

Shack Clock

c1.01

1. Introduction

This is the operation manual for the Shack Clock kit. Please read it in conjunction with the assembly manual for building the kit. The clock display is highly configurable by the operator, you can choose time, date, temperature (if suitable sensors are connected) and GPS parameters (if a GPS receiver module is connected).

2. Operating instructions

The microcontroller has a 1024-byte Electrically Erasable Programmable Read Only Memory (EEPROM). This is used for storing your individual settings such as the data displayed on the LCD. When the kit is switched on, it automatically enters the “run” mode, in which the clock display is as you configured it. A default display format is already factory-programmed into the kit.

However, when you have just built the kit and have not yet configured it, upon power-up the kit will enter “Diagnostic Mode”. If you can see this message on the screen, all is well. Press the Left button to continue. If you do not see this message or any writing on the LCD, please refer to the troubleshooting web page.

2.1 Menu system

The user interface consists of the 16-character 2-row LCD and two push-buttons. A 4-row LCD may also be used. There are 13 user-configurable settings available, which control how the time (and other data) is displayed on the screen. The menu system allows all of the settings to be edited. The use of only two buttons to edit so many settings necessarily means that you must scroll through various options by many button presses. Clearly, there is no full computer keyboard in the kit with which to edit your alphanumeric message. However, the use of these two buttons to control the kit is fairly intuitive.

The menu is a list of items and the LEFT button is used to scroll through these items. When you see the item which you want to edit, press the RIGHT button to start editing it.

After cycling through the list of menu items using the LEFT button, the system is returned to the “Run” mode, transmitting the configured message.

Note the final item “Right button to start!”. When this final item is reached, you must press the RIGHT button, which then resumes the “Run” mode. The reason for this is that if, for example, you only wanted to change the contents of the first mode setting. It would be tiresome to have to scroll carefully through the remaining items until the “Run” mode was resumed. There are many configurations and you could easily miss the run mode, re-entering the menu system again at the first item. With the right button start feature, you can simply keep the LEFT button pressed, relying on the automatic button press repeat to quickly cycle through all the remaining menu items and stop at the end. It is also useful for when you want to start the system at an exact time.

2.2 Editing a menu item

There are two types of menu item: alphanumeric (e.g. display format specification), and numeric (e.g. GPS mode and baud rate settings). Editing a configuration is slightly different depending on the type. When scrolling through the list of menu items using the LEFT button, you enter editing mode by pressing the RIGHT button.

2.2.1 Number editing

When editing a numeric setting, the RIGHT button is used to cycle through the numbers 0..9 until you find the number you want. The LEFT button moves rightwards one position to the next character to be edited. The current character being edited flashes. When the final (rightmost) digit has been chosen, a LEFT button press saves the setting into memory and returns you to the menu list.

Note that in some cases, there are restrictions on the value which may be chosen. For example, when editing the 10's of minutes digit, the RIGHT button only cycles 0..5 then returns to 0.

2.2.2 Alphanumeric editing

The most complex editing is alphanumeric, which also includes certain punctuation. The principle is the same as for Number editing: the LEFT button moves the cursor one character to the right, and the RIGHT button cycles through the letters, punctuation and digits. However facilities are also provided to insert/modify/delete one character, or the whole message.

The order of the letters, punctuation and numbers is as follows:

ABCDEFGHIJKLMNOPQRSTUVWXYZ /+~?.,'=(;:
*° #■→←◀◁⊙123456789

The following characters/symbols have special function:

-  **Delimiter:** This character is used to delimit sub-text inside the text entry.
-  **Insert:** Use this symbol to insert a character in the text. Find this character using the RIGHT button, then press the LEFT button to activate it. All the characters to the right of the cursor position are shifted right one position, including the character which was originally in the current position.
-  **Backspace (delete):** If you select this character as the current flashing character using the RIGHT button, then when you press the LEFT button, the current character is deleted and the flashing cursor moves back left one position.
-  **Delete all:** If selected as the current character, pressing the LEFT button has the effect of deleting the entire message, starting again at the left of the screen. There is no “undo”, so use with caution!
-  **Enter (finished):** If selected as the current flashing character, pressing the LEFT button is used to finish editing the setting. The setting is saved, and you return to the main menu list. Note that the text that is saved is only the text to the left of the Enter symbol. If you select this symbol and

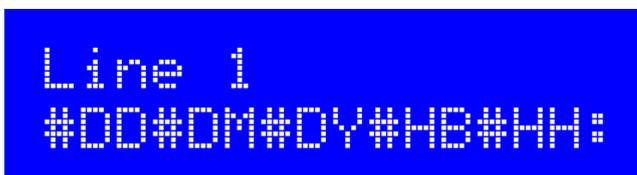
press the LEFT button when you are not at the furthest right position of the message, then everything right of your position is deleted.

Enter Right (finished): The behaviour of this symbol is the same as Enter, except that it preserves all the text, including the text to the right of the cursor. It simply saves the whole line.

Note that when you continue to press the RIGHT button, there is an automatic key-repeat feature so that you can cycle quickly through the characters without having to press the RIGHT button many times. When pressing the RIGHT button continuously, the character will stop cycling at the 'Z', '9' and 'Enter' characters. To resume cycling through the characters, release the button, then start pressing again. This makes editing easier and faster because you are not so likely to go too far past the character you are looking for, and have to cycle through them all again.

2.3 Menu configuration settings

Not all of the user-configurable settings are going to be relevant to your required display, or to your hardware configuration. The following sections explain each setting in detail.



The Line 1, Line 2, Line 3 and Line 4 configurations determine the clock information which will be displayed on the screen rows (Line 1 = top row). The supplied LCD has 2 display rows but the kit is also compatible with 4-line displays. You can enter free fixed text (for example, your callsign). You can also include #tags. Each tag is a # character followed by a two-character identifier. Valid tags are replaced dynamically, by data such as the time, temperature, etc.

The following table lists the available tags:

Tag	Example:	Explanation:
#HH	10	UT hours (24-hour format)
#MM	43	UT minutes
#SS	58	UT seconds
#LH	01	Local time hours (24-hour format)
#LM	43	Local time minutes
#H2	10	Local time hours (12-hour format)
#AP	AM	Local time AM/PM indicator
#GV	A	GPS validity flag ("A" = valid, "V" = invalid, "-" = no GPS data)
#GG	3D	GPS fix status ("3D" = 3D fix, "2D" = 2D fix, "No" = no fix, "--" = no GPS data)
#GF	08	Number of satellites used in solution computation ("--" = no GPS data)
#GT	12	Number of satellites being tracked ("--" = no GPS data)
#GS	31	Average signal to noise ratio of tracked satellites ("--" = no GPS data)
#DD	06	Day of UT date ("--" = GPS data invalid)
#DM	Apr	Month of UT date (3 letters format; "--" = GPS data invalid)
#DY	15	Year of UT date (2 numbers format; "--" = GPS data invalid)
#HB	[Note 1]	1pps heartbeat (see Note 1 below)

#M4	IO90	4-character Maidenhead locator (“----“ = GPS data invalid)
#M6	IO91CG	6-character Maidenhead locator (“-----“) = GPS data invalid)
#T1	24.6	Temperature T1 [see Note 2]
#T2	05.8	Temperature T2 [see Note 2]
#LT	22°32`1799N	Latitude (blank if no GPS data)
#LN	114°01`1823E	Longitude (blank if no GPS data)
#AT	84.0	Altitude (blank if no GPS data)
#LH		

Note 1: The heartbeat is a single-character heartbeat symbol, it beats in time with the received 1pps signal, if a GPS receiver module is being used.

Note 2: Temperatures T1 and T2 are available if temperature sensors have been connected (see assembly manual). In this case, the temperature sensor calibration settings must be configured (see later).

Note 3: The table also indicates the behaviour when no GPS data has been received yet, or when the GPS data validity flag is set to “V” (invalid data). This typically occurs for a few seconds after power up until the GPS has scanned the satellites and received enough for a fix computation.

Many of these tags are derived from data sent by the optionally connected GPS receiver module. This information is updated with freshly decoded data from the GPS every second. It comes from the following NMEA sentences.

\$GPRMC: Latitude, Longitude, Validity flag, Date, Time

\$GPGSA: Type of fix, None, 2D, 3D

\$GPGGA: Number of satellites in fix, Altitude

\$GPGSV: Number of satellites being tracked, signal strength

The default settings for Line 1 and Line 2 stored in the processor EEPROM are:

Line 1: #DD#DM#DY#HB#HH:#MM:#SS

Line 2: #GV #GG F#GF T#GT S#GS

(Line 3 and 4 are empty). These default settings produce a display like the following example:



The display shows date and time on the top line, followed by GPS satellite reception information on the bottom line. The heartbeat will blink in the space between the date and time on the top line.

You can also display multiple pieces of information sequentially on each line. Each line display is delimited by the delimiter character █ (the inverted space character). The display will then loop around all the displays configured, displaying each in turn.

For example, if you enter Line 2 as: “#GV #GG F#GF T#GT S#GS█Long: #LN█Lat: #LT█Alt: #AT”, then you have specified four separate displays, each delimited by the █ character. The bottom line will cycle through the four items:

- i) Satellite information display (#GV #GG F#GF T#GT S#GS)
- ii) Longitude display (Long: #LN)
- iii) Latitude display (Lat: #LT)
- iv) Altitude display (Alt: #AT)

The time each of these sub-lines is displayed is also configurable! See next section.

```
Line 1 Pause
03
```

The number of seconds the sub-lines are displayed for, on Line1. This is only relevant if you have configured multiple sub-lines for the display to cycle through, using the █ delimiter character (see previous section). The default is 3 seconds.

An identical setting is available for Line 2, Line 3 and Line 4. So that each line could, if you wish, have different cycle display times.

```
Temp1 Cal 0C
102
```

```
Temp2 Cal 25C
154
```

These are the calibration values for the temperature sensor when the temperature is 0 and 25 centigrade. The system assumes a linear relationship between the voltage from the temperature sensor, and temperature. In order to calibrate the temperature, two settings are required, at 0C and 25C.

The values are the decimal value of the 10-bit Analogue To Digital (ADC) value measured by the microprocessor at the relevant input pins (see Assembly manual). The full scale value of 1023 represents the Clock supply voltage (nominally 5V).

The default values of 102 and 154 are appropriate for the TMP36 temperature sensor, which has an output voltage of 500mV at 0C, and an output voltage slope of 10mV/C.

The the TMP36 produces 500mV at 0C (0.5V). The corresponding ADC value is $1024 * 0.5 / 5 = 102$. It has an output of 750mV at 25V (0.75V). The corresponding ADC value is $1024 * 0.75 / 5 = 154$.

As an example, suppose the temperature is 21C, which means that the TMP36 is producing an output voltage of 710mV. The value of the ADC will be $1024 * 0.71 / 5 = 145$. The temperature calculation by the processor is:

$$\begin{aligned} \text{Temperature} &= (\text{ADC Voltage} - \text{Cal } 0\text{C}) * 25 / (\text{Cal } 25\text{C} - \text{Cal } 0\text{C}) \\ &= (145 - 102) * 25 / (154 - 102) \\ &= 20.7\text{C} \end{aligned}$$

The displayed value by the #T1 tag will be “20.7”.

Any analogue temperature sensor can be used, with appropriately adjusted calibration values, as long as the voltage/temperature is a linear relationship.

Note also that there is no temperature unit applied by the #T1 tag. If you want a temperature unit, you should include it in the display definition configuration. E.g. to display

20.7°C

You should use the display configuration string “#T1°C”

You can also display in Fahrenheit if you wish; just enter calibration values for Fahrenheit instead of Centigrade. Note also that the LM34Cx sensor chip has an output of 10mV/F directly.

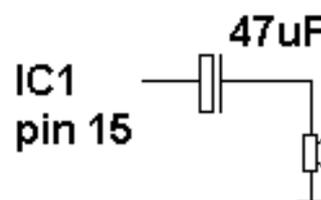
An identical pair of configuration entries applies to Temp2. So you could display two temperatures on the display; for example an inside temperature and outside temperature.



This setting specifies the offset of local time to UT. The time displayed by the #HH, #MM tags is always UT (straight from the GPS, if connected). The #LH, #LM, #H2 tags display local time, offset by the number of minutes in this setting. Positive and negative offsets can be chosen, for time zones ahead of UT or behind UT.



Set the alarm clock here. Alarms operate against the local time. When the local time equals the configured alarm time, an audible alarm is triggered. The alarm tune can be stopped by pressing the right button; otherwise it will play to completion then stop.



This alarm requires a hardware modification as shown (right).

A small speaker, or one half of a pair of in-ear headphones, may be able to be connected directly. If using a more powerful speaker, you may need an audio amplifier.

```
Alarm Enable  
1
```

1 enables the alarm; 0 disables it.

```
GPS (Mode Baud)  
0 009,600
```

The first setting is the GPS mode. This controls how and whether GPS is used. If set to a non-zero value, and a GPS module is connected and producing a valid 1pps signal, then the accurate time pulses from the GPS unit will be used to keep precise time. In the event of a GPS signal outage (for example, poor reception), the kit will continue to use the on-board 20MHz crystal oscillator for time-keeping.

If additionally the serial data connection from the GPS unit is valid, the Maidenhead locator will be computed from the latitude and longitude received from the GPS module, and the internal realtime clock will be set using the time from the GPS module. The other GPS-derived information tags can also be used.

GPS Mode settings:

- 0 GPS is not used at all. The kit is in free-running mode, it will run from it's 20MHz crystal oscillator.
- 1 The kit triggers on a change in the voltage level on the 1pps input. A timer is included to prevent it triggering on both rising and falling edges and to correctly detect the right edge, theoretically. This mode would probably be useful if the pulse width from the GPS is very short.
- 2 The kit triggers on the rising (positive) edge of the 1pps signal. This is appropriate for most GPS modules, where the pulse width is 100ms for example.
- 3 The kit triggers on the falling (negative) edge of the 1pps signal.

Baud Rate setting (default 9,600 baud):

This second setting on the GPS screen determines the baud rate for receiving serial data input from the GPS module. It must be set to match the data output from the GPS module otherwise no data can be decoded. You will need to refer to your GPS module documentation to determine the correct speed.

Any baud rate can be entered here. 9,600 is most common and is the default. The kit should be able to support 115kbps but higher than this may be subject to inaccuracies and may not function properly.

The kit uses no parity, 1 stop bit, and 8-bit data. I have never encountered a GPS module that does not use the same settings, which appear to be very standard.



Sys. Frq.
20,000,000

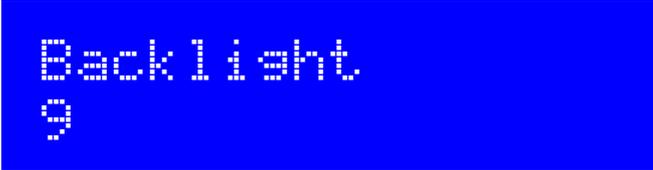
This parameter only needs to be adjusted if a GPS receiver module is NOT connected to the kit. In this case, inputting the correct system frequency must be done to ensure correct timekeeping.

The system clock frequency is the crystal oscillator frequency which clocks the microcontroller. In this kit, a 20MHz crystal is used, and there is no facility for adjusting its frequency – the trimmer capacitor sometimes used in such circuits is omitted here in order to keep the kit as simple and inexpensive as possible.

The system clock is used for timing purposes when there is no GPS module connected to lock the frequency. Where the frequency is slightly different to 20.000000MHz the time-keeping of the real-time clock will become inaccurate.

The best way to measure the oscillation frequency will be to use a general coverage receiver having an accurate digital display, and listen for the 20MHz signal on the receiver, then tune the receiver to zero beat, i.e. until the tone of the audio decreases to 0Hz. Then enter this frequency into the Sys. Frq. configuration setting.

An alternative method may be to measure the time gain or loss over a period of several days, and work backwards to determine the required value to use for the Sys. Frq. Parameter to correct it.



Backlight
9

This setting allows the LCD screen's blue LED backlight brightness to be adjusted. The default value is 9 (maximum brightness). 0 corresponds to minimum brightness – the backlight is switched off.

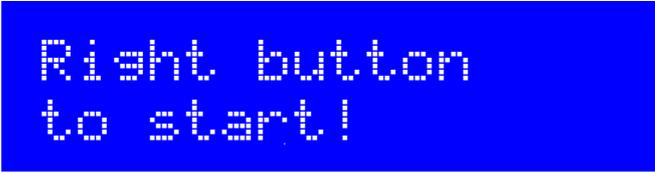
You should also note that the backlight brightness control is achieved by 8-bit pulse width modulation of the LED voltage. The frequency is 610Hz and the duty cycle is varied. Pulsing the 30mA LED could introduce noise onto the power supply so if you are also using a receiver you should check that interference is not caused.



Set Time
00:53

This setting is only required if you have NOT connected a GPS receiver module to the kit. If a GPS is connected, the time should be set automatically.

This configuration allows you to set the real time clock. The clock setting takes effect, and the seconds (internally counted but not displayed) are set to zero, when the LEFT button is pressed after setting the minutes.



Right button
to start!

Finally at the end of scrolling through all the configuration menu items, this screen is displayed. Now simply press the Right button, to start the kit in its display sequence.

You can always reach this screen quickly by keeping the left button pressed to cycle rapidly through the configuration menu items which you do not wish to change.

3. Factory Reset

On powering up the kit, a message is shown for a few seconds on the LCD, which indicates the version number. If the Right button is pressed during the display of this splash screen message, then a confirmation message appears saying "Reset? Sure? Press left btn". Now if you press the left button, the chip EEPROM contents are erased and returned to the original factory settings.

The effect of this feature is to entirely return the microcontroller chip to its original settings, it is the same as buying a new chip and inserting it. All calibration settings are erased and returned to the default settings.

4. Resources

Please see the kit page <http://www.hanssummers.com/clockkit> for any information on latest updates and issues.

Please join the Yahoo group <http://groups.yahoo.com/group/qrplabs/> to for new kit announcements, to discuss any problems with the kit, enhancements you've made, or just to tell everyone how much fun you're having.

5. Version History

1 08-Apr-2015

- Initial version, for firmware version c1.00

2 31-Aug-2015

- c1.01 release
- Support for 4 x 20 LCD.
- Local Time Offset entry, in minutes.
- #LH and #LM tags for local time hours and local time minutes.
- #H2, #AP tags for local time hours in 12-hour format, and "AM"/"PM" display.
- Added alarm function: Alarm, AlarmOn params. To cancel Alarm, press Right button.
- Bug fix: Factory reset copied 2nd display line on 1st, and did not reset second display line
- Bug fix: Factory reset put temperature calibration values to non-Factory values.
- Bug fix: If GPS latitude/longitude displayed on top row, it could cause some display corruption of row 2 in some cases.
- Bug fix: Long message strings, overwrite the top LCD line when looping through menu.

3 02-Sep-2015

- Corrected description of the local time offset (it is 4 numbers, not 3)