

PATENT SPECIFICATION

(11) 1359 593

1359593

- (21) Application No. 8868/72 (22) Filed 25 Feb. 1972
 (31) Convention Application No. 9804 (32) Filed 27 Feb. 1971 in
 (33) Japan (JA)
 (44) Complete Specification published 10 July 1974
 (51) International Classification G04C 3/00//H02M 3/32
 (52) Index at acceptance
 G3T ASX
 G5C 31B 31H 31Q
 H2F 23E2T1 23EY



(54) DRIVING CIRCUIT ARRANGEMENTS FOR PASSIVE DISPLAY DEVICES

(71) We, KABUSHIKI KAISHA SUWA SEIKOSHA, a Japanese company of 3-4, 4-chome, Ginza, Chuo-ku, Tokyo, Japan, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to driving circuit arrangements for what are herein termed "electrical signal operated passive indicator" by which is meant, in this specification, indicators (usually numeric indicators) without mechanically moving parts and which can be caused to give different indications when different signals, or combinations of signals are applied to electrodes provided in said indicators thereof. Such electric signal operated passive indicators, an example of which is provided by the now well-known liquid crystal indicator device, give indications in the form of changes in light values brought about by changes in light scattering, light absorbing, light transmission or light polarisation properties when suitable electric signals are applied. Because electric signal operated passive indicators can be made quite small and of very small power consumption they are very suitable for time-indication in electronic watches, especially electronic watches in which the time-standard is an oscillator or vibrator. Such electronic watches can be made very small—of wrist watch size—and of comparatively high time accuracy.

However, electric signal operated passive indicators, suitable for use for time indication in timepieces, require, in general, relatively high voltage for their operation. Because of this quite small electrical leakage in the driving circuit for such an indicator can cause it not to function satisfactorily and correctly. This will be more clearly understood from a consideration of Figures 1 and 2 of the accompanying drawings, in which:—

Figure 1 is a graphical explanatory figure showing the voltage-brightness characteristics

of typical electric signal operated passive indicators, and

Figure 2 is a simplified circuit diagram showing such an indication and a known driving circuit therefor.

In Figure 1 brightness is plotted as ordinates (the O/y axis) against voltage applied to an electric signal operated passive indicator

as abscissae (the O/x axis), O being, of course the origin. Two typical characteristics are shown, one (1) in pull line and the other 1' in chain line. In characteristic 1, the brightness is zero, or practically so from the origin

O to a threshold voltage V_1 . Between the voltage V_1 and a higher voltage V_2 the brightness of the indicator changes from a very low or zero value (the unexcited state of the indicator) to a state of maximum brightness (the state of maximum excitement of the indicator). The characteristic 1' is the opposite of characteristic 1, this characteristic being that of an indicator the brightness of which is a maximum at voltage V_1 and falls to zero (or nearly so) at the voltage V_2 .

In a known driving circuit arrangement shown in simplified form in Figure 2 the indicator, here represented by the block 4, is in series with a switch 5 between a voltage supply source connected at 2 and one connected at 3. Block 6 represents leakage resistance across the switch 5 when the latter is open. If this leakage resistance is small, the voltage applied to the indicator 4 may exceed the threshold voltage V_1 , thus causing the indicator (here assumed to have a characteristic like that shown in Figure 1 at 1) to assume an excited state even although the switch has been opened to prevent this happening. To connect a shunt resistance across the indicator 4 is not a satisfactory solution of the difficulty because such a resistance, to be effective for the purpose, must have a value smaller than the leakage resistance 6 and

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there would, therefore, be an undesirable increase in the current flowing.

For convenience and simplicity in drawing the indicator in Figure 2, as in Figures 3, 4 and 5 (to be described later) are shown as having only two terminals i.e. as comprising only one indicator element consisting, for example, of a liquid crystal between two electrodes. In practice, of course, a typical numeric indicator would consist of a set of electrodes separated (in the case of a liquid crystal indicator) by a layer of liquid crystal from a common back electrode and a circuit as shown in Figure 2 would be provided for each of the electrodes of the set, the terminal 2 of Figure 2 being connected to the said common back electrode so that, by closing different combinations of the switches 5 potentials would be applied between different combinations of the electrodes in said set (on the one hand) and the common back electrode (on the other) and thus different numerals would be displayed. All this is well-known practice needing no further description here, it being well-known to arrange the electrodes of a set so that energisation of different combinations thereof cause different numerals to light up.

The present invention, though not limited to its application thereto, is very advantageous for and primarily intended for electronic watches having electric signal operated passive indicators for displaying the time e.g. liquid crystal numeric indicators. When so applied the invention provides improved driving circuits for the indicators.

According to this invention there is provided in combination an electric signal operative passive indicator and, for driving the same, a driving circuit including a two-way switching arrangement having three terminals namely an output terminal and two other terminals, said output terminal being connected to one of said other terminals in one switching condition of said arrangement and to the other of said other terminals in the other switching condition of said arrangement; means connecting said indicator between said output terminal and a further terminal; and voltage supply means arranged to apply a first potential to a first one of said other terminals and a second potential, different from said first potential to the second of said other terminals, and a third potential to said further terminal; said first, second and third potentials being so chosen that, in one switching condition, the difference between the potential at said further terminal and said first potential is applied across said indicator and sufficient to excite it while, in the other switching condition, the difference between said potential at said further terminal and said second potential is applied across said indicator and does not exceed the threshold voltage of said indicator.

Preferably the switching arrangement comprises two insulated gate FETs, one of P channel and the other of N channel, with their drains connected together and to the indicator, their sources connected one to one and the other to the other, of the aforesaid other terminals of the switching arrangement, and their gates connected together and to a source of switching control voltage.

The aforesaid first, second and third potentials may advantageously be derived from a battery source by a voltage boosting arrangement comprising an oscillator energised by said battery and providing AC in a transformer primary circuit, said transformer having a tapped secondary from which said first, second and third potentials are derived by rectification.

A preferred timepiece in accordance with this invention comprises a time standard source of electrical oscillations, numeric time indicating means constituted by a plurality of electrical signal operated passive numeric indicating devices each having a plurality of selectably energisable electrodes arranged to display any numeral in dependence upon the selected energised electrodes, and frequency dividing counting and signal processing circuits for deriving from the oscillations time signals for operating said devices, said signals being utilised to operate said devices through the medium of driving circuits in accordance with the invention as above set forth.

Embodiments of the invention are illustrated in Figures 3 to 7 inclusive of the accompanying drawings, in which:—

Figures 3 and 4 are simplified diagrams illustrating two embodiments of the invention in principle;

Figure 5 illustrates a preferred embodiment in which the switching arrangement employed is an electronic switching arrangement equivalent to a double throw switch;

Figure 6 is a simplified block diagram of an electronic watch having numeric time indicating electric signal operated passive indicators and employing driving circuits in accordance with this invention for driving said indicators, and

Fig. 7 is a diagram of a voltage boosting arrangement which can be employed with advantage, in carrying out this invention, to derive usefully high voltages from a D.C. battery source.

Figure 3 is a simplified diagram of the same nature as Figure 2 and illustrates the principle of the present invention. Referring to Figure 3, one voltage source (not shown but hereinafter referred to as source 78) is connected between terminals 7 and 8 and a second voltage source (also not shown but hereinafter referred to as source 79) is connected between terminals 7 and 9. Source 79 is of voltage not less than that of source

78. The contacts of a change-over switch 11 are connected, one to one and the other to the other, of the contacts 7 and 8 and the switch armature is connected through lead 12 and the indicator 4 to the terminal 9. Blocks 13 and 14 represent leakage resistance across the two sides of the switch i.e. between 12 and 8 or 7 respectively.

Figure 4 shows a minor modification of Figure 3. In Figure 4 the change-over switch 11 of Figure 3 is replaced by a pair of ganged switches 111 and 112 which are ganged in such manner that when one is open the other is closed, and vice versa. Although, for simplicity of drawing, the switches 11 (Figure 3) and 111, 112 (Figure 4) are shown as mechanical switches they could be and, in practice, preferably would be, constituted by equivalent electronic switches.

In Figures 3 and 4 when the switch connects terminal 7 to lead 12 the indicator 4 is connected between the terminals 7 and 9 and receives voltage from source 79. When in the other switching position in which the indicator 4 is connected between the terminals 8 and 9, it receives the difference between the voltage of source 78 and that of source 79. Therefore, by making the source 79 of a voltage value enough to excite the indicator 4, and by choosing the voltage of the source 78 at a value smaller than that of source 79 by an amount within that voltage range over which the indicator is not excited, (that is of an amount not exceeding the threshold voltage V_i in the case of characteristic 1 of Figure 1), the excitation condition of the indicator can be controlled correctly by operation of the switching means without being adversely affected by leakage current as in the case of Figure 2.

Because the voltage from source 78 can be smaller than that from source 79 a semiconductor switching element having a leakage resistance which is non-linear with voltage can be used as the change-over switch 11 of Figure 3.

Figure 5 shows in manner similar to that of Figures 3 and 4, a preferred embodiment of the invention. The indicator is again referenced 4 and the terminals 7, 8 and 9 and the lead 12 are as in Figures 3 and 4. The change-over switch 11 of Figure 3 is now replaced by two insulated gate field effect transistors (FETs) 23 and 24, the former of which is an enhancement type P channel insulated gate field effect transistor and the latter of which is an enhancement type N channel insulated gate field effect transistor. This indicator 4 is a liquid crystal indicator using a nematic liquid crystal. The potential between terminals 7 and 9 here termed the "second potential" exceeds that between terminals 7 and 8 and is such as to produce indicating excitation of the indicator. The difference between the second positive poten-

tial and the first positive potential is arranged to be smaller than the threshold voltage of the indicator 4.

The switching transistors 23, 24 are controlled by voltages applied at terminal 20 and obtained in any convenient known way. Terminal 20 is connected to the gates G_P and G_N of the FETs 23 and 24. If the potential at 20 is nearly equal to that at 7 (approximately zero potential) the potential of gate G_N becomes zero and the resistance between the source S_N and the drain D_N of FET 24 is of very large value. However, in this condition of the potential at 20, the potential of gate G_P of FET 23 is such that the resistance between its source S_P and its drain D_P is small. Therefore, the potential on lead 12 becomes substantially equal to the aforesaid first positive potential, and the indicator 4 receives a potential nearly equal to the difference between the aforesaid second positive potential and the aforesaid first positive potential, that is, a potential lower than the threshold voltage. The indicator is therefore not excited. If, at this time the current flowing from the terminal 9 to lead 12 exceeds the current flowing from the drain D_N to the terminal 7 this will tend to cause the drain D_P to become positive in relation to the terminal 8, but because of the effective diode between the drain D_P and the substrate Su_P , the potential in question becomes almost equal to the potential at terminal 8.

Similarly if terminal 20 is given a positive potential nearly equal to the potential at terminal 8, the resistance between the source S_P and the drain D_P becomes very large and the resistance between the source S_N and the drain D_N becomes small. In consequence the potential at 12 becomes substantially equal to that at 7 and the indicator receives a potential nearly equal to the aforesaid second potential, resulting in excitation. The substrate of the FET 24 is represented, in manner similar to that adopted for the FET 23, at Su_N .

Figure 6 is a simplified block diagram of an electronic watch having numeric time indication means driven by a driving circuit arrangement in accordance with this invention. The indicating means is of the liquid crystal type and of form known per se, indicating hours and minutes in Arabic numerals by means of indicator units each comprising a set of seven electrodes separated by a nematic phase liquid crystal layer from a common counter electrode, the electrodes of each set being arranged, in known manner, to display any numeral in dependence upon the combination of signals applied at any time.

Referring to Figure 6 the time-standard of the watch is a crystal oscillator 25 the oscillations from which are divided down to 1 second signals by a frequency divider 26, and these are further divided down into 10

second signals by a 1/10 ratio counter 27. The 10 second signals are fed into a 1/6 ratio counter 28 which delivers a 1 minute signal. This is fed to a known signal converter 32 which provides outputs corresponding to each sector of a sector type second indicator 45 the counter electrode of which is represented at 47. These outputs are fed to logic gate circuits 54 to which are also fed 1 second signals from terminal 56. The outputs from the gate circuits are fed to drive control elements in a driving element group 37. These drive control elements are represented as change over switches referenced 55 in Figure 6. Each corresponds functionally with a switch 11 as shown in Figure 3 and is actuated as described in connection with that Figure. The switches 55 in groups 37 (and 38, 39 and 40) in Figure 6 may each be a switch in a drive circuit as described with reference to Figure 3 or with reference to Figure 4. To simplify Figure 6 only one switch 55 is shown in each of the groups 37 and 38. The switches in groups 37 are associated each with a different sector in the indicators 45 to 47. The arrangement is such that each sector is caused to "flick" at a position corresponding to each 10 seconds.

A 1/10 ratio counter 29 fed through a gate 48 delivers a tens of seconds signal output from the 1 minute signal input it receives from 28 and its output is connected with a 1 minute digit electrode 44 through a signal converter 33 and a driving circuit group 38. This group comprises seven driving control switching elements 55 one corresponding to each electrode of a set in a numeric indicating device. A 1/6 ratio counter 30 fed with output from 29 through a gate 48 gives a 1 hour signal output from the 10 minute signal input it receives. This output is fed to a signal converter 34 which provides drive to a 10 minute digit electrode 43 through a driving circuit group 39 also consisting of switches 55 as described already.

A 1 hour signal input fed to a 1/12 ratio counter 31 from 30 through a gate 48 is used to operate time-segment indicator electrodes 41 and 42 through a signal converter 35 and a driving circuit group 40 which also comprises switches 55 as already described. A switch 52 resets the states of the respective frequency dividers and counters to their initial states, and switches 49, 50, 51 set the respective digits of 1 minute, 10 minutes and 1 hour to the desired figures. Each time these switches are moved to the "ON" position they add logically to the counter outputs of the preceding step (individually for each figure) and provide clock signal inputs to the counters, the states of the counters being advanced by 1 digit.

The potentials of the individual selectable electrodes in the display indicators are changed over in each case by the switches 55

in the appropriate group 37, 38, 39 and 40 between values substantially equal to V_H or substantially equal to V_E in correspondence with the time to be indicated, while the common electrodes 46, 47 opposite to the selectable individual electrodes 41, 42, 43, 44 in the numeric indicators and the electrode 45 are maintained at a potential V_L . Therefore, the potential difference between each selectable electrode and its associated common electrode is, at any time, either

$$V_c = V_H - V_L$$

or

$$V'_c = V_E - V_L$$

If the threshold voltage of any indicator is called V_{TH} and the voltage sufficient for indication is called V_{ON} , the arrangement is made such (in correspondence with description already given in connection with Figures 3 and 4) that:—

$$V_c > V_{ON}$$

and

$$V'_c < V_{TH}$$

Since,

$$V_c > V_H - V_E,$$

the result is achieved by the use of the driving circuits as described and in accordance with this invention, that it is possible to make each indicator considerably larger than that applied to the driving circuit therefor, with consequent advantages of better clarity of indication, simplification of design of driving circuit, and reduction of electric power consumption.

Figure 7 shows an example of a voltage boosting circuit for obtaining potentials V_H , V_E , V_L from a single battery. In Figure 7 a toroidal core 60 is used in order to obtain high boosting efficiency and reduction of physical size.

In Figure 7 oscillation is continuously maintained by utilising energy from a battery 61, by means of a driving coil 63 driven by a transistor 62 and a detecting coil 64. A biasing resistance 65 is provided. The desired potentials V_H , V_E , V_L are obtained as indicated from the oscillating AC voltage delivered to secondary coil 66 through rectifiers 67 and smoothing condensers 68.

WHAT WE CLAIM IS:—

1. In combination an electric signal operated passive indicator and, for driving the same, a driving circuit including a two way switching arrangement having three terminals



second signals by a 1/10 ratio counter 27. The 10 second signals are fed into a 1/6 ratio counter 28 which delivers a 1 minute signal. This is fed to a known signal converter 32 which provides outputs corresponding to each sector of a sector type second indicator 45 the counter electrode of which is represented at 47. These outputs are fed to logic gate circuits 54 to which are also fed 1 second signals from terminal 56. The outputs from the gate circuits are fed to drive control elements in a driving element group 37. These drive control elements are represented as change over switches referenced 55 in Figure 6. Each corresponds functionally with a switch 11 as shown in Figure 3 and is actuated as described in connection with that Figure. The switches 55 in groups 37 (and 38, 39 and 40) in Figure 6 may each be a switch in a drive circuit as described with reference to Figure 3 or with reference to Figure 4. To simplify Figure 6 only one switch 55 is shown in each of the groups 37 and 38. The switches in groups 37 are associated each with a different sector in the indicators 45 to 47. The arrangement is such that each sector is caused to "flick" at a position corresponding to each 10 seconds.

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in the appropriate group 37, 38, 39 and 40 between values substantially equal to V_H or substantially equal to V_E in correspondence with the time to be indicated, while the common electrodes 46, 47 opposite to the selectable individual electrodes 41, 42, 43, 44 in the numeric indicators and the electrode 45 are maintained at a potential V_L . Therefore, the potential difference between each selectable electrode and its associated common electrode is, at any time, either

$$V_C = V_H - V_L$$

or

$$V'_C = V_E - V_L$$

If the threshold voltage of any indicator is called V_{TH} and the voltage sufficient for indication is called V_{ON} , the arrangement is made such (in correspondence with description already given in connection with Figures 3 and 4) that:—

$$V_C > V_{ON}$$

and

$$V'_C < V_{TH}$$

Since,

$$V_C > V_H - V_E,$$

the result is achieved by the use of the driving circuits as described and in accordance with this invention, that it is possible to make each indicator considerably larger than that applied to the driving circuit therefor, with consequent advantages of better clarity of indication, simplification of design of driving circuit, and reduction of electric power consumption.

Figure 7 shows an example of a voltage boosting circuit for obtaining potentials V_H , V_E , V_L from a single battery. In Figure 7 a toroidal core 60 is used in order to obtain high boosting efficiency and reduction of physical size.

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WHAT WE CLAIM IS:—

1. In combination an electric signal operated passive indicator and, for driving the same, a driving circuit including a two way switching arrangement having three terminals



namely an output terminal and two other terminals, said output terminal being connected to one of said other terminals in one switching condition of said arrangement and to the other of said other terminals in the other switching condition of said arrangement; means connecting said indicator between said output terminal and a further terminal; and voltage supply means arranged to apply a first potential to a first one of said other terminals and a second potential, different from said first potential to the second of said other terminals, and a third potential to said further terminal; said first, second and third potentials being so chosen that, in one switching condition, the difference between the potential at said further terminal and said first potential is applied across said indicator and sufficient to excite it while, in the other switching condition, the difference between said potential at said further terminal and said second potential is applied across said indicator and does not exceed the threshold voltage of said indicator.

25 2. A combination as claimed in claim 1 wherein the switching arrangement comprises two insulated gate FETs, one of P channel and the other of N channel, with their drains connected together and to the indicator, their sources connected one to one and the other to the other, of the aforesaid other terminals of the switching arrangement, and their gates connected together and to a source of switching control voltage.

30 3. A combination as claimed in claim 1 or

2 wherein said first, second and third potentials are derived from a battery source by a voltage boosting arrangement comprising an oscillator energised by said battery and providing AC in a transformer primary circuit, said transformer having a tapped secondary from which said first, second and third potentials are derived by rectification.

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4. An electronic timepiece comprising a time standard source of electrical oscillations, numeric time indicating means constituted by a plurality of electrical signal operated passive numeric indicating devices each having a plurality of selectably energised electrodes arranged to display any numeral in dependence upon the selected energised electrodes, and frequency dividing counting and signal processing circuits for deriving from the oscillations time signals for operating said devices, said signals being utilised to operate said devices through the medium of driving circuits as claimed in any of claims 1, 2 or 3, and which provide operating voltages to the electrodes of said devices.

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5. Driving circuits for electric signal operated passive indicators and timepieces incorporating the same substantially as herein described with reference to Figures 3 to 7 inclusive of the accompanying drawings.

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