Simple Travel Clock

Construction and Operation Guide

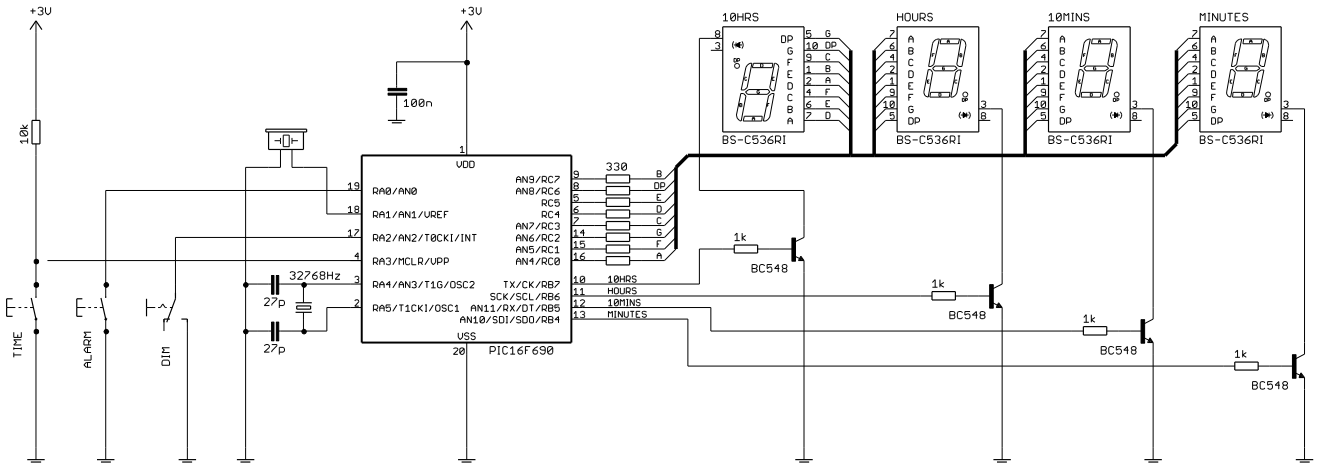
This simple digital clock is intended for travel: light and portable, with an easy-to-read glowing LED display, and yet won't take much room in your luggage and will fit easily on a typical hotel's small bedside table. It has an alarm, can be dimmed for night time, and is battery powered. The batteries should last at least two weeks; enough for a typical trip.

Features

- Four digits displaying hours and minutes (12 hour time)
- Alarm (piezo speaker)
- PM and alarm-on indicators
- Flashing seconds indicator
- Display can be dimmed for night time, using slide switch
- Simple pushbutton operation
- Battery powered (2 × AAA batteries)
- Low-battery indication
- Power-saving standby mode
- Time adjustment is locked in standby and dimmed modes, to prevent accidental time change.

How it works

The circuit, built around a PIC16F690 microcontroller, is shown below.



Two AAA batteries provide a nominal 3V power supply. The PIC can operate down to 2.0V, so there is no need for regulation. However, as the battery voltage falls, the display will become dimmer. A "low battery" condition is indicated (by quickly flashing the seconds indicator) when the power supply falls to 2.2 V.

There is no power switch. Power is always supplied to the PIC, but it draws less than 5 µA when in standby mode, where the displays are blanked and only the PIC's Timer1 oscillator, driven by the 32.768 kHz crystal (loaded by the two 27 pF capacitors), is running. The batteries can supply this tiny standby current for years.

A 100 nF bypass capacitor helps stabilise the power supply to the PIC.

Common-cathode 7-segment LED displays (actually, eight segments including a decimal point) are used. The LED anodes are driven directly by the 16F690 (using PORTC), via 330Ω current limiting resistors. These values were selected to limit LED current to 3 mA, assuming a 1.8 V forward voltage drop across each segment LED and an output high voltage on the PIC of 2.8 V. This current is found to give more than adequate brightness, especially given than the clock is intended for use mainly at night. But if you find you want a brighter display, you can replace these resistors with a smaller value, at the cost of reduced battery life.

The 16F690's I/O pins can supply or sink up to 25 mA. In theory, the common cathodes of each display could be connected directly to an I/O pin, but when all eight segments are lit, the cathode current will be a nominal 8 × 3 mA = 24 mA, which is uncomfortably close to the maximum, especially if you increase the display brightness. Therefore, NPN transistors, driven by pins RB4 – RB7 via 1 kΩ resistors, are used to sink the cathode current.

The displays are multiplexed; the transistors are enabled one at a time, and the appropriate pattern output on PORTC, to turn on the LED segments corresponding to the digit to be displayed. This is repeated almost 1000 times per second, meaning that, although only one digit is ever displayed at once, the overall display (all four digits) is refreshed almost 250 times per second; quickly enough that each digit appears to be continuously on.

The "Time" and "Alarm" pushbuttons are normally open, and each pulls one of the PIC's input pins (RA3 for Time, RA0 for Alarm) to ground when pressed. RA0 is held high by a "weak pull-up" within the PIC, while RA3 requires an external 10 kΩ pull-up resistor. So the RA0 and RA3 bits normally read as a '1', but change to '0' when the attached button is pressed.

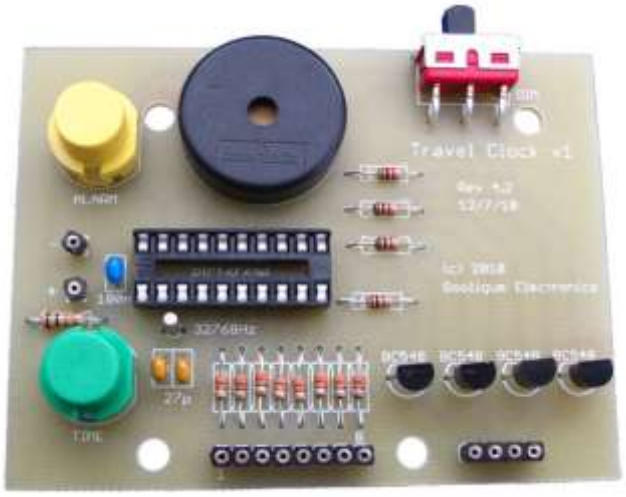
The dimmer switch is a two-position slide switch, connected to pin RA2, with one side of the switch grounded and the other left floating. The internal pull-up is enabled on RA2, so the input reads as '1' with the switch in one position, and '0' in the other.

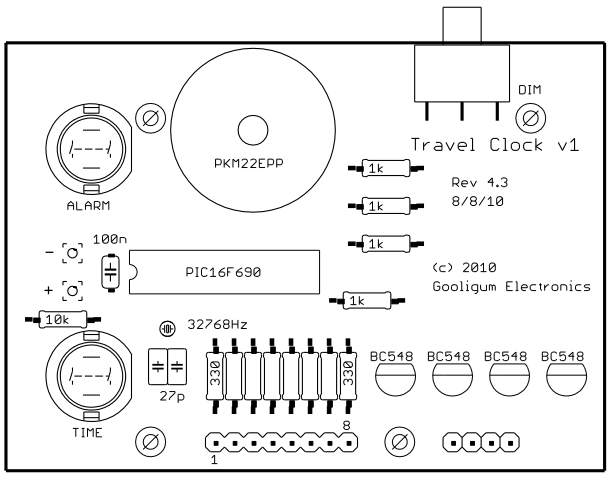
The alarm "buzzer" is an externally-driven piezo sounder, meaning that it must be driven by a signal at the desired frequency to produce a sound. In this case it is driven directly by the PIC's RA1 output – a square wave at approximately 500 Hz. The sounder's peak response is at 4 kHz, so the 500 Hz tone is not as loud as a 4 kHz tone would be. But, it's still annoying enough to wake most people up…

Construction

The kit contains two single-sided printed circuit boards, connected by ribbon cable – a main board holding the microcontroller and switches, and a display board on which the 7-segment displays are mounted.

The main board is shown below, with a component overlay diagram on the right.



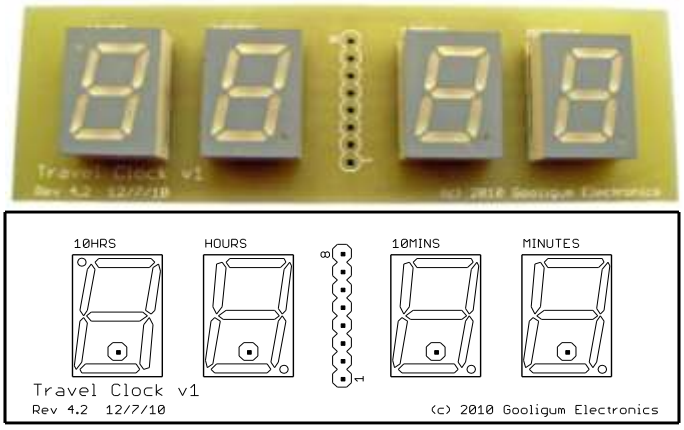


The pin headers are used to connect the ribbon cables and the battery holder. This makes assembly a little easier, but if you wish, you can leave these out, and solder the cables directly to the board.

It is often easiest to build up a PCB by starting with the lowest-profile components, so begin by soldering the resistors to the main board, followed by the capacitors and IC socket. The pin headers can now go in (use pliers to snap them off to form the groups of eight and four, and two single pins, as shown), followed by the crystal and transistors – orienting them as shown in the overlay.

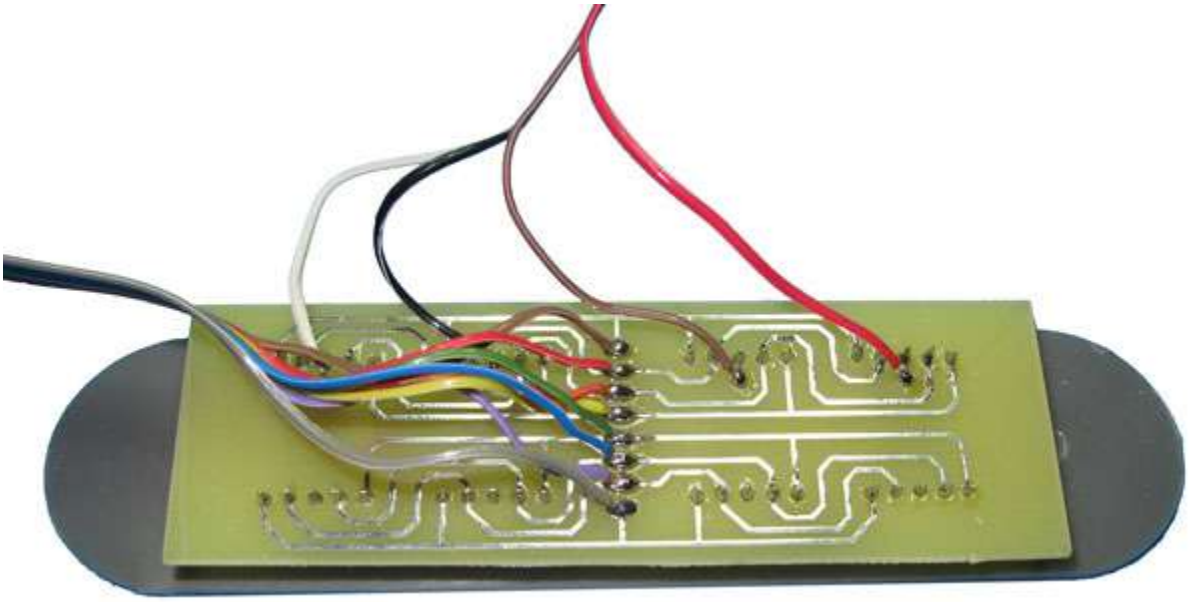
Finally, install the buzzer and the pushbutton and slide switches. Note that the buzzer sits approx. 1mm off the board, and be careful to orient the flat face on the pushbutton switches as shown.

The display board, and component overlay, are shown on the right.



Solder the 7-segment digits to the board as shown, but **note that the left-most, "10 hours" digit is oriented upside-down, compared with the others!** Otherwise, the display will not work correctly.

Next, separate the ribbon cable into 8-way and 4-way cables and solder them to the back of the display board, as pictured below[1].



The 8-way cable drives the LED anodes, while the 4-way cable connects each digit's common-cathode to its corresponding driver transistor on the main board.

The ribbon cables should be cut about 5-8 cm (2-3") long, and the ends tinned (as illustrated on the right), ready for insertion into the pin headers on the main board.

You should also cut the battery holder leads to around 5 cm (2") and tin them, in the same way.

[1] In the picture, the display PCB has been attached to the front panel, as described later.

It is a good idea to test that the circuit operates before continuing with further assembly, so you can at this point plug the ribbon cables into the pin headers. Pin 1 (the bottom-most connection) on the 8-way interface on the display board connects to pin 1 (the left-hand edge) on the 8-way header on the main board, with the other pins connecting in order: bottom-to-top on the display corresponds to left-to-right on the main board. The left-most (10 hour) digit cathode connects to the left-most pin on the 4-way header, with the rest of the 4-way cathode cable connecting left-to-right, in order.

You should also plug the battery wires into the corresponding '+' and '–' pin headers.

Finally, insert the PIC16F690 into the IC socket, taking the usual anti-static precautions – the notch in the chip aligns with the notch in the socket, and the PCB overlay.

If you now install the batteries into the battery holder, the display should light up, reading "12 00", with the seconds indicator (decimal point on the hours digit) flashing once per second. The display should be dimmed when the slide switch is in the left (from the front) position, and bright when the switch is to the right. Pressing the rear "alarm" switch should toggle the alarm indicator (decimal point on the seconds digit) and, with the dimmer switch in the "bright" (right) position, holding down the front "time" switch should make the displayed time advance.

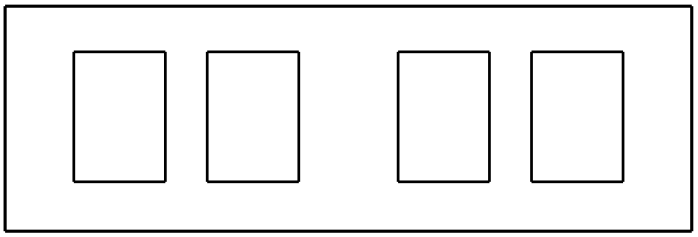
If anything does not work, check your soldering and connections. For example, if the display reads "12 00" but the seconds indicator is not flashing, there may be a problem with the crystal. If one of the digits doesn't work, there may be a problem with the corresponding transistor or connection. If the displays appear to work on the numbers don't look right, perhaps one of the ribbon cables has been connected backwards. Or, if only the "10 hours" digit looks wrong, perhaps it was not installed upside-down. And, if nothing at all seems to work (and you've tested the batteries), you may have a problem with your PIC chip and it may need to be reprogrammed or replaced.

Once everything is working, you can remove the batteries and unplug the battery holder and ribbon cables, ready for the case assembly.

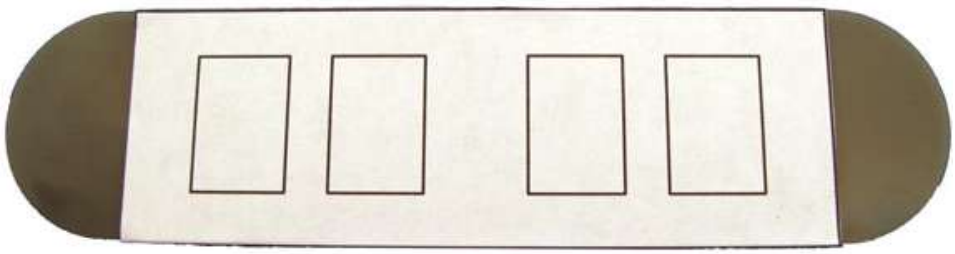
Final Assembly

The PC boards are designed to be installed into a plastic enclosure, with top and bottom sections and rounded front and back panels.

Use the guide on the right (also available as a PDF file, downloadable from www.gooligum.com.au) to cut holes in the front panel for the four digits.



Tip: print the guide, cut it out and glue it to the front panel, using water soluble glue, as pictured below.

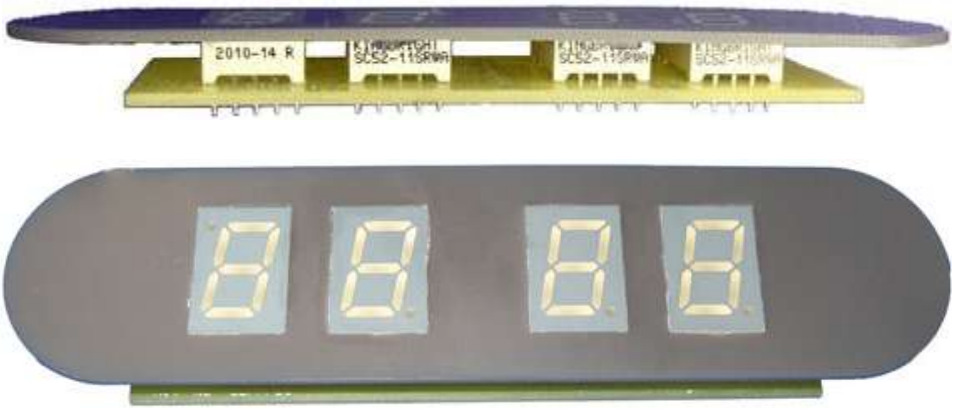


The cut-outs can be made fairly easily by drilling a line of small holes just inside the lines, and then cleaning the edges with a small file.

If you work carefully, regularly checking the holes against the display board, you should be able to achieve a close fit.

When you are satisfied with the cut-outs, simply wash the panel in water to remove the guide.

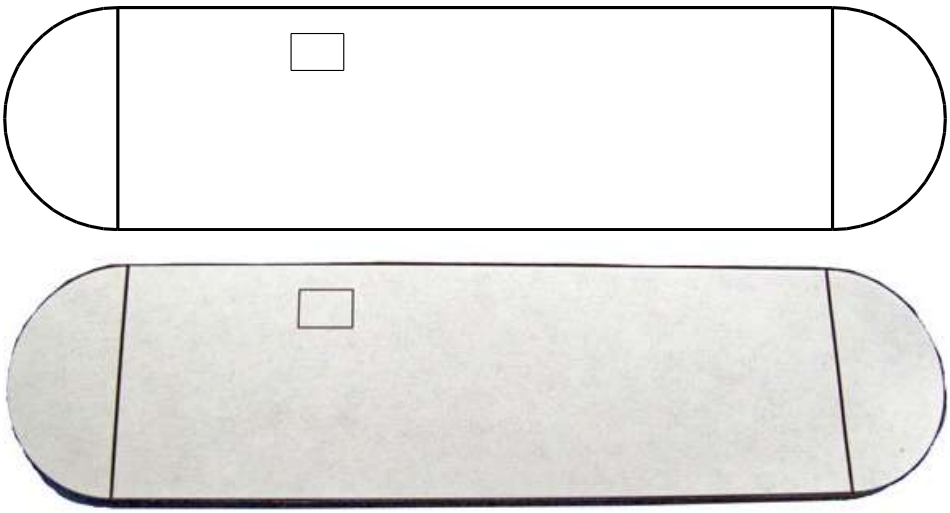
You can now attach the display board to the front panel, as shown.



A little (very little!) "Super Glue" on the inside of the display holes is enough to hold the board firmly in place, if you have made the fitting snug enough. Be careful to work quickly, before the glue sets!

Next comes the back panel.

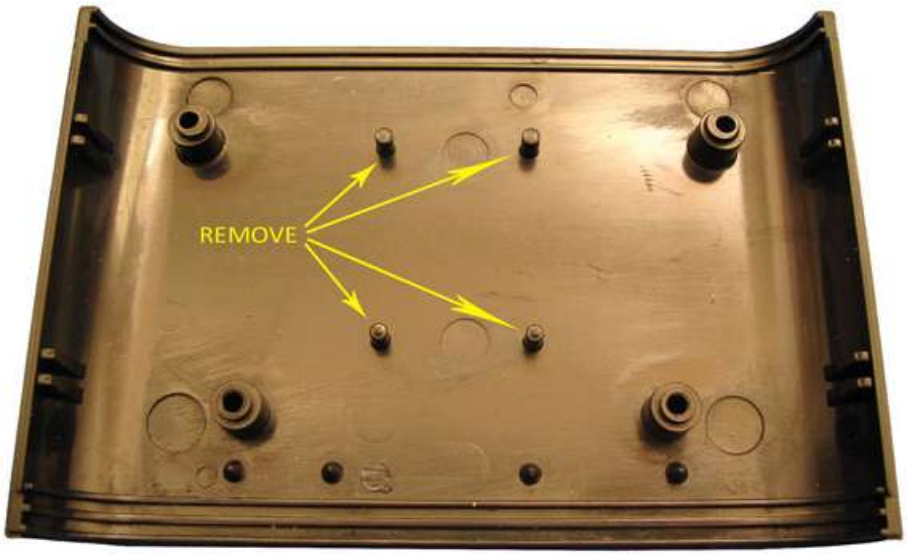
Use the guide shown here to cut a hole for the dimmer switch.



Again, the guide is available for download, and can be printed and glued to the back panel, as pictured.

You can then cut out the dimmer switch hole, the same way as the display holes in the front panel.

Before mounting the main board, you need to remove four plastic tabs from the bottom of the case, as shown below:



They can be removed using side cutters and then filed flat, or you could use a rotary tool with a cutting wheel attachment.

You should now insert the PCB supports into the four mounting holes in the main board.

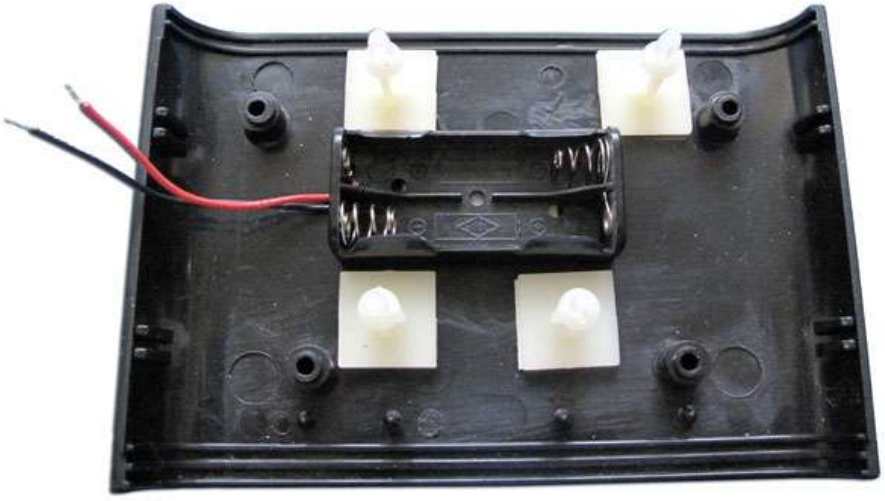
The main board must be mounted so that the back of the board is flush with the panel groove at the

back of the case, and positioned so that dimmer switch lines up with the hole you cut for it in the back panel.

This is most easily done by holding the back panel in position (with the dimmer switch through the panel hole) as you lower the main board into place. It is a good idea to practice this, checking that the board will fit correctly, before you remove the protective tape under the PCB supports; once these are in place, they are difficult to move!

The pictures below illustrate how the main board should be mounted.

With the PCB supports firmly attached to the base, remove the main board from the supports, and affix the battery holder between the PCB supports, using double-sided tape, as shown.

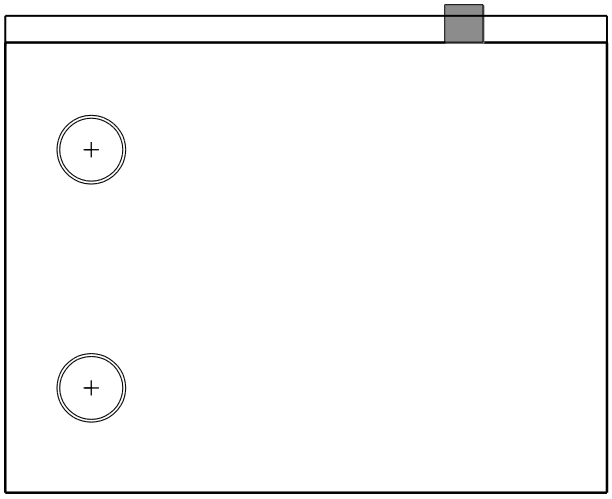


After putting some batteries in the battery holder, the main board can be re-mounted on the PCB supports, and the front panel mounted in the front-most groove in the case.

The cables can then be re-connected, as shown.

When the PIC16F690 is installed in its socket, the clock should be working, but we still need some holes in the top of the case, for the pushbuttons!

These can be drilled, using the guide shown on the right. Again, it can be downloaded, as a PDF file, from www.gooligum.com.au.



The guide should be glued to the top of the case. It should be placed with the thin line along the back of the case, and the shaded square directly above the dimmer switch cut-out in the back panel (the heavy line corresponds to the main circuit board), as pictured below.

When drilling holes in plastic, it's usually easiest to drill a smaller pilot hole first, and then expand the hole with a series of larger drills, checking after each that the hole is on track, by trying to put the case top in place.

After drilling, you will probably need to tidy up the holes with a file or sandpaper.

Finally, after putting the case together, you can affix the adhesive rubber feet to the bottom.

Note that the feet are "intended" to cover the screw holes – but if you do that, you won't be able to unscrew the case to change the batteries!

Therefore, you should position the feet as shown here.

Completed, your simple travel clock should look like this (perhaps a little less dusty):

Operation

The simple travel clock is quite straightforward to use, with only three buttons or switches.

Dimmer switch

The dimmer switch at the back controls the display brightness.

Move the switch to the left (as seen from the front) to dim the display, and to the right to make it bright. Note that the batteries will drain more quickly when the display is brighter.

Setting the time

To set the time, first move the dimmer switch to the "bright" position.

> When the display is dimmed, the time cannot be changed.
>
> This helps prevent the time being changed accidentally, especially at night.

If you now press the "Time" button (the one closest to the front of the clock), the time will advance – slowly at first. After the button has been pressed for a while (fifteen counts), the time will advance rapidly. Remember that "PM" is indicated by an LED in the upper-left of the display. When you are within ten minutes of the correct time, release the "Time" button, and then press it again, to advance the display slowly to the correct time. If you go too far, you'll have to go around again; there is no "reverse" time adjustment!

Setting the alarm

Whenever you press the "Alarm" button (closest to the back of the clock), the stored alarm time will be displayed, and the "alarm on" indicator, in the lower-right of the display, is toggled.

To set the alarm time, first move the dimmer switch to the "bright" position.

> When the display is dimmed, the alarm time cannot be changed.
>
> This helps prevent the alarm time being changed accidentally, especially at night.

Now, while holding down the "Alarm" button, press the "Time" button to adjust the alarm time, in exactly the same way as for the current time.

That is, the "Time" button, when used on its own, adjusts the current time. But when it is pressed while the "Alarm" button is also pressed, it is used to adjust the alarm time.

Note that the "PM" indicator forms part of the alarm time display. This is important, if you want to ensure that you are woken at 6am and not 6pm!

Having set the alarm time, check that the "alarm-on" indicator is lit and, if it is not, press the "Alarm" button (on its own) once more, to turn the alarm on.

Using the alarm

When the "alarm-on" indicator is lit, the alarm is set, and it will sound whenever the current time, displayed by the clock, matches the stored alarm time.

When the alarm is sounding, pressing the "Alarm" button will turn it off. Being a simple alarm clock, it has no "snooze" function…

Remember that you will need to turn the alarm back on (by pressing the "Alarm" button) when you go to bed the next night, if you also want to be woken the following morning!

Sleep mode

To put the travel clock into a low-power sleep (or standby) mode, first move the dimmer switch to the "dimmed" position, and then press both the "Alarm" and "Time" buttons.

The display will now turn off, and the clock will not respond to any button presses – but it will continue to maintain the time!

> Put the clock into sleep mode when packing it into a suitcase. This will not only save the batteries; it also prevents the time being changed through unintended button presses.

To bring the clock out of sleep mode, flick the dimmer switch to the "bright" position. After a delay of a second or two, the display should come back on – and still showing the correct time.

Low-battery indicator

Normally, the decimal point on the hours digit acts as a seconds indicator, flashing once per second.

However, when the battery voltage falls from the nominal 3.0 V of fresh batteries, to only 2.2 V, the "seconds" indicator flashes four times per second.

By the time the batteries get so low, the display will have noticeably dimmed, but if you see the "seconds" indicator flashing quickly, you should definitely change the batteries.

That's all there is to it – have fun using the simple travel clock!

Parts List

1	Pre-programmed PIC16F690-I/P
1	32768 Hz "watch" crystal
2	27 pF ceramic capacitors
1	100 nF monolithic capacitor
8	330 Ω 1/4W resistors
1	10 kΩ 1/4W resistor
4	1 kΩ 1/4W resistors
4	BC548 NPN transistors
4	0.52" common-cathode 7-segment LED displays (e.g. Kingbright SC52-11SRWA)
2	9 mm PCB push button switches
1	Sub miniature horizontal PCB SPDT slide switch
1	PCB ext drive piezo sounder, 10mm spacing (e.g. muRata PKM22EPPH4001-B0)
1	12-pin snappable 0.1" pitch SIL pin header strip
1	20-pin DIP IC socket
1	2-way AAA flat battery holder with fly leads
2	AAA cell batteries (preferably alkaline)
	Double-sided foam tape (to mount battery holder)
4	16 mm adhesive PCB supports
	Suitable instrument case, at least 120 mm × 80 mm × 35 mm (e.g. Jaycar HB-5960)