Counter Driver and Numeral Display Projects

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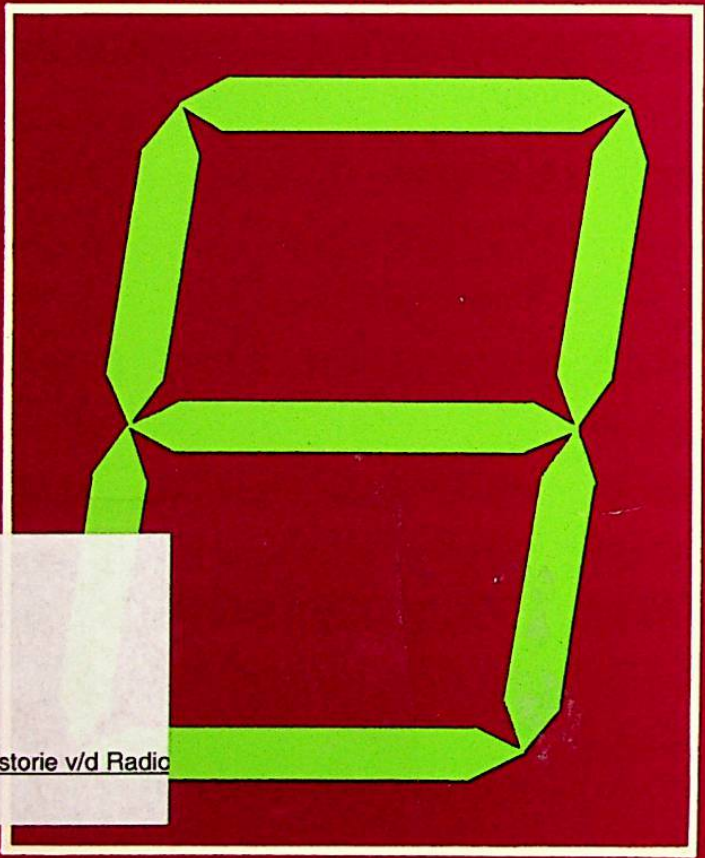

COUNTER DRIVER AND NUMERAL DISPLAY PROJECTS

by
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Numeral Indication

Numeral indicating devices have come very much to the forefront in recent years, and will undoubtedly find increasing application in all sorts of equipment. With present-day integrated circuits, it is easy to count, divide and display numerically the electrical pulses obtained from a great range of driver circuits. Probably the best known device of this kind is the electronic clock, which shows time by counting the cycles of the household mains, or the oscillations of a crystal, or some other "timekeeping" device.

Figure 1 will clarify the general operation of an electronic counter. Its purpose may be to count megahertz, audio frequencies, or the 1-second pulses of a clock, to mention only a few applications. But in all cases this section of the equipment – the counter – can be basically much the same.

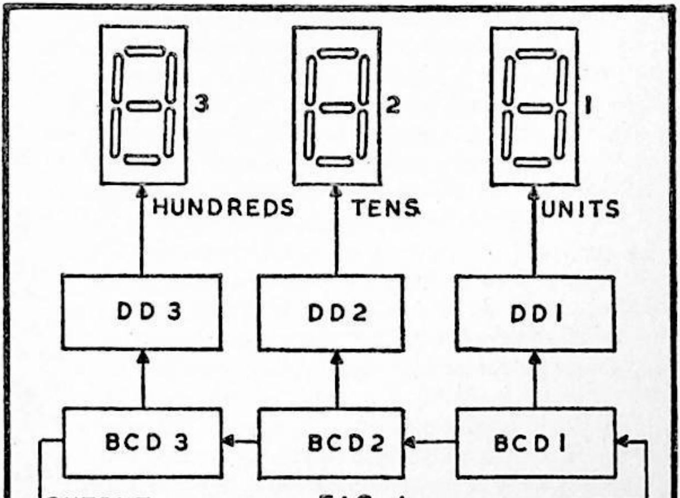


FIG. 1.

An input is taken to the first integrated circuit, marked BCD1. This input may be a regular train of pulses from a clock or oscillator, or could be random, isolated pulses which are to be counted. BCD1 is a binary coded decimal decade counter. The purpose of the BCD decade counter is to receive the input pulses, and convert them into a count running from 0 to 9. This count comes out of other circuits of the BCD decade counter, and is in the form of binary. That is, 0000 = 0, 0001 = 1, 0010 = 2, 0011 = 3, and so on, as explained and described in detail later. The BCD decade counter has four output circuits. These will provide electrical outputs corresponding to 0000 for 0, 0001 for 1, and so on, up to 1001 for 9, according to the usual binary counting sequence.

The output of the BCD or binary coded decimal decade counter could run to four lamps or other indicating devices, and the number could be read from these, in binary, according to which lamps were lit. This was in fact done with some early counters.

As such a form of presentation would be inconvenient for general use, the outputs of the BCD are taken to DD1. DD1 is a decoder-driver. Its purpose is to receive the binary coded output of the BCD, and change it into a form which will allow a number to be displayed. Both the decoding of the binary input to a decimal output equivalent, and circuit functions to allow the decoded signal to operate the numerical device, are available in the single integrated circuit, DD1.

The type of decoder-driver used depends on the kind of numerical display. The decoder-driver can furnish outputs, in sequence, to ten circuits. These ten outputs could operate ten lamps, numbered from 0 to 9. Then each time a pulse were received by BCD1, it would be counted in BCD1, and BCD1 would provide outputs, in binary, for the decoder-driver. The latter would then step along the lamp circuits, displaying these in the usual order, 1, 2, 3, 4, and so on. This would continue until 9 were reached, and the next count would then start again from 0.

Such displays have been employed, but generally numerical tubes would be used with this method. These have wire numbers from 0 to 9, and the wanted number glows when the circuit to it is completed by the decoder-driver. (See Nixie Tubes).

With another type of display, each number is made up from two to seven segments. By illuminating appropriate segments, any number from 0 to 9 can be displayed. For these numerical displays, the decoder-driver has to be of different type, as its purpose will be to illuminate particular segments for each numeral. (See 7-Segment Light Emitting Diodes, and Minitrons).

By working in one of these ways, BCD1, DD1 and Numeral 1 are able to count and display up to 9. With the next pulse input to BCD1, Numeral 1 reverts to 0, and a pulse is passed from BCD1 to BCD2.

The binary coded decimal decade counter BCD2 acts in the same way as BCD1, but will be counting the "Tens". It will provide binary coded input for the decoder-driver DD2, which in turn operates Numeral 2. So the count can now proceed to 99, Numeral 1 running through all its digits for each single step ahead of Numeral 2. The display is thus as if writing down numbers from 1 to 99, except that the unrequired zero is present – 01, 02, 03, etc., up to 09, then followed by 10, 11, and so on, up to 99.

When BCD2 has reached 9, the next pulse into it will change Numeral 2 to zero, and a pulse will pass from BCD2 to BCD3. From this input, BCD3 will step ahead the Numeral 3, via its decoder-driver. The count will then be up to 999, after which all numbers return to zero, to begin again.

The output of BCD3 may go to a further binary coded decimal decade counter, with its decoder-driver and numeral, to allow the display to count up to 9999. Other counters or dividers, drivers with decoders, and numerical indicating devices can be added, for as many numbers as are required.

In some cases a count up to 9 is not required. As example, with the "Minutes" section of a clock, Numeral 1 would count up to 9, but Numeral 2 only up to 5. Then when 59 is reached, the next pulse passes to BCD3, for 1 hour. In a similar way, numerals will only need to run to 12 or 24, for the hours display.

Counts of this kind can be obtained by using other types of divider-counter, or by altered connections or similar methods. It is in fact possible to divide by almost any number which could be needed, and no difficulty arises with division by 2, 5, 6, 10, 12 and similar "round" numbers which are often necessary.

Displays

The 7-segment light emitting diode is in general use. It needs only a low voltage, and its current consumption is not very great. Details of commonly used numerical displays of this kind will be found later. Minitrons have a somewhat similar application.

It is found that Nixie tubes are sometimes available at quite low cost as surplus. These require a high voltage, but this is only at low current. Where a device is to run from the mains supply, as is often the case, a suitable supply is easily obtained.

As mentioned, the decoder-drivers suitable for one type of display numeral will not be correct for the other type. So the kind of numerals used must be decided before obtaining the decoder-drivers. This is dealt with fully later.

Thus the kind of display selected can depend on the purpose in view, as well as the availability of components, or cost.

Frequency

Numerical displays are also used for equipment such as digital frequency meters, or the digital read-out of signal generators. For this purpose, a decimal counter as in Figure 1 is employed. It may have as many digits as considered necessary.

To allow the indication of frequency, the count is allowed to take place for only a known length of time. An example, if the count is enabled for 1 second, and the numerals read 50 at the end of that time, then the frequency of the input to the counter is 50 pulses a second, or 50 Hertz. In the same way, a read-out of 650 would indicate a frequency of 650 Hertz, if the count had proceeded for 1 second.

The count may be enabled for one-tenth of a second (or some other interval). A read-out of 50 would then show that the counter had received 50 pulses in one-tenth of a second, or is indicating a frequency of 500 Hertz. Similarly, with counting for one-tenth of a second, a count of 650 would show 6500 Hertz, or 6.5kHz.

A frequency counter or similar device thus has a counter section similar to Figure 1, probably with four or five numerals, and a section which controls the interval of time over which counting can take place.

BCD's and DD's

Figure 1B shows a typical binary coded decimal decade counter, the 7490. This is a single package integrated circuit of 14-pin dual in line type, and fits 0.1in matrix perforated board. Though it normally divides by 10, this can be changed by appropriate connections. It operates from about 5v, and working data will be found later.

The decoder-driver shown here is the 7441, for use with Nixie tubes. By connecting the 7490 to the 7441, the latter will allow a Nixie tube to display all figures from 0 to 9, in accordance with the number of input pulses received by the 7490. The 7441 runs from about 5v also.

Numberings in Figure 1B are when viewing the ICs from the top. A dot or mark indicates the 1-14 end, which must of course be correctly placed for correct connections on a circuit board.

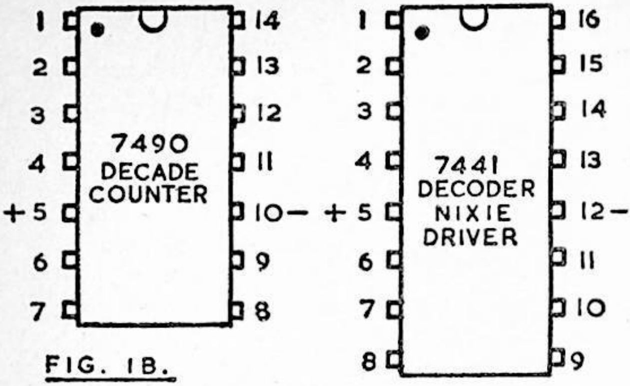


FIG. 1B.

Binary

When counting in the usual way, a count is made up to 9, then is followed by 0, and the count from 1 to 9 repeated to the left. Decimal counts of this type are required to put into a counting device, and to receive as output.

As the count of 0 to 9 would require 10 defined voltage levels a decimal count of this kind is impracticable. Instead, binary is used. This requires only two voltage levels, low and high. There is some latitude in these levels, as explained later, so that the equipment will continue to operate satisfactorily despite spreads in manufacture, or some changes in working voltage or load.

One state can be expressed as 0, and the other state as 1.

As no further states (or numbers) are available, it is necessary to move one place to the left, when 1 is reached. It will thus be seen that counting proceeds as follows:

Binary	Decimal Equivalent
0000	0
0001	1
0010	2
0011	3
0100	4
0101	5
0110	6
0111	7
1000	8
1001	9

Counting can naturally proceed to higher numbers, but only these are required here. Decimal numbers have the base 10, so have 10 as multipliers. Binary is based on 2. Thus 0101, as example, is no eights, plus one four, plus no twos, plus one one, or 5. In the same way 0110 is no eights, plus one four, plus one two, plus no ones, or 6.

A divider may be operated by input pulses, which may be derived at known frequency from AC mains, or may be obtained from a highly stable oscillator, or from any other source where required. Assuming that the input pulses are from 0 to 9, logic obtained from the output circuits providing binary would be 0000 for 0, 0001 for 1, 0010 for 2, and so on, up to 1001 for 9, as just shown.

With a decade counter or divider, counting would return to 0 after 9. For higher counts, output would be taken on to a further decade counter or divider, whose function would be to deal with the "tens" column. Output from this divider could pass to a further divider, for the "hundreds" column.

As direct binary display would be inconvenient for the user, the decade counters or dividers provide inputs for a decoder. This takes the binary inputs 0000, 0001, 0010, and so on, and translates them into outputs which can display the numerals 0, 1, 2, and so on, by means of suitable numerical devices.

Dividers may divide by 2, 4, 5, 6, 8, 12, 16 and combinations of dividers make possible almost any result wanted. Thus a divide-by-5 followed by a divide-by-10, or a divide-by-6 followed by a divide-by-10 will provide 1 second pulses from 50 hertz and 60 hertz mains.

Pulses having high frequency stability can also be obtained from crystal controlled oscillators. In other circumstances frequency accuracy is not required, and a free-running multivibrator or other oscillator can then be used. Pulses to be counted may also be received from some external source, to permit counting of unknown numbers of objects or actions, or counting over a pre-set interval to determine frequency.

The counting of pulses, however derived, would be expected to have no error. With division and counting to obtain a frequency display, accuracy depends on correct timing of the interval over which the count is made. Thus if a count of 1000 (one thousand) were made in 1 second, the frequency shown would be 1 kHz. But if the interval were slightly shorter or longer, the count would be under or over 1000, the inaccuracy of frequency indication depending on the degree of error in timing. The 1000 counter could read up to 10 kHz if its input were gated on for one-tenth of a second; or up to 100 kHz if input were for one-hundredth of a second.

Inputs to be counted may be obtained from optical or sound operated devices, switches, and other sources. Counting could be up to any desired magnitude.

In items such as a clock, early dividers may simply operate to meet the division requirements, or may also drive decoders which in turn operate numerical indicators – e.g., as for the optional display of seconds. Re-set circuits allow stepping the dividers forward to obtain correct numerals when starting.

Decoders

The decoder receives a number input in binary form, and from this provides an output which will result in the display of the correct numeral. The decoder input is in the form 0000, 0001, 0010 and so on, as described earlier.

The manner in which the decoder output is presented depends on the kind of numerical display to be operated. The decoder thus has to be chosen to suit the display.

As example, with a Nixie numerical tube, numbers 0 to 9 will be displayed. The number depends upon which individual pin of the tube receives current. The binary input thus has to be translated into output for any one of ten output circuits, for the numbers 0 to 9.

A different situation arises with a segmented LED numeral display. Here, the numerals are made up from sections, and any wanted numeral is obtained by providing current for a number of sections. The decoder thus has to provide output at a selected number of points for each numeral. The various illuminated sections combine to provide the wanted figure.

Detailed decoder and display circuits will be seen later. Decoders are available which permit the direct driving of displays, and this allows minimum circuitry. Where the power handling capacity of a decoder is too small, it is necessary to provide buffer circuits at the decoder outputs, between decoder and display.

Binary Display Unit

A counter which produces a display in binary requires only one decimal counter and four light emitting diodes, plus a few other small items, for each stage.

Figure 2 shows connections to the 7490. The circuit can be run from a 4.5v or 5v supply. The four series resistors may be chosen to suit the LEDs, or brightness required.

Input can be from any type of "events" pulser, to count seconds, minutes, interruptions to a light beam, or other activities, as shown elsewhere.

The reset switch is normally closed. Momentarily opening this returns the count to zero. The display will be in the form

0000, 0001, 0010 and so on, from zero to 9, which is 1001. *(See Binary).*

The output may be taken to a second identical unit, for a further decade divider. Further stages can be added. Thus three such stages would count up to 999. The same reset switch can control all stages by joining 2 and 3 throughout.

As the 7490 effectively switches the LEDs to negative for the 0 output state, 0 is indicated by an illuminated LED, and 1 by a LED not lit. With input from the UJT pulser shown later, the display can readily be followed. LED polarity must be correct.

The few components and simple circuit make this an easy "first project" using a decade divider. Figure 2B shows a

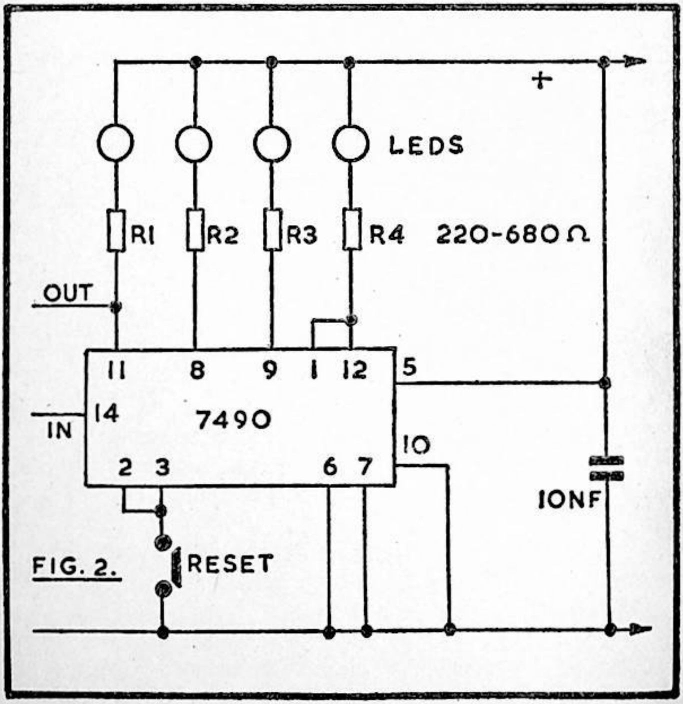


FIG. 2.

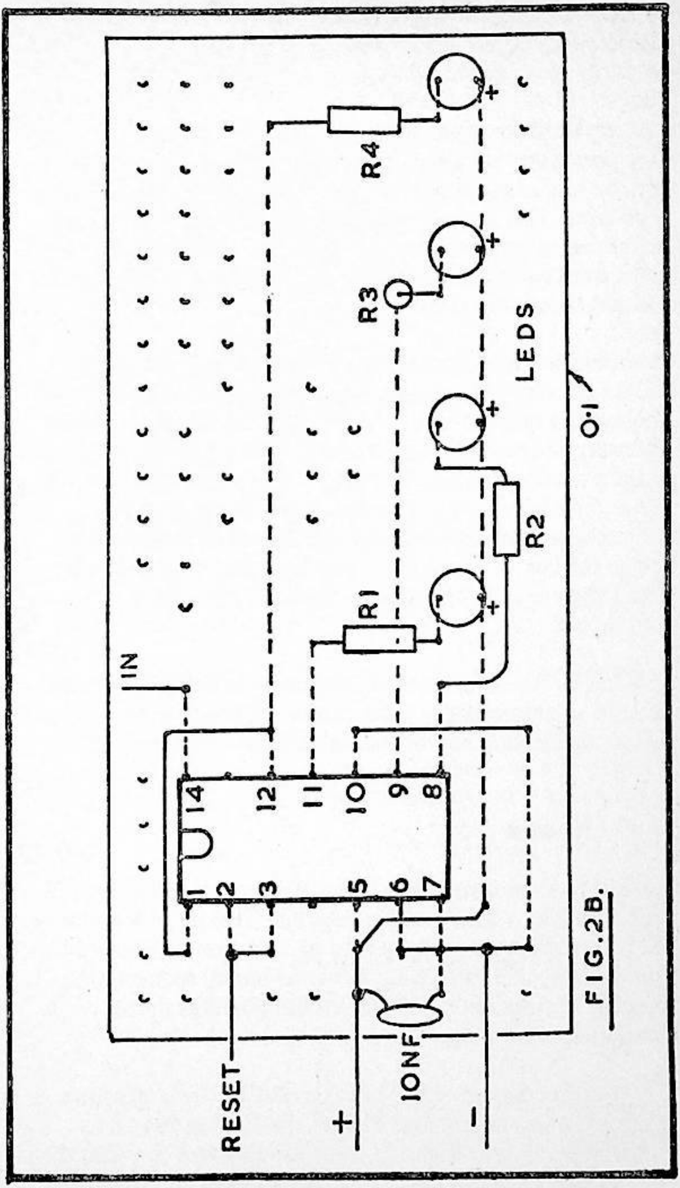


FIG.2B.

suitable layout. The board should be 0.1in matrix, and the divider, or a 14-pin holder for it, fits this correctly. A board 10 x 22 holes will be satisfactory.

An easy method of preparing this and similar boards is to use bare tinned copper wire. This can be 20 swg or similar for the positive and negative circuits, but much thinner (say 30 swg) elsewhere. This is easily run from point to point as needed, and is passed through holes in the board, so that circuits are made from a single, uncut lead. If the wires are taut, sleeving will not be needed here.

If a board with foil conductors is used instead, the strips should run along the longer dimension. Wires will be needed only on top of the board, as shown by solid lines. It will be necessary to provide breaks in the foils at all places where short circuits would otherwise be caused. These can be made with a cutter, or a few turns with a sharp drill. Make sure the conductors are completely cut, and that fragments do not bridge the cut, or touch the adjoining foils. Assembly will take a little longer than when using wire conductors throughout.

Pins can be fitted for positive, negative and other external circuits, or colour-coded leads can be soldered on here. Input pulses can be from any of the circuits shown later.

Display Inverter

The logic can be inverted so that 1 is shown by an illuminated LED, and 0 by a LED not illuminated. This may be preferred, and it is perhaps more easily read by someone unaccustomed to the other form of display, or to the binary sequence, it being more naturally assumed that illumination shows 1, and non-illumination zero.

The inversion can be obtained for each LED by a transistor as in Figure 3. Assuming that 11 is 0, the LED in Figure 2 would be lit. But in Figure 3 this state removes base bias from TR1, so that collector current virtually ceases, and the LED is not illuminated. At state 1, TR1 receives base bias through R1 and R2, so collector current results in the LED being illuminated.

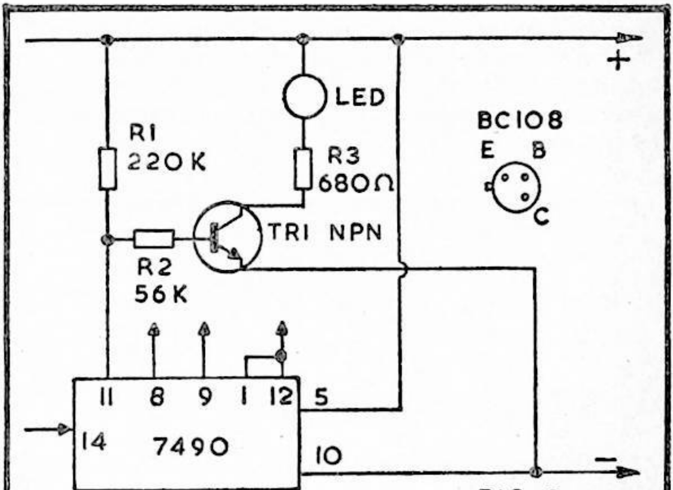


FIG. 3.

Many high gain audio and other transistors will operate in this circuit e.g., BC108 and similar types. The resistor values are not critical and may if wished be changed to suit transistors or LEDs.

Quad Inverter

The 7404 is a sextuple (six-fold) inverter, so four of the six available gates can be used to obtain an illuminated (1) and un-illuminated (0) LED display.

With the inverter, 0 as input provides 1 as output, and 1 as input results in 0 as output. So by its use the binary outputs of Figure 2 can be changed in the way described for the 4-transistor inverter circuit.

Input-output pins of the 7404 are as follows: 1-2, 3-4, 5-6, 9-8, 11-10, 13-12. Pin 7 is negative, and 14 positive. Any of the gates may be used. Inputs of unused gates can be grounded.

Figure 4 shows the inverter circuit. The divider, inverter, and LEDs are all operated from the same 4.5v or 5v supply. Resistors R1 to R4 may be 680 ohms, though these values may be modified. Remember the LEDs must be connected in the correct polarity.

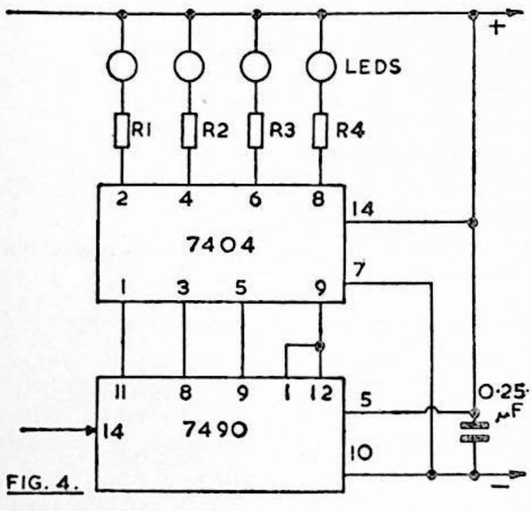


FIG. 4.

To obtain a display numeral from the divider, a decoder-driver is required, as shown elsewhere.

Inverter and Other Gates

Individual AND, NAND and INVERTER gates find application in some circuits. Their symbols and uses will become clear from Figure 5.

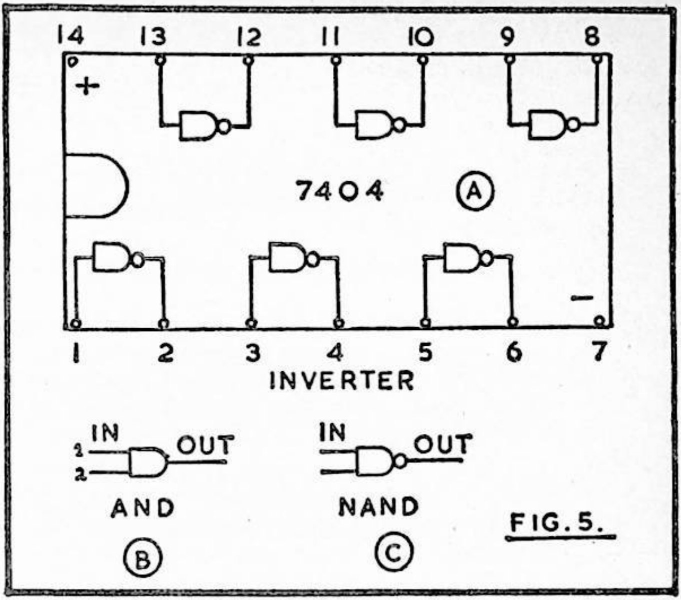


FIG. 5.

Inverter. This is shown at A. The gate output is an inversion of its input. Thus a high input provides a low output, and a low input a high output. The 7404 is a sextuple inverter, having six individual and separate inverters.

NOR. A NOR gate has two inputs. Both are low for the output to be high. If either input is high, the output will be low.

AND. The 2-input AND gate at B provides output corresponding to inputs simultaneously at 1 and 2 of input.

NAND. C shows a 2-input NAND gate in which both inputs are high for low output. With either input low the output is high.

The inverter and NAND gates find considerable application in the circuits here. As explained later, high may be around 3.5v, and low near 0v. With 1 for high, and 0 for low, input-output operation of these gates can be expressed as follows:

Inverter	0 = 1.	1 = 0.		
NAND	1, 1 = 0.	0, 1 = 1.	1, 0 = 1.	0, 0 = 1.

Decoders and other devices have gates internally arranged to perform the required operations, and reference to internal circuits need not be made.

7400 Operating Conditions

The 7400 series of devices include the 7490 decade counter, 7492 12-counter, and numerous other ICs, as listed elsewhere, and general operating conditions for these are given below.

Supply Voltage. This is normally within the range 4.75v to 5.25v. Ripple and regulation change should not exceed 5 per cent. To avoid erratic operation, a capacitor of about 22nF to $0.1\mu F$ will generally be required across the supply at the board. One such capacitor may serve several ICs, depending on layout etc. Common grounds in particular should be of low resistance or impedance. These can be obtained by wide foils where necessary, or equivalent wire conductors, located and connected to avoid common impedances which may provide unwanted coupling between ICs.

Normal operating temperature with free air circulation is $0°C$ to $70°C$.

Logic Levels. The logical 0 output voltage is typically 0.2v, with a maximum of 0.5v when driving normal loads, and can be under 0.1v for light loads.

Logical 1 output is typically 2.4v to 3.5v, with average loads.

Logical 0 input current is 1.0mA to 1.6mA and logical 1 input current 0.1mA, for each input.

These can be measured as described; or determined to lie in the logical 0 or logical 1 levels.

Unused Gates. Inputs are grounded.

Unused Inputs. These may be connected to used inputs or to positive via a limiting resistor of about 1k. A number of unused inputs may be connected together and to a single limiting resistor.

Further information will be found relating to specific gates.

Fan-Out. For many ICs this is up to 8. Assuming an input of 1.6mA per gate, which is the least favourable situation, total output loading would be approximately 13mA, and the 0.2v to 0.5v logical 0 output voltage quoted is for this.

Other related characteristics, such as those for decoder-drivers, will be found in those sections where these are dealt with, while suitable conditions can be seen from the circuits which apply to them.

High and Low Tests

For correct and reliable working of a gate, its inputs will lie within the limits described. According to the inputs and function of the gate, the gate output will then be either High, or Low. The High situation can be taken as about 3.5v, and the Low situation as about 0.2v to 0.5v, loaded.

Logical 1 is approximately 3.5v, and logical 0 may be put at 0.1v-0.2v. These are the voltages which will be found if a high resistance voltmeter or testmeter is used to take measurements at the gate output. The meter is returned to negative. The logical 0 state provides conduction from the negative line, and the maximum current which can flow is determined by the dissipation which can be permitted without harming the gate or IC.

Figure 6 illustrates tests for logical 0 and logical 1, with a meter as described. The actual voltage readings will depend on the loading on the gate, as well as on the IC tolerances. However, no confusion can normally arise, since high will be around 3v to 4v, and low almost zero.

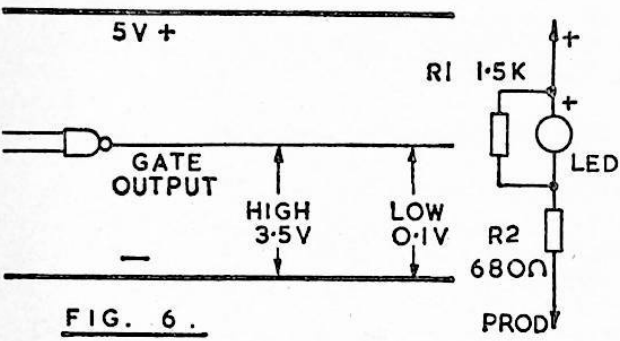


FIG. 6.

In some circumstances it may be more convenient to use a prod such as that shown in Figure 6. This can be made in a small tube or similar case, with a flexible lead and clip to take to the positive line. The LED lights for logical 0, but does not light for 1. If R1 is not present, the LED may light with a very small current, so that results are not always definite. R2 limits the LED current and thus the load on the gate output circuit.

With the prod, the logical circuits can be traced rapidly and identified as 0 or 1. With the logical 0 condition, the gate is providing continuity to the negative line, so that the LED passes current. A small LED will require about 5mA or less. It must be assembled into the circuit with correct polarity. The LED prod can be used wih all circuits where maximum loading is not already present.

Switch Pulsing

When making point by point tests through a counting or similar circuit, to check conditions at input and output of sections of the ICs, it can be useful to provide pulses singly, from a switch. Figure 7 is one method of doing this.

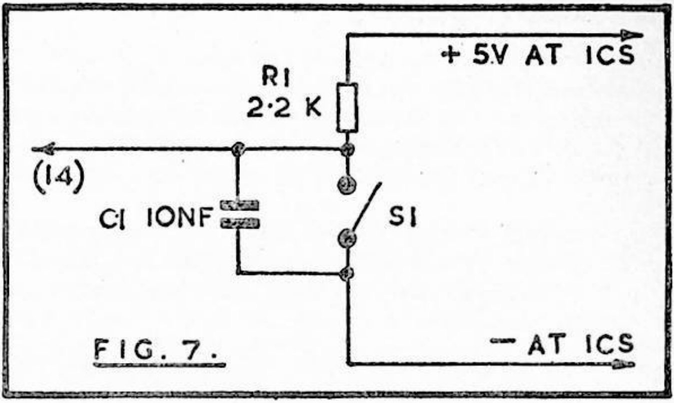


FIG. 7.

Positive and negative connections are made to the lines supplying the IC board. The junction of R1 and S1 has a lead to take to the required input point (e.g., 14 of the 7490 or 7492). Any existing clock or pulse circuit is temporarily disconnected. Pulses can now be applied singly, by operating switch S1. The conditions at the IC output tags, and elsewhere in the following circuits, can then be checked as necessary. Failure to obtain the anticipated high or low states in some parts of the circuit will then be found, and faults can be localised, to show interrupted foils, imperfect joints or other open circuits, shorts between conductors, or non-working gates.

S1 must provide good on-off switching without bouncing, or intermittent contact when closing. Such defects can produce a number of almost instantaneous pulses so that a divider or counter is stepped on farther than expected. C1 reduces the liklihood of this, but cannot be of very large value, because of the charging time when S1 is opened. However, there should be no particular difficulty in stepping the divider or other gates with single pulses to allow systematic tests.

Where single pulses are essential the electronic manual switch shown later can be used.

Slow Auto Pulser or Clock

With various counters it is useful to have a slow clock which will automatically pulse the divider input. A suitable circuit for this is shown in the Random Numeral Selector, (see Figure 16). Two transistors are used in a multi-vibrator, and very many different transistors will be satisfactory.

Using the values shown in Figure 8 pulses are at roughly one second intervals. This allows enough time for S1 to be opened, to stop the divider and leave it in some state where circuit investigation is needed.

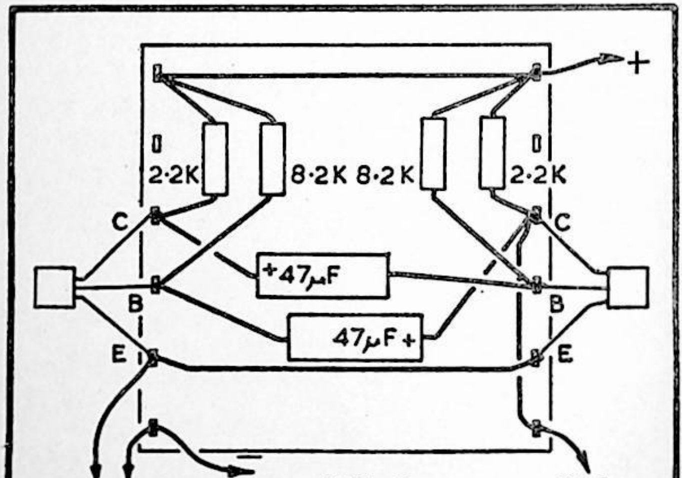


FIG. 8.

Current is drawn from the IC board supply lines, and input will be to 14 for the 7490 or 7492, as described for the switch pulsing.

As an example of the use of this pulser for circuit tests, should a numeral not appear, or be incomplete, operation would be halted as this is reached. Systematic tests can then be made, to find at which point in the whole circuit wrong conditions arise. In this way the fault can be localised at a driver, associated circuits, or display.

With cascaded counters too long an interval would often be required if the slow clock input were taken to the first divider. This is avoided by moving the input along the divider chain, as necessary.

The pulsing speed can be increased by reducing the values of the capacitors. This can be of advantage to test the operation of a series of counters, but will generally only allow the pulses to be stopped at particular figures for those dividers later in the chain. With given capacitor values, frequency can be changed by replacing one of the 8.2k resistors by 4.7k, with a 50k potentiometer in series.

The components can be assembled on a tagboard, Figure 8. Provide positive and negative leads with clips, for the power rails. The switch may be on the board, fitted to a small box taking the board, or on flexible leads so that it is easily manipulated while watching a display or testing circuits.

UJT Pulser

A unijunction transistor oscillator which can be operated from the 5v supply is shown in Figure 9. Capacitor C1 charges until the emitter circuit reaches a level where it conducts, so that the capacitor is discharged. This is then repeated, the charge being obtained from R1 and VR1. VR1 allows adjustment of the charging time of C1, and thus the frequency obtained. With values as shown, this is from about 1 Hz (1 pulse per second) to 150 Hz (150 pulses per second).

C1 should not be a leaky component, or the oscillator may not function, or may fail to do so with the whole of VR1 in circuit. An easy way to check for oscillation is to connect high resistance phones across R3.

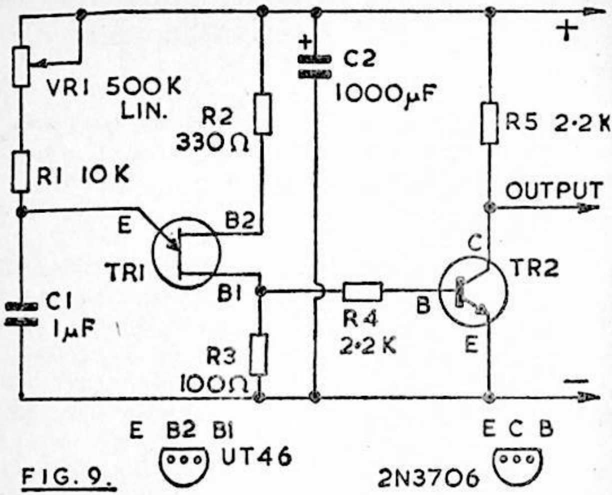


FIG. 9.

Other values may be used for VR1, R1 and C1, and these may be changed to increase frequency. Reducing the capacitance of C1 will raise the maximum frequency.

The pulses available at Base 1 of the UJT TR1 go to the output transistor TR2. A wide range of transistors (NPN) will operate here. Output from TR2 collector passes directly to the input pin of the decade or other counter.

In some circuits TR2 can be omitted, with R4 and R5. The output is then taken directly from Base 1. However, it will be found that a pre-set potentiometer is generally then needed for the circuit of Base 1. This can consist of a 47 ohm fixed resistor and 250 ohm potentiometer in series. The potentiometer is adjusted until a suitable and correct display is obtained. If numerals remain unchanged or appear incorrectly, the potentiometer is not set at a suitable value. The need for this adjustment is removed by fitting TR2 as shown.

This circuit can be used to drive the dividers and numerical display units shown elsewhere, when an exactly maintained frequency is not necessary. An example of this is found in the response indicator. Here, output from TR2 can be taken directly to the first decade counter, and the setting of VR1 can be found by timing the display for ten seconds. Adjust VR1 as necessary until the display agrees closely with a timepiece showing seconds.

The pulser will be found to have various applications, such as testing individual divide, decode-drive, and numerical sections of a counter, and for random number indicators, and other devices where the actual frequency of pulses does not need to be maintained exactly. Though a 5v supply is shown, and will often be available, the pulser can run from 4.5v, so allows battery operation of some units. UJTs other than that shown can be fitted.

A scale can be provided for VR1, and can be calibrated with good accuracy (for a given supply voltage) by reference to the counter. For the higher pulse speeds, a counter with at least three numerals is necessary. Observation will show if the count overflows and begins again at zero, and timing can be for ten seconds, for greater accuracy, the display then being divided by ten.

IC Test Board

With IC pins at 0.1 in intervals, a doubling of space will be of advantage when checking the operation of gates or otherwise investigating the performance obtained. For such purposes, a holder with leads running out to pins as in Figure 10 will simplify handling.

A 14 pin holder is used here. A 16 pin holder will take 14 and 16 pin ICs but numbering should be in distinctive colours. The holder is placed in the centre of the 0.1 in matrix board and leads are soldered to its pins underneath. These fan out to double spacing and two rows of push-in pins form connecting or test points. It is convenient to number these pins by any suitable method.

The IC must of course be inserted the correct way round. When first placing it in any holder, carefully check that each pin engages correctly in its socket. If many ICs are to be dealt with, one of the inserting tools designed for this purpose will be useful.

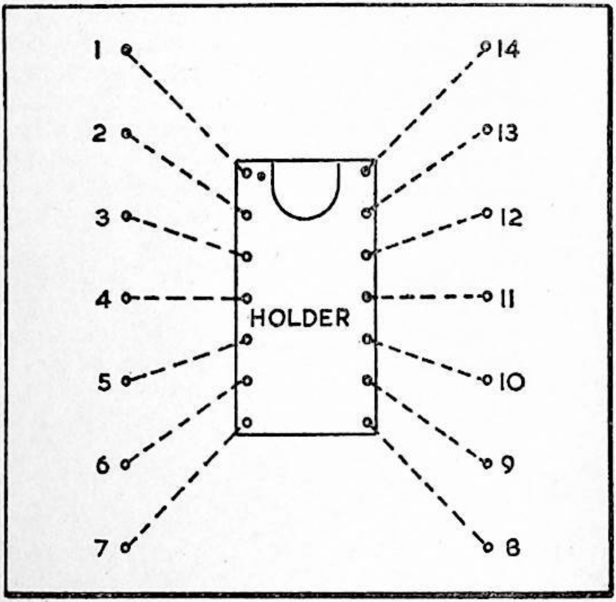


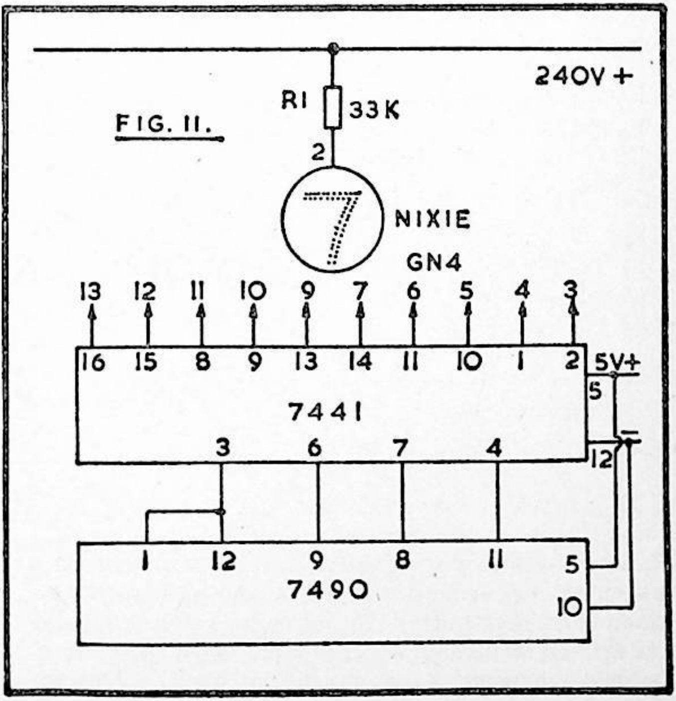
FIG. 10.

IC holders are recommended for the circuits here. They allow changing of ICs so that if part of a circuit does not operate, the IC can be tried as replacement for an equivalent in a working part of the circuit. If an IC is soldered directly to a foil board, it is very difficult to remove it with no aid except that of a small soldering iron, and pins are likely to be distorted or broken.

To check operation of an individual IC on the board, provide positive and negative supplies to the correct pins. Inputs can be taken high via a 1k or 2.2k resistor to positive. Operating conditions should be as given elsewhere.

7441 Nixie Driver

The 7441 is a decoder which accepts input from a binary divider and provides an output which may be employed to drive a Nixie numerical tube directly. According to the input supplied to the 7441, output is present at one of ten output points. Changes in the input step the output along these circuits, so allowing the numerals 0 to 9 to be selected and displayed.



Output circuits of the 7441 are connected so that the numerals 0 to 9 are displayed in sequence, and 9 is followed by 0, to repeat the sequence. By making these connections appropriately, the "carry on" needs of circuits with two or more numerals are met. For a single numeral random number indicator, decoder outputs can be connected so that any numeral is displayed with any output.

Figure 11 shows the output circuits for the 7441. Inputs are to the points 3, 6, 7 and 4, and outputs are obtained from the points 1, 2 and 8 to 16. Correct application of the decoder inputs at 3, 6, 7 and 4 will be necessary for correct display outputs for 0 to 9 to be obtained.

If inputs at 3, 6, 7 and 4 are measured with a high resistance voltmeter, "low" will be near zero volts, and "high" around 3.5v. By stepping the decoder driver one numeral at a time, these circuit conditions can if necessary be checked by this.

The following table shows the input conditions for each of the outputs. Here "low" is shown by 0, and "high" by 1.

Decimal	*Inputs*				*Output at*
	1	*2*	*3*	*4*	
0	0	0	0	0	16
1	0	0	0	1	15
2	0	0	1	0	8
3	0	0	1	1	9
4	0	1	0	0	13
5	0	1	0	1	14
6	0	1	1	0	11
7	0	1	1	1	10
8	1	0	0	0	1
9	1	0	0	1	2

Where circuits are checked with a high resistance voltmeter at the output tags, conductors, or Nixie tube, meter negative is taken to the negative line. The reading will then be approximately zero for a lit numeral, and some 25v to 50v or more for an unlit numeral circuit, according to the IC and meter. Conditions can thus be checked at 1, 2, 8, 9 and other output points.

The divider, driver, tube and associated circuit will be dulpicated for each numeral. Numerical tubes will be present for units, tens, hundreds and so on; or to display minutes and hours, according to the equipment. It is necessary that connection from the driver to numerical tube are arranged so that the carry-on impulse to the next divider arises with the correct numeral displayed.

Figure 11 shows the connections for the 7490 decimal divider which provides a binary coded input for the 7441. The latter changes the binary coded input to decimal output, as described. A GN4 type numeral tube is shown, but other types could be used.

Viewed from its underside, the GN4 has 13 pins. Counting these clockwide from the space, 2 is for the common positive circuit, taken to R1. The pins to display numbers 0 to 9 are as follows:

Pin	*No.*	*Pin.*	*No.*
3	0	9	5
13	1	7	6
12	2	6	7
11	3	5	8
10	4	4	9

No buffer stages are required between the 7441 decoder-driver and the Nixie tube, as the IC outputs are able to deal with the voltages and currents required.

Positive input to 5 of the 7441 is from the 5v supply line. A single stage consisting of 7490 divider and 7441 decoder can be expected to draw about 40mA to 50mA from this supply.

Drain from the high voltage supply is that of the tube, and is around 2mA to 3mA, the voltage from negative to pin 2 being about 150v when the circuit is operating.

Nixie Tubes

These have internal wires shaped in the form of numerals, and each connected to a separate pin or external lead. A further pin or wire provides a common positive connection to allow operation of all the numerals, and operating current is drawn from a high voltage supply, and through a series limiting resistor.

Tubes for end viewing are short but of quite large diameter, and are mounted with the top or end of the tube displayed. Side viewing tubes are longer but of smaller diameter, with the numerals so positioned that the display is seen from one side.

Inexpensive surplus tubes of these types can generally be used satisfactorily. Used tubes can be easily tested with a high voltage supply and series resistor. Complete failure of a tube can arise from a cracked seal (possibly from undue force when inserting a tube in a holder). The failure of some numbers only would suggest fractured pin connections or leads.

Tubes of this kind need a minimum supply of about 170v to 200v to operate, and typically draw about 2mA to 3mA from this. This supply is easily obtained with mains operated equipment, from a 250v or similar transformer.

The indications are generally 0 to 9, but some tubes are made with various signs only, so are of little use. Some have decimal points. The size of the numerals is generally about 0.55 in (13mm) to 0.6 in (15mm) high. Tubes may be tinted or clear glass.

Basic operating conditions for various tubes are given below. The side viewing tubes listed have wires.

GN4. B13B plug-in base. End view. 1.122 in (28mm) diameter. 1 in (25mm) long. Operate with 33k series resistor from 240/250v supply.

XN13. Wires. Side view. 0.75 in (19mm) diameter. 1.9 in (48mm) long. Operate with 47k series resistor from 240/250v supply.

XN3. As XN13 but operate with 56k resistor.

5870 Series. Wires. Side view. 0.5 in (13mm) diameter. 1 in (25mm) long. Operate with 39k series resistor from 240/250v supply.

General Operation

Where a decimal point is present (5870 series) a 560k series resistor is suitable for this.

Tubes will in general continue to operate satisfactorily with some reduction in supply voltage, or an increase in the series resistor value. The drop in brightness, or failure to obtain any numeral, will depend on temperature and other factors.

Tube life is aided by changing from one numeral to another, and in most applications this will arise in normal operation. It is not recommended that a single numeral remain displayed without change for a very lengthy period – say two or three days. Typical operating temperature range is from about – 20°C to + 70°C.

The 5870 series lead-outs match 0.1 in matrix perforated board. Two outer wires, to left and right, are for left and right decimal points. Viewing the tube from the base end, with these outer wires towards the top, two vertical rows of wires, each of six leads, will be seen. With the tube in this position, and the display upwards, connections are as follows:

Wire	*No.*	*Wire*	*No.*
1	1	6	6
2	2	8	7
3	3	9	8
4	4	11	9
5	5	12	0

This is counting upwards from bottom right, to bottom left. Wires 7 and 10 are joined, and form the common positive connection to the series resistor.

(GN4 pin connections are given in the section on the 7441 Nixie driver).

In the 5870 series, S, ST and L types are clear; and SF and TF types have a red filter.

Lead or pin connections for unknown types can be found with the aid of a high voltage supply such as shown later, and a series resistor, which may be typically 100k. Temporary connections to leads or pins will provide identification. E.G., the common positive will remain unchanged, while moving the other connection displays numerals according to the lead or pin selected, these being noted. Insulated test prods or similar means to avoid shocks must be used.

Nixie Power Supply

Cold cathode numerical tubes require a high voltage direct current supply. This can be obtained from AC mains by using an isolating transformer, rectifiers and smoothing, with a current limiting resistor in series with the tube supply.

Figure 12 is a circuit for this purpose. The mains transformer has a 250-0-250v secondary, and two silicon rectifiers (type 1N4006) provide full-wave rectification. C1, R1 and C2 allow smoothed direct current to be drawn. R2 is a parallel bleeder resistor to help obtain a more stable supply, while R3 is the dropping series resistor for one tube.

After rectification, the 250-0-250v transformer will provide approximately 350v peak voltage across C1. This is dropped to about 250v across C2, with R2 drawing a little under 20mA.

It is possible to use a transformer having a secondary with no centre tap, either by employing a single rectifier for half-wave rectification, or four rectifiers in a bridge circuit. A 220v to 250v winding is suitable for half-wave redification. If necessary, the voltage obtained at C2 can be modified by altering the value of R1. Reducing the value of R1 increases the voltage obtained at C2. Increasing the value of R2 has a similar result.

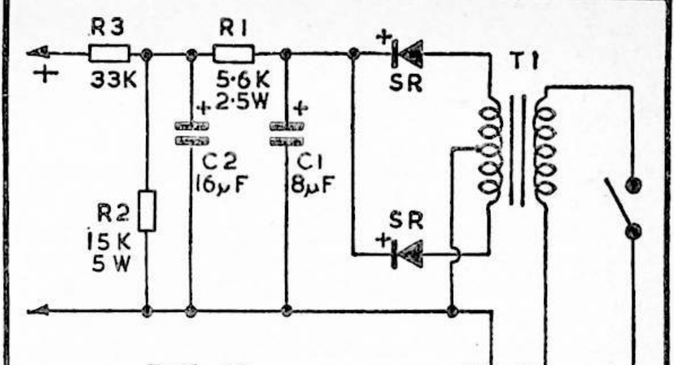


FIG. 12.

The tubes are only expected to draw about 2mA to 3mA or so each, so the load from this source is small. The steady current taken by R2 helps to avoid too much change in voltage, with changes in load. The total load is within the rating of a 40mA transformer secondary. Transformers with a higher current rating are of course suitable if to hand, and if space is available.

Popular mains transformers as used for valve equipment will have one or more 6.3v windings. A 5v supply for dividers and other ICs can be obtained from these.

In practice, the voltage of the DC supply is not too critical. Good numeral brightness is obtained with some reduction in voltage. Excess voltage is expected to reduce tube life. Best results are obtained with supply conditions similar to those shown for the various tubes.

Note that if other rectifiers are used, these should be a PIV (peak inverse voltage) rating of 750v or higher, with a 250v transformer secondary.

Mains Safety

All equipment operated from the mains, even if only requiring a low voltage, *must* be arranged to avoid chances of shock hazards. Equipment must remain safe, even if a fault arises.

All equipment circuits must be isolated from the mains. This means that a double wound transformer is necessary. An auto-transformer with a low voltage tapping is unsuitable.

The transformer is connected as in Figure 12. The core or frame, and negative line of both the low and high voltage supplies, are grounded by the earth lead. A 3-core mains cord is thus necessary, and the earth conductor allows earthing at the mains plug. It is recommended that a low rating fuse (say 2A) is present in the L or Live conductor circuit. A single pole on-off switch is also in this circuit. The transformer primary is returned to N or Neutral, and no fuse or switch is placed in this circuit.

The earth circuit should only be omitted with a double-insulated transformer of the type approved for use without earthing.

Connections to the transformer primary circuit should be properly anchored. No accessible bare joints should exist when the equipment is placed in its case. For added safety when constructing and testing, it is best to use shielded or covered connecting blocks for mains leads, or to position joints so that they will not be touched while handling the equipment. Metal cases or panels should be earthed.

Shocks may also arise from the rectified high tension supply, so care must of course be exercised when testing or dealing with the high voltage circuits. In general, the same care needs to be exercised as when dealing with a mains operated radio or amplifier.

Easy 5v Power Supply

With many circuits only a single and relatively simple 5v power supply will be needed. Where a 250-0-250v or similar transformer has been used to provide a high voltage for numerical tubes, a 6.3v winding will often be available. This may be brought into service for the 5v supply.

Figure 13 shows one way of doing this. Half wave rectification from the 6.3v winding provides about 9v across the reservoir capacitor C1. VR1 drops this to 5v, and the supply is smoothed by C2. It is not necessary that C1 and C2 be the exact values shown, provided they are of large capacitance, and rated at the voltages present or of higher voltage rating. R1 is essential, and draws 500mA constant current, so that the output voltage remains substantially the same, with some changes in power drawn.

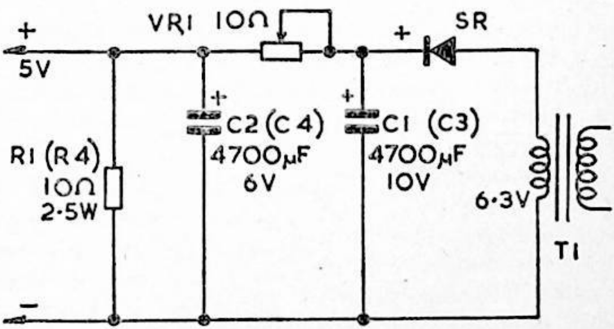


FIG.13.

VR1 needs to be rated at 1A. When first setting up the circuit, connect a high resistance and accurate voltmeter across the supply output terminals, and adjust VR1 for 5v. When an integrated circuit board is connected, the voltage will drop slightly. Current drawn by the board is likely to be small, compared with that taken by R1, so that the change in voltage is insignificant.

If VR1 is re-adjusted with the supply providing power for one or more boards, care must be taken that the voltage will not rise under some working conditions to more than about 5.25v. This means that VR1 should be set while the board is drawing minimum current encountered during normal operation.

Full-wave rectification is also possible. This provides an improvement in the smoothness of the DC supply, beneficial if C1 and C2 are of somewhat smaller values. Other parts of the circuit remain as shown.

These power supply circuits are convenient where the total current required at 5v will be quite small, as when a small number of ICs which do not require much power are fitted in a device. This would be so with dividers operating a small number of numerical tube drivers which with the tubes will be drawing current from a high voltage supply.

It is possible to raise the current available by using a 2A or larger 6.3v winding, reducing R1 to take 1A, and changing VR1 to suit. The larger the current drawn by R1, the less change in output voltage will arise with varying loads on the supply. However, a limit is obviously set by the transformer winding and rectifier.

By combining the HT circuit shown with that for 5v, an inexpensive dual voltage power supply can be made, which will allow many circuits to be operated satisfactorily. A check should be made to find the low voltage output for all operating conditions, as mentioned. This ought to be between about 4.75v and 5.25v. If the voltage is too low, some or all circuits may cease to operate correctly.

A similar mains supply, but for low voltage only, can be made by using a transformer with low voltage secondary. A transformer having a 6.3v 1A winding only could thus be used in Figure 13. Other secondary voltages can be used, provided C1 and VR1 are modified to suit.

Where supply conditions do not fall within the capability of a simple PSU of this kind, a regulated supply should be used.

Building the Dual PSU

Figure 13B will assit in construction. This combines the circuits in Figures 12 and 13, and the transformer has 250-0-250v HT and 6.3v low voltage windings. It is the only component mounted above the chassis, and its leads run through grommets as shown. The mains cord, connected as already described, is anchored at the small tag strip near the mains switch.

Two long tag strips provide supporting points for the resistors, capacitors and rectifiers. VR1 is mounted on the front of the chassis, and its spindle is slotted for adjustment by means of a screwdriver, to set the low voltage (LV) output as explained. The other positive socket is for the high voltage (HV) output.

Referring to Figure 12, the tube series resistor R3 has to be duplicated for each Nixie, so one such resistor is necessary at each Nixie holder. All resistors here are returned together to the HV socket.

With construction arranged as in Figure 13B, and a transformer with colour coded flexible leads, no joints or bare connections will be present above the chassis. A case is thus unnecessary, provided the bottom of the chassis is covered with a metal plate. This should have a few ventilating holes, and some holes are also punched in the chassis. Air circulation is then possible, with the unit raised on four small rubber feet. If the transformer has tags, then the whole PSU should be enclosed in a case.

Regulated Low Voltage Supply

A circuit with a Zener diode and current passing transistor is shown in Figure 14. The transformer may deliver 6v or 6.3v, and may be for low voltage only, or a second winding may

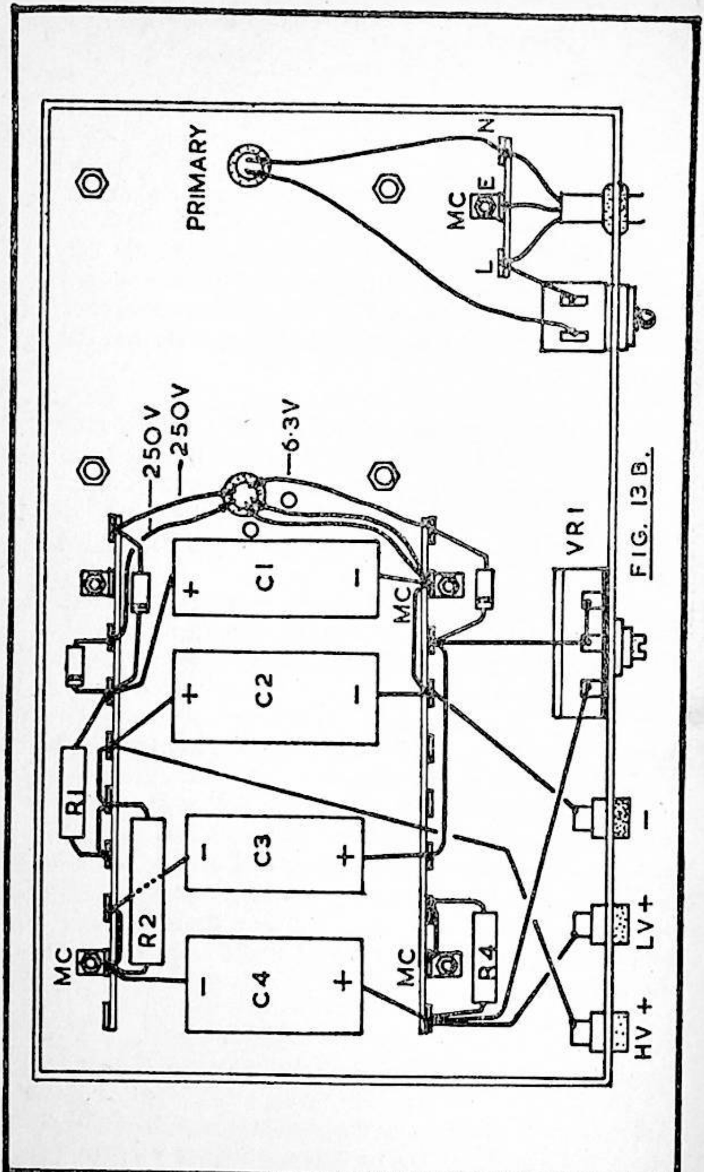

PRIMARY
MC
L
E
N
250V
250V
6·3V
C1
C2
C3
C4
R1
R2
R4
MC
MC
MC
VR1
HV +
LV +
−

FIG. 13 B.

also provide a high voltage supply, as described.

For rectification, four 1N4001 or similar silicon diodes may be used, or a 1A or 2A bridge rectifier. The rectifier voltage rating need only be low, but 50v rectifiers would often be used as these are readily available.

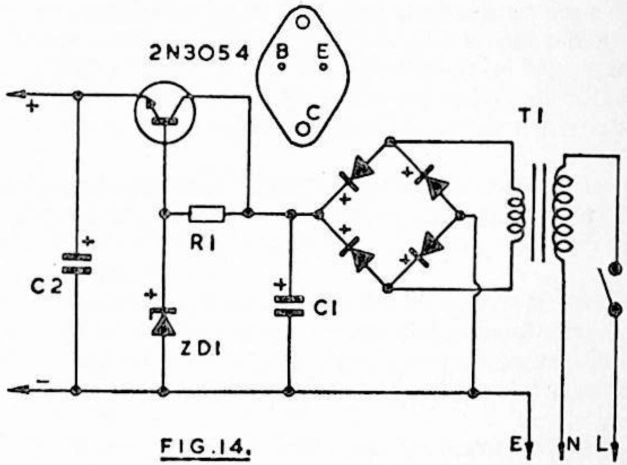


FIG.14.

Capacitor values are not very critical. Nearly 9v will be present across C1. This is dropped by R1 for the 5.6v Zener diode. With these values, diode current will be about 35mA, so a 400mW diode is adequate. The base of TR1 is held at this voltage, so that the potential at the emitter circuit is a little lower, and changes only slightly with normal alterations in the current taken.

Power transistors other than the 2N3054 may be used. This component will normally be mounted on a metal surface (chassis or panel) with an insulating set, as the case is common to the collector. The power dissipated in TR1 is small (about 4w with 1A drawn) so no heat sinking problems will arise.

The exact output voltage will depend on TR1 and the Zener diode, and can be checked with a meter, for normal operating conditions. TR1 emitter potential is slightly lower than that at the base.

Construction Notes

With many circuits the transformer and associated items can be fitted in the case used for the numeral tubes and other parts, so that the equipment is a single, self-contained unit, operated from AC mains. This is convenient for counters, clocks, various games, and similar devices.

For testing and other purposes, the PSU can be constructed as an individual unit, with sockets for low voltage power supply leads.

Whatever form of construction is employed, care should be taken that the equipment is both safe to use and handle. Reference should be made to the precautions which are necessary for safety given earlier.

Should it be necessary to check the overall current drain of the IC boards, this can be done by placing a meter in series with the positive connection from the PSU. A 1A supply is going to be easily adequate for many circuits, even if of the type where individual light emitting diodes are used as indicators.

With a non-regulated low voltage supply, two main points have to be remembered. First, the total load (including bleeder current) must not exceed the transformer or rectifier rating. And secondly, current drain of 7-segment numerals is minimum with 1 displayed, and maximum with 8, and the voltage should remain sufficiently near 5v with these conditions throughout.

Components for Figure 14

T1 240v/6.3v 1A transformer, for approximately 5v

	1A only. For high voltage in addition, 6.3v and 250-0-250v or 6.3v and 0-250v secondaries are required.
Rectifiers.	Bridge rectifier, 1A or larger; or four 1A or similar individual rectifiers (1N4001s suitable).
C1	1000μF or larger, 12v.
C2	2200μF or larger, 6v.
R1	100 ohm ½w.
ZD1	5.6v or 5.4v 400mW Zener diode.
2N3054.	

Nixie Battery Supply

A supply powered by a battery and delivering a high voltage for Nixie tubes can be of use for some games and counters which are not to be run from mains. Operation is practicable from dry batteries.

Direct current voltage converters intended to supply a high voltage usually have two power transistors in push-pull, and operate from an accumulator. However, a Nixie tube can be of satisfactory brilliance with a current of about 1mA, so only very small power is necessary. The voltage must of course be high enough for the tube to operate.

Figure 15 is an easily made circuit which will draw about 50mA from a 6v supply. This is within the capacity of dry cells, even with quite long periods of intermittent use. Running is possible from a lower voltage, but with reduced output.

A speaker transformer with 8k primary and two 3 ohm secondaries is suitable. The two 3 ohm secondaries are connected in series to obtain a centre-tap. Phase must be correct, or oscillation is not obtained. If necessary, reverse the two connections to one secondary to correct this. The overall ratio is about 37 : 1. A small 230v/12-0-12v ¼A mains transformer is also suitable.

No doubt other transformers could be used. With a multi-ratio component, various tappings can be tried on both

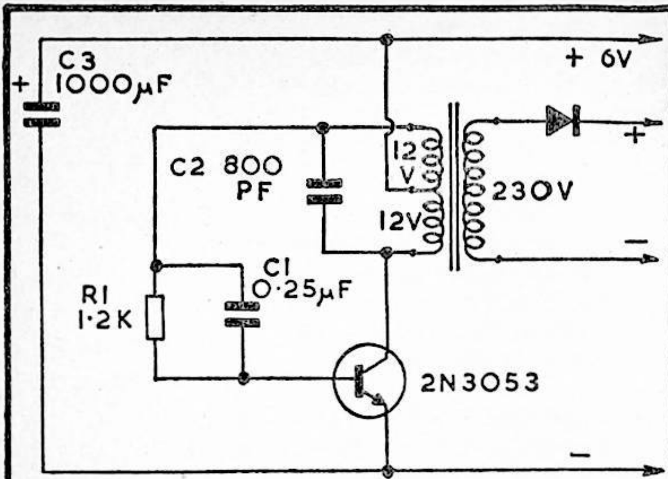


FIG. 15.

primary and secondary. A high resistance voltmeter connected to the high impedance winding should indicate 200v or so.

Should current taken from the 6v supply be very high, and no output be realised from the transformer, the circuit is probably not oscillating. This may be caused by wrong phase of feedback to the base, as mentioned, or the use of an unsuitable transformer. If the output voltage is unnecessarily high, it can be reduced by increasing the value of R1.

With the circuit used, it was found that the addition of a reservoir or smoothing capacitor stopped oscillation. If needed, some adjustment in value can be made to the Nixie series resistor.

Transistors other than that shown are possible, though there will be little saving in cost when smaller types are found to need a heat sink. The actual power which has to be provided depends on the brilliance wanted, and number of tubes. A BFY51 or 2N3053 will be found suitable for a smaller output, and especially a single Nixie number indicator. A clip on sink is needed, and a check must be made to find that overheating does not arise when first testing the circuit.

In all cases the value of R1, and of the two capacitors, can be modified experimentally, with a view to obtaining adequate output with the lowest battery drain. C2 ought not to be omitted, or be of unnecessarily low value, or interference is likely to be noticed with near-by radio receivers. Unnecessary coupling of pulses at the oscillator frequency into counting circuits has to be avoided.

Random Numeral Selector

A circuit which will select and display a random number from 0 to 9 can be used in a wide range of games. It is easy to construct, needing only two transistors, two ICs, and a numerical tube, with a few other small components and power supply. Apart from its use, it will provide an introduction to building more complex circuits having several tubes.

Figure 16 shows the complete circuit. TR1 and TR2 in the oscillator section conduct alternatively, each driving the other. The frequency of operation depends on the capacitor and other values, and is high enough to prevent any chance of stopping the display at a wanted number. This part of the circuit operates only when the push switch S is closed. So long as it is running, pulses are available from TR2 collector, for the divider.

If wished, the frequency of this type of multivibrator can easily be modified by changing values, as described elsewhere, (see Figure 8.)

The pulse input to operate the divider is to 14. Points 2, 3, 6 and 7 are resets, not required for this application. The 5v positive supply is to 5, and common negative to 10.

Output 12 and input 1 are connected, and outputs are taken from 12, 9, 8 and 11. These outputs, in the order 11, 8, 9, 12

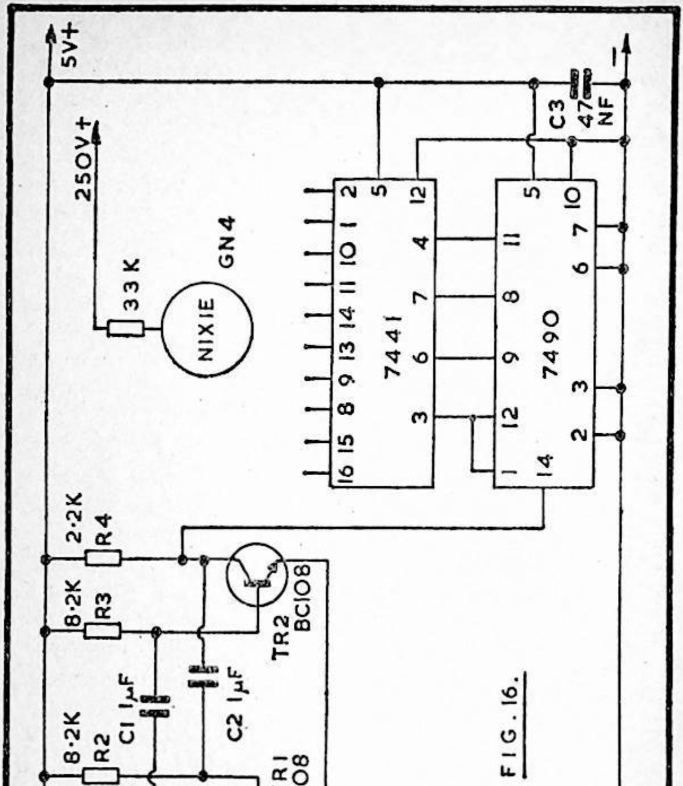


FIG. 16.

provide binary in the sequence 0000, 0001, 0010 and so on, as described, for a decimal count from 0 to 9. As they are not suitable for display in binary form, they are taken to the 7441 decoder.

The inputs 4, 7, 6 and 3 receive inputs in the form 0000, 0001, 0010 and so on. The internal logic functions allow these inputs to select one of the outputs in turn, in the way explained.

One of the output circuits, 16 to 2, will thus be enabled to operate the external display. This is done by the decoder switching on the appropriate numeral through connections to the related individual pins. Tubes other than that shown can be used, with the series resistor described.

In use, the numbers shown change in rapid succession so long as switch S is held down, one figure remaining displayed when S is released.

Assembly is most conveniently on 0.1 in matrix perforated board, Figure 16B. Holders are not essential for the ICs, but have the advantage that the ICs may be removed, or others of the same type may be tested in their place. Heating of the ICs during soldering is also avoided. When inserting them in the holders, be sure they are the correct way round and that all pins line up correctly with the sockets.

The end view tube is very easily located so that it comes behind a circular aperture in the panel, and the circuit board can be in the same plane as the panel. A side viewing tube will need to be located behind a rectangular opening. Tubes with wires fitting the 0.1 in matrix board can fit vertically on the edge of the board which is fixed horizontally with brackets attached to the panel.

Two such circuits, with their own multivibrators, will provide random numbers up to 99. Three such circuits, again with their own multivibrators, can form an electronic numerical equivalent of the popular type of fruit machine. Odds can be worked out for any pair of numbers, a specific pair of numbers, any three, or a specific three numbers. For simultaneous operation of two or three displays, the push switch is arranged to control all the multivibrators.

Wiring of the board in Figure 16B is most easily carried out in the manner described earlier. That is, by running thin tinned copper wire up and down through the perforations, as required to complete the circuits from point to point. Positive and negative conductors should be of reasonably stout wire.

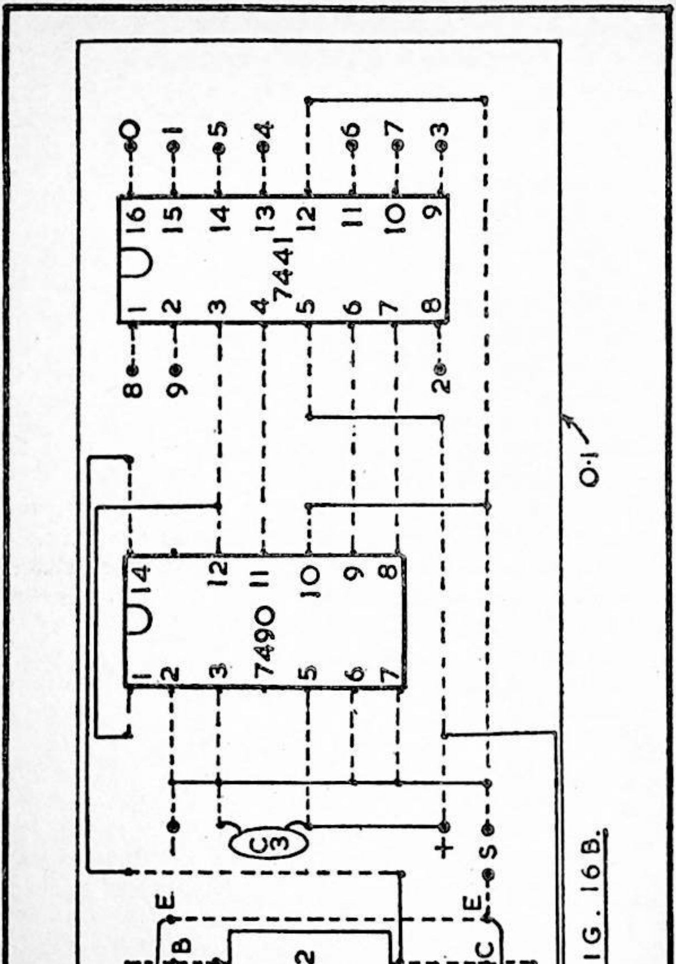


FIG. 16B.

Pins or flying leads can be provided for the switch S, and positive and negative connections.

With reference to the 7441, connections are taken from 16, 15 and the other points number 0 to 9, to the Nixie tube. Pins and leads for various tubes have been shown earlier. Thin flexible connections between board and Nixie holder will allow the latter to be placed as requied. Or the board may be extended to carry the Nixie tube in addition. For the purpose in view, the leads to the tube could be connected at random, since numerals need not appear in the usual sequence.

7-Segment LED's

These displays have vertical and horizontal sectors which may be illuminated individually, to produce the figure required. In Figure 17 the sectors are lettered A to G. A combination of these segments is obtained by using circuits to the various pins, as follows:

A pin 1
B pin 13
C pin 10
D pin 8
E pin 7
F pin 2
G pin 11

The numbers are when viewing the numeral from the front. These are individual cathodes for a common anode display, and so are taken to the negative side of the circuit. In addition, a decimal point may be obtained by means of pin 6.

A common anode connection is from the display to positive. This connection is to pin 3 for the DL707 and equivalent types. However, inexpensive displays filling the same purpose are available in which 3 is the common anode for F, decimal point, E and G, with 9 for D and C, and 14 for A and B, so it is necessary to connect 3, 9 and 14 together externally for the common positive circuit.

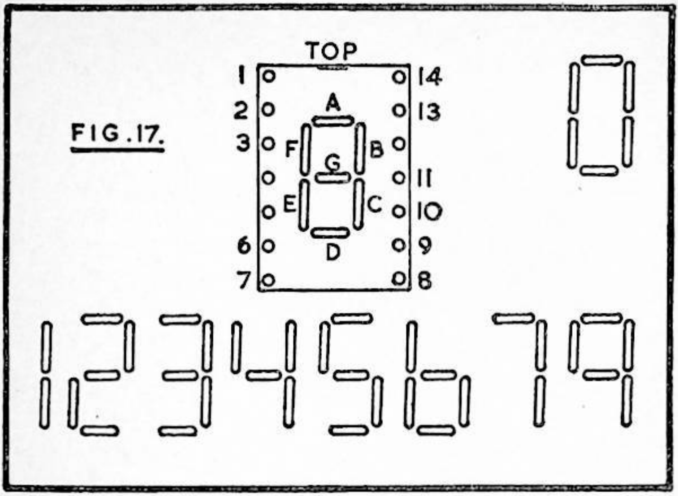


FIG. 17.

It will be noted that decoder driver ICs of the 7447 type are placed between negative and individual segment pins of the display, so that the latter must be of the type having a common anode. In these circumstances no inverter or buffer is necessary when the decoder driver is able to supply the segments direct (via limiting resistors) and circuits are simplified.

The DL707 and similar individual numerals will fit DIL 14 pin holders. Some types of holder are not very suitable for some numerals, however, as the individual sockets cannot readily accept the pins. This should be checked before soldering the holders to the circuit board. Holders and display mounts for LED displays are available, and these allow the numerals to be fitted side by side without the need for individual sockets, and give an attractive finish to the equipment. The mounting may fit in a cut-out in the panel and have a surrounding bezel.

The 7-segment displays are available in red, yellow and green. Heights for the digit include 0.1 in, 0.15 in, 0.3 in, 0.4 in, 0.5 in and 0.6 in. The 0.3 in numerals can be used for many purposes. Displays are available with a number of digits.

Common anode displays include the DL707 (0.3 in), MAN52

(0.3 in), DL727 (0.4 in) and DL747 (0.6 in). Common cathode displays include the DL704 (0.3 in), MAN54 (0.3 in) and FND500 (0.5 in). Numerous other types are to be found.

The numerals 0 to 9 are obtainable as follows (referring to Figure 17).

0	ABCDEF	5	AFGCD
1	BC	6	AFEDCG
2	ABGED	7	ABC
3	ABCDG	8	all sectors
4	BCFG	9	GFABCD

The numeral 6 may be obtained by FEDCG and 9 by means of GFABC as in Figure 17. The omission of tails for these numbers is usual with some circuits.

Current Drain

The overall current required by the numerals is not going to be very important, except where battery running is in view. For a 0.3 in numeral, a current of about 10mA to 15mA per sector gives excellent brightness, and 10mA would be satisfactory. Maximum battery drain would arise with 7 sectors illuminated, being 70mA. A device with two or three numerals would require up to 140mA or 210mA for these, plus that necessary for the operating circuits. This is within the range of ordinary dry batteries of modest size, for intermittent use in games etc.

With lower LED currents, brightness falls. The lower level can be expected to lie around 3mA to 5mA per segment. If some battery operated device is to be made, and it is wished to economise as far as possible, a test should be made with an experimental series resistor. If brightness is inadequate for the purpose, this series resistor needs to be reduced in value. Current depends on various conditions, but can be around 3mA with a total series resistance of 1k, rising to 10mA or so with a total series resistance of 270 ohm.

It will be noted that it is not sufficient to include a single series resistor in the common anode circuit (as with Nixie tubes) because voltage drop in this would rise with the number of segments receiving current.

The 7-segment light emitting diode numerals such as shown in Figures 18 are of the common anode type. All anodes are connected together, and to the positive supply. The wanted display is obtained by completing the circuit to particular segments from the negative line, via a transistor, decoder-driver, or similar means (with the inclusion of a series current limiting resistor).

The individual series resistors for each segment are necessary, to avoid excess current. All are of the same value, and each is circuit with one sector.

0-9 Counter

Figure 18 is a circuit counting from 0 to 9 and using a 7-segment LED numeral. It will find application in various games, and can also prove to be useful as a quick means of testing 7490 and 7447 ICs and numerals.

Pulses to be counted are taken to 14 of the 7490. This is a divide by 10 IC, with outputs coded in the way described in the use of this IC with Nixie numerical tubes. Positive supply is at 5 and ground at 10. Operation can be from a 5v supply, or from a 4.5v dry battery. A supply derived from the mains will be needed for long periods of continuous running, but current drain is only a little over 0.15A (number 8 displayed) so that for games and similar intermittent usage a dry battery is practical.

The push switch S1 is normally closed so that the re-set line (2 and 3 of the 7490) is connected to negative. Momentarily opening this switch returns any count shown by the LED to 0.

A large capacitor may be required across the positive and negative lines. This depends on the impedance and other

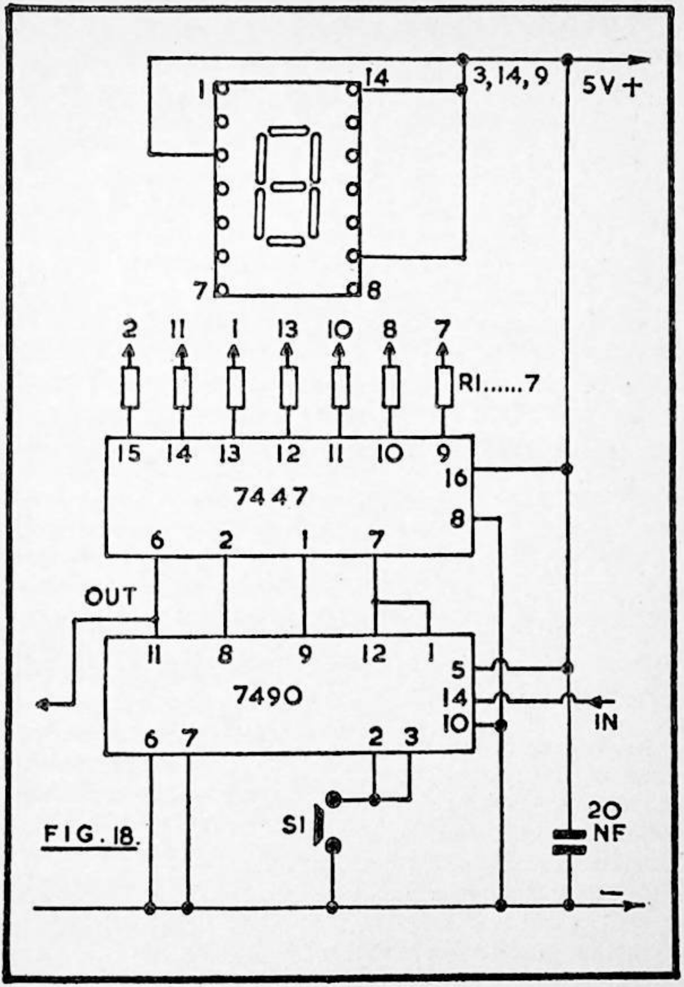


FIG. 18.

details of the supply. It can be 1000μF 6v, and will make the circuit less susceptible to variations in supply or battery voltage when switching.

The 7447 decoder-driver is intended for 7-segment numerals and outputs are available simultaneously at a number of pins.

Referring to Figure 18 it will be seen that output is necessary at 9, 10, 11, 12, 13 and 15 for the numeral 0; at 11 and 12 for the numeral 1, and so on, being required at all points for 8, and 11, 12, 13, 14 and 15 for 9.

The individual outputs can be up to 20mA, which is easily enough for the display. The output circuit is for up to 15v. If greater power is necessary then transistor buffer-amplifiers can be added. With the values shown, only a single supply of about 5v will be required. Pin 8 is the common negative, and 16 for the 5v supply.

Input to 14 (7490) can be from optically controlled or other circuits shown elsewhere. This will allow moving objects or repetitive movements to be counted.

For use as a random number generator for games, a 2-transistor astable circuit can be used, as shown earlier, controlled by a push switch. The pulse frequency must be high enough to avoid any possibility of selection by the player, or needs to be maintained for a short while after releasing the push button by means of a capacitor.

When first testing this circuit, check that the supply is near 5v under all conditions, if from a mains unit. Insufficient voltage, whether from a battery or mains unit, will result in wrong or unchanging displays. Some individual ICs will have a greater tolerance to low voltage than others. Should a display prove to be incorrect with the recommended voltage, a 7-segment LED can if necessary be checked with a 330 ohm series resistor and 4.5v or 5v supply, to assure that all sectors will light.

The ICs themselves can be assumed to be in order, if from a reliable source. Cheap individual or pack ICs may be defective in some respects. This may result in some figures not being obtained, or incomplete numerals. If necessary, outputs from the 7490 can be checked at 8, 9, 11 and 12, as explained earlier. If these are correct, so that the 7447 receives the proper inputs, the outputs of this IC need to be checked, and also connections to the LED numeral. Sectors which should receive current for each number have been given, or can

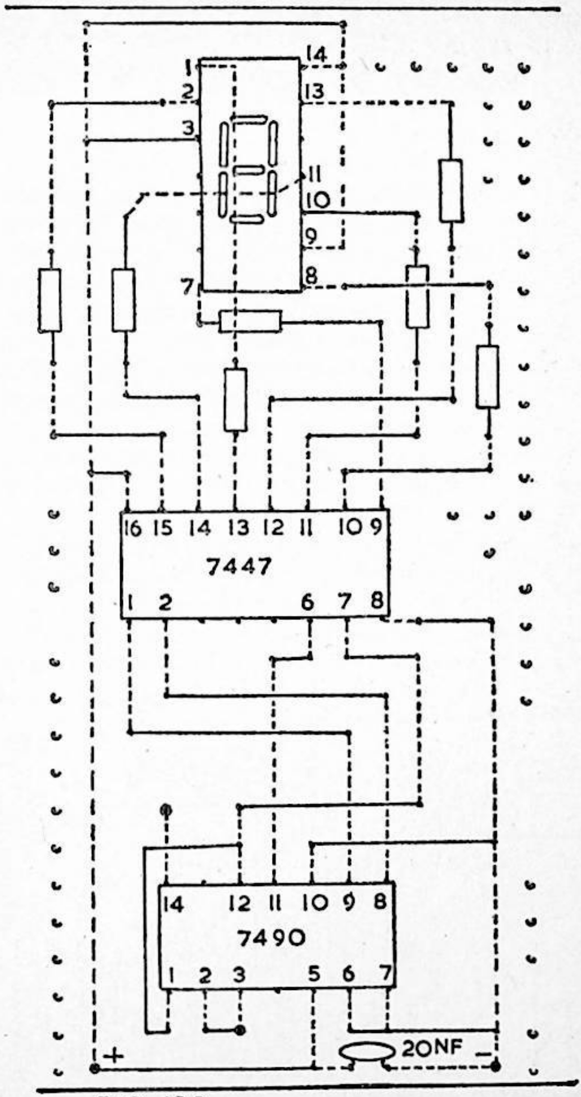

14
1
2
13
3
11
10
9
8
7
16 15 14 13 12 11 10 9
7447
1 2 6 7 8
14 12 11 10 9 8
7490
1 2 3 5 6 7
+
20NF
–

FIG. 18B.

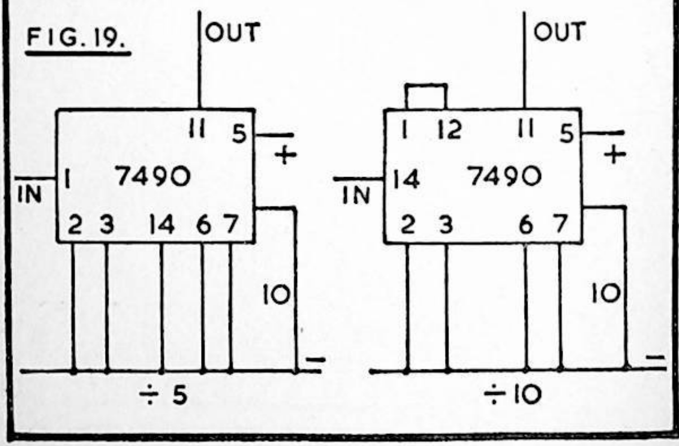
readily be seen. Figure 18B shows assembly and wiring on a board, as described earlier. The board can be large enough for two or more numerals, with their decoders and dividers.

Count Extension

When the number indicated changes too rapidly to have any significance, or is not required, a divider is placed before the 7490 input. One example of this is in a clock run from 50 Hertz mains. Adding a 5 x 10 or 50 divider would result in the numeral showing seconds. For minutes to be shown, a further 60 divider would be required as well. In other circumstances, as when counting shaft revolutions, a units figure may not be wanted, and a single IC providing division by 10 could then be used. The numeral would then count in 10s to 90. Similarly, it could count in 100s, or in other multiples such as those dealt with in the section on dividers.

The count may also be extended by taking an output from 11 on the 7490 to the input (14) of a following similar IC. This would duplicate the circuit in Figure 18 and allow counting up to 99. From here, output can be carried to another similar circuit, for 999, and so on, if wished. For a display requiring

FIG. 19.



seconds and minutes, division and decoding will be arranged to suit. The seconds count will be to 60 only, as will that for minutes, while hours may run to 12 or 24 before repeating.

Figure 19 shows a divide by 5 circuit which may be placed directly before the divider in Figure 18. Input is to 1, and output from 11 directly to 14 in Figure 18. The only other connections are to the positive and negative lines, as shown.

With the divide by 10 circuit also shown, input is to 14, and 1 and 12 are joined. With both circuits 2 and 3 may be taken to a re-set line, as shown in Figure 18.

For division by 2, 6 or 12, the 7492 will be used. Reference can be made to circuit details showing this IC.

50 Hertz Driver

If 50 Hertz mains are taken as a source of pulses, followed by a circuit dividing by 50, then one second pulses will be available. If these are used as input to the 0-9 counter, the latter will change by one number each second, with display by the 7-

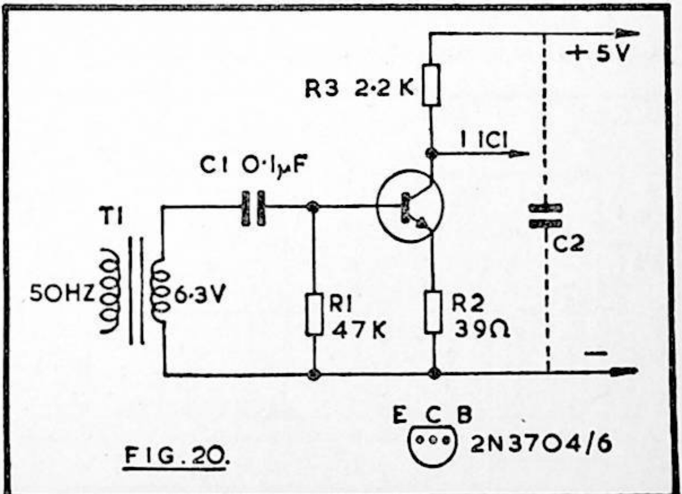


FIG. 20.

segment LED. It is only necessary to follow this by further dividers, with their decoder-drivers and LEDs, to obtain display of seconds, minutes and hours as required for an electronic clock.

Figure 20 shows the circuit of the 50 Hertz driver. As the equipment will be mains operated, T1 will be supplying direct current for other items, as shown elsewhere. It is not essential that the secondary of T1 is 6.3v. Satisfactory working is obtained with a lower voltage, and this also means that pulses may be taken from a bridge circuit where the AC peak available at C1 will be lower.

When C1 swings positive, TR1 conducts, and voltage drop in R3 provides a negative output for the first divider. Various small NPN transistors, including the 2N3704 and BC108, are suitable. The capacitor C2 will not be necessary when already present in the power supply circuit. No difficulty should arise when using a supply with adequate reservoir capacitance, but this should be checked if the numerals displayed jump sequence or are otherwise incorrect, as it is possible for pulses on the supply line to the ICs to carry back to earlier ICs.

Figure 21 shows the 50 divider. IC1 has input to 1 and output from 11, and divides by 5. Output from IC1 is to 14 of IC2. This IC has 1 and 12 joined, and output is from 11 to 14 of

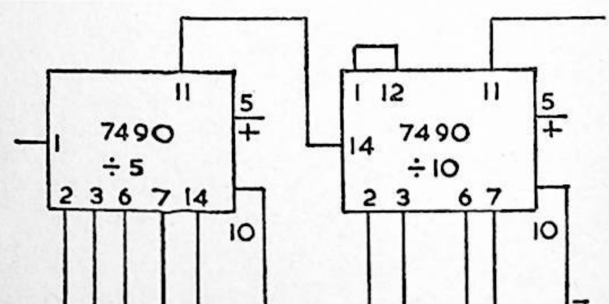


FIG. 21.

the IC divider in the divider-driver-display circuit. IC2 divides by 10. (For 60 Hertz mains, it would be necessary to use 7490 and 7492 ICs connected for 5 x 12 or 10 x 6 dividing).

The 5v positive pins (5) derive power from the same 5v line as used elsewhere. The resets, negative and other points shown are all common negative. A reasonably stout conductor is needed here. It can be 22 swg or 20 swg for wired boards, or a foil area offering low impedance around the board. The negative line can be duplicated, or travel completely round the board. With reasonable care no difficulty is likely, but a poor return circuit, or one having a common impedance to some ICs, may cause incorrect display of some numerals.

It is not necessary to reset IC1 or IC2, in view of the short time interval this would cover. The resetting of seconds to zero, so that the clock will show correct time, is by means of a switch which is normally open. If wished, the circuit may be taken to dividers IC1 and IC2 as well. As resetting returns numerals to zero, it is not practical to use this method for minutes or hours. Instead, the output from an oscillator or switch can be used to step forward minutes and hours rapidly, to the wanted time. Resetting circuits will depend to some extent on whether it is considered adequate to start the clock on the hour, or whether immediate setting, or setting of accuracy better than 1 second, is required. Manual electronic switching will also allow setting to time.

Reduced Counts

As the indication of seconds up to 99 will not be required in a clock, the following divider, decoder-driver and numeral circuit is arranged to operate up to 6. This numeral, advancing once each 10 seconds, is placed to the left of the units numeral described.

Figure 22 is the circuit used here. The 7492 is used instead of the 7490, and is connected to the 7447 decoder-driver and 7-segment LED to provide a display of 0 to 5. When used in conjunction with the previous 7490 divider, from which it receives

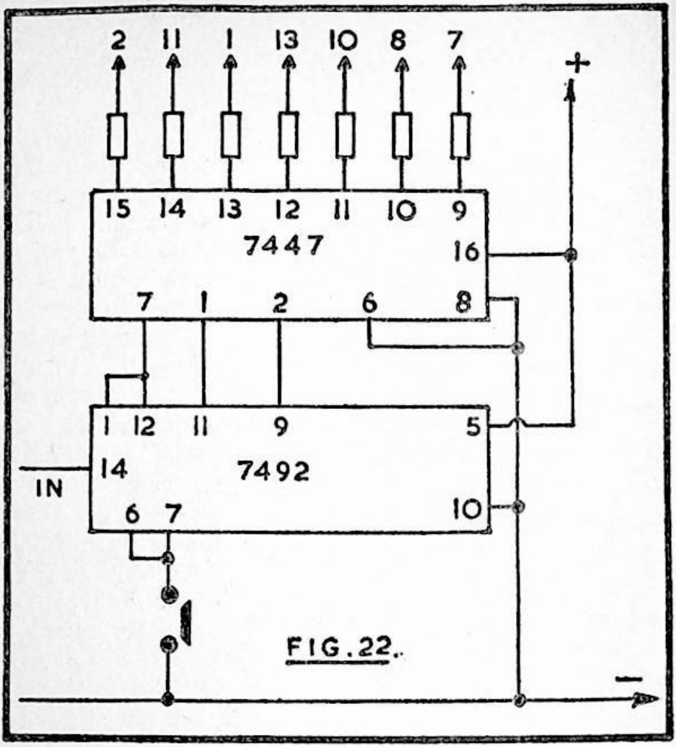


FIG. 22.

pulses, the count shown by the two LEDs is up to 59, returning to 00.

The 7490 with its decoder-driver and numeral, and 7492 with decoder-driver and numeral, will form the "seconds" part of a digital clock, when receiving 1 Hertz pulses from the 50 hertz driver with its 50 divider as described.

For the "minutes" section of a clock, one pulse per minute will be taken from the 7492 divider. This is from 9, which moves negative at 0-0 displayed.

Two further numerals, used in the same way, will provide a display for 0 to 59 minutes. The 7490 will receive pulses at 1 minute intervals, and the 7492 will provide a pulse at hourly intervals, to operate the "hours" display.

Reduced Display

If seconds are not required, the 7490 and 7492 are connected as shown, except that the 7447 drivers and LEDs are not included. Output from the 7492 divider will then be pulses at 1 minute intervals, for operation of the "minutes" display.

Where the "seconds" numerals are omitted, with their decoder-drivers, a simple LED with flashing periodicity of 1 second may be fitted. Its purpose is to show that the clock is running without needing to wait for up to 1 minute. The circuit in Figure 23 operates from the 1 Hertz point, pin 11. The LED must be connected in the correct polarity. It could be fitted anywhere on the clock front.

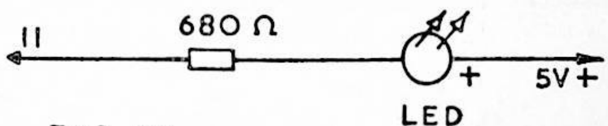


FIG. 23.

24 Hours

The "hours" display can follow similar lines, with a divider, decoder-driver, and numeral for the tens and units positions. It is necessary to use some means of allowing the display of 04 to continue to 05, and so on, but to return the display to 00 after 24. This can be arranged by employing an IC with NAND gates, suitable connected.

The NAND gate performs the following logic, where 0 is low or zero volts, and 1 is high or about 3v. Actual voltages depend on circuit elements. Two inputs are present. With both high, output of the gate is low. With either input high, output

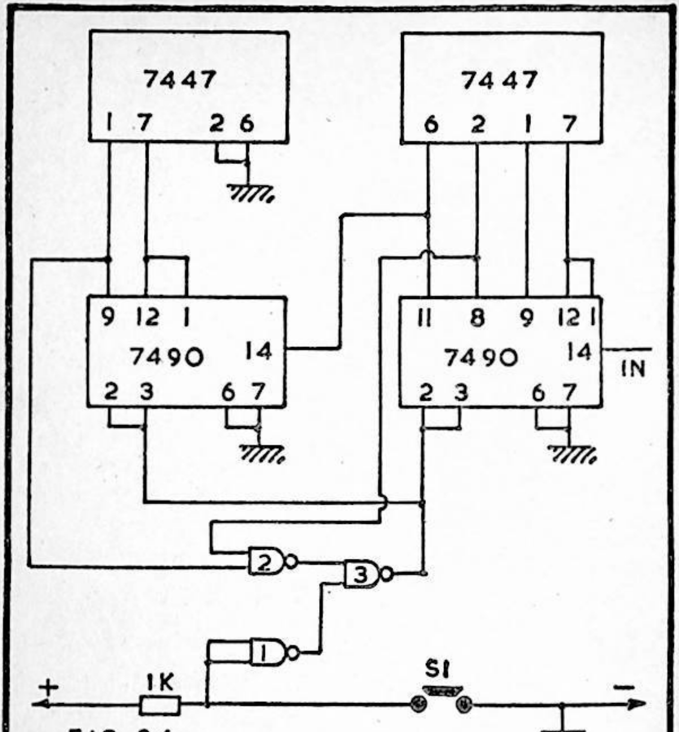
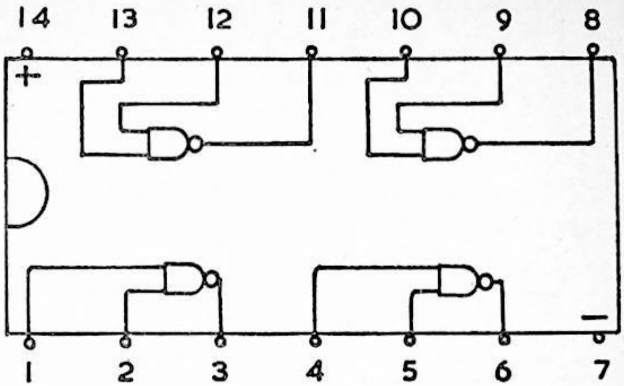


FIG. 24.

is high. This can be shown as follows: 1, 1 = 0. 0, 1 = 1. 1, 0 = 1. 0, 0 = 1. The 7400 is convenient, having four such gates.

Referring to the circuit in Figure 24 only three of the gates are used here. Figure 25 shows connections to the 7400.

In Figure 24 the reset button controlling the reset line is normally closed so that both inputs to gate 1 are low, or input is 0-0. Gate 1 output is thus high, or 1. Where output from gate 2 is high, or 1, inputs to gate 3 are 1-1, so output is 0, so the 7490 re-set inputs 2 and 3 are grounded and the dividers operate.



7400 QUAD NAND GATE FIG.25.

If the re-set switch is opened, inputs to gate 1 are high, so output is low. Thus one input to gate 3 is low or 0, whatever the other input (from gate 2) may be. Gate 3 output is thus 1, and the dividers are re-set.

Input to IC1 operates this divider as described earlier, and its binary output is taken to the decoder-driver, which in turn operates the numeral, as shown in those sections for seconds and minutes. The numbers displayed thus change from 0 to 9 at intervals of 1 hour. When the next pulse is received, a pulse is passed to IC2, and the IC1 circuit returns to 0, so the display is 10.

When IC2, through its decoder-driver, displays 2, pin 9 is high or 1, so that one input of gate 2 is 1. When IC1, through its decoder driver, displays 4, pin 8 is high, or 1. Thus both inputs to gate 2 are 1, and output is 0. The 0 or low input to gate 3 allows gate 3 output to go high, thus re-setting IC1 and IC2.

Note that the usual power line supplies will be made to all the ICs, though these are omitted for clarity. These are pins 5 and 10 for 5v positive and common ground for the 7490; 16 and 8 for the 5v positive and common negative of the 7447.

The 7447s are connected to the segments of the display as already shown, though this part of the circuit, and the essential series resistors, are also not shown.

The 7492

Figure 26 shows the 7492 IC connected to divide by 2, or by 6. It may also be used for division by 12.

FIG.26.

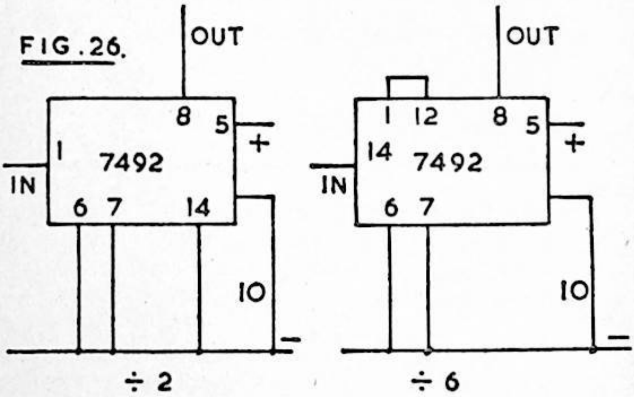


Figure 27 shows connections for the 7490 and 7492 for division by 10 x 6, or 60. With input at 1 Hertz, this allows an output of one pulse per minute to be obtained, for a minutes display.

Where clock timing will be from 60 Hz mains, the following divider can be as in Figure 27, to obtain 1 Hz pulses. In Figure 27, the final IC has a re-set switch, connected to 6 and 7. This is not required where the divider is providing 1 Hz output, in normal circumstances, but will be necessary with longer intervals.

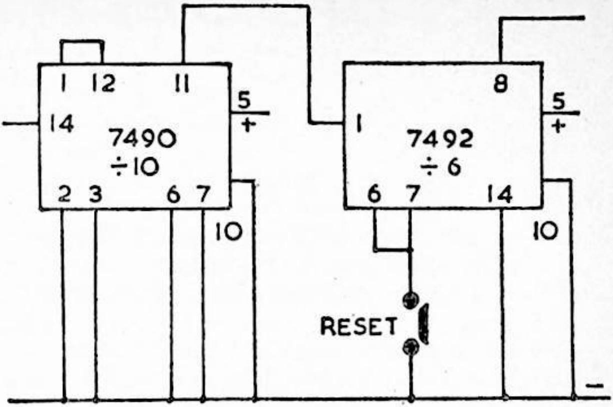


FIG. 27.

Battery Operation

Many circuits can be run successfully from dry batteries. A battery supply is particularly suitable for numeral indicators as used for some games, because the unit is then smaller and completely portable. The current drain will depend on the type of display, and other factors, and even small cells can provide a worth-while life. Circuits having only one or two ICs, with possible LEDs for display, are likely to be most economical. An example of this is the use of four individual LEDs for a count of up to binary 1000 or 6, with the 7492 divider.

For moderately short periods of intermittent operation, the 3-cell type of battery used in small hand lamps will allow running circuits taking up to about 0.25A or so. Some circuits can draw substantially less current than this, so that smaller cells can be used if wished.

Where a supply of approximately 5v is indicated, a 3-cell or 4.5v battery will be used. Normally, the supply voltage would be maintained at a minimum of 4.75v, but the 3-cell battery is generally satisfactory, despite this.

A failing voltage will cause erratic operation, disappearance of some display indications, or complete failure of the circuit. The voltage at which such faults arise will vary a little from one IC to another, as well as in accordance with the changing load thrown on the battery.

With running from a 3-cell battery, there is fortunately no general need for stabilising or other precautions, so the power needs of many circuits will be met with a minimum of difficulty. A 4-cell pack or 6v battery should not be used.

Battery holders have polarity marked for correct insertion of the cells. Many other batteries have polarity indicated. If not, check for this with the usual type of DC meter. With popular carbon-zinc cells, the outer case is negative.

Should some supply other than a 4.5v dry battery be improvised, an accurate test of its voltage ought to be made, for circuit conditions providing maximum and minimum load. The supply voltage should remain within the recommended limits (4.75 – 5.25v).

Component List for Figure 28.

R1	47k
R2	47k
R3	2.2k
R4	2.2k
	(Resistors 5% ¼w)
C1	270pF (see text)
C2	50pF
C3	1nF 5%
C4	10nF
TR1	2N706
TR2	2N3706
XTAL	100kHz
L1	Approx. 2500μH with adjustable core (Denco Blue Range 1 suitable).

Crystal Frequency

Some circuits derive an operating control frequency from a quartz crystal oscillator, instead of from the AC mains. This allows higher frequencies to be obtained for radio-frequency equipment calibration, provides independence from possible fluctuations in the domestic mains frequency, and allows shorter gating intervals with frequency counters.

Some quartz standards of this kind use a 100 kHz crystal, and five decade dividers will provide frequencies to 1 Hz. Others use 1 MHz crystals, with an extra decade divider. It is also possible to employ 5 MHz or 10 MHz crystals, with dividers to suit. Or some quite different frequency may be required, for digital read-out of a receiver oscillator frequency, or other purposes.

There is generally no particular difficulty in providing a crystal frequency standard for any ordinary purpose. A high frequency limit is set by the upper frequency limit of the first decade divider, while some low frequency crystals tend to oscillate less readily than those for higher frequencies. It is also necessary to have means of trimming the crystal frequency, if maximum possible accuracy is wanted. It is also essential to obtain an output which is satisfactory for the first decade divider.

Figure 28 is the circuit of an oscillator-driver for 100 kHz. Base bias conditions for the oscillator TR1 are set by R1 and R2, with emitter bias by R3. Numerous transistors other than the 2N706 will operate here.

L1 with C3 is resonant at about the crystal frequency. L1 can be a receiver type long wave coil with adjustable core – an inductance of about 2500μH will be necessary, with C3 being 1000 pF. L1 core is adjusted, if necessary, to bring the circuit into oscillation, the setting not being critical. (L1 may be the Denco, Clacton Ltd., Blue Range 1 coil, valve or transistor type). C3 may be changed in value if necessary, to suit the inductor.

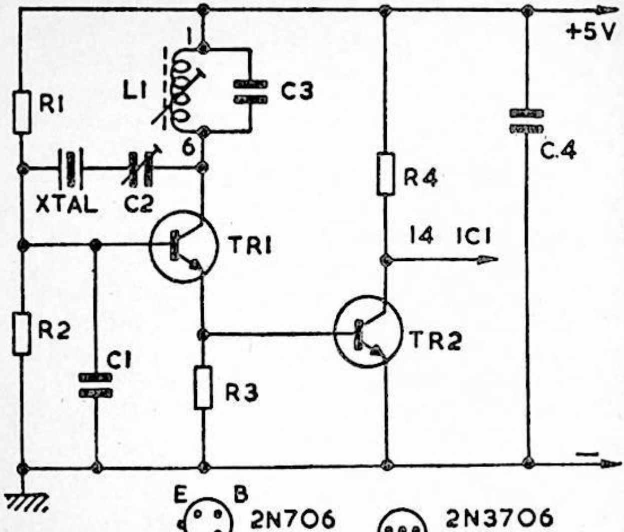


FIG.28.

A check that TR1 is oscillating can be made by listening for the 2nd hormonic with a receiver tuned to 200 kHz long wave; or by noting with a meter that the supply line current changes when the crystal is removed; or by observing the operation of a counter connected after the divider chain.

An accuracy of about 0.01 per cent would be expected, without adjustment, when the crystal is intended for this type of circuit, and it may be possible to omit C2. Otherwise, using surplus items, it may be necessary to adjust C1 and C2, or to place a trimmer in parallel with the crystal, so that frequency may be shifted a few Hertz or.cycles per second, as required for maximum accuracy.

Accuracy can be checked with a radio receiver. One method is to tune in the 200 kHz long wave transmission, and provide enough coupling from the 100 kHz oscillator to the receiver, for an audio beat to be obtained. Adjustment will be most easy during silent moments in the transmission. With the quartz oscillator harmonic very near 200 kHz, the difference in frequencies will be heard as a low frequency flutter, or very slow rise and fall in transmission.

Adjustment is easier with a short wave receiver tuned to the standard frequency transmission on 2.5 kHz (identified by announcement and 1-second pulses). Adjust coupling or the aerial input until the oscillator harmonic is not swamped, and set the crystal frequency as already explained.

Suppliers of new crystals can give information on the correct circuit capacitance for good accuracy, and a fixed capacitor can then be used if adjustment is not wanted. But with surplus crystals, and crystals originally intended for valve equipment, adjustment may be needed. Some frequency standard crystals for valve oscillators are intended for a quite high parallel capacitance.

TR2 is an amplifier, and provides a pulse able to drive the first divider of the chain. Other transistor types are possible. Current can be drawn from the 5v or similar supply which runs the dividers.

Figure 29 shows the divider chain. Each IC is wired in the

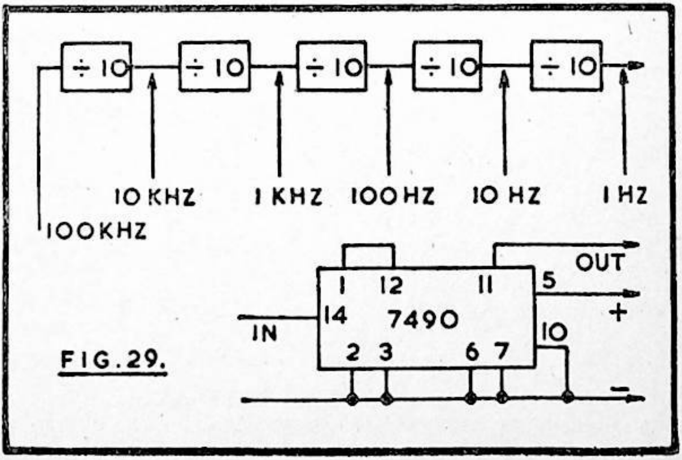


FIG. 29.

same way, as indicated. An output may be taken off anywhere along the chain. Frequencies available are thus 100 kHz after two dividers, and so on, through 100 Hz and 10 Hz to 1Hz.

Though five decade dividers are needed, the chain requires no other components except a 100 nF disc ceramic capacitor across the supply lines, so it can be constructed quite readily and in small space. It is convenient to have oscillator, driver and divider chain on one board in many cases. Should only a higher frequency be needed, as foi digital read-out, dividers later in the chian can be omitted.

Current Buffer

Where the current which can be passed by the 7490 divider is not sufficient for the output indicating device, a buffer stage may be added. A circuit for one lamp is shown in Figure 30.

When the divider output dircuit is at logic 0, base current for the transistor is supplied via R1. Current for the lamp is from the transistor collector. Bulbs such as those for 6v 0.06A, 6v 0.1A, or 6.3v, 0.15A may be run conveniently from the 5v

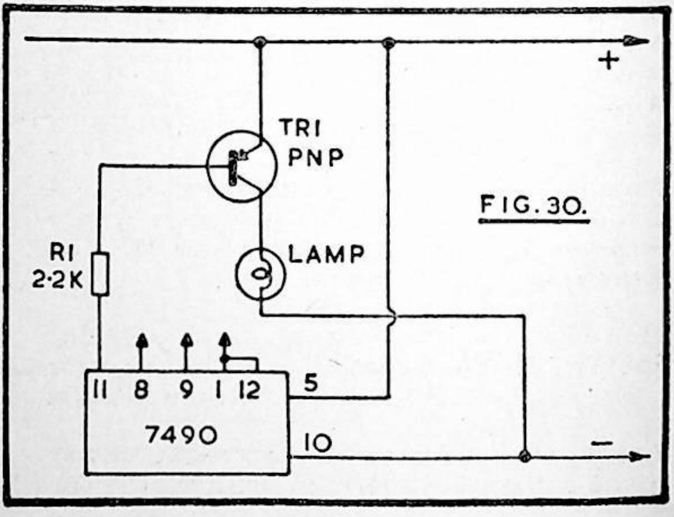


FIG. 30.

supply. If wished, the emitter circuit can be separated, so that a higher voltage may be applied to the transistor and lamp, to allow the use of larger bulbs.

An AC128 and similar PNP transistor will be adequate for the smaller bulbs. Larger PNP transistors may be fitted for higher current and voltage.

The circuit is duplicated for each indicating device. There will thus be four transistors for the four bulbs with a binary display as shown earlier.

Similar circuits can be used, operated from a decoder-driver, to allow more powerful indicating devices to be utilised. A 7-segment LED type decoder-driver, with seven small power transistors, will allow switching bulbs, or pairs of bulbs, to form a home-built, large size numeral. This will require cut-out masks, so that the display resembles that of the 7-segment LED numerals in form.

Minitrons

The Minitron numeral has filaments arranged as in Figure 31. By selecting these, numbers from 0 to 9 can be produced, A decimal point and other signs are also available. The various sectors are lettered A to G, as for the 7-segment LED. Thus current would be supplied to filaments B and C for 1, or to A, B, G, E and D for 2, and so on, all sections being in use for 8.

Figure 31 also shows connections, the numerals being of 16 pin DIL type. All sectors have a common return, by external connection of the pins. Then current at 14 and 11 would illuminate segments B and C, for 1, and so on.

The 3015 Minitron has characters approximately 3/8 in or 9mm high. The BM8 and BM15 types are for 8 mA or 15 mA approximately, each segment. Operation is from about 5v.

They may be controlled by a 7447 decoder-driver without current limiting resistors. However, some form of limiting

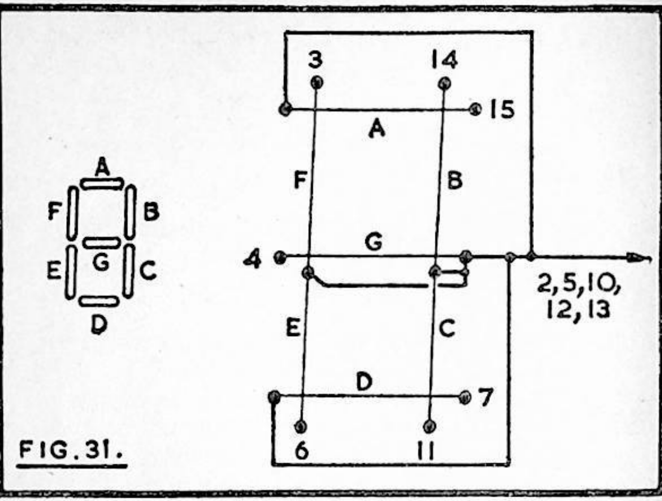


FIG. 31.

protects the IC from the surge at the moment of switching on, when filaments are not at working temperature and current is thus high. The surges are greatly reduced by the use of series resistors. Actual filament voltage can also be lowered, provided brightness is satisfactory for the purpose. The 8 mA type

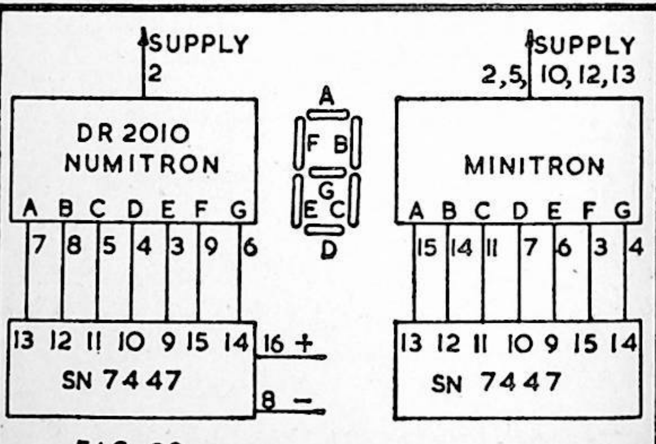


FIG. 32.

imposes the smaller surge load on the decoder-driver. Excess surge or load will damage the IC. For maximum brightness with surge limiting resistors some increase in supply voltage to the numeral will be needed. The 7447 is for 15V 20 mA maximum, and the 7447A for 15V 40 mA.

Figure 32 shows the RCA 2010 Numitron with side filamentary display. Numerals are 0.6 in high. Both these circuits can run from a lamp supply of about 3v.

In some units the type of numerical indicator fitted can be modified or changed quite readily.

Events Counters, Accuracy

A digital display of events may be taken up to any wanted number, by providing a divider, driver and numeral for each figure. Inaccuracy is only to be expected when there is bounce in the switch operated by the events. As ordinary mechanical switches are normally unsuitable, a noiseless electronic switch becomes necessary between the mechanical switch and first stage of the counter. Without this, a single operation of the switch may advance the counter incorrectly.

Noiseless Switch

Figure 33A shows a circuit for mechanical switching without bounce. Two gates of a 7400 are employed. These are so connected that when the switch S1 is at B, 3 is high, and when the switch is moved to A, 3 goes low and the count is advanced by 1. S1 has to be a 2-way switch, but can be spring loaded. Contact at the A position initiates the change-over, which is locked, so that further pulses due to switch imperfections have no effect, and the circuit is only returned to its previous condition by S1 contacting B.

A relay may substitute for S1 where operation must be by some single contact device, such as a pressure mat.

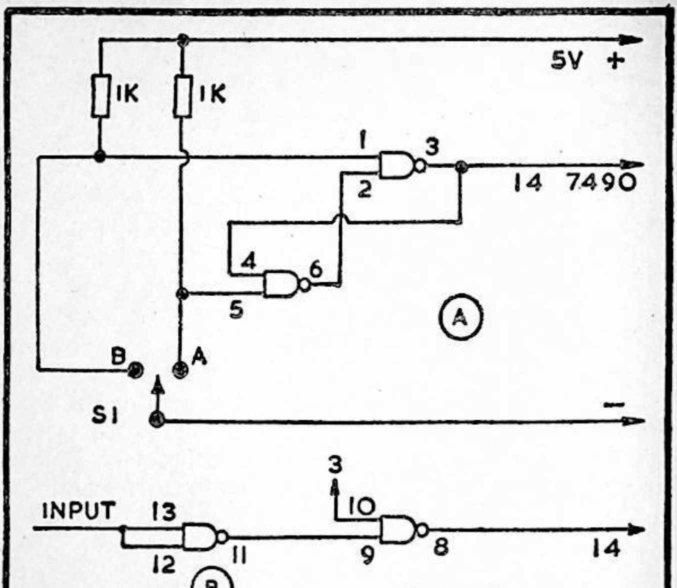


FIG. 33.

Clock Setter

Since returning an electronic clock display to 00:00 by opening the reset line requires that the clock be started at this time, a manual reset to any required display can be obtained by using the circuit in Figure 33B. The remaining gates of the quad NAND IC are employed. Input from the counting circuit is to 12 and 13, and output is from 8 to the first divider operating a numeral. The noiseless switch point 3 connects to 10. Then operation of S1 allows the clock display to be set to the correct time.

One such setting circuit is required for the minutes display and one for the hours display, to avoid laborious adjustment of the hours. Seconds can be adjusted by resetting to 00 by the re-set switch at the minute, minutes and hours then being set by the switches S1 for each.

Events Counter Uses

A manually or mechanically controlled counter can be used for any purpose where a switch may be closed automatically, or by a competitor or player. It is thus practical for progressive scores (Bezique etc.), replacing the usual card scorers. Units, tens and hundreds indicators, with individual hand setting, can be provided as explained.

Automatically operated counters can show revolutions per minute, the number of persons passing through a shop door, or any other event, as described.

Other applications will also be readily found. As example, the number of "mistakes" or contacts made when threading a ring on a shaped metal rod (See 50 Projects Using Relays, SCRs & Triacs – BP37), or number of contact made by a coin on a studded board, and so on.

Dual NAND Oscillator

One half of the quad NAND 7400 IC can be employed as an oscillator by using the circuit in Figure 34. This is for a 1 MHz crystal, and fine frequency adjustment is possible by setting the trimmer, this allowing pulling to the extent of a few Hertz. For many purposes accuracy will be easily sufficient without any crystal adjustment. Where such adjustment is made, it will be by beating a harmonic of the crystal against a standard frequency transmission such as that available on 5 MHz. This adjustment is carried out in the same way as with a transistor oscillator, described earlier.

Operation of the two NAND gates allows feedback in the right phase to maintain oscillation. The resistors help to maintain suitable operating conditions. The crystal series resistor may be altered in value if found more satisfactory with an individual crystal, higher values reducing feedback.

The remaining gates of the IC can be usefully employed as buffer amplifiers. Harmonics will have useful strength up to

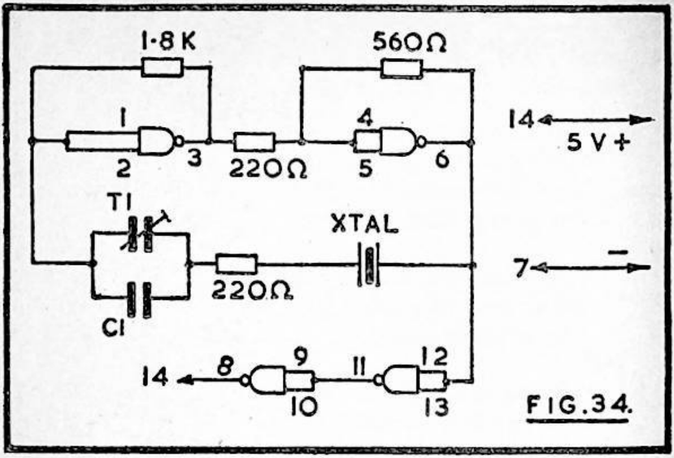


FIG.34.

frequencies of 30 MHz and higher, for calibration purposes. The output of the final gate is also suitable for driving a divider, or string of dividers, to obtain a pulsed output of any required periodicity.

Light Controlled Counter

The use of an optical counter will allow the finding of the speed of rotation of machinery, or show the number of items passing on a conveyor, or translate any interruptions or reflections of a light beam into numbers.

Figure 35 is the circuit of an optical driver for the counter which has adequate sensitivity for almost any purpose. The light dependant resistor LDR has a low resistance when illuminated, this rising to a high value as light falling upon it decreases. With the LDR illuminated, the base of TR1 is held negative, so that collector current is negligible. The voltage drop in R2 is thus small, and the output to the counter input is held high. When illumination of the LDR is interrupted, its resistance rises so that TR1 base moves positive. Collector current and the voltage drop in R2 increase, and a negative output is received by the counter. The latter is stepped

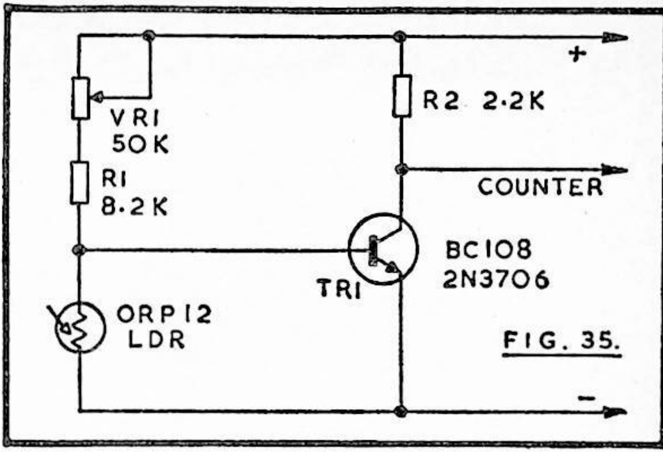


FIG. 35.

forward each time the light beam is interrupted.

TR1 can be a BC108, 2N3706, or other high gain NPN transistor. VR1 allows setting operating conditions and sensitivity. An easy way to check adjustment of VR1 and the whole circuit is to clip a high resistance voltmeter across R2. With light falling on the LDR and VR1 at maximum value, the voltage shown should be approximately zero. Set VR1 so that there is an abrupt rise in voltage to the extent of some 4v or so, when illumination of the LDR is interrupted.

Construction can best place the LDR at the inner end of a short tube, blackened inside, so that the effect of general illumination is reduced, Figure 35B. Lighting of the LDR may be from a battery and lamp, torch, or by a mains operated filament lamp. With the latter, take care VR1 is not set to a position which is sensitive to the flicker of the lamp itself due to the AC supply.

For use as a revolution counter for machinery, rotation has to interrupt the light beam. It may be possible to direct the beam through slots or holes in a faceplate, or through a spoked wheel, or some other rotating component. Where this will provide a number of interruptions for each revolution, the count must of course be divided by this number. An initial

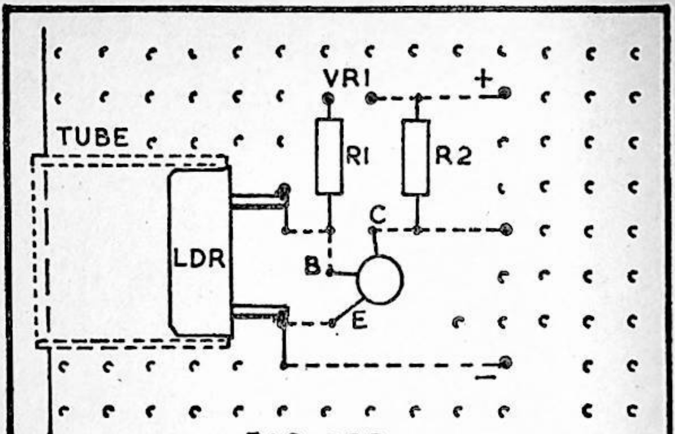


FIG. 35B.

check on working may be possible by rotating the wheel by hand.

In other cases it may be more convenient to have the light source and LDR near together at the same side of the rotating component. Source and LDR must be shielded from each other (the tube mentioned will do this). A mark or sector on the rotating part must then be made of sufficiently different light reflecting power as to allow operation. This can be arranged by a dab of whitewash or matt black paint, depending on the kind of surface. Check by hand that the counter operates correctly. There should be some latitude in the setting of VR1, but lighting conditions should be left substantially as when initially checking.

With the help of a watch with second hands, switch on for one minute. This will show the number of revolutions per minute. In some cases a more brief interval may be suitable, such as 30 seconds, afterwards multiplying by two.

Care should be taken to keep clear of rotating or other moving machinery. Should no setting of VR1 allow a rise and fall of voltage across R2 to be obtained as described, ambient light may be at too high a level. With more subdued lighting, the setting of VR1 should prove to be quite uncritical.

Current can be drawn from the same circuit as the counter. The pulse from TR1 may be taken to a divider which does not operate a display, if the read-out is to be to the nearest tens. A zero is then added to the display. E.g., 542 would be5,420 R.P.M.

The circuit can be used for any purpose where an interruption of light can be obtained. This can be to count persons passing a doorway, items of merchandise on a conveyor, circuits of a model car on a race track, and so on.

Operation is possible over a long distance by using a lens to concentrate the beam of light, and with the LDR adequately shielded or in subdued light. At the limit of sensitivity trouble may arise with AC operated filament lamps, as described, and a low voltage lamp, such as 12v 12w, operated from a transformer with rectifiers and smoothing capacitor, will become necessary. However, filament lamps run directly from AC are suitable for all purposes where no great range is required.

Process Clocks

Many photographic and other processes fall within a 10 minute time period. A digital clock for process timing can readily be arranged to suit the purposes in view. The simplest form of timer for up to 9.9 minutes will consist of two numerals, and does well for developing, egg-timing, and such applications. By having the display on a decimal basis, only two dividers, drivers and numerals will be required for this section. Thus 3 minutes 30 seconds, as example, will be displayed as 3½ minutes or 3.5. The smallest interval shown will be 6 seconds (0.1 minute). This is easily adequate for many uses.

For longer periods – e.g., such as photo fixing – it is necessary to provide a further numeral, and this allows up to 99.9

minutes. This numeral will be operated from its own divider and driver, as shown elsewhere.

An alternative is to employ dividers providing a read-out of 59:59, allowing timing up to 1 hour with conventional display. On this basis, three numerals will read up to 9 minutes 59 seconds, with indications at second intervals instead of the 6-second intervals of the decimal display. This allows the same clock to be used for enlarging exposures.

The cost per digit is not very great, consisting primarily of the need for one binary coded decimal decade counter, one decoder-driver, and one numral (7-segment LED or Nixie) per figure. The 7492 is convenient for the "tens" numerals of seconds and minutes displays, as shown.

No means of altering the figures shown will be needed, except re-set to 00:00. This is obtained by momentarily opening the reset line, as described, the count commencing when this line is closed.

For AC mains operation, pulses can be derived from the low voltage transformer, Figure 20. These pulses are reduced in frequency by dividers operating in the usual way (with no displays) to obtain 1-second pulses by 5 x 10 division (two 7490s are suitable) or by an additional 6-divider (7492) for pulses at 6-second intervals for the decimal display. These dividers have been covered in detail.

An alternative is to obtain pulses at 1-second or 6-second intervals from the type of UJT oscillator described. Small drifts in accuracy will arise, but may be unimportant for many purposes. If battery running and accuracy are both essential, then pulses can be derived from a 100 kHz or other crystal, with appropriate dividers, in the way explained.

For photographic use the periods required will naturally depend on equipment and processing details. Usually, up to 60 seconds with 1-second indications will cover enlarging, with up to 10 minutes for developing, and up to 30 minutes for fixing, while up to 60 minutes will cater for washing. For some purposes (e.g., egg-timing) great accuracy is not needed.

0–99 Random Number Generator

A numerator showing 00 to 99 at random may be used for roulette and various other games. Such a unit is readily made by employing two decade counters such as the 7490, for units and tens. The binary outputs of these will be taken to 7441 or similar decoder-drivers for Nixie numerals, or 7447 decoder-drivers for 7-segment LED idsplays. A reset switch in the reset line is not necessary, as each numeral display can remain until the next is initiated.

Input to the units decimal decade counter can be from various sources. The unijunction transistor oscillator is suitable, and its operating frequency is readily adjusted as described elsewhere. A push switch will complete the circuit to the UJT emitter so that pulses are only obtained when this is depressed. Frequency must be sufficiently high so that the selection of a number by releasing the push switch is impossible.

Where mains operation is intended, pulses may be obtained from the secondary of the transformer providing power.

As the moment when the count ceases depends wholly on the instant when the switch is released, a random selection will be obtained. If sequences of numbers arise which are obviously not random, the fault may be found in the oscillator and drive conditions. A 2-transistor multivibrator may be found to operate, in some circumstances, in which a way that odd (or even) numbers are favoured. This cannot arise with the UJT pulser. But with the latter a weak pulse input to the first decade counter may result in certain numerals being favoured, or others being omitted. This will be avoided by providing an adequate pulse, with a transistor as buffer-shaper between the UJT and decade counter. Alternatively, NAND or inverter gates may be employed here.

To avoid flexible leads, construction can best place the UJT oscillator, dividers, drivers and displays on a single board, so arranged that the numerals can appear in apertures cut in the case. The push switch may be a pear type on a flexible cord, when the device may be operated by several people.

Bandits

A decade counter, with decoder-driver and LED or Nixie display, driven by an oscillator, will form one section of an electronic bandit. Two numerals will require duplication of the circuit, including the source of pulses for the counter. The pulses should be at different frequency, and this is readily arranged with individual UJTs. The periodicity can be much lower than with the 0-99 counter, as each numeral operates on a 0-9 basis separately.

A 3-figure display is more usual, while the super-bandit may use a 4-figure or 5-figure display. All pulse circuits, dividers, decoder-drivers and numerals are operated individually, as described for two numerals.

A single push switch providing current for all the oscillators will result in all numbers changing continuously at different rates until the switch is released.

With several numerals, mains running becomes preferable. It is possible to simplify the overall circuit slightly by driving one divider at mains frequency (thus avoiding the UJT) and also by taking an output of one or more decade counters to the input of a second counter with its display. This does not provide random counting on a separate basis throughout, but is not important with a game machine of this type.

Construction can be in line with that for the 0-99 random number unit, with numerals visible in apertures in the panel.

Response Indicator

This will show the time required for a person to respond or carry out some competitive task, with a numerical read-out from one tenth second to 9.9 seconds. For very brief intervals, it shows the person's response time in tenths of a second, and can be employed in a similar way to that of the simulated driver's braking test. For longer intervals all sorts of competitions can be devised – finding an announced word in a dictionary, placing a number of marbles through the hole of an upturned flower pot, or completing some short obstacle course.

The arrangement of the counter is shown in Figure 36. It has three switches in addition to the usual on-off switch. The counter itself consists of two decade counters, which are connected as described earlier.

Output is taken from the clock driver already dealt with, but instead of division by 50 for 1 second pulses, only one divider is used, for division by 5. Pulses to the counter are thus at 10 Hz, or ten per second.

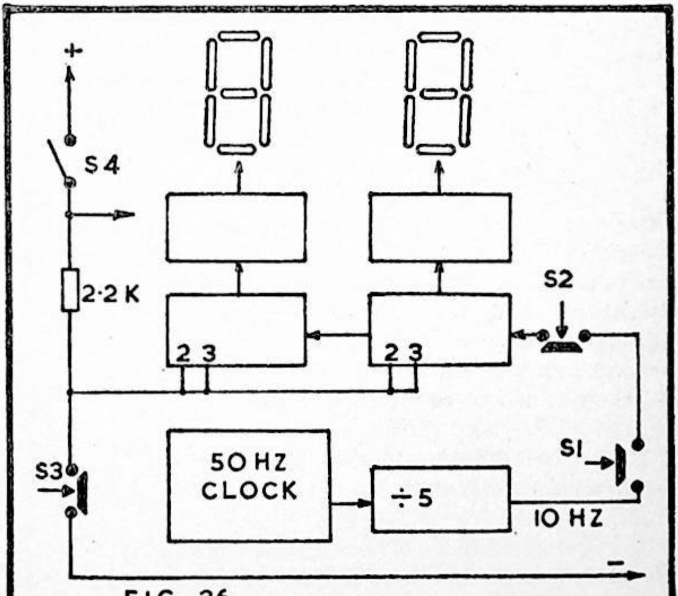


FIG. 36.

There are three spring loaded push buttons, S1, S2 and S3, S1 and S2 are preferably of the electronic zero-bounce-type described earlier. S1 is normally open, S2 is normally closed, and S3 is normally closed. S3 operates on the re-set line, and is necessary to return the numbers to zero when starting or after an attempt. In these circumstances, counting begins from zero immediately S1 is closed. For an immediate response test, the competitor then has to press S2 as quickly as possible. His delay, in tenths of a second, can be read from the display. For longer tests, the competitor must perform the assigned task, then press S2. To avoid any need for a more elaborate counter, the person operating S1 can note if the time runs beyond 9.9 seconds, as after this the display returns to zero. The competitive task should be one which can generally be done in this interval.

Ordinary toggle switches may if preferred be substituted for S1 and S2. In this case, S1 is opened after noting the time shown, and S2 is closed ready for the next attempt.

The display can be 7-segment LEDs, or Nixie numerical tubes, with the appropriate decoder-drivers, as described. Simple power supply circuits can be incorporated with the 50 Hz clock driver.

With 7-segment LEDs, battery running is feasible, all circuits running from 4.5 volts, or three cells. (Four cells or 6v must not be used). As no 50 Hz pulses from the mains will be available, it is necessary to employ a different source of pulses. A unijunction transistor pulser can be utilised. Whatever form of oscillator is used, it should be of adjustable frequency. The frequency is then set, as accurately as possible, while timing the 1 second to 9 second display against the movement of a clock or watch with second hands. In this way quite close agreement can be obtained.

The whole equipment should be assembled in an attractive case and S1 and S2 may be on flexible leads, when this is more convenient. With only two numerals the current required is within the capacity of cells of medium size.

Battery Operated Random Numerator

This can be used for the random selection of numbers digit by digit, or as a substitute for a dice in games. Numbers from 0 to 9 are displayed on a Nixie tube, and change rapidly while the competitor presses a push switch. When this is released, one number remains displayed until the push switch is operated again.

As will be seen from Figure 37 the numerator consists of three sections. These are the UJT pulser; divider, driver and display tube; and power supply.

When the push switch S1 is closed, capacitor C1 charges through R1. When the emitter potential or voltage across C1 has reached a particular level, the unijunction transistor conducts, and C1 is discharged. The process is then repeated. Frequency can be changed by modifying the values of C1 and R1. With the values shown, numerals change at such a speed that they are momentarily visible, but not so slowly as to allow selection of any particular figure. If wished, R1 can be changed for a 50k pre-set potentiometer, with 8.2k series resistor. The frequency can then be adjusted between wide limits.

A series of pulses is obtained from Base 1 of the UJT, and pass to the decade counter. VR1 allows shifting working conditions at the counter input, so as to obtain reliable operation. It is only necessary to adjust VR1 so that the numerals change regularly and correctly. With wrong adjustment, the display may not change, or some numbers may be missed.

The numerator can be run from a 5v supply instead of the 4.5v battery, but VR1 will then have to be re-adjusted.

Connections for the decade counter and 7441 decoder-driver are shown elsewhere, with a description of working. Referring to Figure 37 the 7490 counter provides binary output which is decoded by the 7441, which completes ten circuits in sequence, for a display of 0 to 9 on the Nixie tube.

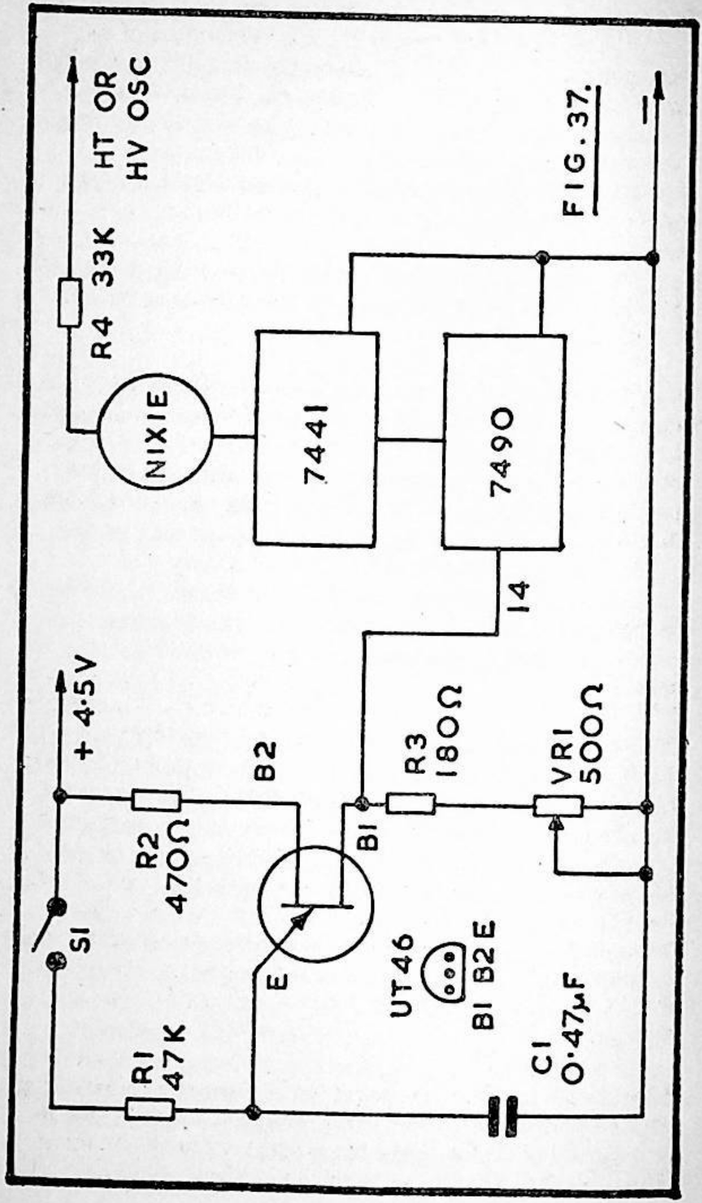

HT OR
HV OSC
R4 33K
NIXIE
7441
7490
14
+ 4·5V
S1
R1
47K
R2
470Ω
B2
B1
E
R3
180Ω
VR1
500Ω
UT46
B1 B2E
C1
0·47μF
—

FIG. 37.

The high voltage oscillator for the Nixie supply is wired as in Figure 15. It uses a BFY51 or 2N3053. Operation of the power supply is as described. About normal full brightness of the Nixie tube should be easily achieved. The GN4 end view tube is suggested, though other tubes may of course be fitted.

The complete circuit will run from a single 3-cell battery as used for hand-lamps, or from a battery made up of three non-miniature cells in series. A 1000μF or similar large capacitor is necessary across the supply. A 4-cell pack could be tapped at 4.5v for the decade counter and decoder-driver, the full 6v being used for the high voltage oscillator.

The more popular type of 7-segment LED will present a rather smaller numeral, but could be substituted for the Nixie tube. It is essential to use the 7447 driver (instead of 7441) in this case, connected as shown elsewhere. The high voltage power supply is then unnecessary. Its purpose is to allow use of the surplus Nixie tubes.

Compact 4-Digit Counter

By making use of the low-cost side viewing Nixie numerical tubes designed to fit 0.1 in matrix perforated board, a compact counter can be assembled as in Figure 38. Four digits allow counting up to 9999. Overflow results in the counter starting again from 0000. There is a re-set line, so that the count can be returned to 0000 at any time.

The items can be accommodated on a board 92 x 60 mm, using eight holders (4 off 14 pin, and 4 off 16 pin) for the counter and decoder ICs. More details of operating conditions etc. will be found earlier. The top of the board carries the ICs, Nixies, by-pass capacitor, and four individual resistors for the HT supply circuit.

If necessary carefully straighten the IC, holder, and Nixie tags with tweezers, so that they pass correctly through the board holes, and so that the ICs fit the holders correctly. Position the ICs so that pins emerge as shown in Figure 39. The

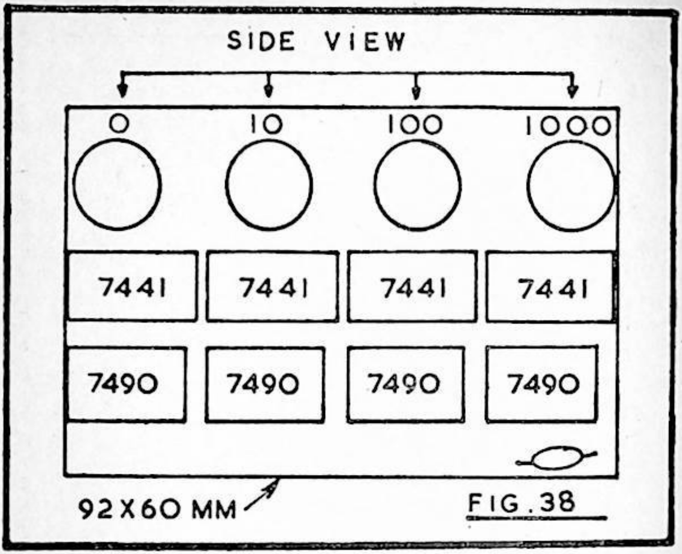


FIG. 38

numeral figures face the near edge of the board, so that Units will be at the right, Figure 38, when viewed.

Wiring is directly point to point, Figure 39. Here, one section is shown – the counter, decoder-driver, and tube. This wiring is duplicated four times for the four sections.

It is probably best to wire the 5v positive and negative lines first, using reasonably stout wire (say 24 swg). Fit coloured sleeving, red for positive and black for negative.

Other connections are best of thinner wire – 30 or 32 swg tinned copper, with small diameter heat-resistant sleeving. With the 0.1 in matrix board, soldered joints need to be small to avoid shorts to adjoining circuits.

The tube numbers in Figure 39 refer to the numeral displayed when the appropriate circuit is grounded. The series resistors may all be 22k for 200v, or 39k for 250v.

Connect a switch between the reset and negative lines. This

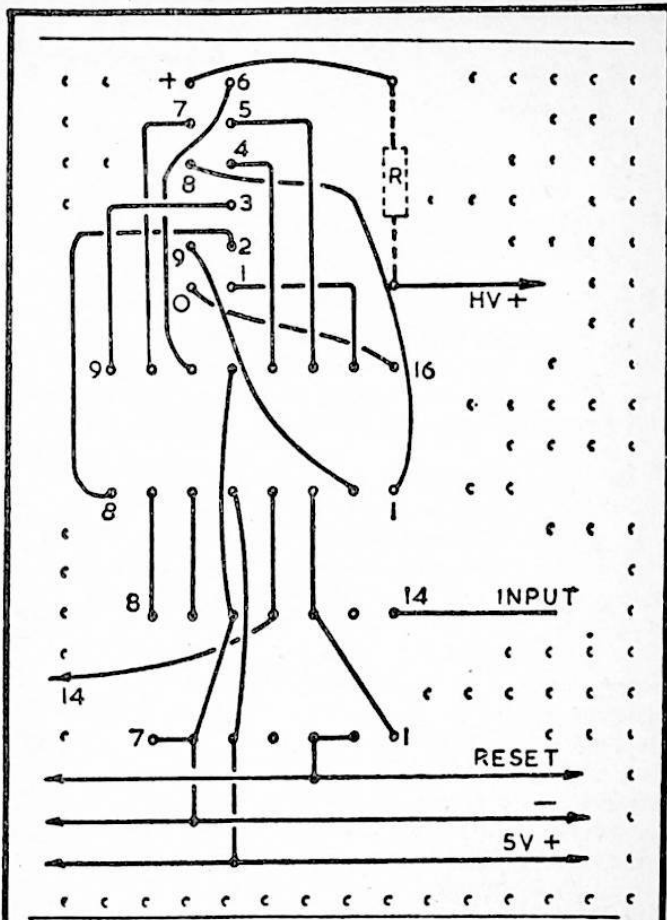


FIG. 39.

may be of ordinary type, or preferably a switch which opens when pressed. A display is only possible when the re-set line is connected electrically to negative.

The carry-on pulse is from 11 to 14 of the next divider, Figure 39. It may prove helpful to wire only the Units section first, and to test this to assure that it operates correctly, and provides a count of 0-9. The later sections can then be wired in exactly the same way.

The counter could be modified as explained earlier, if required. As the small tubes are often sold in packs of five, an additional numeral could be provided, for a display of up to 99,999. Should higher counting be wanted, without reference to the least significant figure, a further 7490 could be used to divide input by 10, and a 5-figure display would then read to 999,990, with the last figure absent. Such an arrangement is not uncommon, to extend the count available.

Frequency Counter

As mentioned earlier, a digital counter can be used to indicate frequency. This is arranged by switching the counter on for a known interval. Manual switching is only practicable for low frequencies – as example, to determine the number of revolutions per minute. For electronic or audio purposes, the period during which a count is taken will be brief, typically 1 second or less. Assuming the interval for counting is 1 second, the counter will show the frequency directly in Hertz. Thus if the counter reads 4975 after receiving pulses for 1 second, then the frequency is 4975 Hz.

By utilising the small 4-digit counter described earlier, frequencies may be read up to 9,999 Hz. This can be extended to 99,999 Hz by adding a further digit, or used with 4 digits x 10, or to 99,990 Hz, by placing a 10 divider ahead of the counter, or by allowing the count to occupy only 1/10th second instead of 1 second.

The digital counter can use any of the numerical circuits shown earlier. It is necessary to have a connection to the re-set line, so that digits can be returned to zero before each count. This poses no difficulty.

Gating

An electronic switch or gate is used to allow pulses to pass to the counter for the required interval. This is one-quarter of the quad 7400, IC4, in Figure 40. Here, the signal input is the unknown frequency to be counted, taken to pin 9. Counting only takes place while the gate is opened by input at 10, from the control circuit IC3. By arranging that this ahppens for 1 second, the signal input at 9 will be present at the gate output 8 for this interval, to operate the counter.

A control circuit which merely provides 1 second pulses at 10 would be unsuitable, as the count would continue until the counter overflowed, and no reading would be possible. So it is necessary to obtain a single, 1-second pulse, from IC3.

Some method of obtaining a reliable series of pulses is also necessary. A 100 kHz crystal is often used. This can be followed by decade dividers to obtain 10 kHz, 1 kHz, 100 Hz, 10 Hz and 1 Hz control pulses. Circuits of this kind have been shown earlier.

An alternative method is to utilise 50 Hz or 60 Hz mains, with 5 and 10, or 6 and 10 dividers, to obtain 1 Hz. This is done in Figure 40.

Input to C1 is from a 6.3v transformer secondary, and the transistor operates to produce a pulse across R3 for each cycle. IC1 is connected to divide by 5, so that 10 Hz pulses are obtained at 11. These go to 14 of IC2, which is connected to divide by 10. Output from 11 of IC2 is thus at 1 Hz. These 1 Hz pulses go to 1 of IC3.

IC3 contains two separate JK flip flops with clear, and they are interconnected in such a way that when switch S1 is closed, the next pulse arriving from 11 of IC2 opens the gate IC4. The gate remains open until the subsequent pulse from 11 (e.g., for 1 second) and is then closed, remaining locked in this condition until S1 is again operated. Thus when S1 is closed, the counter will count for 1 second, and the display will then

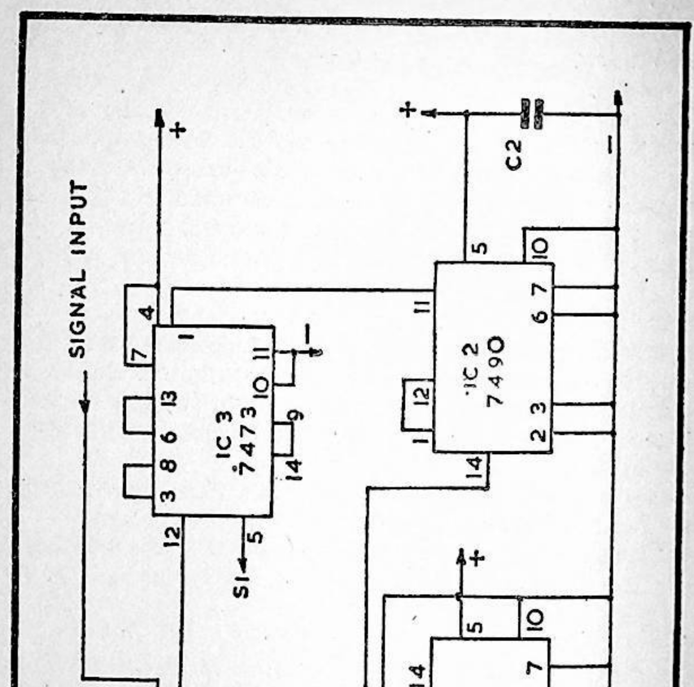

COUNTER
4 9 7 5
SIGNAL INPUT
IC 3
7473
IC 4
7400
1/4
S1
IC 2
7490
IC 1
7490
C2
C1
R1
R2
R3
50HZ

FIG. 40.

remain unchanged until S1 is used again. This provides the count in Hz, held as long as required.

Each time S1 is closed a 1 second count is obtained, and if the counter were left in this state, each subsequent operation of S1 would merely add to the number displayed. It is thus necessary to return the counter to zero, before each count. This is achieved by momentarily opening the re-set line of the counter.

With the 4-numeral counter described, momentarily disconnecting the re-set line from negative returns all numerals to zero. This can be done by connecting a push-switch (press-to-open type) between re-set line and negative. S1, Figure 40, is between 5 and negative line, and is of ordinary type (press-to-close). Operation of the frequency counter is by means of these two switches. Pushing S1 sets the circuit in action to count for 1 second. After this interval, the numerical display is locked, and the figures remain until the re-set switch is pushed.

Circuit Board

The underside of this is shown in Figure 41 and is wired point to point in the way described earlier. C1 is 0.1μF, C2 50 nF, R1 47k, R2 39 ohm and R3 2.2k. A BC108 or similar transistor is used.

The 50 Hz supply is derived from a 6.3v transformer, wired to C1 and the board negative line. The same transformer can provide DC for the ICs.

IC1 and IC2 are best wired first. A temporary lead may then be taken from 1 of IC1, and later from 11 of IC2. Timing for 1 minute should give counts of 3000 and 60. If these are higher, mains transients are probably triggering the circuit. These can be suppressed by placing a capacitor of 0.1μF across the secondary, or 50 nF (600v) in parallel with the primary. IC1, pin 11, should provide 10 Hz.

With the board, Figure 41, the three remaining gates of the

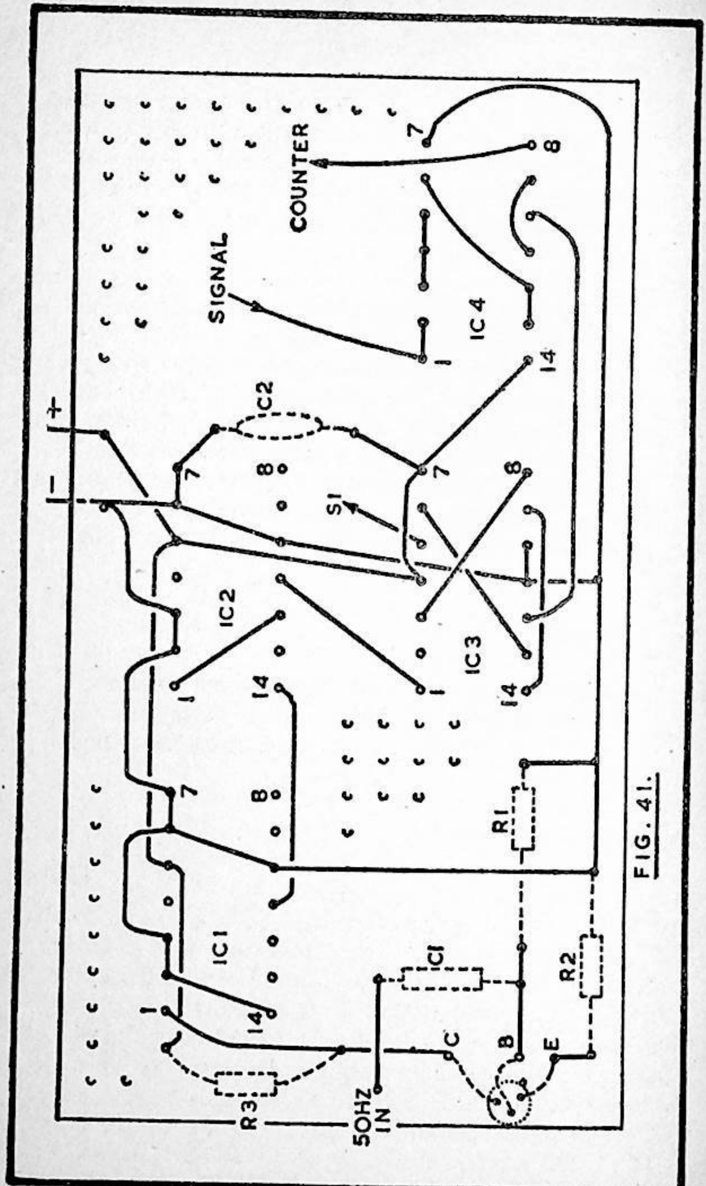


FIG. 41.

7400 are used as a signal shaper, the final gate driving pin 9, Figure 40. Pin 8 connects directly to the counter input.

The "signal" and "counter" leads from the board, in particular, need to be reasonably short, or otherwise of screened type. If interference is picked up or unnecessary stray coupling can take place the numerical display may be advanced by this means, with obvious errors.

A supply at 5v (about 100 mA) is required for the board. All the positive points in Figure 40 connect together.

Operation can be checked with signal input from a device such as the 2-transistor pulser described earlier. Connect the common negatives of all equipment items together. When S1 is closed, the count should start when the 1 second pulse arrives, and continue for 1 second, the display then halting and remaining. Operate the re-set switch described before each reading.

Signal input has to be at a sufficiently high level (approaching 1v). This will often be available. If not, an amplifier is necessary to boost the signal level before it reaches the counter board. If the input is too low, no reading will be obtained. Where DC isolation of signal and counter input circuits is necessary, a 47 nF or larger coupling capacitor may be used.

Alternative types of I.C.

The table lists descriptions and alternative equivalents of ICs finding use in circuits shown here, and for similar purposes.

7400	Quad 2-input NAND	FLH101. FJH131
7402	Quad 2-input NOR	FJH221. FLH191
7404	Hextuple INVERTER	FLH211 FJH241
7441	BCD decoder/Nixie driver	FJL101
7447	BCD decoder/7-LED driver	FLL121T
7475	Quad bistable LATCH	FLJ151. FJJ181
7490	BCD decade counter	FLJ161. FJJ141
7492	12-divide counter	FJJ251. FLJ171

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Counter Driver and Numeral Display Projects

- Numeral indicating devices have come very much to the forefront in recent years and will, undoubtedly, find increasing applications in all sorts of electronic equipment.

- With present day integrated circuits it is easy to count, divide and display numerically the electrical pulses obtained from a great range of driver circuits.

- In this book the well known author, Mr. F.G. Rayer, discusses and features many applications and projects using various types of numeral display and popular counter and driver IC's. These projects should be of interest to both the novice and more experienced experimenter alike.

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