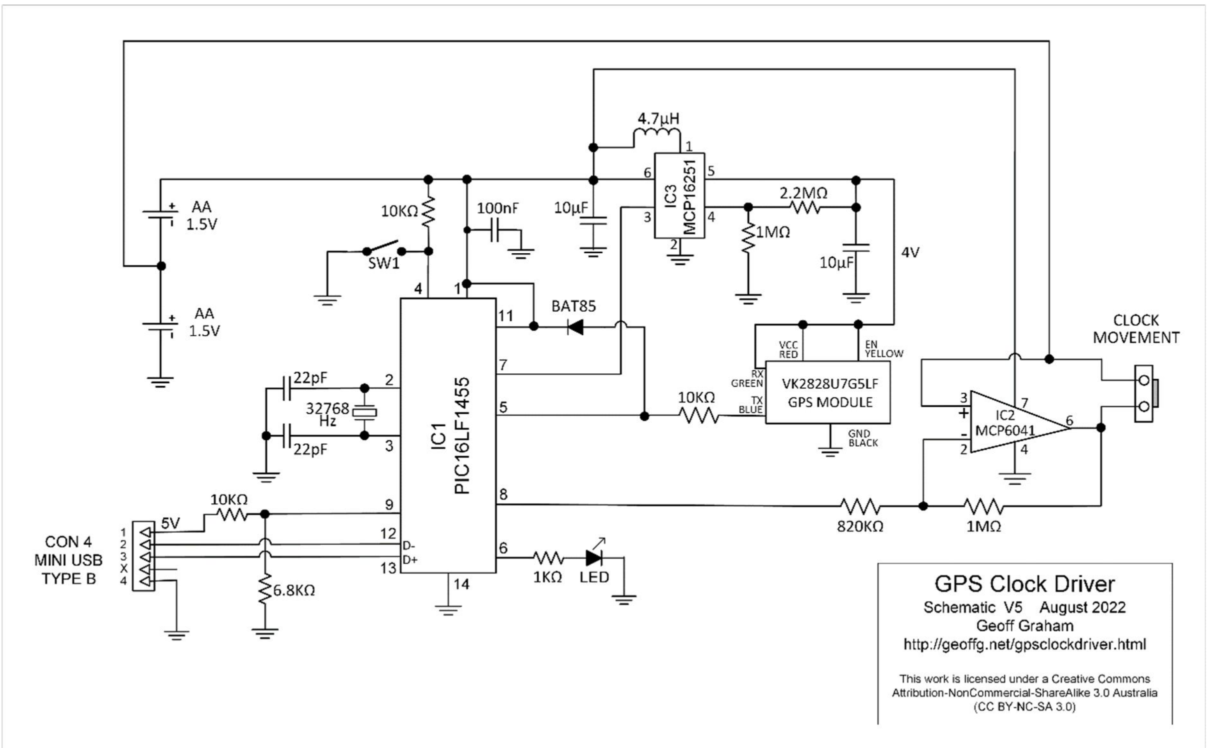
Precision Analog Clock

Construction Notes



The schematic is dominated by IC1 which is a PIC16LF1455 microcontroller. This is a low voltage version of the standard PIC16F1455 and is guaranteed to operate with a supply voltage as low as 1.8V (ie, less than the voltage at which the clock's motor would have stopped running).

Pins 12 and 13 are the USB signal lines – the PIC16LF1455 includes all that is needed for the USB interface including the amplifier/drivers and the pullup resistors. So interfacing to USB is easy. The PIC16LF1455 will also sense the host's clock rate and trim its internal USB clock accordingly so we do not need a crystal oscillator for this.

Pin 9 senses the USB +5V from the host so that the firmware can detect if the USB is plugged in or not. The dropping resistors ensure that the voltage is not too high when the microcontroller is running on a low battery voltage (ie, near flat).

Pin 7 is the enable signal to IC3 which is a Microchip MCP16251T DC to DC converter. This can operate with an input below 1.8V and will generate an output of 4V on pin 5. This voltage is determined by the ratio of the 2.2MΩ and 1MΩ resistors. The MCP16251T has a low leakage when turned off and will also disconnect its output when turned off, an unusual feature in DC to DC converters but important as it prevents the GPS module from drawing current when it is not needed.

The GPS module is a V.KEL VK2828U7G5LF which can operate with a supply voltage between 3.3V and 5V. Its output is clamped to the battery voltage by the 10K resistor and BAT85 diode to prevent it from damaging the microcontroller at low battery voltages. Other GPS modules that can run on 4V can be used in this position as the firmware will search the most common baud rates (4800, 9600 and 19200 baud) for a signal.

Instead of the GPS module you can use the WeMos D1 Mini WiFi module. With the correct firmware loaded this will use your WiFi network and Internet connection to get the time from a public time server. This works the same as a GPS module with no change to the circuit or firmware.

IC2 (a Microchip MCP6041) is an operational amplifier used to drive the clock's motor. The microcontroller will set its output either high or low which results in IC2 driving its output low or high with respect to the midpoint between the batteries. At idle between pulses the microcontroller will set its output to high impedance which will result in IC2's output being at the midpoint.

The MCP6041 was selected because it can operate at below 1.8V, has a very low quiescent current and can swing its output from rail to rail.

Parts List

1 PC board 99mm x 56mm (see the zip file in the Construction Pack).
1 GPS module V.KEL VK2828U7G5LF **-or-** WeMos D1 Mini WiFi Module (ie, Altronics Z6441)
1 32.768KHz Clock Crystal (eg, Altronics V1902 or similar).
1 4.7 µH, 4.3A Wire-wound SMD Inductor with a Ferrite Core, EPCOS, B82464-A4 or similar
1 Mini Type B USB Socket SMD Mount, Oupiin SS-8969-B05C00DBU (Altronics P1308)
1 Momentary Push Switch (eg, Altronics S1120 or similar)
2 Single AA Battery Holder PCB Mount (eg, Altronics S5029 or similar)
1 2-way Header Plug, 2.54mm Pitch (eg, Altronics P5472 or similar)
1 2-way Header Socket, 2.54mm Pitch, PCB Mount 90° Pins (eg, Altronics P5512 or similar)

Semiconductors

1 PIC16LF1455-I/P microcontroller (IC1). PDIP-14 package.
1 MCP6041-I/P Operational Amplifier (IC2). PDIP-8 package.
1 MCP16251T-I/CH DC-DC Boost Converter (IC3). SOT-23 package.
1 BAT85 Schottky diode (D2)

Capacitors

2 10µF 16V Ceramic Capacitor X7R Radial, TDK FK26X7R1C106M or similar
1 100nF Monolithic Ceramic
2 22pF Ceramic

Resistors (0.25W 5%)

1 1KΩ
1 6.8KΩ
3 10KΩ
1 820KΩ
2 1MΩ
1 2.2MΩ

Notes:

Part numbers used by Altronics (https://www.altronics.com.au/) have been used as a reference for some components, but this is not mandatory and there are many other suppliers and you can use the Altronics description to verify that their parts are compatible.

Use https://octopart.com/ to find semiconductor suppliers.

The V.KEL VK2828U7G5LF GPS module is recommended and can be found on eBay and Banggood.com However, many other modules can be used (they must operate with a 4V supply and have TTL level outputs at 4800, 9600 or 19200 baud).

The WeMos D1 Mini WiFi Module or clones of it can be purchased from Altronics or Jaycar (cat XC3802) or many other suppliers on eBay.

Do not substitute the BAT85 Schottky diode. It has a low reverse leakage which is required to minimise battery consumption.

For the PCB I used JLCPCB (https://jlcpcb.com/). Just drag and drop the zip file. They charged US$6 (including postage) to make and supply 5 boards with excellent quality.

Assembly Notes

Refer to the high-resolution image of the PCB for component placement and assembly details.

With surface mount components always use plenty of liquid flux and very little solder. For a tutorial on soldering surface mount see this video:
http://store.curiousinventor.com/guides/Surface_Mount_Soldering/101/

If you are going to mount the batteries separately you should remove the battery connectors on the PCB before starting assembly. Using a sharp craft knife to deeply score the PCB along the lines marked and snap the excess PCB off.

There are four solder pads on the PCB marked EXT BAT and they should be used to connect the external batteries.

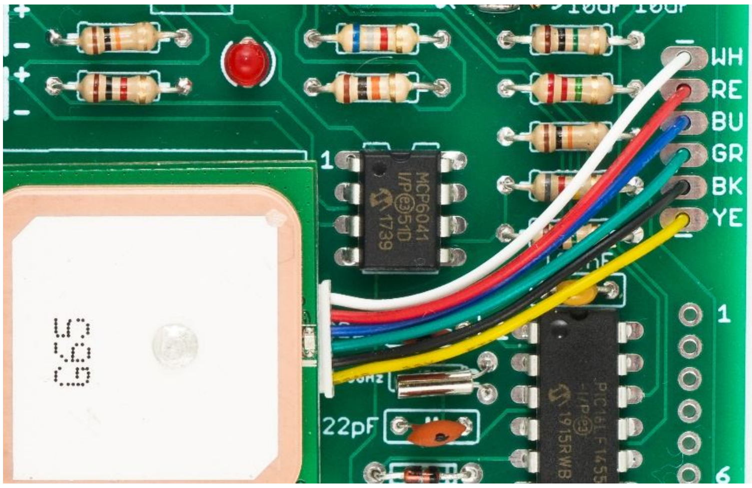
Do not put a battery into the clock movement. The internal controller is disconnected when the movement is modified (see next page) and does not have to be powered.

Start assembly with the MCP16251T DC-DC Boost Converter (IC3). It is a small chip so you will need at least a 10x magnifier. A dot on the top identifies pin 1 but it is easier to read the four letters engraved on the top – the first two should be “MB” while the last two can be anything (they are a trace code). With the letters correctly orientated pin 1 will be the bottom left-hand pin.

Next should be the Mini USB connector followed by the 4.7 µH inductor (both are surface mount). Everything else is thru hole and you should start with the low profile components (resistors, the diode, etc) and work up to the taller components (capacitors, battery holders, etc).

GPS Module

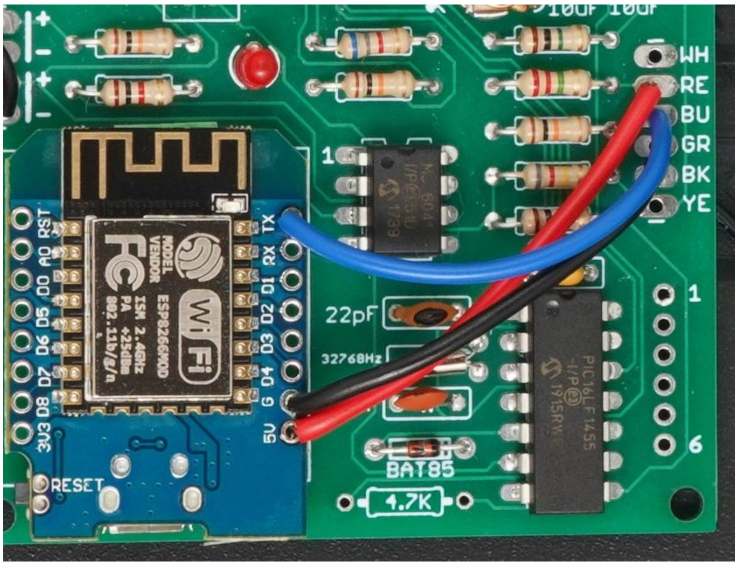
The V.KEL VK2828U7G5LF GPS module is supplied with flying leads and a matching connector. The solder pads for these leads are on the right of the PCB and are coded with the colours (RE = red, WH = white, BU = blue, BL = black, etc).



Mount the GPS module on the PCB using double sided foam adhesive tape. The ceramic antenna must be on top and the metal shield (with the part number, etc) should be against the PCB.

WiFi Module

The WiFi module must first be loaded with the firmware to emulate a GPS module. See the folder *MeMos D1 Mini Firmware* in this ZIP file for the firmware and instructions.



Connect the module as follows:

- Pin **5V** should connect to the solder pad **RE**
- Pin **G** should connect to the solder pad **BK**
- Pin **TX** should connect to the solder pad **BU**

Fasten the module on the PCB using double sided foam adhesive tape. The metal shield (with the part number, etc) should be on top.

Loading the Clock's Firmware

There are six solder pads on the lower right corner of the PCB for programming the microcontroller. Populate this with a six pin header and use a PIC programmer (PICkit 3 or 4 programmer recommended) to program the firmware.

The firmware is included in this ZIP (*GPS_Clock_Driver_Firmware_V1.01.hex*).

See this webpage for a detailed tutorial on the process:
https://geoffg.net/programming_pics.html

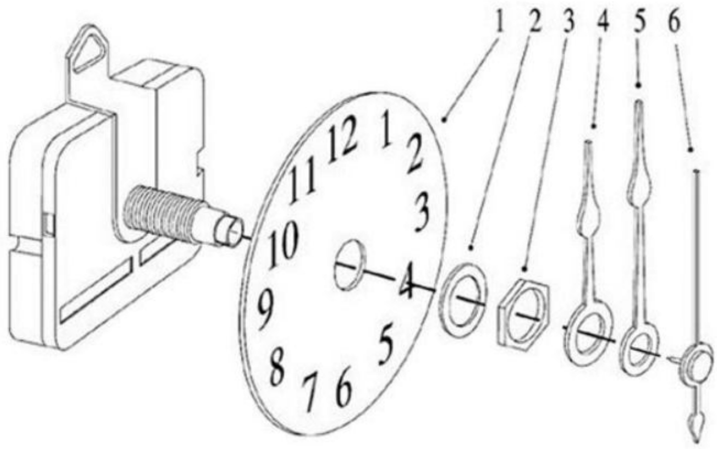
Mounting the Controller PCB

The PCB can be mounted on the back of the clock using double sided foam adhesive tape.

Modifying the Clock

The aim is to remove the clock's movement, dismantle it then disconnect its internal controller and connect two flying leads to the clock's motor.

To remove the movement you will need to first remove the clock's hands. Most are a friction fit on the shaft and can be gently pulled off the shaft.

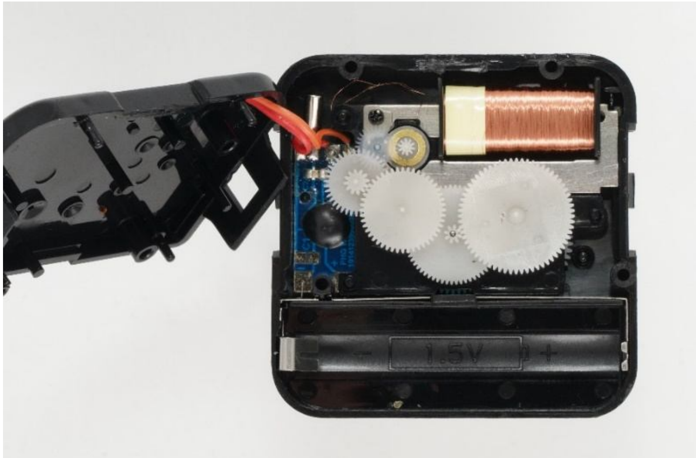


1 The clock's face
2 Washer
3 Retaining nut holding the movement to the clock face. In some clocks the movement is held onto the clock face by clips on the back of the face.
4 Hour hand (a friction fit)
5 Minute hand (on high end clocks this is held down with a circular nut)
6 Second hand (a friction fit)

With the movement free you can remove its back cover.

Important:
1. Take <u>plenty</u> of photos as you progress. Inevitably the gears will fall out and you will need detailed photographs to help put them back.
1. Keep everything VERY clean. Do not let any debris from cutting the PCB track or drilling the hole in the lid anywhere near the gears in the movement.

In the photo on the right you can see the motor's coil (top right) and the controller board (blue PCB on the left). The motor's coil is terminated on the controller board.



The best approach to isolate the clock's controller chip is to cut a PCB track from the coil's termination point to the controller chip (hidden under a blob of black epoxy).

Then (as illustrated) solder two flying leads to the coil's termination points and feed the leads out via a hole drilled in the movement's top cover.

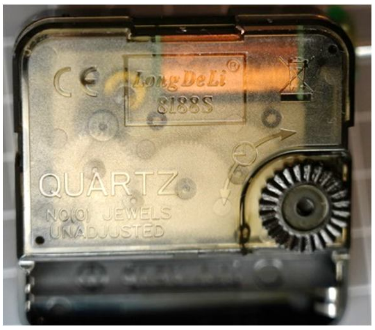
Finally, terminate the leads with a 2-way Header Plug (2.54mm Pitch). For example: Altronics.com.au part number P5472.

If you have a stepping clock you can test the modification by connecting a single AA battery to the leads. Every time you reverse the polarity of the battery the second hand should make one step.

This video shows someone dismantling and exploring a stepping clock and might be helpful: https://youtu.be/LGnbOOF1oeo

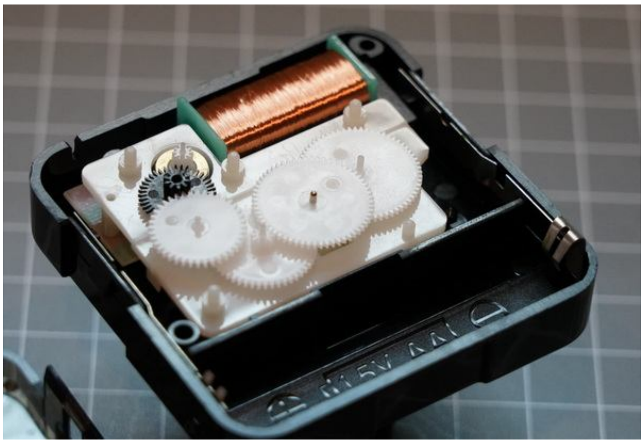
Example of modifying a clock movement

The following images show the progress while modifying an Ikea TJALLA clock movement.

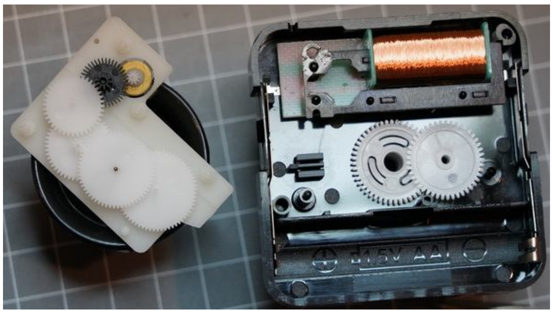


First, the unmodified movement.

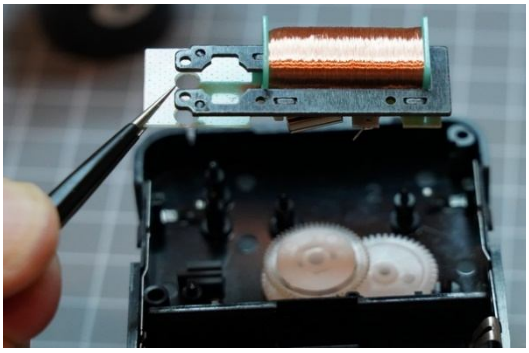
Then the movement with the cover removed.



Below is the movement with the top plate removed. This holds most of the gear train. The clock’s motor and the control board can be clearly seen at the top of the photo.

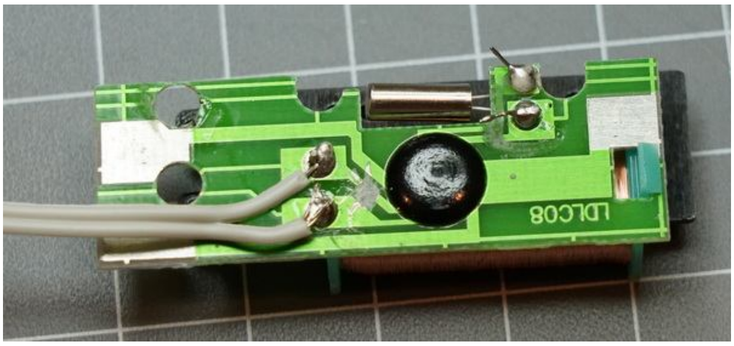


This is the motor + control board removed from the movement.



The reverse side of the motor + control board modified for the GPS Clock Driver.

You can see the termination points for the clock’s motor and the flying leads connected to these. Also, you can see where the PCB track from the clock’s controller IC (hidden under the black blob) has been cut thereby isolating it.



This is the clock movement reassembled and placed back into the clock’s housing. The flying leads can be seen exiting the movement via a hole drilled in the top cover.

This version of the GPS Clock Driver uses two external C sized alkaline batteries.