Multi-event Alarm Clock

In control of many daily events

Design by K.-U. Mrkor

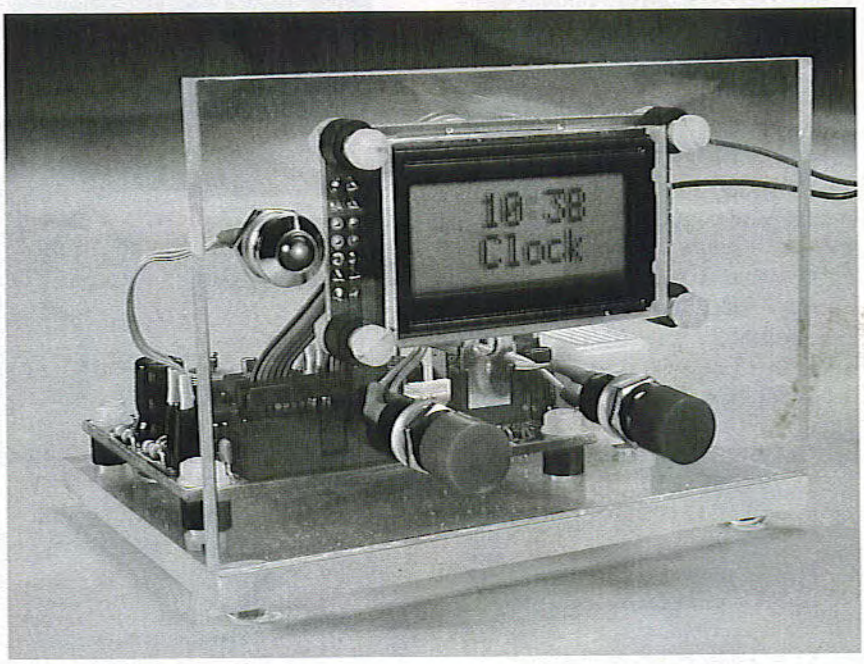
A regular alarm clock, whether stuffed with electronics or of the mechanical variety, will not get you very far if you need to be reminded of several events during the day (for example, taking your medication). What you need is a multi-talent like the circuit described here.

The circuit diagram of the Multi-event Alarm Clock shown in **Figure 1** is easy to understand, the central parts being a contemporary combination of a microcontroller, a real-time clock and an LC display. At the heart of the circuit sits a powerful yet inexpensive and widely available 8051-compatible 8-bit microcontroller type AT89C2051 from Atmel. Its main features may be summarized as follows:

- full 8051 software compatibility;
- 2 kbytes of Flash memory;
- integrated analogue comparator;
- multiple outputs with LED drive capability;
- static architecture (0-24 MHz)
- extended supply voltage range (2.7-6 V).

Quite important for this application, the chip comes in a small enclosure with 'just' 20 I/O pins. Port 1 and Port 3 (with the exception of the P3.6 line) provide 15 freely programmable port lines. This should be more than adequate to connect the following peripherals: an LCD to display time and menus, two pushbuttons to set the clock and the alarm times, an LED and a piezo buzzer as an acoustic alarm.

To these elements should be added a real-time clock (RTC) component type DS1307 which communicates with the MCU via an I²C link. Thanks to a 3-volt Lithium backup battery, the DS1307 will keep 'ticking' in the absence of the supply voltage. Suitably programmed, the chip supplies a seconds pulse at the SQW/OUT pin.



Clock reference adjustment

In real life, the clock output of the DS1370 will rarely supply a pulse with a period of exactly 1.000000 seconds. This is because the quartz crystal used in the RTC clock oscillator circuit is subject to a certain production tolerance. The author purchased and tested a number of these quartz crystals and found pulse periods of up to 1.000008 seconds at the chip output. Unfortunately, what appears to be a totally harmless error in the sixth decimal position can well be the cause of serious degradation in the clock's final accuracy, amounting to an error of four minutes per year.

Although the error may be compensated by adjusting trimmer C5, that really makes sense only if you have a reliably and extremely well calibrated frequency counter boasting a microseconds range. Assuming you have such an instrument (or have access to it) then the probe may be connected to pin 7 of the DS1307 and the trimmer adjusted for a reading that's acceptable. Failing the above, C5 is best omitted from the circuit.

Power supply

The power supply for the circuit is of a less conventional design, consisting of a low-drop voltage regulator, IC3, with its usual satellite parts. Its function is to turn the external supply voltage (from a battery or a mains adapter) into a stable 5-V supply rail for all circuit parts except the LCD backlight. Jumper JP1 ensures that the backlight current is never drawn from a battery — after all, we're looking at something between 40 and 240 mA depending on the LCD type you decide to use. The current circuit around T2-T3-T4 (actually a current mirror) only works when a mains adapter is used to power the circuit, supplying the necessary current for the backlight lamp(s).

The current consumption of the circuit with the exception of the LCD amounts to just 5 mA which may be lowered even further by a small reduction in the MCU clock frequency. The MCU itself does not execute time-critical tasks and will happily run at a clock frequency as low as 2.4576 MHz. The only consequence of a relatively low MCU clock frequency (determined by the quartz crystal) is a slightly sluggish menu when the clock and alarm times have to be set.

Obviously the DS1307 is not affected by these changes because it employs its own timebase.

Software

The software for the project was written in the 'C' higher language, using Keil's µVision2 package as a development platform of which a free evaluation version may be downloaded from

www.keil.com/demo/eval/c51.htm

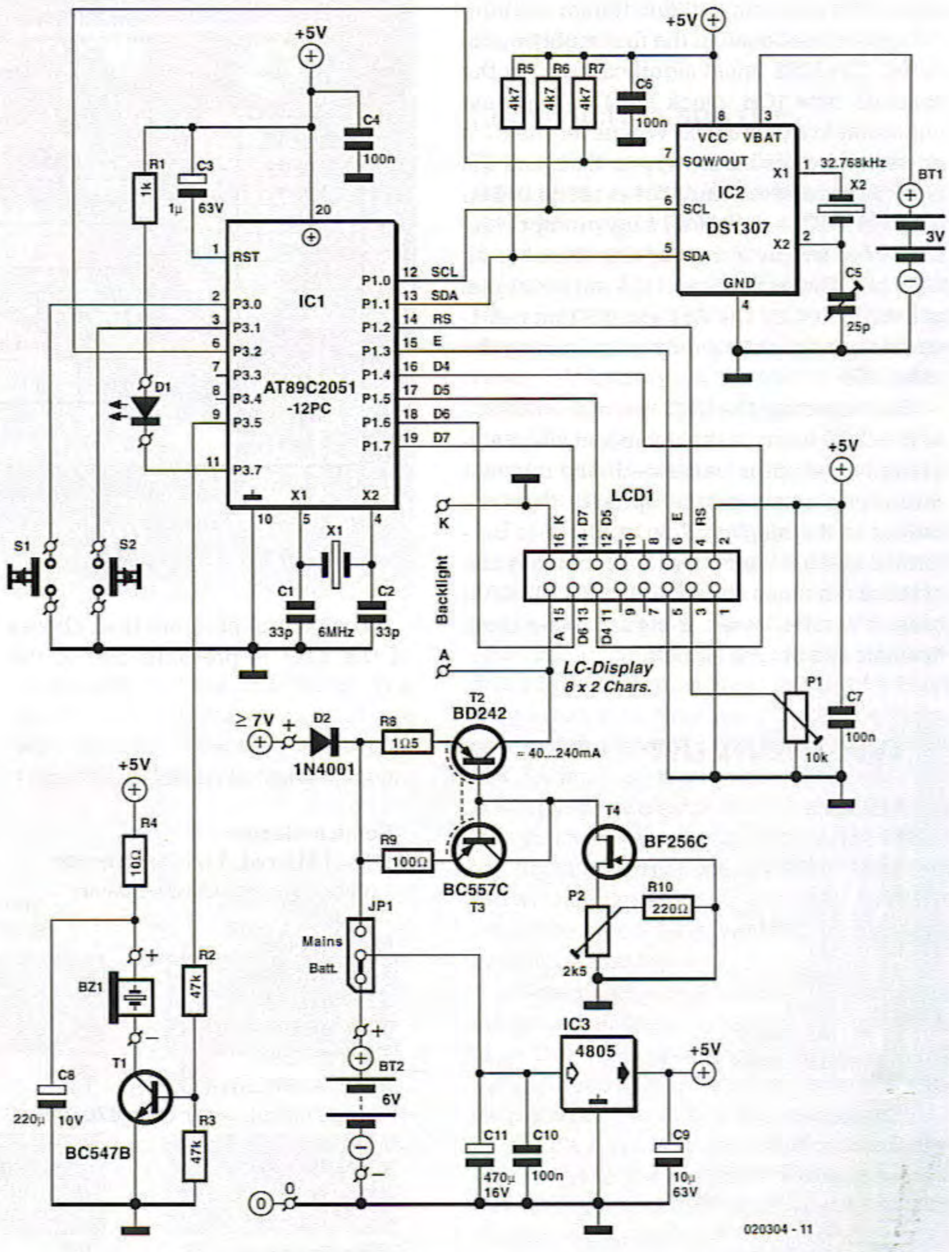


Figure 1. The main components in the project are a microcontroller, a real-time clock chip, an LCD and two pushbuttons.

The only limitations of this version are (1) non-commercial use and (2) a maximum object code size of 2 kbytes. The latter limitation is hard to object to if you realize that the size of the AT89C2051 Flash memory is also 2 kbytes!

The microcontroller executable code looks after several tasks including outputting the current time, communicating with the user via a menu structure and, last but not least, enabling the acoustic actuator when an alarm time is reached.

The seconds clock pulse that's crucial to the function of the Multi-event Alarm Clock is generated by the DS1307 and fed to the AT89C2051 MCU by way of an I²C bus interface. Unlike some other 8051 derivates from Philips, the AT89C2051 does not have an on-chip I²C interface, hence a few I²C routines had to be written based on an example supplied by Keil.

Access to the real-time clock is similar to reading/writing a memory device. The only point to keep in mind is that the first eight bytes in the RTC RAM are reserved for the clock itself. The battery backup makes the remaining 56 free memory locations ideal for the storage of alarm times. However, the DS1307 has to be initialised before it can be used as a timebase. The initialisation comprises adjusting the clock and loading the control bytes. The memory map in **Figure 2** shows the meaning and function of the individual bits contained in the first eight control bytes. The MSB (most significant bit) in the seconds byte (CH, clock halt) is the most important in this respect. Whenever the IC is powered up, this bit always reads 1, and the clock is not started until CH is made 0. Setting the OUT and SQWE bits prompts the DS1307 to supply a rectangular signal at its OUT pin. The frequency of the output signal is determined by the RS1 and RS0 bits. A 1-second pulse is obtained by programming the value 00b.

By connecting the OUT line of the DS1307 to the $\overline{INT0}$ input of the microcontroller, a 1-second interrupt is generated. The relevant interrupt service routine updates the time output to the display. Next, a check is performed to see if the current time matches one of the alarm times stored in the DS1307 RAM area. If so, that event is signalled by three acoustic and optical signals.

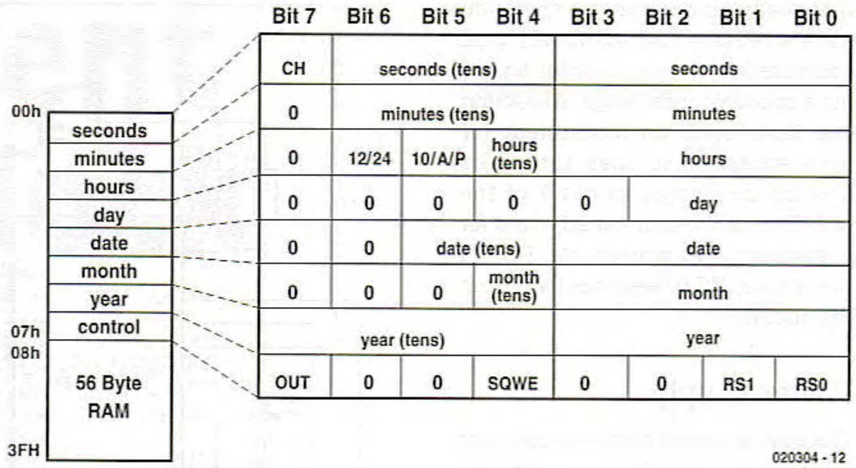


Figure 2. DS1307 memory map.

The control program then checks if the user is pressing one of the pushbuttons to call up the menu. If so, the menu is made available, else,

COMPONENTS LIST

Resistors:
R1 = 1kΩ
R2,R3 = 47kΩ
R4 = 10Ω
R5,R6,R7 = 4kΩ7
R8 = 1Ω5
R9 = 100Ω
R10 = 220Ω
P1 = 10kΩ preset
P2 = 2kΩ5 preset

Capacitors:
C1,C2 = 33pF
C3 = 1µF/63V radial
C4,C6,C7,C10 = 100nF
C5 = 25pF (trimmer)
C8 = 220µF 10V radial
C9= 10µF 63V radial
C11 = 470µF 16V radial

Semiconductors:
D1 = LED, red, 5mm, low current (optionally with chassis-mount holder)
D2 = 1N4001
T1 = BC547B
T2 = BD242
T3 = BC557C
T4 = BF256C
IC1 = AT89C2051-12PC, programmed, order code **020304-41**
IC2 = DS1307
IC3 = 4805

Miscellaneous:
JP1 = 3-way pinheader with jumper
S1,S2 = pushbutton, 1 make contact, chassis mount
LCD1 = LC display, 16 characters (2 lines x 8), e.g. AV0820 from Anag Vision) plus 16-way boxheader
X1 = 6MHz quartz crystal (parallel resonance)
X2 = 32.768 kHz quartz crystal
BT1 = 3V Lithium cell type CR2032 with PCB mount holder (22.75mm diam.)
BT2 = see text
BZ1 = 5V or 6V DC buzzer (active piezo)

PCB, available from **The PCB Shop**

Disk, microcontroller C (source) and hex files, order code **020304-11** or Free Download

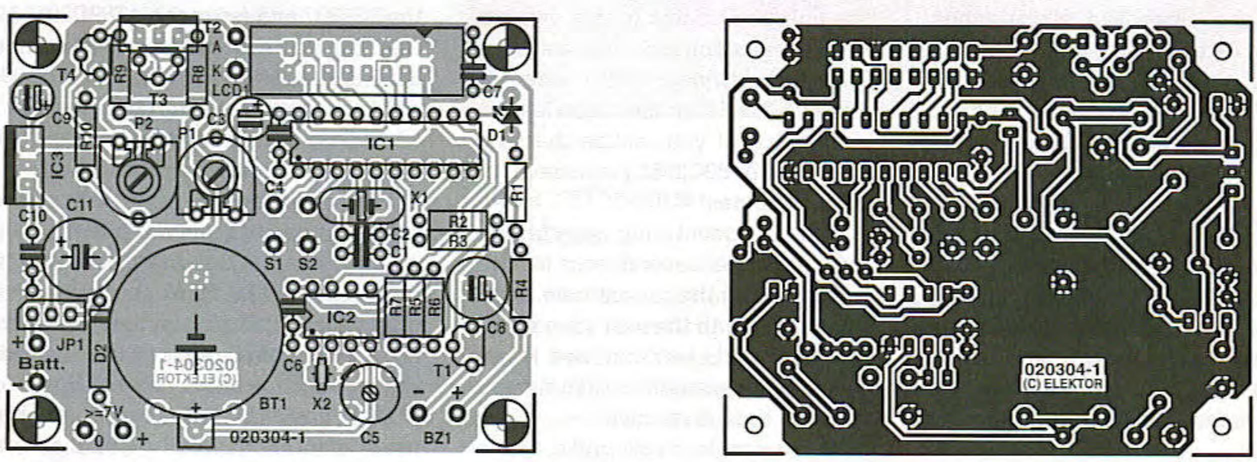
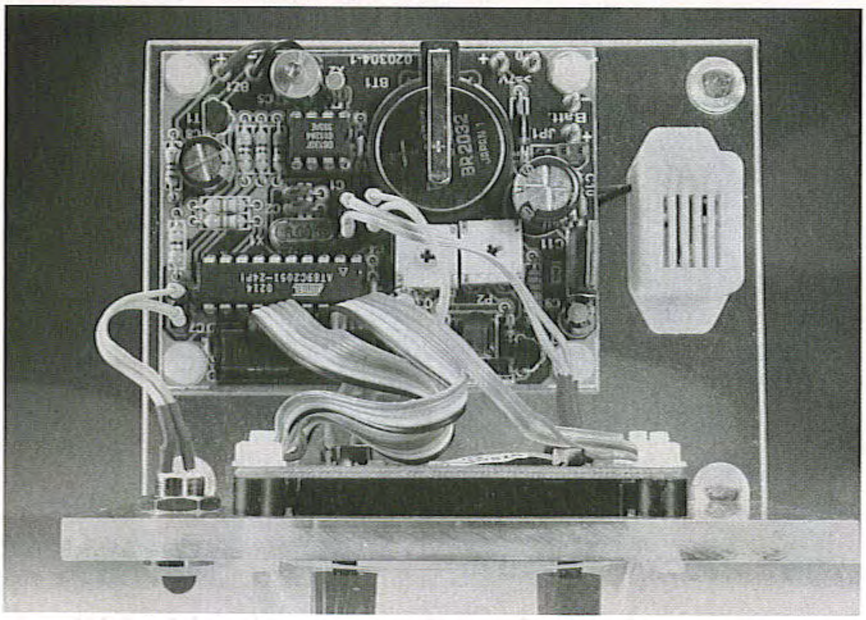


Figure 3. Copper track layout and component mounting plan of the PCB designed for the Multi-event Alarm Clock.



the microcontroller changes to 'sleep' mode. In this energy-saving mode, the AT89C2051 consumes just 1.6 mA as opposed to 7.5 mA (assuming a clock of 6 MHz). The MCU does not wake up until the next interrupt is request is received from the DS1307, when the display update and pushbutton check routines are run again.

Construction and use

The circuit is conveniently built on the single-sided printed circuit board of which the layout is shown in **Figure 3**. It should be noted that a number of components are not accommodated on the board — these include the 'large' battery, BT2 (which may take the form of two Lithium cells, four Alkaline cells or a single 9-V battery), piezo buzzer BZ1, pushbuttons S1 and S2 and, of course, the LC display. The latter is connected by way of a 16-way pinheader and two extra solder pins (A and K for the backlight).

Populating the board should not cause problems as there are no unusual components to deal with or special mounting methods to observe. As a matter of course, electrolytic capacitors, transistors and integrated circuits must be mounted the right way around as they are polarized components. Transistor T2 and voltage regulator IC3 do not need heatsinks as they pass relatively low currents. As illustrated in the introductory picture, the two pushbuttons are fitted directly onto the case panel, just below the display (S1 to the right, S2 to the left). The alarm LED may also be mounted below the display.

All user settings are guided by the in-built menu and entered using the two pushbuttons. The menu is entered by keeping one of the pushbuttons pressed for about one second. Within the menu, the items to define invariably have two options, which are displayed in the lower of the two display lines. The desired option is selected by pressing the pushbutton below the relevant text on the display (i.e., left or right).The three main functions, clock adjust, alarm adjust and alarm clear, are shown pictorially in **Figure 4**.

(020304-1)

Web pointer

DS1307 datasheet at

http://pdfserv.maxim-ic.com/en/ds/DS1307.pdf

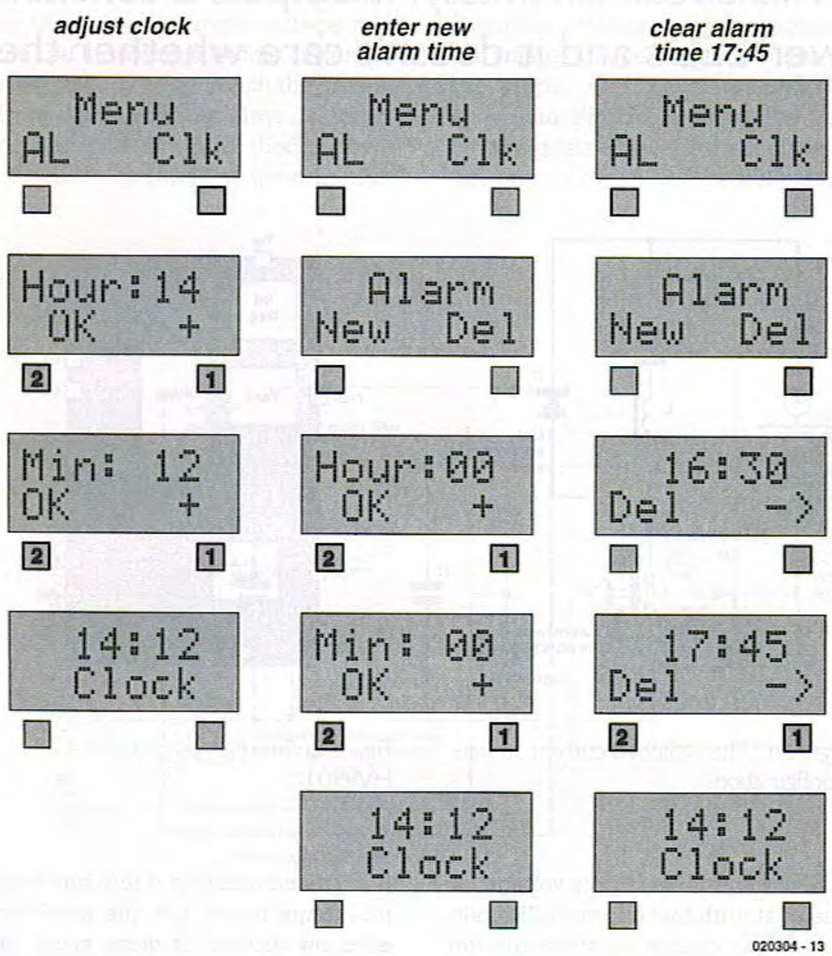


Figure 4. Operating the clock could not be easier using the built-in menu.

Free Downloads

Microcontroller C (source) and hex files.
File number: **020304-11.zip**

PCB layout in PDF format.
File number: **020304-1.zip**

www.elektor-electronics.co.uk/dl/dl.htm, select month of publication.