Main Screen information
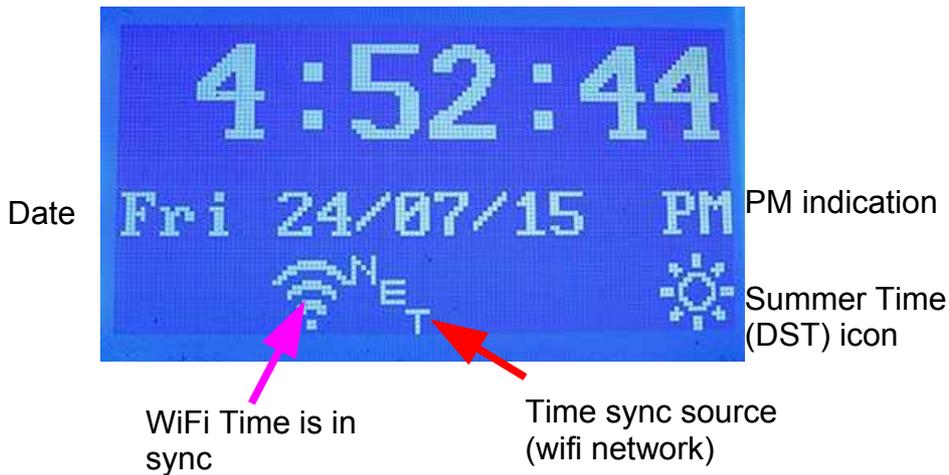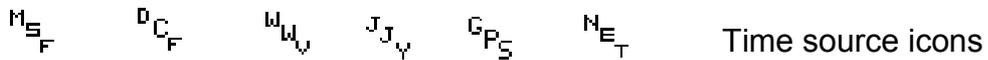
This screen shows the time & date plus some status icons.

Time always shown in 12 Hour format

Date

PM indication

Summer Time (DST) icon

WiFi Time is in sync

Time sync source (wifi network)

The time sync and time source icons are only displayed when a time source is configured. (The icons vary according to the type of time source in use)

   Time source icons

The four radio time sources also display an animated radio transmitter icon with waves to indicate data reception activity.

The GPS source reception is shown using a satellite dish icon.

A clock icon appears briefly whenever a good sync is received.

A phone handset icon is shown on the left when a call is in progress.

A cross indicates calls will not be accepted due to a problem with the time.

(time is not valid)

LED indicators

Green LED: Power on
Yellow LED: Time has been synchronised within the last 72 hours.
Red LED: A call is in progress
Blue LED: Data activity indication from the selected time sync device.

There are also two small surface mount internal LEDs
Red LED on RTC module: RTC module power on
Green LED on Catalex Sound module: Sound file being played.

Controls

A volume control (with switch) turns on and adjusts the loudspeaker volume to locally check the voice announcements. (this does not affect the volume of the telephone line announcement).

A rotary encoder with built-in push-button provides clock configuration and information facilities.

- Turn the knob one click to view the call statistics.
    - The screen shows the number of calls received in the current and previous Hour/Day/Week and Month
- Turn another click to view the information screen.
    - This screen shows the:
    - Firmware version
    - Total uptime in days
    - A UTC time-stamp for the last time sync received
    - The average call length (in seconds) for the last 8 calls.
- Turn the knob again to return to the time display(the time display also resumes automatically after 3 minutes of inactivity)

- Press the button while viewing the time to enter the configuration menu. In the main menu screen, turn the knob to scroll up/down through the menu and press the button to select an item to view or adjust.
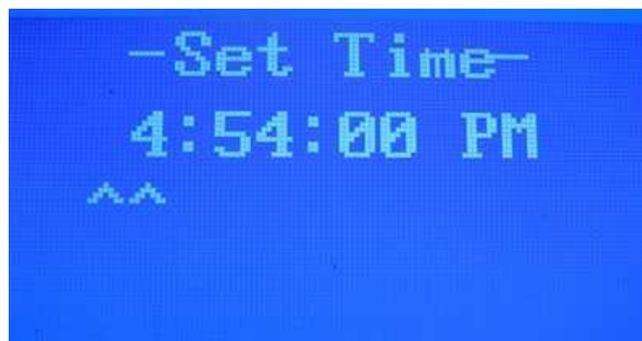
The configuration menu is accessed by pressing the button from the time display screen.
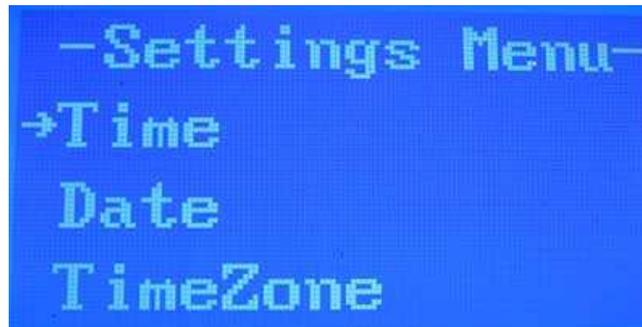
Turn the knob to scroll up/down the menu, press the button to access an item.
(Hold the button pressed for 2 seconds to quit)

Time setting

The vertical arrows show the field being adjusted. Each button press moves to the next field. Turn the knob to adjust the value. After setting AM/PM the button press shows a Save/Quit option.

Selecting "Save" updates the time immediately (seconds are always set to zero).
Selecting "Quit" exits without making any changes to the time.

If a call is in progress, a warning will be displayed when accessing this menu item.
(The call can either be terminated to allow setting the time or quit).

Date setting

Date configuration is required for automatic DST hour changes.

The date is shown in UK format and adjusted in a similar way to the time (see above).

If the day is set to an invalid value for the month (e.g. 30th February) an error message will be shown and the date save will be rejected.

Timezone

Turn the knob to select a positive or negative timezone offset from GMT.

The time will be shown with the specified offset applied.

This setting is intended for applying the local timezone offset to the received time sync obtained from radio, wifi or gps time sources.

If a call is in progress, a warning will be displayed when accessing this menu item.
(The call can either be terminated to allow setting the timezone or quit).

DST region

Turn the knob to enable and select automatic DST (Daylight Savings Time) hour correction for your region.

Preset rules are available for UK, Europe, USA, Australia, New Zealand and Mexico.

Use the "Custom" option to manually configure rules for other regions or if your country changes their DST rules.

(NOTE. This clock doesn't support the small number of locations that don't use Sunday as the DST changeover day).

Voice

The SDcard contains the files for the default voice (Pat Simmons)

If other voice files are added to the sdcard they will be selectable here.

If USA format voice files are found, a message will be displayed to indicate this.

(USA voices include Morning, Afternoon and Evening announcements and the announced time is synchronized using a single tone).

Any one of up to 16 voices can be selected if available

Voice Volume

This sets the voice volume sent to the telephone line (usually set to the maximum level 30)

It also affects the volume heard on the loudspeaker)

As the knob is turned, the voice will speak the selected volume setting.

Time Source

The time can be synchronized with external time sources.
These sources require compatible optional receiver hardware to be connected to the clock.
The following settings are available:

- **None** The clock does not sync with any time source (Time and Date must be manually setup and timekeeping accuracy depends on the internal temperature compensated crystal oscillator.

- **MSF** Sync with the 60Khz radio time signal broadcast from Anthorn Radio Station in Cumbria UK. (Requires external radio receiver module).

- DCF77 Sync with the 77.5Khz radio time signal broadcast from Mainflingen Radio Station in Germany. (Requires external radio receiver module).

- JJY Sync with the 60Khz or 40Khz radio time signal broadcasts from Japan. (Requires external radio receiver module).

- WWVB Sync with the 60Khz radio time signal broadcast from Fort Collins, Colorado USA (Requires external radio receiver module).

- GPS Sync using GPS NMEA 0183 $GPRMC timestamps (Requires a suitable externally interfaced GPS module) (Cannot be used if a Wi-Fi module is installed).

- **Wi-Fi** Sync to a server via your wifi network. (requires the internal Wi-Fi module configured to access your network (SSID & password)

- **Auto** The clock attempts to use any available time sync device found. (this may take some time).

Once a time source has been setup, the clock will initially attempt to receive the time signal and sync to it. Synchronisation is indicated by the display icons. The Blue LED will flash to indicate data activity and the Yellow LED will light when a successful sync has be received.
The radio time sources will continually be received and the time will be updated every minute if the data is validated (no errors detected).
A sync will be deferred if a call is in progress to avoid any sudden time announcement changes.

The Wi-Fi or GPS module will subsequently only be powered-up at a random time between midnight and 7am each night until valid time is received or a time-out occurs. (This ensures the module does not waste power and also prevents the wifi module becoming blacklisted for excessively requesting the time from a server.)

If the clock fails to receive any valid time sync update after 72 hours, the Yellow LED will turn off to indicate the time is no-longer synced. (The clock will continue to keep time using its internal oscillator which should be accurate to within about +/- 5 seconds per month).

Timekeeping

This allows very fine-adjustment of the clock's RTC module internal crystal oscillator which can improve the timekeeping accuracy to better than the manufactures specification of +/- 5 seconds per month.

If the RTC module has been calibrated to a better accuracy by the maker of TIM2015 a calibration value will be written on the module. (Enter this value as the timekeeping setting for improved accuracy)

The crystal accuracy can drift with age so you may need to adjust this value slightly each year to maintain the same quality of timekeeping.

Call Duration

This setting terminates a call after the specified number of seconds (default = 70s to allow a caller to listen to a whole minute of announcements).

If the caller hangs-up before reaching that duration, the clock may be able to detect the call-ended signal and clear the line ready for another call to be received.

Some phone systems don't provide any call-ended signal or use a different protocol. You may therefore need this setting to force the clock to end a call.

Back-light Level

Adjusts the LCD display back-light brightness level.

Masterpulse

The clock provides a pulse output every 30 seconds (available on the "30S" Molex socket at logic level)

This pulse can be connected via a suitable external interface to drive some types of old mechanical impulse slave clocks.

There are options to adjust the pulse width and polarity (low to high or visa-versa) and facilities to send manual step pulses or advance the time.

If DST has been configured, the masterpulse facility also advances or retards the slave clock hour by sending rapid (1 second) pulses or stopping it for an hour at DST changeover.

Voice Audition

This allows you to step though and listen to all of the currently selected voice files. (May be useful for checking that all voices are present and working on the sdcard.)

Diagnostic messages

The clock performs various diagnostics at power-on.

If a problem is detected one of the following messages may be displayed:

"Please set Time"

✖

This indicates no valid time has been set and retained in the RTC module.

Set the time, if it is not retained after power-off, check the CR2032 coin-cell.

"Please set Date"

This indicates no valid date has been set and retained in the RTC module.

Set the date, if it is not retained after power-off, check the CR2032 coin-cell.

Error:01 VoiceHW

The Catalex sound module is not responding.

Try powering off and on again. If it still persists check the module connections and try re-seating the microcontroller IC in it's socket.

Error:02 SDCARD

The SDcard is not inserted or correctly formatted

Try powering off and on again. If it still persists, re-seat the SDcard in it's socket. Try using another SDcard or check the card for file corruption etc. using a PC card reader.

Error:03 Folders

No file folders have been detected on the SD card.

Try powering off and on again. If it still persists,check the card for file corruption etc. using a PC card reader. (the card must have between 1-16 folders containing voice files)

Error:04 RTCchip

There has been an error communicating with the RTC module chip. (this can also be reported while the clock is running)

Try powering off and on again. Try removing the CR2032 coin-cell for a few minutes. Try re-seating the microcontroller IC in its socket.

Error:05 RTCdata

There has been an error with the RTC time or date . (this can also be reported while the clock is running)

Try removing the CR2032 coin-cell for a few minutes to reset the stored time data.

Factory Reset

Clock configuration and RTC module time/date settings can be reset by holding the button pressed at power-on until the following message is displayed:

Factory Reset?
      Yes >No

Turn the knob to move the pointer to "**Yes**" and press the button.
The reset is confirmed by "**Done**" and the clock will restart and prompt for the time to be set.

A factory reset may be required if the clock behaves abnormally or you want to easily reset the user settings back to defaults.

(The reset does not change the network configuration stored in the Wi-Fi module)

Wi-Fi Module setup

The clock can sync the time to the nearest second with network servers using the Wi-Fi module to connect via your own network.

- Enable the Wi-Fi module by selecting it in the "Time Source" menu (save the setting).
- The clock will immediately attempt to get the network time from a server.
- If the module has not been previously configured or is unable to connect to your network for any reason, after a time-out the following screen will be displayed:

"* No WiFi Connection*"
"Use a mobile device, "
"Connect to network: "
 TimeSync-xx
"Use a web browser and"
"address: 192.168.4.1 "
"Then enter your SSID "
"And Network password."

- Use a laptop, tablet or smart-phone. Browse the list of available Wi-Fi access points.
- Connect to the access point "TimeSync-xx" (where xx is the last 2 bytes of the Wi-Fi module mac address.

- When connected, open a web browser and enter the address http://192.168.4.1
- A configuration web page should now be seen on your web browser:

List of local SSID networks
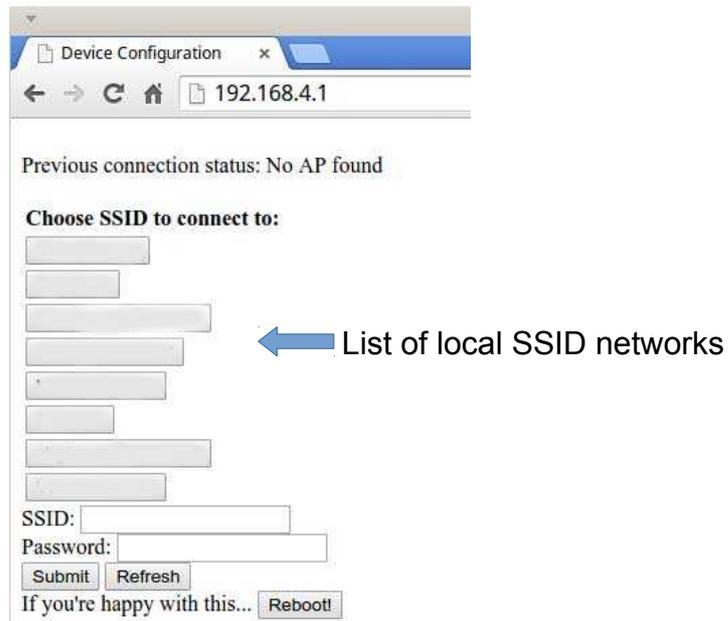
- The clock should also show a screen saying:

"Web Browser Connected"

"Select your Network. "

"And type the password"

- Choose your wifi network from the list shown (or enter the name in the SSID box)
- Enter your network password (case sensitive) then click on "Reboot"
- The module will then reboot,attempt to connect to your network and get the time. (After rebooting the module will no-longer provide an access point or web page and you should re-connect your mobile device back to it's usual network)
- The blue data led should flash briefly whilst requesting the network time and the yellow led should light when successfully synced.
- The Wifi module will then power-off and wait until a random time between midnight and 7am to get the next time sync.
- The module will store your network SSID and password internally. If you change your password or network name you will need to repeat the above configuration process to store the new details.

Serial Data output

The clock provides a logic level serial Time & Date output from the socket marked "SER". This could be used for synchronising other devices via a suitable external interface.

The serial data is sent exactly every 10 seconds at 4800 baud as ASCII chars as shown below:

$hhmmss,ddmmyy*checksum

Example (time=12:25:30 date=4th June 2015   (xx=the calculated checksum)
$122530,040615*xx<CR><LF>

(The time is the current local time in 24hour format)

The checksum is calculated using the bytes after the $ and before the *

Circuit Description

The clock is controlled by a Microchip PIC18F25K22 microcontroller running assembler code at 32Mhz from it's internal oscillator.

Timekeeping is provided by a Maxim DS3231 RTC (Real Time Clock) chip (fitted to module MOD3.)
This chip has an integrated temperature-compensated crystal oscillator (TCXO) and 32768Khz crystal for timekeeping accuracy of ±2ppm (or better) from 0°C to +40°C.
A long life CR2032 lithium 3v coin-cell maintains timekeeping during power failure.

The DS3231 communicates with the microcontroller using a serial i2c Interface and also provides a 1 second pulse to synchronise the voice and time display updates.

(Module MOD3 also contains a separate memory chip which is not used).

The voice time announcements are handled by the Catalex module (MOD4)
This contains a dedicated YX5300 stereo audio processor chip usually used for MP3 players. (It also plays the WAV files used for the voice announcements)
It supports audio sampling frequencies of :
 8 / 11.025 / 12 / 16 / 22.05 / 24 / 32 / 44.1 / 48 (kHz)
Only one audio channel is being used for the mono recordings used here.

The microcontroller controls it using command strings sent at 9600 baud.
Voice files are stored in folders on a micro SDcard. For each time announcement the microcontroller compiles a list of required files and commands the Catalex module to play each one in sequence. The module reports when each file has been played ready for the microcontroller to request the next one.

The audio output is filtered by IC3B (MC33072) op-amp to reduce hight frequencies over 3300Hz as they are above the range used by telephony.

The audio then goes to Module MOD5, a specialized telephone line interface to handle the transmission of audio, call ringing detection and line seize/release.
This module isolates the phone line voltages and provides logic level control lines for the microcontroller to detect incoming calls (ringing) and answer/release them.

The audio announcements are also sent via a volume control (R26) to a audio power amplifier module (MOD6). This contains a PAM8403 stereo 3Watt class-D amplifier chip. This chip uses digital audio processing to achieve an efficiency of up to 90% resulting in lower power consumption. Only one audio channel is used.
The volume control also incorporates a switch output which is inverted by transistor T5 to put the PAM8403 chip into very low power shutdown mode (<1 µA) when the volume is turned off.

A separate part (IC3A) of the MC33072 op-amp provides an audio output for headphones monitor etc. and has its own volume preset (R20).

An 128x64 pixel graphic ST7920 type LCD module (QC12864B) is used for the display. It uses a 3 wire serial SPI interface to communicate with the microcontroller.
Display brightness is controlled using a PWM output from the microcontroller to driver transistor T3.

The user interface is provided by a mechanical rotary encoder (with switch).
When it is turned between each detent it sends a series of logic level pulses via the two wires (A & B). By analysing the phase of these pulse edges the microcontroller determines the turn direction.

Power for the whole clock is provided by the 3Amp regulator module MOD1.
This module contains an MP1584 switching regulator chip running at around 1Mhz for about 85% power efficiency with a 12v input.
The high switching frequency should also reduce any EMI interference which could have degraded a 60/77.5 kHz radio time receiver reception.

Transistor T4 periodically provides power to a small 3.3v regulator (IC1) under the control of the microcontroller.
This 3.3v supply is needed for the Wi-Fi module (MOD2) or can alternatively be used by an externally connected GPS module.

The Wi-Fi module (MOD2) contains an ESP8266 processor which runs a program to handle the initial Wi-Fi configuration and then periodically requests the time from network servers.
This module uses a lot of power when active (about 200mA) Although there is a low power sleep option, the module does not have the necessary sleep pin connected to the header.
This is solved by using transistor T4 to completely cut the 3.3v power when the module is not being used.
Communication is handled by a serial 3.3v logic link to the microcontroller. (The module is not 5v tolerant,needing resistors R17 & R18 to lower the microcontroller output 5v logic levels to prevent damage to the wifi chip).

Optional 30second and serial time data outputs are provided. These are buffered by general purpose transistors T1 & T2.
A separate external interface/power supply will be needed if you want to use these outputs for your own projects such as driving mechanical slave clocks or synchronising other devices.

Coin-Cell battery fitting/replacement

WARNING
- Danger of explosion if battery is incorrectly replaced.
- Be sure to observe the correct polarity when installing the battery
- Do not short-circuit the battery.
- Replace the battery only with a CR2032 lithium battery.
- Use of another battery may present a risk of fire or explosion.
- Battery may explode if mistreated. Do not recharge, disassemble or dispose of in fire.
- Do not expose the battery to excessive heat.
- Dispose of used battery promptly and in accordance with local waste disposal policies.
- Keep away from children.

A **CR2032** Lithium Coin Cell is required for timekeeping backup.

(The clock may be supplied without a battery to comply with postal regulations)

Insert the battery so that it clips into place with the "**+**" marker visible.

The clock allows any one of up to 16 different voices to be selected if available.

The default supplied voice is Pat Simmons from the United Kingdom's speaking clock service from 1963 until 1985.

Files for each voice must all be together in a 2 digit numbered folder e.g. 01 02 03 04 etc. Only .wav or .mp3 files can be used with sampling frequencies of:
 8 / 11.025 / 12 / 16 / 22.05 / 24 / 32 / 44.1 / 48 (kHz)

All files use a 3 digit number. (Don't put any other files/folders on the SDcard or use any file names.)

File nos.	Description	Contents
080	Pips	**Pip pip pip**
081	At the third stroke	**At the third stroke it will be …**
001 to 012	Hours	**'One'** … *up to* **'Twelve'** …
100 to 159	Minutes	**'One'** … *up to* **'Fifty Nine'** … *Or* **'o'clock'** … (100 = 'o'clock', 101 = 'one', 159 = 'fifty-nine')
200 to 250	Seconds	**'And ten seconds'** … *up to* **'And fifty seconds'**… *or* **'Precisely'** … (200 = 'precisely', 210=10, 220=20, 230=30, 240=40, 250=50)

File changes for USA format voices
(the clock uses USA mode if file 082 is found in the selected folder)

080	Tone	**Tone**
081	At the tone	**At the tone it will be …**
082	Morning	**Good Morning...**
083	Afternoon	**Good Afternoon...**
084	Evening	**Good Evening...**

If editing or adding voices, each complete announcement file sequence must not exceed 9.8 seconds.

Manual revisions

v1.0   - Original version.