin 2) and 272 seconds (pin 3). Each output is high for one-half of its square-wave period.

The time interval that the Auto Closer will hold the door open before automatically closing it is selected by connecting *R4* to one of the output pins of *IC1*. If, for example, *R4* is connected to pin 1, no base current will flow into *Q1* for 34 seconds and the garage door will remain open. At the end of that time, pin 1 will go high and source base current for *Q1* through *R4*. When *Q1* begins to conduct, the coil of reed relay *K1* becomes energized.

This causes the contacts of *K1* to place diode *D4* across the 24-volt ac line. The negative half-cycle of the ac control input is shorted out by the diode. This not only triggers the control circuit to close the door, but also allows the Auto Closer circuit to remain active until the door closes far enough to reopen sense switch *S1*. Capacitor *C3* is connected across the coil of *K1* to keep the relay from chattering and to protect *Q1* from inductive transients. When *S1* reopens, *R5* discharges the Auto Closer capacitors and effectively resets the circuit after a few seconds to ready it for another cycle. Cutout switch *S2* allows you to keep the garage door open for extended periods of time by effectively deactivating the Auto Closer.

Two other time periods are available. If *R4* is connected to pin 2, the garage door will be closed after 68 seconds

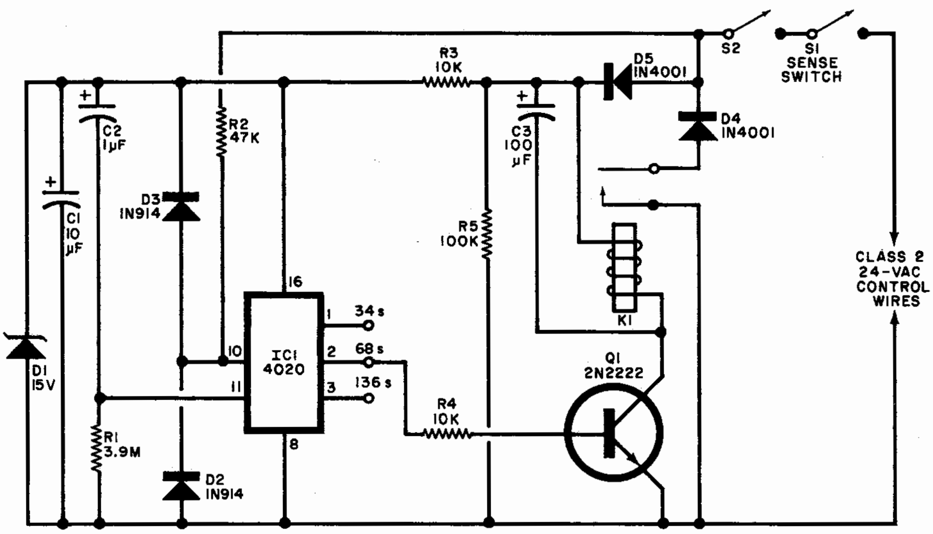


Fig. 1. Schematic of circuit. CMOS counter IC1 develops the delay interval from the 60-Hz line frequency.

PARTS LIST

C1—10-μF, 25-volt electrolytic
C2—1-μF, 25-volt electrolytic
C3—15-μF, 25-volt electrolytic
D1—15-volt, 400-mW zener diode
D2, D3—1N914 switching diode
D4, D5—1N4001 rectifier
IC1—CD4020 or MC14020 14-stage CMOS ripple counter
K1—12-volt reed relay (Arrow-M DA-1A or equivalent)
Q1—2N2222 npn silicon switching transistor
The following are ¼-watt, 10% tolerance carbon-composition fixed resistors:
R1—3.9 megohms
R2—47,000 ohms
R3, R4—10,000 ohms
R5—100,000 ohms
S1—SPST spring-loaded, normally open lever switch or other suitable door sense switch (see text)
S2—SPST toggle switch
Misc.—Printed circuit or perforated board, IC socket or Molex Soldercons, suitable enclosure, hookup wire, solder, machine hardware, etc.
Note—The following are available from William Vancura, 4115 35th Avenue, Moline, Illinois 61265: kit of parts, less enclosure and switches $15 plus $1 postage and handling; 12-V reed relay, $5 plus $1 P&H; etched and drilled pc board, $4 with SASE.

have elapsed. Connecting the resistor to pin 3 results in a 136-second delay. The latter interval is enough time for one person to move two cars out of the garage and into the driveway. A delay of 68 seconds is enough time to open the trunk, place a package in it, close the trunk, enter the car, buckle up, start the car once or twice and coax the car into the driveway. A 34-second delay is ideal for an efficient individual who moves quickly but is a cautious driver. Any time delay less than 34 seconds increases the possibility of hitting the door.

The Door Opener. A typical garage door opener employs a "Class 2" wiring system. Basically, this means that the control system comprises a low-voltage supply (usually 24 volts ac derived from a step-down transformer), a control relay which applies power to the motor, and one or more activating switches. The low-voltage power supply cannot cause any serious accidental shocks and permits the use of relatively inexpensive bell wire in connections to the activating switches and relay. A typical system schematic is shown in Fig. 2.

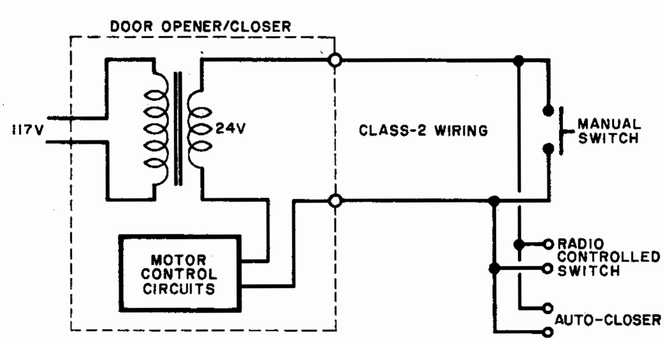


Fig. 2. Class 2 wiring of a typical garage door opener.

Several activating switches can be and usually are wired in parallel across the opener's control input terminals. The system schematic shows a manual pushbutton switch, a radio-controlled switch, and the Auto Closer so connected. Normally, the control circuit is designed to be able to supply power to several low-power switching devices via the Class 2 control wiring itself. This is how both the Auto Closer and radio-controlled switch's receiver are powered.

Construction. Wire-Wrap, point-to-point or printed-circuit techniques can be employed in the construction of the Auto Closer. Parts placement and lead dress are not critical. Although the printed circuit board (see Fig. 3) has been designed to accommodate a reed relay, a perf-board version of the project could use a standard low-power relay such as the Radio Shack No. 275-003.

In any event, use an IC socket or Molex Soldercons with the CMOS counter. Do not insert the IC into its socket at this time. Select the delay period suitable for your application and connect the lead of *R4* to the corresponding pin of the IC socket. Be sure to observe polarities and pin basing of semiconductors and electrolytic capacitors.

The Auto Closer should be housed in a metallic or plastic enclosure approximately 4" x 2¼" x 2¼" (10.2 x 5.7 x 5.7 cm). An on/off switch (*S2*) should be mounted on the enclosure if a remote power switch is not used. The mounting of the sense switch depends on how the door-open condition is to be sensed. One possibility is to install the switch in the Auto Closer enclosure and attach a lever arm to it. The arm can be extended to the door to sense the door-up position. Alternatively, you can replace the travel-limit switch of the motor control circuit with one that has an extra set of contacts. The normally open contacts can be used as sense switch *S1*.

If your garage door opener applies low voltage dc across the control lines instead of 24 volts ac, the Auto Closer circuit should be modified as follows. Replace *Q1*, *C3*, D4 and *K1* with a 1-ampere SCR. The anode of the SCR should be connected to the anode of *D5* and the pole of *S2*. The cathode should be connected to pin 8 of *IC1*, the bottom leg of *R5*, etc. The gate should be connected to *R4*, whose value and that of *R3* should be changed to 1000 ohms. Instead of connecting one end of *R2* to the *D5S2* node, apply 60-Hz CMOS-compatible square waves between it and pin

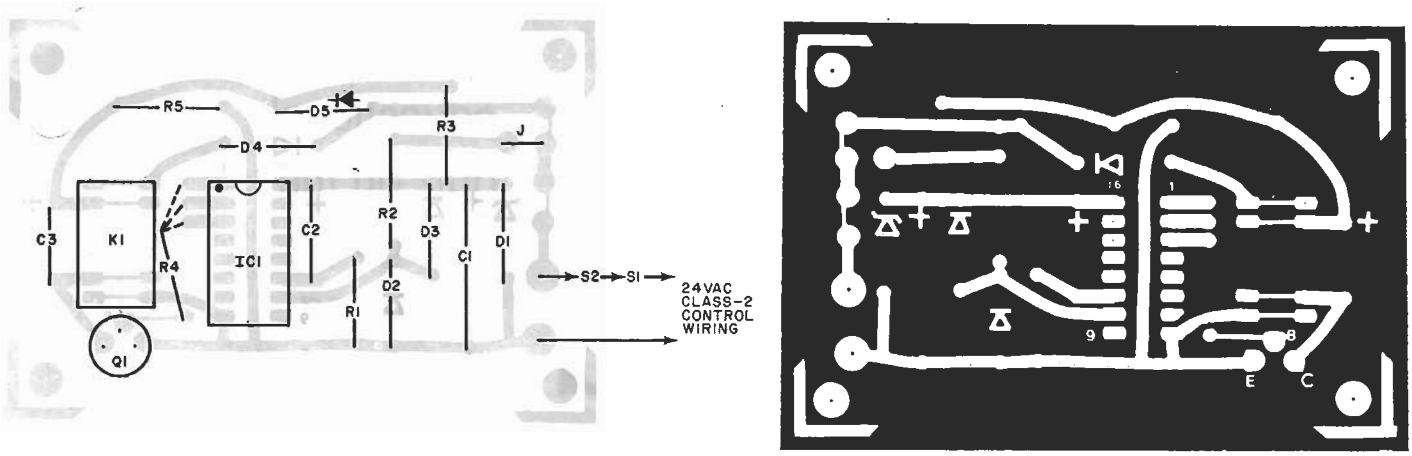


Fig. 3. Etching and drilling and parts placement guides for a suitable pc board.

8 of *IC1*. Zener diode *D1* can be eliminated if the dc control voltage is greater than (or equal to) 12 volts and less than 15 volts.

Checkout. After the Auto Closer has been assembled, but before the CMOS counter has been installed in its socket, temporarily connect one end of a convenient length (about 4 to 6 feet or 1.2 to 1.8 m) of hookup wire to pin 8 of the IC socket. Connect one end of a similar length of hookup wire to the anode of *D5*. Next, attach the two free ends to the Class 2 control wiring of the garage door opener and measure the ac voltage between the anode of *D5* and pin 8 of the IC socket. You should obtain a reading of about 24 volts. Measure the dc voltage between pins 16 and 8 of the IC socket. It should be about +15 volts. Finally, measure the voltage between pins 10 and 8. The meter should read about +15 volts in the dc mode and slightly more in the ac mode. If you have an oscilloscope, look at the signal waveform. You should see a sine wave clipped at 0 and 15 volts.

Momentarily clip a jumper between pins 16 of the IC socket and that to which R4 is connected. The relay coil should become energized and the door opener activated. Removing and replacing the jumper should cause the door opener mechanism to reverse its direction. If the relay chatters while the jumper is connected, the door will jerk back and forth and the Auto Closer will not reliably close the door. This problem can be caused by a defective *C3* or one with insufficient capacitance.

When the Auto Closer is working reliably, it is time to install *IC1* in its socket. The normal precautions should be taken when handling this CMOS device. Disconnect the Auto Closer from the Class 2 wiring and place the circuit board on a 10" x 10" (25.4 x 25.4 cm) sheet of aluminum foil. Also, place the IC (still in its protective foam carrier) and both hands on the foil, which should be grounded. Keeping the heels of both hands on the foil, remove the IC from its protective carrier and insert it into the socket, paying close attention to pin locations. Then permanently install the circuit board in the project enclosure. Reconnect the Auto Closer to the Class 2 control wiring.

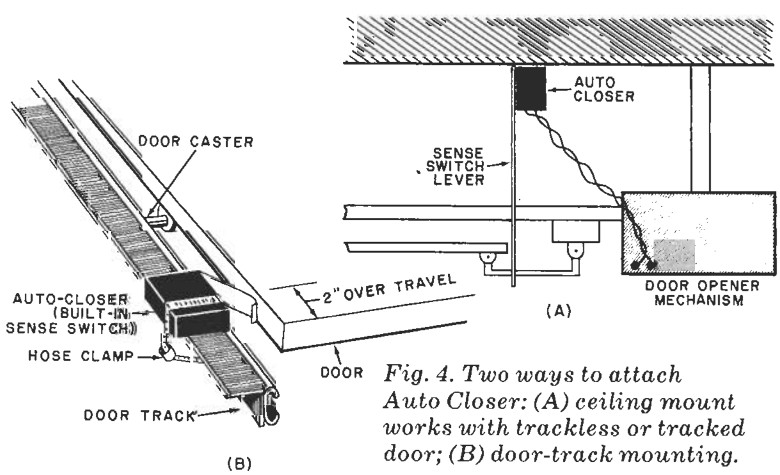


Fig. 4. Two ways to attach Auto Closer: (A) ceiling mount works with trackless or tracked door; (B) door-track mounting.

If all is well, the door (after having been opened) will begin to close only after the selected delay has elapsed. When the door begins to close, momentarily disconnect the Class 2 control wires from the Auto Closer so that the relay drops out. Each time the Auto Closer is disconnected, the counter will reset itself. Complete the wiring of the sense and power switches and verify the operation of both.

Installation. The Auto Closer is now ready for permanent installation. If a remote sense switch is used, the Auto Closer can be mounted in any convenient location. Just be sure that the control and sense switch wires are positioned so that they do not interfere with the proper operation of the door opener mechanism.

Two methods of mounting an Auto Closer equipped with a built-in lever sense switch are shown in Figs. 4A and 4B. The latter installation is less sensitive to minor variations in the stopping position of a door riding on tracks beside the sense switch lever. A slight bend at the tip of the lever arm prevents the door from snagging and damaging itself. The mounting method shown in Fig. 4B allows the project enclosure to be mounted easily on the door track using a 4" (10.2-cm) hose clamp. The ceiling mount (Fig. 4A) will work equally well with either a single-piece trackless door or a multi-section tracked door.

In Conclusion. You will surely find the Auto Closer to be a great convenience and an effective security device. Keep in mind, however, that you can very easily lock yourself out of the house should you forget your keys, the opener's pocket transmitter, or to disable the Auto Closer! ◇

NEW IDEAS

Model rocket launcher

MODEL ROCKETRY IS A FASCINATING HOBBY that is enjoyed by millions, young and old alike. It teaches the principles of aerodynamics and gravity, among other subjects, in a way that can't be duplicated by using a textbook or slide rule.

Model rockets are generally ignited by heating a nickel-chromium wire that is inserted into the engine so that it touches the propellent. The wire is heated by passing a current through it, and the usual power source is a standard lantern battery. The circuit described here adds some class to the launch procedure. It allows the user to move up to 300 feet away from the rocket (normally, you're limited to a distance of 10-15 feet). Among the advantages is that it aids tracking and recovery, not to mention safety. With a few modifications, the launcher could be used for such things as a timer, sequencer, or reflex tester.

The circuit, shown in Fig. 1, consists of two parts—the launch timer itself and an automatic-off timer. The heart of the launch timer is IC1, an LM3914 (National) bar-graph display driver. When power is applied to that IC, the countdown LED's sequence on until they are all lit. When the last one, LED1, is fully lit, transistor Q1 saturates, energizing RY2. When that happens, a circuit between the lantern battery at the launch pad and the nickel-chromium wire is completed; the wire heats up as before, and the rocket is launched. Resistor R4 and capacitor C3 determine the countdown timing; with the values shown it should be approximately 10 seconds. Resistors R3 and R5 set the LED brightness.

In a project of this type, safety is of the utmost importance. That's the purpose of the second half of the circuit. When RY2 opens, the current flow to Q2 is disrupted. But, because of the presence of R2 and C4 in the circuit, the transistor remains saturated for about 3 seconds. After that, however, the transistor stops conducting and RY1 is de-energized. That cuts off the power to the rest of the circuit, and RY2 de-energizes again, breaking the circuit to the launch pad. Speaking of safety, that's the purpose of S2—it is there so that the launch circuit can be disconnected from the timer; disconnecting that circuit eliminates the possibility of an accidental launch.

Operating the launcher is very simple. Switch S3 is used to reset the countdown. Once that is done, pressing S1 starts the launch sequence; the rest is automatic. Switch S4 is used to latch RY1 manually if needed. That's all there is to it.

The circuit can be built on perforated construction board using point-to-point wiring. Assembly is very easy (incidently, I'm only 13 and had very little trouble with it). As I said, with the values shown, the timing period is about 10 seconds; however, nothing in the circuit is very critical. Lead lengths should be kept as short as possible, however; if they get too long, oscillation may occur. To prevent that, C2 can be installed in the circuit as shown.

You can use any PNP transistor for Q1 and Q2, although the 2N404 seems to be a good choice. Switches S1 and S3 are normally open momentary pushbuttons. Switch S2 is DPDT, and S4 is SPST. The relays, RY1 and RY2, are SPDT, Radio Shack 275-004 or equivalent. The power source, B1, is 6 "C" cells wired in series—*John Miles*

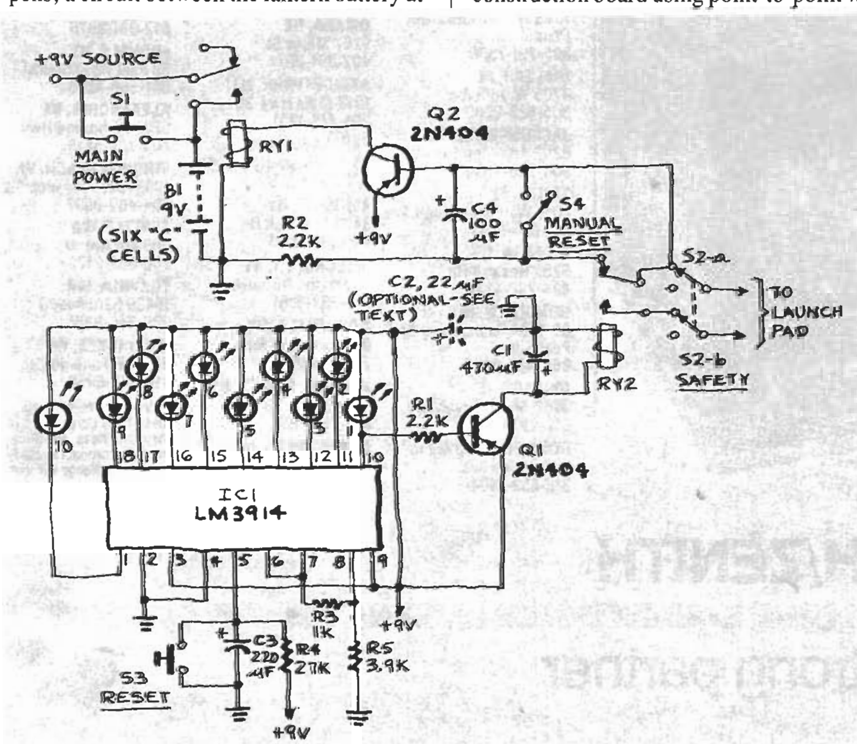


FIG. 1

Measuring the use time of interactive terminals

by Thomas A. Lutke
Bunker Ramo Corp., Falls Church, Va.

If you've ever tried to determine the actual use time of an interactive computer terminal, you already know what a troublesome task this can be. But, it's sometimes necessary to know, with reasonable accuracy, how long the terminal is actually being used to assess the load or amount of traffic on the terminal.

Generally, the terminal's use time is greater than the time recorded by the computer's central processing unit, but smaller than the total time that the terminal in on-line with the computer. One way for you to determine this figure is to keep a log sheet by the terminal and hope that it's filled in, rather than forgotten. Another way, one that eliminates the policing required by the log sheet, is to install a time meter that is actuated by a pressure switch in the seat of a chair used by the operator.

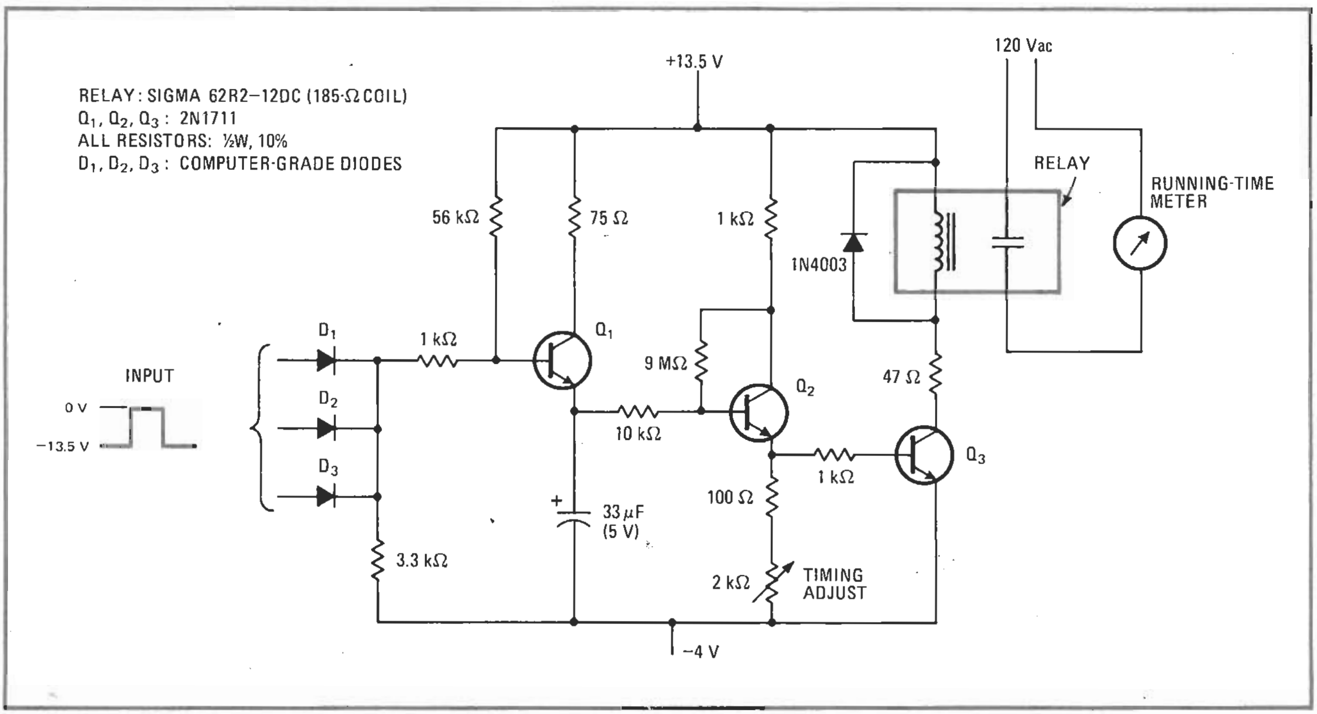
An even better method is to use the circuit in the diagram to drive a running-time meter. This circuit is conveniently activated by a 1-millisecond communications pulse or pulse train, which can be taken from the computer's interrupt line.

There is a delay between the time the input to the circuit resets and the time the meter is deactivated. This delay lets the meter run continuously all the while the operator is using the terminal, provided that he interrupts the computer often enough to keep the circuit from resetting.

An input pulse at either diode D_1, D_2, or D_3 turns on transistor Q_1, which in turn charges the timing capacitor. Now transistors Q_2 and Q_3 also conduct so that current is supplied to the relay coil, energizing the relay and running the meter.

When the input resets, transistor Q_1 turns off, and the timing capacitor discharges through the base of transistor Q_2. This reduces the base current to transistor Q_3 so that the relay is eventually de-energized. The circuit's timing, which can be varied from 1 to 50 seconds, is controlled by the 2-kilohm potentiometer. □

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.

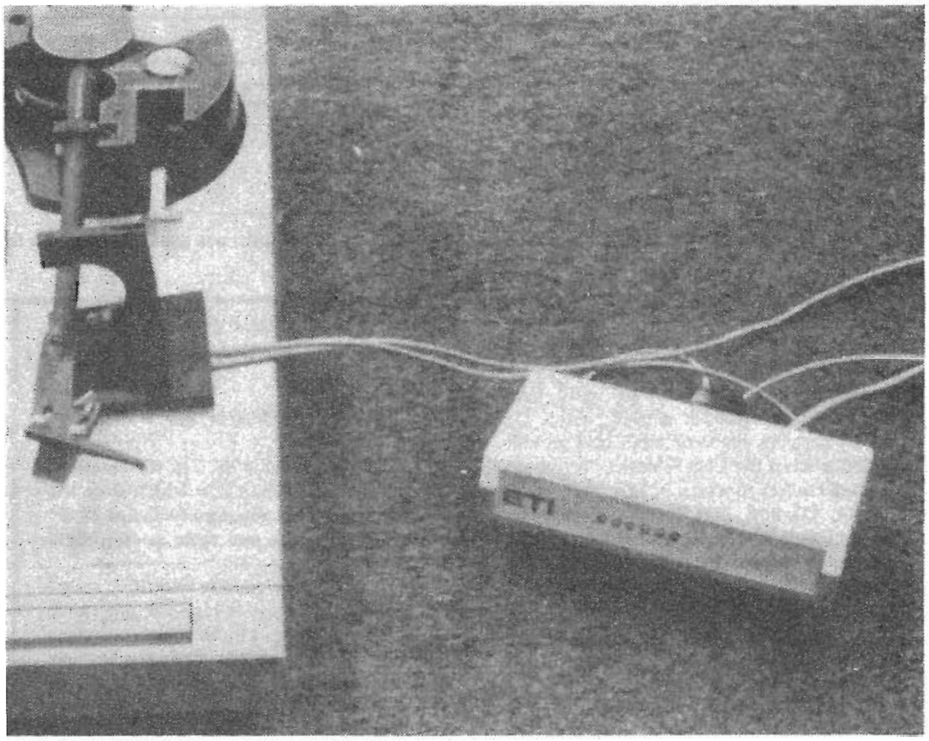


Making an accurate record. Circuit employs running-time meter to determine the actual use time of an interactive computer terminal. A pulse from the computer's interrupt line activates the circuit, so that the reading on the meter is reasonably accurate.

Stylus Timer Project

PROJECT

Do you play your records with a smoothly-contoured, precision-engineered, highly-polished stylus — or a worn-out nail? Check your playing hours with the ETI Stylus Timer. Design and development by Phil Walker.



FOR modern styli and cartridge combinations, the life of the stylus may run to many hundreds or even thousands of hours before replacement is necessary. The trouble is that even at five hours each and every day (which is quite a lot) it will take over six months to accumulate 1,000 hours playing time. If you are like us, you could easily forget whether you changed the old nail last week or last year, quite apart from knowing how long it has been used since then.

Don't worry, help is at hand — this device is designed to measure the total number of hours your stylus has been in use since you last changed it and give some indication of that measurement.

The device has six LEDs which, in the basic configuration, change every 167 hours, totalling 1,000 hours. This could be used to indicate that a check on stylus condition would be carried out either at home or by your local dealer. When the last one comes on it will stay on until the device is reset (assuming the power is on).

As mentioned above, the basic design allows for 167 hours per step, the last one occurring after 1,000 hours. This can be modified to 330, 400, 830, or even 1,700 hours per step giving replacement times of up to 10,000 hours for the very lightest equipment (or Scrooges), or 83 hours per step if your equipment is a little heavier than some or you want to keep your stylus in tip-top condition all the time.

In order to eliminate dependence on mains supplies when the equipment is not in use, the device contains a rechargeable battery which provides the microamp or so needed to keep the CMOS devices active. Also, the LED display is turned off when not required to conserve battery power. To prevent accidents, the reset facility is disabled when the device is on standby.

Designs Discussed

The circuit uses standard CMOS integrated circuits for most functions in order to keep the standby power as small as possible. This enables us to use a 8V4 rechargeable Ni-cad battery ensuring that with intermittent use the device should operate almost indefinitely. (In fact a normal dry-cell 9V battery will give a very long life but may not like the charging current flowing into it via R7).

The power for the LED display and the timing signal for the logic are taken from the AC input. This is any 60 Hz voltage source giving between 12 and 20 V at about 50 mA. For preference this supply should be switched with the turntable or equipment mains supply.

The first method of detecting stylus use we considered involved detecting the presence of a music signal from the pickup. However, if the signal was tapped off after the RIAA preamp, we realized the project couldn't be built by readers who lacked the confidence to muck about inside their expensive commercial hi-fi. On the other hand, putting the project between the deck and the preamp would lead to the knotty design problem of not degrading the pickup performance. Thus we opted for a mechanical solution, but adventurous readers may care to adapt this project for their own needs. Note that we CANNOT give any technical advice if you do try it.

The circuit operates by detecting when the tone arm is away from its rest position and then allowing the rest of the circuit to count at 60 or 120 Hz. The 60 or 120 Hz is divided by about 72 million in order to driver the final counter at one pulse every 167 hours. The already decoded outputs of this device (IC5) are used by the output drive (IC6) to power the display.

The final counter (IC5) has ten decoded outputs of which only the first six are used. These control IC6 and thus the display. When the sixth output of IC5 goes high, it disables the counter chain causing the sixth LED to remain on indefinitely.

IC6 contains six inverting buffers which have three-state outputs. This facility is used to switch off the LEDs and conserve power.

A transistor (Q2) was used in the standby battery circuit so that when operating from the AC input, the supply voltage to the ICs was a little different to that when operating from battery alone.

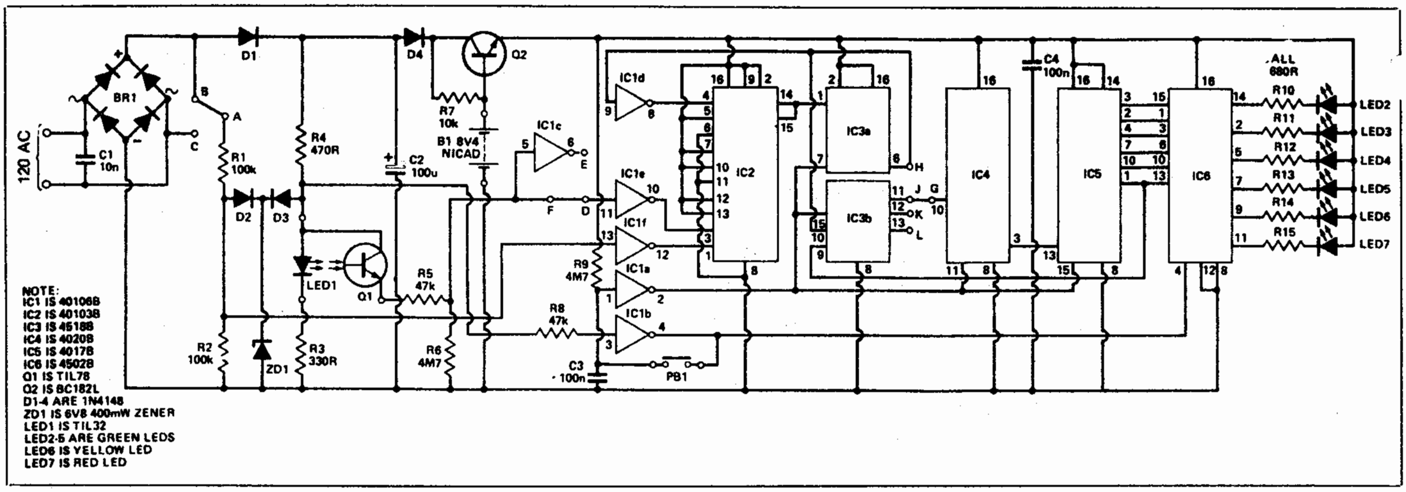


Fig. 1. Circuit diagram of the ETI Stylus Timer. The various lettered links are used to select the timing period (see text).

HOW IT WORKS

The 60 Hz power input is rectified by BR1 and charges C2 via D1. Q2 and R7 form a simple voltage regulator using the battery B1 as a reference. If there is no AC input, then D6 isolates the rectifier circuitry from Q2 and B1 supplies the very small bias current needed to keep the CMOS devices active via the base-emitter junction of Q2.

R4, D3 and ZD1 form a moderately stable voltage for the optical sensor and an input to the power detection circuitry IC1b. The output from the optical sensor (LED1 and Q1) is taken via R5 and R6 to IC1e either directly or via IC1c. This allows the circuit to operate with either an open or blocked light path as required.

Depending on the position of link A-B or A-C a 60 or 120 Hz signal will be applied to IC1f. The voltage of this signal is limited to R1, R2, D2 and ZD1 to prevent damage to IC1.

IC2 is connected such that it divides by 220 or 219 as determined by the input from IC1d. This is accomplished by the device loading its internal eight bit counter with the binary number on its inputs each time it reaches a count of zero. In this case the most significant seven bits are wired to 1101101X = 218_{10} while the least signficant bit (X) is switched between 0 and 1. The output from this stage drives IC3, a dual decade divider. The Q4 output from IC3a controls the division ratio of IC2 as outlined above. As the Q4 output is only high for two clock periods out of 10, the effective division ratio of IC2 is:

$$8/10 \times 220 + 2/10 \times 219 = 219.8$$

IC3b is used to divide by 2 in the standard circuit and then drives IC4 which does the rest of the division required (a factor of 2^{14} or 16384) to give a one cycle in 167 hours signal.

IC5 is a decade counter with 10 decoded outputs. Each output is high for one clock period of the 167 hour input signal (or longer if counting is suspended). Only the first six outputs are used to drive IC6 and the sixth output also inhibits IC3b to prevent further counting. IC6 is a hex buffer with three-state outputs which have a fairly high impedence state by a signal on pin 4. This facility is used to prevent the LED display taking current while the AC supply is off.

The reset switch PB1 is connected in an unusual place so that it can only pull the input to IC1a low when the power sense circuit indicates that the AC supply is present. When operated, the reset circuit applies a high logic level to the reset inputs of IC's 3, 4 and 5 for about a second. IC2 is not reset and will cause an error of two or four seconds in the timing, but in a hundred hours or so, this is not significant.

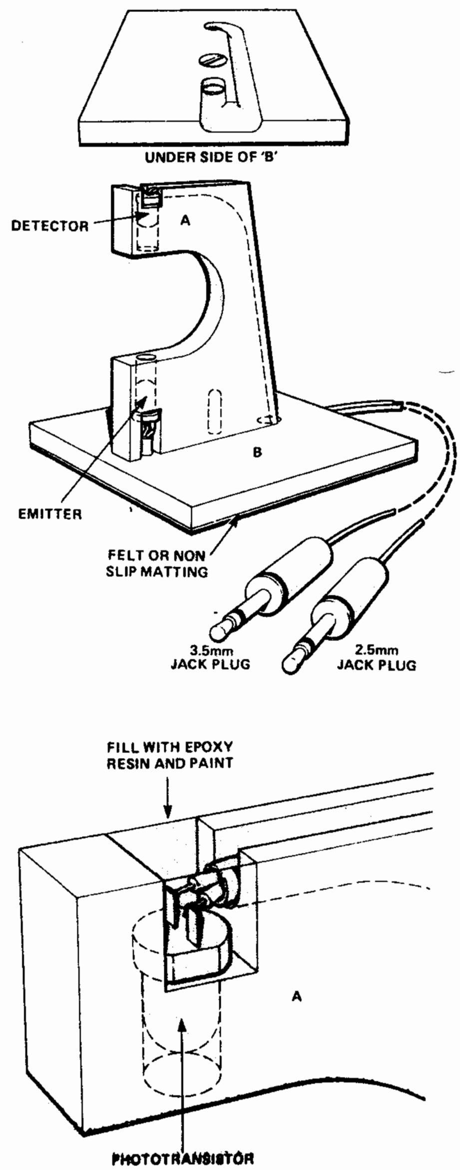


Fig. 2. Constructional details of our sensor. Using different sized jack plugs will prevent incorrect connection.

Also the LED voltage can be stabilized at the correct value. The configuration allows the battery to be trickle-charged from the same supply.

Construction

The construction of the main unit is straightforward if a little fiddly on account of its small size. Assemble the components onto the PCB including the three links but excluding LED 2-7. Place the assembled PCB in the bottom of the box and align it over the wider spaced fixing holes with C2 next to the space for the battery. Mark the positions for the LEDs on the front panel and the jack sockets and PB1 on the back panel. Also mark a position for the power cable grommet. Drill all these holes in sizes to fit your components.

Wire up the switch and sockets. The common connection from R4 on the board should go to the sleeve connections on the jack sockets to prevent accidental short circuits via the panel. The LEDs should now have their leads bent so that they will go into the board while the LED body protrudes through the panel. Finally connect the battery connector and the AC power lead. The latter should be a twin lead shielded cable terminated in a three pin DIN plug or similar to pick up the supply.

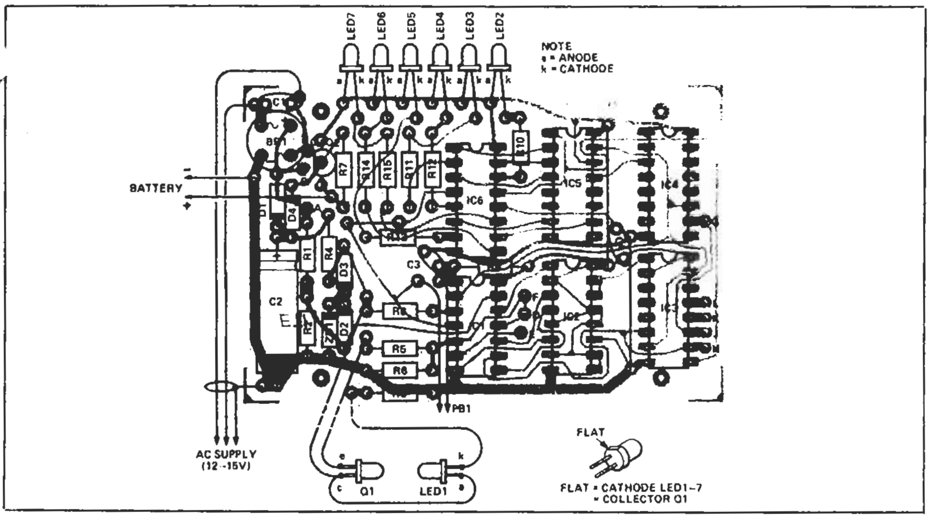
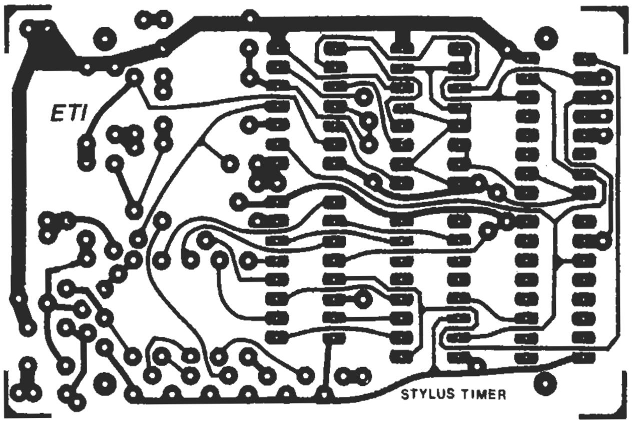


Fig. 3. Component overlay.



The Sensor

The purpose of the sensor housing is to hold the emitter and receiver in line and exclude some of the ambient light. Our sensor was constructed from an offcut of black Plexiglas about 90 × 55 × 55 mm). A U-shaped slot was cut out of the longer side of the smaller piece; then a hole was drilled in the thickness of the material in both legs of the U to take the optical devices and hold them in line. The back edge of the U was slotted to take the shielded wire from the phototransistor.

Three holes were drilled along the centre line of the other piece of Plexiglas; two to take wires and one to take a mounting screw. The underside of the base piece was channelled out using a rasp attachment in a hobbyist drill to conceal the wires.

The sensor device is mounted in the top hole to reduce the amount of ambient light reaching it. The screened wire from the phototransistor is run along the slot in the plastic and down the hole in the base. The slot can be filled with resin and painted when finished.

If a small three-way connector can be obtained, this could be used in place of the two jacks and a single length of shielded cable would suffice to connect the sensor.

Power Supply

The AC power supply is very simple and consists of a small transformer, fuse, neon indicator and three pin DIN socket mounted in a small box. Construction is very straightforward and, if the specified box is used, most small 6 VA transformers will fit onto the moulded pillars in the box, obviating the need for external screws.

Use and Modifications

To use the stylus timer, the sensor should be positioned so that the tone arm interrupts the light beam when it is in the rest position. Make sure that it does not foul the arm at any time if you have any sort of automatic control.

If possible, the AC power supply for the device should be obtained from your system. Anything from 12 to 15 V AC may be used without modification. Up to 25 V may be used, but R4 and R7 should then be 1k0 1 W and 27k respectively. If the supply is greater than 25 V, one side of any available supply is grounded, or if you prefer not to tamper with your system, then use the simple power supply described.

With the sensor in position and a suitable AC supply connected, press the reset button on the unit. The first green LED should light and stay lit for 167 hours of playing time, followed by the next LED until the red LED lights to indicate replacement overdue. If the power supply is switched off at any time, the accumulated time is stored until the power is restored.

Other time intervals can be used in the device by changing the link positions. Changing A-B to A-C doubles the time period. Changing G-J to G-K or G-L increases the interval by 2½ or 5 respectively while changing it to G-H halves it, although it will not stop on the last count as before. In some of these other positions the intervals between the lighting of each LED may not be as regular as before (especially G-K). If it is desired to have counting enabled when the light path is obstructed, then link D-F should be changed to D-E.

PARTS LIST

Resistors (all ¼W, 5%)	
R1,2	100k
R3	330R
R4	470R
R5,8	47k
R6,9	4M7
R7	10k
R10-15	680R
Capacitors	
C1	10n ceramic
C2	100u 40 V axial electrolytic
C3,4	100n ceramic
Semiconductors	
IC1	40106B
IC2	40103B
IC3	4518B
IC4	4020B
IC5	4017B
IC6	4502B
Q1	TIL78 IR receiver
Q2	BC182L, 2N3904, etc.
D1-4	1N4148
ZD1	6V8 400 mW zener
BR1	50 V, 1 A bridge rectifier
LED1	TIL32 IR transmitter
LED2-5	2 mm green LED
LED6	2 mm yellow LED
LED7	2 mm red LED
Miscellaneous	
PB1	subminiature push-button
B1	8V4 Ni-cad

PCB battery clips; case 125 × 65 × 30 mm (Vero 75-2682A); 3.5 and 2.5 mm jack plugs and sockets; three pin DIN plug (if required to connect to power unit); thin twin cable; small grommet; 100 × 55 × 6 mm acrylic sheet.

AC Power Unit (If Required)
12 V, 6 VA mains transformer; 100 mA fuse and fuseholder; mains neon; case 125 × 65 × 50 mm (Vero ref. 75-2684B); three pin DIN socket; line cord; grommet; solder tags.

ETI

BY M. T. VALESCU

AN APPLIANCE "OFF" REMINDER

A low-cost project provides an audible alert when an appliance indicator light goes off

IT IS often useful—sometimes vital—for the user of an appliance to know if and when it ceases to operate, whether by design or due to a power failure. Usually, this is not difficult to accomplish, since most appliances are equipped with indicator lights that show when they are working. But if the appliance is not in direct view, keeping track of it can be a great annoyance.

One solution to this problem is to use an electronic "eye" that senses the radiation from the indicator light and sounds an alarm when it is interrupted. For convenience, only the sensor is required to be physically at the monitoring point; the alarm can be located where it is easily heard.

The Lights-Out Alert described here provides the answer. It is battery powered and reliable; can be built from low-cost components; and is usable with almost any sort of power-on light indicator.

Circuit Operation. As shown in Fig. 1, phototransistor *Q1* and Darlington-connected *Q2* form a high-gain optical-to-electrical transducer that drives a charge pump made up of *Q3* and *Q4* and associated components.

When no light strikes *Q1*, its resistance should be high enough so that *Q2* is cut off. Any slight leakage from *Q2* should produce less than 0.7 volt across *R1*—not enough to turn on *Q3*. Assuming that capacitor *C1* has been discharged by the operation of *S1*, *Q4* also lacks the voltage required to turn it on. Thus, all four transistors are off and current from the battery is almost nil.

When light strikes *Q1*, its resistance drops, depending on the illumination level, and *Q2* is turned on. The voltage developed across *R1* turns *Q3* on provided *C1* is discharged. Thus *Q4* is driven deeper into cutoff. Current flows through *Q3* and *R2* to charge *C1*. When the voltage across *C1* rises to within 0.7 volt of that across *R1*, *Q3* is cut off. This condition will last as long as transistor *Q1* is illuminated.

When the illumination ceases, the voltage across *R1* drops. Since *C1* is charged high enough to reverse-bias *Q3*, this transistor cuts off and turns on *Q4*. Discharge current from *C1* now flows through *R2* and *Q4* to drive alarm *A1*.

After some time (about one minute per 10,000 microfarads of *C1*), *C1* becomes discharged and the alarm turns off. The circuit is then ready for the next illumination period, with no current drawn from *B1*. Switch *S1*, in conjunction with *R3*, provides manual silencing of the alarm. This switch should not be operated during the charging cycle of *C1* because this will tend to deplete the battery's charge.

Construction. The circuit consists of two physically independent sections—the light-sensitive portion and the alarm/power package, with the two interconnected by a length of flexible four-conductor cable.

The four transistors and two resistors that form the photosensor can be assembled on a small piece of perforated board or a small printed-circuit board. Make sure that the sensitive face of *Q1* is in the clear so that light can pass through a hole in the case and shine on this surface. Select a low-leakage device for *Q2*. If phototransistor *Q1* is a low-gain device (units vary with manufacturer), increase the value of *R1*. However, to avoid false alarms do not make the circuit too sensitive.

The board can be mounted in a small enclosure having a hole drilled so that external light can fall on the sensitive face of *Q1*. Another small hole can be used for the four-conductor cable. The alarm/power elements are mounted in a separate enclosure with holes near the alarm so that it can be heard.

To test the project, expose the photosensitive surface of *Q1* to an ordinary household light bulb at a distance of about 18 inches. When the light source is removed, the alarm should sound for approximately one minute. Changing the value of *C1* changes the alarm-on time. The alarm can be silenced by operating switch *S1*. ◇

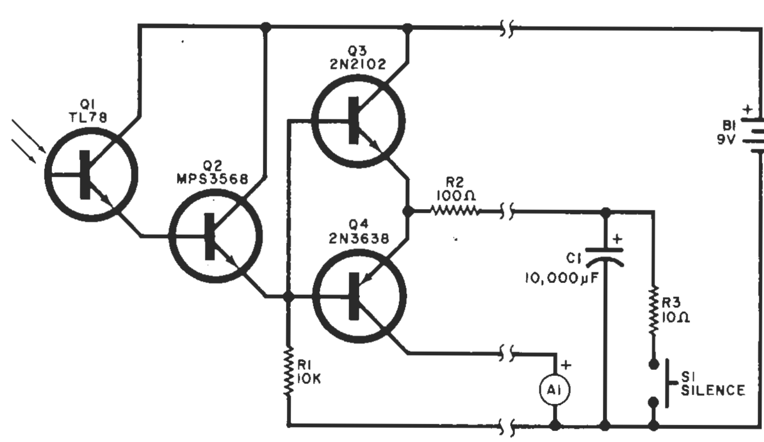


Fig. 1. Phototransistor Q1 senses when the light impinging on it goes off. The signal is then amplified to energize alarm A1.

PARTS LIST

A1—Alarm (Sonalert SC628 or similar)
B1—9-volt battery
C1—10,000-µF, 10-V capacitor (see text)
Q1—TL78 phototransistor (Radio Shack FPR-100)
Q2—MPS3568 transistor (Radio Shack S0015)
Q3—2N2102 transistor (Radio Shack S5026)
Q4—2N3638 transistor (Radio Shack S0029)
R1—10,000-Ω, ¼-W resistor
R2—100-Ω, ¼-W resistor
R3—10-Ω, ¼-W resistor
S1—Normally open pushbutton switch
Misc.—Length of four-conductor cable, suitable enclosures, perf board, printed-circuit board, mounting hardware, etc.

10 Short Projects

Eggtimer

by A. Flind

In the circuit of Fig. 1, IC1a, b, and c form the timer. Pressing S1 discharges C2 and sets the timer running. RV1 sets the oscillator's rate and is used as a calibrator to set the range. When the timer completes its run, IC1c's output goes low. This pulls IC1d's input low via C3, and its output goes high and stays high for about 5 seconds, until R5 manages to charge C3 sufficiently to take it low again. While it is high, the oscillator comprising IC2c and d is able to run, producing an audio tone. This completed the circuit as specified, but left two spare gates available in IC2. It seemed a shame to waste them, so they have been wired to form a second astable, IC2a and b, with a frequency of about 2 Hz, gated on while the timer is running. The outputs of the two astables are fed to the output stage, so the net result is a quiet ticking noise while the circuit is running, culminating in a 5 second bleep when the time is reached. D3 and D4 cause the output to consist of short pulses rather than a square wave, as this greatly improves battery economy. R14 keeps the volume to a reasonable level.

A large piece of Vero was used to hold all this circuitry, 24 strips of 50 holes. Fig. 2 shows the 48 breaks, and Fig. 3, the component layout, including 23 links. Wire RV1 to decrease resistance when rotated clockwise. RV1 and RV2 then both increase the period for a clockwise rotation. To set the circuit up, turn RV1 fully anti-clockwise (minimum period) and adjust RV2 to provide a time of just under one minute. Then check that RV1's maximum setting gives over 6 minutes. The control can then be calibrated by trial and error for times of 1 to 6 minutes. The current drawn by this circuit is minimal at all times, even when giving the output tone it is no more than 5mA, so a 9 V battery should last for a very long time.

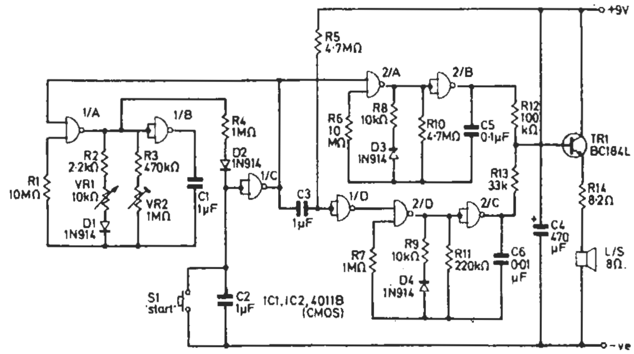
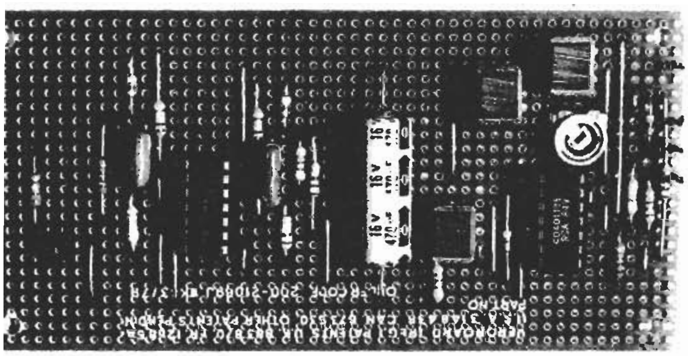


Fig. 1. Eggtimer circuit.



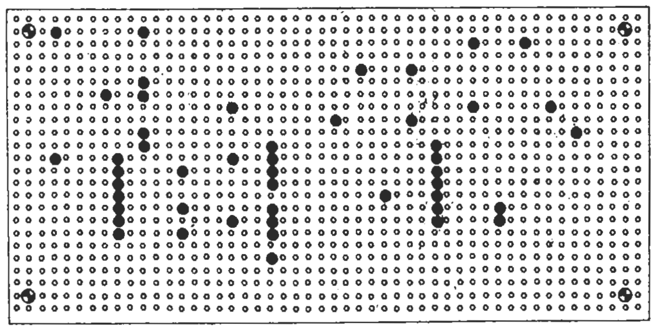
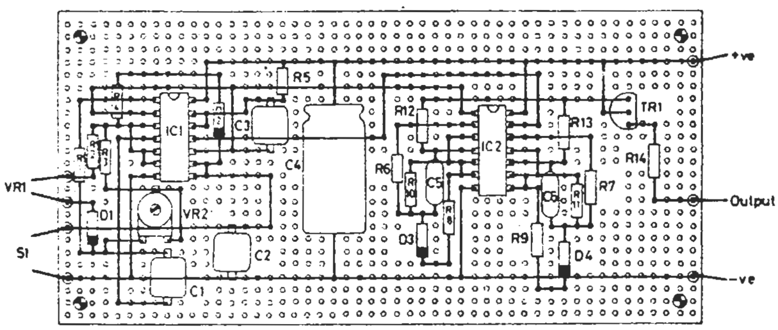


Fig. 2. Eggtimer, copper side.



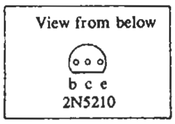


Fig. 3. Eggtimer, component layout.

continued on page 51

Using the 4060 as a Timer

BY T.A.O. GROSS

MENTION timing circuits, and most people tend to think of the ubiquitous 555 IC. While the 555 is excellent for most timing applications, other devices are worthy of consideration. These are the CMOS CD4060A and SCL4060AB 14-stage ripple-carry binary counters from RCA and Solid State Scientific, respectively.

Among other advantages, the 4060-series devices can be less expensive to implement in a given application because they require less critical and less expensive resistors and capacitors. A second advantage is that 4060-series devices can deliver a number of output frequencies from the same RC components; the 555 delivers only one.

Technical Details. In a 555 timer circuit, external frequency-determining resistor and capacitor values must be selected to produce the desired oscillator frequency directly. As a result, in many cases where relatively long time constants (low frequencies) are desired, the RC product requires the use of bulky, expensive electrolytic capacitors with, often, inaccurate values and high losses.

Devices of the 4060-series use oscillator frequencies much higher than what is required at the output. The oscillator frequency goes through a 14-stage binary counter that divides it by as much as 16,384 (2^{14}) before it is used as the final timing frequency.

Using a much higher oscillator frequency than the 555 timer to obtain the same timing frequency the 4060 has a correspondingly smaller RC product. Hence, there is no need to use inaccurate and unstable electrolytic capacitors or humidity-sensitive, very-high-value resistors.

While the CD4060A and SCL-4060AB are interchangeable in most cases, the two are different. In the CD

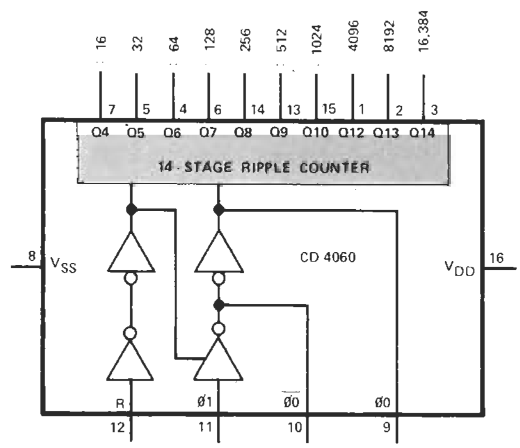


Fig. 1. Internal schematic arrangement of the RCA CD4060 timer integrated circuit.

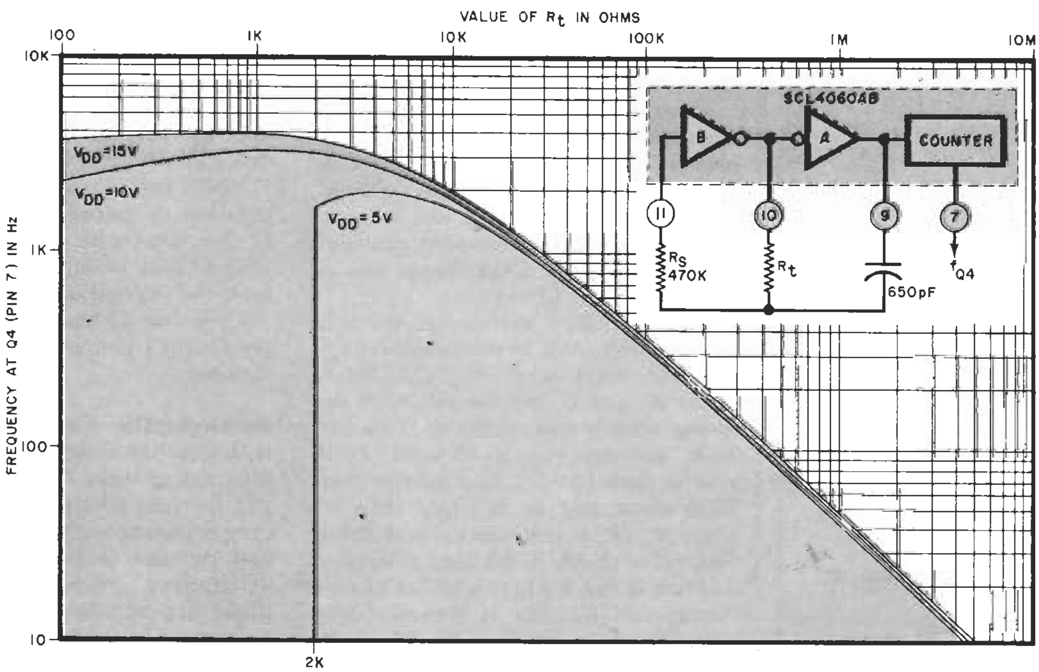


Fig. 2. With low values of timing resistor, R_t, the frequency of the circuit can vary with applied dc operating voltage.

device, the oscillator is keyed by the reset input, whereas in the SCL device, the reset operates on the dividers, leaving the oscillator in continuous operation.

Basic internal logic of the CD4060A is shown in Fig. 1. Two of the four inverters serve as the active elements of the internal oscillator whose output is passed through the 14-stage ripple-carry binary counter. Oscillator frequency is set by an RC network, or an external crystal oscillator can be connected to pin 9 to eliminate the need for the internal oscillator. When the internal oscillator is used, the input at pin 12 is provided to reset the counter to zero and disable the oscillator.

It is not necessary to use all 14 stages of division. As shown in Fig. 1, you can select division factors of 16, 32, 64, 128, 256, 512, 1,024, 4,096, 8,192, or 16,384, simply by picking off the output from the appropriate pin of the IC.

Timing resistance values of 4060-series devices should not be less than 10,000 ohms to avoid changes in frequency with changes in applied dc operating voltages. As can be seen in Fig. 2, the frequency/resistance function reverses at about 4500 ohms with a 5-volt supply and at 1300 ohms using 10 volts.

The frequency calculation formula for the 4060 given in manufacturer application notes is $F = 1/(2.2R_tC_t)$, where R_t and C_t are the values of the timing resistor and capacitor. This formula assumes V_{DD} is 10 volts, C_t is greater than 100 pF; R_t is greater than 1000 ohms, and R_s is larger than 10 times R_t. (R_s is the external stabilizing resistor, as shown in the inset schematic diagram in Fig. 2.) In this author's experience, this formula is accurate only when R_t is greater than 50,000 ohms. With values less than 50,000 ohms, observed frequency was lower than predicted by the formula.

Data given in Fig. 2 was obtained at the pin-7 (÷16) output from an SCL4060AB. With time delays of more than a few hours, it was determined that use of R_s is not necessary.

Practical Timer. Shown schematically in Fig. 3 is the circuit for a practical 1-minute timer built around a 4060-series device. A 330,000-ohm resistor and 0.01-μF capacitor are doing a job that would require a 60-megohm/microfarad *RC* product in a 555 circuit.

and

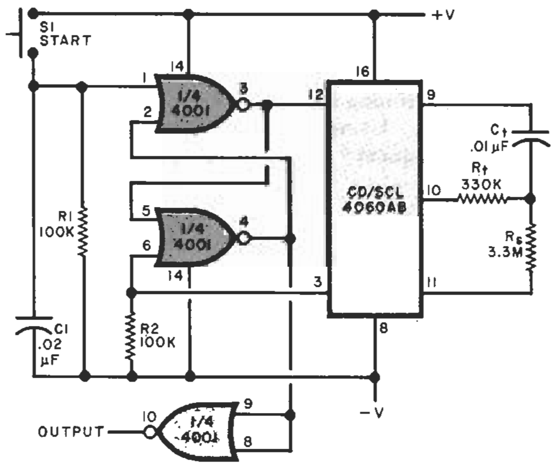


Fig. 3. With the values shown, this circuit has a one-minute delay period. The output strobe goes high after timeout.

Momentary closure of START switch *S1* causes the set-reset flip-flop made from two gates in a 4001 quad 2-input NAND IC to produce a high output at pin 12 of the 4060. After the timing interval (oscillator frequency) determined by R_t and C_t, pin 3 of the 4060 goes low and toggles the flip-flop to stop the counter. At the same time, the output of the bottom 4001 gate, held low during the timing interval, goes high. (Since the 4001 contains four on-chip gates, the fourth gate can be paralleled with the output stage to provide more driving current for an external circuit.)

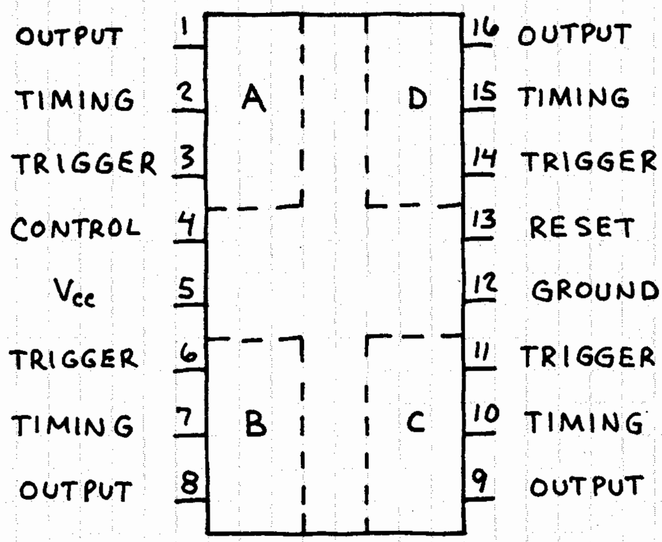
Much longer timing intervals can be obtained by cascading the pin-3 output of the 4060 with a 4020, a 14-stage counter that is similar to the 4060 but lacks the internal oscillator.

Capacitor *C1* and resistor *R1* improve the circuit's immunity to noise and are optional.

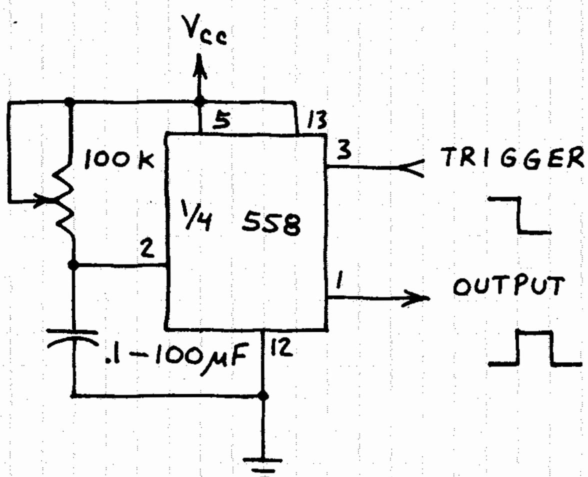
Summing Up. Once you start working with 4060-series devices, you will probably think of them as often as you do the 555 for your timing applications. Their easy implementation into circuit designs and reduced demands on frequency-determining resistors and capacitors make them particularly attractive where costs must be kept down and hardware space is at a premium. And they offer a number of different output frequencies from a given RC network that gives them an important advantage over single-frequency-only timing devices. ◇

QUAD TIMER
558

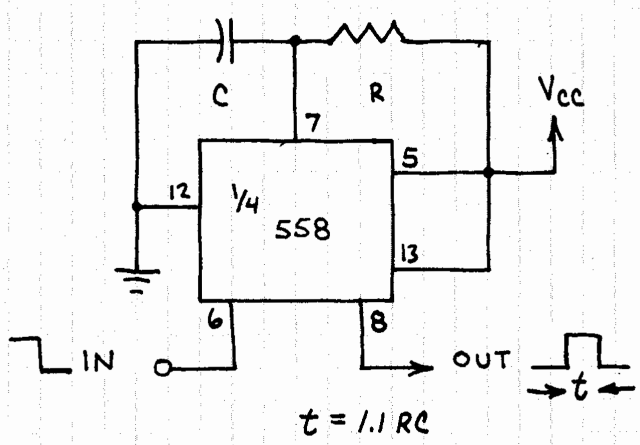
CONTAINS FOUR INDEPENDENT MONOSTABLE TIMERS. EACH TIMER IS SIMILAR TO PART OF A 555 TIMER. ASTABLE OPERATION POSSIBLE WITH ONE TIMER. V_{cc} = +4.5 TO 18 VOLTS. CONTROL AND RESET PINS ARE COMMON.



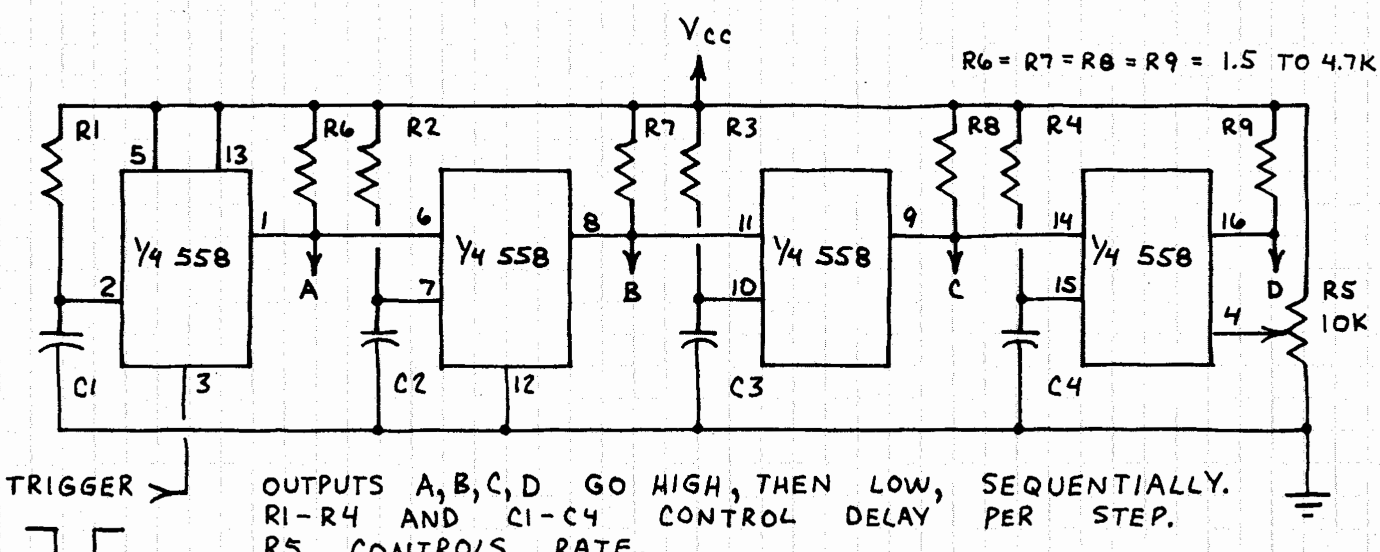
BASIC TIMER



ONE-SHOT



PROGRAMMABLE SEQUENCER



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

CHESS TIMER

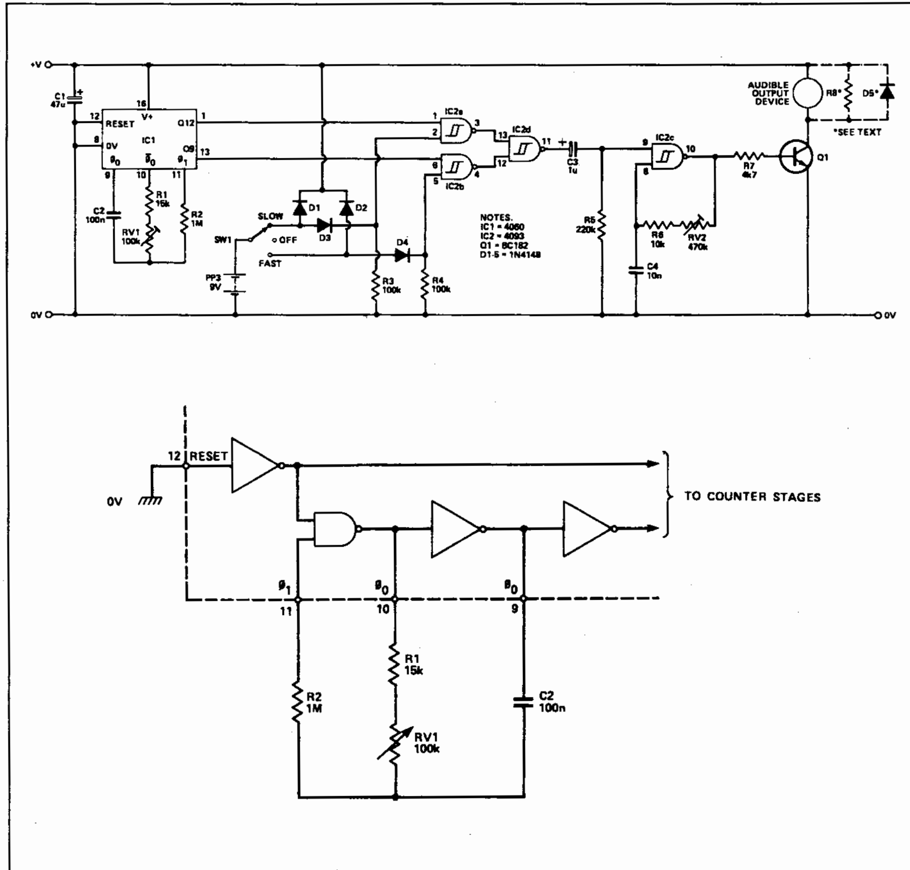
THE oscillator is a standard circuit, and the values of C2, R1, R2 and RV1 have been chosen to give an output frequency in the range 40-320 Hz. The rest of the 4060 is a 14-stage binary counter with the outputs from every stage being available — except for stages 1,2,3 and 11.

Since so many outputs are available, two speed ranges are provided by utilizing the Q9 and Q12 outputs. For the fast range, this gives intervals between 'buzzes' of approximately 1.5-12 seconds, and for the slow range of approximately 12-96 seconds.

Choosing to use different outputs of the 4060, one can of course have other ranges if one wished, Q10 giving half the speed between Q9 and Q12 is achieved by IC2a and IC2b.

Diodes D1, D2, D3 and D4 are included so that a single pole centre-off switch can act as both speed-range select and on/off. When the switch is in the slow position, power supply current flows through D1 and pin 2 of IC2a is taken to a high logic level via D3.

If a piezoelectric transducer is used, it may be necessary to fit R8, and this will have to be chosen by experiment to match the chosen transducer. The other possibility is to use a small loudspeaker, and under these circumstances, R8 will become diode D5, and will need to be fitted as shown.



The Chess Timer will sound between 1.5 and 96 seconds.

Achieving linear control of a 555 timer's frequency

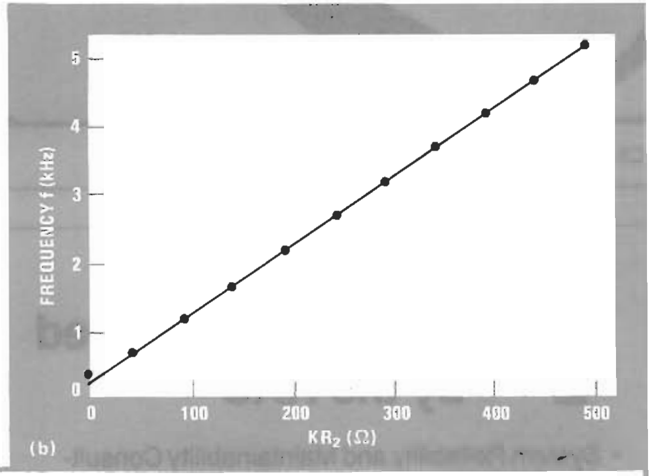
by Arturo G. Sancholuz
Caracas, Venezuela

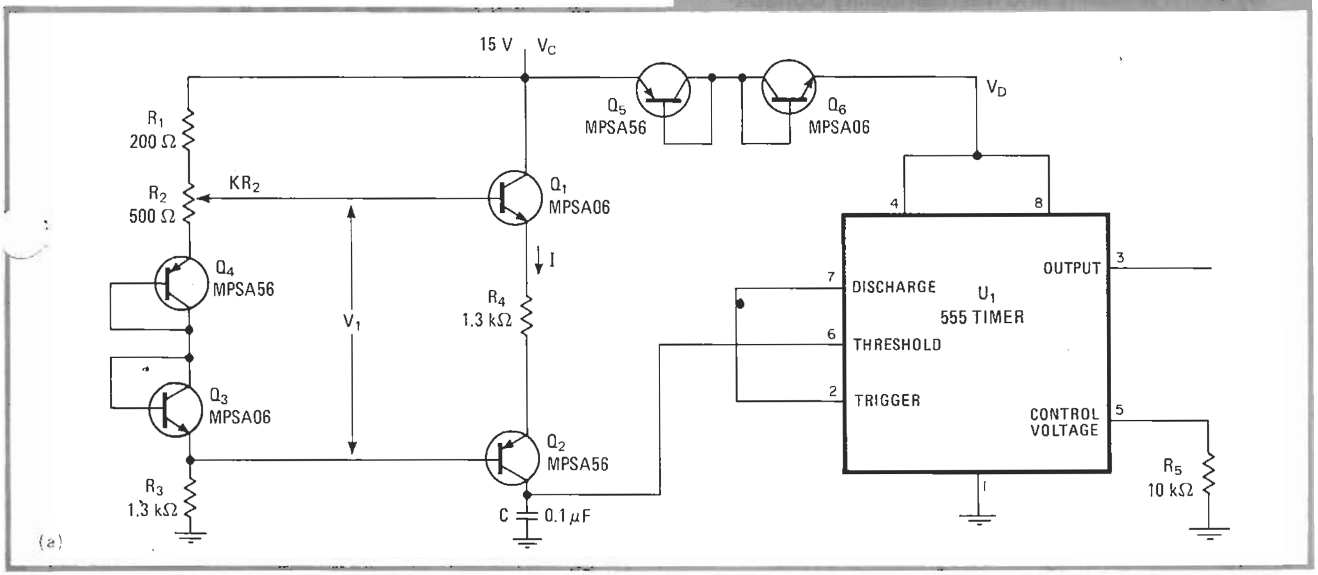
Though widely used as an astable multivibrator, the ever-popular 555 integrated-circuit timer is cursed with a nonlinear frequency response. However, in this configuration (a), the 555 is made to provide an easy, linear means for frequency calibration. In addition, it is unaffected by power-supply variations.

Capacitor C is charged by transistor Q_2, which is connected as a constant current source, and then discharged through pin 7 of timer U_1. Charging current $I = (V_1 - V_{be1} - V_{eb2})/R_4$, where V_{be1} and V_{eb2} are the base-to-emitter and emitter-to-base voltages of Q_1 and Q_2, respectively. When V_c is the common source voltage, K is a constant, and V_{be3} and V_{cb4} are the base-to-emitter and emitter-to-base voltages of Q_3 and Q_4, respectively, voltage V_1 can be expressed as:

$$V_{cb4} + V_{be3} + \frac{(V_c - V_{cb4} - V_{be3})KR_2}{R_1 + R_2 + R_3}$$

If the previous two equations for I and V_1 are combined and if it is assumed that voltages $V_{be1} = V_{be3}$ and $V_{eb2} = V_{eb4}$, when matched transistors are used, the charging





Linearity. Connected as an astable multivibrator (a), the 555 timer has an output frequency that is linearly controlled with potentiometer R_2. Capacitor C is charged by Q_2 at constant current I. Imperfect matching of transistors Q_1 to Q_4 and Q_2 to Q_3 may introduce nonlinearity at low frequencies. The calibration curve (b) shows that frequency can be linearly adjusted from a few hertz to 5 kHz.

current reduces to

$$\frac{(V_c - V_{eb4} - V_{be3})KR_2}{R_4(R_1 + R_2 + R_3)}$$

Because a 10-kilohm resistor is connected to the control voltage at pin 5, C charges from one quarter to half of supply voltage V_d instead of the normal third to two thirds. This change reduces the maximum voltage across C, which in turn provides a sufficient voltage drop across R_4 for Q_1 and Q_2 operation. The oscillation period can be obtained from the relationship $\tau = CV_d/4I$ where $V_d = V_c - V_{eb5} - V_{be6}$ and where V_{eb5} and V_{be6} are the emitter-to-base and base-to-emitter voltages of Q_5 and Q_6, respectively.

Rearranging the equations and assuming that $V_{eb4} = V_{eb5}$ and $V_{be3} = V_{be6}$ yields:

$$f = 1/\tau = \frac{4KR_2}{CR_4(R_1 + R_2 + R_3)}$$

where f is the oscillation frequency. The above relationship shows that the output frequency can be linearly controlled with potentiometer R_2. The experimental calibration curve (b) indicates that this frequency can be linearly adjusted from a few hertz to 5 kilohertz. The unnoticeable departure from the straight line occurring at very low frequencies can be attributed to imperfectly matching transistors Q_1 to Q_4 and Q_2 to Q_3. □

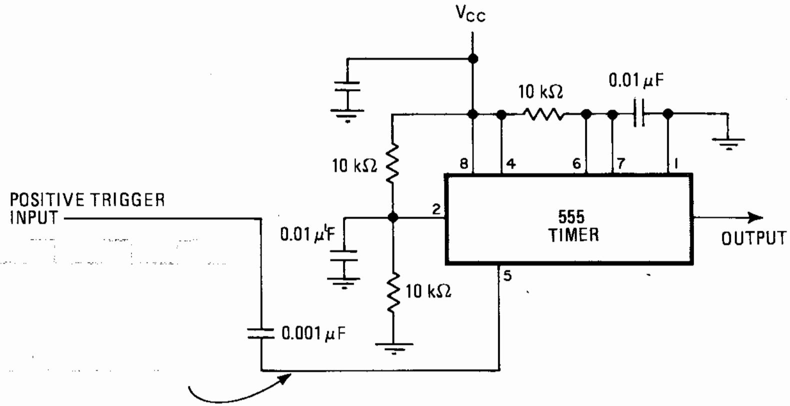
Positive pulse triggers 555 integrated-circuit timer

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 the 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.

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Talk Timer

A. G. Mitchell

This circuit was designed for use as a timer for educational talks, pro--viding a timing period of 5 minutes. During the talk, a green LED is turned on, but half a minute before the end, the green LED is extinguished and the yellow LED lit, giving a warning that only half a minute remains. At the end of the 5 minutes, the yellow LED turns off and the red LED turns on.

The circuit is simply two one-shot monostables connected together, the first with a timing period of 4½ minutes, and the second ½ minute.

Timing is started by momentarily closing S1, pin 3 of both ICs go high turning on the green LED and off the red and yellow LEDs.

At the end of the first timing period, pin 3 of IC1 goes low turning the green LED off and the yellow LED on. When at the end of the second timing period, pin 3 of IC2 goes low, the yellow LED is turned off and the red LED lit.