QCX/QCX+/QCX-mini 5W CW Transceiver kit
OPERATING INSTRUCTIONS

Firmware version 1.06

This is the Operating Instructions manual for the QCX, QCX+ and QCX-mini CW transceivers.

All versions of the firmware are compatible with all PCB revisions and all models of the QCX family. However there are features which are specific to certain models.

1) CAT control can only be used on the QCX+, QCX-mini, and the more recent PCB revisions of the QCX (unless you have modified your older QCX to add the three components that facilitate the CAT port).

2) Control of the LCD module LED backlight is only applicable to the QCX-mini and these settings have no effect in the QCX and QCX+ models.

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1. Overview of features

This 5W CW transceiver kit includes a large number of features defined by the firmware in the ATmega328P microcontroller chip. The following is a brief summary of the features to explore and enjoy. Read the subsequent sections for more detailed information on these features.

Synthesised VFO with rotary encoder tuning

The VFO is an Si5351A Synthesiser chip, configured by the microcontroller. A rotary encoder tunes the VFO, with a variable tuning rate. The radio includes two VFOs, A and B. You can swap from one to the other, copy the contents of the active VFO to the inactive one, or operate Split (Transmit on VFO A, receive on VFO B). There is also a RIT mode offering a receive offset of up to +/- 9,999Hz. The CW offset is also adjustable, and CW-R (sideband swap) mode is supported.

Memory features

There are 16 frequency presets for your favourite operating frequencies. Each frequency preset can be edited in the configuration menu, or loaded/saved into/from the currently operating VFO.

Message mode

The firmware supports storage of 12 messages. Four of these are 100 characters long, the other eight are 50 characters long. A single button click shows the list of messages to send. Message sending can be configured to send just once, or a configurable number of times, or indefinitely repeating. The interval between transmissions is also configurable. The message feature can be useful, for example, for setting up a repeated CQ call with a pause between repeats, during which you can listen for any answers. As soon as you touch the key the message sending is canceled. When message sending is in progress an 'M' character appears near the top right of the display.

CW Keyer

Operation with a Straight key is possible, but the firmware also includes an Iambic keyer, for connection of a paddle. The keyer can be configured to operate in Iambic modes A or B, or Ultimatic mode. The keyer speed is variable both from the configuration menu and via a single button press during operation.

With its solid-state, microcontroller operated transmit/receive switch, the radio can operate in full break-in "QSK" mode, or if you prefer, semi-break in.

CW Decoder

A CW decoder operates in the chip. This can be useful on air, particularly for newcomers to CW, though it is never anywhere near as good in QRM or weak signal conditions as a good CW operator using the wet-ware between his ears. The decoder has a "Practice" mode too, for you to practice your CW sending without actually generating RF. The decoder can also be used to conveniently enter text in the message storage, or for configuration of any of the other menu items. The decoder can also be switched off if desired.

CW or WSPR Beacon mode

A beacon is included too, and this can be configured to operate in CW mode or WSPR mode. Owners of the QRP Labs Ultimate-series weak signal mode transmitter kits will be familiar with the operation of WSPR. A GPS module such as the QRP Labs QLG1 GPS receiver kit can optionally be connected to this CW transceiver kit to provide frequency and time discipline, as well as setting the Maidenhead locator (from latitude and longitude) that is encoded in the WSPR message.

S-meter and Battery voltage

An S-meter and battery voltage indicator can be enabled for display on the LCD. These are both configurable to your needs. The battery voltage indicator would be useful if you intend to operate the radio portable on battery power.

Real time clock

A real-time clock can be displayed at the bottom right of the LCD. The time can be set by connecting a GPS receiver such as the QRP Labs QLG1 temporarily to the QCX. When power is disconnected from the QCX, the time is lost and will start at 00:00 at next power-up.

Built-in alignment tools

One of the nicest features of this CW transceiver kit, is the built-in alignment tools menu. The radio can act as its own signal generator, injecting an appropriate signal into the receiver front end, then measuring the audio amplitude after single-sideband demodulation. The menu items allow you to easily peak the Band Pass Filter adjustment, and to adjust the I-Q balance and audio phase shift adjustments for best unwanted sideband cancellation.

Built-in test equipment

For those times when the assembly didn't quite go as well as we hoped, and we need to do some debugging – the radio includes its own suite of test equipment too! None of these items of test equipment are going to replace a $100,000 lab any time soon – but they provide very useful measurements for helping people without much test equipment, to debug the radio. They can even be used for testing other projects too!

- Voltage meter
- RF Power meter
- Audio channel amplitude measurements
- Frequency counter (0 to 8MHz)
- Signal generator (3.5kHz to 200MHz)

CAT control - PC Control commands

The QCX kit also supports CAT control commands by a 38400 baud serial data interface (TTL voltage levels). This implements a subset of the Kenwood TS-480 command set, with one or two minor exceptions.

It is intended to allow easy operation of the QCX in conjunction with logging software, which typically queries the transceiver to determine operating frequency and other operating parameters. The CAT control interface also supports some basic control features for remote control of QCX if required.

GPS Interface

The QCX kit has a GPS interface, which is used for calibration, setting the real time clock, and for frequency and time discipline and locator setting during WSPR operation. The GPS interface (1pps and 9600 baud serial data) shares the same pins as the paddle dit and dah signals (necessary due to limited processor I/O).

The GPS should ONLY be connected during oscillator calibration menus 8.11 and 8.12, or when the beacon is enabled (menu 6.1 is ON). Connection at other times puts the radio into practice mode (no RF emitted) to protect the PA, and may also corrupt menu entries. You may temporarily connect the GPS while in ordinary operation mode, for the purposes of setting the real time clock.

2. Display elements

The kit uses a 2 row, 16 character LCD module. In the QCX and QCX+ models, this has a blue backlight. The QCX-mini has a yellow/green LCD module with backlight that can be switched off to lower current consumption.
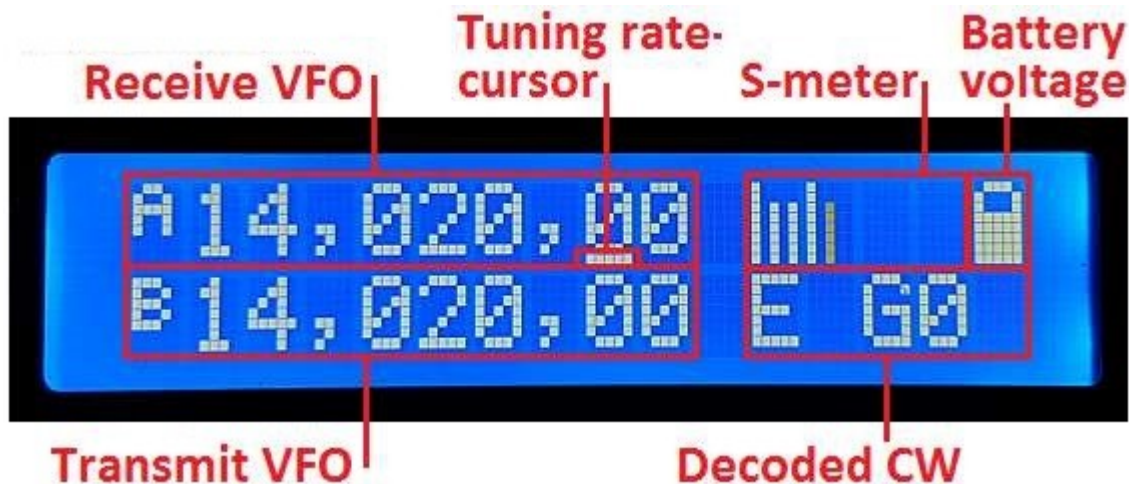
The main display layout during ordinary operation (which will be called "main operating mode") is shown in the above photograph. The display during beacon or message transmission modes, menu editing, alignment etc. differs. The main display elements are as follows:

- The receive VFO frequency is always displayed, to 10Hz resolution, at the top left. This may be VFO A or VFO B. The nominally 700Hz CW offset is automatically applied. Ordinarily this frequency is also used for transmission.
- Tuning rate cursor: the underline appears under the digit which is currently tuned by the rotary encoder. In this example, the tuning rate is 100Hz per click, because the cursor is under the 100Hz digit.
- S-meter: these 4 characters display a basic (and not calibrated) S-meter. The scale is configurable (see later description). The S-meter may be shown or hidden.
- Battery voltage: a battery icon appears to indicate the battery voltage in 7 user-definable steps: from full to empty and 5 steps in between. It may also be shown or hidden.
- Transmit VFO: in SPLIT mode, the transmit VFO is displayed on the bottom row of the display.
- RIT (Receiver Incremental Tuning): when not in SPLIT mode, and when the RIT is non-zero, the RIT value is displayed in the bottom left (where the photo shows the VFO B frequency). When RIT is non-zero, and when not in SPLIT mode, the reception frequency is the transmit VFO frequency (which may be VFO A or B) plus the RIT (which may be a negative offset).
- Decoded CW: The remaining space on the bottom row is used for displaying the decoded CW text. When RIT is zero, and you are not operating SPLIT, the whole 16 characters of the bottom row are used for the CW decoder display. When adjusting RIT or keyer speed, only the right section of the screen is used for decoded CW. The CW decoder may be disabled in the Decoder configuration menu.
- Practice mode: when in CW practice mode (actual transmitting disabled), a 'P' is displayed to the right of the frequency on the top row. If the practice mode was caused automatically as a self-protection, by plugging in the GPS, a 'G' is displayed.
- The bottom right 5 characters can also be used as a real time clock in HH:MM format, which is set either manually in the beacon menu "Set time" or via GPS serial data stream parsing. The clock is enabled by the "Clock" item in the "Other" menu.

3. Operator Controls
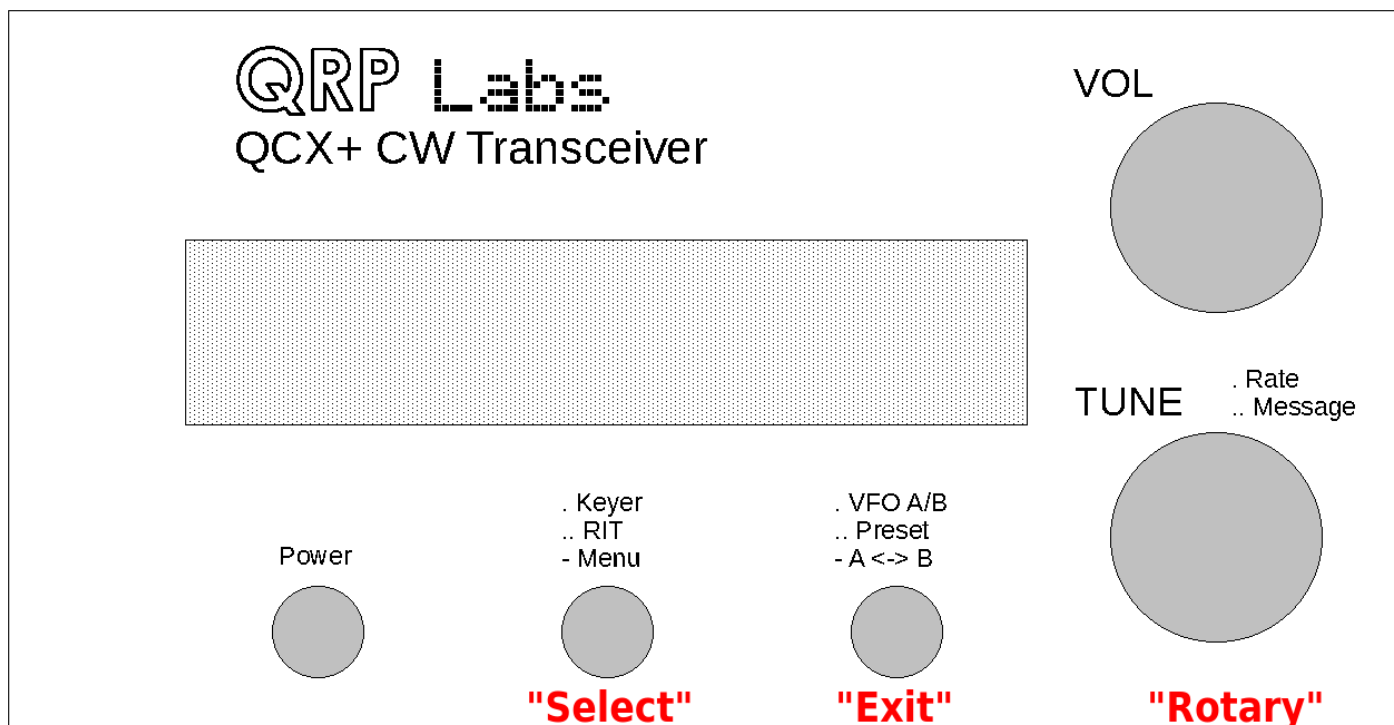
This diagram shows the operating controls of the QCX+ radio as an example. All of the controls except the Gain potentiometer have multiple functions, depending on the operating mode, menu editing, etc. The tuning rotary encoder at the bottom right has a button on its shaft that is activated by pressing it, and this button also has multiple functions.

In this document, the three buttons are referred to as "Select", "Exit" and "Rotary". The button names "Select" and "Exit" respectively, refer to the common actions during configuration menu editing. Select edits a menu item or steps down into a sub-menu; Exit saves an edited menu item or backs up to the parent menu.

It is well worth remembering while you are familiarising yourself with the operation of the radio, that if you get into any unexpected function or menu – you can nearly always press the "Exit" button to cancel and get back to the main operation mode.

Each of the buttons may be pressed once, pressed twice (a double-click) or pressed for a long-hold. This facilitates three different functions for each button. In practice, the "Rotary" button is stiffer and it is difficult to achieve a double-click; therefore the centre button double-click has no function.

3.1 Tune rate

The rotary encoder tunes the active VFO. The rate of tuning is indicated by the underline cursor. In the example below, the underline cursor is under the comma between the 1kHz and 100Hz digits. This means the tuning rate is 500Hz.

The available VFO tuning rates are 1kHz, 500Hz, 100Hz or 10Hz.

A press of the "Rotary" button (in the rotary encoder shaft) causes the tuning rate to change, in the cycle 1kHz -> 500Hz -> 100Hz -> 10Hz -> 1kHz etc.

The default tune rate up at start-up is a configuration item in the VFO menu (see later).

You can also press-and-hold the rotary encoder shaft button, then turn the rotary encoder to move the cursor to the left or right; this allows selection of steps up to 1MHz; turn the rotary encoder within 0.3 seconds of the button press.

3.2   Keyer speed

The default keyer speed (in words per minute) at start-up is a configuration item in the Keyer menu (see later). During operation of the radio, the keyer speed can be easily adjusted. Click the "Select" button once, and the speed will be displayed on the screen:

Now you can adjust the speed using the rotary encoder. Press any button to return to the main operating mode. You may operate the radio while the Speed setting is shown. You can also press the rotary encoder shaft button to select sending a stored message, while the Speed adjustment setting is active.

Setting speed to 0 enables "Straight" Key mode regardless of the keyer mode setting; this is useful for quickly being able to key down for antenna tuning purposes. It is much easier than going into the Keyer menu, selecting straight key mode, doing the tune up, then going back into the menu to change to Iambic again. The normal configured keyer mode is automatically restored when you increase the speed above zero.

3.3   RIT

RIT (Receiver Incremental Tuning) allows the receive frequency to be adjusted while the transmit frequency (the displayed VFO frequency) remains the same. It is useful if the other station is off-tune, or drifting; other uses include working DX stations who may be listening on a different frequency some kHz away from their transmit frequency.

This radio transceiver allows RIT values from -9,999Hz to +9,999Hz.

The default RIT at start-up is a configuration item in the VFO menu (see later). RIT can be easily adjusted during ordinary operation by double-clicking the "Select" button:


Now use the rotary encoder to tune the RIT. As you do so, you will hear the RIT immediately applied to the VFO.

The tune rate of the RIT control is again indicated by the underlined digit (here 100Hz). In order to change the tune rate, press and hold the "Rotary" button (in the rotary encoder shaft) and turn the

rotary encoder at the same time. You will see the cursor move to the left or right 1 digit at a time. Again, the cursor under the comma indicates 500Hz tuning steps.

To cancel RIT tuning (reset the RIT to zero), press the "Exit" button; this returns to main operating mode and sets the RIT to zero.

To return to the main operating mode, press the "Select" button. Now the RIT is displayed under the VFO, for example:
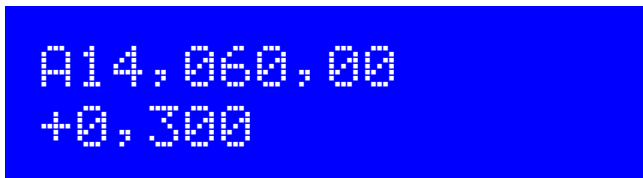
Remember that cancelling RIT mode is easy, just double-click the "Select" button to show the RIT editing, then press the "Exit" button to cancel it (which means, set it to zero).

Transmitting is possible while the RIT display is active. You can also press the rotary encoder shaft button to select sending a stored message, while the Speed adjustment setting is active.

3.4   VFO mode

A single press on the "Exit" button changes the active VFO mode. There are two independent VFOs named A and B. There are three VFO modes for using these VFOs:

- VFO A is active as transmit and receive VFO; if non-zero, RIT is applied during receive
- VFO B is active as transmit and receive VFO; if non-zero, RIT is applied during receive
- Split: VFO A is used for receive, VFO B is used for transmit; RIT is ignored completely

Split mode is often used by DX stations, they transmit and receive on separate frequencies.

3.5   VFO A/B operations

Frequency swap: the contents (frequency) of VFO A and B can be swapped by a single long key-press to the "Exit" button. This can be useful when setting up the VFO frequencies.

Copy VFO A to B: To copy VFO A to B, press the "Exit" button with a long key-press then a single short press. It is similar to tapping a CW 'N' slowly on the "Exit" button.

Copy VFO B to A: To copy VFO A to B, press the "Exit" button with a long key-press then a quick double-press. It is similar to tapping a CW 'D' on the "Exit" button.

3.6   Frequency Presets

There are 16 frequency presets which may be used for storing your favourite frequencies, or for just temporary use, or however you wish!

The presets are labelled 1 to 16, and can be individually edited in the Preset menu (see later). Often it is more convenient to just save them from the current VFO frequency.

To show the list of preset frequencies in normal operation mode, double click the "Exit" button. The display now shows something like this:

The top row of the display shows the currently active VFO frequency as usual.

The bottom row shows a "1" in the 4th character, this is the number of the preset displayed. The next number (here 14,035,00) is the frequency stored in Preset 1.

Use the rotary encoder to scroll through the list of presets until you find the one you want. Once you have selected the desired preset, press one of the three buttons to Save, Cancel or Load the preset, as follows:

- SAVE the current VFO to the selected preset, by pressing the "Select" button
- CANCEL the preset operation (back to main operating mode), by pressing "Rotary" button
- LOAD the selected preset frequency into the current VFO, by pressing the "Exit" button

The "S" in the first character and "L" in the 16th character at the far right, are intended as a reminder of which button to press to Save and to Load.

3.7   Automated message transmission mode

My favourite use of the automated message transmission mode is to send a CQ call repeatedly. If a station answers, you can tap the key to cancel the message sending mode, then transmit.

There are 12 message memories. The first four memories are 100 characters long; the remaining eight memories are 50 characters long.

In order to send a pre-saved message, press the "Rotary" button with a single long press. The first of the saved messages is shown on the screen, for example if a CQ call is stored in Message 1, you may have something like this:

The bottom row shows the message number at the far left (here it is message 1) followed by the first part of the stored message. If it is blank, that means of course that you have not stored any messages yet!

You can now use the rotary encoder to scroll back and forth between the 12 stored messages and find the one which you want to transmit.

The message can be transmitted multiple times according to the "Repeats" parameter in the Messages menu (see later description). The interval between the repeated transmissions is also defined in the Messages menu, in the "Interval" parameter.

Once you have selected the message that you want to transmit, press one of the three buttons as follows:

- REPEAT: Transmit the message repeatedly by pressing the "Select" button
- ONCE: Transmit the message only once by pressing the "Rotary" button
- CANCEL: Cancel the messages operation by pressing the "Exit" button

When REPEAT message transmission mode is activated, the number of repeats and the interval between repeats is as specified by the Repeats and Interval parameters in the Messages menu.

The stored message transmission is sent at the currently defined keyer speed.

During the actual stored message transmission, you can immediately cancel the transmission at any time by pressing the "Exit" button or by keying the transmitter with the Morse key or paddle if you are using one.

While the RIT or Speed adjustment modes are active, you may still operate the radio (key the transmitter) and may also press the rotary encoder center shaft button to initiate stored message sending.

4. Menu System

There is an extensive menu system with more than 80 different configuration or operating parameters stored in non-volatile memory (EEPROM). These are editable to control every aspect of the radio's behaviour.

The menus are organised into 9 groups as follows:

- 1. Preset
- 2. Messages
- 3. VFO
- 4. Keyer
- 5. Decoder
- 6. Beacon
- 7. Other
- 8. Alignment
- 9. Test equipment
- Save settings!

To enter the menu system, give a single long press to the "Select" button. Use the rotary encoder to scroll back and forth between the nine sub menu groups listed. To enter one of them, press the "Select" button. To return to the main operating mode, press the "Exit" button.

The golden rule while in the menu system, is to press the "Select" button to go in to a deeper menu level or edit an item, and the "Exit" button to back up.

In order to edit a menu item, navigate to the menu item then press the "Select" button to start editing. When you have finished editing the item, press the "Exit" button to save it.

NOTE that changes to configuration parameters only take effect on the radio, when you leave the menu system and return to the main operating mode. During viewing or editing of menu items, the radio remains in receive mode on the currently selected VFO frequency. The exception to this is certain alignment and test equipment tools, where these need to use parts of the radio.

4.1 Saving current operating parameters (VFO frequency etc)

The final (10th) item "Save settings!" is a special item which causes certain operating parameters to be stored to EEPROM. These then are the defaults the next time you power up the radio. This is very convenient if you want to recommence operating next time you switch on, with exactly the

configuration your radio is in now. The controls sequence to save the settings is very simple. This makes it easy and quick to save your current configuration when you wish to switch off the radio.

a) Single long press to the "Select" button, to enter the configuration menu system
b) Turn the rotary encoder one click anticlockwise to show "Save settings!" on the screen
c) Press the "Select" button once more, to actually save the settings

The list of items saved is:

- VFO Mode (A, B, Split)
- VFO A frequency
- VFO B frequency
- Tune rate
- RIT
- RIT tune rate
- Signal generator frequency

4.2   Types of configuration menu item

There are five types of menu configuration item, and editing these is a little different depending on the type.

1) LIST: a fixed list of values applicable to that menu item, for example Keyer mode
2) BOOLEAN: an ON/OFF parameter, such as used to control whether the battery icon shows
3) NUMBER: a numeric parameter such as a stored frequency preset
4) TEXT: a text configuration item such as a stored message
5) UNEDITABLE: some menu items are display-only, such as the alignment or test tools

4.3   Editing a configuration menu parameter

To start editing a parameter, navigate to the desired parameter in the appropriate menu, and then press the "Select" button. When editing is active, you will see a cursor appear under the digit being edited. For example, here is menu item 2.13, the message repeat interval:

The underline cursor below the 4 indicates that editing is active; turning the rotary encoder will change the parameter value.

When you are finished editing, press the "Exit" button to conclude editing. This saves the parameter in the microcontroller's EEPROM memory.

A flashing inverted cursor is also available, you can choose that in the "Cursor Style" parameter in the "Other" menu (see later section).

4.4   Editing a LIST parameter

Editing a list parameter is very simple, it is just a matter of turning the rotary encoder. The display scrolls through the list items. For example, this is the Keyer mode parameter, menu 4.1:

Note that the editing indicator cursor appears under the leftmost character.

When you are happy with your selection, press either "Select" or "Exit", to save the change.

4.5   Editing a BOOLEAN parameter

Editing a BOOLEAN parameter is exactly the same as editing a LIST parameter, except that now the list of items is always restricted to just ON and OFF (representing True/False).

4.6   Editing a NUMBER parameter

When editing a number parameter, the cursor underline appears under the currently edited digit. The cursor starts at the far left (most significant digit). The rotary encoder tunes the digit. The operation is very similar to tuning a VFO in ordinary operation. This example shows editing the default (power-up) VFO A frequency:

To alter the "tuning rate", you can either

a) Press the "Select" button to move the cursor to the next digit to the right OR
b) Press and hold the "Rotary" button, while turning the rotary encoder shaft – this allows you to move the cursor left or right.

Editing of the number is concluded, and the number is stored to EEPROM, when either:

a) You press the "Exit" button OR
b) You press the "Select" button so many times that the cursor falls off the right hand side

Yet another way to input numbers, which is a REALLY convenient way, is to use the Morse key and CW decoder! During editing of numeric parameters, the CW decoder is activated but only decodes number characters 0-9. The CW decoder expects well-timed CW, with correct spacing between words and characters. The CW decoder expects you to key in the numbers at near to the configured Keyer speed. If you start keying at a much different speed, the CW decoder will adapt to your keying but this may take several characters to "sense" your keying speed, so some characters can be missed.

When you have keyed in the whole number, the number is automatically saved to EEPROM, which leaves editing mode. Once you are used to editing numeric parameters by keying in CW, it becomes the easiest and fastest way to edit menu parameters.

4.7   Editing a TEXT parameter

An example of a text parameter you may wish to edit is the stored messages. For example, stored message 2 is edited in menu item 2.2:

By far the easiest way to edit TEXT parameters is simply to use the CW decoder! As before, it expects well-timed CW, with correct spacing between words and characters. The CW decoder expects you to key in the characters at near to the configured Keyer speed. If you start keying with a straight key at a much different speed, the CW decoder will adapt to your keying but this may take several characters to "sense" your keying speed, so some characters can be missed.

Editing of the parameter is concluded either when you press the "Exit" button, or when no more characters are available for editing; for example, if you filled up the chosen Message memory.

It is also possible to edit a text parameter entirely with the buttons and rotary encoder, though this is usually a slower way to edit text parameters. Owners of the QRP Labs Ultimate3S (or earlier) QRSS/WSPR transmitter kits will already be familiar with this style of editing text.

The text parameter supports all of the characters which the Message keyer can encode, which is the same as the CW decoder can decode. Specifically, A to Z, 0 to 9, Space, then punctuation characters / = ? . , Note = is the break character, CW -...- (dah dit dit dit dah).

The following characters/symbols have special functions.

Insert: Use this symbol to insert a character in the text. Find this character using the rotary encoder, then press the "Select" 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 character using the rotary encoder, then when you press the "Select" button, the current character is deleted and the cursor moves back left one position.

Delete all: If selected as the current character, pressing the "Select" 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 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.

Enter (finished): If selected as the current character using the rotary encoder, pressing the "Select" button is used to finish editing the setting. The setting is saved, and you leave editing mode. 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 "Select" button when you are not at the furthest right position of the message, then everything right of your position is deleted.

You can also move the cursor backwards and forwards within the text being edited, by pressing and holding the "Rotary" button, then turning the rotary encoder. This moves the cursor position within the text parameter.

4.8 Frequency presets menu

There are 16 frequency presets, labelled 1 to 16. This example shows Preset 5:

```
1.5 Preset 5
14,020,000
```

All of the Preset menu items are NUMBER types. Refer to the "Editing a NUMBER parameter" section above for instructions on how to edit a NUMBER parameter.

It is also convenient to load the current VFO into the preset memories as described in the section above titled "Frequency Presets".

4.9 Messages menu

There are 14 configuration items in the Messages menu:

2.1   Interval
2.2   Repeats
2.3   Message 1 (100 characters text stored message)
2.4   Message 2 (100 characters text stored message)
2.5   Message 3 (100 characters text stored message)
2.6   Message 4 (100 characters text stored message)
2.7   Message 5 (50 characters text stored message)
2.8   Message 6 (50 characters text stored message)
2.9   Message 7 (50 characters text stored message)
2.10   Message 8 (50 characters text stored message)
2.11   Message 9 (50 characters text stored message)
2.12   Message 10 (50 characters text stored message)
2.13   Message 11 (50 characters text stored message)
2.14   Message 12 (50 characters text stored message)

The 2 stored message presets are 100 or 50 characters long, according to the list above. For example:

```
2.3 Message 1
```

Turn the rotary encoder to select the Message from 1 to 12 which you wish to edit, then press the "Select" button. Now you can edit the message text in one of two ways:

1) Choose each character individually from the list, using the rotary encoder. When you have chosen the correct character, press the "Select" button to move to the next character. This process is described in more detail in the preceding section on editing text parameters.
2) Key in the desired text on the straight Morse key on the board, or using your external paddle. The CW decoder must be enabled for menu editing (see "Enable edit" parameter).

PROSIGNS: Morse prosigns are typically pairs of concatenated characters which are sounded without a gap. The most common examples are AR, KN and SK (also known as VA). You can include any such prosigns in your saved messages. To specify a prosign, use the _ character. When the _ character is included in a saved message, it indicates that the following two characters are to be sent without a gap between them. You would typically use AR, KN and SK but there is nothing to stop you concatenating any pair of characters, to form other prosigns less commonly used.

```
2.1 Interval
20
```

The Interval is a NUMBER parameter that specifies the interval in seconds, between repeated transmission of a stored message (if repeats are configured: see next parameter).

```
2.2 Repeats
0
```

The Repeats parameter specifies how many times the message transmission will be repeated, in the repeat transmission mode. The Repeat parameter is actually a LIST type, since it can be a number from 1 to 99, or 0. In the latter case (zero), the Message transmission continues indefinitely.

4.10   VFO menu

The VFO menu contains a number of configuration parameters which affect the VFO operation and CW reception. Many of these parameters are only power-up default parameters for the VFOs. The current VFO frequency, mode etc is not stored in these parameters. If you wish to save the current VFO frequency, mode etc into EEPROM so that when the radio is next powered up, the exact same state is available from power up, use the "Save settings!" feature described previously.

These configuration items in this menu are explained below.

```
3.1 VFO mode
A
```

This parameter specifies the VFO mode at power-up. It can be A, B or Split. The current VFO mode during ordinary operation is not stored in this parameter unless you "Save settings" as described previously.

```
3.2 VFO A
14,027,500
```

This parameter specifies the VFO A frequency at power-up. The current VFO A frequency during ordinary operation is not stored in this parameter unless you "Save settings" as described previously.

```
3.3 VFO B
14,032,500
```

This parameter specifies the VFO B frequency at power-up. The current VFO B frequency during ordinary operation is not stored in this parameter unless you "Save settings" as described previously.

```
3.4 Tune rate
100 Hz
```

This LIST parameter specifies the Tune rate power-up. Available values are: 10MHz, 1MHz, 100kHz, 10kHz, 1kHz, 500Hz, 100Hz, 10Hz or 1Hz. The current Tune rate during ordinary operation is not stored in this parameter unless you "Save settings" as described previously.

```
3.5 RIT
+0,000
```

This parameter specifies the RIT at power-up. The current RIT amount during ordinary operation is not stored in this parameter unless you "Save settings" as described previously.

```
3.6 RIT rate
10  Hz
```

This parameter specifies the RIT tuning rate at power-up. The current RIT tuning rate during ordinary operation is not stored in this parameter unless you "Save settings" as described previously.

```
3.7 CW-R
OFF
```

This boolean parameter enables the CW-R mode. Ordinarily CW is received in Upper sideband with a 700Hz offset. There may be some occasions where operation on the other sideband is desired (lower sideband), for example to exclude an interfering nearby station when the CW filter performance is asymmetric. In these cases you can switch on CW-R by setting this menu item to ON, to select Lower sideband reception mode.

```
3.8 CW offset
700
```

This parameter specifies the CW offset in Hz. It is the difference between the VFO frequency during transmit and receive. It is automatically applied during receive in order to resolve a perfectly netted transmission on the same frequency as yours, at 700Hz audio output.

If you wish to change the CW offset frequency you may do so using this parameter. However, be warned that the 200Hz audio analogue filter in the circuit is still centred on (approximately) 700Hz. If you moved the configured CW offset frequency too far away, then the received audio will fall outside the CW filter and be attenuated.

4.11 Keyer menu

The Keyer menu contains a number of configuration parameters relating to the CW keyer, which are described below.

```
4.1 Keyer mode
Straight
```

The mode of the CW keyer function in the firmware. Possible modes are:

- Straight
- IAMBIC A
- IAMBIC B
- Ultimatic

If you wish to use a traditional up/down Morse key, these are called "straight" keys and you should select the "Straight" mode. If you wish to use a modern paddle then select the desired operating mode e.g. IAMBIC A.

```
4.2 Keyer speed
12
```

This is the default power-up speed of the Keyer function in Words Per Minute (wpm). The current Speed during ordinary operation is not stored in this parameter unless you "Save settings" as described previously.

Keyer speed can be altered easily from the ordinary main operating mode, with a single press of the "Select" button, as described previously.

Keyer speed is also used for stored message sending, and for the beacon function when in CW mode.

The keyer speed is also used to configure the CW decoder during transmit or during menu item editing. When transmit or editing are commenced, the speed is copied into the CW decoder and initialises it. Thereafter if you transmit (or enter data during editing) at a different speed, the CW decoder will adapt to your speed. However, if the speed difference is large, the adaption can take several characters to correctly "sense" your keying speed, which can result in incorrectly decoded characters or missed characters.

```
4.3 Keyer swap
OFF
```

This is a BOOLEAN parameter which lets you swap the "dit" and "dah" connections in software, if you find that your paddle is reversed.

```
4.4 Keyer Weight
500
```

Ordinarily Morse dit and dah durations have a 1:3 ratio. The space between symbols is equivalent to 1 dit, between characters 3 dit lengths, and between words 7 dit lengths. This is standard Morse timing. However, some people may wish to alter this, for various reasons.

The Keyer Weight parameter allows variation of the ratios. The value has three digits. The default value of 500 corresponds to 50.0%. This means the "duty cycle" of a stream of dits is exactly 50%. The key-down dit length is therefore the same as the key-up inter-symbol pause.

If the weight is increased from the default 50.0%, then the key-down "dit" is made longer. A "dah" is lengthened by the SAME amount. The corresponding inter-symbol (or character, or word) gap is shortened by the same amount. The additional time spent on the key-down is therefore taken from the key-up period. The keyer speed is unchanged by altering the weight parameter.

As an example: suppose you want to make your Morse sound "harder" by shortening the dits and dahs. You could set the parameter to 450, which means 45.0%.

The parameter range is 050 to 950 (5% to 95%) though you would not normally ever need to go anywhere near these unreasonable limits. In the event that you enter a value outside this range, the firmware automatically applies these limits to the actually used parameter.

```
4.5 Auto Space
OFF
```

Auto-spacing means that the pause between CW characters is forced to be 3 dit lengths (more or less, if you have CW weighting configured, see above).

The majority of keyers do not implement auto-spacing. You use the paddle to send your dits and dahs making up the Morse character you wish to send. As soon as you next press the paddle, the next character is started. The keyer forces correct 1:3 ratio of dits and dahs and inter-symbol spacing, but it does not force you to wait for the correct duration of 3 dits between transmitted characters.

Some keyers do implement automatic character spacing, such as the old (1973) Accu-Keyer design by James WB4VVF see https://inza.files.wordpress.com/2011/01/accu-keyer.pdf .

This configuration therefore allows you to switch on automatic character spacing if you wish. In this case, if you press a paddle too SOON, before the 3 dit durations have elapsed after the last character completed, the keyer will wait until the correct time to start the next character.

In the even that you press the paddle too LATE, there is nothing the keyer can do to travel back in time and force it to 3 dit lengths for you. You might have intended an inter-word space, for example. So pressing the paddle too late cannot be corrected.

```
4.6 Semi QSK
OFF
```

This setting defines the break-in (QSK) behaviour of the radio. Two settings are possible:

OFF: indicates Full QSK mode. After the delay time for RF envelope shaping, the Transmit/Receive switch is set to "Receive" shortly after key-up. In this way, you will hear the other station (or any QRM, QRN etc) transmitting in between the dits and dahs of your own transmissions. Many experienced operators like to be able to have a feel for what is happening on the band, in between their key-downs. In some ways you feel like you are listening to your own sidetone audio as just another signal on the band, and you can still hear other signals too.

ON: Semi-QSK mode is enabled. After key-up, there is a delay before the Transmit/Receive switch is set back to "Receive" mode. The receiver is therefore kept muted during your whole CW transmission, not listening to the band in between your transmitted symbols. Many operators prefer to avoid the distraction of hearing the band between their dits and dahs. In Semi-QSK mode the Transmit/Receive switch is set back to "Receive" only after a suitable delay (of 8 dit lengths), long enough to occur only at the end of the transmission.

```
4.7 Practice
OFF
```

Normally you would leave Practice mode switched OFF. However if you want to practice sending CW, and see if the CW Decoder can decode you, then you can switch Practice mode to ON. In practice mode, the radio does everything it normally would, except that it never sends any RF power to the antenna!

During practice mode, a 'P' is shown in the display to the right of the frequency on the top row.

```
4.8 Sidetone frq
700
```

This NUMBER parameter allows you to change the Sidetone frequency if you wish. Sidetone is the audio tone which is generated by the microcontroller on key-down and injected into the audio signal path. Sidetone is ONLY an operator convenience to let you hear your keyed signal, and has no impact at all on the transmitted RF amplitude or frequency.

It is strongly recommended to leave the Sidetone frequency set to the same frequency as the CW Offset frequency in the VFO menu. Your ears will get used to recognising the 700Hz audio tone, and it makes it then much easier to accurately tune to a station you hear transmitting on air, such that his signal will also be at 700Hz audio in your receiver. When you hear him at 700Hz, he will be in the middle (near, anyway) of your CW audio filter. When you transmit you will also be netted accurately to his frequency. All being well, this should mean that your signal also ends up nicely in his CW filter passband too. Then you can QSO!

The minimum sidetone frequency is 350Hz; below this, the system automatically uses 350Hz.

```
4.9 Sidetone vol
099
```

You can use this parameter to reduce the volume of the sidetone audio. Most people will find the default setting of 99 too loud. So experiment with lower values until you find a sidetone audio level which you find comfortable.

When you adjust the sidetone volume by turning the rotary encoder after selecting a digit, the QCX will play the sidetone at the new volume briefly so that you can hear how it sounds and easily adjust it to a comfortable volume.

The sidetone generation uses some subtle digital signal processing to superimpose a 700Hz tone on top of an ultrasonic audio frequency (at 42kHz by default); this retains an average 50% duty cycle and thereby allows variation of sidetone volume without altering the DC bias at the feedpoint in the audio signal path; this is found to eliminate a "click" that occurs on Rx / Tx changeover and is most prominent at lower volume settings. A consequence of this change is that the apparent sidetone volume becomes lower, if you reduce the "Sidetone frq" setting far below the default

700Hz. Therefore in version 1.02b the sidetone volume setting was increased from 2 to 3 digits. If low sidetone frequencies are your preference, and if you find the sidetone too quiet, you can try increasing the volume setting. There is a maximum which is given by the formula

166,666 / SidetoneFrequency – 2

If you set the sidetone volume louder than this maximum value, the system will automatically limit the volume to the maximum value.

```
4.10 Straht mode
Both
```

Available settings are "tip", "ring" and "both". This controls the action of a key plugged into the key jack during Straight Key mode only. If a 3.5mm mono plug was used with the QCX+, the longer ground barrel shorted the ring to ground causing continuous keying. This configuration menu is the solution to that problem. If you are using a mono 3.5mm plug with your straight key, then set this configuration to "Tip" so that the ring connection (available only on stereo plugs) is ignored.

4.12   Decoder menu

The Decoder menu contains a number of configuration parameters relating to the CW decoder, which are described below. Some of these parameters control some aspects of the decoder behaviour. Some constructors may find it interesting to experiment with these settings and see if you can improve the performance of the CW decoder in your specific circumstances. For example, some stations may experience more noise interference than others, depending on your location etc.

Note that the Decoder is able to decode the Morse prosign symbols AR, KN and SK/VA. When shown in the decoded text section of the display, they appear as two characters, for example AR. When using the keyer to enter text into message menus, the two characters are prefixed by the _ character to indicate to the QCX that when replaying the message, the following two characters should be strung together without any gap.

```
5.1 Noise blnk.
10
```

This parameter defines the duration of the noise blanker in milliseconds. The microcontroller's 10-bit ADC samples audio at 12.019 samples per second. 48 samples are analysed by an implementation of the Goertzel algorithm (kind of a single bucket of a Fourier Transform), which results in a digital filter bandwidth of 250Hz. In other words, it results in a measurement of the amplitude 250 times per second, i.e. once every 4 milliseconds. The amplitude is analysed by logic which compares it to a threshold amplitude to decide if a tone has been detected or not. Impulse noise that generates shorter pulses than the noise blanker parameter, is ignored.

If the noise blanking period is too short, then noise impulses will not be blanked effectively. On the other hand, if the noise blanking period is too long, then it will impair the decoder's ability to decode high speed Morse. For example, 24wpm Morse has dits lasting 50 milliseconds.

```
5.2 Speed avg.
07
```

The duration of dits and dahs is measured in order to define a threshold at which to define a tone burst as a dit or a dah, and whether to define no tone at all as an inter-symbol, inter-character or inter-word gap. The measurement of this timing is implemented via an exponential moving average, whose averaging duration is determined by this parameter (the weight of each new measured symbol in the accumulated average).

If the exponential moving average is too fast (the parameter value is too low) then noise etc will throw off the timing averages too easily. If the exponential moving average is too slow (the parameter value is too high), then too many characters of the other station's transmission will be missed, while we try to adjust to the speed of his sending. This can be particularly offensive in some contest or pileup situations where exchanges are very short.

```
5.3 Ampl. Avg.
60
```

The decoder maintains an amplitude threshold, which it uses to decide whether a tone is detected or not. The level of this threshold must be varied automatically in order to cope with stations having a wide range of different signal strengths. Other perils may include QSB (signal fading) of the station you are listening to. The amplitude threshold is implemented via an exponential moving average. The weighting of each new sample (every 4ms) added to the accumulated exponential moving average value is the reciprocal of this parameter.

If the exponential moving average is too fast (the parameter value is too low) then noise etc will too easily throw off the amplitude threshold and it may take time to recover to its proper level. If the exponential moving average is too slow (the parameter value is too high), then it may take too long to adjust to the received station's amplitude, resulting in missed characters while the decoder slowly adjusts itself. It would also be too slow to automatically respond to QSB (signal fading).

```
5.4 Enable Rx
ON
```

An experienced CW operator may well dislike the CW decoder scrolling across the display all the time. With this setting you can switch "Enable RX decode" to OFF and the receiver decoding is disabled.

```
5.5 Enable Tx
ON
```

With this setting you can switch "Enable TX decode" to OFF and the transmit decoding is disabled. When this setting is ON, the CW decoder will decode your own keying and display it on the screen while you transmit. For an experienced CW operator that may be distracting too!

```
5.6 Enable edit
ON
```

This parameter enables CW decoding while editing. When ON, anything you key during editing of NUMBER or TEXT type configuration parameters, edits the parameter. This is a really useful feature that makes it very easy to enter frequencies or stored messages, for example.

```
5.7 VA
ON
```

This parameter only controls whether the SK/VA pronoun character, when decoded, is shown as "SK" (this setting is OFF) or displayed as "VA" (this setting is ON).

The proper definition of this pronoun character is somewhat disputed; some people believe passionately that it is SK, others that it is VA. For the sake of universal harmony this parameter therefore lets you choose your preference.

4.13   Beacon menu

The beacon function is an added bonus feature of this QRP Labs CW transceiver kit! We already have extensive experience for several years, developing the Ultimate-series QRSS/WSPR transmitter kits (current incarnation, the Utimate3S). These have a huge array of functionality and modes including CW, QRSS, DFCW, FSKCW, Hellscreiber (full speed and slow FSK), WSPR, JT9, JT65, ISCAT, Opera and PI4. The vast majority of people use the Ultimate3S kit for WSPR operation. Since it costs nothing (no extra hardware, at least) to add this functionality to the CW transceiver, why not! Let's do it!

The CW transceiver beacon function therefore contains a simplified WSPR implementation which can transmit standard WSPR messages. It also has a GPS interface for discipline of time, frequency and Maidenhead locator. The implementation of course does not have the full range of flexibility and functionality as the Ultimate3S kit.

WARNING: WSPR transmissions operate a continuous 100% key-down duty-cycle for almost 2 minutes. You should check carefully whether the BS170's get too hot during this period. WSPR is much more demanding on the PA transistors than CW. If you are operating with higher output powers (by using a relatively high power supply voltage) then you might notice the

BS170s get unreasonably hot. Even though the output stage is Class-E, nothing is 100% efficient! It will still dissipate some power as heat. In the QCX+ and QCX-mini, the heatsinks are bolted to the PCB as a heatsink, to help dissipate the heat.

The beacon function can also operate a CW beacon.

Weak Signal Propagation Reporter

WSPR stands for Weak Signal Propagation Reporter. It is digital message format filled with clever forward error correction. The message consists of three parts: the operator's callsign, Maidenhead locator (4-character, e.g. IO90) and two digits specifying the power. At the receiving station, messages are decoded and uploaded to a central internet database. At any time you can go to WSPRnet http://wsprnet.org and click on the map, enter your callsign (and other filters if you wish), and see a map of where your signal is being heard.

You could also undertake more in-depth propagation studies by downloading the database of reception reports.

The WSPR message is encoded into a set of 162 symbols, each may be 0, 1, 2 or 3, using a compressed data format with forward error correction. The symbols are transmitted as tones, each tone separated by 12,000 / 8,192 Hz i.e. approximately 1.46Hz. The duration of each symbol is the reciprocal of the tone spacing, which is approximately 0.683 seconds. WSPR messages take about 110.6 seconds to transmit, and always start at even minutes past the hour.

Due to the very narrow 6Hz bandwidth of the transmission, and the clever forward error correction, WSPR signals can propagate globally even with a fraction of a watt.

In WSPR, timing is critical, so when using WSPR you must set the time configuration parameter as exactly as possible. Be sure to keep the editing cursor under the rightmost (1-minute) digit of the time parameter, watch your clock until the seconds turn over to 00, and then press the "Select" button. This will ensure the seconds are in sync with your real clock time. If careful attention is given to setting the frequency and the real time clock, then successful WSPR reports will be obtained. Of course these things are easier if you are using a GPS module: the Maidenhead locator will be calculated from the received latitude and longitude, and the time decoded nicely from the GPS serial data stream.

The microcontroller in this kit takes care of the WSPR message encoding algorithm, without any assistance from a PC host computer. It also calculates the tone spacing and symbol duration.

In between message transmissions, the display will show instead just a clock (see below), while we wait patiently for the next WSPR transmission to begin, according to the settings of the configuration parameters Frame and Start. This is useful for checking that the time on your kit is accurately set. The display also shows the minute at which the next frame will start transmitting. In the example below, the time is 14:55:31 UT and the next frame will start at 14:56:01.

When a GPS unit is connected, the firmware automatically uses the 1 pulse-per-second signal to measure the transmit frequency and compensate for any inaccuracy due to calibration error or frequency drift due to temperature. The serial data stream from the GPS is used to set the real time clock (for syncing the WSPR transmission timing). The Maidenhead locator is computed from the latitude and longitude information parsed from the GPS serial data.

A WSPR transmission takes 1 minute and 52 seconds. The GPS time and location data is parsed from the GPS serial data stream at the END of every WSPR transmission. On the first WSPR transmission after power up, the time may not be accurate. The 27MHz synthesiser reference frequency is measured and adjusted, in a 4 second period after the end of the WSPR transmission. Parsing the time and location, and adjusting the 27MHz reference frequency, all takes place in under 7 seconds. The process is completed before the start of the next WSPR transmission slot. Nevertheless, you should not configure your kit for continuous WSPR transmissions in every 2-minute WSPR slot (Frame parameter is 2), which is considered very antisocial to fellow WSPR operators.

A GPS receiver isn't essential for WSPR operation but it is highly recommended because it makes operation more accurate, easy and fun.

During the actual WSPR message transmission, the display shows something like this:


The elements of this display are explained as follows:

- 14,097,140   Transmission frequency (tone 0)
- 122   Current symbol is 122 (of 162 symbols making up a WSPR transmission)
- 2   Current tone being transmitted (one of 0, 1, 2 or 3)
- G0UPL   Callsign encoded into the transmission
- IO90   5-character Maidenhead Locator square, encoded into the transmission
- 37   Power in dBm, encoded into the transmission

On a PC spectrum display such as the Argo software http://www.weaksignals.com/ WSPR messages look something like the screenshot below when received locally (or usually worse, because you probably are over-driving your receiver when receiving your own signal!):

WSPR decoding takes place in the WSPR program by K1JT (see http://physics.princeton.edu/pulsar/K1JT/wspr.html). Below is a screenshot showing the WSPR 2.0 screen following reception of a few transmissions (output frequency = 1,500Hz, Frame = 02, Start = 00).
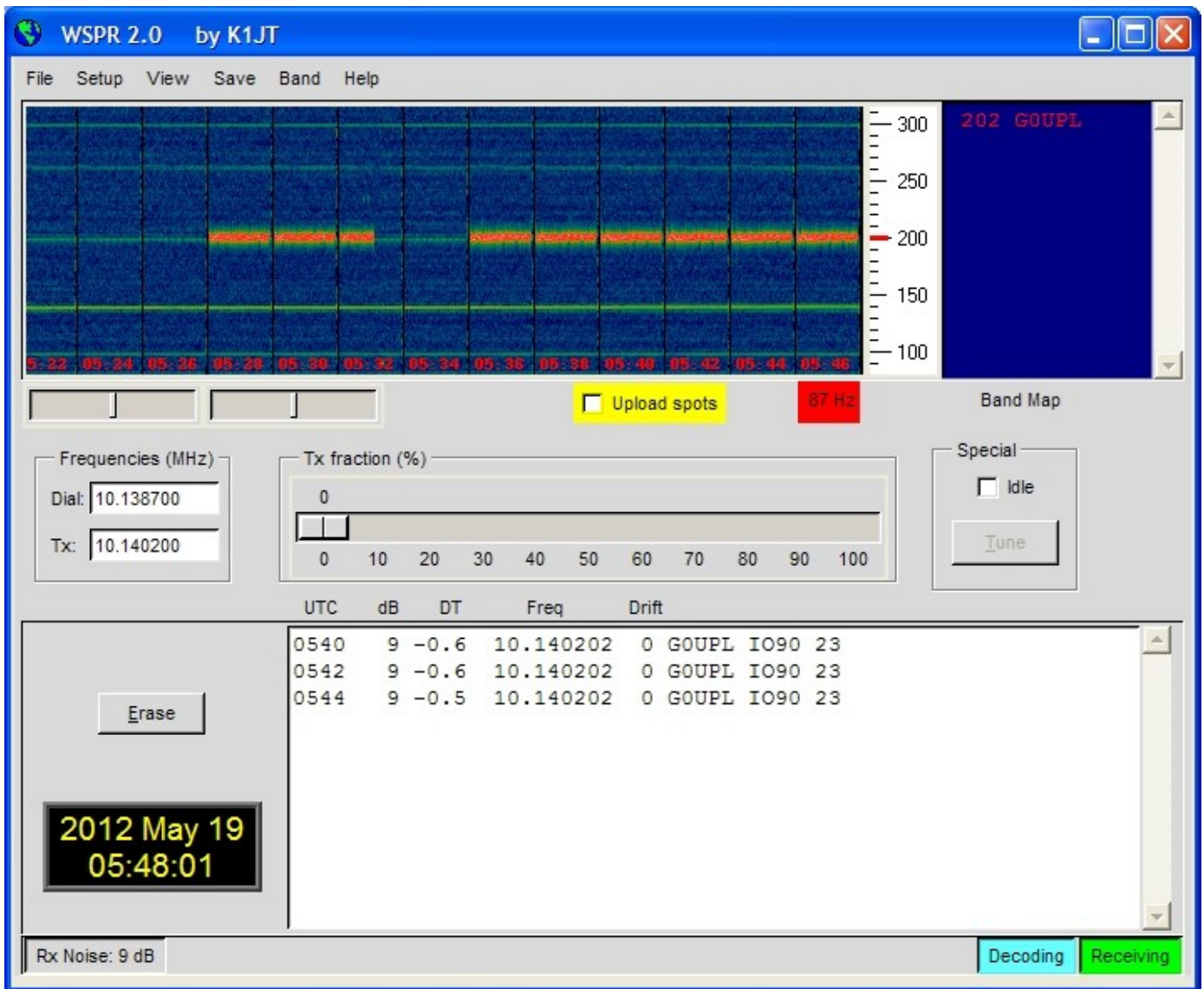
A number of other software packages are now also capable of decoding WSPR transmissions.

NOTE: the GPS interface is connected in parallel in the circuit, with the paddle. Therefore, you should NOT have the GPS connected, while operating the radio as an ordinary CW transceiver. If you do, the GPS serial data and 1pps will key the transmitter! Disconnect the GPS before using the radio as a CW transceiver.

The following sections describe the configuration parameters in the Beacon menu.

6.1 Beacon
OFF

This is the master switch controlling whether beacon mode is enabled or not. If beacon mode is enabled, then the radio starts operating in beacon mode on power-up.

While beacon mode is operational, it can be cancelled immediately at any time by pressing the "exit" button. Remember that you should not have a GPS connected, when in ordinary CW

transceiver mode – it would key the transmitter since the GPS and paddle share the same processor I/O signals.

Beacon mode is entered upon leaving the configuration menu system, if the beacon is enabled by having this parameter set to ON.

```
6.2 Mode
WSPR
```

This parameter determines the transmission mode during beacon operation. There are two possible beacon modes:

CW: the kit simply sends stored message 1 repeatedly, according to the configured Keyer speed, and with message start timing determined by the Frame and Start parameters (see next sections).

WSPR: the kit sends WSPR according to the configuration parameters in the following sections.

```
6.3 Frequency
14,097,140
```

This parameter determines the transmission frequency during beacon operation. In WSPR mode, this is the frequency of tone 0.

It should be noted that the WSPR sub-bands on the bands are only 200Hz wide. You need to have your 27MHz reference oscillator accurately calibrated so that you can be sure your actual transmission frequency is close to the frequency specified in this parameter. You also need to specify the correct frequency so that your transmission is inside the appropriate 200Hz sub-band.

Note that these are the actual transmission frequencies, there is no CW offset, no RIT, no other modifications. The specified frequency is also DIFFERENT from the "USB dial frequency" specified at WSPRnet http://wsprnet.org – the "USB dial frequency" is 1500Hz lower than the actual transmit frequency, so that the decoded audio is at 1500Hz.

Therefore, ensure that for WPSR transmissions, you choose a frequency in one of the WSPR sub-bands according to the following table:

80m:	3.570000 – 3.570200
60m:	5.288600 – 5.288800
40m:	7.040000 – 7.040200
30m:	10.140100 – 10.140300
20m:	14.097000 – 14.097200
17m:	18.106000 – 18.106200
15m:	21.096000 – 21.096200
12m:	24.926000 – 24.926200
10m:	28.126000 – 28.126200

```
6.4 Frame
 10
```

This parameter defines the repetition rate of the WSPR transmission. In the example shown here, Frame 10, this means that the WSPR message will be transmitted once every 10 minutes.

Transmission in every 2 minute WSPR slot is considered anti-social. 10 minute repeat transmissions is usually considered normal.

```
6.5 Start
 04
```

If everybody transmits with 10 minute repetition rate starting on the hour, then there will be bursts of activity every 10 minutes where everyone is transmitting at once, and the potential for interference from another station will be large. To avoid this, you can define the start timer. In this example a start time of 04 means that the first transmission will start at 4 minutes past the hour, and subsequent transmissions will commence at Frame minutes after that – in this case, 14, 24, 34 etc minutes past the hour.

```
6.6 WSPR call
  G0UPL
```

The WSPR callsign is the first parameter which is encoded into the WSPR message. Your callsign must obey certain restrictions imposed by the WSPR protocol. These restrictions helps ensure that the WSPR encoding process can compress callsigns efficiently, along with the Maidenhead Locator square and Power level, into only 50 binary bits of information in total.

The callsign can only be 4 to 6 characters long. The callsign must consist of the following:

1) One character which can be A-Z or 0-9 or a SPACE
2) One character which can be A-Z or 0-9
3) One character which must be a number 0-9
4) Three characters which can be A-Z or a SPACE

For callsigns such as mine, consisting of 5 characters, I must enter a space character as the first character in order to satisfy these callsign rules.

If the callsign you enter does not obey the necessary rules, then an error message is displayed on exiting the configuration menu system:

```
Beacon error:
WSPR call
```

In this case, go back to the WSPR Call parameter and try to understand how to correct it in order to make your callsign satisfy the requirements.

Note that if entering the callsign text using the key, you cannot enter a space with the key! So, you will need to enter the initial space character (if required) using the buttons and rotary encoder as discussed in the earlier section on editing TEXT parameters.

```
6.7 WSPR locator
IO90
```

The Locator is the second parameter which is encoded into the WSPR message. It is the 4-character Maidenhead square. The text you enter here, must be a valid Maidenhead square, otherwise an error message will be generated on exiting the configuration menu system.

If you have connected a GPS receiver, the GPS receiver will update the Locator, computing it from the latitude and longitude information contained in the serial data string from the GPS receiver module.

```
6.8 WSPR power
37
```

The third and final parameter encoded into the WSPR message is the transmitter power, defined in dBm. Note that this parameter is manually edited here and is encoded into the WSPR message. It does NOT indicate a measured power which is actually transmitted. This is a common misconception. It only indicates what number the operator configured for the WSPR message encoding.

WSPR powers are constrained to certain values 0, 3, 7, 10, 13, 17, 20, 23, 27, 30, 33, 37, 40, 43, 47, 50, 53, 57 and 60dBm. If you specify a value not in this list, then an error message will be generated on exiting the configuration menu system.

In this example, the configured value is 37dBm which corresponds to 5 watts of RF transmitter output.

```
6.9 Set time
15:56
```

The kit has an internal real time clock which is used for timing the beacon (WSPR and CW) transmissions. 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 editing of this menu is concluded: either by pressing the "Select" button after setting the minutes, or by pressing the "Exit" button at any time.

Accurate timing is critical for the WSPR (etc) modes. With careful adjustment of the "System frq." parameter, the 20MHz oscillator will keep accurate enough time for WSPR for up to a week, even without GPS.

Note that if using a GPS module and if there is a valid serial data stream properly decoded, then the time is set automatically.

An accurate real time clock is not required other than for the WSPR beacon transmission timing.

A real time clock display is available that occupies the lower right corner of the display. The time set in this menu item is the time displayed in this real time clock display. The time is displayed in HH:MM format.

4.14   Other menu

This menu contains miscellaneous other settings which do not fit well in other configuration menu categories.

```
7.1 Dbl. click
300
```

This is a NUMBER parameter which controls the decisions on what type of press has been made to a button. By default, it is set to 300 milliseconds (as shown here) but you may alter this if you wish.

It is the number of milliseconds after first pressing the button, at which certain decisions are made:

a) If you have not pressed the button again after this interval, then it means you intended a single press.
b) If you are STILL pressing the button all this time later, 300 milliseconds after the first press, then it means you executed a "single long press".
c) If you pressed the button again before the 300 milliseconds elapsed, it is a "double click".

```
7.2 Battery
OFF
```

This BOOLEAN parameter controls whether or not the battery icon is displayed on the screen at the top right corner. Measurement and display of battery voltage may be useful to those operators who intend to operate the radio from battery power, for example during portable operations.

In order to measure and display the battery voltage, it is necessary to jumper the "DVM" input header pin to the supply voltage header pin. This hardware wiring is described in the assembly manual.

```
7.3 Batt. full
13,800
```

This is the voltage, specified in millivolts, at which the battery is considered "full".

```
7.4 Batt. step
1,000
```

This is the step, specified in millivolts, for each bar of the battery icon.

In this example, Batt. full is defined as 13.8V and the step is 1V. The battery icon has 7 possible states, ranging from empty to full and 5 intermediate states in between. The meaning of the displayed icon will be, in this example:

- Full: 12.81V to 13.8V (and indeed, above 13.8V also)
- 5 bars: 11.81V to 12.8V
- 4 bars: 10.81V to 11.8V
- 3 bars: 9.81V to 10.8V
- 2 bars: 8.81V to 9.8V
- 1 bar: 7.81V to 8.8V
- Empty: 7.8V and below

```
7.5 Cursor blink
OFF
```

Two different cursor styles are possible. You can select your favourite, here. The two possible values are an underline cursor (the default), and a blinking cursor (the display alternates between the edited character, and a solid white block).

When set to ON, the cursor style is Blink. When OFF, the cursor style is Underline (default).

Note that this setting only affects the cursor that is shown during menu system editing. In normal operating mode, the underline cursor is always used for tuning rate indication, regardless of the Cursor style setting.

```
7.6 S-meter
OFF
```

A rudimentary S-meter is shown in the top right of the display, if this parameter is set to ON.

```
7.7 S-meter step
100
```

This NUMBER parameter effectively defines the sensitivity of the S-meter. The S meter has 12 bars maximum. Each bar of the S-meter equates to the specified "S-meter step" number on the amplitude measurement scale. So, in this case the scale of the 12 bars of the S-meter will mean 0 to 1200 in amplitude measurement terms.

A lower S-meter step number makes the S-meter more sensitive; a higher number makes it LESS sensitive.

The S-meter reading is indicative only, it does not have any highly accurate meaning. In any case the audio sampled by the Analogue to Digital converter is after the audio amplifier gain stages so the amplitude depends on the receiver gain setting.

```
7.8 Custom splsh
OFF
```

You can use this configuration to display your own customized "Splash" screen on powering up the QCX+. Ordinarily when you power up the QCX+ it will show this screen:

```
5W CW Tcvr 1.06
QRP Labs, 2019
```

It shows the firmware version number (1.06 in this example). When you set the "Custom splsh" configuration parameter to ON, the contents of message memories 11 and 12 are displayed on the top and bottom rows respectively. You would then not normally use these message memories for sending CW (though the system does not prevent it). If either memory 11 or 12 are blank, the default splash screen contents for the upper or lower row respectively will be shown. Therefore it is possible to customize one or the other or both rows, as you wish.

```
7.9 Clock
OFF
```

When set to ON, a real time clock is displayed in the bottom right part of the screen during operation. The time is NOT maintained when the QCX+ is powered down. This clock may be set in the "Set time" menu item in the "Beacon" menu. You may also set the clock by connecting a GPS such as the QRP Labs QLG1. Remember that the GPS and the paddle share the same microcontroller inputs (see schematic) and therefore the GPS signals key the transmitter. The QCX+ automatically detects the presence of GPS serial data and enables "Practice mode" to

prevent keying (a P appears on the top line of the display) that due to the high duty cycle, could damage the Power Amplifier transistors. The QCX+ automatically parses the serial data when the GPS is connected (without needing to be in a GPS calibration menu in the Alignment menu, or operating in beacon mode). When the GPS is disconnected, the temporary Practice mode is automatically disabled, restoring normal operation of the transceiver. Therefore you may simply connect a GPS, wait for the real time clock to be updated, and then disconnect the GPS. This is a convenient way to set the time easily, if you have a shack GPS operational.

```
7.10 Delim.
,
```

This parameter configures the delimiter character that appears between the MHz, kHz and Hz parts of frequency or numeric displays on the QCX+ screen. The default is a comma. Now the operator may select a dot if preferred; for example European convention is the use of a dot as the thousands separator. Technically you can choose ANY of the characters available in the QCX+ text string selection but, most commonly, comma or dot are expected to be the usual choice.

```
7.11 Backlight
OFF
```

This parameter is only applicable to the QCX-mini model, and it controls whether the backlight is ON or OFF. This setting is saved in EEPROM and is applied at the next power-up automatically.

You may also temporarily control the backlight, without saving the state in EEPROM, by double-tapping the rotary encoder shaft button.

```
7.11 Factory rst
Sure? enter 17
```

This menu item can be used to cause a factory reset. Factory reset returns you radio to the supplied default factory configuration. Everything is erased and set back to the default parameter values.

In order to prevent accidentally triggering this drastic step, the factory reset is implemented as a virtual 2-digit numeric parameter. To cause a reset:

- Press the "Select" button to start editing this menu item. 00 is displayed
- Use the rotary encoder to change the value to 17
- Press the "Select" or "Exit" buttons to enter the value 17, which causes the factory reset

Factory reset takes a few seconds while the entire EEPROM contents are written. After the factory reset you will see the "Select band" prompt again, the same as when you first power up the radio.

4.15 Alignment menu

The alignment menu contains several tools for alignment and calibration of the radio, using the built-in signal generator to inject a test signal back into the receiver's front end.

Correct use of these alignment tools makes it possible to adjust and align the receiver without any external test equipment at all.

Please also refer to the alignment/adjustment section at the end of the assembly part of the assembly manual, which describes how to use these tools to peak the Band Pass Filter response, and to minimise the unwanted sideband using the I-Q balance and audio phase shift adjustments.

```
8.1 Align frq
14,020,000
```

The Align frq. parameter specifies the frequency which the alignment tools operate. You should ensure that the frequency specified is in the centre of the CW section of the band of operation of your radio.

```
8.2 I-Q bal frq
700
```

The audio frequency at which the I-Q balance adjustment is performed. By default this is set to 700Hz, the centre of the audio filter and what is usually used for the CW offset frequency.

```
8.3 Phase Lo frq
600
```

The audio frequency at which the LOW audio frequency 90-degree phase shift is performed.

```
8.4 Phase Hi frq
800
```

The audio frequency at which the HIGH audio frequency 90-degree phase shift is performed.

```
8.5 Ref frq
27,004,000
```

The reference frequency for the Si5351A synthesiser chip. If you set this to the actual oscillation frequency of the 27MHz crystal, then the output frequency of the radio will be accurate.

Usually the 27MHz crystals oscillate between 3 to 5kHz too high. This is the reason for the default setting of 27.004MHz (4kHz high).

You can measure the 27MHz reference value yourself if you have a reliable general coverage receiver whose frequency is known to be accurate. There are other methods too! You could set the signal generator to a certain frequency such as 10MHz. Then beat it against a 10MHz reference, for example. Measurement of the audio offset would enable a calculation of what the correct 27MHz reference value ought to be.

If a GPS unit is available, then this makes everything very simple – then you can use the GPS calibration tools to calibrate this value (see below).

NOTE: When using the TCXO option in the QCX+ and QCX-mini models, you MUST set this parameter manually to 25,000,000 priort to using the GPS calibration function.

To build the QCX radios for 160m operation, you must use a 12MHz crystal (in place of the 27MHz crystal) and manually set this parameter to 12,000,000 before operating the radio.

```
8.6 System frq
20,000,000
```

The system oscillator frequency. In this radio, the microcontroller clock is a 20MHz crystal. If you are able to measure the actual 20MHz frequency (without disturbing it), you can enter the frequency here. You could, for example, listen for the 20MHz radiation on a general coverage receiver whose frequency indication you trust.

The 20MHz system clock is used for timing purposes only. It is not very critical, unless you intend to operate the WSPR beacon function without a GPS.

If a GPS unit is available, then you can use the GPS calibration tools to calibrate this value (see below).

```
8.7 Peak BPF
Press Select!
```

Pressing the "Select" button activates the signal generator on the configured frequency and displays a bar on the screen showing the measured audio amplitude at 700Hz. The Band Pass Filter trimmer capacitor should be adjusted for maximum measured amplitude. This process is

described in the earlier section "Adjustment and alignment" at the end of the assembly part of the assembly manual.

Use a 50-ohm dummy load during alignment!

```
8.8 I-Q bal
Press Select!
```

Pressing the "Select" button activates the signal generator on the configured frequency with an offset to put the received signal in the unwanted sideband. It displays a bar on the screen showing the measured audio amplitude at 700Hz. The I-Q balance trimmer potentiometer should be adjusted for minimum measured amplitude. This process is described in the section "Adjustment and alignment" at the end of the assembly part of the assembly manual.

```
8.9 Phase Lo
Press Select!
```

Pressing the "Select" button activates the signal generator on the configured frequency with an offset to put the received signal in the unwanted sideband at the audio frequency configured (for example, 600Hz). It displays a bar on the screen showing the measured audio amplitude. The Low frequency phase adjustment trimmer potentiometer should be adjusted for minimum measured amplitude. This process is described in the section "Adjustment and alignment" at the end of the assembly part of the assembly manual.

```
8.10 Phase Hi
Press Select!
```

Pressing the "Select" button activates the signal generator on the configured frequency with an offset to put the received signal in the unwanted sideband at the audio frequency configured (for example, 800Hz). It displays a bar on the screen showing the measured audio amplitude. The High frequency phase adjustment trimmer potentiometer should be adjusted for minimum measured amplitude. This process is described in the section "Adjustment and alignment" at the end of the assembly part of the assembly manual.

```
8.11 Cal ref osc
Press Select!
```

If you have connected a GPS receiver module such as the QRP Labs QLG1 GPS receiver http://qrp-labs.com/qlg1 with a one pulse per second (1pps) output signal, then when you press

the "Select" button the microcontroller uses the 1pps as a frequency counter gate. The 27MHz reference value is divided by 4 and routed to the Timer1 input of the microcontroller, where it is counted for 4 seconds to obtain a frequency count. This value is stored in the EEPROM in the configuration parameter editable in menu item "8.5 Ref frq".

The firmware calculates compensation adjustments to correct for the frequency error and ensure an output frequency precisely on target (typically with sub Hz accuracy). Naturally changes in ambient temperature will also cause the crystal oscillator frequency to change somewhat.

Using the GPS to calibrate the reference oscillator, system oscillator also automatically parses the serial data stream and sets the real-time clock and the Maidenhead Locator square (computed from latitude and longitude); these are used by the Beacon mode when using the radio as a WSPR beacon.

The system is capable of calibration of 27, 25 and 12MHz reference oscillators.

NOTE: If using the OCXO option in the QCX+ and QCX-mini models, make sure you set menu 8.5 manually to 25,000,000 before using the GPS calibration function.

NOTE: If building the kit for 160m operation, use a 12MHz reference crystal and set menu 8.5 manually to 12,000,000 before anything else, including using the GPS calibration function.

When you press "Select" the calibration will go quickly through several phases, resulting in a measurement of the reference frequency. Calibration takes 6 seconds, once the GPS module has satellite lock. The bottom line of the display will show the status as follows:

- **Waiting**   **Y**ou have just pressed select; the QCX is waiting for the GPS receiver to achieve a valid satellite lock, and the presense of the 1pps signal

- **6**   The start of the countdown to zero, in seconds; followed by 5 and 4

- **3 27,003,623**   Countdowns 3, 2, 1 are three successively closer measurements of the reference frequency

- **0 27,003,620 OK!**   Final calibration value, which is saved in EEPROM and can be seen in menu 6.5

When the calibration is complete, you can unplug the GPS or proceed to calibrate the system reference frequency etc.

If you have connected a GPS receiver module such as the QRP Labs QLG1 GPS receiver http://qrp-labs.com/qlg1 with a one pulse per second (1pps) output signal, then when you press the "Select" button the microcontroller uses the 1pps as a frequency counter gate. It counts the 20MHz system clock internally for 4 seconds to obtain a frequency count. This value is stored in the EEPROM in the configuration parameter editable in menu item "8.6 System frq".

Refer to the previous section for a description of how the display will update during the calibration process.

4.16   Test equipment

The test equipment menu provides several items of test equipment, which can be used to diagnose faults in your radio, and even for other testing purposes too!

The diagram below shows the connection points for the test equipment on the QCX+. **If you are attempting to measure external equipment or circuits, then you will also need to make a ground connection between the CW transceiver and the external circuit. Ground connection pins are provided next to the corresponding input pins.**

These items of test equipment are described below. All except for the signal generator, are display-only items, with no corresponding stored configuration parameter.
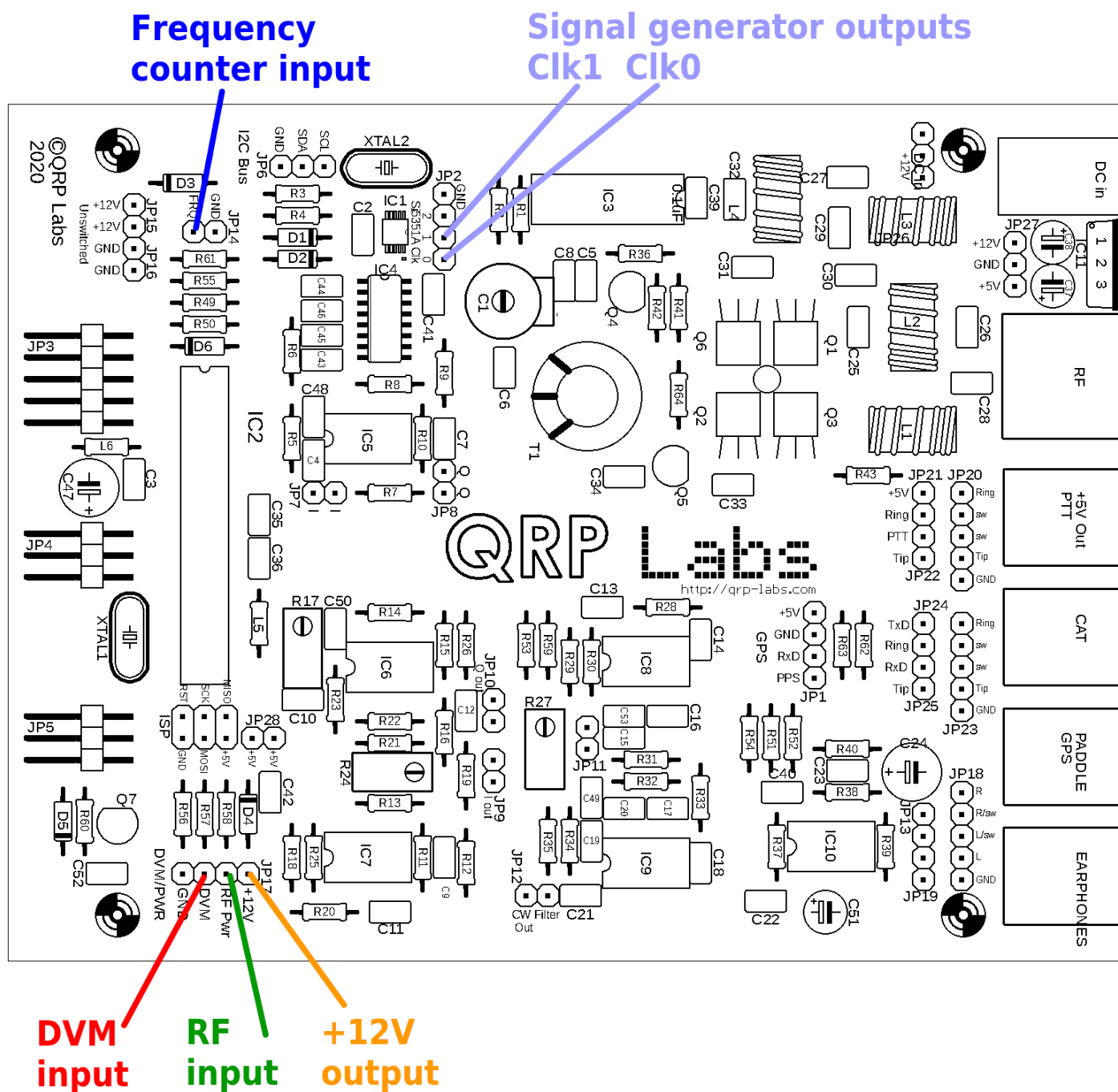
```
9.1 Voltage
11.67V
```

This the Digital Voltmeter (DVM) function. The measurable voltage range is 0-20V DC.

When the on-screen battery voltage display is used, you must connect the DVM input pin to the +V output pin (refer to previous diagram showing these connections).

In this example, a 12V power supply is being used to power the radio. The DVM input pin is jumpered to the +V output pin shown. The measured voltage of 11.67V is 12V minus the voltage drop over the reverse polarity protection diode D3.

```
9.2 RF Power
4.52 W
```

This the RF Power meter function. The measurable power range is 0-5W. The RF power measurement circuit uses a simple diode detector. There are non-linearities in the diode function, and differences from diode to diode; therefore, the measured power output is not highly accurate. However, it is certainly a very good indication and debugging tool.

Note that the RF Power meter and the DVM use the SAME Analogue to Digital (ADC) microcontroller input. You must not try to use the RF Power meter and the DVM at the same time! Ensure only one or the other is connected.

```
9.3 Audio Ch.1
01,652
```

This item just displays the raw amplitude number calculated by the Goertzel algorithm for the audio channel 1, which is connected to the output of the audio amplifier. The value shown here will depend on the input signal level but also on the gain control. You can easily verify that as you turn up the gain control knob, the displayed value increases.

```
9.4 Audio Ch.2
00,008
```

This item just displays the raw amplitude number calculated by the Goertzel algorithm for the audio channel 2, which is connected to the output of the phase nulling circuit. The value shown here is independent of the gain control. The value is much less than that measured on Audio Ch.1. This is because one ADC least significant bit equates to a voltage of about 5mV. The signal

amplitude at that point in the receiver signal path is too low to produce much output from the ADC unless the received signal is very strong.

```
9.5 Frequency
4.21523 MHz
```

This is the frequency counter. The resolution is 10Hz, which results in an update rate of around 8 times per second approximately.

The frequency counter input is connected directly to the Timer1 input of the microcontroller. There is no pre-amplifier or level adjustment. The ATmega328P processor operates from a 5V supply. It expects the frequency counter input signals to be of an appropriate amplitude.

According to the ATmega328P datasheet, a "low" has a maximum input voltage of 1.5V and a "high" has a minimum input voltage of 3.5V. Therefore, the minimum amplitude signal to drive the frequency counter successfully would be 2V peak-peak centred on a 2.5V DC offset. Exercise great care to ensure that the voltage levels are correct, to avoid damaging the ATmega328P input pin.

Additionally, since the ATmega328P has synchronous timer inputs, the highest frequency which can be counted is limited to about 40% of the system clock (20MHz).

Therefore, this frequency counter has range of 0 to 8MHz. The upper frequency end of this range will only be achieved in the case of a nice tidy squarewave of adequate amplitude an 50% duty cycle. Lower quality signals will result in a lower upper frequency limit.

```
9.6 Signal gen.
25,124,093
```

The signal generator function is switched off until you press the "Select" button to enable it. Then the cursor appears under the 10MHz digit. You can then adjust this number just like any other configuration parameter. Use the rotary encoder to increase or decrease the frequency. Press-and-hold, then turn the rotary encoder, to change the tune rate (move the cursor left or right).

As you adjust the frequency, the output frequency of the synthesiser is tuned to match.

The output frequency range is from 3.5kHz to 200MHz. The Si5351A Synthesiser chip datasheet maximum frequency specification is 200MHz. However, in practice it has been found to still operate reliably up to almost 300MHz.

The output waveform is a squarewave with amplitude about 3.5V peak-peak. The output is at the Clk0 and Clk1 terminals (see diagram, above).

Note that the output is directly connected to the Si5351A Synthesiser chip's output pin. Take very great care not to short the output to ground or in any other way abuse this output! If you damage the Si5351A chip it is very difficult to replace

Note that where possible, the Si5351A's Clk0 and Clk1 outputs are operated in quadrature with a 90-degree phase offset. The relationship does not hold at frequencies below 3.2MHz and may not hold into VHF (To Be Determined).

4.17   CAT Control commands (PC remote operation)

The CAT command system is intended to allow the QCX+ to be used with logging software (general and contest) which uses CAT control commands to query the transceiver for information entered into the log, typically operating frequency, mode etc. A subset of the Kenwood TS-480 command set is implemented, with a few minor modifications.

Hardware description:

All microcontroller pins are already in use. The microcontroller serial port peripheral is already used by the LCD_D4 and LCD_D5 signals. Therefore sharing is necessary. Two resistors R49 and R50, together with one diode D6, allow this sharing. In the QCX+ and QCX-mini models, these components are already installed and there is a 3.5mm jack for the CAT serial port. In the QCX later PCB revisions, the components are installed and there are PCB pads for a 3-pin header. Earlier QCX PCB revisions would require you to modify them by adding the three components.

Remember QCX+ RxD connects to the computer TxD, and the QCX+ TxD connects to the computer RxD; there is a swap as shown. Most PCs do not have actual serial ports anymore and the typical set-up will be to use a USB to Serial converter. **Be sure to use one with TTL level serial data, NOT RS232 which is a different (higher) voltage.**
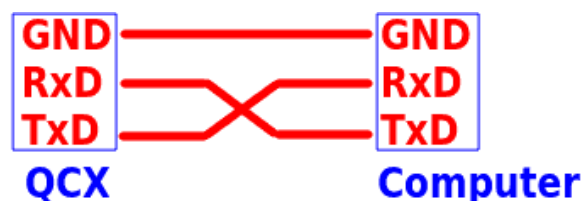
These three signals are routed to a 3.5mm stereo jack connector at the rear panel of the QCX+ and QCX-mini models, with the following connection scheme:

Tip: **QCX+ RxD**
Ring: **QCX+ TxD**
Sleeve: **Ground**
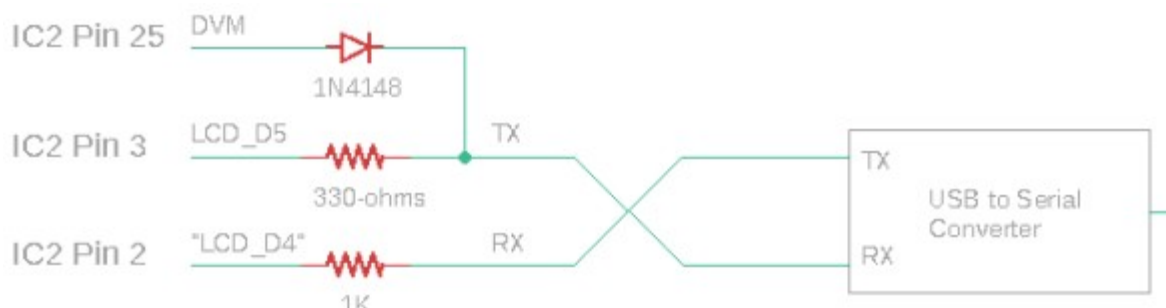
The microcontroller only writes to the serial port or the LCD, in atomic operations; it does not attempt to write to the LCD while serial port write is in progress, nor write to the serial port while an LCD write is in progress. To prevent conflicts, LCD_D4 (processor's RxD signal) is driven by the external serial device TxD signal via 1K resistor R49. This prevents two circuits trying to drive each other, if an LCD-write and serial port write occur at the same time. The processor TxD signal is shared with LCD_D5. When writing to the LCD, this signal pulses and would be interpreted by the remote serial device as some spurious characters. To prevent this, a 270-ohm series resistor is used, and a diode to IC2 Pin 25 (which is also the DVM analog measurement channel). During

LCD writes, IC2 Pin 25 is driven high, which forces a high (idle) signal to the remote serial device, thereby preventing any spurious character transmission.

Configuration:

The serial data format is 8-bit, 1 start bit, 1 stop bit, at 38400 baud (bps). No parity is used. This is the most common serial data configuration normally used in most applications by default.

No flow control is used (no RTS, CTS signals). A CTS signal could be created by a simple transistor circuit to invert the IC2 PIN 25 signal, which is High during LCD write. This is the opposite polarity to that required by the CTS signal, which is set low to indicate to the remote computer that the transceiver is not ready to receive data.

Note that without flow control, there will inevitably be some occasions when the remote computer queries the QCX+ for information, but the incoming characters arrive during LCD update and are therefore missed.

CAT command format:

All CAT commands consist of a 2-character command code, optionally followed by a parameter and a semicolon as the terminator. Commands to SET a parameter in the QCX+ are the 2-character command code, followed by the parameter value, followed by a semicolon terminator. Commands to GET a parameter back from the QCX+, are the same but without the parameter value. For example:

FA00007030000;   Sets the QCX+ VFO A to 7.030MHz

FA;   Asks the QCX+ what the frequency of VFO A is. The QCX+ will respond with "FA00007030000;" to indicate VFO A is set to 7.030MHz.

All the commands are like this. Two character command code followed by ; to read a value. To set a value, just insert the parameter value between the two-character command code and the semicolon terminator. If an invalid command is issued, then a value "?;" is returned. Replies from the QCX+ do not have carriage return or linefeed characters, only the CAT standard ';' character (semicolon) as the terminator.

Note that a limited subset of the TS-480 command set is used, due to the limited program space available in the QCX+ and because many TS-480 transceiver commands are not applicable to the QCX+. Some of the commands are read-only and cannot be used to write parameters to the QCX+; an attempt to write (SET) a parameter which in the QCX+ implementation is read-only, will be ignored; the QCX+ will answer with the parameter reply, just the same as if a read (GET) command had been issued. The commands implemented should be sufficient for operation with popular logging programs. Note also that in the interests of compact code, minimal error checking is undertaken. Setting the VFO frequency to something invalid or out of band is not prevented, for example.

The following lists the commands and responses in alphabetical order:

AG: Get AF Gain
Get: Always returns 0000 – the audio gain on the QCX+ is an analogue control and the processor does not have a way of reading it; this CAT command is supported because certain software requires it to return a value; the actual value 0 returned has no meaning.
AX: Get/Set auxiliary I/O pins.
Set: The two least significant bits of the value are written to the LCD_D6 and LCD_D7 signals. For

example, "AX2;" will set LCD_D7 high and LCD_D6 low. These signals can be used to control external equipment. Bear in mind that there will be short micro-second duration glitches on these signals every time the LCD is written; any external equipment will need to ignore these short glitches.

Get: The value written to LCD_D6 and LCD_D7 is read back, plus 4 if the DVM signal is high, and plus 32 if the FREQ signal is high. This allows the AX; command to read the state of the QCX+ DVM signal and FREQ signal as two general purpose input pins. For example, if FREQ is high and DVM is low, command "AX;" would return "AX34" to read back the previously set AX value (2) plus the FREQ high state (adds 32).

Therefore the AX command allows control over two output signals and reading signals from two inputs, that can be used to sense and control additional equipment connected to the QCX.

FA: Get/Set VFO A

Set: Sets VFO A value. Example: FA7030000; sets VFO A to 7.030MHz

Get: Returns the VFO A contents as an 11-digit number. Example: "FA;" returns "FA00007030000;"

FB: Get/Set VFO B

Set: Sets VFO B value. Example: FB7016000; sets VFO B to 7.016MHz

Get: Returns the VFO B contents as an 11-digit number. Example: "FB;" returns "FA00007016000;"

FR: Get/Set Receive VFO Mode

Set: Set VFO Mode: 0, 1, 2 correspond to VFO A, VFO B or Split respectively. This is the case for both the FR and FT commands (which are nominally Receive and Transmit VFOs) because in the QCX+ the VFO mode use does not correspond exactly to TS-480.

Get: Get Receive VFO Mode: 0 means VFO A is used for receive (could be due to VFO mode being VFO A, or VFO Mode being Split); 1 means VFO B is being used for receive (must be VFO Mode B).

FT: Get/Set Transmit VFO Mode

Set: Set VFO Mode: 0, 1, 2 correspond to VFO A, VFO B or Split respectively. This is the case for both the FR and FT commands (which are nominally Receive and Transmit VFOs) because in the QCX+ the VFO mode use does not correspond exactly to TS-480.

Get: Get Transmit VFO Mode: 0 means VFO A is used for transmit (must be VFO Mode A); 1 means VFO B is being used for transmit (could be due to VFO mode being VFO B, or VFO Mode being Split)

FW: Get filter bandwidth

Get: Always returns 0200 meaning, 200Hz (the QCX's CW filter bandwidth)

ID: Get radio ID

Get: Always returns 020 (Kenwood TS-480)

IF: Get transceiver information (TS-480 format).

Get: Returns a composite information string containing the state of the transceiver, as follows (excluding command ID and ; terminator character):

- 11-digit operating frequency (VFO A or B, according to the VFO mode setting and transmit/receive state
- 5 spaces
- 5-digit RIT frequency, as +/-9999Hz e.g. RIT up 200Hz returns "+0200" in this field
- RIT status: 0 = RIT OFF, 1 = RIT ON
- XIT status: always 0 because QCX+ has no XIT
- Memory channel bank number: always 0
- Memory channel number: always 00
- Transceiver status: 0 = RX, 1 = TX
- Operating mode: always 3 (CW)
- Receive VFO: 0 = VFO A, 1 = VFO B
- Scan status: always 0
- Split: 0 = Simplex operation (VFO mode A or VFO mode B), 1 = Split
- Tone: always 0
- Tone number: always 0
- Space character

KS: Get/Set Keyer speed

Set: Sets the Keyer speed to the specified number of words per minute

Get: Gets the current Keyer speed setting (in words per minute)

KY: Get/Set message for immediate sending

Set: Initiates a CW message transmission at the current keying speed. The format of the command is KY followed by a space, followed by the message to be sent, followed by a semicolon termination character. For example command
`KY HELLO;`
will initiate CW transmission of the text "HELLO".

Get: Returns:
KY0; if message sending is in progress and the transmit text buffer is not more than 75% full
KY1; if message sending is in progress and the transmit text buffer is more than 75% full
KY2; if no message is being sent, therefore the transmit text buffer is emtpy
?; if the attempted message would overflow the transmit buffer; in this case it is canceled

Note: The KY transmit text buffer is 80 characters long. It is a circular buffer. It is acceptable to send new messages with KY before the message sending is complete, they are simply appended to the transmit buffer. You may not send a message that would overflow the buffer, if attempted the message will simply be ignored and error code ?; returned.

MD: Get operating mode

Get: Always returns 3 (CW)

OM: Get the radio's model number

Get: Returns the radio's model number. For QCX+ this is QC so the result is simply **OMQC;**

QM: QCX+ Menu

The QM command allows get/set of any item in the QCX+ menu system. It is not part of the TS-480 CAT command set, it is specific to the QCX. Please refer to the paragraph below for a full description.

QU: QCX+ Update

This is an unsolicited notification sent by the QCX+ to the host computer; it is not part of the TS-480 CAT command set. Please refer to the paragraph below for a full description

RD: Set negative RIT offset amount

Set: Sets negative (down) RIT; for example "RD-200;" sets the RIT to -200Hz

RT: Get RIT status

Get: Returns RIT status: 0 = RIT off, 1 = RIT on

RU: Set positive RIT offset amount

Set: Sets positive (up) RIT; for example "RD150;" sets the RIT to 150Hz

RX: Set the radio into Receive mode immediately

Set: Command RX; immediately puts the radio into receive mode. It is equivalent to TX0; The effect is immediate. A CW symbol, character or word being transmitted is abandoned. If a message memory or message initiated by KY is transmitted, it is cancelled immediately.

SM: Get S-meter value

Get: Returns the S-meter value (signal strength), it is a 5-digit number in the range 0 to 16,383.

TB: Command to retrieve decoded text from the QCX's CW decoder text buffer

See paragraph below for full description of this functionality.

TQ: Get/Set transmit state

Set: Sets transmit state: 0 = RX, 1 = TX. For example "TQ1;" keys the transmitter

Get: Returns the transmit state: 0 = RX, 1 = TX. The effect is immediate. A CW symbol, character or word being transmitted is abandoned. If a message memory or message initiated by KY is transmitted, it is cancelled immediately.

Note that when the transmitter is keyed using "TQ1;" closing the paddles or keying the straight key has no further effect until either a "TQ0;" command is received, or the operator enters the menu system via a long press on the "Select" button. Either of these two actions return the transceiver to Receive and from then on, the paddle inputs are active.

Note that if the command TX1; is sent while the QCX+ operator is inside the configuration menu system, the command has the same effect as TX0; (i.e. the radio is not set to Transmit)

QM: QCX+ Menu query and set

The QM CAT functionality allows the CAT host application to build up a complete replica of the QCX+ menu structure. The CAT host computer can retrieve and set the menu parameters over CAT. When values are set, they are written into QCX+ EEPROM just the same as they would be by the QCX+ operator normally.

The QCX+ Menu commands ONLY work while the system is in ordinary running mode. If you run menu CAT commands while the operator has actually entered the menu system on the real QCX+, then you will just get back a ?. This is to prevent concurrency issues when the operator is editing a menu item at the QCX+ itself, and at the same time the CAT host tries to change the same configuration item.

<u>QM get command</u>

The structure of the GET command is:

QMmqss;

where:

QM   The CAT command identifier

m   the number of the main menu. For example in the QCX+, menu 3 is the VFO menu

q   Query type. To simply return the value in the configuration menu, use a . (period). To specify a verbose response that includes the title of the configuration menu, and in the case of a list menu item, the list of possible values it can contain, use ? (question mark). This feature could be useful for the host application to build up a model of the QCX+ menu system.

ss   the number of the sub-menu. ss must be provided as two digits, even if you are reading the value from a sub menu less than ten; for example to read menu 4.3 of the QCX+, you would send QM4.03; (sub menu 03, including the leading zero).

;   Command termination character

The CAT host application does not need to know a priori how many menus and submenus there are in the QCX+, because you can simply stop incrementing the submenu and asking, when the return is ?

As an example, consider the keyer mode menu which is menu item 4.1, and assume it is in IAMBIC A mode. The simple query is:

QM4.01;

The return is:

`QM4.1  .IAMBIC A;`

The return format is:

QMm.s .v;

where:

QM   The CAT command identifier

m   the number of the main menu. In this case menu 4, the Keyer menu

.   a period, that separates the menu and the submenu number

s   the number of the sub-menu. This could be 1 digit or 2 digits. Note that unlike the command query, the response is NOT forced to be 2-digits with the leading zero.

.   a space character and a period, which separate the sub-menu number from its value

v   The value of the configuration menu item

;   Command termination character

This is the short version of the query, having a period between the 4 and the 01. Note the space and dot between menu number, and the value. To be clear, this is the format always. QM then the menu number as m.s (or m.ss if the submenu is 10 or more), then a space then a period, then the value, and a semicolon to finish.

The verbose version of the QM command, has a question mark delimiter between the menu and the sub-menu, as follows:

QM4?01;

The return format is in this case:

```
QM4.1 Keyer mode.IAMBIC A.Straight#IAMBIC A#IAMBIC
B#Ultimatic;
```

The return format here is:

QMm.s t.v.l;

where:

QM   The CAT command identifier
m   the number of the main menu. In this case menu 4, the Keyer menu
.   a period, that separates the menu and the submenu number
s   the number of the sub-menu. This could be 1 digit or 2 digits. Note that unlike the command query, the response is NOT forced to be 2-digits with the leading zero.
        a space character which separate the sub-menu number the menu title
t   The title of the sub-menu, in this case "Keyer mode".
.   A period character which separates the title from the menu item value
v   The value of the configuration menu item
.   OPTIONAL: Another period which delimits the following field, only if present
l   OPTIONAL: A #-delimited list of possible values for the configuration menu item
;   Command termination character

The two OPTIONAL fields are only present if the queried menu item is a list menu item. For numeric and text menus, these are not present.

QM set command:

As an example consider the command:

```
QM4.010;
```

The set command format is:

QMm.ssv;

where:

QM   The CAT command identifier
m   the number of the main menu. In this case menu 4, the Keyer menu
.   a period, that separates the menu and the submenu number
ss   the number of the sub-menu. ss must be provided as two digits, even if you are reading the value from a sub menu less than ten; for example to read menu 4.1 of the QCX+, you would send QM4.01; (sub menu 01, including the leading zero).
v   The value to be written to the configuration menu item

The value v depends on the type of menu being written. For a numeric menu item, it must be only numeric digits (without any thousands separators). For a text menu, the text can contain any text that would be appropriate in the context, but not the semi-colon character. For a list menu, v must be a number indexing the value in the possible list of values.

Therefore in our example above,

```
QM4.010;
```

Menu 4.01's value is set to the 0'th value in the list of possible items; this is "Straight" [key mode].

A subsequent query

`QM4.01;`

would now return:

`QM4.1 .Straight;`

Note that not all menu operations would make sense. For example, some of the QCX+ menus involve activating test equipment or alignment functions, they do not have an actual value which may be queried or set.

QU: QCX+ Update notification

In certain applications, it would be useful for the host computer application to be notified whenever the operator makes a change on the QCX. This does not apply to standard PC software packages such as logging software, because the QU feature implemented on the QCX+ is not part of the Kenwood TS-480 CAT command protocol. It is specific to the QCX. The notification could be useful for people homebrewing their own control interface for the QCX.

This feature is enabled by sending the CAT command QU1; to switch on notifications. QU0; switches off notifications. When the set command is used, any pending unsolicited update flags are cleared.

When enabled, the QCX+ issues a QU (QCX+ Update) notification to the CAT host, whenever the operator changes anything on the QCX+, that the CAT command interface is capable of reading. It also provides information on what was changed. Depending on what was changed, and how, and when, it is possible that more than one parameter in the QCX+ could be changed and notified in a single QU update to the host. The QU format therefore implements a 2-digit numeric field, which is bit-mapped to 6 event flags that indicate what changed on the QCX.

The format of the notification is QUnnn; where nnn is the 3-digit number made up of the event flag bits.

There are seven possible events, i.e. parameters in the QCX+ which the operator can change, and which are readable over the CAT interface. In this way, the host application knows what parameters in the QCX+ were changed, and can send the appropriate CAT commands to the QCX+ to find out the new values.

The possible event codes are as follows:

- 0b 0000 0001 (decimal 1): VFO A was changed
- 0b 0000 0010 (decimal 2): VFO B was changed
- 0b 0000 0100 (decimal 4): RIT was changed
- 0b 0000 1000 (decimal 8): the Transmit/Receive state was changed
- 0b 0001 0000 (decimal 16): the Keyer speed was changed
- 0b 0010 0000 (decimal 32): the VFO mode was changed
- 0b 0100 0000 (decimal 64): Decoded CW now available (if notification enabled)

The numeric field nn is made up of the sum total of the event identifiers which were triggered. For example if the host receives the notification "QU003;" then this would indicate that VFO A and VFO B were both changed. This could for example, have occurred because the operator executed the VFO Swap function. It could also indicate that the QCX+ was momentarily busy (such as, handling some existing queue of commands from the CAT host) and the operator changed both VFOs before the QCX+ was able to send the notification. It's unlikely, but possible.

The QU notification is only issued ONCE until its sent flag is cleared by the host computer executing CAT commands to read the changed data. In this way, the host computer is not flooded by a long stream of identical QU notifications in instances such as the operator quickly turning the tuning knob.

In the event that a QU notification was sent, and the QCX+ operator made more changes, which the host computer does not know about, then when the host computer sends CAT commands, the QCX+ will send a new QU notification to inform the host of the new events.

Note also that in the ordinary execution of CAT commands by the host, which may change parameters such as the VFO frequencies etc., no QU notification is sent back to the host for these changes. Only changes which are initiated by the QCX+ operator at the QCX+ controls, generate a QU notification.

TB: QCX+ Text Buffer Decoded CW retrieval

There is now a special 40-character buffer, where incoming decoded CW is stored for sending to CAT. This buffer is NOT a circular buffer. When it fills up, it simply discards any new incoming characters. Therefore if the host application wishes to receive decoded CW from the QCX+, it should ensure that it reads the buffer sufficiently often that it does not fill up.

TB;

This GET command reads the contents of the decoded CW buffer to the CAT host, and empties the buffer, so decoding CW will CW filling it up again.

The format of the response is:

TBtnns;

where the field meaning is:

TB   two-character result code, the same as the command i.e. "TB"
t   indicates whether message sending is in progress via the KY command, and how many characters remain to be sent. If more than 9 characters remain to be sent, then this parameter is 9. If this character is 0 then the QCX is in receive mode
nn   the number of decoded characters
s   the string of nn decoded characters
;   CAT response terminator

You can also have the presence of decoded CW characters in the buffer indicated to you by the unsolicited QU notification message, if you wish, and if you have enabled the unsolicited notifications via a QU1; command. The QU notification is sent as soon as there is are least one character waiting on the buffer, and if QU notifications are enabled, and if the QU notification flag for decoded CW is enabled.

TB1;

This SET command enables the CW decode flag in the unsolicited notifications QU message (bit event flag 64)

TB0;

This SET command turns off the CW decode flag in the QU notifications.

Therefore in order to receive QU notifications for decoded CW, you must have issued CAT commands QU1; and TB1; first.

Also note that in the QCX+, CW is always decoded, even if it is not configured for display on the QCX's own display; therefore decoded CW over the CAT interface is independent of whether or not it is being shown on the QCX+.

CAT Limitations

The QCX CAT implmentation is necessarily limited due to the relatively meagre resources available on the ATmega328 processor. Aside from the limited (but powerful) command set, which is a subset of TS-480 protocol, plus some QCX-specific commands, you may also need to be aware of the following limitations on buffer sizes.

Incoming CAT command characters go into a 128-character circular buffer to be processed by QCX. If you overflow this buffer further incoming characters are simply ignored, and this will result in a ?; error code returned to the CAT host.

CAT Command buffer is a 85 characters long linear buffer and is the maximum size of a single command in the incoming CAT command bufffer. If multiple commands are concatenated together and sent in one continuous string, the maximum length of each individual command is 85 characters. Each single command is copied out of the incoming CAT command buffer into the CAT command buffer, and the commands processed one by one.

Message transmit buffer is an 80-character circular buffer, used by the KY command, to send messages to the QCX to be transmitted. Any attempt to send text which would overflow this buffer is supressed and simply returns the ?; error result code.
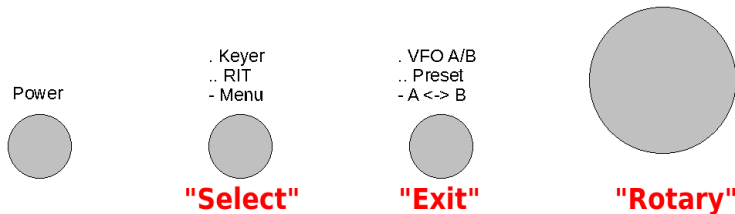
Decoded CW is stored in a 40-character linear buffer. It is retrieved from QCX using the TB; command. The TB; query returns the whole contents of the buffer, which may be up to 40 characters (if it is full). If the buffer is left full without collecting its contents, newly decoded characters are not put in the buffer, they are simply lost.

CAT result buffer is a 120-character circular buffer that holds the output of a CAT query command, ready to send back to the CAT host over the serial port. If the buffer becomes full, further CAT command results are simply discarded.

These limitations on the buffer sizes mean that if you send a LOT of CAT commands too quickly and don't wait for the results – you are likely to overflow the buffers. The QCX won't crash but you'll get back the ?; error code or in perhaps unexpected erroneous results.

Another limitation is that the CAT serial port is shared with the LCD data pins, necessarily due to the limited number of processor I/O pins. When the QCX has started communicating with the CAT host over the CAT serial port, the LCD is made to wait until all CAT communication has completed. If the processor is writing to the LCD at the time the CAT host tries to issue a command to the QCX, then the QCX will most likely receive a partial command which will result in an error code ?; whereupon the CAT host would normally simply re-issue its command.

5. Operation reference "cheat sheet"

. Keyer
.. RIT
- Menu

. VFO A/B
.. Preset
- A <-> B

Power

"Select"   **"Exit"**   **"Rotary"**

Main controls functions:

"Select" single press: Keyer speed adjust, then "Select" again to select, or "Exit" to cancel. **Double press**: RIT adjust, then "Select" again to select, or "Exit" to cancel **Long press**: Enter the configuration menu (see below)	**"Exit" single press**: change VFO mode: A, B, Split **Double press**: Select frequency preset. Then press "Select" (save VFO to preset), "Exit" (load preset to VFO) or "Rotary" (cancel) **Long press: swap VFO A and B frequencies**	**Encoder turn**: tuning, menu selection, editing, etc **Encoder press**: change tune rate 1kHz->500Hz->100Hz->10Hz **Encoder dbl or long press**: choose stored message. Then "Select" to send repeatedly, "Rotary" to send once, or "Exit" to cancel

Configuration menu items:

1 Preset

Preset 1 to Preset 16: Enter frequency presets.

2 Messages

2.1 Interval: gap between message transmissions, in seconds
2.2 Repeats: number of message repeats, 1 to 99 or 0 means infinite
2.3 Message 1 to Message 12: Stored messages. First four are 100 characters, rest are 50 characters.

3 VFO

3.1 VFO mode: A, B or Split
3.2 VFO A: startup frequency
3.3 VFO B: startup frequency
3.4 Tune rate: startup rate, 1kHz, 500Hz, 100Hz or 10Hz
3.5 RIT: Receive incremental tuning
3.6 RIT rate: 1kHz to 1Hz
3.7 CW-R: Enable CW-R mode
3.8 CW offset: default offset (700Hz)

4 Keyer

4.1 Keyer mode: Straight, Iambic A/B, Ultimatic
4.2 Keyer speed: in words per minute
4.3 Keyer swap: swap paddle inputs
4.4 Keyer weight: alter dit:space ratio
4.5 Auto space: enable keyer autospacing (default OFF)
4.6 Semi QSK: Enable semi QSK
4.7 Practice: enable practice mode, keys but no RF output
4.8 Sidetone frq: normally set to same as CW offset (700Hz)
4.9 Sidetone vol: volume, 0 to 99
4.10 Strght mode: both/dip/ring allows use of 3.5mm mono plug

5 Decoder

5.1 Noise blanker: period in ms
5.2 Speed Avg: for speed detection
5.3 Ampl. Avg: for ampl. detection
5.4 Enable Rx: enable Rx decoder
5.5 Enable Tx: enable Tx decoder
5.6 Enable Edit: enable CW decoding during menu editing (useful!)
5.7 VA enable VA prosign (not SK)

6 Beacon

6.1 Beacon: On/Off enable beacon operation
6.2 Mode: CW or WSPR
6.3 Frequency: beacon frequency
6.4 Frame: frame duration in minutes
6.5 Start: minutes past the hour to start
6.6 WSPR call: Callsign to encode in WSPR message
6.7 WSPR locator 4-character Maidenhead square
6.8 WSPR power dBm power level to encode in WSPR message
6.9 Set time: set real time clock

7 Other

7.1 Dbl click: dbl click delay time in milliseconds (300)
7.2 Battery: enable battery icon on the display top right
7.3 Batt. Full: set millivolts for a "full" battery icon indication
7.4 Batt. set millivolts for each battery bar step level in the icon display
7.5 Cursor blink: Enable blinking cursor
7.6 S-meter: enable S-meter display on the screen
7.7 S-meter step: set value of each S-meter bar (in amplitude units)
7.8 Custom splsh: enable custom splash screen

7.9 Clock : enable real time clock
7.10 Delim.: set thousands delimiter
7.10 Backlight: enable QCX-mini LCD module backlight LED
7.11 Factory rst.: Factory reset, if set to value 17 – use with caution

8 Alignment

8.1 Alignment freq: frequency for BPF alignment
8.2 I-Q balance freq: audio frequency for I-Q balance adjustment (700Hz)
8.3 Phase adj Lo freq: audio freq for low audio phase adj (600Hz)
8.4 Phase adj Hi freq: audio freq for high audio phase adj (800Hz)
8.5 Ref. frq.: 27MHz synth reference frequency used for synthesiser
8.6 System frq.: 20MHz system clock frequency used for system timing
8.7 Peak BPF: do the actual BPF peaking alignment
8.8 I-Q bal.: do the I-Q balance adjustment
8.9 Phase Lo: do low audio phase adjustment
8.10 Phase Hi: do high audio phase adjustment
8.11 Cal ref. osc: do GPS calibration of 27MHz osc if GPS is connected
8.12 Cal sys. osc: do GPS calibration of 20MHz osc if GPS is connected

9 Test equipment

9.1 Voltage: measure voltage
9.2 RF Power: measure RF power
9.3 Audio Ch.0: measure audio channel 0 amplitude
9.4 Audio Ch.1: measure audio channel 1 amplitude
9.5 Frequency: measure frequency
9.6 Signal gen.: enable and adjust signal generator output

Save settings!: save current VFO etc settings to be the default on power up; press "Select" to save, "Exit" to cancel

6. Resources

- For all updates relating to this kit, and to download the assembly manual, please visit the QRP Labs CW transceiver kit page http://qrp-labs.com/qcxp
- For any questions regarding the assembly and operation of this kit please join the QRP Labs group, see http://qrp-labs.com/group for details

7. Document Revision History

| 0.01 | 27-Oct-2020 | Firmware version 1.06 |
| 0.02 | 06-Nov-2020 | Added a section about the GPS interface and restrictions using it, to section 1 (bottom of page 4) |