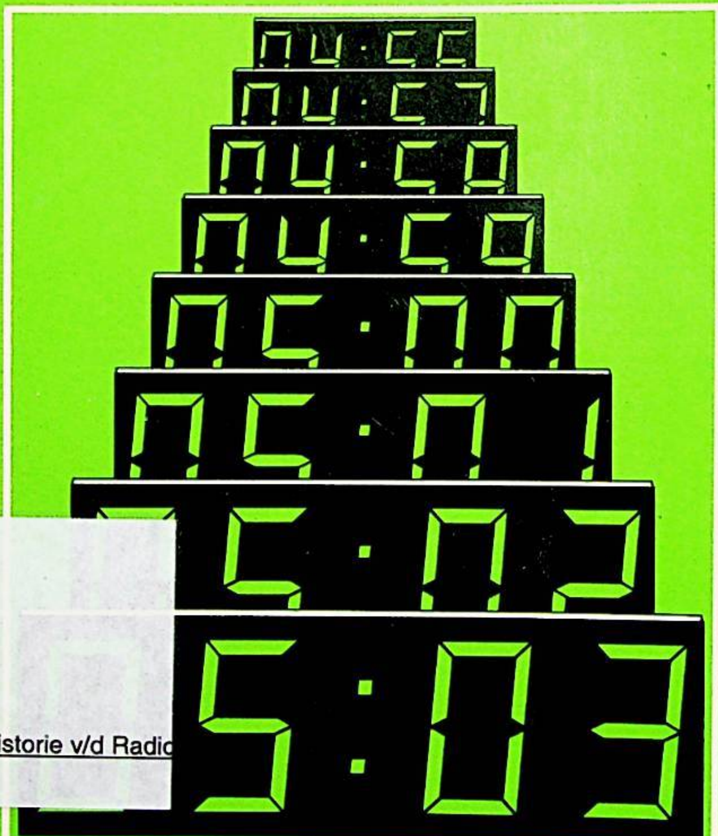
Electronic Timer Projects

F. G. RAYER



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ELECTRONIC TIMER
PROJECTS

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ELECTRONIC TIMER PROJECTS

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INTRODUCTION

Electronic timing circuits are easily able to meet many needs. Such timers may switch on or off indicator lamps, buzzers or oscillators, either at a preset time, or after a time elapsed period. Or the controlled circuit may be extended, to operate a radio, heater, general lighting, or other equipment. Many and varied uses arise for both on and off switching of this kind.

Interval or elapsed time indicators are useful for processes such as time and temperature development, cooking, etching and activities normally completed within a set period. They are also of interest for various games, where competitors attempt some more or less difficult task within a set period. These can introduce dexterity (number of nuts screwed on their bolts in a period), recognition (sorting cards into sets) and other factors.

Quartz controlled accuracy is easily available where it is wanted, with associated digital timers indicating to 0.01 second (or smaller fractions if wished). This will be useful for long interval timers, sports, and any purposes where accuracy is essential.

For numerous purposes, high accuracy is not necessary. An egg timer does not need high accuracy; nor does a short interval timer for competition purposes where each person will in turn have the same interval for his attempt. Simplified circuits are then in order, and some require very few components.

Some timers will have a low or modest current drain, so that they can be used with success from a battery supply. They are then self contained and portable, and may fit the pocket.

More ambitious timers and especially those with several numerals in a display will generally need to be operated from a mains supply. At the same time it is feasible to adopt this as the means of obtaining the necessary clock pulses, upon which timing depends.

The circuits here should fill a wide range of interests. Means of modifying and adapting them for particular needs are shown, so as further to extend their utility.

Display Hardware

To give an attractive finished appearance to a timer or other device with a number of numerals, a bezel or mounting bezel can be used. A bezel for 0.3in LED numerals can locate these at 0.5in centres, and would be approximately 2.6in long for four numerals, or 3.6in long for six numerals. They allow panel mounting with concealed studs. The screen or window is commonly neutral, red or polarised, to reduce or cut off reflected light, and give maximum apparent brightness. A red transmitting screen suits red LEDs. For 1in LED numerals, a 4-section type would be about 4.6in long and place the LEDs at 0.9in centres.

A satisfactory appearance can be obtained by making an individual aperture in the panel for each LED numeral. For the LEDs having 0.3in numerals, each aperture needs to be approximately 0.8in x 0.4in, or 20 x 10mm. These can be marked out accurately on the panel and rectangles can be removed by drilling rows of small holes closely together. Each aperture should then be finished off carefully with a small file. If there is slight clearance for each numeral, a board carrying these can be brought up behind so that the LEDs come into the openings. Panel and board are fixed together at the right distance by means of 8ba bolts with extra nuts to allow adjustment.

A simpler method is to use a single aperture, or transparent panel or part panel, and to cut a mask for the numerals from black paper or card. Fit this behind the window or panel with adhesive.

Resistors and Capacitors

All resistors here can be ¼ watt 5 per-cent, unless otherwise stated. Potentiometers of near value are normally suitable – thus 470k could be used instead of 500k or 0.5 megohm, or 220k instead of 200k or 250k.

With capacitors, it will be noted 1nF is 0.001μF or 1,000pF. These terms stand for nanofarad, microfarad and picofarad. In the same way 0.047μF is 47nF, and 0.01μF is 10nF, and so on.

Unless otherwise noted, near values are suitable, so that 47nF or 0.047μF could be used instead of 0.05μF, or 0.5μF is interchangeable with 0.47μF. This also applies to high value electrolytic capacitors, where 470μF could replace 500μF, or 220μF replace 200μF or 250μF. The voltage rating should at least equal the voltage present. Some typical ratings are 3v, 6v, 6.3v, 9v, 10v, 12v, 16v, 25v and higher. They must be connected with correct polarity.

Battery Operation of Timers

Some timers are of a kind which only require to be used for short intervals, or will have occasional and not very critical use in conjunction with children's games, etc. They may also use circuits which draw a small current. It can be convenient to have dry battery supplies with these, making them portable, perhaps more suitable for small children, and simplifying construction.

Other timers will run for long periods, and require a larger current, or a fully stabilised voltage. These are run from a mains power supply circuit. In a few cases (e.g. vehicle) a large battery of more than adequate voltage may be available.

The popular 74 type integrated circuits are intended for 4.75v to 5.25v and are normally provided with approximately 5v. Many of the simpler circuits run satisfactorily from a 3-cell (4½ volt) dry battery, or pack made from three cells connected together. Occasionally an IC may be encountered which proves unsatisfactory for this, a display or output may be partial, or incorrect; or the IC may fail to operate at all.

Where dry battery running is wanted, and three cells give a satisfactory performance, this is the easiest way to provide power. Various 4½v batteries are available. Or medium or large sized cells can be taped together, and connected in series. Be sure the battery is always connected in the correct polarity.

Where a supply of near 5v is required and enough current and voltage will be available, A in Fig. 1 can be used. The zener diode ZD1 can be 5.1v, or selected with a meter. If of 1 watt rating, its maximum current is a little under 200mA. If the supply V1 is 12v to 13v, then 7v to 8v must be dropped in R1. A 47 ohm 1½ watt resistor will allow a small safety margin. With no load, the whole current will flow through ZD1. As the

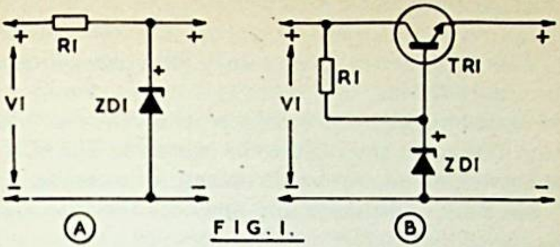


FIG.1.

load rises, less current flows through ZD1, until at a total load of about 200mA control is lost and output voltage falls. Where a load will always be present, as is so with many circuits, the minimum load can be added to the current ZD1 can pass, and used to calculate R1. R1 will then be of smaller value, and the total current available will be larger.

Circuit B is more economical in current, as ZD1 only needs to control the base of Tr1. If V1 is approximately 12v, R1 can be 220 ohm ¼ watt. Current through ZD1 is under 35mA. ZD1 is 5.6v, to allow for the base-emitter potential of Tr1. A 400mW diode may be used. Tr1 will usually not need to be over 500mA or so rating. Wattage dissipated here can be found by multiplying the voltage dropped across the transistor (collector-emitter) by the current, and for other than small loads a clip-on or other sink will be needed. As example, if Tr1 drops 7v at 500mA dissipation is 7 x 0.5 = 3½W.

Circuit B can be used with dry batteries, but to avoid needless waste of power ZD1 current and voltage drop in Tr1 should be quite low.

The 5v regulators, as used for mains supply units, can be employed for accumulator or other battery circuits. Generally, for 5v output, at least 7v to 8v input must be available. Such regulator ICs will be seen later, and can be used with 12v and higher inputs.

Mains PSU for Timers

A supply derived from a transformer and AC mains will provide adequate current and a regulated voltage, allowing reliable working of the circuits. Two forms of construction will be found convenient. One places a suitable PSU in the timer itself, so that the unit can be operated from a mains point. With some timers, quite a small PSU, giving limited current, can be fitted.

The second method is to build a separate PSU, with an adequate output for any timer to be operated. The PSU should have either non-reversible sockets for matching plugs, or red and black sockets, and any timer can then be plugged in at once.

Fig. 2 is the circuit which may be used for a wide range of loadings. T1 is the mains transformer, with primary P to suit the voltage of the mains. Secondary S needs to provide at least 7v to 8v across C1 on full load, and can be 9v. The winding is rated at 1A for up to 1 ampere, or 2A for 2 amperes, or as required.

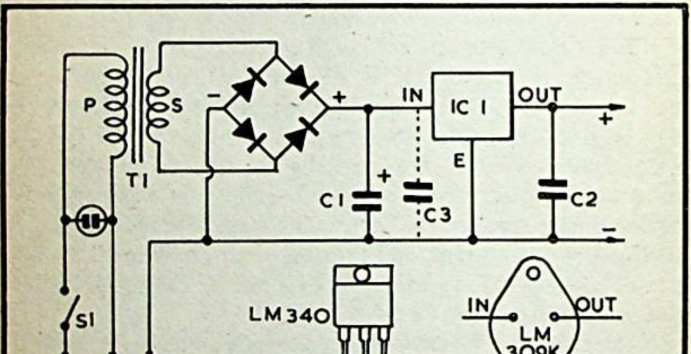


FIG. 2.

A 1A or 2A or other appropriate bridge rectifier is used, or four individual 50v silicon diodes, such as 1N4001s. With a 9v secondary, about 12v to 13v will arise across C1, so this can be a 15v component, 2200μF for the lower currents, and 4700μF to 10,000μF for the higher rating. If T1 secondary is of higher voltage, C1 is rated to suit, peak voltage being nearly 1.5 times the normal RMS or secondary voltage.

C2 is about 0.47μF. The neon "on" indicator is optional, and S1 is the main on-off switch. C3 helps suppress transcients and maintain stability, and can be 0.22μF.

For small timers, a small 9v transformer, with 500mA regulator, will not occupy very much space. T1 will be much more bulky in the larger ratings, and for heavy currents IC1 will be bolted to a heat sink, or the case.

Where a number of digital timers or associated circuits each have a fairly large current drain, it is often preferred to obtain the main supply at a somewhat higher voltage, and to fit a small fixed 5v regulator to the individual boards. The LM78LO5CH is suitable for 100mA and also the LM7805CZ, with the LM341P5 for 500mA maximum. Distribution at 8v regulated up to 1.5A can be from the μA7808KC, or at 12v 1.5A from the LM340T12 positive regulator, or from a zener diode transistor regulator. This method avoids the difficulties arising from voltage drop in long, low-voltage leads which may arise with distributing a 5v supply, and also reduces any chances of interference between units.

Typical items for Fig. 2 would be: T1, 240/9v 1A, 50v 1A bridge rectifier, C1 4700μF 15v, IC1 LM309K, C2 0.47μF, C3 0.22μF for 5v 1A.

Other fixed, positive 3-terminal regulators may be used, to suit the current required. The LM309K is rated at 1A, LM340T5 at 1.5A, and LM323K at 3A, 5v. Negative regulators are not suitable here. Adjustable 3-terminal regulators could be used, if to hand, and are set with a potentiometer for 5v output.

For IC regulation of a large battery supply (e.g. vehicle) omit T1 and rectifiers, and provide DC input for the IC from the battery, maintaining at least 8v.

Easy 0–5 Minute Timer

This circuit uses a capacitor charge system, and thus cannot have the great accuracy of a quartz oscillator followed by dividers. Despite this, it has sufficient accuracy for many purposes, and has the great advantage of requiring few components. It is constructed as a self-contained mains operated unit, switching on an indicator lamp when the required time has passed.

Timing is adjusted by means of VR1, Fig. 3. This potentiometer has a calibrated scale. The periods available extend from approximately 10 seconds to 5 minutes, and are split into two ranges by the switch S1. When S1 is open, R2 is added in series with VR1 and R1, thus lengthening the period.

Normally 3 of the 555 timer integrated circuit is positive. When C1 has charged to approximately 6v, internal devices conduct, discharging C1 and moving 3 negative. A tantalum capacitor is indicated for C1, this being better than an electrolytic here. The circuit can be operated with an electrolytic capacitor, but if this passes a significant leakage current charging times will be delayed, or the trip voltage may never be reached when the charging resistance (VR1, R1 and R2) is high. Where an electrolytic capacitor is fitted, it should be of good make, new, and 12v to 25v type.

During timing, Tr1 base is held positive by R6, so that the collector current in the relay RLY will close contacts A and B. When the interval set by VR1 has elapsed, Tr1 base moves negative and relay current falls. B is released, contacting C, and so lighting the indicator lamp. At the same time, B interrupts the circuit to A so that the timing section is put out of action. R7 drops about 7.5v at 100mA for the 6v 0.1A lamp.

Pressing the spring loaded switch S2 starts timing, as current then reaches this part of the circuit, and Tr1. S3 is the main on-off switch. Transformer T1, with a bridge rectifier (or four separate rectifiers) will provide around 12v to 13v or so across C3.

D1 is to suppress back emf developed by the relay windings. The relay can best have a DC resistance of some 250 to 500

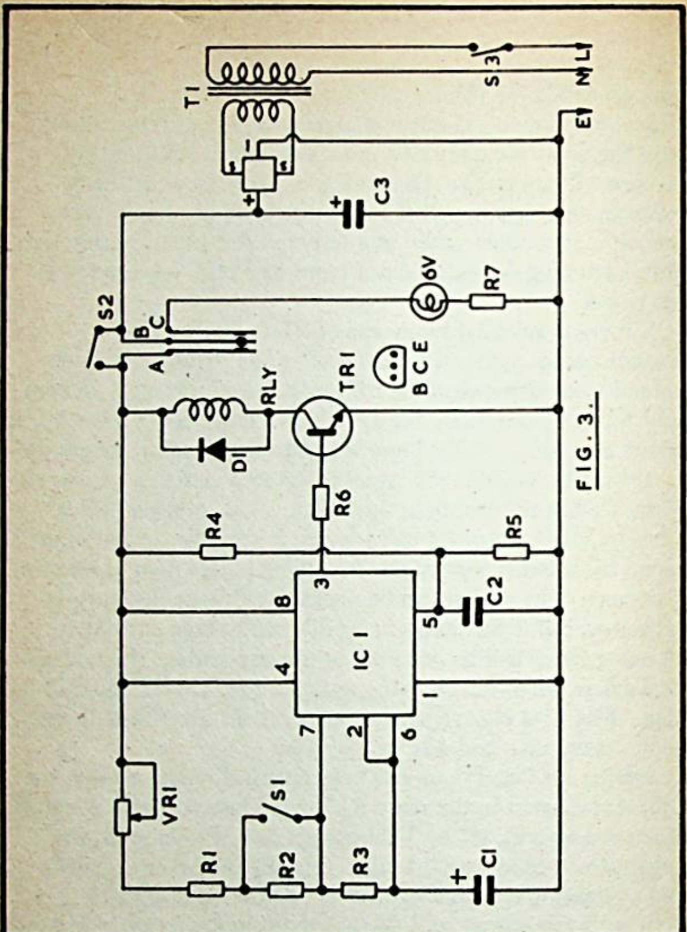


FIG. 3.

ohms or so, this being unimportant, provided it operates correctly with the 12–13v supply, and does not exceed Tr1 collector current.

VR1 should have a knob with pointer, and a reasonably large scale. Times can be marked directly on this. Begin with S1 closed and VR1 at minimum resistance, for the shortest interval. Intervals can be timed with a watch or clock with seconds' hand, and in this way the two ranges can be filled in.

Components for Easy 0–5 Minute Timer (Fig. 3)

R1, R4	100k	R2	2 megohm
R3	2.2k	R5	15k
R6	8.2k	R7	75 ohm 1w
C1	100μF tantalum	C2	10nF
C3	1000μF 16v	VR1	2 megohm linear pot.
IC1	555. DIL 8 pin holder	Tr1	2N3706
T1	250v/9v 100mA transformer	D1	1N4002
S1	slide type on-off switch	S2	push type switch
S3	mains voltage toggle switch		
6v 0.1A lamp and holder		250 ohm 12v or similar relay	
Case, etc.		Bridge rectifier or 4 x 1N4001	

Board Layout

Fig. 3B shows the layout on plain perforated board, wired from point to point below. This is an easy method of assembly which can be used for many circuits. Where an integrated circuit needs 0.1in perforations, 0.1in matrix board is necessary as here. But 0.15in board can be employed when this is not so, and gives a little more space between joints and leads.

It is of course possible to use board with foil strips, cutting these where a circuit must be interrupted, in the way described later. As example, in Fig. 3B, foils could run the long way of the board, and be used for numerous circuits. It is feasible to remove foils in advance by using an etching solution, as for printed circuit boards; or to do this (preferably out of doors) with a mechanical abrasive disc.

To wire up as in Fig. 3B, fit a few items at a time, turn the board over, and connect as required. Where necessary, use wire for connections (about 24swg is adequate for most circuits). When leads run near joints or cross, put insulated sleeving on.

Thin flexible leads are provided for VR1, S1 and the lamp, etc. A small bridge rectifier can of course replace the four diodes shown.

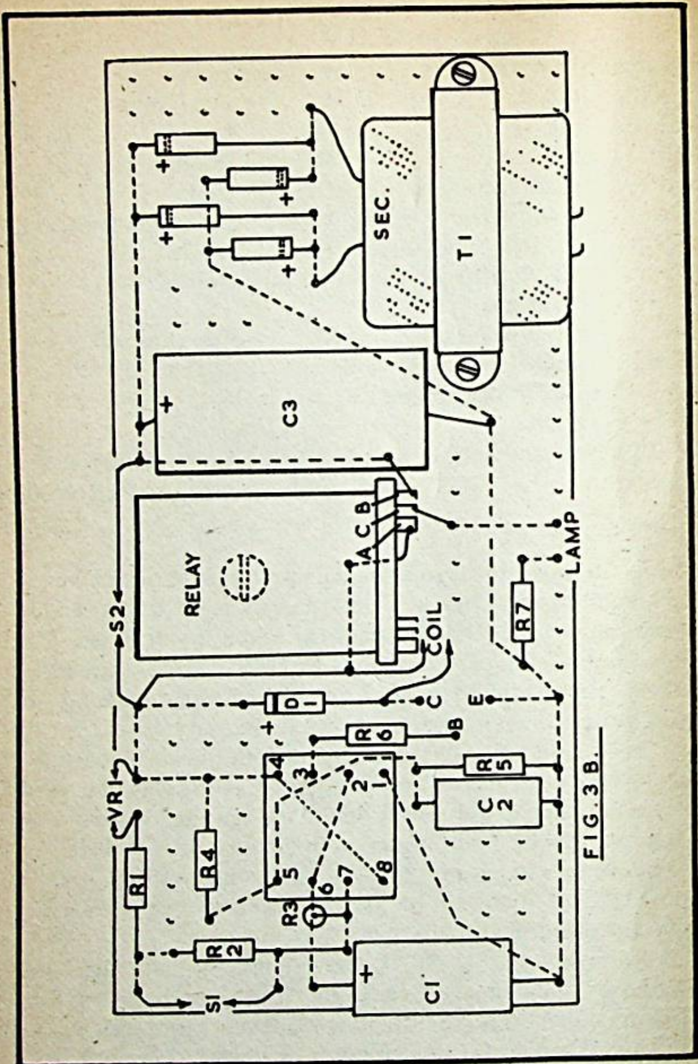


FIG. 3 B.

Single Numeral Timer

The single numeral timer can time fractions of a second, seconds, minutes, or hours, up to 9. Operating with a range of

0 to 9 minutes, it will be suitable for various processing and similar uses. A range of up to 9 hours would do for lengthy processes, while the 0.9 second rate would be appropriate for some kinds of reaction timer, where timing is automatically halted, leaving the interval displayed.

The basic single numeral is shown in detail, because by adding the same circuit one or more times, a decimal type timer can be made with any required number of digits. In this way, timing can be up to 99 seconds in 1 second intervals for two numerals; or three numbers may show up to 99.9 seconds with 0.1 second intervals, while four could show up to 99.99 seconds, with 0.01 second intervals.

Each numeral will require its own divider, driver, and display. Using the single numeral timer circuit, each such stage will divide by 10. Except where time elapsed is to be expressed as a decimal fraction of a larger unit – such as in a 2-digit timer reading up to 9.9 hours – intervals beyond 99 seconds are best displayed as minutes and hours. This can be arranged as shown later.

In Fig. 4 IC1 is the binary coded decimal decade counter. It has positive supply at 5 and negative supply at 10. As these are always required they are often not shown in complex circuits. C1 is a suppressor capacitor, used to avoid interference when there are a number of ICs all running from the same power line.

Input to IC1 is at tag 14. Decimal output in binary form is at 1 and 12, 9, 8 and 11. If these outputs are examined, they will be found to change each time a pulse is received at 14. A voltmeter or similar means can be used to check this. The outputs from IC1 correspond to 0 to 9. At the next pulse after 9, output reverts to 0, and the sequence is repeated.

S1 is a reset switch. It is normally closed, taking 2 and 3 to negative. When it is momentarily opened, outputs revert to zero, and this allows displays to be set back to 0.

The four binary coded outputs are taken into IC2 at 7, 1, 2 and 6. This IC decodes the binary inputs, and provides outputs to illuminate sections of the numeral. IC2 receives its positive supply at 16 and negative at 8, and these connections may not be included in a larger diagram.

Outputs from IC2 appear along 15, 14, 13, 12, 11, 10 and 9.

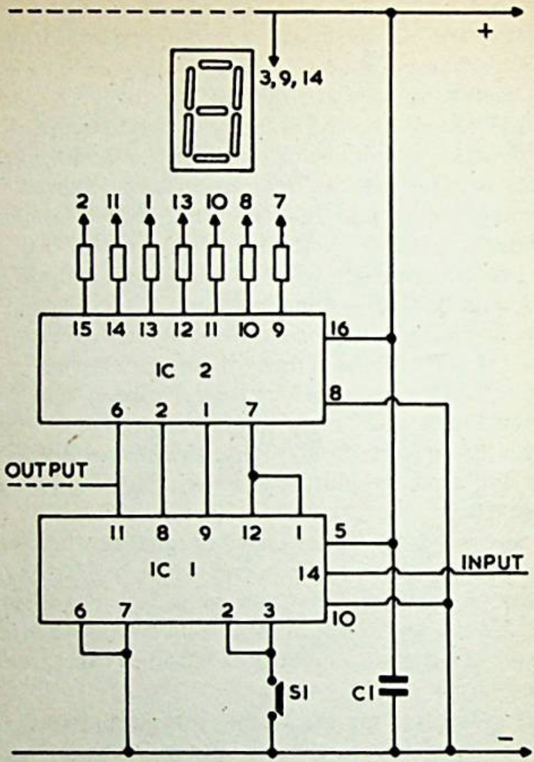


FIG. 4.

When any of these output points conduct, current can pass through the associated limiting resistor, and through a sector of the numeral so that a figure is displayed.

The numeral is a 7-sector light emitting diode array, and the resistor circuits go to pins 2, 11, 1, 13, 10, 8 and 7, as shown. A common anode numeral is required (not common cathode type) and here pins 3, 9 and 14 form the common positive connection. Some numerals do not use all these pins for positive, and most also have a decimal point.

By illuminating the appropriate sectors of the numeral, any figure from 0 to 9 can be shown. For 8, all sections are lit, while two sections form 1, and so on.

The series resistors are generally from about 180 ohm to 270 ohm each. The higher values save current, but slightly reduce brightness. For uncritical applications, a single resistor in the common positive supply to the numeral itself may be adopted. This does not give such uniform brilliance, due to the varying number of segments drawing current through it.

Thus, with S1 normally closed, and the 5v supply provided, the single numeral will count and display pulses put in at 14, and these may be at 1 second intervals, or any rate chosen.

When IC1 has reached its full count, a pulse passes from 11. This can be taken directly to 14 on a second, identical circuit. The second numeral will then extend the time ten-fold. That is, its number will advance 1, each time the first number has run through its 0–9 sequence. In the same way, the second decade counter or equivalent of IC1 can drive a third, and the third a fourth. This would give a timer reading from 0000 to 9999 and by insertion of the decimal point times can be measured in 0.01 second intervals up to 99.99 seconds.

Components for Single Numeral (Fig. 4)

IC1	7490N	DIL 14 pin holder
IC2	7447N	DIL 16 pin holder
7-segment LED, common anode		DIL 14 pin holder
C1	10nF	0.1in matrix board

Displays with numerals approximately 8mm high are suggested as these fit holders as used for the ICs. Other sizes are available. Holders suit 0.1in matrix board.

Board Layout

Fig. 4B shows assembly on perforated board, with the foil conductors running vertically. These are shown in broken lines, and are under the board, and only indicated where they are required to complete circuits. This means that foil breaks have to be made at other points. That is, between 1 and 14, 2 and 13 on to 7 to 8 of IC1; between 1 and 16 and on to 8 to 9 of IC2, under some resistors, between the circuit from 14 of IC1 to the circuits to 1 of IC2, and so on. This will prove

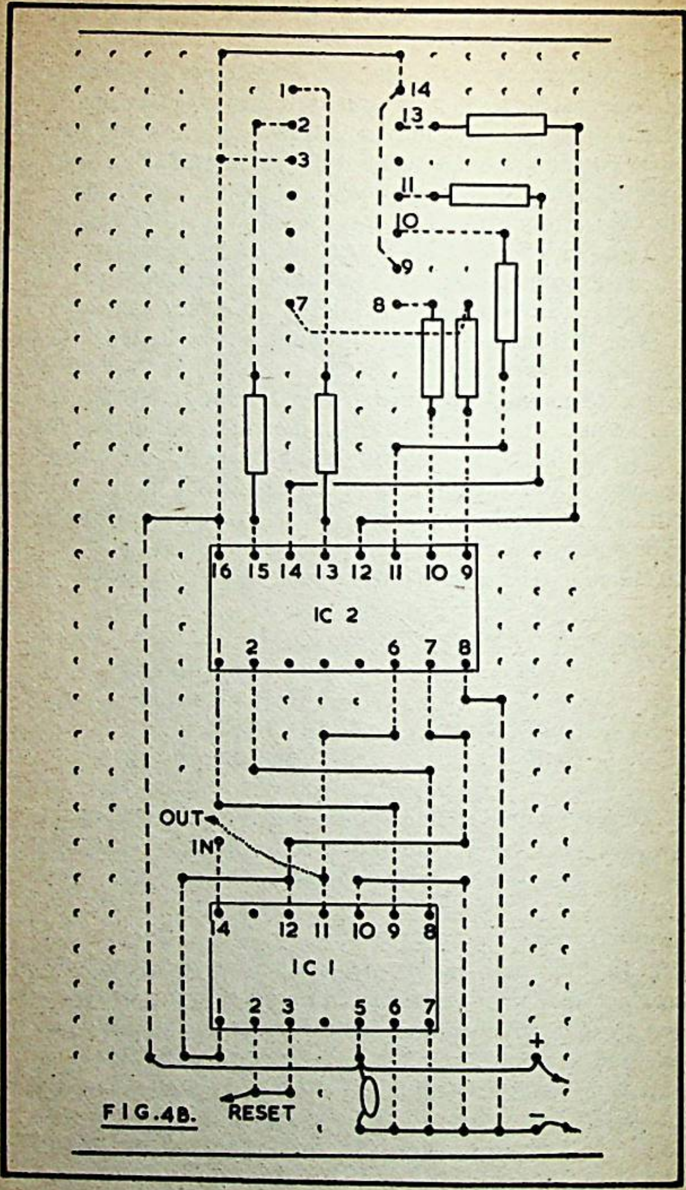

1
2
3
7
14
13
11
10
9
8
16 15 14 13 12 11 10 9
IC 2
1 2 6 7 8
OUT
IN
14 12 11 10 9 8
IC 1
1 2 3 5 6 7
+
−
RESET

FIG. 4B.

to be quite straightforward if carried out systematically. Use a foil cutter, or a sharp 3/16in or similar drill. Check that each foil is completely cut, and that fragments of foil do not bridge the cut, or turn outwards to touch adjacent foils.

If the numeral holder is fitted in the same way as the holders for IC1 and IC2, the figures come too far apart when more than one will be used. This makes it necessary to cut away the foil from the pin positions before inserting the numeral holder (or 1 to 7 will be all shorted one side, and 8 to 14 the other side).

Note that Fig. 4B shows the board from the top, or that side carrying the ICs and numeral, so that the pins are counted from 1 to 14 (or 1 to 16) in the way shown.

Solder the pins to the foils. Positive and negative lines can be 22 swg wire. This may be used elsewhere, though thinner wire is adequate and more easily fitted. As example, solder a short wire from IC1 pin 1 foil to adjacent foil, then a wire from this foil to the foil for pin 12. From this foil carry a wire out level with 8 of IC2, completing the circuit to the foil for pin 7, as shown. Other circuits are made in a similar way.

For the single numeral, the positive, negative, and reset leads are thin flex, to take to the power supply and reset switch. With only one numeral, the carry line "out" is not required.

When the board is to be extended to the left, to take another numeral, the positive, negative, and reset lines run on to this. It is wired as in Fig. 4B. The carry line is also included now, and runs from 11 of IC1, to the next divider, providing input there at 14.

After checking that foils are cut where necessary, and no joints short to adjacent conductors, a check can be made by applying 5v and taking the reset line to negative. This should display 0. Suitably timed pulses in at 14 will then step forward the numeral to 9. If any fault exists, check that the ICs are the correct way round, and the numeral is not upside down.

A faulty display is not to be expected, provided no short is present, or circuit omitted, or unless untested surplus ICs are fitted. (Book No. BP84, "Digital IC Projects" by the same author and publishers explains how to test binary output dividers of this type, in full detail.) Any input at 14, used to check this part of the circuit, should be a single pulse, from an electronically noiseless switch or from the clock. An ordinary mechanical switch is almost sure to be of little use, due to multiple contacts when making, so rapid that the numeral appears to miss some figures.

Provided C1 and the resistors are flat on the board, nothing will prevent the numeral coming behind a suitable opening in the case front. Any switch or other controls must be clear of the board to allow this.

An alternative method of assembly which reduces the panel size for several numerals is to have IC1, IC2 and resistors only on the board, with numerals on a small board fixed at right angles to this. By this means the total height of the case can be much reduced, and the numerals can be brought closer together, by bringing connections inwards from the outermost ICs.

UJT Clock

Clock pulses can be obtained from a unijunction transistor. A circuit for this purpose is shown in Fig. 5. Adding this to the numeral board completes the timer.

C1 charges through R1 and VR1, and when a critical emitter potential has been reached, the UJT conducts, discharging C1, and also producing a pulse at Base 1. This is amplified by Tr2, and provides input for the decimal divider, at pin 14.

For an indication in minutes, C1 and R1 with VR1 will be quite large. Much smaller values are used for seconds. It is practical to provide 0.1 second intervals (10Hz) or faster rates, which would be appropriate when the timer is to have several digits and show parts of a second. The presence of R1 makes VR1 easier to adjust, as some resistance remains in circuit.

This type of clock will operate with various unijunction transistors, and can have quite a good degree of accuracy. It is thus suitable for non-critical purposes (egg timer, games timing, rapid fixing and processes where extreme accuracy is not essential). Its advantage lies in the few components required. Reliable operation with a 5v supply is obtainable by omitting R4, R5 and Tr2, and taking pulses directly from B1 to 14, but

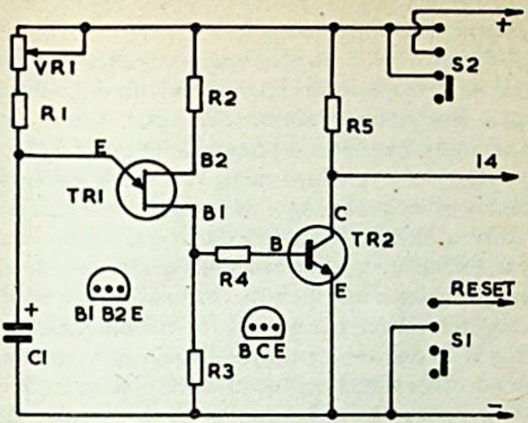


FIG. 5.

the value of R3 may need modification, or a small pre-set may be necessary here, to obtain reliable working of the IC divider, without Tr2.

The components in Fig. 5 can be accommodated upon an extension of the circuit board. VR1 is adjusted with a screwdriver, observing the numeral in conjunction with a clock or watch with seconds hand.

A slide switch with three positions and two poles is used for on-off switching. Section S2 closes in middle and final on positions, but S1 closes the reset line circuit only after current has been applied. This results in the display starting at 0.

No special care arises with C1 for the faster rates. But when a larger value is needed here, a paper capacitor (or other component with negligible leakage) is preferable to an electrolytic capacitor. When the latter is used, it should be a good quality one. Varying leakage will upset charging time, and thus the reliability of the clock pulses.

Tr1 may be TIS43, UT46, 2N2646 or similar unijunction transistors. Tr2 can be 2N3704. R2 may be 220 ohm, R3 680 ohm, R4 1k, and R5 1k. Operation is from the 5v line.

VR1, R1 and C1 can be selected according to the rate wanted. In the event of modifications being made, rate can be speeded by reducing VR1, R1, or C1 in value. Increasing the values here has the opposite result.

No difficulty arises with the 0.1μF or 0.25μF capacitors, which can be 150v paper or other types with negligible leakage. This type is also preferred for the 1μF value. For the largest value, a tantalum capacitor is preferable to electrolytic. When R1 and VR1 total a very high value, very small leakage in C1 considerably effects charging time from the theoretical value. Satisfactory working is possible with an electrolytic, but there can be considerable variation from one component to another. An alternative which may be adopted to avoid the need for a long time interval is to arrange Tr1 for one pulse each 6 seconds, and to follow by a simple divider, to secure pulses at one minute. This would consist of an IC used as for IC1 in Fig. 4 with input at 14 and output at 11, and no decoder IC or numeral.

Interval	*VR1*	*R1*	*C1*
0.01 sec.	50k	100k	0.1μF
0.1 sec.	220k	560k	0.25μF
1 sec.	470k	1.2M	1μF paper
6 sec.	470k	1.8M	1μF paper
1 min.	2M	220k	25μF 25v electrolytic.

VR1 may be less than 2 megohm for the slowest rate, if R1 is found to suit the capacitor.

LED 0–10 Rotary Indicator

This circuit has application for domestic and other purposes where an indication of how time is going on is required, as well as showing when the final time is reached. Uses include developing, rapid fixing, and cooking for short periods. Amusement usage includes puzzles and problems to be attempted within a short timed interval, and similar games.

A rotary effect can better convey an appearance of passing time and is achieved by placing ten light emitting diodes in a ring. When the timing interval is begun, the top LED (zero or 10) lights. From here, the diodes step round one by one in the usual clockwise direction, at 1 minute intervals. As egg-timing, toasting, games and other activities to be timed are going to be under more or less continuous or at least fairly frequent observation, no circuit is included to indicate when 10 is reached. If wished, it is easy to add an "overflow" indicator, which lights when 10 is passed, as shown elsewhere. Counting then proceeds for a further rotation. This extends the timing to beyond 10 minutes.

Fig. 6 shows the divider, driver and display circuit. Input to 14 of IC1 is from any of the clocks providing one pulse per minute. This may be a unijunction transistor with timing capacitor; or other of the circuits shown, if preferred.

If IC1 is merely switched on by completing its supply, any random output may be present, and may be decoded and result in any LED being illuminated. To avoid this, the 3-position slide switch S1/S2 controls the reset line at 2 and 3 of IC1, as well as the negative line. It is so wired that S2 completes the supply line before S1 closes the reset line. In this way, output from IC1 is correct, bringing on the top LED, for zero or 10. The timing circuit starts at the same operation of S1/S2.

IC2 decodes the binary from IC1, and each input pulse at 14 of IC1 changes its output, and thus the input of IC2, and step the LED circuit from 16 to 15, then from 15 to 8, and so on. In this way each LED lights for 1 minute, and is followed by the next. R1 limits current, and can be modified somewhat with different LEDs, though about 180 ohm to 220 ohm is usually satisfactory in terms of LED current and brightness.

Components for LED 0–10 Rotary Indicator. (Fig. 6).

IC1	7490 14 pin DIL holder	IC2	7441 16 pin DIL holder
R1	220 ohm	C1	10nF
S1/S2	2-pole 3-position slide switch, make before break		
10 off LEDs, any colour		Box, board, etc.	

Constructional Details

It is convenient to build the clock on the same board, so it needs to be large enough for this. A ring of holes is carefully marked out on the case for the LEDs. These may be a push fit

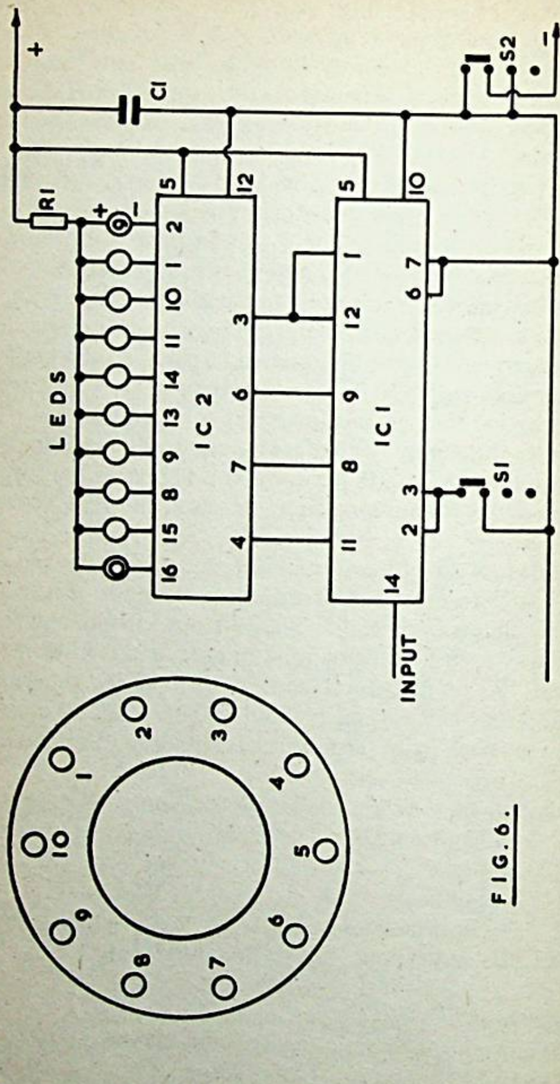

+
C1
R1
LEDS
IC 2
IC 1
S1
S2
-
INPUT
5
12
10
2
1
10
11
14
13
9
8
15
16
3
6
7
4
12
11
14
6 7
3
2
1
2
3
4
5
6
7
8
9
10

FIG. 6.

in grommets intended for them, and ten thin flexible leads can run to the board, connecting to 16 to 2, IC2. All positives are joined, and a further lead runs to R1. Check LED polarity is correct, as they cannot light if reversed.

An alternative method of assembling the LEDs, which has been found convenient, is first to drill clearance holes for them in the case. Then position the LEDs to agree on the circuit board, with their leads full length. Solder one lead of each only to the board foils, taking care all LEDs are at the same height from the board. It is then possible to make any small adjustments to position, so that the LEDs will pass through the case holes, before soldering the remaining legs. With both leads soldered, some movement is prevented. Force must not be used, or damage to the LED may result in it not lighting. All wiring can then be completed here on the board itself.

S1/S2 is most conveniently screwed to a slot in the case front, with thin flexible leads to 2, 3 and negative lines.

Battery running is possible, as described elsewhere. Total current drain depends on the ICs and R1, as well as clock, and can be around 50mA to 60mA. This makes a very small mains pack suitable, and this can be incorporated in the case. Numerals 1 to 10 are put in a circle adjacent to the LEDs.

555 As Clock Source

The 555 integrated circuit timer is particularly suitable for devices where some loss of accuracy or error in timing over lengthy periods is not important. It can be fitted where the high accuracy of a quartz clock is not necessary, and where its simplicity is an important advantage. For many purposes, it can be adequate.

The 555 normally runs from 4.5v to 16v, and can conveniently operate from the 5v line used with TTL devices, or from 9v, −12v or similar supplies, as available. Current drawn is about 3mA to 10mA depending on working conditions, so the IC is suitable for battery running.

By suitable choice of values, frequency can be set between wide limits. To operate clock and timing devices, output rates of 10Hz (1 pulse per 1/10th second), 1Hz (1 pulse per second) and 1 per 10 seconds can be convenient. Use of the longer intervals may allow one or more dividers to be avoided, and 1 minute or 100 second intervals are practical.

Fig. 7 is a circuit which may be employed for 1/10th second, 1 second, or 1 pulse per 10 seconds, by fitting 1μF, 10μF or 100μF at C1. In each case VR1 is set for the correct rate. The slower pulses can be counted against a watch with seconds' hand, and adjusted as accurately as possible by this means. The 10Hz pulses can be counted when followed by a 10 or other divider. There is no point in providing 10Hz output with a divider if 1 pulse per second will be wanted, but for some purposes the 1/10th second rate will be needed for gating.

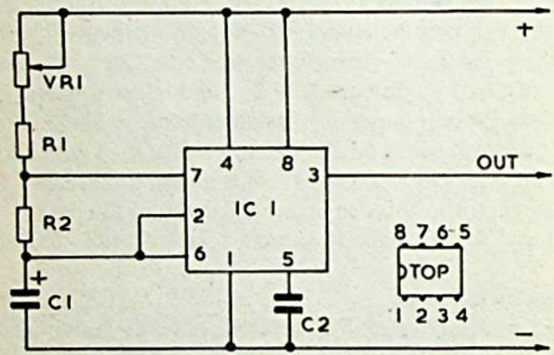


FIG. 7.

Variations in rate may arise from drifting in the resistor values, and in leakage through C1. C1 may be tantalum, or paper in 1μF and lower values. Ordinary electrolytic capacitors can be suitable. Increasing R1, or VR1, in value, lowers the pulsing rate. If needed, R1 may be reduced to 47k, for C1 having a value of 100μF. Over a wide range results tend to change from the theoretical value, due to the effect of leakage in C1. This increases with high value capacitors. Thus if C1 and R1/VR1 are all increased in value for very long timing intervals, a point eventually arises where C1 never charges to the level needed to trigger the IC.

By obtaining the total value by means of VR1 and R1 in series, VR1 is made easier to adjust. R1 may be larger, and VR1 can be reduced accordingly, provided sufficient adjustment remains for the wanted rate.

The 555 fits the 8-pin DIL holder, and assembly can be on 0.1in perforated board, this usually carrying other components as well. VR1 should be placed so that it can be readily adjusted with a screwdriver. In some forms of adjustable timer it may be panel-mounted, with knob and a calibrated scale.

Components for 555 As Clock Source. (Fig. 7)

R1	47k	R2	2.2k
VR1	100k linear pre-set	C2	0.1μF
C1	1μF, 10μF or 100μF	IC1	NE555

8-pin DIL holder.

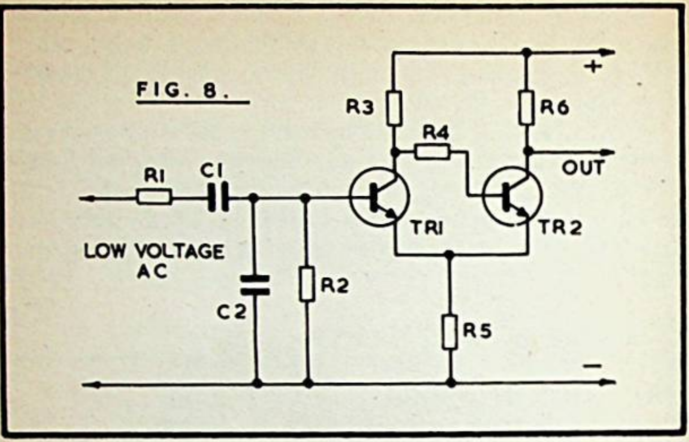
50 and 60 Hz Drivers

Where a timing unit is operated from AC mains, it can be convenient to derive frequency control from the 50Hz or 60Hz supply. This will already be available at the low voltage secondary of a transformer which supplies power for other circuits.

This is satisfactory where the mains supply is relatively free from interference, or where the driver circuit can be arranged so that it does not respond to interference spikes on the supply. Where it does respond to these, the timing device will tend to gain. This can be of no practical significance; or can with continuous interference make the mains source unreliable.

Fig. 8 is the circuit of a 50Hz or 60Hz driver employed to drive digital clocks and timers. The alternating current input to C1 is from a low voltage isolating transformer, usually providing power for 5v or other circuits. C2 helps to suppress transients (caused by the operation of domestic power switches, thermostats, etc.) to which the counter would respond. Tr1 and Tr2 shape the output, so that it can drive the first divider directly.

It is of advantage to make the circuit as unresponsive as possible to interfering pulses, and to keep the threshold of



operation low so that 50Hz or 60Hz cycles operate the counter, but not interfering pulses of lower level. Response to HF pulses falls as C2 is increased, but too high a value here will prevent working. Interference suppressor capacitors may also already be present across the transformer primary or secondary.

R1 is as large as possible, providing reliable operation is not lost. The value of R1 depends somewhat on the transformer secondary voltage. This will generally be about 6v to 9v AC. With a bridge rectifier, R1 can be taken to one secondary tag, as neither will be negative, and this results in a lower AC voltage at R1.

A driver of this type is readily checked when an appropriate divider or equivalent circuit is available. This will be 50 for 50Hz, and divide by 60 for 60Hz, so that output will be at one pulse per second, and can be checked against a watch. No count shows that the output from Tr2 is insufficient, and could arise from R1 being too large, C2 too large, or insufficient input or wiring errors. Dividers to obtain 1Hz are shown later.

Typical Component Values for Fig. 8

R1	22k	R2	47k
R3	2.2k	R4	3.3k
R5	68 ohm	R6	2.2k

C1	0.5μF, 0.47μF	C2	0.1μF
Tr1	2N3706	Tr2	2N3706

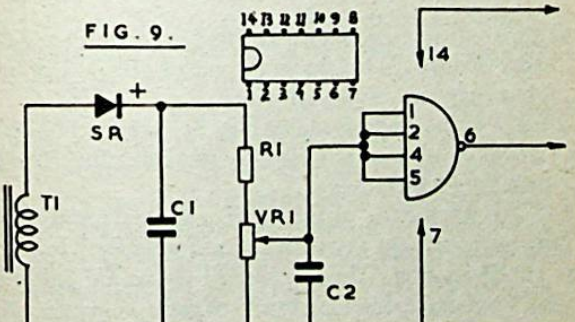
Schmitt Trigger

A good mains frequency driver can be arranged with one-half of the dual 4-input Schmitt triggered NAND gate 7413. The Schmitt trigger provides different threshold levels for positive and negative of about 800mV, and will operate on slow rise and fall inputs, which allows filtering against transient interference spikes.

Fig. 9 shows a circuit, with 14 and 7 for positive (5v) and negative lines. Inputs are at 1, 2, 4 and 5, and output at 6. The second trigger, here unused, has inputs at 9, 10, 12 and 13, and output at 8.

Drive is obtained from the secondary of T1, which will usually provide around 6v to 9v AC. C1, C2 and R1 help suppress interference, and R1 also reduces the input level. This may be set by the potentiometer VR1 just high enough for reliable working, or may be obtained across a 220 ohm fixed resistor replacing VR1. An unnecessarily high input can increase the chance of interference operating the trigger, and thus the timer or other circuits it controls, though good freedom from interference should be obtained.

FIG. 9.



Typical Component Values for Fig. 9

R1	1k	VR1	470 ohm	SR	1N4002
C1	0.1μF	C2	0.1μF	IC	7413

Output is taken directly to the input of the divider, which will divide by 50 or 60, for 50Hz or 60Hz mains, to obtain 1Hz pulses. These can be checked with a counter, or as described.

Mains driving can be satisfactory for many timing applications with digital circuits.

For battery running, or the highest accuracy, a quartz crystal source will be used. This does not rely on mains frequency.

Quartz Crystal Drivers

For greatest accuracy, and freedom from drift or mains interference, a crystal oscillator is generally used for frequency control. This also allows accurate timing with battery operation, as with a vehicle supply.

The crystal frequency is often 10MHz, or 1MHz, but 100kHz (and other frequencies) may be used. The following shows the frequencies obtained after one and more stages each dividing by 10.

Crystal	
10MHz	1MHz. 100kHz. 10kHz. 1kHz. 100Hz. 10Hz. 1Hz
1MHz	100kHz. 10kHz. 1kHz. 100Hz. 10Hz. 1Hz.
100kHz	10kHz. 1kHz. 100Hz. 10Hz. 1Hz.

It is apparent that the higher frequency crystals need one or two further dividers to obtain an output of 1Hz or 1 pulse per second, but these are readily provided.

With any of the crystals pulses may be taken at one-tenth second or faster rates, as required, by switching the drive point back down the divider chain.

Fig. 10 shows the use of the 7400 quad dual-input NAND IC. Two gates are used as oscillator, and frequency is controlled by the 10MHz crystal. The trimmer T1 allows a slight pulling of crystal frequency, for adjustment of rate. One gate acts as buffer, and output goes directly to the first divider input.

The crystal is typically intended for a series capacitance of about 15pF, obtained by C1 and T1. Normal adjustments make only a very slight change to the rate. Where this is too low, T1 or C1 would be reduced. If too high with T1 fully closed, T1 or

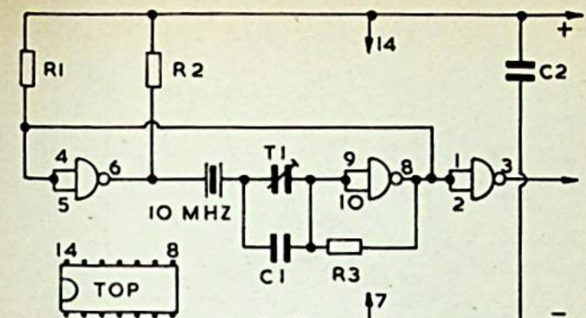


FIG. 10.

C1 can be increased in value. Such modification may be required when using surplus or unknown crystals. If excess oscillation causes other frequencies to appear, place a resistor of about 47 ohm to 560 ohm in series with the crystal.

A crystal for 1MHz may be intended for approximately 30pF series capacitance, and T1 may then be increased to 25pF or 30pF, and C1 to 22pF or so.

Tags 14 and 7 are the positive and negative supplies for the IC, requiring 5v.

Fig. 11 shows a 2-transistor driver. Here, Tr1 is the crystal controlled oscillator, and Tr2 a buffer-amplifier. Output again goes directly to the first divider.

C1, C2 and C3 should preferably be silver mica, as these capacitors form part of the oscillator circuit. With some surplus crystals it may be necessary to change C2 or C3 to secure oscillation, and re-adjustment of T1/C1 may then be needed. Exact frequency may be raised or lowered slightly as described for the earlier circuit. Some crystals, especially for lower frequencies, may be intended for 60pF series capacitance, and C1 can then be 47pF.

The adjustment provided by T1 is very small – generally a rate change of up to 1 part in 10,000 or so. The setting of T1 can be accomplished with the aid of some external standard.

One method which can be used when a clock, timer or counter of sufficient capacity is available is to reset this to zero

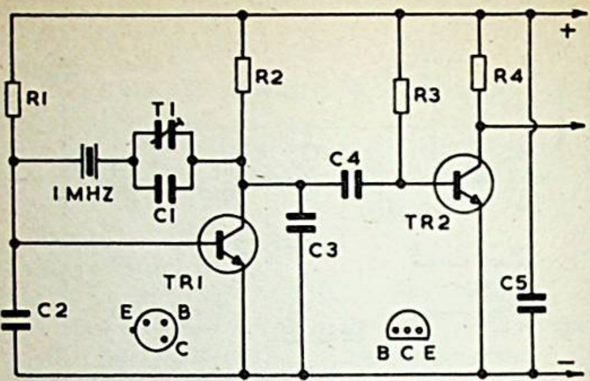


FIG. 11.

by radio broadcast time pips, and observe whether there is a gain or loss after 12 hours or some other suitable interval. The rate can then be adjusted with T1, and the check repeated.

An alternative requiring no delay is to tune in a radio transmission of known frequency, and beat a harmonic of this from the oscillator. Standard frequency transmissions audible on 2.5MHz, 5MHz and other frequencies may be used for this purpose. The 200kHz broadcasts on long wave may also be used, as the second harmonic of the 100kHz output will fall here.

Difference in frequency will be heard as a low pitched note, or flutter, and T1 is adjusted to obtain the lowest difference between oscillator and radio transmission. When using a portable or similar receiver for this purpose, it may be necessary to turn it to reduce pick-up of the 200kHz signal, and to place a short insulated wire near the 100kHz output and ferrite rod winding, to avoid swamping the harmonic.

Though it is usually convenient to use the 5v supply for the transistor oscillator, other voltages can be used. Unless the supply is already regulated, it should be stabilised with a zener diode. This may be 5.6v 400mW, with a series resistor depending on the voltage of the supply.

Components for 10MHz Oscillator. (Fig. 10)

R1, R2	680 ohm	R3	150 ohm
C1	10pF	C2	47nF
T1	10pF pre-set	10MHz	crystal (15pF)
SN7400		14 pin DIL holder	

Components for 1MHz Oscillator (Fig. 11)

R1	47k	R2	3.3k
R3	270k	R4	2.2k
C1	22pF	C2	147pF (150pF suitable)
C3	470pF		
C5	47nF	C4	47pF
Tr1	2N706	1MHz	crystal
T1	30pF pre-set	Tr2	2N3704

Multi-Rate Precision Source

When making and testing precision timers, a source of pulses at various precise rates will be of utility. The precision source here provides pulses at 100kHz, 50kHz, 10kHz, 5kHz, 1kHz, 500Hz, 100Hz, 50Hz, 10Hz, 5Hz and 1Hz, or one pulse per second. Any of these can be selected by means of a multi-way switch.

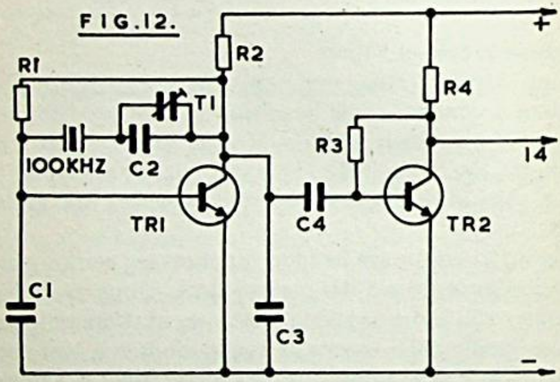
The 50Hz output can be used for checking working of timekeepers run from 50Hz mains pulses. Using much higher input rates will allow checking operation of those numerals which normally only operate at long periods in a quite brief interval. Thus, as example, the 24 hour section of a timer can be run through and observed for correct display in a minute or two. In the same way, the tens and units numerals of a 4-digit timer showing to 99.99 seconds can be observed at normal rate, and the tenth and hundredth numerals run at a reduced speed to check they display correctly. At normal rate, the 0.0 to 0.9 numeral will change too quickly to be observed fully, while the 0.00 to 0.09 numeral will appear as a continuously lit 8 until halted.

By having a considerable range of rates, sections of timers or clocks having up to eight numerals (hours, minutes, seconds and decimal parts of a second) can be checked in any section at a speed which is convenient for observation or measurement. The precision source output can be taken to various divider inputs of the timer or other device, as well as to the first divider input.

Frequencies are derived from the crystal oscillator Tr1, Fig. 12. R1 supplies base, and R2 collector. T1 and C2 together usually need to total about 30pF. C1 and C3 form part of the oscillator circuit. The operation of this type of oscillator has been covered, and it should be adjusted to frequency, in the way described, when construction is finished.

Tr2 is a buffer-amplifier, with base resistor R3 and collector load R4, and connection is directly from here to 14 of the first divider (14).

FIG.12.



The divider chain employs ICs wired in the same way, Fig. 13. Pins 2, 3, 6, 7 and 10 of each connect together and to the negative line, of 20swg conductor. Pins 5 are similarly connected, for the positive line. Input to each is at 14. Output from each is at 1 and 12 joined for division by 2, and at 11 for division by 10.

Points 1 to 11 go to a 11-way switch, connected to the output socket. Thus any of the frequencies provided, from 100kHz to 1Hz may be selected as output.

Power is readily provided, as the oscillator, buffer, and five dividers require only about 120mA at 5v. Battery running,

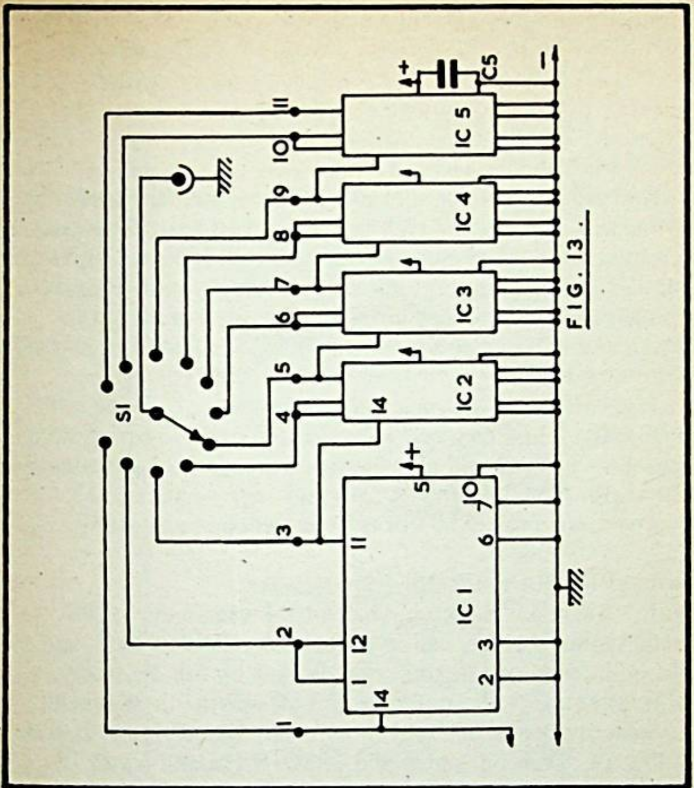


FIG. 13.

running from a small mains PSU, or borrowing current from the equipment being tested can all be appropriate. Where supplies are separate, the negative lines are connected.

Components for Multi-Rate Precision Source. (Fig. 12)

R1	1.2 megohm	R2, R4	2.2k
R3	220k	C1	330pF
C2	15pF	C3	800pF
C4	10nF	T1	30pF trimmer
Tr1	2N706	Tr2	2N3706

100kHz crystal for 30pF capacitance

Components for Fig. 13

IC1, IC2, IC3, IC4, IC5 7490	5 off 14 pin DIL holders
C5 0.1μF	11-way rotary switch
Socket	Case, etc.

Board Layout

A board about 4¼ x 2in (108 x 50mm) will take oscillator, buffer and dividers, and is 0.1in matrix, to accept the socket spacing. Place the crystal and Tr1 one end, followed by Tr2, and IC1 to IC5. Wiring to these can be duplicated. Provide flying leads for the connections 1 to 11, afterwards cut to length and soldered to S1. Switch positions should be marked with the output frequencies obtained.

Fig. 13B shows the underside of the board, carrying both the oscillator and dividers. This is wired point-to-point, using 20swg for positive and negative lines, though 26swg is adequate elsewhere. The link from R2/R4 and positive line can be removed when the oscillator is to be switched separately.

Dividers for 50Hz and Other Frequencies

With 50Hz mains supplying the control frequency, 1/10th second interval pulses can be obtained by division by 5, and 1 second interval or 1Hz pulses by division by 50. Similarly, with 60Hz mains, division by 6 and 60 provide these results.

Such division is generally obtained by two dividers, as at A in Fig. 14. Division is by 5 and 10 for 50Hz, and 6 and 10 for 60Hz, and this allows pulses at 10Hz to be taken, if required. A rate of 5Hz or 6Hz, such as would result from placing the decade dividers first, is not suitable for gating, but the order of the dividers is not material when only 1Hz or lower rates will be needed.

B shows use of the 7490 for division by 5. Pin 10 is negative, while 6 and 7 are also taken to this line. Pins 2 and 3 form the reset line. This is taken to negative for normal operation, but can be temporarily disconnected by switching or other means, where a logical zero output is necessary. Tag 5 is positive. Input is to 1, and output from 11.

C shows the use of the 7492 for division by 6. Pins 5 and 10 are for positive and negative, but 6 and 7 are for the reset line (if used). Where resetting is not required, 6 and 7

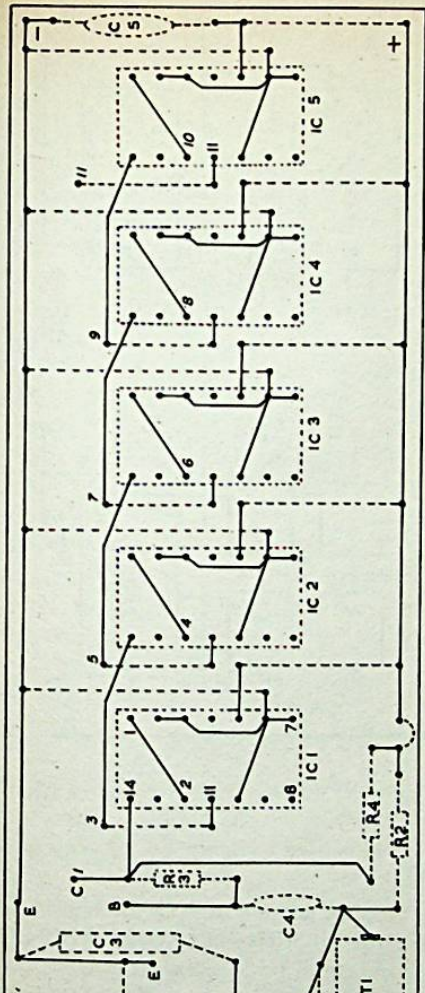


FIG. 13 B.

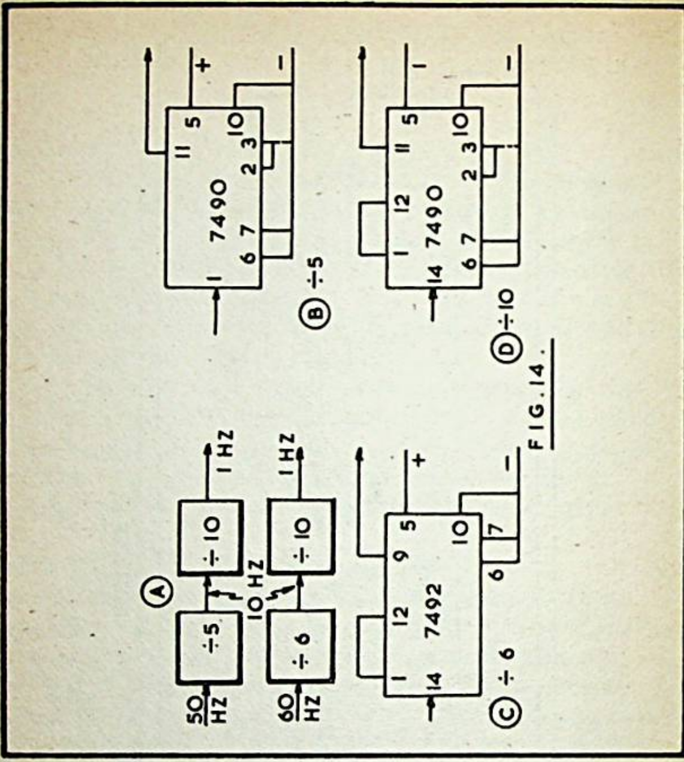


FIG. 14.

connect permanently to negative. Input is to 14, and output from 9.

At D, the 7490 is used to divide by 10, with input at 14 and output at 11.

The stages employ direct connections. Thus 11 of B will connect to 14 of D for 50Hz mains, and 9 of C to 14 of D for 60Hz, for 1Hz output in both cases.

A common 5v supply is required. When several such ICs operate together, one or more by-pass capacitors will be used across the supply, near the ICs, to help suppress the effects of the rapid switching in various circuits.

When first completing such a 2-stage divider, it is worthwhile to check its operation. One method needing no special equipment is to count the 1Hz pulses against the seconds' hand of a watch. Wrong rates may be traced to omitted or shorted connections or errors, and lack of output to similar causes, or ICs inserted wrongly, or faulty.

The correct operation of a clock or timer, or display with a counter, naturally depends on intervals being as required, which in turn depend on working of the dividers.

Should counts generally be correct, but occasionally be higher, spurious pulses carried on the mains are probably triggering the first divider. These will be divided here, and in later ICs, but will result in an input of over 50Hz (or 60Hz) effectively arising. This may coincide with operation of local switches or equipment, or the source may not be clear. Typically, a clock would run fast, due to the extra pulses in the form of unwanted, transcient interference being superimposed on the 50Hz supply. This gain could be irregular. Ways of overcoming this trouble are described in the section of obtaining control pulses from the mains.

Additional Numerals

The use of three (or more) numerals will be clear from Fig. 15. Clock input is to 14 of binary coded decimal divider BCD1, whose binary output operates the decoder D1, which in turn controls the "units" numeral. Output from 11 of BCD1 goes to 14 of BCD2, which operates D2 and "tens" numeral. Similarly, output from 11 of the IC BCD2 passes to input 14 of the IC BCD3, whose binary output goes to the deocder D3, which operates the "hundreds" numeral. Others could follow.

With no decimal points, timing would be to 999, and not generally employed in this form. With a decimal point at DP1, timing is to 99.9 (e.g., 99.9 seconds). With the point at DP2, timing is to 9.99 (e.g., 9.99 seconds). The first input, to 14 of BCD1, is at 1 second, 0.1 second, or 0.01 second intervals, in these examples.

The wanted decimal point is illuminated by taking a resistor of about 270Ω to 1k from pin 6 of the numeral to negative line.

Longer intervals will be displayed in minutes and hours, as necessary, using the dividers shown later.

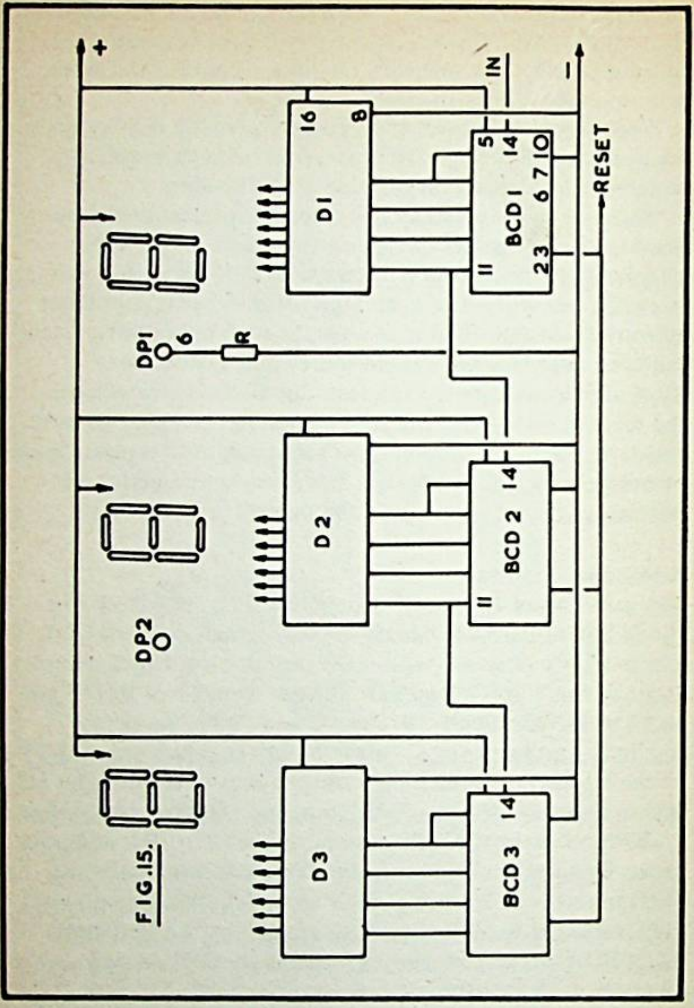


FIG.15.

Second, Minute and Hour Timers

Up to 99 allows maximum capacity with two digits, but times in excess of this are best expressed in seconds, minutes, and hours. The seconds may be absent in long duration timers. For great accuracy, a decimal point and one or two numerals, for tenth and one-hundredth second may be included. The way of arranging this has been shown.

To show minutes or hours, a divider circuit is used where two numerals display up to 59, a pulse passing to the minutes or hours from seconds or minutes section at the next count, the display here then reverting to 00. This is arranged by using a 10 divider for the units, and 6 divider for the tens column. The same circuit can be used for seconds or minutes, based on 60.

A pulse will be passed on from the minutes section each hour. The hour indicator can be a single numeral, for up to 9 hours. For longer times or ordinary use, the hour indicator may best have two numerals, for 24 hour indication. The circuit is a little more complex, because the units numeral has to run from 0 to 9 twice, but a pulse has to pass on when this number passes 3 at 23 hours. Similarly, the tens number is required to show 0, 1 and 2 only. The whole 24 hour display runs to 23:59. Seconds could of course be present, and decimal parts of a second, if wished.

The break between seconds, minutes and hours, may be shown by a raised point (numeral reversed) or by decimal points pulsed to operate each second. Or a space may be left between the sets of figures, or a LED can be used. Some displays with no decimal parts of seconds use an ordinary decimal point between hours and minutes.

To make a timer along these lines, a 60 divider with 60 display will be needed. Also a 24 divider, with its appropriate decoding and display.

All these timers can be immediately set to zero throughout by opening the common reset line. This is done at the beginning of any timing interval. Merely applying power to the circuit will result in a random or defective display.

Fig. 16A is the 60 divider section and numerals. Input is to 14 of IC1. The associated decoder IC2 results in a display of 0 to 9. Pin 11 of IC1 drives 14 of IC3. This is a different type of divider, arranged to operate the tens numeral by means of its driver decoder IC4. This section displays to 59, returning to 00 at the next clock pulse. The reset line for IC3 is 6 and 7. A pulse passes from 9 of IC3. If this section is displaying seconds, this pulse will go to a second similar section, for

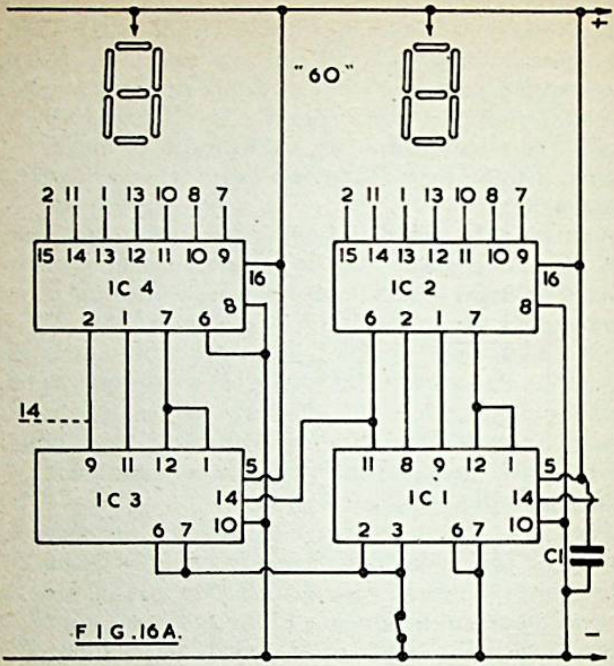


FIG.16A.

minutes. But if minutes are shown here, the pulse goes to the hours section.

Fig. 16B is the circuit for 24 hours. IC5 is connected to display 0 to 9 after decoding by IC6. At 0, a pulse passes to IC7, so that the numeral driven by decoder IC8 changes to 1. At the pulse following 3 from IC5, the NAND gates 4–5 to 6, and 1–2 to 3 open the reset line for IC5 and IC7, returning these to the binary output giving 00, when IC7 output at 9 gives a display of 2. As a result, the sections A and B display up to 23:59, and the next pulse reverts to 00:00.

NAND gate 9–10 to 8 is connected to allow manual resetting of IC5 and IC7 to the state resulting in the 00 display, to commence a period of timing. A quad NAND IC is convenient for these functions, one gate being unrequired.

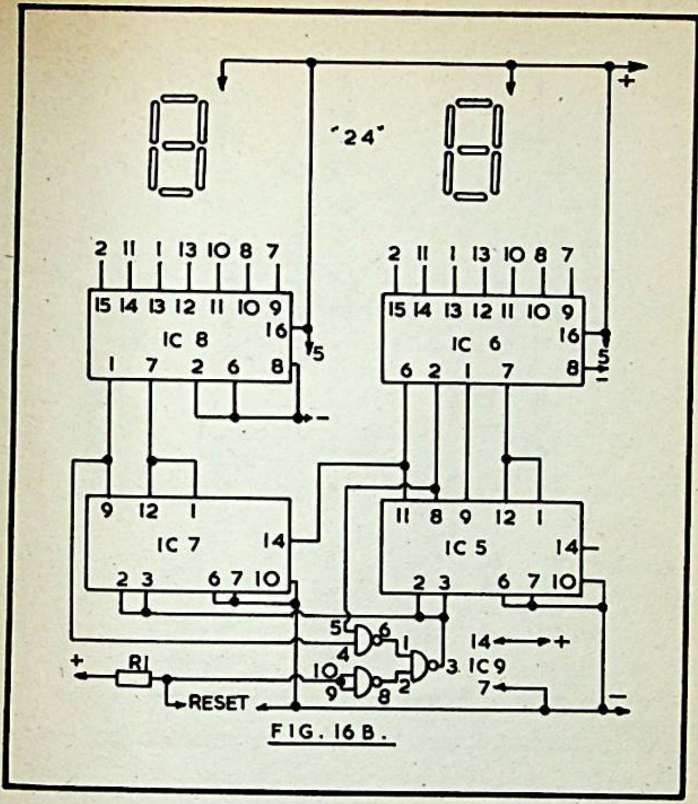


FIG. 16B.

Components for Figs. 16A and B.

IC1, IC5, IC7	7490N	IC3	7492N
IC2, IC4, IC6, IC8	7447N	IC9	7400N
9 off 14 pin DIL holders		4 off 16 pin DIL holders	
4 off DL707 0.3in common anode numerals			
32 off 270Ω resistors		R1	1k
C1	10nF	board etc.	

Board Layout

Fig. 16C shows wiring of dividers and decoders for seconds or minutes. Connections are point-to-point, with thin tinned copper wire (about 26swg to 30swg or so) being most con-

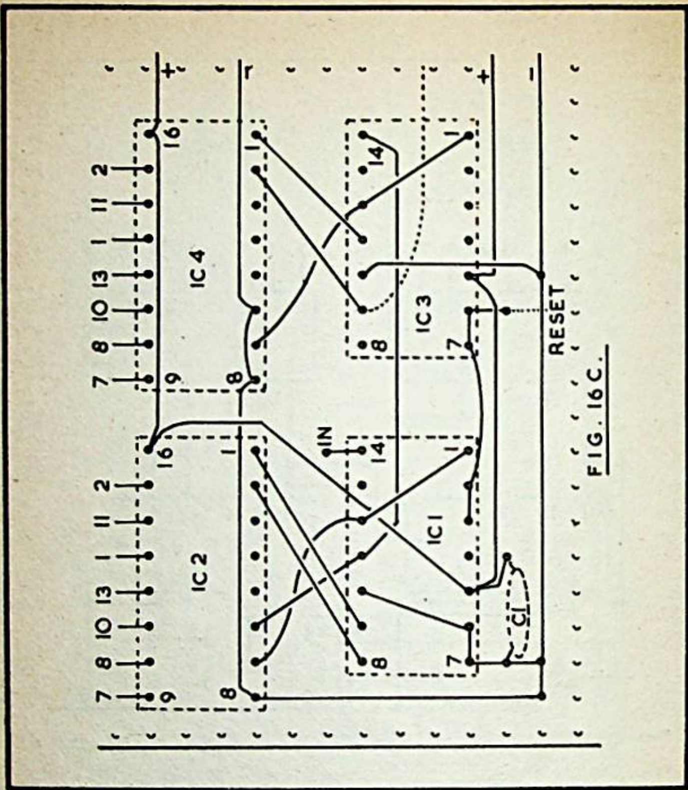


FIG. 16C.

venient, with 20swg for the positive and negative lines. These run on along both the dividers, and the decoders. They are joined at the end of the board, and the positive circuit run up and along for the numerals.

24 Hour Clock

A quartz controlled 24 hour clock is an interesting and useful project, and will be obtained by using the various circuits given in detail elsewhere. Any difficulty about the way in which these are connected will become clear from Fig. 17.

The clock is controlled by a 100kHz crystal, with oscillator Tr1 and buffer-amplifier Tr2. IC1 to IC5 are decade dividers,

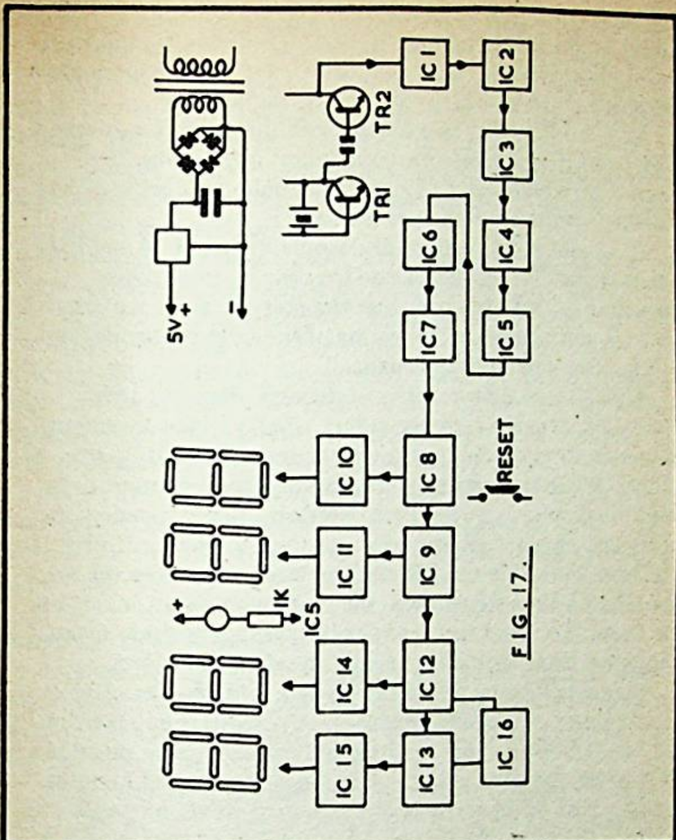


FIG. 17.

so that output from this section is at the rate of 1 pulse per second. If a 1MHz crystal is used, one more decade divider will be necessary. This part of the clock can if required be regulated as to rate in the way explained. Alternatively, the accuracy obtained without any adjustment may be considered adequate.

Pulses from IC5 go to IC6 and IC7. These divide by 60, to obtain 1 pulse per minute. IC6 and IC7 are used in the same way as those for the minutes display, but no decoder-drivers and numerals are included. If a seconds display is wanted, add two decoder-drivers and numerals here. Connections duplicate those used for the minutes section. The numerals will change at 1 second intervals, reading up to 59. The next pulse produces 00 and a pulse passes to the minutes section.

IC8 and IC9 are for minutes, with their decoder-drivers IC10 and IC11. These decoder-drivers operate the "60" numerals, which run to 59, the next pulse producing 00 and passing a pulse to the hours section.

IC12 and IC13, with their decoder-drivers IC14 and IC15, operate the "24" hour section (reading up to 23, then reverting to 00). In order that the units numeral can run to 9 and 19, but change at 23, gating of the reset is provided by IC16. This operates automatically.

Thus the oscillator, series of dividers, decoders and numerals, provide a 24 hour clock display of great accuracy. Some method of time setting is required, for starting the clock. When it is switched on, divider-decoders produce a random display, or even part numerals. Briefly opening the reset line changes all divider states to give zeros as display. If the user were able to wait until midnight, and close the reset switch at a time signal then, the clock would start indicating on time. To avoid the need for this, generally either manual clocking ahead or rapid clocking ahead can be added.

Manual clocking ahead can be by a noiseless switch as shown later. To change minutes, this transfers pulses from IC7 to IC8 for normal running, but manual operation allows IC8 to be operated at will, to produce any wanted minutes display. As 60 operations of this switch would be needed to change the hours display by 1 hour, a second such switch is generally fitted between the output of IC9 and input of IC12. In this way hours and minutes can be adjusted to agree with a time signal. For setting seconds, a similar switch is needed at the input to IC6.

For fast running instead of this method, a switch transfers the input of IC8 so that it receives pulses from earlier in the divider chain. Suitable rates are x1000 and x100. When hours are almost correct for a coming time signal, switch to a lower speed, then to normal when minutes are nearly correct, and to normal speed until the clock indicates for the anticapted time signal. Stop pulses by opening a switch controlling Tr1 and

Tr2. Close this switch when the time signal arises. As example, set the clock to 12:00 and start the oscillator at this signal.

The power supply can incorporate a transistor with zener diode, or a 5v positive regulator. The latter is a little simpler. A bridge rectifier is shown, but individual rectifiers, or two rectifiers with a centre-tapped transformer secondary, may be used, as explained for the power pack circuits. Current drain is about 450mA to 550mA.

The decade drivers are 7490, 7490N or equivalents, and the stages providing division by 6 are 7492 or 7492N. Numerals may be the size to fit DIL 14-pin holders, which also take the 7490 and 7492. Decoder-drivers are 7447N, using 16-pin holders. The 7400N is 14-pin. A by-pass capacitor of about 10nF can be added for 100kHz to 1Hz section, and clock display section. A larger capacitor (say 100μF) on one or both sections will avoid trouble from switching and other spikes.

The LED with series resistor is placed between hours and minutes sections, and pulses at 1 second intervals. It is connected to the 1Hz output of IC5 and also shows the clock is running.

Executive Binary Display Clock

A clock displaying directly in binary is notably modern, is a novelty, and apart from showing that its owner is fully up-to-date and conversant with such things also acts as a timekeeper for those with the knowledge to decode it.

Binary has the digits 0 and 1 only. They represent powers of 2, right to left. Since there is only 0 or 1, there is overflow to the left when a column is full. (In the same way, with decimal based counting, when "units" column is filled, the next count overflows to the "tens" column – 9, 10 and so on). Four binary digits are sufficient for each number up to 15. Numbers from 0 to 9 are:

0000	0
0001	1
0010	2
0011	3
0100	4
0101	5

0110 6
0111 7
1000 8
1001 9

One method of conversion is to regard 0010 as one 2; so 0011 is one 2 and one 1 or 3; 0101 is one 4 and one 1 or 5; 0111 is one 4 one 2 and one 1 or 7. In a little while any of the numbers 0 to 9 will be at once obvious.

The binary clock displays time in this way. So, as example, 12:25 is 0001 0010: 0010 0101. Light emitting diodes provide the displays. Time can soon be read at a glance.

Fig. 18 shows the timing part of the clock. Input is at 1Hz (1 pulse per second) from quartz oscillator and divider chain, as described. There are two sections, for up to 23:59. The next pulse reverts to 00:00 (24 hours). No display is associated with the two first dividers, which receive the 1Hz input and provide output at one pulse per minute.

A common reset switch takes 9/10 of IC7 high when open and also opens the reset line to the earlier dividers, so that all return to zero. This is prior to time-setting. Time-setting is obtained by a 2-way switch with central off taking optional input from a divider earlier in the chain so that the clock can be run at one-hundred times normal speed, and stopped at 6, or some other convenient time when it can be started at a time signal. To do this easily, run it fast until near 6, put the 2-way switch to normal speed to allow halting at 6, and re-start at 6 on the signal.

The hours section displays to 24. Only two LEDs are necessary for the 2 and four need not be fitted. Four are needed for the second digit here (for 9 and 19). Four are used for both minutes sections for regularity of display.

The method of connecting LEDs as at A, Fig. 19 is attractive because of its simplicity, and has the advantage that some are always illuminated. To read the number in this way, an illuminated LED is 0, and not illuminated LED is 1. Thus ON, ON, ON, ON is 0, ON, ON, ON, OFF is 1, and so on. This was found to be an interesting method of working the display.

For ON to indicate 1, and OFF to show 0, a 7400 quad

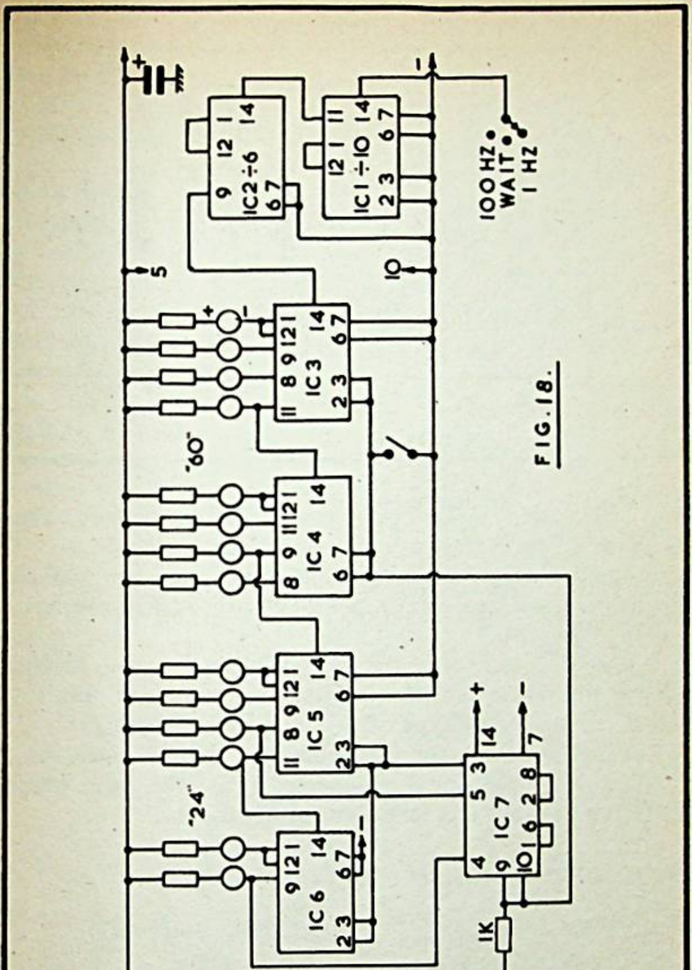
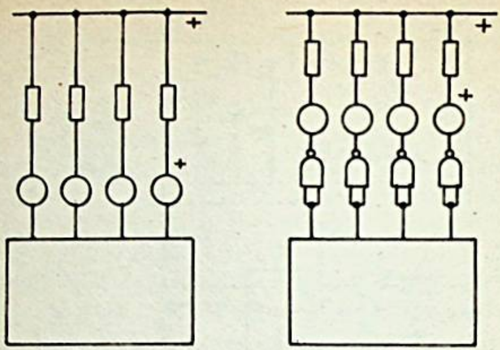


FIG. 18.

NAND IC is suitable, one for each divider. These reverse the logic, B in Fig. 19. Then OFF, OFF, OFF, OFF is 0, OFF, OFF, OFF, ON is 1, and so on.

With the method at A, the use of 1.2k series resistors will



Ⓐ **FIG.19.** Ⓑ

limit LED current to 3mA or so. For B, 1k may be used. The 7490N and 7400N (high current) ICs can be used with advantage. Total power dissipated in the 7490 is small when the inverters are used. Maximum total load without inverters is at 0000 (all lit).

It is possible to operate filamentary lamps (low voltage) by using an individual transistor inverter for each output. But for a small, compact desk-type clock, LEDs are more suitable.

The high and low state of outputs from all the dividers can be checked by observing the connected LED. This lights when the IC pin to which it is taken goes low (negative).

Components for Executive Binary Display Clock.
(Figs. 18 and 19)

4 off 7490	2 off 7492; 1 off 7400
7 off 14 pin DIL holders	10nF capacitor
Single-pole 2-way (central off) switch	
14 off 5mm or similar LEDs	14 series resistors (see text)
Optional: 4 off 7400 with holders	
Reset switch	1k resistor
Case, etc.	1Hz clock source.

Layout on 0.1in matrix board can best resemble that when the decoder-drivers are fitted, and the LEDs can be arranged above the ICs, and fit into clearance holes in the panel. The case should accommodate a transformer, capacitor, 5v positive IC regulator and rectifiers, for the clock operating supply.

Manual Setters

It is sometimes necessary to set numerals to a particular number, and this can be done by providing manual input pulses to step it to the wanted figure. Ordinary switches tend to give erratic results, from intermittent contact shown by the count changing several times. This can be avoided by using a setting circuit.

In Fig. 20 one-half of the quad 7400 NAND IC is used. The switch S1 is normally at A. When it is moved to B and back to A, a single output pulse is obtained. If this is connected to the input of a divider this (and numeral) advances by 1. Operation of the setter arises because each gate can pull the other over only on the complete movement of S1, and so is not affected by momentary breaks at A or B.

The 7400 receives its 5v positive supply at 14, and the negative line is 7. S1 can be an ordinary 2-way switch, or a push-button or spring loaded type.

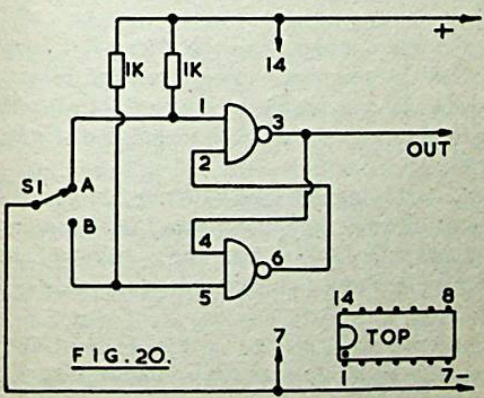


FIG.20.

The circuit in Fig. 21 incorporates the manual setter with the two remaining gates of the 7400. This allows the clock input to run through, or be added to manually. Input to the divider chain is to 12 and 13, so that this gate serves as an inverter. Output from the manual switch at 3/4 is to one input of the last gate at 9, whose other input is at 10, with output at 8.

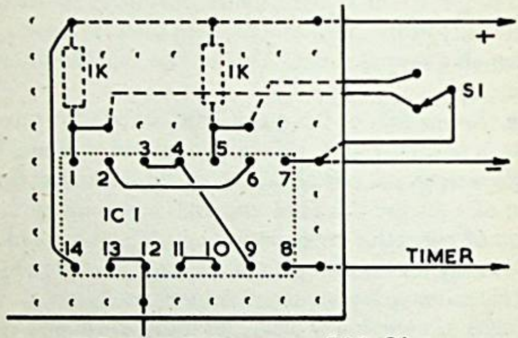


FIG.21.

Assuming that the clock input pulses are at 1 minute intervals from the appropriate divider chain, the lead from 8 is input to the minutes section of the clock. But operating S1 manually allows extra pulses to step ahead the minutes, for setting to time. S1 remains in the position shown, after manual setting, so that the usual clock pulses at 1 minute intervals can pass.

The same circuit may be used between minutes and hours sections, and will allow stepping forward the hours manually. In this case, input at 12/13 is from the overflow of the minutes (1 pulse per hour) and 8 goes to the divider normally fed from this point.

The circuit in Fig. 20 may be used for testing a faulty divider, decoder, or display circuit, by stepping ahead one at a time, measuring outputs of divider, decoder and display at each interval.

Precision 1/100th Second Timer

Details of this will be clear from the circuits given. Pulses are required at 100 per second, from a crystal oscillator with dividers. A 1MHz crystal is convenient, though other frequencies can be used. Timing commences when the oscillator is switched on, and ceases when it is switched off. No practical advantage arises from leaving the oscillator running continuously.

The display section will have maximum capacity if four numerals are used, for up to 99.99 seconds. This will be adequate for many sports and other activities. Should longer intervals be wanted, then minutes, or minutes and hours, can be displayed as described. Battery running is more practicable when the total number of digits is not too great, but this also depends on the periods for which the timer will be used. For several numerals and other than fairly short working periods, accumulator or mains-derived supplies will be preferred.

A reset switch operating on all numerals and dividers allows these to be started from the zero output condition. This switch is operated before any timing period. A third switch, for all power consuming circuits, is for on and off. The display will remain for reference until the timer is switched off (or reset).

Precision 0–9 Minute Timer

Fig. 22 will make clear the assembly and method of operation of a precision timer suitable for sports and other activities. Overall timing is up to 9 minutes 59.99 seconds, in 0.01 second intervals, as frequently used for such purposes.

The indicator section has five numerals, connected in the way shown to read up to 95999. These are spaced, and with a decimal point as in Fig. 22. After 0.09 next pulse carries to the 0.1 digit which in turn carries to the units of the seconds numerals, at the pulse after 0.99. The numerals for seconds carry to the numeral for 0 to 9 minutes, by using the "60" circuit described, at the pulse following 59.99. Input to the indicator or display section is at 100Hz, or 100 pulses per second.

The main on-off switch S1 brings the numerals and other circuits into operation. It is left closed so long as a timed activity is in action and until time has been noted. Switching

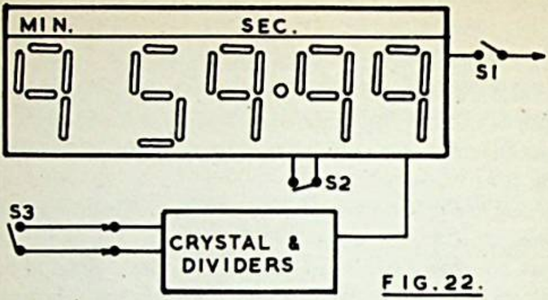


FIG. 22.

off here between timing sessions will conserve batteries, but is scarcely needed with a supply derived from the mains.

Switch S2 is a push-button or spring-loaded type, normally closed, and is placed between negative and reset lines. It is momentarily opened after closing S1, to set the display to zero, either when starting, or between timing periods.

S3 is a push-button switch, on a flexible cord, closing when pressed. It completes the circuit to the crystal oscillator and dividers here.

The crystal oscillator may use a 100kHz or 1MHz (or other frequency) crystal, with appropriate dividers, so that output from this section is at 100Hz. S1 can be marked "ON", S2 "SET ZERO" and S3 "TIME" so that operation is clear to anyone who may use the equipment. It is possible to use an ordinary toggle switch for S3, fitted to the case, and marked "TIMING: ON – OFF" or to have this in parallel with sockets to connect hand-held S3 for short intervals only.

When initially testing this circuit, S1 should light all numerals and point, while S2 should set these to zero, and timing of minutes and seconds should agree with any other reference.

Phone Payometer

This shows the approximate cost of a telephone call as it is being made. This is useful when others use the phone, and readily indicates the great difference between rates, and how costly high-rate calls can be. Indications are in pence, to 99p.

Fig. 23 will make the method of working clear. The 555 timer IC produces pulses which go to the divider IC2, and to the driver IC3, to produce a display on the units numeral. Pulses pass to IC4 in the usual way, and are divided, then decoded by IC5, and operate the tens numeral.

For local calls and cheap rates, the pulse period from IC1 is long, so that total pence spent is relatively small. For higher rates and distant calls, pulses are made to arrive much more

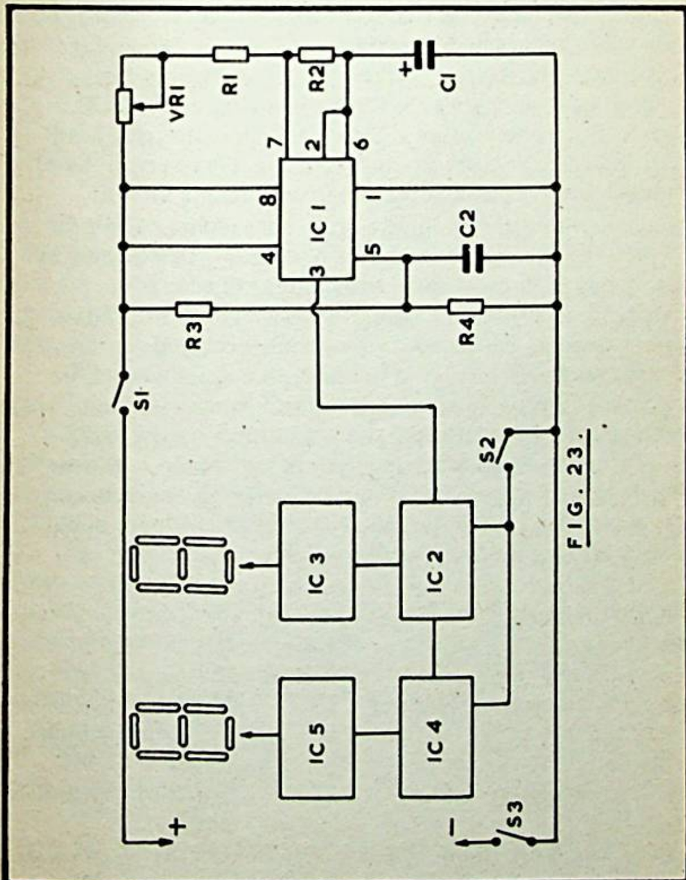


FIG. 23.

rapidly at IC2, and the pence total mounts quickly.

VR1 has a pointer knob and scale, and the phone user sets this to the appropriate position for the rate tariff. A list should be drawn up showing the hours for cheap, normal and peak rates, as an aid to economical use of the phone. These details can be found in the call charges list. Assume a rate of 5p for 2 minutes, mark VR1 for 5 pulses in this time. Similarly, for ½ minute for 5p, set VR1 for 6 seconds. In the same way, a rate of 60p for 3 minutes would require pulses at the rate of 20 per minute.

Rates are marked on the scales for local, up to 56km, and over 56km, and each calibrated for the cheap, standard, and peak rates. The digits will then run at the appropriate speed.

Detailed connections for the decimal dividers IC2 and IC4, with their decoder-drivers IC3 and IC5, and numerals, have been shown. The reset and on switching is arranged so that the numerals always begin at 00, in the way described. The payometer is switched on when the caller replies. The total can be noted when the receiver is replaced, or can be held by opening S1 with the display remaining illuminated.

It is apparent that the charge is shown in terms of 1p, so cannot be rounded out to the pence units charged. In use, this seems a relatively small disadvantage. It may, if wished, be overcome by providing calibration to show the number of units spent, and to place an appropriate multiplier by the digits. Thus, if units are 5p each, and 7 units have been used, then the charge is 7 x 5 = 35p. Where the numerals are registering in terms of 1p, ending the call at slightly earlier times could give an error of up to 4p, with a 5p unit.

Components for Phone Payometer. (Fig. 23).

R1	8.2k	R2	2.2k
R3	100k	R4	15k
VR1	1 megohm linear pot.	C1	220μF
C2	10nF	IC1	555 with 8 pin DIL holder
S1	on-off type switch	S2	switch for on and reset
2 off 7490, 4 off 14 pin DIL holders		2 off 7447, 2 off 16 pin DIL holders	

2 off common anode LED numerals   Case, etc.
S3   on-off switch.

The values for VR1 and C1 were found to allow settings of approximately 6 seconds to 2 minutes. If necessary, VR1, R1 and C1 can be modified, as explained elsewhere.

For moderate use, running from a 4½v battery consisting of three fairly large cells is practicable. This allows the unit to be portable. However, mains running is preferred, and a 5v supply can be obtained from a small transformer, 5v fixed positive regulator, rectifiers and capacitor. A mains on-off primary switch is then most suitable, with a separate reset push-button. Each of the controls should be clearly marked, so that operation is obvious to anyone. That is, "ON," "ZERO SET", and "TIME" for the three switches and "RATE" for VR1.

Count Down Timer

For some games, competitions and other purposes it is convenient to use a timer which counts down to zero, and which shows the time remaining, instead of the time which has elapsed. The circuit in Fig. 24 acts in this way.

A 555 integrated circuit pulser IC1 is used for overall simplicity. The Run switch S1 allows charging of C1 through VR1 and R1, in the usual way, for pulses at 1 minute intervals. When the Fast Set button S2 is pressed, the rate is greatly increased, so that the display can quickly be altered to any starting position required. IC1 pulses at 3 pass to 14 of IC2.

The reset switch S3 here sets the display to 9, when it is temporarily opened. IC3 is the decoder-driver, and connections are arranged so that the counting sequence of the display is downwards, from 9. When zero is reached, diode D1 conducts, so that C1 cannot charge, and the timer stops in this condition. It is then able to be reset to 9 by S3, or to lower numbers by S2 after S3. S1 is closed to begin the "count down".

The indicator LEDs are arranged in a circle, as described for the rotary indicator.

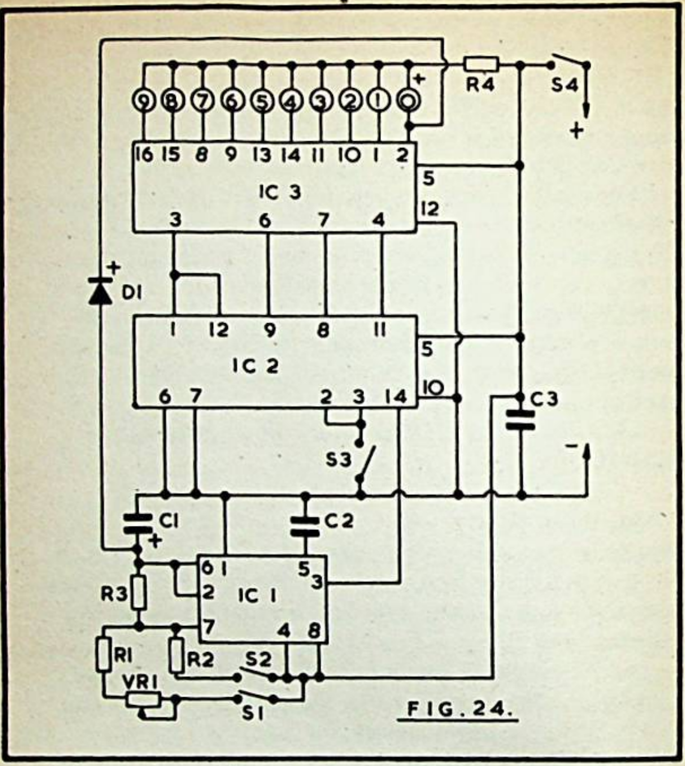


FIG. 24.

Components for Count Down Timer. (Fig. 24).

R1	390k	R2	10k
R3	2.2k	R4	270 ohm
VR1	500k linear pot.	C1	100μF 10v
C2	0.1μF	C3	10nF
IC1	555	IC2	7490N
IC3	7441N	8, 14 and 16 pin DIL holders	
D1	1N4148	10 off LEDs	

S1, S4, on-off, S2 push to make, S3 push to break switches.

Note that the 1N4148 has a black band for positive. Other similar diodes will operate here. It is possible to fit ordinary on-off switches in all positions. R4 may if wished be modified to some extent, depending on brightness wanted and current available (e.g. battery or mains supply).

Construction requires only a small 0.1in matrix circuit board. This can be wired directly underneath in the manner described earlier. Thin flexible leads can then come away from the board to the LEDs and switches.

After switching on and operating S3, 9 should be shown. Set VR1 with a watch or clock so that changes in the count are at 1 minute intervals. S2 is for fast setting to lower numbers. It would be possible to employ one of the other source of clock pulses, as described.

Car Trip Timer

Actual time spent on a journey will be registered by this timer, which operates from the vehicle accumulator supply. The total time which can be covered is up to 23 hours 59 minutes, using four digits for a 24-hour display.

Fig. 25 shows the method of working, and Fig. 26 the way to obtain the necessary 5v regulated supply from a DC input of about 10v to 15v. The clock display is arranged in the way which has been explained in detail, with dividers and drivers to provide for the required 60 minute and 24 hour working. No clock setting circuit is incorporated, because timing must commence from 00:00. This is obtained, as described, by

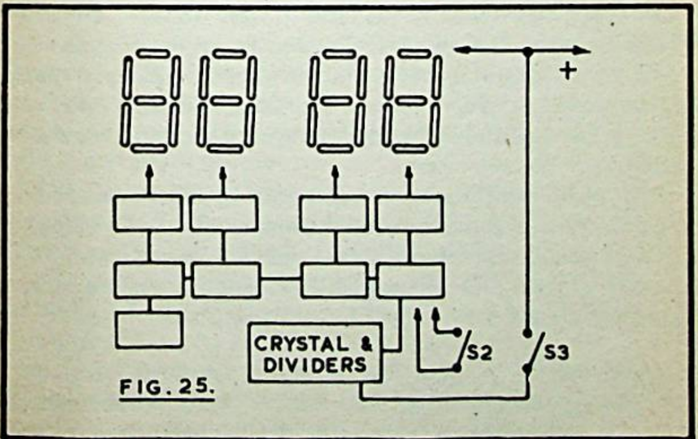
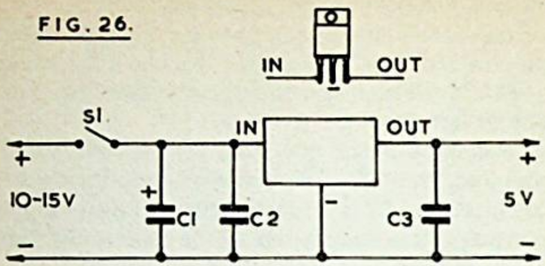


FIG. 25.

FIG. 26.



opening and closing the reset line of the dividers.

S1 is the main on-off switch, and has to be closed in advance of setting to zero. This puts power on. S2 can be spring loaded, or a push button type. It is then momentarily opened. The display is then at 00:00 and ready to run, but actual timing does not commence until S3 is closed. At the end of a trip, or during an untimed interval, S3 is opened, but S1 left closed. When timing is to continue and S3 is closed, this continues from where the display was left. So by operating S3, any number of periods can be added together, the total being displayed.

Operation is always clear if the switches are marked for "ON" (S1), "ZERO SET" (S2) and "TIME" (S3).

S3 interrupts the supply to Tr1 and Tr2 of the crystal oscillator. This is followed by the dividers described, so that pulses are obtained at 1 per minute. To provide a seconds display, two additional decoder-drivers and numerals would be fitted, as shown elsewhere.

The power supply section uses a 7805 or other positive 5v regulator able to provide about ½ ampere output. C1 is for smoothing and suppression; also C2 and C3. Power can be drawn by means of a 2A twin cord, with non-reversible plug, from a matching socket wired to the car accessory fuse.

Components for Car Trip Timer. (Figs. 25 and 26).

S1, S3	toggle or slide switches	S2	Push to open switch
C1	1500µF 16v	C2, C3	0.1µF

5v positive regulator
Quartz oscillator with dividers etc. for minute pulses
Dividers, decoders, etc. for 24-hour type display.

It is convenient to mount the regulator by its metal lug on the back or bottom of a metal case, or on a metal plate. Very little heat is produced. Pulses from vehicle equipment should not reach the counting circuits at sufficient magnitude to influence the display. This is quite readily checked by operating accessories. Interference effects can be reduced by a grounded metal case, or by a ½A suppressor choke in the positive supply, and by a 100μF capacitor from positive to negative lines close to the dividers.

Wiper Timer

An adjustable delay of up to about 30 seconds is provided by the automatic wiper timer, Fig. 27. The sweep of the wipers is at normal speed. Such operation is of advantage during conditions of slight rain or mist, where there is not sufficient water to clear mud or grit with continuous wiper operation, and is made available on some vehicles.

VS is the normal vehicle switch. So long as this is closed, current flows from battery positive to the wiper motor at M, through the motor to VS, and to battery negative. This provides continuous operation of the wiper motor. When VS is opened, the circuit is through the automatically operated contacts AS. These only open when the wipers are in the usual parked position. So when VS is opened, the motor runs to park the wipers, and then AS opens, and so the motor and wipers stop. This automatic switch AS is worked mechanically from the wiper motor gearing.

The wiper timer is connected to the positive line at X, and negative at Y. The positive supply for the timer from X is obtained through the motor windings M–M.

To put the timer into operation, the timer switch TS is closed. VS is open because the wipers are off, and AS is open because the wipers are parked, so a small current flows through the motor windings to the timer. Tr1 is not conducting, its emitter E is negative, so gate G of SCR1 is negative, and the silicon controlled rectifier is not conducting.

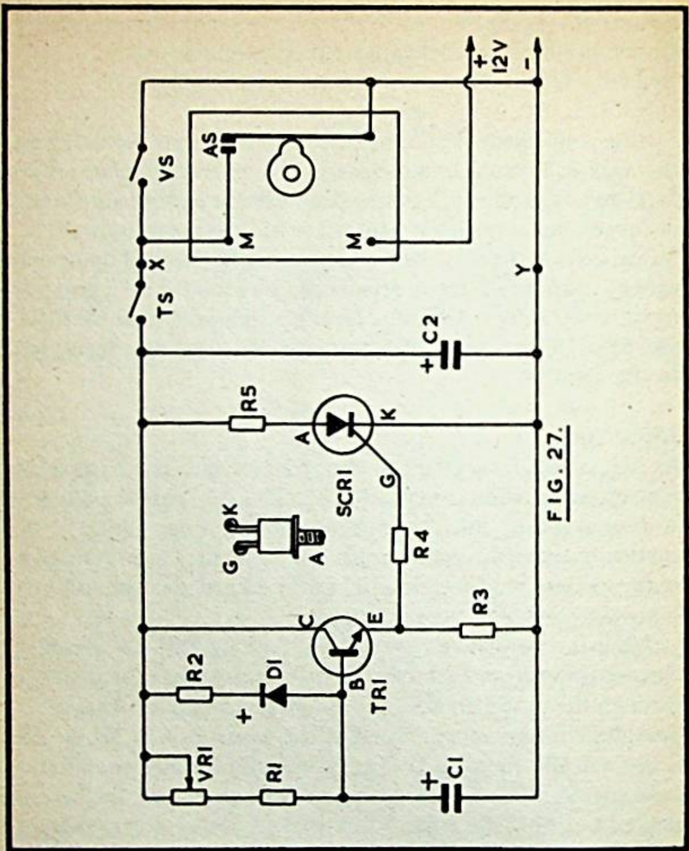


FIG. 27.

C1 charges slowly through VR1 and R1 so that Tr1 base begins to move positive. Voltage drop in R3 moves SCR1 gate positive. Eventually SCR1 is triggered into conduction. The circuit is then from battery negative, through SCR1, R5, TS and the motor windings, and the motor commences to run, closing contacts AS. These contacts remain closed until the wipers have completed their sweep. When they are closed, point X is negative, and C1 is discharged through diode D1 and R2. When contacts AS open, the motor stops running, X again receives a positive supply through the motor, and the cycle begins again. The wiper blades thus make one sweep, at normal speed, at intervals where the delay is set by VR1.

R5 limits the motor starting current, to ease the situation for SCR1. Using 2.5 ohm here limits SCR current to around 5A at the moment of starting, and a normal running current of about 2A is expected. A 5A silicon controlled rectifier or thyristor was found suitable in these circumstances. In some cases a larger rating would allow R5 to be omitted.

Connecting point X has to be found at the motor, automatic switch, vehicle switch, or connecting block, if used. Point Y is the battery negative line.

The triggering sensitivity of silicon controlled rectifiers varies considerably. If it is triggered by closing TS, C2 can be increased in value, or a capacitor can be connected from gate to cathode (0.047μF). Triggering when emitter E of Tr1 has reached only a low voltage so that insufficient delay arises can be avoided by increasing the value of R4. Leakage in C1 can prevent working with VR1 set for long intervals. This will be shown by a high resistance voltmeter across R3 failing to register a slow increase in voltage.

Components for Wiper Timer. (Fig. 27).

R1	47k	R2	120 ohm
R3	3.3k	R4	1k
R5	2.5 ohm (5 ampere wire) see text		
C1	470μF 25v	C2	47μF 25v
Tr1	2N3706, etc.	SCR1	50v 5A SCR
VR1	470k linear pot.	TS	low voltage 3A or 5A switch.

Constructional Details

Fig. 27B shows assembly on a tagboard. R1 and other items lie over the tags, but are displaced in Fig. 27B for clarity. The stud of the SCR, which is also anode, is clamped to a small metal plate, fixed vertically with bolts.

VR1 and the unit switch are attached to the cover of the case used, flexible leads running to these. A twin flexible cord from Y and the switch (X) passes through a hole in the case, to the connecting points described.

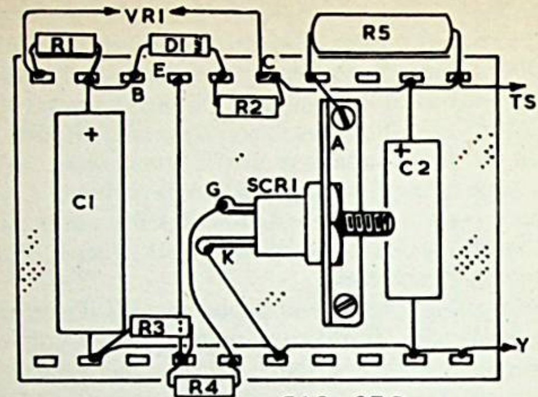


FIG. 27B.

Audio/Visual Metronome

An electronic metronome can replace the clockwork type, and will run economically from a 9v battery. The circuit here can provide a beat to feed into an existing amplifier, or may operate with its own internal speaker, or can flash a light emitting diode indicator.

In Fig. 28 the unijunction transistor Tr1 furnishes the beat. Capacitor C1 charges through VR1 and R1 until a particular emitter voltage, at which the UJT conducts, is reached. C1 is then discharged, and a pulse appears at Base 1. This is repeated, the rate depending on VR1 and other values. VR1 is thus used to set the speed or periodicity, from about 40 to 200 beats per minute.

R1 limits the fastest rate obtained (with VR1 at minimum). If the highest rate is too low, R1 can be reduced slightly in value. The slowest beat depends on R1 and VR1 in series, so a lower rate is obtainable by fitting a larger value potentiometer. In addition to the UJT listed, the UT46, E5567 and 2N2646 were found to be suitable. Altering C1 would change the range of speeds, and this component is preferably paper or a low-leakage capacitor. The leakage of an electrolytic capacitor can begin to upset working, especially with VR1

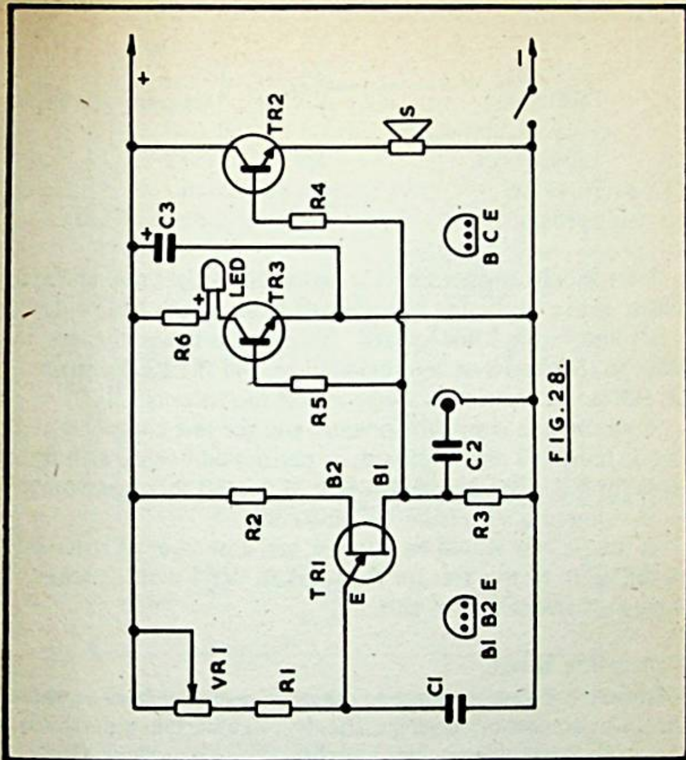


FIG.28.

adjusted for lower rates.

The on-off switch is separate from VR1, so that this can be left set if wished. C2 couples to a socket, taking a plug and lead to feed input into any convenient audio amplifier with speaker.

For reproduction within the unit, B1 drives Tr2. This circuit gives enough volume for most purposes, with a 15 ohm speaker, and sound output resembles that of a musician's clockwork instrument.

If a visual indicator is wanted, Tr3 may be fitted. Pulses to the base are from R5, and R6 limits the LED current. This gives a good indication where the instrument is located near the performer's music.

Components for Audio/Visual Metronome. (Fig. 28).

R1	100k	R2	220 ohm
R3	240 ohm	R4, R5	1.5k
R6	100 ohm	VR1	1 megohm linear pot.
C1	1μF (paper, etc.)	C2	0.1μF
C3	100μF 10v	Tr1	TIS43
Tr2/3	2N3706	On-off switch	
15 ohm speaker		5mm or similar red LED.	

VR1 should be fitted with a reasonably large knob and scale, which can be calibrated as explained later. If the LED polarity is not known, find this by trial. Should significant changes be made in transistors or working voltage, and the LED remain lit, R3 can be reduced in value until it flashes correctly.

Construction is straightforward, and the few components can be mounted on a tagboard, or perforated board, with flying leads for VR1, speaker, and switch. Fig. 28B shows assembly on perforated board, from the underside.

A plastic case would be suitable, and a number of holes can be drilled to form a fret for the speaker. VR1 with its scale can be set to one side of this.

Metronome Speed

Musicians use a metronome to maintain a regular beat or speed through passages of varying difficulty; to ascertain a particular speed; or to provide guidance while working a difficult performance up to its eventual speed. There is thus an interpretation in rate, depending on circumstances, as well as on the type of music. However, a typical musician's metronome is calibrated as follows:

Grave	42	Moderato	80
Largo	46	Allegretto	100
Larghetto	50	Allegro	116
Adagio	54	Vivace	126
Andante	60	Presto	144
Andantino	66	Prestissi	184

Actual numbers provided on a scale are: 40, 42, 44, 46, 48, 50, 52, 54, 56, 58, 60, 63, 66, 69, 72, 79, 80, 84, 88, 92, 96, 100, 104, 108, 112, 116, 120, 126, 132, 138, 144, 152, 160,

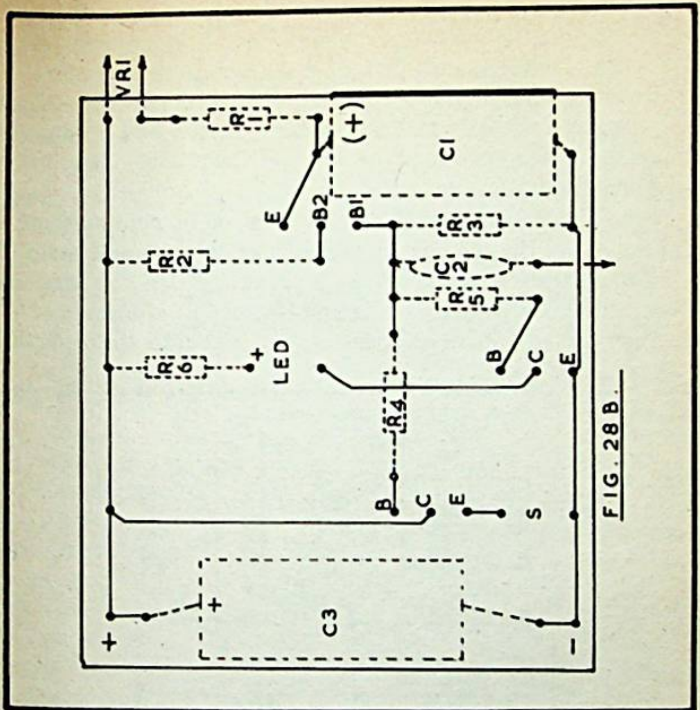


FIG. 28 B.

168, 176, 184, 192, 200, 208.

These are beats per minute. There is of course a continuous range from the slowest to the fastest. A good method of marking is boldly by name and corresponding number, and with other intermediate numbers on a second, less bold scale. Some instruments omit the unnamed numbers. Some electronic meters have an instrument type scale with numbers only.

Calibration of the scale for various settings of the potentiometer can be with a stop-watch or watch or clock with seconds hand, to count the beats per minute. Fit the scale and knob permanently first.

Self-Timed Courtesy Light

This circuit allows a mains operated lamp to be switched on and it will then switch itself off after an interval of a few minutes. This is useful for a cupboard light, which may only be needed briefly, and which might be left on unnoticed, or for a light to illuminate a path or gate from garage to house, or for similar purposes. The user can then make his way indoors, knowing that the light will go off automatically after a short interval. At the same time the complete light control circuit switches itself off.

Fig. 29 is the circuit. Control is obtained by commutating the anodes of the silicon controlled rectifiers by the capacitor C2. When the starting switch S1 is pressed, power becomes available for the primary of the transformer T1. Silicon rectifier SR1 produces an operating voltage across the capacitor

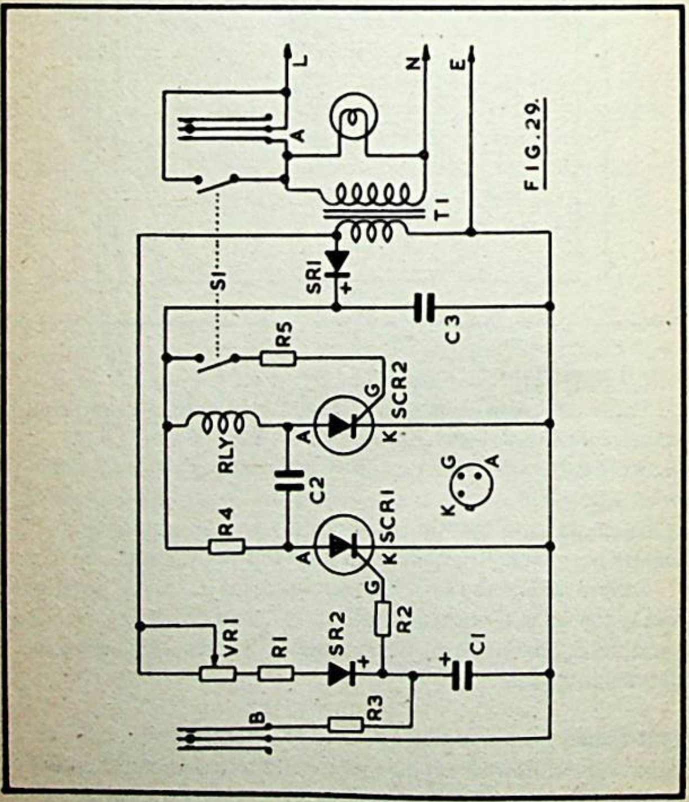


FIG. 29.

C3. SCR2 gate is positive via R5, while SCR1 gate is negative. SCR2 conducts, energising the relay, and closing relay contacts A. These contacts maintain the primary circuit to T1, when S1 is released. SCR2 remains in conduction, as continuous gate current is not necessary for this.

When the relay operates, contacts B open, and capacitor C1 begins to charge. Current is obtained from T1, via VR1, R1 and the rectifier SR2. Gate current becomes available through R2 for SCR1. Since SCR1 is not conducting, this pole of C2 is positive, while SCR2 is conducting, and the circuit here for C2 is negative. At a particular state of charge for C1, SCR1 abruptly conducts. Its anode swings negative, due to voltage drop in R4, and C2 momentarily carries the anode of SCR2 down past zero. As no positive supply is available for SCR2 gate from R5 to initiate conduction again, SCR2 remains in the non-conducting state, and the relay is released. This opens contacts A, switching off the lamp and removing all power from the timer. Contacts B close, to discharge C1 rapidly through R3, in case another interval of operation should be wanted before this charge has otherwise leaked away.

With VR1 at 10k, operating time was found to be about 3 minutes. Using a 50v 1A SCR, and R2 at 100k, triggering arose when 8v appeared across C1. Changes to VR1, R1, C1 and R2 will alter the interval, with any particular SCR. For a courtesy light only, VR1 and R1 may be replaced by a fixed resistor, as the interval is not too important. The use of a variable potentiometer, fitted with a scale, and calibrated with a watch, extends the uses to which the circuit can be put.

Some silicon controlled rectifiers will commutate with 0.47μF at C2. This depends to some extent on the relay windings. The relay used was 100 ohm, 12v, mains contacts type (R.S. 348–835, Home Radio, Mitcham) but other relays can be used. T1 can deliver 9v to 12v, 250mA. Where the voltage obtained after rectification is somewhat higher than that for which the relay is designed, a resistor may be added in series with the coil.

S1 is a spring-loaded double-pole toggle switch. Note that the contacts at A close, and those at B open, when the relay is energised. The relay contacts must be intended for switching mains voltage. Those of the relay mentioned are rated at several amperes, so that any required lamp of mains voltage can be controlled.

Components for Self-Timed Courtest Light. (Fig. 29).

R1	1k	R2	100k
R3	150 ohm	R4	390 ohm
R5	3.3k	VR1	10k linear pot.
C1	4700μF 16v	C2	1μF paper
C3	220μF 25v	SR1, SR2	1N4002

SCR1, SCR2 50v 1A silicon controlled rectifiers
RLY 12v relay, 110 ohm, or similar, mains contacts
T1 9v or 12v secondary, 250mA, or similar transformer
S1 2-pole spring-loaded toggle switch
Case, lampholder, etc.

Electronically Timing Clock or Watch

If a spring or weight-driven watch or clock is timed by usual means, it is accurately set by reference to a time of known accuracy, then compared with this again after an interval of perhaps 24 hours. If it is running too fast or slow, the regulator or pendulum bob is adjusted, and the process repeated. Eventually a setting providing good timekeeping can be found. The reference source may be broadcast time signals, a quartz clock, or other timekeeper of known accuracy.

Quite a long time may be taken to set a clock by this means. A quicker method is to check mechanical clock periodicity against that of a quartz standard. There are several methods of doing this. The method can most easily be understood by first assuming a clock with a pendulum having 1 second periodicity (long-case or regulator). A source of audible pulses at 1 second intervals is available in the standard frequency transmissions which can generally be heard on 2.5MHz, 5MHz or 10MHz, according to time of day and conditions. If the ticks of the mechanical clock are heard to remain in the same relationship to these, the mechanical clock is keeping time. If the clock is gaining, its ticks will slowly advance on and overtake those of the SF transmission. Should the clock ticks slowly drop behind, they are losing on the SF transmission pulses, and after some time the clock will be visibly slow.

This method of timing may be used as a scope display. Use a preamplifier of sufficient sensitivity for both SF transmission pulse and clock tick to produce a vertical deflection. The scan should be slow – say 1 second or so sweep. Synchronisation will make the display easier to observe, but is not essential. If the clock is keeping time, its pulses will stay in the same relative position to the SF transmission pulses, over a period. If it runs fast, its pulses arise too early, so they move relatively to the right; if slow, they arise too late, so move relatively to the left.

The effect of changes to the bob position can be observed at once, and can be corrected one way or the other as needed. In this manner the best position can be found, where motion of the pendulum agrees as far as possible with the SF transmission pulses.

Smaller pendulum clocks, including some regulator clocks, have ½-second and shorter pendulums. If there are 120 ticks per minute, two clock pulses will arise for each single standard frequency transmission pulse, but best timing will still arise when these do not move one way or the other in relationship to each other. This also applies to clocks and watches with balance wheels, and a much more rapid motion, but one bearing a fixed relationship to 60 – 2:1, 3:2, 3:1, and so on.

Inexpensive watches or clocks will suffer from mechanical and other effects which influence timekeeping. These include temperature, position of watch, degree of winding and other factors. A weight driven or regulator clock, with gravity or other improved escapement, temperature-compensated pendulum, and of high quality, would be used for exact timekeeping before other means were easily available, and should be capable of an exceedingly good performance. So would a chronometer. Ordinary watches will vary according to position (dial up, winder up, etc.) and mechanical sophistication.

A pulse output, at 1 second intervals, or any rate required, can be obtained by using a quartz oscillator and dividers. A 1MHz crystal would be convenient. The dividers needed for pulses at 1 second are shown earlier. Two pulses per second would be obtained by using one stage arranged to divide by 5 instead of by 10.

"Difference" Timer

This has two switches for two competitors, and a timer to show the interval between their operation or the difference in their action times. Electronically latched indicators are included, to show which competitor was first. Various games can be played with a device of this kind, and scoring can be by noting down and totalling the differences, the person with the lower total winning. Timing is up to 9.99 seconds, in 0.01 second intervals. Games include Snap, with ordinary or Snap cards turned by a third person; reaction to a specified letter found in any word as someone reads; mental arithmetic and quiz puzzles.

In operation, each competitor has a switch. When one competitor presses this, his indicator light is illuminated, for identification. The timer also begins to run. When the second competitor operates his switch, the timer stops, but the first competitor's light remains on.

Fig. 30 shows the circuit. S1A/B is one switch, and S2A/B the other. Spring loaded double pole push-button switches are most suitable, but slide or toggle switches can be used. If

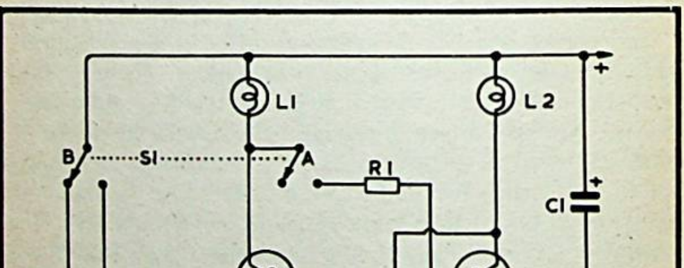


FIG. 30.

S1 is closed first, Tr2 receives base current through L1 and R1, and collector current lights L2. At the same time the collector voltage of Tr2 falls to nearly zero, so if S2A is closed, L1 does not light. In the same way, if the competitor operating S2 is first, closing S1A will not light L2 when L1 is already lit. The lamps L1 and L2 accordingly indicate which competitor was first.

S1B and S2B are the other poles of the switches S1 and S2. With both in the off position as shown, no current passes to the pulser. When either switch is operated, the circuit is closed, so that 100Hz pulses operate the timer. Operating the second switch again opens the circuit, so that timing stops, the display remaining at the total reached.

Overall construction is simplified by using the 555 timer IC as 100Hz source. Circuits are shown elsewhere. Here, use a 10k potentiometer and 10k resistor from positive to 7, 2.2k to 2/6, and 0.47μF or 0.5μF capacitor to negative. Pins 4 and 8 are for positive, 1 for negative, and 5 is by-passed by a capacitor of 0.1μF. Output is from 3 to 14 of the first divider.

The switching circuit from S2B is to the positive line and 10k potentiometer for this IC. Setting up is by observing the seconds numeral against a watch or clock and adjusting the potentiometer for the correct rate. S3 is a spring-loaded push-to-break switch, momentarily pressed to set to zero after noting the time.

Three decade dividers are used, each with its decoder-driver and numeral, as shown in detail.

Components for "Difference" Timer. (Fig. 30)

Tr1, Tr2	2N3706	R1, R2 2.2k
2 off 6v 0.06A bulbs and holders		
C1	100μF 6v	2 off 2-pole 2-way switches
S3	Push-to-break switch	Timer described
3 each off 7490, 7447, common anode LEDs		
6 off 14 pin DIL holders		3 off 16 pin DIL holders
Board, case, etc.		

Construction can place S1A/B and S2A/B either on about 1 metre of multi-core flexible cord each, or on the case. The latter is best arranged so that the numerals and S3 are on top, so that S3 can be pressed and L1 and L2 seen from all directions A quite low, flat box is most suitable. Though battery running is possible from reasonably large cells, a small internal mains PSU is better. Or a general purpose 5v PSU may be employed for this and other items, by having a twin lead, with non-reversible plug, for the purpose.

¼ Minute Repetitive Print Timer

This timer will switch off a mains voltage enlarging or printing lamp automatically at a set interval of up to ¼ minute, and is useful when making a number of similar prints. It contains its own mains operated power supply, and a socket for plugging in the enlarger, so that it can be immediately placed in circuit.

Fig. 31 is the circuit, and needs relatively few components. C1 charges through VR1 and R1 until the unijunction transistor trigger voltage is reached, and a pulse is then applied to the gate G of the silicon controlled rectifier SCR1. This initiates conduction from cathode K to anode A.

The mains transformer T1 has a 9v or similar secondary, and bridge rectifier of four individual rectifiers, making available about 12v across C3. This is the supply for Tr1 and SCR1.

S1A/S1B is the control switch. When no current is flowing in the relay windings, relay contacts A are open and B are closed. When the switch is moved to "TIME" current is through relay contacts B and S1B to the enlarger lamp. The low voltage supply is also completed by S1A, but SCR1 is not conducting. C1 begins to charge. When SCR1 is triggered into conduction as described, current flows in the relay winding and contacts B open, switching off the enlarger lamp. At the same time the other contacts discharge C1 through R6 (to secure equal periods). The circuit remains in this state, with lamp off, until S1A/S1B is put to "OFF". SCR1 then goes out of conduction because voltage is removed from its anode, but the enlarger lamp does not light as S1B is open. The enlarging paper is then changed, and S1A/S1B moved to "TIME", when the enlarger lamp is again on for the same period, then automatically switche off. This can be repeated as often as needed.

With 500k at VR1 and 16μF for C1, a maximum time of a little over 15 seconds was obtained, which was suitable in use for condenser illumination and prints up to about 4 x 5in.

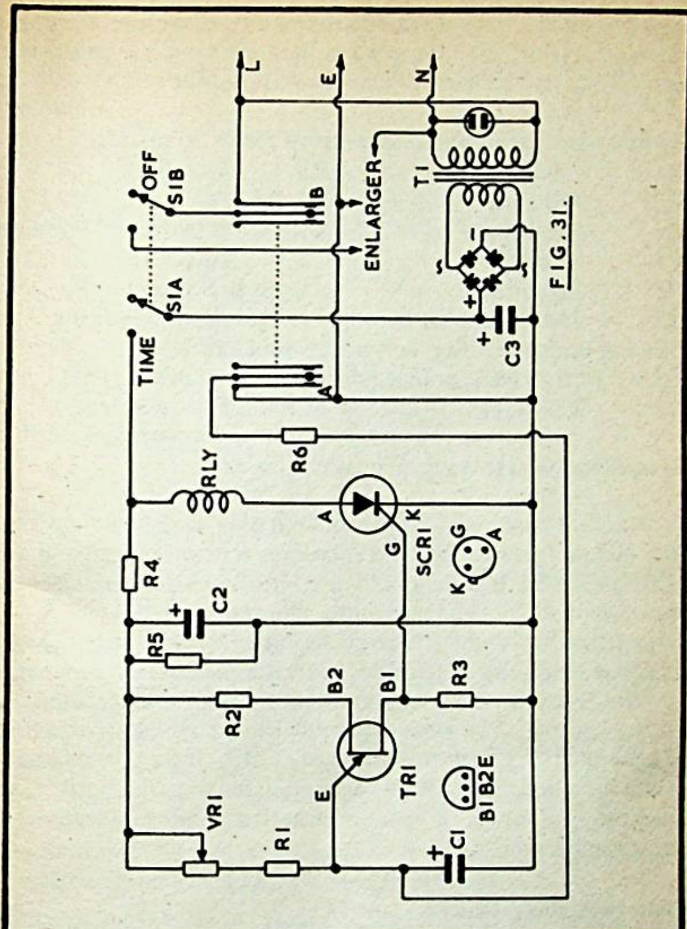


FIG. 31.

The interval can be lengthened if needed for diffusal illumination or other reasons, by increasing C1, R1 and VR1. The SCR is a low-voltage type, and requires only a low trigger voltage. R4, R5 and C2 are present to avoid triggering SCR1 by the surge of closing S1A. With a thyristor of less sensitive type, R4, R5 and C2 may be omitted.

The relay is 100 ohm, 12v, with mains voltage contacts. It is not essential to use a relay of this coil resistance, provided it operates reliably with the voltage obtained from T1, rectifiers and C3. S1A/S1B must be a mains-voltage type switch.

Components for ¼ Minute Repetitive Timer. (Fig. 31)

R1	4.7k	R2	390 ohm
R3	470 ohm	R4, R5	1k
R6	100 ohm	VR1	500k (470k) linear pot.
C1	16μF 12v	C2	100μF 12v
C3	220μF 25v	S1A/S1B	See text

T1 240/9v 250mA transformer. Mains neon indicator
50v ½A bridge rectifier; or 4 off 1N4002 etc.
RLY 12v, 110 ohm, double pole mains contacts.

Tr1	TIS43, etc.	SCR1	50v 1A silicon controlled rectifier

Socket for enlarger plug, mains cord, case, etc.

Fit the 3-core mains cord to a 3-pin plug, with 2A or 3A fuse. The matching socket is to take the enlarger cord plug. Do not omit the earth. It is then only necessary to plug the enlarger into the timer, and the timer into the mains outlet. It is intended to switch off at the mains outlet (or remove the plug) after use, and the indicator neon serves as a power-on reminder.

VR1 is fitted with a scale and calibrated in seconds from a clock or watch. The whole assembly can be in an insulated box. If a metal box is used, it should be earthed. If S1A/S1B has a metal bush and dolly, fitted to an insulated box, the bush ought to be earthed. Proper construction in this way will reduce any shock hazards.

Battery Audible Timer

This circuit requires few components, and has a single adjustable range of up to about 6 minutes. An audio tone is produced after the set interval. This is useful for all sorts of processes in the home. The current drain is negligible when timing is in progress, and about 20mA while the tone is sounding, so a small 6v battery pack is suitable.

Tr1, Fig. 32 is the timer, with C1 charging through VR1 and R1. Tr1 is a unijunction transistor, and when its emitter voltage has reached a certain potential it conducts, so that Base

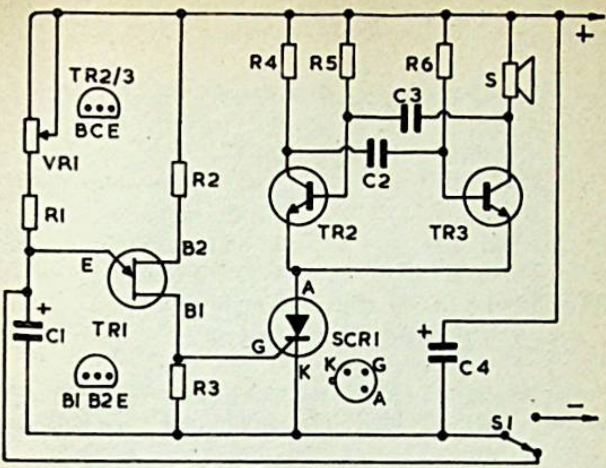


FIG. 32.

1 moves positive. The delay between switching on and this happening depends on the setting of VR1, which has a scale calibrated in time intervals.

S1 is the on-off switch, and when in the off position this shorts C1, to discharge it completely. This helps to obtain the same time interval if the timer is used repeatedly at short intervals.

Base 1 is connected to the gate G of the silicon controlled rectifier SCR1. The SCR is normally not conducting. When the gate is pulsed from B1, the SCR moves into conduction and stays in this state until S1 is moved to the off position.

Tr2 and Tr3 form the audible part of the timer. Each collector feeds the base of the opposite transistor via one of the capacitors C2 and C3. The audio tone is heard from the small 75 ohm speaker which forms the collector load of Tr3. Tr2 and Tr3 are brought on by the SCR switching their emitters to the negative line.

In operation, the required interval is set on the scale for

VR1. Timing begins when S1 is put on. After the elapsed time, the speaker tone is produced, and continues to sound until S1 is put to off.

Components for Battery Audible Timer. (Fig. 32)

R1	4.7k	R2	390 ohm
R3	470 ohm	R4	2.7k
R5, R6	47k	VR1	2 megohm linear pot.
C1	100μF 10v	C2, C3	0.1μF
C4	100μF 10v	75 ohm 2¼in (58mm) speaker	
Tr1	TIS43, UT46	Tr2, Tr3	2N3706
SCR1	50v 1A silicon controlled rectifier		
S1	2-way slide switch	Case, etc.	

A knob with pointer is fitted to VR1, and calibration is by means of a watch or clock. This should be for the individual component fitted at C1.

Speakers of other size can be used, and a fairly high impedance is most suitable (30–80 ohm). The required 6v supply is most easily obtained from a pack taking four 1.5v cells.

Various low voltage silicon controlled rectifiers (thyristors) will operate. The SCR should trigger with a fairly low gate voltage. This means that some large, high voltage SCRs (as intended to control mains power equipment, etc.) may not operate.

A small plastic box will accommodate components and battery, and assembly can be on perforated board or tagboard. Fig. 32B is for 0.15in matrix perforated board.

Visual Timer

This operates in the same way as the audible timer, but uses a LED indicator and series resistor instead of the audio oscillator, Fig. 33.

If the LED polarity is not known, check this with R4 and the battery, as the diode cannot operate if reversed. Current drain is about 10mA with the indicator on. A very small timer can be made with this circuit, and can be used for egg-timing, and all sorts of processing where great accuracy is not essential.

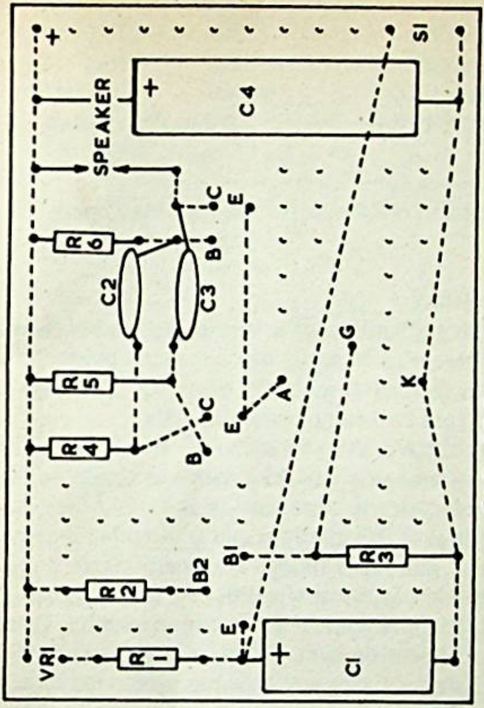


FIG. 32 B.

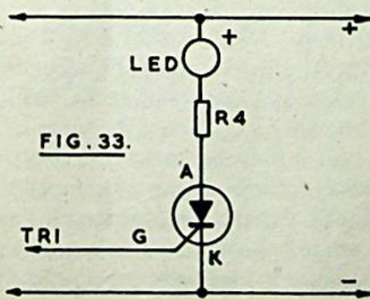


FIG. 33.

Components for Visual Timer. (Fig. 33)

R1	4.7k	R2	390 ohm
R3	470 ohm	R4	470 ohm
VR1	2 megohm linear pot.	C1	100µF 10v
5mm or other LED		Tr1	TIS43, UT46
SCR1	50v 1A SCR	2-way slide switch	
Case, etc.			

Calibration of VR1 is as for the Audible Timer.

Darkroom Timer

A clock with LED numerals is very easily read in the darkroom. The timer here is of an easily made type, as pulses are derived at various rates directly from a 555 timer IC. There are three ranges to secure best use of two numerals.

The first range runs to 99 seconds. This is for enlarging exposures, often some 5 to 30 seconds or so, depending on degree of enlargement, illumination and other factors. The second range is to 9.9 minutes, and is intended mostly for tank development, and rapid fixing. It can also be used for enlargement development when the 99 second range is too short. The decimal point appears automatically. Thus 2.5 is 2½ minutes development. The last range runs to 99 minutes, and is suitable for fixing and washing, which may run to 1 hour.

Separate LED indicators show when Seconds or Minutes will be obtained. The timer is of course suitable for all sorts of other purposes.

Fig. 34 shows the circuit. Section S1A of the 3-pole 3-way switch selects the range. VR1 with R1 is for 1 pulse each second. VR2 with R2 gives 1 pulse per 6 seconds, and VR3 and R3 provide pulses at 1 minute intervals. With the values shown, adjustments fell easily within the range of the preset potentiometers. But it must be noted that electrolytic capacitors vary considerably. If any potentiometer is fully in circuit, and the rate is still too fast, increase the value of the associated fixed series resistor. Should the rate be too slow with the potentiometer at minimum (very unlikely except possibly with VR3/R3) reduce the value of the series resistor. Potentiometer and series resistor values can be altered provided

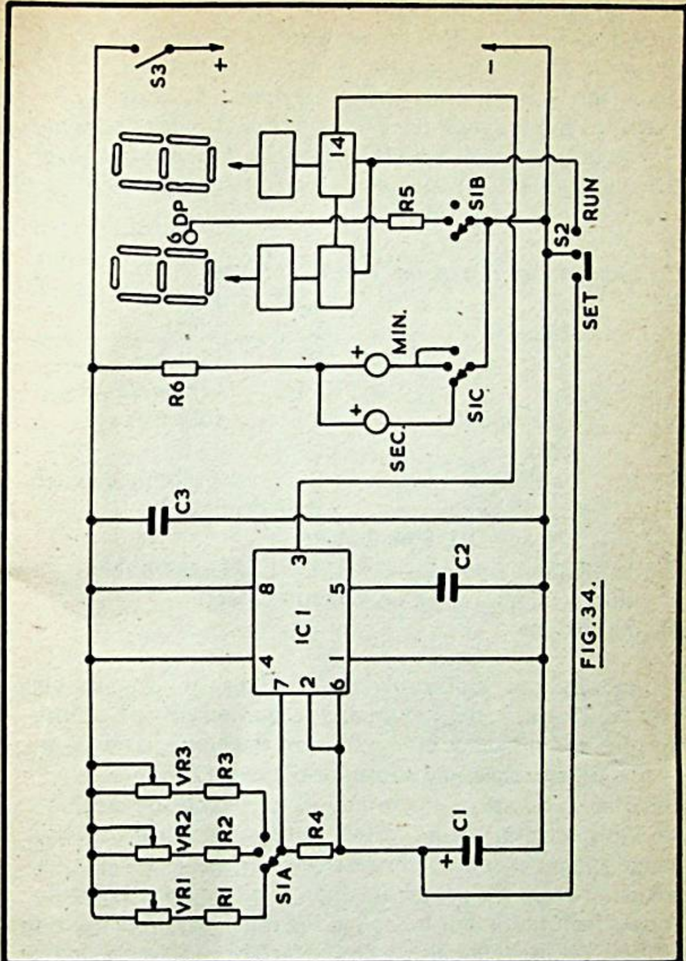


FIG.34.

the combination can be set to the wanted value. Having some of the resistance present as fixed resistors R1, R2 and R3 makes adjustment of the potentiometers easier.

Section S1B of the switch lights the decimal point, for the 9.9 minutes range. Section S1C switches on a left-hand red LED for seconds, and right-hand LED for minutes. The range to be obtained is thus clear.

Slide switch S2 opens the reset line of the dividers, to set the numerals to zero, and also shorts C1, so that the first timing has to begin from when S2 is operated. When S2 is moved to run the reset line is closed, and C1 begins to charge.

The display consists of decade divider and decoder-driver for each numeral. These are connected to operate as 00 to 99 counter in the way explained.

Components for Darkroom Timer. (Fig. 34)

R1	4.7k	R2	47k
R3	390k	R4	2.2k
R5	1k	R6	470 ohm
VR1	10k	VR2	47k or 50k
VR3	220k or 250k	C1	100μF 10v
C2	0.1μF	C3	47nF
S1	3-pole 3-way switch	S2	2-way slide switch
S3	On-off switch	2 off 5mm LEDs	
IC1	555 and DIL 8 pin holder		
2 off 7490 and holders		2 off 7447 and holders	
2 common anode LED numerals and holders			
Board, case, etc.			

A plastic case is probably most suitable, and can be arranged to hang on the wall if required. It is convenient to have the five ICs and numerals on the front of the board, leaving space below for switches, and above for the range LEDs. VR1, VR2 and VR3 are on the reverse of the board, so that they can be adjusted from behind. When setting these, deal with one range at a time, and watch the change of numerals against a watch or clock with seconds hand. The first pulse is a trifle longer than those that follow, in the usual way with this type of timer. For regular use, a small 5v stabilised supply derived from the mains is most suitable. S3 can then be omitted from the positive low-voltage line, as a mains switch will be used at the transformer primary instead.

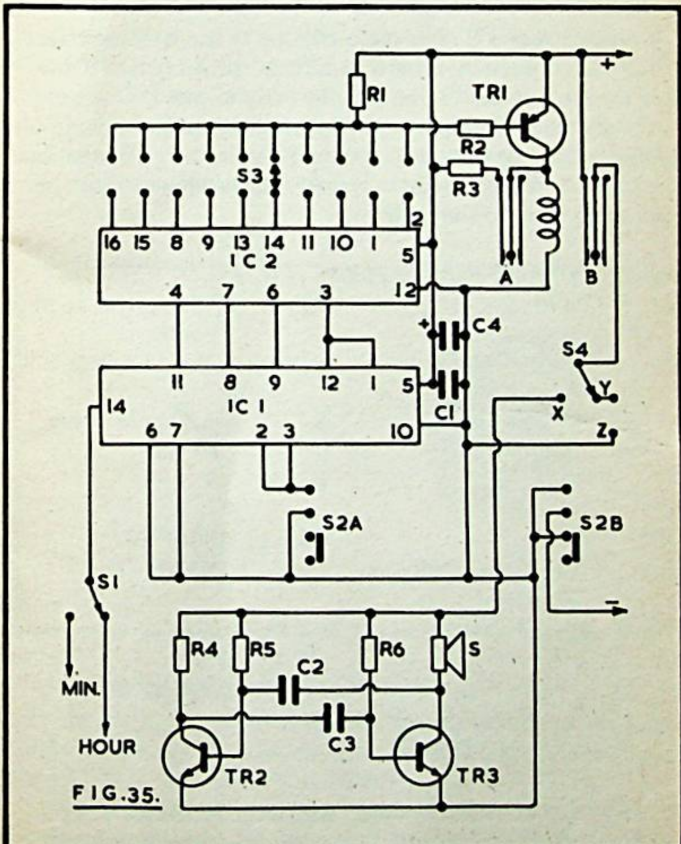
2-Purpose Timer

This circuit will operate its own internal tone oscillator, or will switch on a warning light, buzzer or bell situated elsewhere.

It is intended for precision timing, up to 9 minutes at 1 minute intervals, and up to 9 hours at 1 hour intervals.

Fig. 35 shows the circuit. S1 selects either 1 minute or 1 hour pulses, from quartz oscillator with dividers. Details of this have been given. IC1 is the decimal divider. The switch S2A/S2B closes the negative line before the reset line, to assure starting is always at zero. This is a 3-position 2-pole slide switch, make before break.

Binary output from IC1 passes to IC2. Here, it is decoded and steps along the 10 output points which are connected to



F I G.35.

S3. A slide type or programming switch is convenient here. Assuming this switch has been set at 5, when IC2 provides this output (low) Tr1 base is taken negative. This is a PNP transistor, so collector current energises the relay. Contacts A close, drawing current through R3 to maintain the relay when IC2 is coded to the next output. Contacts B also close. If S4 is set at X, current flows to the oscillator Tr2/3, and the internal speaker produces an audio tone. If S4 is at Y, an external lamp, bell or buzzer, connected to Y–Z, will be operated. The closure of contacts B may also be used to switch on some other device, such as a radio receiver, by arranging connections to them.

Contacts A and B remain closed, due to the latching effect of R3 and contacts A, until S2A/S2B is opened (off). IC1 is then returned to zero state, and the relay released.

If only an external piece of apparatus, or indicator lamp on the timer, is to be operated, the tone oscillator can be omitted. The relay must have mains voltage contacts where mains equipment is to be controlled.

Components for 2-Purpose Timer. (Fig. 35)

IC1	7490, with 14 pin holder	IC2	7441N, with 16 pin holder
S1	single-pole 2-way switch	S2	2-pole 3-way switch
S3	10-way single-pole switch	S4	single-pole 2-way switch
R1	33k	R2	1k
R3	47 ohm		
C1	10nF	C4	100μF 10v
RLY	100 ohm to 200 ohm, 6v relay	Tr1	2N3702

Tone Oscillator:

R4	2.7k	R5, R6	47k
C2, C3	0.1μF	Tr2, Tr3	2N3706

Small 75/80 ohm or similar speaker
Timing source, as described.

A 6v relay normally operates well with 5v. Some 12v or similar relays can be adjusted to work satisfactorily with 5v.

R3 may be changed to suit the relay, as the holding-on current is less than that necessary to energise it and close contacts A.

Controlling Mains Circuits

A timer may be required to control an item of mains equipment, either to switch it on, or off. "ON" switching at a pre-set time can be required with lights, a heater, TV for selected programme, radio used as alarm, etc. "OFF" switching may be wanted for these, for concealed cupboard light or soldering iron (to avoid leaving them on), or for a toaster, etc.

The simplest way to deal with the high voltage and current, and to isolate timer and power circuits, is to use a relay. Fig. 36 shows a relay with a coil intended for 12v operation, and having two sets of change-over contacts, rated at 250v AC, 7 amperes. The maximum load is thus 1,750 watts, or 1¾kW.

When the relay is not energised, the circuit is from B to A, and from E to D. When operating current flows in the relay coil, the contacts move, and the circuit is from B to C, and from E to F.

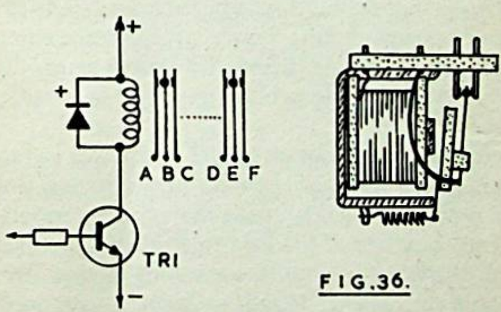


FIG.36.

The coil is typically about 110 ohms, and with about 10v to 12v the current required is approximately 100mA, depending on Tr1. The rectifier is to suppress back emf which may damage Tr1. The 1N4002 is suitable.

Assuming Tr1 has a current gain of 100, about 1mA base current will operate the relay, and thus switch the connected load. This will be supplied by a timer, counter, or other circuit.

It is apparent that with exactly the same timer and relay operation, an external load could be switched either on or off, depending whether B–A, or B–C were employed. Advantage can be taken of this in some circuits.

In other circuits it will be necessary to arrange that "OFF" is always obtained when no current flows in the relay coil. The whole unit including timer can then be off and needs no further attention. This can be used for a soldering iron or cupboard light, where the circuit operates for some time after being switched on, but switches itself completely off if left (e.g., courtesy light). Switching on for a set period is also appropriate for photographic enlarging and some other processes.

To switch "ON" after a set period (or at a preset time) it is better to have the relay used so that it is energised when the period has passed, and to use those contacts which close. Then no relay current flows during the interval. Also, failure of the current leaves the controlled circuit off, instead of allowing it to come on. The presence of change-over or 2-way contacts allows this, as described.

The two sets of contacts may be used for 2-pole switching of the mains power circuit. This is done in some equipment. Where only one pole is switched, this should be the "live" conductor. A single pole switch should not be present in the neutral.

The contacts can of course be used for lower voltages, to controls motors, lamps, or circuits where electrical isolation is wanted. A check should be made that the appropriate current rating of the contacts of the particular relay is not exceeded.

For most transistor circuits, something around 10v to 15v or so will be convenient. Higher resistance relays need less current. Various small relays are suitable for providing complete electrical isolation between circuits, but are not intended for mains voltages. It is not safe to use them for these.

In Fig. 37, A shows the method of arranging for the relay to release when the logical input moves negative. The resistor provides base current for Tr1, so that the relay is energised until this happens. Tr1 base is then carried negative, and

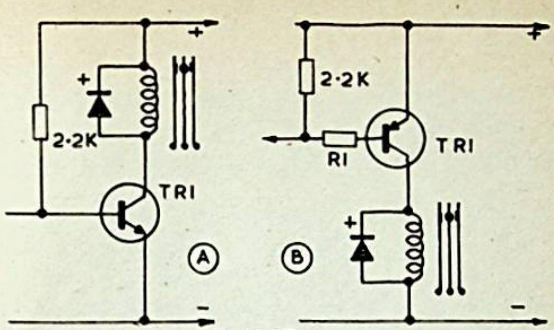


FIG. 37.

collector current cannot hold the relay. Numerous switching, audio and other NPN transistors can be used.

At B the transistor is a PNP type, and the resistor holds the base positive, so that collector current is very small, and the relay is not energised. When the logic here moves negative, base current is supplied through R1, and collector current operates the relay. R1 can generally be about 4.7k to 15k or so. Tr1 current is limited by R1, relay resistance, and Tr1 gain.

Adoption of the switching provided by B–A or B–C with A in Fig. 37, or B–A or B–C with B, allows any of the required on-off situations to be obtained. These are, ON with relay energised, OFF with relay energised, ON with relay not energised, OFF with relay not energised.

Nixie Tubes

LED numerals receive considerable use, and have been shown for projects. Each of the seven sectors is a light emitting diode. Appropriate sectors are illuminated to display the wanted figure.

From time to time Nixie tubes are seen as inexpensive surplus. These have internal wire numbers, 0 to 9, each connected to a pin. Another pin is a common positive. The decoder-driver switches to any of the pins, to display 0 to 9 as wanted. Nixies may be for end or side viewing. A single current limiting resistor is placed between positive and the common positive pin. This can generally be 47k for large tubes, and 68k for small tubes, or 220k for a decimal point connected separately. Current required is only about 1mA to 2mA or so per tube. The positive supply line, for the tubes only, has to be about 230v to 250v. This is easily obtained from a small mains transformer, with rectifiers and smoothing capacitor.

Connections for Nixies of unknown type can usually be located easily by finding which pin or lead, taken via the limiting resistor to positive, allows each numeral to be displayed, when other pins are connected to negative. This also allows pins (or leads) to be numbered in terms of the figures they produce.

Nixies will operate directly from 7441 decoder-drivers (instead of the 7447 for LEDs). These decoder-drivers receive binary input from the dividers, exactly as with circuits using LED numerals. In this way surplus Nixie tubes may be brought into useful service. More details on their use will be found in "Counter, Driver and Numeral Display Projects" Book number BP67, published by Bernard Babani (publishing) Ltd.

Clock ICs

Various integrated circuits are produced largely for the commercial manufacture of clocks. A single IC may contain divider, driver and other circuits, including oscillator, or may be driven from 50Hz or 60Hz mains. Such an IC might be 28 pin, and externally might require mains transformer and rectifiers, capacitors and possibly one or two transistors and other components, as well as a suitable numerical display. It might be for 12 or 24 hour operation, or intended for battery running.

Because of the specialised nature of these ICs, and their differences in voltage, connections, and operating circuits, and the fact that particular types available as surplus to manufacturers needs may cease to be available, no details of them are included here. If a straightforward clock is to be made with such an IC, it is probably wise to obtain the IC, suitable numerical display, fully detailed circuit information for assembly, and all other essentials together at the same time, to avoid difficulty or disappointment.

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Electronic Timer Projects

- Electronic timing circuits are able to cover many different kinds of need. They may switch on or off either at a preset time or after an elapsed time. They may need to have a high degree of accuracy with quartz control or they may be quite simple designs, using only a few components.

- This book covers many of the possible applications of timer circuits and should fulfill a wide range of interests. Some of the more complicated timer and clock circuits are made up from a number of simpler circuits which the author deals with individually. He then goes on to show how these may be combined together in various ways to make some quite sophisticated projects.

- Also included are a number of specialist timer projects such as, car windscreen wiper delay unit, darkroom timer, metronome etc.

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