

PATENT SPECIFICATION

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(54) ELECTRONIC CIRCUIT FOR QUARTZ CRYSTAL WATCH

(71) We, KABUSHIKI KAISHA DAINI SEIKOSHA, a Japanese company of 31-1, 6-chome, Kameido, Koto-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 circuits for timepieces, and in particular, although not so restricted, to driving circuits for watches.

Conventional watches employing quartz crystals to produce a time standard have used conventional bi-polar transistors in their driving circuits despite the excellence of field effect transistors. This is because it was, up until now, impossible to actuate field effect transistors with a low voltage supply such as that from a battery.

It is common practice that complicated electronic circuits are of integrated circuit construction to save space and, indeed, integrated circuit construction has been employed in conventional watches of the type described above. Field effect transistors are advantageously miniaturised relative to conventional transistors and thus this is another reason why their use in watches is advantageous.

Field effect transistors have virtually no stand-by current (dark current) and consequently when one of a pair of field effect transistors goes ON, the other, having a common drain therewith goes OFF upon which it has a very high resistance. Therefore, the power consumption is virtually negligible.

It has been found that a threshold voltage of less than 0.8 volts can be realised for both P and N channel field effect transistors by using a gate film.

According to one particular aspect of the present invention there is provided a driving circuit for a timepiece and comprising: an oscillator circuit including a quartz crystal oscillator for producing a relatively high frequency output signal, a capacitor for providing a coarse adjustment of said output signal, a variable capacitor for providing a fine adjustment of said output signal, and a

capacitor for compensating changes in the frequency of the output signal resulting from changes in ambient temperature; a frequency dividing circuit having a plurality of stages each stage including complementary field effect transistor circuits for providing a relatively low frequency signal from said output signal; a wave shaping circuit including a complementary field effect transistor circuit for shaping the relatively low frequency signal; a reset switch for resetting said frequency dividing circuit and wave shaping circuit; a switching circuit triggered to one state by the output of the wave shaping circuit for applying a first current to a driving coil of an electromechanical transducer; and a pulse generating circuit controlled by the output of the wave shaping circuit and arranged to trigger the switch circuit to its other state for applying a second current, opposite in direction to said first current to the driving coil.

Preferably the frequency dividing circuit has fourteen stages.

According to a further aspect of the present invention there is provided a timepiece having a driving circuit as recited above.

The invention is illustrated, merely by way of example, in the accompanying drawings, in which:—

Figure 1 is a circuit diagram showing a driving circuit according to the present invention for a timepiece;

Figure 2 shows, in greater detail, a frequency dividing circuit and wave shaping circuit of the driving circuit of Figure 1; and

Figure 3 shows a transducer arranged to be driven by the driving circuit of Figure 1.

A driving circuit according to the present invention, for a timepiece e.g. a quartz crystal watch, will be described with reference to Figure 1. The timepiece comprises an oscillator circuit 1, an integrated circuit block 2 composed of field effect transistors, namely, complementary metal oxide semi-conductor transistors (hereinafter referred to as "complementary MOS transistors") for dividing a relatively high frequency signal produced by the oscillator circuit and producing therefrom

a relatively low frequency signal and for shaping the relatively low frequency signal, a re-set switch 3 for switching the block 2 in response to movement of a crown (not shown), a driving block 4, a pulse generating circuit 5 for positively driving a transducer, and a battery 6 for supplying power to the driving circuit.

The oscillator circuit 1 comprises a quartz crystal oscillator 1a producing a high frequency signal of 16384 Hz (2^{14} Hz), a transistor T_{11} for causing the quartz crystal oscillator to oscillate, a capacitor C_{11} for compensating changes in the high frequency signal resulting from changes in the ambient temperature, a variable capacitor C_{12} for providing a fine adjustment of the frequency of the high frequency signal, and a capacitor C_{13} for providing a coarse adjustment of the frequency of the high frequency signal. Consequently, the high frequency signal is adjusted by the capacitor C_{13} to the correct frequency which is further finally adjusted by the capacitor C_{11} to ensure correct timekeeping of the timepiece.

The block 2 will be described in detail with reference to Figure 2. The terminals 2a to 2e of the block 2 shown in Figure 1 correspond to those of Figure 2: that is the terminal 2a corresponds to the input terminal ϕ , the terminal 2b to a positive voltage terminal V_{DD} , the terminal 2c to the negative voltage terminal, the terminal 2d to an output terminal OUT, and the terminal 2e to a re-set terminal R. Although not shown in Figure 1, all the points indicated by the symbol V_{DD} are connected to the battery 6.

At the input terminal ϕ there appears the output from the quartz crystal oscillator 1a i.e. a signal having the frequency 16384 Hz. This signal is fed to the input signal of a block DIV A1 *via* an inverter, and at point Q_1 there appears a signal of frequency 8192 Hz (i.e. the block DIV A1 has divided the input signal by a factor of 2), and at a point Q_2 there appears a signal having the same frequency but 180° out of phase. Blocks DIV A2 to DIV A9 and DIV B1 to DIV B5 are arranged in series, each producing an output which has a frequency which is one half the frequency of the input. Thus it will be appreciated that the frequency of the output from the block DIV B5 is 1Hz. The blocks, therefore, form a fourteen stage frequency dividing circuit. The blocks DIV A2 to DIV A9 are of identical circuit construction to the block DIV A1. The block DIV B1 and the blocks DIV B3 to DIV B5 are of identical circuit construction to the block DIV B2. The construction of each block will be self-evident from Figure 2 and, therefore, will not be described. Each block, it will be seen, includes complementary MOS binary circuits.

Thus, the output signal having a frequency

of 1Hz from the last stage DIV B5 of the frequency dividing circuit is applied to a wave shaping circuit WS at points Q_{14} and Q_{14} . The wave shaping circuit WS is of complementary MOS binary circuit construction. The pulse width of the output signal from the block DIV B5 is approximately 500 milliseconds. The wave shaping circuit is arranged to produce an output signal of the same frequency but with a pulse width of 8 milliseconds in order to reduce the power consumption of the driving circuit. This output signal appears at the output terminal OUT.

The re-set switch 3 is connected to re-set the blocks of the frequency dividing circuit subsequent to the tenth stage i.e. subsequent to the block DIV B1. Referring back to Figure 1, the re-set switch 3 comprises two movable contacts 3a, 3b, a fixed contact 3c engageable with the movable contact 3a, and fixed contacts 3d, 3f engageable with the movable contact 3b. Thus, it will be seen the re-set switch is of double construction so that it will operate correctly even if there is failure at one of the contacts. This enables the timepiece to be highly reliable and not prone to failure.

The re-set switch 3 is controlled by a crown of the timepiece. Thus a positive potential is applied to a re-set terminal 2e when the watch is in operation and the crown is in a first position. On the other hand a negative potential is applied to the re-set terminal 2e when the movable contact 3b is in electrical contact with the fixed contact 3f and when the crown is moved to a second position. In this state, the timepiece stops and is re-started when the crown is moved to the first position. The hands (not shown) are set mechanically by the crown to the correct time in the conventional manner and then the crown is moved to the first position on a given reference time signal so that the watch is synchronised with the reference time.

The driving block 4 and the pulse generating circuit 5 will now be described. The output signal at the output terminal 2d of the block 2 is, as will be appreciated from the above discussion, a series of positive pulses which are applied to the base of the transistor T_{41} to render the latter conductive, thereby causing a current to flow in a driving coil L in the direction shown by the arrow A. When the voltage at the output terminal 2d increases, this has no effect on the pulse generating circuit 5 due to the provision of a diode D. However, when the voltage at the output terminal 2d decreases, the voltage at the collector of a transistor T_{52} decreases, thereby causing a normally conductive transistor T_{51} to become temporarily non-conducting. When the transistor T_{51} becomes non-conducting the transistors T_{43} and T_{43} are permitted to become conducting, thus causing a current to

flow in the driving coil L in the direction shown by the arrow B. In the meanwhile a capacitor C_{s1} is charged to increase the voltage on the base of the transistor T_{s1} which voltage, when it reaches a predetermined level, renders the transistor T_{s1} conducting. The transistor T_{s1} is non-conducting for a period determined by the time constant of a resistor R_{s1} and the capacitor C_{s1} .

Figure 3 illustrates a transducer arranged to be driven by the driving circuit illustrated in Figure 1. The transducer comprises the driving coil L wound around magnetic material 7, a pallet 8 having a permanent magnet 9 mounted on an axle, a seconds wheel 10 having an axle 11, a wheel 12 coaxial with the wheel 10 and having twice the number of teeth as the wheel 10, a seconds hand 13 attached to one end of the axle 11, and a limit spring 14 engaged with the wheel 12.

When current flows in the driving coil 11 in one direction, the pallet 8 is rotated due to an attractive force between the magnetic poles of the magnetic material 7 and the permanent magnet 9 so that the wheel 10 is rotated by one half of the pitch thereof. On the other hand, when current flows in the opposite direction, the magnetic material is oppositely magnetised, and accordingly the pallet is urged to rotate in the opposite direction to rotate the wheel 10 by a further one half of the pitch thereof. This operation is repeated with a period of one second. The seconds hand 13 is kept in position by the limit spring 14 when there is no current flowing in the driving coil L.

The advantage of a timepiece having the above driving circuit are as follows: the space utilised by the driving circuit is comparatively small because of the miniaturisation of the block 2 which is of integrated circuit construction and which employs complementary MOS transistors; the lifetime of the battery is comparatively long because the driving circuit consumes only little electrical power; the seconds hand starts to operate one second after the crown is moved to the first position, and is easily calibrated to be synchronised

with a reference time; and defective electrical contacts sometimes encountered in the known watches, resulting in non-operation, are eliminated so the timepiece is highly reliable.

WHAT WE CLAIM IS:—

1. A driving circuit for a timepiece and comprising: an oscillator circuit including a quartz crystal oscillator for producing a relatively high frequency output signal, a capacitor for providing a coarse adjustment of said output signal, a variable capacitor for providing a fine adjustment of said output signal, and a capacitor for compensating changes in the frequency of the output signal resulting from changes in ambient temperature; a frequency dividing circuit having a plurality of stages each stage including complementary field effect transistor circuits for providing a relatively low frequency signal from said output signal; a wave shaping circuit including a complementary field effect transistor circuit for shaping the relatively low frequency signal; a reset switch for resetting said frequency dividing circuit and wave shaping circuit; a switching circuit triggered to one state by the output of the wave shaping circuit for applying a first current to a driving coil of an electromechanical transducer; and a pulse generating circuit controlled by the output of the wave shaping circuit and arranged to trigger the switch circuit to its other state for applying a second current, opposite in direction to said first current to the driving coil.
2. A driving circuit as claimed in claim 1 in which the frequency dividing circuit has fourteen stages.
3. A driving circuit substantially as herein described with reference to and as shown in the accompanying drawings.
4. A timepiece having a driving circuit as claimed in any preceding claim.

J. MILLER & COMPANY,
Agents for the Applicants,
Chartered Patent Agents,

262 High Holborn, London WC1V 7EF.

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