550.340.8

MICROPOWER DIGITAL CRYSTAL CLOCK FOR FIELD USE

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Abstract

A small digital crystal-controlled clock has been designed for field measurements. As the clock is constructed of C-MOS integrated circuits, the input power is very low (0.4 mW). The clock has a binary parallel output for seconds and minutes and −1 Volt output for ¼ sec, 1 sec, 1 minute and 1 hour time marks. At room temperature the clock is accurate to within 10 ms/day.

Description of the clock

Figure 1. shows the logic diagram of the clock. The frequency of a micropower crystal-controlled oscillator is divided by a 21-stage binary counter. The clock rate of 1 Hz from the output of Q21 is combined with the outputs of Q20 and Q19 to give the width of second pulses to 125 ms. The ¼ second mark is combined similarly from the output of Q19, Q18 and Q17.

The second mark is then led to a 6-stage binary counter, which gives the logic '1' to the outputs of Q3, Q4, Q5 and Q6 after 60 second pulses starting the minute mark. The minute mark enables the counter to take in a 16 Hz signal from the output of Q17 of the previous counter after the 1 Hz signal from the output of Q21 of the same counter has gone

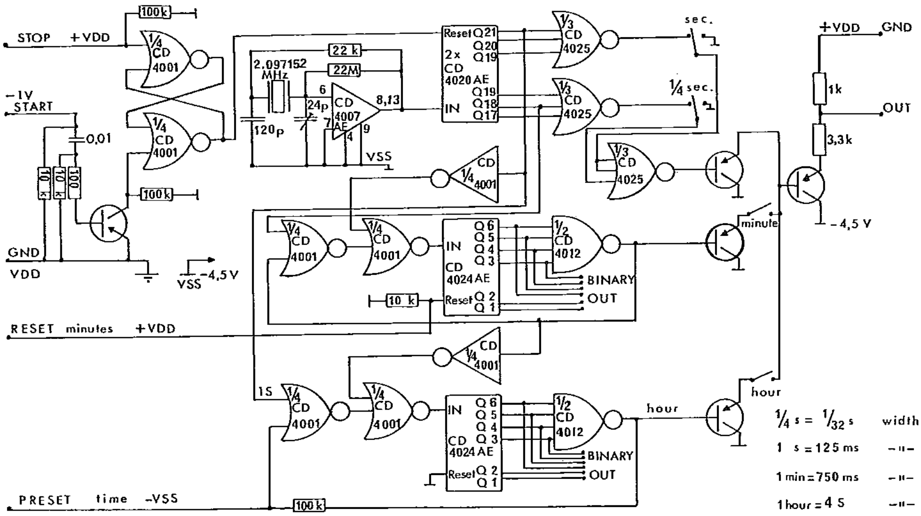

Fig. 1. Logic diagram of the clock.

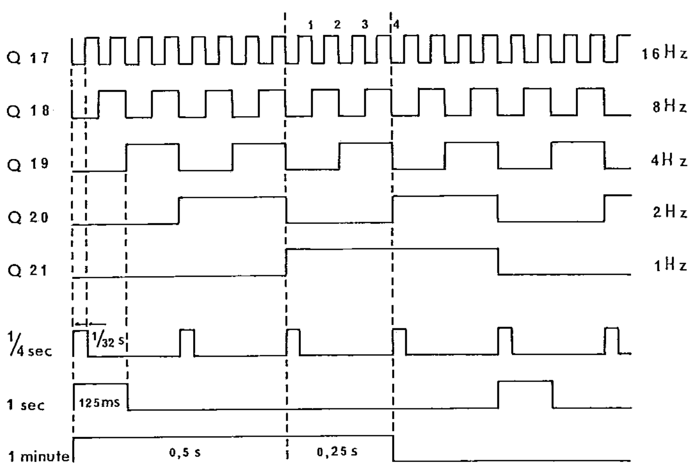

Fig. 2. Wave forms of the clock.

high, resetting this 1/60 counter. The minute pulse thus lasts 750 ms (0.5 sec + 0.25 sec).

An hour mark is made similarly from the minute marks, and is reset by four second pulses. The length of an hour mark is thus 4 seconds.

When the above mentioned method is used for time pulses, the

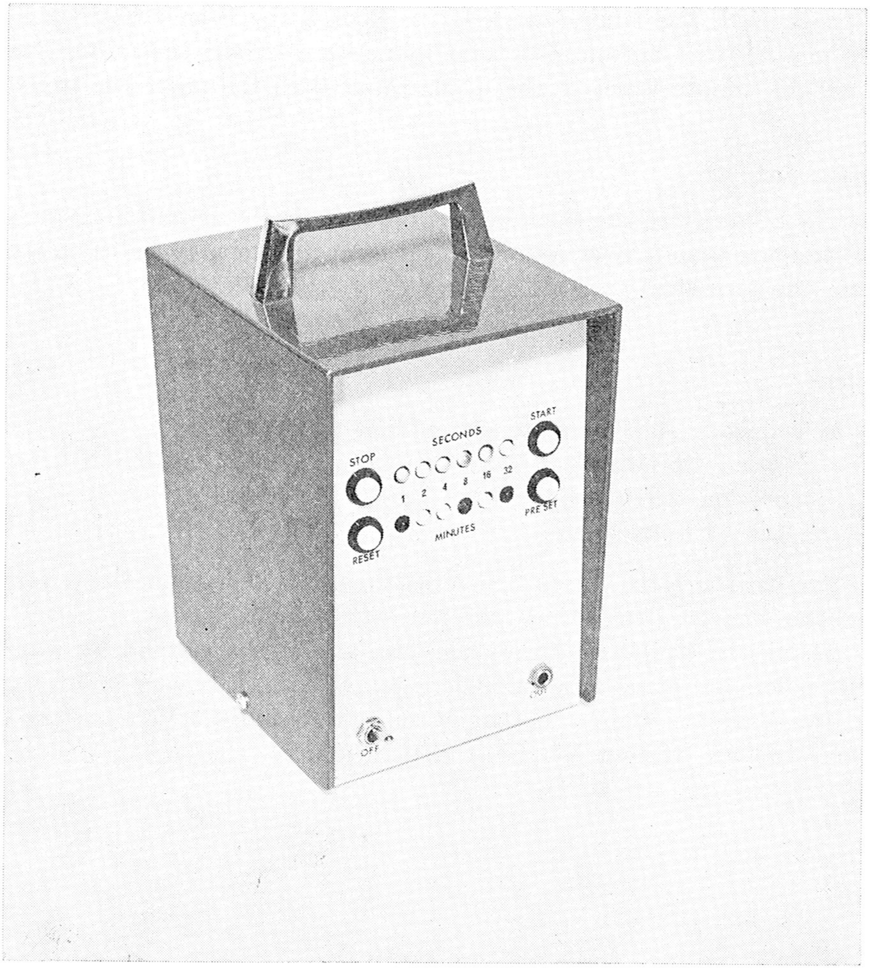

Fig. 3. Digital crystal clock.

number of the components is reduced and very accurate widths are obtained for the time marks. Fig. 2 shows the wave forms of the clock pulses.

Updating the clock

Second pulses from a radio time receiver are led to the input of the clock at about 1 Volt level. When the clock has been stopped, it starts automatically from the next radio time pulse. The seconds are thus synchronized. The minute mark of the clock is synchronized by pushing the minute reset button after next minute mark from the radio. Then the right minute is set to the display unit with the pre-set button.

Discussion

The accuracy of the clock mainly depends on the crystal. In general, the frequency shift over any specified temperature may be calculated from the formula:

$$-\Delta f = K(T_0 - T)^2$$

where

Δf = frequency shift in parts per million
K = parabolic constant
T_0 = inversion temperature
T = specified temperature

Standard 2 MHz crystals have $K = 0.04—0.05$; thus a 2°C temperature change gives a time difference of about 5 ms/day.

Thanks to C-MOS integrated circuits and to the method by which time pulses are made only by logic gates, this clock is very insensitive to transient noise pulses. The input current from a 4.5 Volt battery is about 100 μA without the LED display unit.