Shack Clock

c1.02a

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).

This clock features include:

- GPS date, time and other parameters, using a GPS module such as the QRP Labs QLG1
- Location (latitude, longitude and altitude) and Maidenhead grid square or subsquare
- Display of UT date and time
- Configurable time zone offset, with display of local date and local time
- 10 alarms, which can be configured to switch on and off 6 different external relays or output signals
- Flexible configuration of the display contents
- Multiple messages can be set up to display sequentially on the display lines, for configurable durations
- Support for 4-line displays

2. Operating instructions

The microcontroller has a 1024-byte Electically 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 multiple 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 though 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 three types of menu item: alphanumeric (e.g. display format specification), numeric (e.g. GPS mode and baud rate settings), and boolean (ON/OFF). 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:

Lowercase characters are also available if the "Lowercase" menu setting is set to "ON" (see below). 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 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 though 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.

2.2.2 Boolean editing

Editing a Boolean configuration parameter is very easy. Pressing the right button simply toggles between ON or OFF. When you have set the parameter, press the Left button to save the setting.

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.
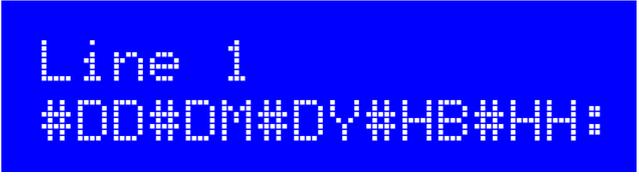
The Line 1, Line 2, Line 3 and Line 4 configurations determine the clock information which will be displayed on the screen rows (Line 1 = top row). The supplied LCD has 2 display rows but the kit is also compatible with 4-line displays. You can enter free fixed text (for example, your callsign). You

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
#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)
#GD		Ground speed (blank if GPS data invalid)
#GC		Ground course (blank if GPS data invalid)
#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)
#ND	06	Day of Local date ("--" = GPS data invalid)
#NM	Apr	Month of Local date (3 letters format; "--" = GPS data invalid)
#NY	15	Year of Local 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 ("-" if no GPS data): degrees and decimal minutes format
#DT	22°5363N	Latitude ("-" if no GPS data): decimal degrees format
#ST	22°32`10"794N	Latitude ("-" if no GPS data): degrees, minutes, decimal seconds format
#LN	114°01`1823E	Longitude ("-" if no GPS data): degrees and decimal minutes format
#DN	114°0197E	Longitude ("-" if no GPS data): decimal degrees format
#SN	114°01`10.938E	Longitude ("-" if no GPS data): degrees, minutes, decimal seconds format
#AT	84.0	Altitude (blank if no GPS data)
#AL		An alarm icon is displayed if the alarms are enabled globally
#R0	1	State of the relay output pin for relay 0
#R1	2	State of the relay output pin for relay 1
#R2	3	State of the relay output pin for relay 2
#R3	4	State of the relay output pin for relay 3
#R4	5	State of the relay output pin for relay 4
#R5	6	State of the relay output pin for relay 5
#A0	19:03 19:04 -0	Definition of alarm 0

#A1	19:03 19:04 -0	Definition of alarm 1
#A2	19:03 19:04 -0	Definition of alarm 2
#A3	19:03 19:04 -0	Definition of alarm 3
#A4	19:03 19:04 -0	Definition of alarm 4
#A5	19:03 19:04 -0	Definition of alarm 5
#A6	19:03 19:04 -0	Definition of alarm 6
#A7	19:03 19:04 -0	Definition of alarm 7
#A8	19:03 19:04 -0	Definition of alarm 8
#A9	19:03 19:04 -0	Definition of alarm 9
#I0	573	Raw value of the ADC input 0 (refer to later section)
#I1	573	Raw value of the ADC input 1 (refer to later section)
#I2	573	Raw value of the ADC input 2 (refer to later section)
#I3	573	Raw value of the ADC input 3 (refer to later section)
#I4	573	Raw value of the ADC input 4 (refer to later section)
#I5	573	Raw value of the ADC input 0 (refer to later section)

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), and if the relay 1 and relay 5 alarm outputs are NOT being used. 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.

Additional formatting options

Each of the data tags can be modified with additional formatting options. These can be used to display a subset of the text in the data field. The two formatting options are:

1) Start character

2) Number of characters to display

These numbers are single digits and are inserted between the #, an additional #, and the 2-character tag specifier. So, when the # is doubled, it means you must specify two digits specifying the additional formatting options.

An example will make this clear:

Suppose you want to limit the resolution of the latitude to fewer characters. If the full text displayed is for example,

114°01`1823E

Then if you use the tag with additional formatting options: ##07LT, this will start the displayed text at character 0 (the leftmost character) and show only 7 characters. The displayed text will be:

114°01`

However, now you have lost the E/W suffix (East/West). You could resolve this by concatenating two tags as follows: ##07LT##B1LT. The second tag specifies taking 1 character at the 11th position in the field. 11 is specified by the B – because each of the characters in the format specifier (start character and number of characters) are actually hexadecimal. They accept the decimal range of values 0 to 15, represented in hexadecimal as 0 to 9 and A to F. Now the displayed text is:

114°01`E

Alternating between multiple displays

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.

```
Lowercase
OFF
```

This is a Boolean parameter. If it is ON, then the lowercase letters a to z will appear after the uppercase A to Z, when editing alphanumeric parameters (the display lines).

```
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:

Temperature = (ADC Voltage – Cal 0C) * 25 / (Cal 25C – Cal 0C)

$$= (145 – 102) * 25 / (154 – 102)$$

$$= 20.7C$$

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.

Note, if you use T1 and T2 you cannot use Alarms with I/O pin (Relay) assignments 1 or 5 respectively: they will use the same I/O pins, and the Alarm outputs override temperature.

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. 9,600 baud is appropriate to most modules, including the QRP Labs QLG1 kit.

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.

```
GPS Checksum
OFF
```

This Boolean setting controls whether the checksum validation is performed on the GPS data NMEA sentences. If set to ON, and the checksum validation fails (for example due to noise corrupting the data on the wires), then the invalid data is ignored.

```
Local Offset
+120
```

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, #AP and #H2 tags display local time, offset by the number of minutes in this setting. Additionally, Local date tags are available, these are #ND, #NM and #NY representing day, month and year respectively.

Positive and negative offsets can be chosen, for time zones ahead of UT or behind UT.

```
3] On Off  Rly
19:03 19:04 -0
```

This is one of the 10 alarm settings. The number of the setting is indicated by the digit in the top left of the display (from 0 to 9). In this example, it is alarm #3.

The screen allows you to configure the following fields, as you press the left button to move the editing position from left to right across the display:

- Whether the alarm is active or not
- Alarm On time (24-hour format)
- Alarm Off time (24-hour format)
- Positive or negative signal on the I/O pin (active High, or active Low)
- Which I/O pin will be controlled by the alarm
- Whether or not the Big Ben (Westminster chimes) tune will be played when the alarm is activated

The alarm tune activation is indicated by a bell icon, which is not available in the HD44780 Windows font. So, below is a photo.

The alarm icon position is indicated by the icon on the top row (label row). The icon in the bottom right corner indicates that the audible "Westminster Chimes" (a.k.a. the Big Ben theme tune) alarm is enabled on this alarm. When not enabled, the bottom right corner is blank.

Start time   **End time**   **Relay**   **Tune**
**Active High/Low**   **enabled**
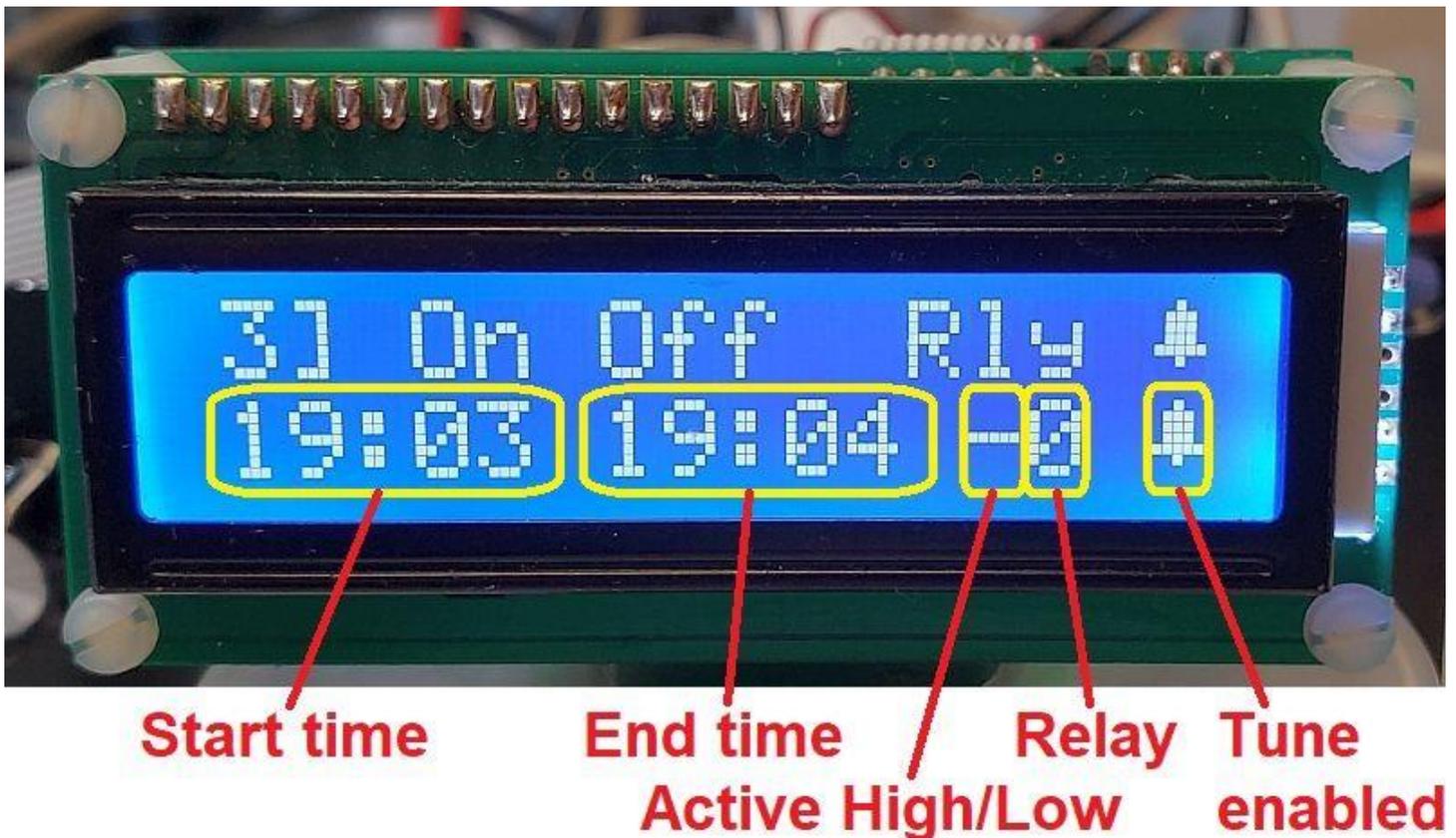
The audible alarm requires a a hardware modification as shown (right). A small speaker, or one half of a pair of in-ear headphones, may be able to be connected directly. If using a more powerful speaker, you may need an audio amplifier.
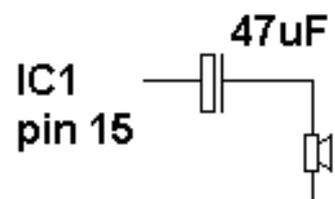
When the alarm is triggered, the Westminster Chimes tune is played, through to completion, then stops. If you want to stop it immediately, you can press the right button.

Scroll through the menu using the left button, to find the Alarm entry you want to edit. Press the right button twice, this will toggle between the Alarm being enabled, and disabled. When the alarm is enabled, it appears as the illustration above. When the entire Alarm is disabled, it is shown with horizontal dashes in the spaces as follows:
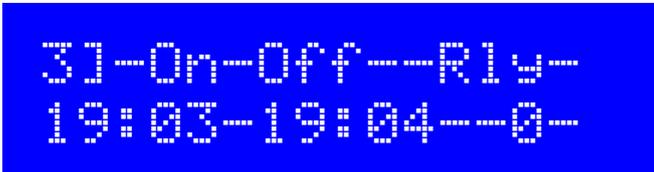
To edit the other fields of the alarm configuration, scroll through the menu using the left button, to find the desired alarm. Press the right button ONCE to begin editing. The top left corner character begins to flash. Now press the left button again, to move the cursor to the 10's of hours digit of the alarm ON time. The alarm ON time is the time at the bottom left.

Press the left button each time you want to move the cursor to the right, one character at a time. Then press the right button, to change the flashing character (at the cursor).

In this way, you edit the Start time (bottom left), and the End time (bottom center).

Note that if you only want an audible alarm, you need only set the Start time. The End time is not required in this case.

Controlling I/O output pins the alarms

There are six available output signals. These are numbered 0 to 5. You can connect to these signals in the locations shown on this diagram:
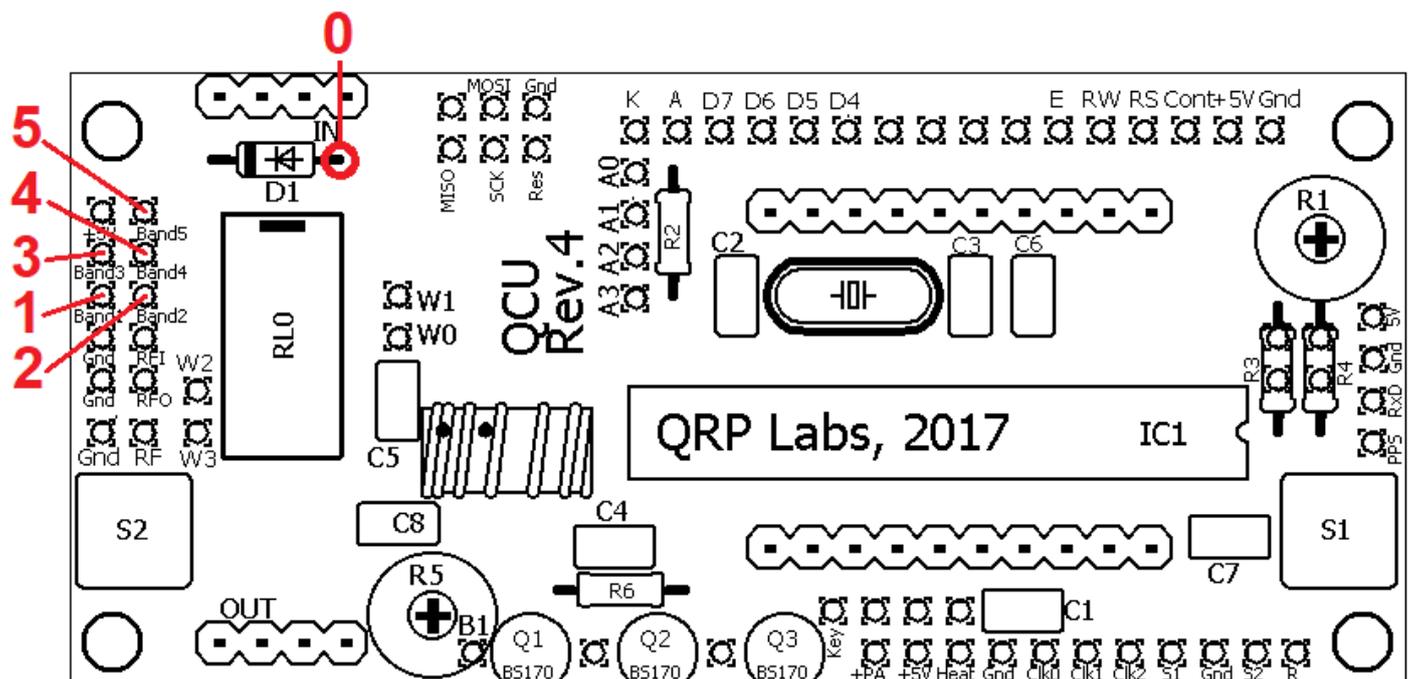
"High" means +5V, "Low" means 0V. You can control whether an output is "Active High" or "Active Low" using the "Active High/Low" character in the alarm display. This is toggled between + (meaning "Active High") and – (meaning "Active Low").

The next field, labelled "Rly" on the display top line, and "Relay" in the former diagram, configures which of the six outputs is controlled by this alarm. You can set it from 0 to 5.

When the "ON" time matches the current time, the corresponding output is set to "High" or "Low" depending on the setting of the "Active High/Low" field of the alarm. When the "OFF" time matches the current time, then the corresponding output is switched Off – the meaning of "Off" depending again, on the setting of the "Active High/Low" field.

For example, if you want to switch output 3 to +5V when the ON time occurs, and 0V when the OFF time occurs, then set up an alarm with the "Rly" field set to 3, and the "Active High/Low" field set to +.

IMPORTANT: it is important to note that the output signals are modified by the Alarm setting, only when the Alarm is enabled and the current time matches the ON or OFF times. The initial state of the output signals is determined by the "Relay Init." configuration parameter, which is explained later in this document.

If you configure alarms using relay outputs 1 and 5 respectively, you cannot use temperature tags #T1 and #T2 respectively.

Controlling QRP Labs TX2/5V Relays with the alarms

The alarms may be used to control relays. One application of this could use the onboard Relay position on the Clock PCB. Suitable TX2/5V relays are available from the QRP Labs shop. The traces are already routed from the microcontroller to the relay coil.

You would need to use the PCB trace diagram below to understand where the traces are connected to the relay. If a relay is installed, you must also install a diode D1 (such as 1N4148, the exact diode type is not critical). The TX2/5V relay is a 2-pole relay, two 2-way switches. Also known as DPDT (double pole double throw). The diagram shows which contacts are common, Normally Closed (N.C.) and Normally Open (N.O.). When the coil is unenergized, Common is connected to N.C. When the coil is energized, the coil is connected to N.O.
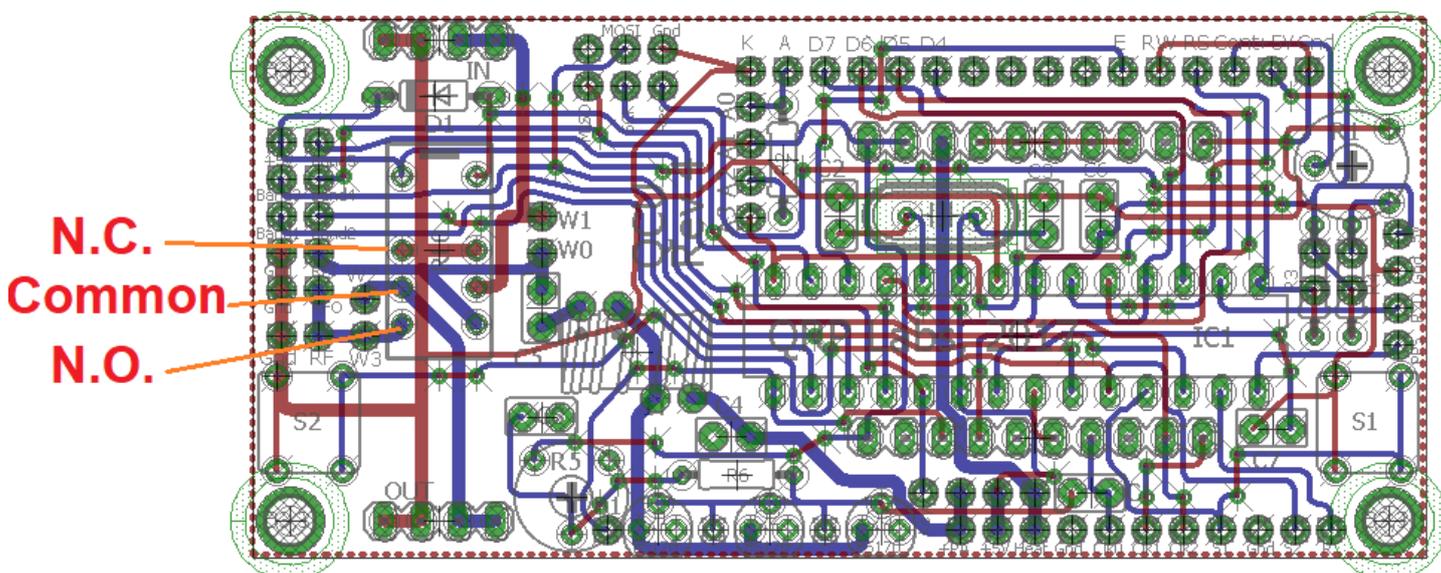
The trace diagram does not show the ground plane which covers the entire top surface of the PCB. It could be difficult to disconnect the N.C. terminals, these are connected to ground. If you wish to use these terminals, you could carefully drill out the through-hole plating from those holes, and use a larger drill bit by hand, to gently remove PCB trace around the hole. Then you could solder wires directly to the relay pin as it protrudes through the PCB.

The Clock kit may also be used with the QRP Labs 6-band relay-switched kit. That kit includes a PCB, six relays and six diodes, and connectors between relay PCB and main Clock PCB. This kit is designed for output Low Pass Filtering for the Ultimate3S transmitter kit; to use it in your applications you may need to cut traces, drill out through-hole plated holes etc.

Note that if the TX2/5V relays are used (on the Clock PCB and/or the relay PCB), the "Active High/Low" field should be set to – (active low), because the relay coils are connected on the PCB between the microcontroller I/O pin and +5V. Therefore, the relay pin must be driven LOW to put 5V across the coil and activate the relay. Corresponding bits in the "Relay Init." parameter (see below) should be set to 1.

The TX2/5V relays have low-current 5V coils, that consume about 28mA of current according to the specification. The AVR microcontroller pins can provide that amount of current. However, **to avoid overloading the AVR and risking damage, it is recommended that no more than TWO relay coils be activated concurrently**.

Driving other relays with the Alarms

If you wish to:

- Drive more than 2 relays concurrently OR
- Use larger relays which have higher current coils
- Use relays with higher voltage coils

you can use this simple circuit (right) to drive relays. Any NPN transistor should be fine. The 1K resistor is required to limit the base-emitter current in the transistor, do not omit it. The 1N4148 (or any other similar diode, it is non-critical) is required to protect the transistor from voltage spikes as the magnetic field of the relay coil is created and destroyed suddenly, do not omit D1. The supply voltage (12V is shown) should be chosen to match the relay coil used.
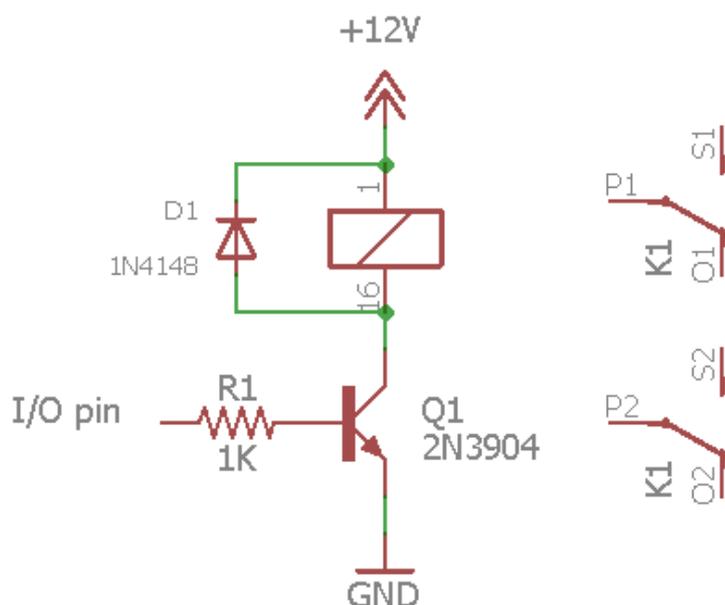
In this circuit, a positive voltage from the microcontroller is needed to switch on the relay, since the transistor has an inverting effect. Therefore, the "Active High/Low" field should be set to + (active high) and the corresponding initialization bits in the "Relay Init." parameter (see below) should be set to 0.

This circuit safely drives the relay from the microcontroller, protecting the microcontroller both from excessive current draw, and the higher voltage supply to the relay. **Remember that the Clock must always be supplied with only 5V, never exceed a 5V supply to the clock circuit.**

Local time or UT time

The alarms can be configured to either operate on the UT time (as it arrives directly from the GPS) or on the Local time. This is a subsequent configuration parameter, it applies to all ten alarms (see below).

If you are operating the Clock without a GPS, then use the "UT time" which is the time which you will set in the "Time" configuration menu.

Alarm parameters in the runtime display

All of the alarm settings can also be shown in the runtime display by using the #A<n> tags where <n> is the alarm you wish to display. For example, if you set the Line2 configuration to the text "#A3" then in the above example, during running of the clock, the bottom row will show:

19:03 19:04 -0

(with the alarm bell icon on the right side).

If you wish to show only limited information about the alarm, you can use the extended formatting feature of the display line configuration. For example, to show only the ON time of the alarm, you could use ##05A3. The double "##" part means that extended formatting is used, with the following two characters indicating the extended formatting. The "05" part of the configuration text means Start character 0, and how 5 characters. "A3" means it is Alarm 3 which is being displayed.

The bottom row of the runtime display will be:

19:03
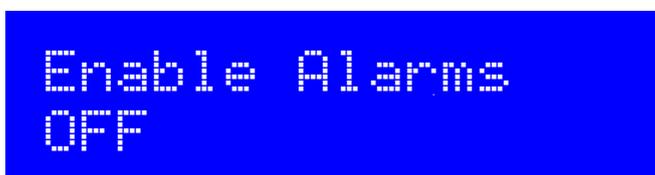
This Boolean parameter comes after the 10 alarms. **It enables or disables all ten alarms together**. It is a global enable override for the alarm system. In order for a particular alarm to be activated, the following three conditions must all be met:

- The "Enable Alarms" parameter must be set to ON
- The particular alarm must be enabled (not dashed out with – characters)
- The ON time must match the current time (which could mean UT time or Local time, depending on the "Alarm Local" parameter).

The state of this configuration parameter can be shown on the runtime clock display, using the #AL parameter. When "Enable Alarms" is ON, the alarm icon will be displayed. When "Enable Alarms" is OFF, just a blank space.
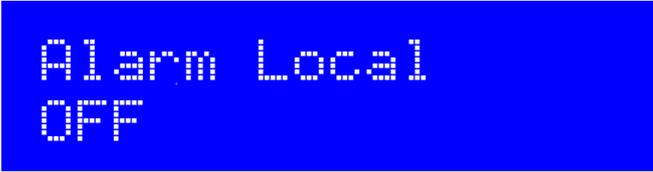
```
Alarm Local
OFF
```

When set to ON, Local times are used all ten alarms.

When set to OFF, UT time is used for all ten alarms.
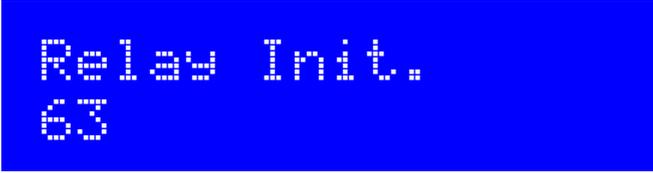
```
Relay Init.
63
```

This parameter specifies the initial state of the Relay outputs (or I/O pins), on power up. The 6 control lines are put in this state at first power up, and thereafter every time the menu system is exited (putting the clock into Run mode).

This setting is the summation of the binary bits specifying the six control lines. You must therefore calculate the value by summing the control line values that will be set to 1 (High, +5V) as follows:

Relay 0: 1
Relay 1: 2
Relay 2: 4
Relay 3: 8
Relay 4: 16
Relay 6: 32

In this example, "Relay Init." is configured to 63. This means all control lines will be 1 (High) on initialization. This is the appropriate setting to use if you have connected QRP Labs TX2/5V relays, which have their coils connected between +5V and the I/O signal. They are "Active Low".

If using other relays and the driver circuits shown, with the Alarm signals set to "Active High", then you could set the initialization parameter to 00.
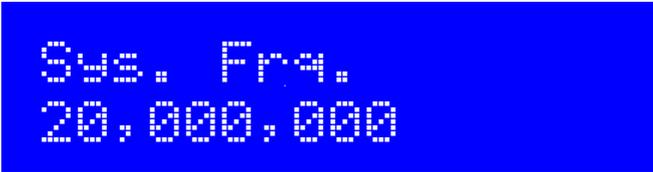
```
Sys. Frq.
20,000,000
```

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 though the configuration menu items which you do not wish to change.

3. Analogue inputs

Using the analog input tags #I0 to #I5 requires that the corresponding processor I/O pins are not in use by any other devices. Not all of the inputs 0 to 5 make sense in all cases.

Refer to the circuit diagram earlier in this manual.

The table below lists which port designations are used for the analog measurements (all are port C), and which processor pin number they are. The table also lists the alternative functions of each pin, and under what circumstances you are able to use it as an analog input pin.

Input	Port (pin)	Alternative function
0	C0 (23)	Shared with Temp 1 and Relay 1: you cannot read analog on this pin, if any of the enabled alarms are configured to use Relay 1. Temp 1 (#T1) also uses this pin. #I0 therefore measures the same value as #T1, but is the raw, unprocessed ADC value.
1	C1 (24)	Shared with button S2 (the right button). A weak pull-up resistor (about 50K) is internally configured on this pin. You *can* measure analog voltages on this pin, but when the button is pressed, the pin is shorted to ground. You may need to use a series resistor from your analog source, such that it is not damaged when shorted to ground. In combination with the internal pull-up resistor, however, this could distort the measured value – therefore try to keep the series resistor as low as possible.
2	C2 (25)	Shared with button S1 (the left button). A weak pull-up resistor (about 50K) is internally configured on this pin. You *can* measure analog voltages on this pin, but when the button is pressed, the pin is shorted to ground. You may need to use a series resistor from your analog source, such that it is not damaged when shorted to ground. In combination with the internal pull-up resistor, however, this could distort the measured value – therefore try to keep the series resistor as low as possible.
3	C3 (26)	Shared with Temp 2 and Relay 5: you cannot read analog on this pin, if any of the enabled alarms are configured to use Relay 5. Temp 2 (#T2) also uses this pin. #I5 therefore measures the same value as #T1, but is the raw, unprocessed ADC value.
4	C4 (27)	Connected to the pad labelled "R" at the PCB edge, and not shared with any other function.
5	C5 (28)	Shared with the GPS 1pps signal. You cannot not use this pin for analogue measurements unless GPS is disabled. Also note that a weak internal pull-up is enabled on this pin (about 50K).

4. 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.

5. Resources

Please see the kit page http://www.qrp-labs.com/clockn for any information on latest updates and issues.

Please join the groups.io QRP Labs group https://groups.io/g/qrplabs 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.

6. 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)

4.   08-Oct-2018

- Firmware c1.02a release, having the following features explained in this manual:
- Support for 4 x 20 LCD.
- Add tags #ND, #NM, #NY for local date days, months and years (taking into account local time offset)
- Upgrade Clock firmware to require only .hex installation, as for other QRP Labs kits
- Added 10 alarm settings, each with start/stop that can control I/O and relays, and be enabled individually
- Add Alarm Local setting, when ON the alarm times use local time (otherwise UT)
- Local time offset configuration parameter changed to 3 digits (enough for all world timezones)
- Add tags #R0 to #R5 which display 1 or 0 to show the state of the specified relay or I/O signal
- Add tag #GD for GPS Ground Speed
- Add tag #GC for GPS Ground Course
- Add tag #AL to show bell icon if the alarm is enabled
- Add tags #DT and #DN for Decimal degrees latitude and longitude
- Add tags #ST and #SN for Degrees Minute Seconds latitude and longitude format
- While running, Right button now toggles enabled state of alarms
- Enable Alarms setting is now an ON/OFF selection
- Add lowercase characters, if enabled by new "Lowercase" setting
- Six new tags #I0 to #I5 which display raw ADC inputs
- 10 new tags #A0 to #A9 which display alarm times
- Optional extended tag formatting ##slNN where NN = tag, s = start character, l = length
- GPS Checksum validation, same as Ultimate3S, if enabled by new "GPS Checksum" setting
- Display "Setting up" message during operator-initiated factory reset
- Bug fix: 6th character of Maidenhead locator incorrect in some cases
- Bug fix: Line1 Factory reset was missing last two characters
- Bug fix: Properly display temperatures of 100 or over