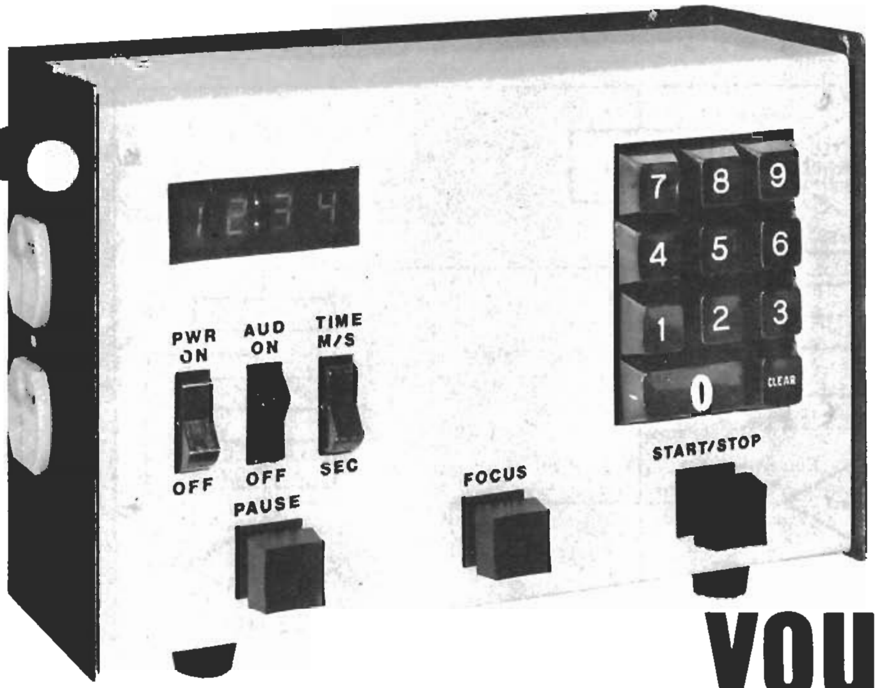


BUILD

Digital Timer for your Darkroom

Modern photographic processes require precise timing for the best overall results. Mechanical timers are going out and electronics are in. This digital timer is the last word.

RAYMOND G. KOSTANTY

HERE'S A MODERATELY PRICED, HIGH-ACcuracy, high-repeatability digital timer with a displayed range from 0.1 seconds to 99 minutes and 99 seconds, and an internal range up to 694.45 days (when 8 nines are entered in the minutes/seconds range). Although originally intended for photo darkroom use, it can be used in any application that requires switching on up to 150 watts for a precise time period.

The desired time is entered via a keyboard and displayed on four 7-segment displays. As the timing interval progresses, the display counts down and shows the remaining time, either in minutes and seconds or in seconds and tenths of seconds. An audio signal consisting of 0.1-second bursts of a 1000-Hz sinewave, once a second, is available as an aid in dodging and burning-in operations, when looking at the display would divert too much of the printer's attention. At the end of the timing interval, the last selected time will automatically be entered into the display and be ready for repeat use. This allows multiple prints from the same negative to be made without the nuisance of entering the same time over and over.

Calculator IC controls operation

The heart of the timer is a General Instruments calculator IC. In conjunction with peripheral logic IC's, it functions as shown in Fig. 1. Initially, the desired time is entered with the mechanical keyboard, and the START/STOP button pressed. Internal control circuits now come into play and activate an *electronic* keyboard. First, the selected time is entered into the calculator's memory and the "minus" function is activated. If the TIME switch is in the SECONDS position, the number 1 is next entered. Then, the "equals" key is electronically pressed at a 10-Hz rate, and .2 seconds later the enlarger and then the audio are turned on. Each operation of the "equals" key subtracts one (decrements) from the display until the contents of the display are −1. Then the enlarger is shut off and the audio is terminated. Next the contents of the calculator's memory are recalled, and finally the memory is cleared. At this point we are back to where we originally started, with the display showing the last selected time, and the memory cleared. If the same timing interval is still required, merely press the START button to start the sequence again. If a new time is desired, enter it via the keyboard. The first key pressed automatically clears the previous time out and enters the new number in the extreme right position. Additional entries always appear in the rightmost position and shift previous entries to the left.

If the TIME switch is in the MIN/SEC position, the selected time is stored in memory and then a loop whose sequence is −, delay, 4 and 1 is executed once a second until the contents of the D8 display become minus. Although the loop's sequence is −, delay, 4 and 1, the entry of the 4 is inhibited unless the two rightmost digits are both zero as determined by the zero-zero detector. So for 59 cycles out of each 60, the sequence is effectively −, delay, blank and 1. When a whole number of minutes is displayed, such as 3:00, 41 is subtracted so the display next shows 2:59. After the display shows minus in the D8 position, the same ending sequence described above is executed.

Time intervals up to 9999999.9 seconds or 999999 minutes and 99 seconds may be entered, but only the last four entries will be displayed. If more than 4 digits are entered, the OVERFLOW LED between the first and second digits of the display lights to remind you that the interval will be longer than the display contents. It extinguishes when the remaining time becomes 99:59 minutes or 999.9 seconds.

When the TIME switch is in the MIN/SEC position, the last two entries are always interpreted to be seconds (even if they are greater than 60), and earlier entries become minutes. Thus, an entry sequence of 4, 8, 5 will give an interval of 4 minutes and 85 seconds. The same interval could also be obtained by entering 5, 2, 5 (5 minutes and 25 seconds).

The CLEAR button sets the display to zero and allows you to correct mistaken time entries. Since it does not clear the memory or reset the audio latch, it should not be pressed during a timing interval.

The timing cycle can be halted by either pressing the START/STOP button, which will shut off the audio and the enlarger, reset the display to the last selected time, and clear the memory, or by pressing the PAUSE button, an alternate-action switch, which will halt the timing cycle and shut off the enlarger and audio. A second tap on the PAUSE button allows the interval to continue from where it was interrupted.

The FOCUS button, also an alternate-action switch, turns the enlarger on for focusing the first time it is pressed. Its next operation turns the enlarger off and restores control to the timer.

How it works

Figure 2 shows the block diagram of the timer, and Fig. 3 its schematic. The calculator portion consists of IC7, the four displays, four of IC2's buffers, and the mechanical keyboard. The display segment outputs a–g of IC7 contain the numerical information to be displayed in seven-segment format. Each segment output is connected to its corresponding anode of all four displays. The digit outputs, D1–D9, go high, one at a time, starting from D1 and going through D9 (and two additional internal states), and complete the cathode circuits of each display sequentially, thus determining which readout will display the information on the segment lines. The segment outputs are open-drain current sources to

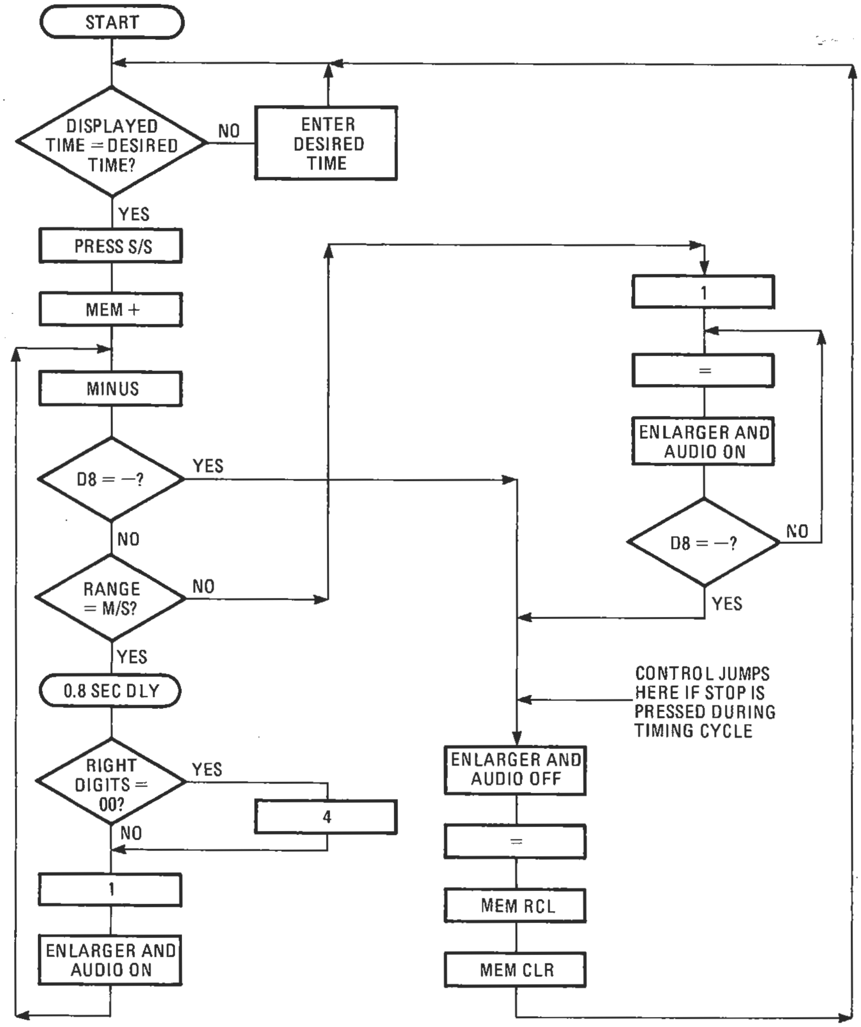


FIG. 1—OPERATIONAL DIAGRAM of the digital darkroom timer. An electronic calculator IC and its memory are vital to the timer operation.

MAIN BOARD PARTS LIST

Resistors ¼ watt, 10% unless otherwise noted
R1—10,000 ohms
R2—22,000 ohms
R3–R5, R10–R13, R15, R17, R19, R20—100,000 ohms
R6–R8—2700 ohms
R9—100 ohms
R14, R16, R18—5600 ohms
R21—75,000, 5%
R22—510,000 ohms
Capacitors 10%, 15 VDC ceramic discs
C1—100 pF
C2, C6–C9—0.1 μF
C3—.02 μF
C4—.05 μF
C5—.01 μF
D1–D3—1N4001, 1N459 or equal silicon diode
LED1–LED3—light-emitting diode, Monsanto MV-50 red or equal
DIS1–4—7-segment LED digits. Fairchild FND357 (0.362 in.) or FND70 (0.250 in.)
IC1—4018 resettable divide-by-N counter
IC2—75492 6-digit MOS to LED driver
IC3, IC15—4001 quad 2-input NOR gate
IC4, IC16—4011 quad 2-input NAND gate
IC5—4071—quad 2-input OR gate
IC6, IC10—4017 decade-counter/divider, 10-line output
IC7—C-685 calculator (General Instruments)
IC8, IC11—4016 quad bilateral switch
IC9, IC12—4081 quad 2-input AND gate
IC13—4019 quad AND-OR select gate
IC14—4027 dual J-K master-slave flip-flop
PB0–PB10—SPST momentary push-button switches. Part No. DC-61-05 (Datanetics, 18065 Euclid St., Fountain Valley, CA 92708)
Key caps for PB0 to PB10. Datanetics part numbers:

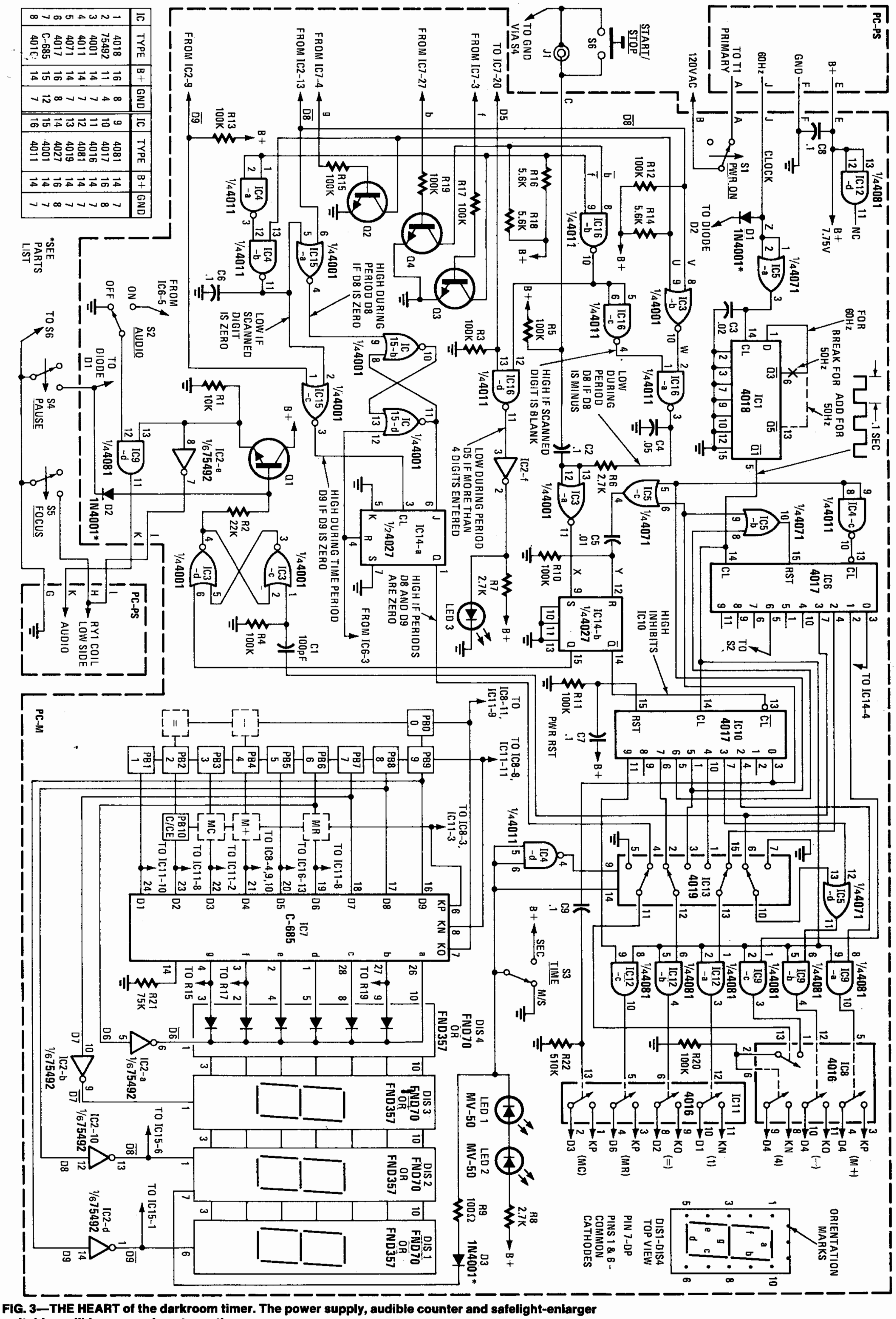
40-3091-03	40-3097-03
40-3092-03	40-3098-03
40-3093-03	40-3099-03
40-3094-03	40-3100-03
40-3095-03	40-7170-03
40-3096-03	

S1–S3—SPDT rocker switch, UID type RSW-06-12-SD-BB-S-B1-BK or RSW-06-12-SD-B1-S-B1-BK (UID Electronics Div., 4105 Pembroke Rd., Hollywood, FL 33021)
S4–S5—SPST alternate (push-to-pock, push-to-release) action switch, Switchcraft UP-501L with PB-11-02 caps
S6—SPST momentary switch, Switchcraft UP-101M with PB-11-02 cap.
J1—RCA-type phono jack
Miscellaneous—Four rubber or plastic feet, 1¼ × 2½-inch red filter for display cutout, duplex receptacle, IC sockets, nuts, bolts, wire and solder.

Note that the following parts are available:

IC7 (C-685) $6.50; case $11.00; main PC board, glass-epoxy etched and drilled with plated-through holes $15.00. The power supply PC board, etched and drilled $6.00. Switches S1–S3 $2.25; S4–6 $2.50; PB0–10 $7.00. Relay $2.30. Complete kit of all parts except solder $90.00. Assembled, tested, ready-to-use timer $120.00. All prices include postage California residents add sales tax as applicable.

Order from R. Kostanty, PO Box 1042, Gardena, CA 90249. Allow 3-4 weeks for delivery; add 2 weeks for non-California checks to clear. Foreign orders same as above, U.S. funds. Power transformer not shipped to foreign countries.



IC	TYPE	B+	GND	IC	TYPE	B+	GND
1	4018	16	8	9	4081	14	7
2	75492	11	4	10	4017	16	8
3	4001	14	7	11	4016	14	7
4	4011	14	7	12	4081	14	7
5	4071	14	7	13	4019	16	8
6	4017	16	8	14	4027	16	8
7	C-685	15	12	15	4001	14	7
8	4016	14	7	16	4011	14	7

FIG. 3—THE HEART of the darkroom timer. The power supply, audible counter and safelight-enlarger switching will be covered next month.

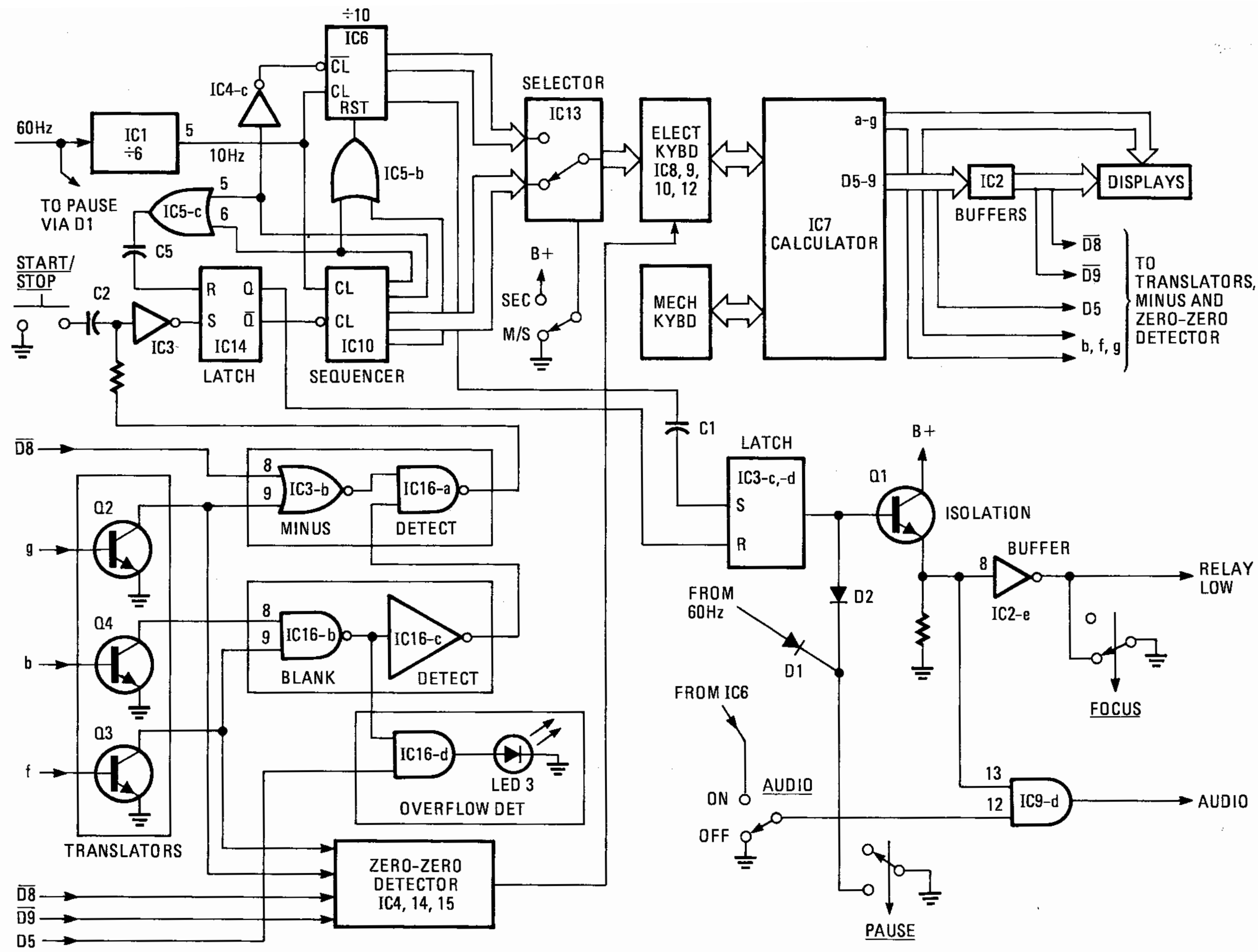


FIG. 2—FUNCTIONAL BLOCK DIAGRAM of the timer. Timing input is via a mechanical keyboard. The electronic keyboard operates from internal commands.

B+ which can directly drive one segment of a LED readout. The digit outputs, also open-drain current sources to B+, do not have the capability of handling up to seven times the current of each segment, so they are inverted through the high-power buffers in IC2 before being connected to the common cathodes of the displays. Each digit output from IC7 is high 1/11 of the time, at a frequency of about 130 Hz.

The calculator IC (IC7) also uses the digit outputs to determine which functions or numbers are being entered. In Fig. 3, PBO to PB10 (the solid squares) are the mechanical keyswitches which, when pressed, short one of the 9 digit lines to one of the 3 "K" inputs. (Functions electronically activated are shown in dotted squares.) The calculator decides what to do based on a combination of the voltage present at KP, KN or KO, and the timing of this voltage with respect to the digit outputs. If, for example, KN is high simultaneously with D5 (as it will be if PB5 is pressed), the number 5 is entered as input data. Similarly, if pins 3 and 4 of IC11 are shorted by the electronic switch inside IC11, a high will appear on KP during interval D6 and the memory recall function will be activated.

(Yes, a complete calculator could have been included as a function of the timer. But in view of the $8.00 cost of ready-to-use commercial units, the additional cost of 5 extra mechanical keyswitches and the 4 extra displays required to display the answer to noneven division could not be justified.)

Each time the START/STOP button is pressed, differentiator C2–R6 produces a negative pulse which lasts about 250 microseconds at IC3 pin 12. This pulse is latched by half of IC14. When pin 14 of IC14 goes low, sequencer IC10 is enabled.

Device IC10 is a decade divider whose 10 outputs sequentially go high, non-overlapping, in the direction from 0 to 9, each time its clock input on pin 14 goes high if pins 13 and 15 are both low. Just prior to the pressing of the START button, the divider is inhibited because pin 13 of IC10 is high, and is resting with only its 0 output high. When IC14's pin 14 is latched low, divider IC10 outputs 1, 2, 3 and 4 sequentially go high at a rate of 0.1 second per step, and in conjunction with IC8, 9, 11, 12 and 13 perform the Memory Add, Minus and, if in the seconds range, 1 functions as shown in the flow chart. When the 5 output of IC10 goes high, the latch which feeds pin 13 of IC10 is reset, causing pin 1 IC10 to remain high for the duration of the timing cycle, IC6 to be enabled, and pin 6 IC12 to be high. Succeeding clock pulses advance decade divider IC6 (which is identical to IC10) and activate the Equals function, which decrements the display once each time it is activated.

The outputs from IC6 reset the zero-zero detector, provide a signal to turn on the audio oscillator and set the latch formed by 2 of IC3's gates 0.2 second after the Equals function is first performed. (The zero-zero detector, IC4-a and b, IC15 and IC14-a, produces a high when zeroes are in the rightmost position on whole-minute intervals.) This delay compensates for a one-time delay in the calculator IC the first time the Equal function is performed. (The fact that latch IC3 is set once a second by IC6-7 is incidental.) IC3's output, after being buffered by Q1, drives a relay on the power supply board which turns on the triac that energizes the enlarger. The relay simplifies gating the triac from low-level logic.

Countdown continues until a minus is detected in the D8 position or until the STOP button is pressed. Either event causes a positive pulse at IC14-9. Integrated circuit IC14 changes state and resets IC3 to turn off the enlarger and allows IC10 to continue sequencing. Output 7 from IC10, which is only required when in the minutes/seconds range, ter-

(continued on page 86)

DIGITAL DARKROOM TIMER
continued from page 36

nates internal calculator modes by activating the Equals function. The 9 output from IC10 recalls the memory's contents and the 0 output clears the memory and resets latch IC14, which, in turn, halts IC10 with its 0 output high.

The 1 and 8 logic outputs of IC10 are not used. By skipping them, more time is allowed for the calculator IC to prepare for its following operation. This gives even a slow calculator IC enough time to complete its preceding operation before the next one is initiated.

Operation in the minutes/seconds range is similar to the operation in the seconds range. The outputs from IC6 and IC10 are combined by IC13 so the algorithm in Fig. 1 is executed.

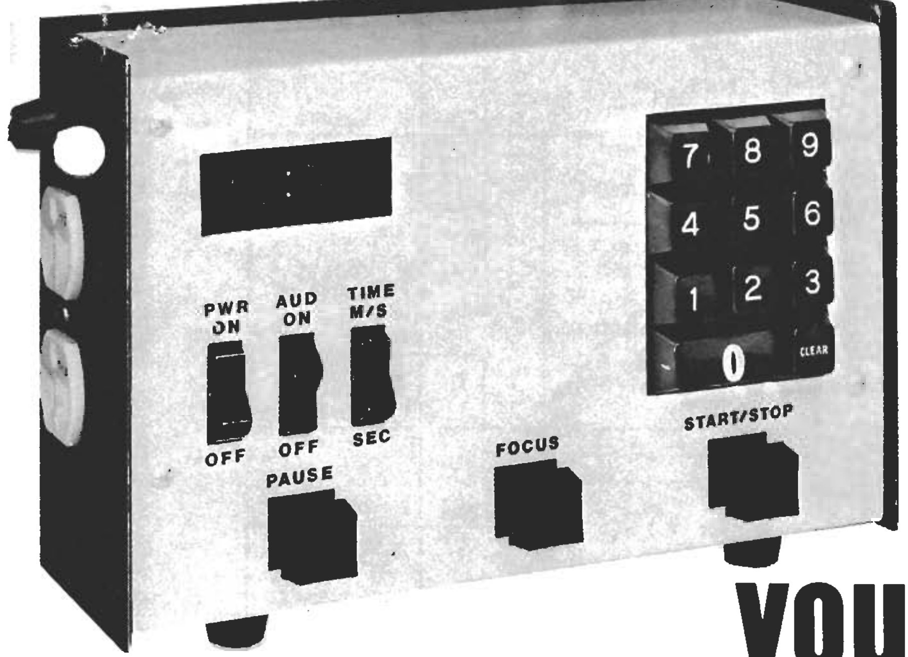
AND gates IC9 and 12, combined with the 10-Hz signal from IC1-5, are required to satisfy the calculator IC's requirement that to recognize successive inputs, there must be a period (about 6 ms) after each input during which no inputs are allowed. The 10-Hz signal disconnects IC9 and IC12's inputs from IC8 and IC11 for 50 ms each cycle.

The electronic keyboard is formed by IC8 and IC11. Each contains four single-pole single-throw switches, which are closed when "pressed" by a high at the gate inputs (pins 5, 6, 12 and 13).

The circuit which detects a minus (this means that only segment "g" is on) in position D8 works as follows. If you make a table that shows which segments are on for each of the numerals from 0 to 9, you will see that segment "b" is on for all numbers except 5 and 6. If we connect segment "b" to one input of a two-input OR gate and connect the gate's second input to any of the segments which are on (high) for both numerals 5 and 6 (segment "f" is used here), the output will be high if any numeral is being displayed. This also means that the output is low only if no numerals are being displayed. Thus by looking at only two of the seven segment signals, we can determine if the display is blank. (Eight other pairs of segments could also have been used—ab, ac, bc, bd, cd, ce, cg or bg.) By combining IC16-4 with D8 and segment "g," IC16-3 will be low only when a minus is in the D8 position.

Transistors Q2–Q4 and their base and collector resistors amplify the small 1.7-volt signal change across the on segments to the higher levels required by CMOS gates for reliable switching.

Next month we conclude the circuit description and will go into details of assembling, testing and operating this versatile timer. **R-E**



BUILD

Digital Timer for your Darkroom

The ideal timer for today's darkroom. This one counts down in your choice of minutes and seconds, or seconds only.

RAYMOND G. KOSTANTY

LAST MONTH WE INTRODUCED THIS unique digital darkroom timer. In this issue we will complete the article, presenting the remaining construction details and final setup, test, and operating steps.

As stated, the timer's internal capacity is 8 digits. To alert you that more than 4 digits have been entered, the output of IC16-10, which is high if any digit is present, is combined with D5 in IC16 and used to unshort LED 3 (allowing it to light) if any digit is present in the D5 position.

In the minutes/seconds range, 41 must be subtracted each time a whole number of minutes (2:00, 5:00, etc.) is displayed. The zero-zero detector output, IC14-1, goes high if a zero is present in both D8 and D9 positions. Pin 11 of IC4 is low when a zero is detected. Recalling that D8 goes high before D9 does, IC15-4 will be high during D8 if a zero is present. Latch IC15-d remembers this high and enables IC14-6, the J input to a flip-flop. If the zero is also present during D9, IC15-3 will go high and clock IC14. This makes IC14-1 go high and enables IC8-13, which changes the normal —, delay, blank and 1 sequence to the required —, delay, 4 and 1 sequence. Latches IC14-a and IC15-b and d are reset each time IC6-3 is high.

Counter IC1 divides the 60-Hz squarewave generated on the power supply board by 6 to produce 10 Hz. The PAUSE switch halts timer operation by grounding the base of Q1 and the clock pulses into IC1.

On the power supply board, Fig. 4, a 555 IC is connected as an astable oscillator to generate the audio tone when gated on by the signal at input K. The tone's frequency is inversely proportional to R6, R7 and C2.

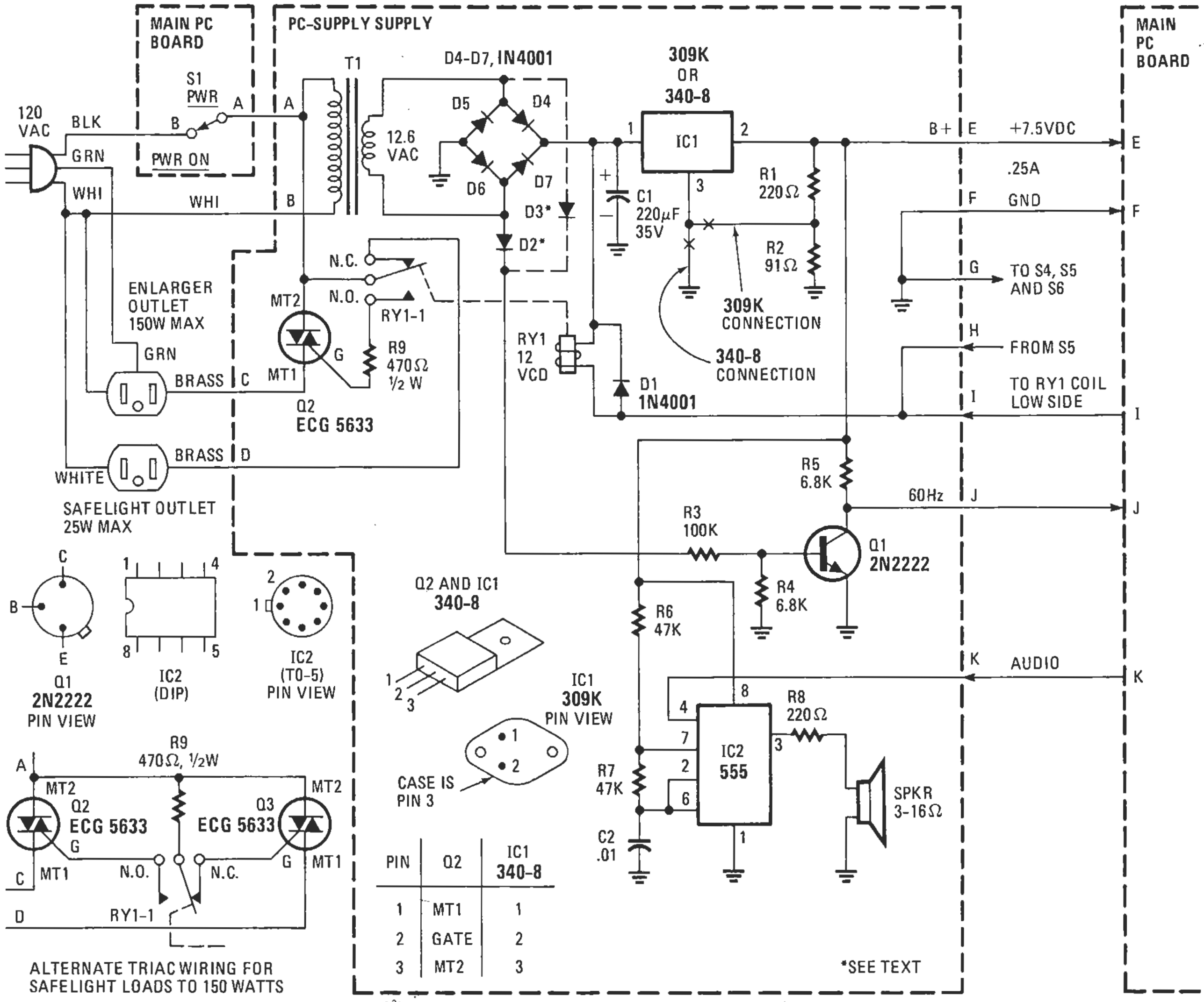
The relay directly switches the line voltage to the low-power safelight outlet when de-energized, and indirectly switches line voltage via the triac to the high-power enlarger outlet when energized. The maximum load that can be connected to the enlarger outlet is determined solely by the triac rating. Heavier safelight loads can be driven by adding a second triac as shown in the Fig. 4 inset.

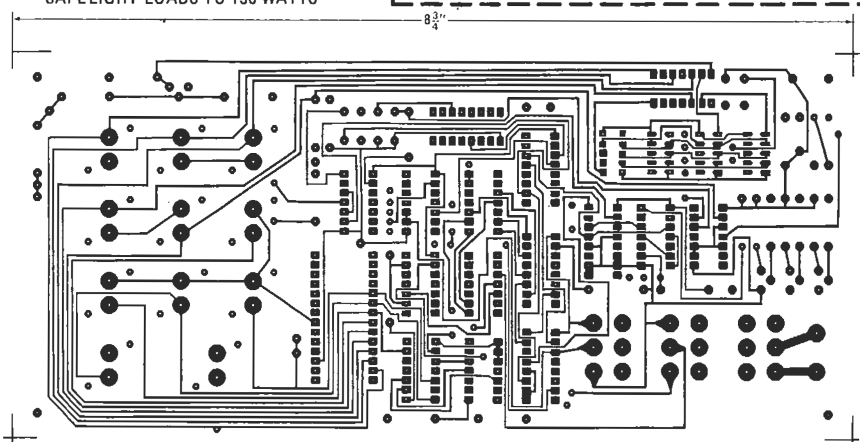
Transistor Q1 amplifies the half-wave rectified 60-Hz signal applied to its base and converts it to an approximate squarewave.

Assembling the timer

Start assembly with the power supply. The board will accomodate speakers up to 2½ inches in diameter, but will be supplied with mounting holes for a 2-inch speaker. If using a larger speaker, drill one No. 28 hole (hole S in Fig. 9) such that the part of the hole closest to the speaker center is just tangent to the diameter of the speaker. Solder all small components into their appropriate locations. If using a 309K as IC1, fasten it with two No. 6-32 × 3/8 screws with the head of one of them in firm contact with the foil which serves as the connection to the case of IC1, and install R1 and R2. Clip leads 1 and 2 to about 1/8 inch. Resistors R1 and R2 are not used when a 340-8 is used as IC1.

If the timer is to be used on 60-Hz power, do not use D2 or D3, but instead solder a jumper in the D2 position. (For 50-Hz operation, use a transformer with a 50-Hz or 50 to 60-Hz primary, and use D2 and D3, which will change the output of Q1 to 100 Hz. On the main board, cut the connection from IC1-1 to IC1-6, and jumper IC1-1 to IC1-13 to change IC1 to a decade divider to give the required 10-Hz output.) Mount the transformer with two No. 6-32 × 3/8 screws, again with the heads on the foil side. Solder the transformer, relay and IC2 in place. The IC may be soldered without a socket. The triac doesn't need a heat sink for loads up to 150 watts, and is supported by its leads. For loads between 150 and 600 watts, mount the triac on a heat sink whose thermal resistance doesn't exceed 3 °C-per-watt. In each of the three speaker holes, install a 6-32 × 3/8 screw, heads on the foil side, and fasten one nut firmly to each screw. If the holes were properly drilled, the speaker should be able to rest on the nuts just installed. Install one additional





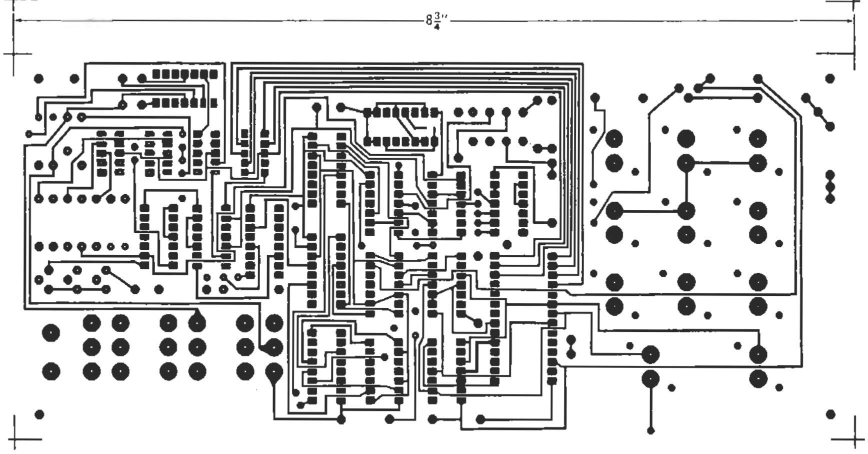


FIG. 4 (above)—POWER-SUPPLY CIRCUIT also contains the audio circuit that develops 1-second pulses.

FIG. 5 (left)—COMPONENTS SIDE of the main circuit board. Note the size marked.

FIG. 6 (bottom left)—FOIL PATTERN on the other side of the two-sided board.

nut on each screw to secure the speaker and solder the two speaker connections to their pads. Refer to Fig. 11 for details. Set the board aside.

Continue with the main board. Sockets are highly recommended for all IC's, and imperative for the calculator IC. The displays are installed in Molex *Soldercon* sockets. When using these sockets, do not press them directly against the board unless you are sure that they will not short to foil patterns running between them. All pushbuttons, rocker switches, LED's and displays go on one side, and the remaining parts and jumpers on the other. Mount components in this sequence: resistors, diodes, transistors, jumpers, capacitors and IC1-16's sockets. On the other side, mount the display's sockets and the three LED's. The LED's mentioned in the parts list were selected for their small diameter, .085 inch, and pleasing appearance. Their lead length, however, is only 0.25 inch. To raise the

POWER SUPPLY PARTS LIST

All resistors ¼ watt, 10%
R1, R8—220 ohms
R2—91 ohms
R3—100,000 ohms
R4, R5—6800 ohms
R6, R7—47,000 ohms
C1—220 μF, 35 volts, electrolytic
C2—.01 μF
Q1—2N222, RS-2031 (Radio Shack) or any NPN silicon transistor with a beta between 50 and 150
Q2—200-volt, 10-amp triac. Sylvania ECG 5633 or equal
Q3—Optional, same as Q2. See text.
IC1—309K or 340-8 voltage regulator
IC2—555 timer
D1, D4-7—1N4001, Radio Shack 276-1101 or any 25-volt, 1-amp silicon diode
D2, D3—Silicon diode, see text.
RY1—Relay, SPDT contacts, 12-VDC coil. Guardian 1345-1C-12D, Essex 64-902 or Cornell-Dubilier 603-12V
T1—Transformer, 120 volts to 12.6 volts, 300 mA. Radio Shack 273-1385 or equal
Miscellaneous—Speaker, 3-16 ohms, 2-2½ inches. Power cord, 8 feet, No. 18, 3 conductors. Strain relief.

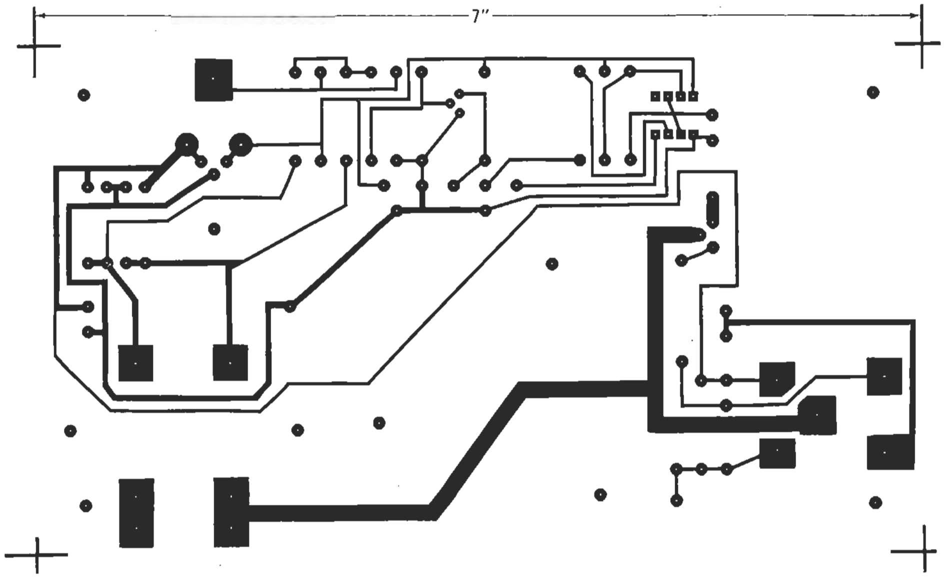
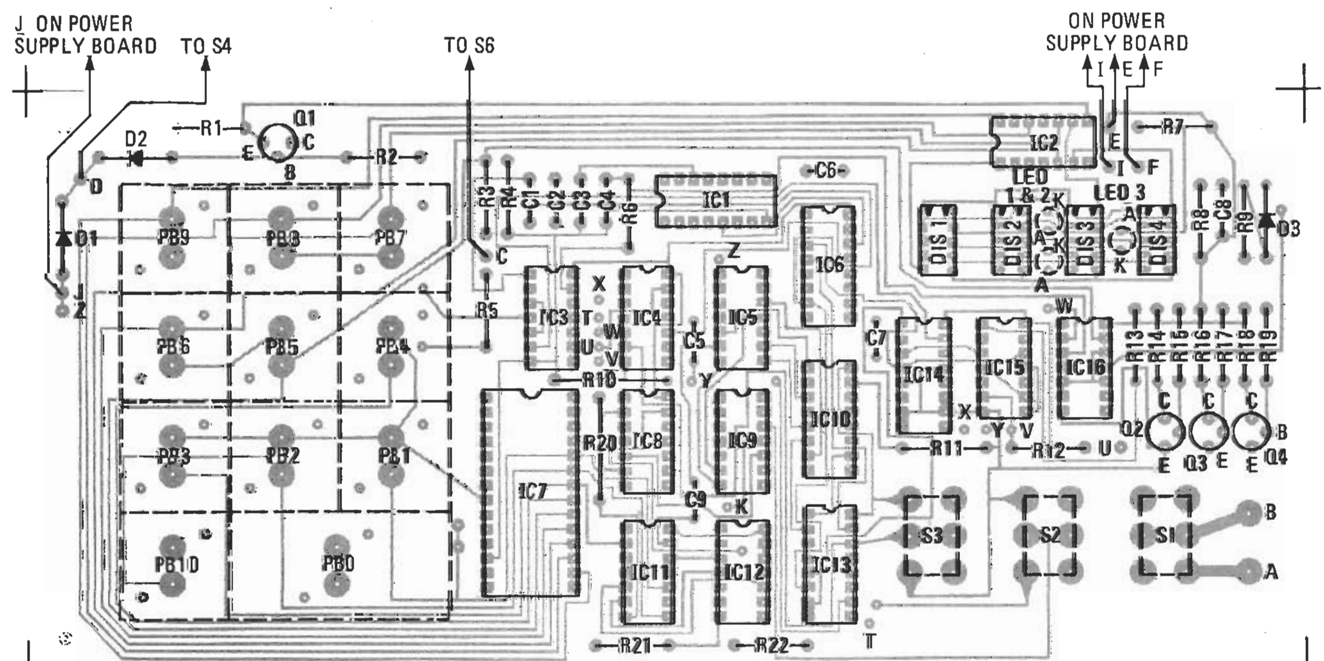


FIG. 7—THE POWER SUPPLY CIRCUIT BOARD is single-sided. Again, be sure to note the dimension across the top as this board is not drawn actual size.

tip of the LED's to the same height above the board as the 7-segment displays (0.6 inch), solder solid-wire extensions to the LED leads or use larger LED's. Finish by installing the switches. Do not install the IC's or displays at this time. Set the board aside.

The case can be easily made as shown in Figs. 10 and 11, or purchased ready-to-use. Strip about 18 inches of outer jacket from the line cord and install the cord through the side of the case with a strain relief. The duplex outlet will have 2 silvery screws in a silvery metal strip on its cold side, and a brass-colored metal strip with either 2 silver or 2 brass-colored screws on the hot side. Break the thin brass strip connecting the 2 screws on the hot side to isolate them from each other. Leave the 2 screws on the cold side in common with each other. Shorten the green and white leads on the line cord from 18 to 6 inches. Connect the green wire to the green screw on the outlet, and the white wire to one of the cold screws. Connect one end of the remaining 12 inches of white wire to the other cold screw, and the other end to one side of T1's primary (hole B in Fig. 9). Connect one end of an 18-inch wire to each of the remaining holes on the power supply board. The wires to holes A and C should be No. 18 gauge. The remaining ones can be No. 24 or 26. Temporarily connect the wire from hole A to the black wire in the line cord. Interconnecting wires should be stranded.

Attach the board to the rear half of the case as shown in Fig. 11. Mount it so the transformer is toward the bottom of the case (when mounted on a wall). The outlets can be on either the right or left side to suit your darkroom's layout. Connect the No. 18 wire from the triac (hole C on the power supply board) to one of the unused hot screws on the outlet sock-



NOTE: HOLES A-A TO K-K ARE JUMPERED EITHER TO POWER SUPPLY BOARD OR TO CABINET-MOUNTED COMPONENTS. HOLES T-T TO Z-Z ARE JUMPERED TO EACH OTHER ON REAR SIDE OF BOARD.

FIG. 8—PARTS PLACEMENT ON THE MAIN CIRCUIT BOARD. Note that the keyboard mounts directly to this board too. As indicated, jumpers connect this board to the power supply board.

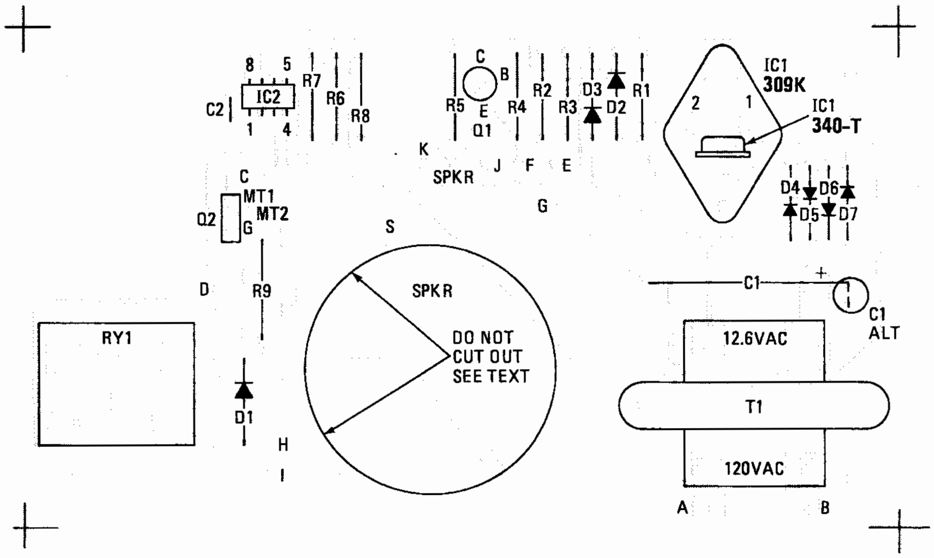


FIG. 9—PARTS PLACEMENT ON THE POWER-SUPPLY BOARD. Note that the speaker and audio circuit components are also placed on this board.

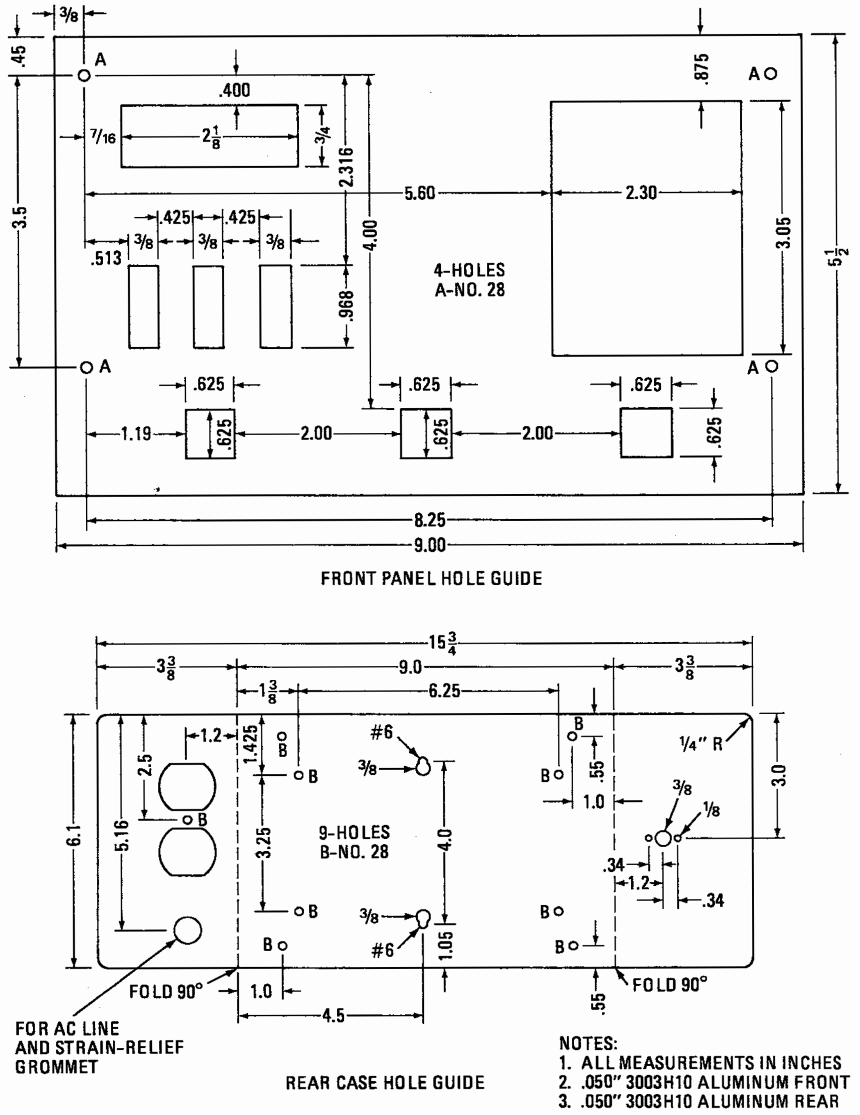


FIG. 10—FOLLOW THESE GUIDES FOR MAKING HOLES in both the front and rear panels of the case. Be sure to follow the listed dimensions accurately.

et, and the wire from hole D to the remaining unused hot screw. Secure the duplex receptacle outlet to the case with a single 6-32 × 3/8 screw in its center hole. Either scrape the paint from below the head of this screw or use a star washer under the head to cut through the paint and into bare metal. It is imperative that the head of this screw be in excellent electrical contact with the case for safety. Mount the phono-type jack used in conjunction with a foot switch as a remote START/STOP switch with two 4-40 × 1/4 screws. Make sure the ground terminal is in intimate contact with bare metal on the inside of the case.

Verify that the clearance between the foil side of the board and the case is adequate, and plug a 15-watt lamp into the socket connected to hole D, the safe-light socket. Plug the line cord into the 120-volt power line. A steady tone should be heard and the lamp should light. Grounding IC2-4 should turn the tone off. Measure +7.5 to +8.5 volts DC at hole E, and 30 to 70 percent of this voltage at hole J. Vary R4 if outside the 30 to 70 percent range. Ground hole H or I and verify that the lamp goes off. Move the lamp to the other outlet and verify that it lights when hole H or I are grounded.

Interconnect the main and power supply boards and the front panel switches and remote START/STOP jack as shown in Figs. 3 and 4. Remove the temporary connection between the line cord's black wire and T1's primary, and make the permanent connections shown in Figs. 3 or 4. Epoxy the red filter in place over the cutout in the panel for viewing the displays. This should be one of the very first things done when assembly initially starts. Connect main board to front panel as shown in Fig. 11.

Testing

With all the IC's and displays removed from the main board, power the unit. Verify that the AC power switch works, and that the FOCUS switch activates the relay. Verify that B+ is present on each of the IC's power pins as shown in the table in Fig. 3. Shut power off and install the calculator IC, the four readouts and IC2. The displays, when power is reapplied, will usually show one, but occasionally two, zeroes in the right position(s). A decimal point will show if the TIME switch is in the SEC position, and a colon if in the MIN/SEC position. The overflow LED and audio will be on. Enter [9], [8], [7], [6] and verify that these digits show on the display. If odd characters appear, look for solder bridges near the display sockets, using a loupe of about 10 power. If none of the numbers appear on the display, check orientation of IC7 in its socket, the voltage at IC7-15 and that IC7-12 is at ground. If these tests pass, measure the voltage at IC7 pins 6, 7 and 8. The voltage at these pins should be high only when a pushbutton is pressed or a switch inside IC8 or IC11 is closed. If high at this time, either one of the pushbuttons is defective, or a solder splash exists somewhere, probably near IC8 or IC11's sockets. After getting the correct results, turn the unit off and then on to clear the display. Enter [5], [4], [3], [2] and verify the display. Again, momentarily turn off the unit, then enter and verify the [1], [0] entry. Turn the unit off and install the remaining IC's, being careful to minimize touching the leads to prevent static elec-

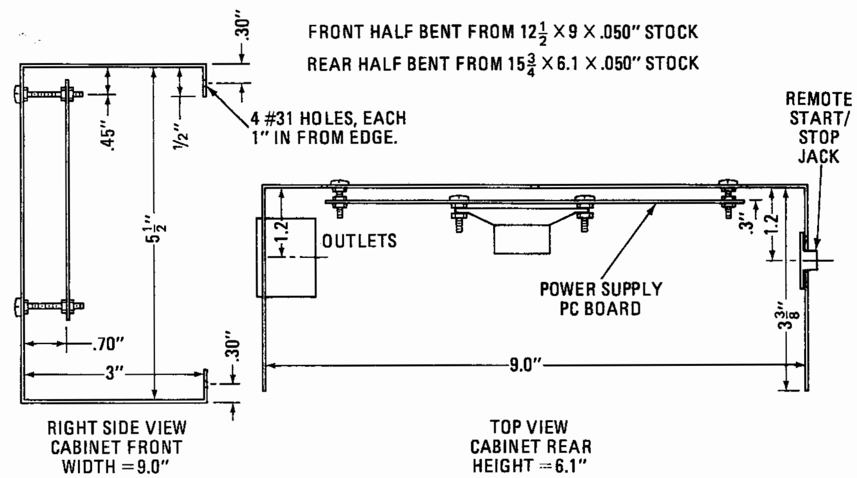


FIG. 11—CASE BENDING INSTRUCTIONS for the builder who wants to make his own case. The detail at the right shows how the speaker is positioned and mounted inside the case.

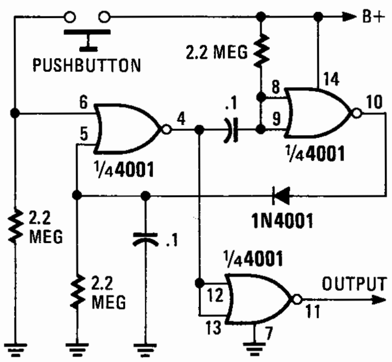


FIG. 12—SIMPLE TEST CIRCUIT produces a single bounce-free output each time you push the switch.

tricity damage. Before applying power to the unit, double check the orientation of the IC's. Apply power and verify that the AUDIO switch works. Enter any 5 digits. When the fifth one is entered, the overflow LED should light. Clear the display using the CLEAR button (one zero will remain). With the TIME switch in the MIN/SEC position, enter any 2 digits and press the START button.

About 0.5 second later, the relay will energize and the timing cycle will begin. Allow it to complete, and verify that the selected time reappears at completion. Enter 2 new numbers and reinitiate the cycle. Interrupt it with a single push of the PAUSE button. A second push should allow the cycle to continue. Interrupt it again, this time with the START/STOP button. The time last entered should reappear in the display.

Enter [1], [1], [0] (1 minute and 10 seconds) and start the cycle. Verify that the display jumps from 1:00 to :59.

Move the TIME switch to the SECONDS position, enter any number and verify operation. The flickering of the display in the SECONDS mode is normal. It occurs because during the computation period, the calculator IC blanks its segment and digit outputs until a valid final answer is produced.

The audio signal produces one beep for each second selected on the minutes/seconds range. In the seconds range, there may be one additional beep more than the number of whole seconds selected, depending upon the size of the fractional seconds entered. For example, an entry of [2] [•] [2] will give 2 beeps, and an entry of [2] [•] [4] will give 3 beeps. An entry of [2] [•] [3] will give 2 solid beeps and maybe a half-hearted third one also, depending upon the speed of your particular calculator IC and the position of its internal oscillator when you happened to start the cycle.

Most discrepancies will be due to construction errors such as miswiring, bad soldering, etc., or defective IC's. I have had difficulties when using 4017's manufactured by MITEL Semiconductor whose part identification prefix is SIL. Usually, one of the 10 outputs refuses to go high. If the failed output is unused, the IC is OK to use since usually the good outputs go high at the correct time. Integrated circuits IC6 and IC10 can be interchanged as can be many other pairs of IC's.

Several innocent-looking capacitors are vital to proper operation. Capacitor C3, if too small or open, will cause timing accuracies to be off as much as 20% or cause the decrementing to look erratic, and make the unit sensitive to line transients. If line transients are suspected of causing large jumps in the display's contents, try increasing C3 to 0.1 μF, adding no more than 0.1 μF from the collector of Q1 on the power supply board to ground, and/or adding capacitance across the secondary or primary of T1.

Capacitor C4, if too small or open, will cause difficulty in entering numbers, self-starting while entering numbers, or premature ending of the timing cycle. If C6 is too small, it could cause 41 to be subtracted at undesired times.

Calculator IC's aren't designed for a 10-Hz counting rate. To make this unit operate reliably at this rate, IC7's internal clock was speeded up by reducing R21 to 75K from the manufacturers' recommended 470K. My prototypes operated properly with three IC's manufactured at widely different times. If R21 is too small, the internal clock will harmlessly stop, while if too large, the timing interval on the SECONDS range will be about double the desired value.

For difficult problems, wire the test circuit in Fig. 12, which produces a single bounce-free output each time the pushbutton is pressed. Break the connection between holes J and J, and connect the test circuit output to hole J on the main board. You can now single-step the timer through its sequences, remembering that 6 pulses are required to produce a single output from IC1-5.

When using a scope to look at the outputs of IC7 or most other points in the circuit, connect the scope's external trigger input to D1 (a convenient test point can be made by inserting a bare loop of wire in the holes adjacent to IC7-10 and IC7-11). Adjust the controls so triggering is on the positive polarity. Connect the vertical input to D1 and adjust the horizontal gain and centering until D1 is high between the first and second vertical lines on the scope's graticule (assuming 10 major divisions and 11 vertical lines). Move the vertical input to D9, IC7-16. If the horizontal controls are properly set, the trace should be high between the ninth and tenth vertical lines. (If your scope's external trigger input is capacitively coupled, add a 100K resistor from D1 to ground.) As an example of using this setup, suppose that pressing the keys would not enter numbers in the display. Suspecting that either KP, KN or KO is always high or continuously being pulsed high, you scope these points. If you noted that KO was high between the fourth and fifth vertical lines, the D4 time slot, you should suspect everything associated with the Minus function (IC8-10, IC8-11 and the drive circuits to IC8-12). Similarly, if 41 isn't being subtracted at whole-minute intervals, enter the numbers [2], [0], [0] and make sure that IC4-11 is low in the D8 and D9 time slots, IC15-4 is high during the D8 time slot, IC15-3 is high during the D9 time slot, IC15-11 is high during the D8 and D9 time slots, etc. Ignore signals occurring during D1 to D4.

Fasten the halves of the case to each other with four sheet metal screws. The timer is ready for use.

Parts substitution

Although the only custom parts are the cabinet and PC boards, several parts are difficult to obtain. For example, Datanetics has a minimum billing of $25, and GI's Los Angeles-area distributors have minimums of $10. But since the calculator IC is not a heavy-demand item, distributors don't stock it and are reluctant to order the necessary quantity from the factory.

The remaining items should all be readily available from **R-E**'s advertisers

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and local parts houses. Most of the IC's are part of Sylvania's ECG series (just add the ECG prefix to the 4-digit designation given in the parts list), and probably part of RCA's SK series. Do not use Motorola's HEP series because even though they designate their CMOS gates with a 4-digit number between 4000 and 4099, their numbers, in no case, correspond to the industry standard numbers given in the parts list. That is, HEP4001 is not the same as CD4001, ECG4001 or the part specified for IC3 and IC15.

Repeatability, accuracy and short-time limits

The repeatability of any selected interval is about 7.8 ms, the period of the digit-scan frequency. This occurs because operation of the EQUALS key is not syncronized with IC7's internal clock.

The uncompensated accuracy of any interval is a constant dependent upon: 1) line-frequency accuracy; 2) the difference between the relay's pull-in and drop-out time; 3) the phase shift across the transformer (which may delay the triac's turn-on if the relay energizes while the line voltage is close to zero); 4) an extra delay of 0.2 second in IC7 the first time the Equals function is activated. The first

DARKROOM TIMER

With respect to my article in the July and August 1978 issues ("Build A Digital Timer for Your Darkroom"), the accuracy of the schematic was excellent. However, there were six errors that must be noted:

1. In the table shown in Fig. 3 that lists the power and ground connections for the IC's, I wrongly listed pins 14 and 7 as power and ground for IC13. The correct pins are 16 for power and 8 for ground.

2. In Fig. 3 again, an LED is missing between pins 10 and 1 of DIS4, but this is an internal LED contained within DIS4 as are the others.

3. The point at which S4 connects to the main PC board should be labeled "D."

4. The Parts List did not have numbers for the transistors. They can be any NPN silicon transistors whose beta is between 50 and 150, such as 2N2222, 2N957, etc.

5. The part number given for S1–S3 is incompatible with the PC board/front panel combination. The correct UID Electronics part numbers are: S1: RSW-0622-SD-BB-S-B1-BK; S2 and S3: RSW-0022-SD-BB-S-B1-BK.

6. One of the key cap part numbers should be 42-3100-03, not 40-3100-03. The "42" indicates double-width, which is what the "0" key cap is.

RAYMOND G. KOSTANTY **R-E**