

DDS VFO 2

CONSTRUCTION MANUAL



 www.ozQRP.com

Important

Please read before starting assembly

STATIC PRECAUTION

The DDS VFO kit contains the following components which can be damaged by static discharge:

- **The DDS chip which is pre-soldered to the PCB and shipped in an anti-static bag.**
- **The microcontroller which is pre-programmed and shipped in an anti-static bag.**

Do not remove the devices from their protective anti-static bags until you have taken precautions against static discharge.

- **If possible use an anti-static wrist strap and conductive mat. These can be purchased readily from electronic retailers.**
- **If these are not available then at least ensure you have discharged yourself by touching an earthed metal surface.**
- **Try not to directly touch the pins of the devices.**
- **Ensure your soldering iron has an earthed tip.**

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1 INTRODUCTION

The DDS VFO 2 is designed as a companion for the MST3 transceiver board although it could be used with many other Superhet or Direct Conversion radios. It is simple to use having only one control yet offers many advanced features. A kit of parts, with the DDS chip already loaded onto PCB and blue backlit LCD, is available from www.ozQRP.com.

DDS VFO Features:

1. Stable frequency – no more drift!
2. Simple to operate using a single rotary encoder control with press button switch.
3. Bright 16 character by 2 line LCD display. Can also be used with a non-backlight display to reduce current consumption if needed.
4. Output frequency range of 10KHz to 10MHz. Frequency range can be extended by 'overclocking' (see text).
5. Selectable 10KHz, 1KHz, 100Hz or 10Hz frequency steps.
6. RIT control allows fine adjustment of receive frequency without affecting the transmit frequency.
7. Display of power supply voltage.
8. Display state of USB/LSB and TX/RX inputs.
9. Programmable IF frequencies. Separate high and low side IF frequencies ensure the displayed frequency is the same as the transmitted frequency when changing sidebands.
10. Programmable option to save the current frequency and step value into memory. These are re-loaded at power up.
11. Fine adjustment of frequency in configuration to allow for master clock tolerance.
12. Voltage display can be trimmed in configuration to allow for voltage reference errors.
13. Can be configured without an IF Offset to allow use as a signal generator or with Direct Conversion transceivers.
14. Draws only around 50mA at 13.8V DC (with LCD backlight).
15. Spurious outputs at least -45dB.
16. Typically 300mV pk-pk sine wave output (200 ohms).
17. High quality double sided PCB with ground plane, plated through holes, solder mask and silk screen.
18. Simple and easy to build using through hole components apart from one SMD chip. To assist constructors the PCB comes shipped with the SMD chip already installed.

2 CIRCUIT DESCRIPTION

Integrated circuit U2 is an Analog Devices AD9834 Direct Digital Synthesis (DDS) chip and forms the heart of the DDS VFO. A 50MHz crystal oscillator module supplies the master clock and gives usable output frequencies up to a quarter of that value or 12.5MHz.

The DDS is controlled by a 3 wire serial data bus from microcontroller U1. The microcontroller is an Atmel ATmega328 and runs an internal 8MHz clock which avoids the use and expense of an external crystal.

A rotary encoder produces quadrature signals when rotated and one line is fed into the microcontroller interrupt input and becomes the reference input. Once an interrupt is detected the state of the other input is read and the direction determined. The rotary encoder also incorporates a press button switch and is used for a number of functions as described later. U1 incorporates pull-up resistors for the encoder inputs so they are normally held high and capacitors C7 and C8 help filter out switch bounce.

The microcontroller has an internal analog to digital converter (ADC) which uses the 5 volt rail as a reference. The ADC measures the incoming power supply rail via a resistive attenuator formed with R5 and R6. The calculated value is displayed on the LCD during use.

The A input is used to monitor the TX/RX state, while the D input is used to detect the state of the USB/LSB switch. The inputs expect a nominal +12 Volt to 0V state change and are buffered by resistive attenuators to protect the microprocessor inputs.

The PCB also includes an ISP connector to allow future software upgrades without having to remove the chip from its socket.

Most of the remaining pins of U1 are dedicated to driving the LCD in 4 bit mode. R9 sets the backlight current and may be left out if a non-backlight LCD is used. VR1 adjusts the LCD contrast and normally only needs to be set once at the commissioning stage.

The outputs from the DDS chip are current sources and the output is converted to a voltage by the 200 ohm resistors R12 and R13. The full scale value of the current and hence the pk-pk output voltage is set by the 5.6K ohm resistor R11. The output is passed through a simple 5 pole low pass filter to attenuate unwanted high frequency components.

R14 is used to terminate the filter if the external load is high impedance. In most circumstances it can be left off the board.

The incoming power supply is regulated to 5V by a 7805 1A regulator which mounts flat on the PCB to act as a heatsink.

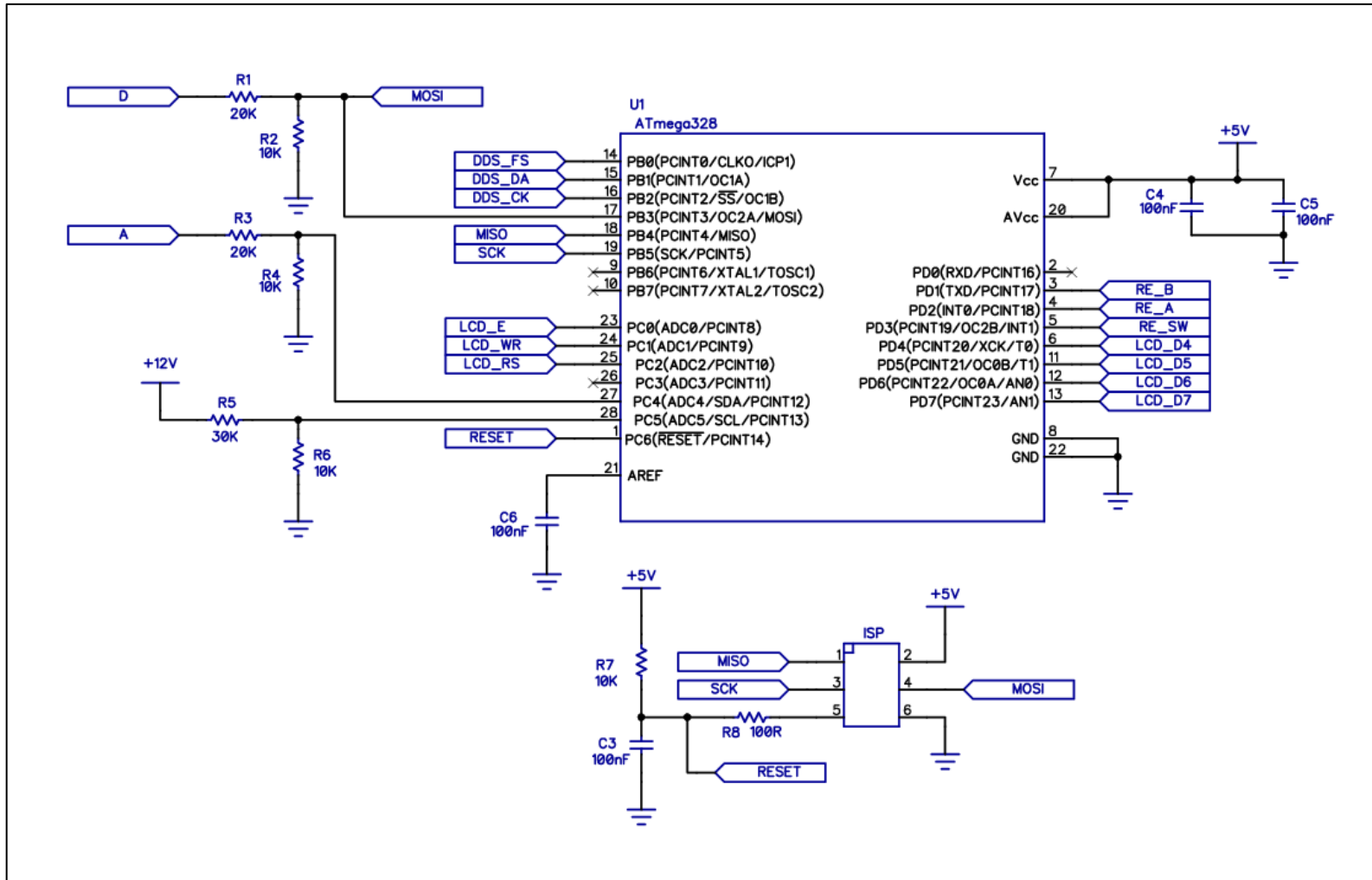


Figure 1 CPU

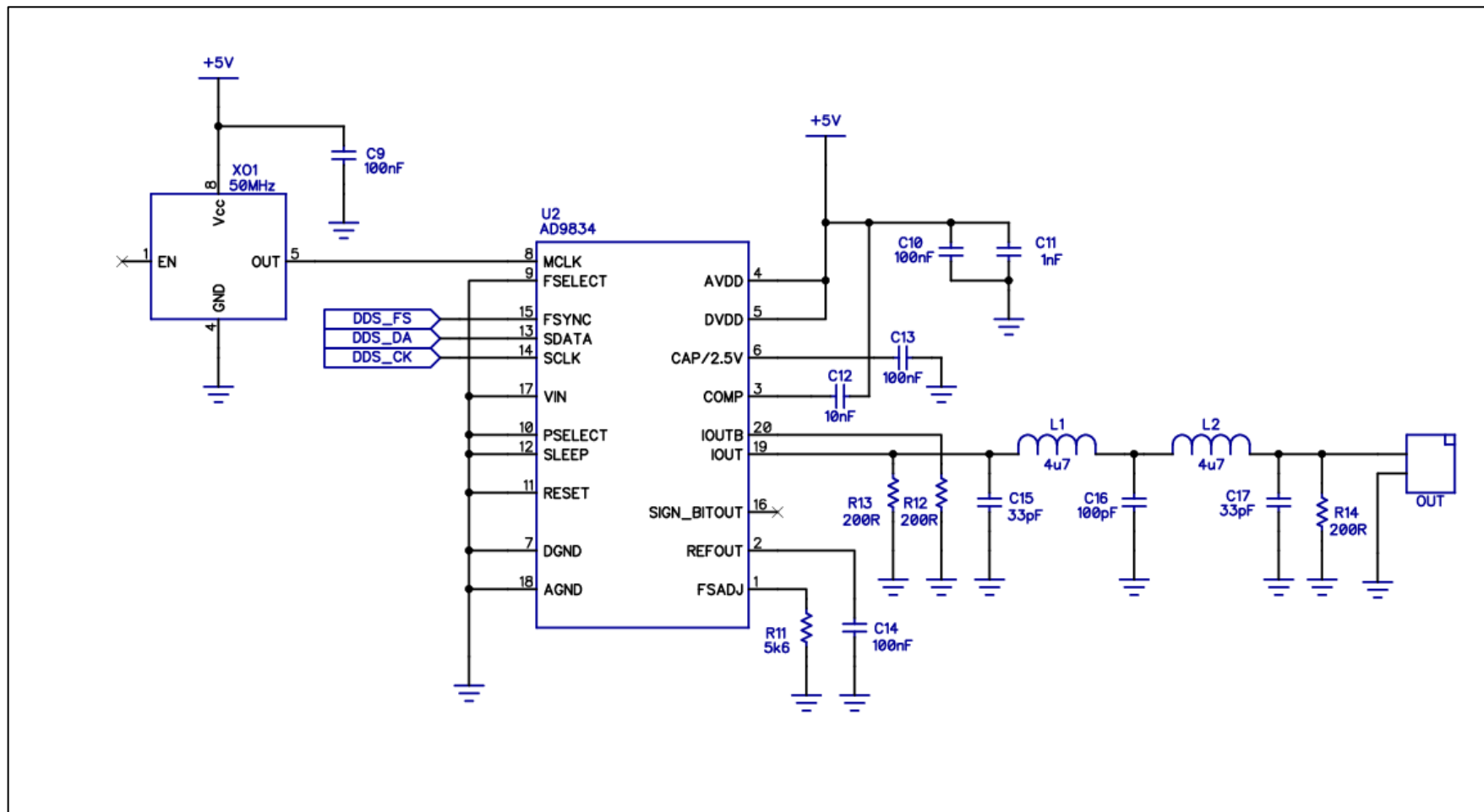


Figure 2 DDS generator

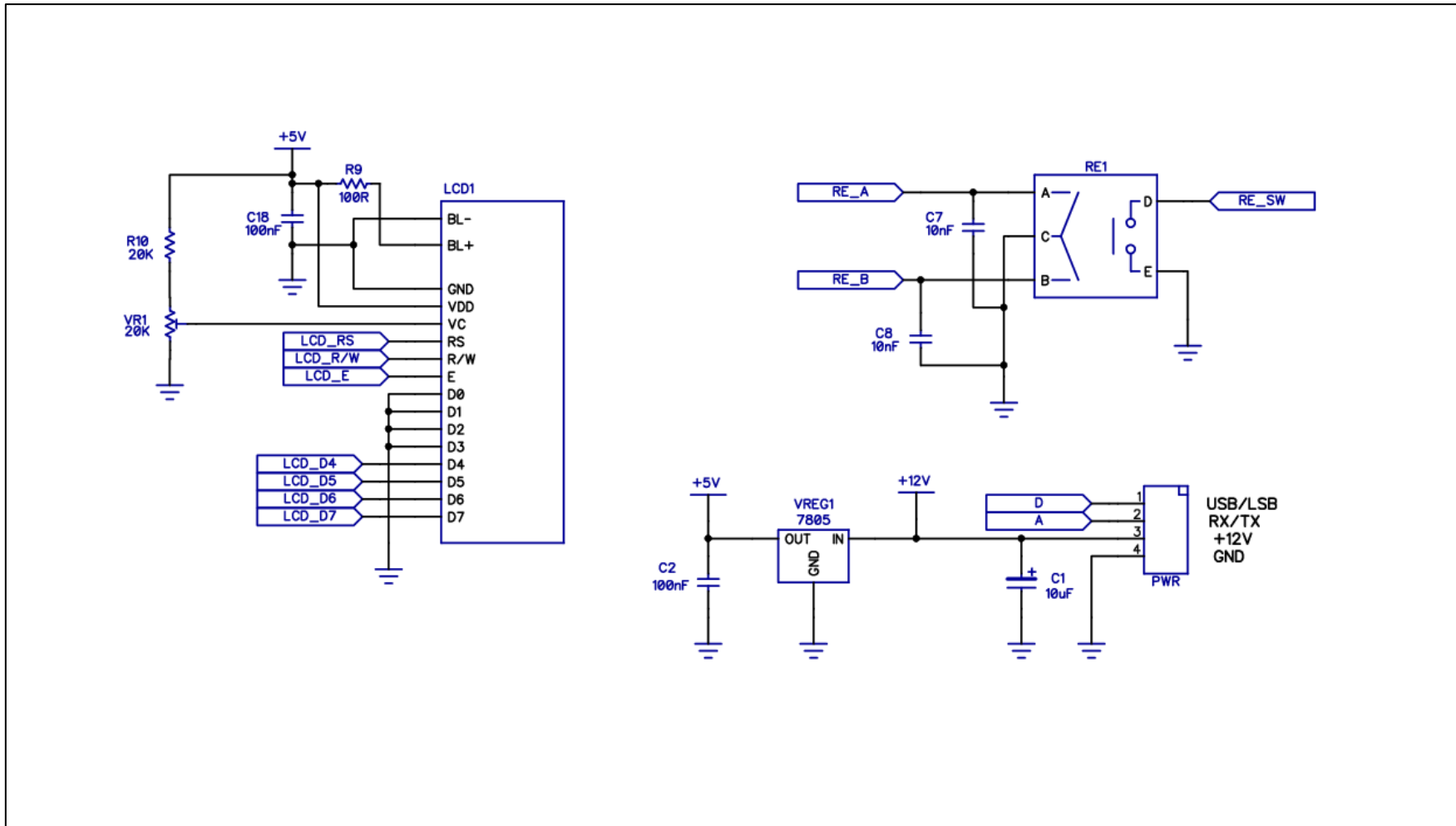


Figure 3 LCD, Rotary Encoder and Power Supply

3 KIT SUPPLIED PARTS LIST

Quantity	Comment	Designator
Capacitors		
2	33pF 50V disc ceramic	C15, C17
1	100pF 50V disc ceramic	C16
1	1nF 50V disc ceramic	C11
3	10nF 50V ceramic MLCC	C7, C8, C12
10	100nF 50V ceramic MLCC	C2, C3, C4, C5, C6, C9, C10, C13, C14, C18
1	10uF 25V RB electrolytic	C1
Resistors		
2	100R 1/4W 1% resistor	R8, R9
3	200R 1/4W 1% resistor	R12, R13, R14
1	5.6K 1/4W 1% resistor	R11
4	10K 1/4W 1% resistor	R2, R4, R6, R7
3	20K 1/4W 1% resistor	R1, R3, R10
1	30K 1/4W 1% resistor	R5
1	20K horizontal trimpot	VR1
Semiconductors		
1	ATmega328 - 28pin DIP	U1
1	AD9834 DDS 20 pin TSSOP	U2
1	7805 5V regulator TO220	VREG1
1	50MHz crystal oscillator module	XO1
1	16 x 2 LCD with backlight.	LCD1
Inductors		
2	4.7uH moulded RF choke	L1, L2
Hardware		
1	DDS VFO PCB	
1	28 pin DIP narrow IC socket	
1	3 pin x 2 row 2.54mm pitch header	HDR1 (ISP)
1	Rotary Encoder	RE1
1	4 pin 2.54mm pitch header RA	SK1 (PWR)
1	2 pin 2.54mm pitch header RA	SK2 (OUT)
1	4 pin plug + pins	
1	2 pin plug + pins	
4	12mm long 3mm nylon spacer	
4	2.5mm x 20mm screws	
4	2.5mm nuts	
1	16 way SIL male pin header	
1	16 way SIL female pin header	
1	3mm x 10mm screw	
1	3mm nut	

4 THE DDS VFO AND THE SUPERHET

When the DDS VFO is used in a Superhet transceiver, the relationship between the displayed frequency, the DDS output frequency and the actual transmit frequency can be confusing. This section contains an example to help illustrate the relationship. The example assumes a DDS VFO connected to a MST operating LSB on the 40M band.

The balanced modulator in the MST takes the nominal 10MHz carrier (BFO) signal and mixes this with the audio signal when you speak. The output of the balanced modulator is comprised of an upper sideband (USB) and a lower sideband (LSB) signal centered on the carrier frequency. The carrier is not present at the output (suppressed) and so we use the term Double Sideband Suppressed Carrier modulation or simply DSB. The DSB signal is applied to the crystal filter.

The filter's upper skirt is at 10MHz, and so the LSB is passed by the crystal filter, while the USB is blocked. The LSB signal is then mixed with the output of the DDS VFO to obtain the final transmit signal.

We will assume the DDS VFO is configured for an IF frequency of 10MHz, and display frequency of 7.100MHz.

The DDS computes the output frequency to be $10.000\text{MHz} - 7.100\text{MHz} = 2.900\text{MHz}$.

The final transmitted signal will be $10.000\text{MHz} - 2.900\text{MHz} = 7.100\text{MHz}$.

Now let's assume that we want to move the carrier frequency 300Hz higher. This could be due to a slightly higher crystal filter response or after testing we find the USB is not suppressed sufficiently.

The new carrier frequency will be 10.0003MHz, however the DDS VFO will still be programmed for an IF frequency of 10.000MHz and generate an output frequency of 2.9MHz. As a result the displayed frequency will be $10.000\text{MHz} - 2.900\text{MHz} = 7.100\text{MHz}$, but the actual transmit frequency will be: $10.0003\text{MHz} - 2.900\text{MHz} = 7.1003\text{MHz}$.

This creates an error situation where the LCD displayed frequency and the actual transmit frequency are not the same.

To fix this we need to measure the actual suppressed carrier frequency and re-configure the DDS VFO IF frequency parameter.

Using this example we would now configure the DDS VFO with IF frequency of 10.0003MHz.

The DDS output frequency will now become $10.0003\text{MHz} - 7.100\text{MHz} = 2.9003\text{MHz}$, and the final transmitted signal will be $10.0003\text{MHz} - 2.9003\text{MHz} = 7.100\text{MHz}$.

The displayed frequency now correctly matches the transmitted signal frequency.

5 CONSTRUCTION

5.1 GENERAL

The DDS VFO is built on a high quality fiberglass PCB. The PCB is doubled sided with tracks on both sides along with a ground plane. The holes are plated through and so it is not necessary to solder both sides to make connections. To assist construction the component overlay is screen printed on both sides and a solder mask is included to guard against solder bridges.

The ground plane is substantial and can sink quite a bit of heat from low wattage soldering irons so ensure you use a good quality iron that can sustain the power required. You may find that sometimes solder doesn't appear to flow through to the top side. This is not necessarily a problem because the plated through holes make a connection to the top side automatically.

Another point to consider is that plated through holes consume more solder than non-plated holes and makes it more difficult to remove components.

The lesson is to double check the values and orientation of components before installation.

There isn't a 'best' scheme for loading the components, however, the suggested procedure is to load the smaller components first and then work upwards.

5.2 CONSTRUCTION STEPS

Refer to the parts list and Figure 4 when installing the components.

Step 1: Resistors

If in doubt check the values with a multimeter before soldering. Pass the pigtails through from the top and bend out slightly underneath to hold them in place. Turn the PCB over and press down slightly to make them rest against the surface and then solder. Cut off the excess pigtail with side cutters. The trimpot can also be installed at this stage. If the DDS VFO is used with the MST3, R14 is not installed. It is included on the PCB to terminate the filter if required when used with high impedance loads.

Step 2: RF chokes

These are not polarized and can go in either way. Make sure they sit flat against the board before soldering.

Step 3: Capacitors

Install the capacitors with minimal lead length. The electrolytic is the only polarized capacitor and the positive lead points towards the edge of the PCB.

Step 4: IC socket

The IC socket is installed next with the notch facing the right side of the PCB.

Step 5: Crystal oscillator module

Ensure pin 1 of the oscillator module faces the bottom left of the PCB.

Step 6: 5 volt regulator

The regulator lays flat against the PCB so needs the leads bent at right angle to fit through the holes in the PCB. Insert into the PCB holes and secure with a 3mm screw and nut before soldering the leads.

Step 7: Connectors

The Output connector is a 2 pin right angle header while the Power connector is a 4 pin right angle header. Push them into the PCB so they lay flat against the board and then solder.

The ISP header is an un-shrouded 3 pin x 2 row header and the shorter pins are inserted into the PCB and soldered.

The LCD connector is a 16 way male pin header and is mounted on the reverse side with the short ends of the pins located in the PCB. Ensure it is pushed in completely and solder the end pins first and check it is at right angle to the PCB before soldering the remaining pins.

Step 8: Rotary encoder

The rotary encoder is mounted on the reverse side. Insert into the holes and check that it is at right angle to the board before soldering. It is not necessary to completely fill the mechanical mounting holes in the PCB with solder.

Step 9: Microcontroller

Remove the microcontroller from the bag and insert into the IC socket ensuring pin 1 points to the top right of the PCB towards the contrast control. It may be necessary to squeeze the rows of pins slightly together to get it to fit into the socket.

Step 10: LCD

Solder a 16 way female pin header to the rear side of the LCD PCB.

The LCD can then be mounted onto the DDS VFO and mate with the 16 way male pin header.

Place four 12mm long nylon spacers between the LCD and DDS VFO PCB at each corner and secure the assembly with 2.5mm screws and nuts.

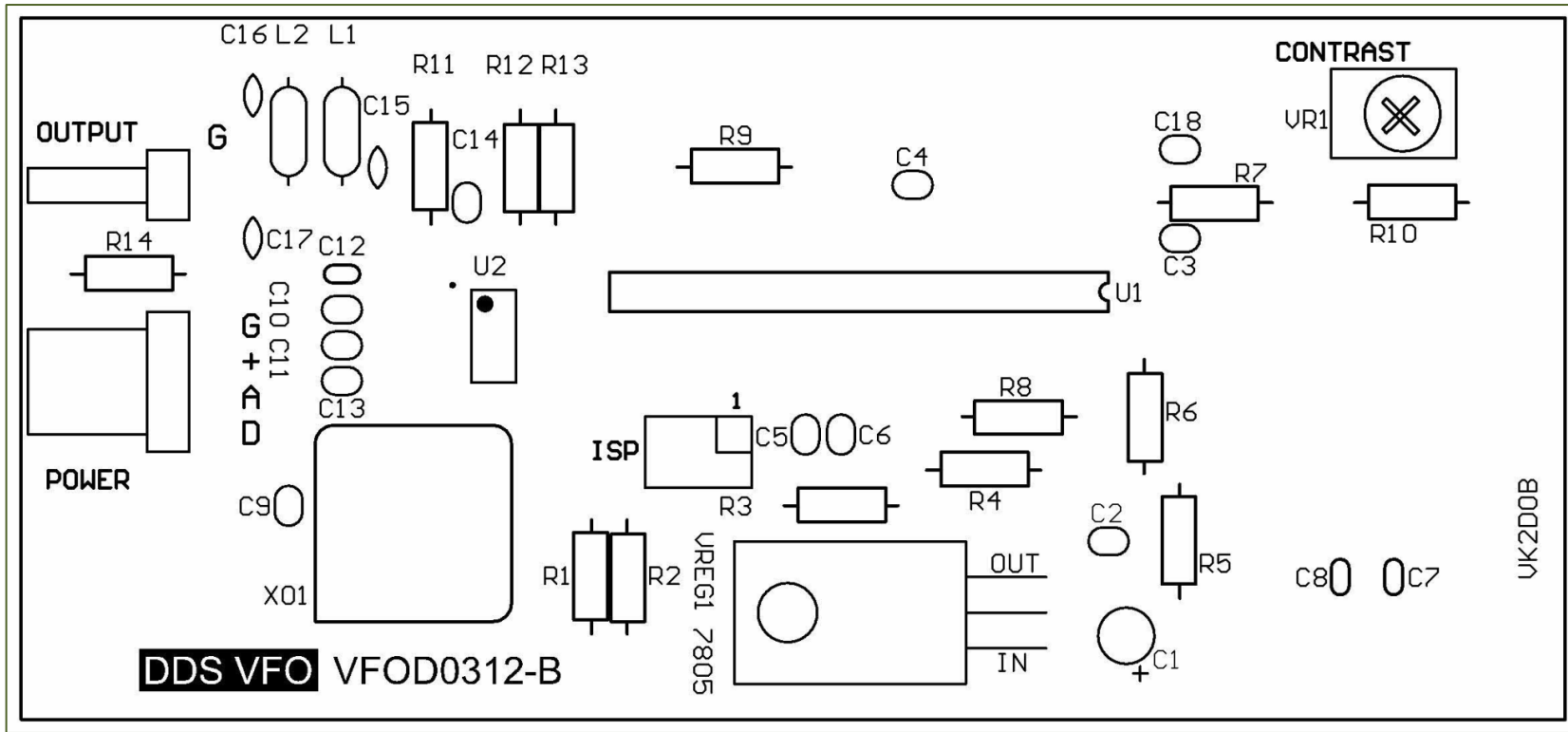


Figure 4 Component overlay

6 FIRST TIME POWER ON

Before applying power check the board over one more time. Look for solder bridges and components in the wrong way. A moment spent here may save a lot of frustrating time later on.

Once you are satisfied connect the DDS VFO to a power supply between 9 and 15V DC. If the power supply has current limiting set this to about 100mA.

Apply power and check that the LCD backlight turns on. Also check with a multimeter that the output of the regulator is between 4.75 and 5.25V DC. The power supply current should be around 50mA. If the LCD installed is not the one supplied in the kit the current may be different depending on the backlight characteristics.

If the readings are way outside this range turn off immediately and look for problems.

At this stage you may or may not see anything on the LCD. Most likely this is because the LCD contrast has not been set. Adjust the contrast trimpot until the characters are clear and easy to read.

Turn the power off then on again and check that the first thing displayed is the firmware version number. This is then followed by the operating display.

As the DDS VFO has not been configured the LCD will display default settings. These are frequency of 7.1MHz and a 1KHz Step. Verify with an oscilloscope or a frequency counter that the DDS is outputting a 2.9MHz sine wave signal of around 300mV pk-pk.

7 CONFIGURATION

7.1 UNDERSTANDING OPTIONS

Master Clock

The DDS VFO requires a master clock to generate the output frequencies. The firmware can accept three clock frequencies of 50MHz, 80MHz or 100MHz. The 50MHz clock rate is the default setting while the other options allows 'over clocking' of the DDS chip to generate higher frequencies if required. See section 10 for more details.

IF Offset

When the **IF Offset** is set to **Yes**, the LCD will display the desired transmit frequency while the actual DDS signal frequency will be equal to the difference between the IF and transmit frequencies.

For example, the MST3 transceiver employs a 10MHz IF frequency. If the desired transmit frequency is 7.1MHz then the DDS VFO frequency would be $10 - 7.1 = 2.9\text{MHz}$.

The relationship between the IF frequency, DDS VFO frequency and transmit frequency when used with the MST3 is shown below:

Band	IF frequency	DDS VFO frequency	Transmit frequency
80M	10MHz	6.5MHz	3.5MHz
40M	10MHz	3MHz	7MHz
20M	10MHz	4MHz	14MHz
17M	10MHz	8MHz	18MHz



Note that the DDS VFO firmware assumes that the DDS VFO frequency is always below the IF frequency.

If the **IF Offset** is set to **No** the DDS output frequency will be the same as the displayed frequency. This is the setting selected when the DDS VFO is to be used as a general purpose signal generator or with a Direct Conversion receiver.

IF Freq High and IF Freq Low

To generate an accurate output frequency the DDS VFO must know the exact IF frequency. To do this the frequency must be measured using a frequency counter and the value entered at configuration. If not the default values will be used and the displayed frequency may not accurately match the transmit frequency.

Also, the MST3 moves the IF frequency when changing sidebands by about 3KHz. So that the displayed frequency and the actual transmitted frequency are matched it is necessary to enter both upper and lower IF frequencies. Using these values the DDS VFO firmware automatically adjusts the output frequency when sidebands are changed.

Band

This option is used in conjunction with the **IF Freq** to determine the actual DDS frequency.

30S Freq Save

This option enables automatic saving of the current frequency and step in EEPROM so that it is recalled the next time the DDS VFO is powered on. The EEPROM has a maximum specification of 100,000 write/erase cycles, so to protect it from excessive writes, the save is performed only once per frequency change and only after a 30 second idle period has elapsed. If the encoder is operated so that there is less than 30 seconds between changes no saves will be performed.

Freq Calibrate

The DDS frequency is directly related to the master clock frequency. Due to component tolerances the master clock may not be exact and as a consequence the transmitted signal will be slightly off frequency when compared to the display frequency. This option allows trimming of the DDS output frequency in firmware. The range is plus and minus 500Hz in 10Hz steps.

Volts Calibrate

The microcontroller measures the battery voltage using an analog to digital converter with the +5V rail as the reference voltage. As the +5V rail is supplied by an ordinary 7805 regulator, it may not be exactly +5V, and therefore the displayed voltage may not be correct. This option allows the displayed value to be trimmed by plus and minus 1V in 0.1V steps to match the correct value.

Frequency

When the **IF Offset** option is set to **No** the DDS VFO displayed frequency is the same as the transmit frequency. This option allows the initial frequency to be set.

7.2 USING THE ROTARY ENCODER

In Configuration the rotary encoder has four states:

1. Rotate clockwise. Used to increment values
2. Rotate counter-clockwise. Used to decrement values.
3. Short (less than 1 second) press of the encoder button. Used to toggle between options or move the cursor to the right.
4. Long (greater than 1 second) press of the encoder button. Used to move to next configuration menu.



When a configuration menu is exited the selected values are automatically stored in memory.

7.3 CONFIGURATION PREVIEW

The configuration parameters are stored in non-volatile memory and recalled at power up. During configuration the current parameters are displayed as each menu is accessed. By simply stepping through the menus without making changes the current parameters can be viewed.

7.4 ENTERING NEW VALUES

1. Hold down the encoder button and apply power to the DDS VFO.
2. Wait until the LCD displays Configuration (about 3 seconds) and then release the button.
3. The **Master Clock** menu will be displayed. Pressing the encoder button for less than 1 second will toggle through the clock options. Once completed press the encoder button for longer than 1 second and release.
4. The **IF Offset** menu will be displayed. Pressing the encoder button for less than 1 second will toggle between Yes and No. Once completed press the encoder button for longer than 1 second and release. If this option is set to No, the IF Freq High and IF Freq Low menus will be bypassed.
5. The **IF Freq High** menu will be displayed and the cursor will be positioned on the 10MHz digit. Rotating the encoder clockwise increments the digit while rotating the encoder anti-clockwise decrements the digit. Pressing the encoder button for less than 1 second will step the cursor onto the next digit. Once completed press the encoder button for longer than 1 second and release.
6. The **IF Freq Low** menu will be displayed and the cursor will be positioned on the 10MHz digit. Rotating the encoder clockwise increments the digit while rotating the encoder anti-clockwise decrements the digit. Pressing the encoder button for less than 1 second will step the cursor onto the next digit. Once completed press the encoder button for longer than 1 second and release. If the IF Offset option has been set to Yes the Frequency menu will be bypassed.
7. The **Frequency** menu will be displayed and the cursor will be positioned on the 10MHz digit. Rotating the encoder clockwise increments the digit while rotating the encoder anti-clockwise decrements the digit. Pressing the encoder button for less than 1 second will step the cursor onto the next digit. Once completed press the encoder button for longer than 1 second and release.

8. The **Band** menu will be displayed. Pressing the encoder button for less than 1 second will toggle through the band options. Once completed press the encoder button for longer than 1 second and release.
9. The **30 second Freq Save** menu will be displayed. Pressing the encoder button for less than 1 second will toggle between the Yes and No options. Once completed press the encoder button for longer than 1 second and release.
10. The **Freq Calibrate** menu will be displayed. Rotating the encoder clockwise increments the value while rotating the encoder anti-clockwise decrements the value. Pressing the encoder button for less than 1 second will toggle the plus/minus sign. Once completed press the encoder button for longer than 1 second and release.
11. The **Volts Calibrate** menu will be displayed. Rotating the encoder clockwise increments the value while rotating the encoder anti-clockwise decrements the value. Pressing the encoder button for less than 1 second will toggle the plus/minus sign. Once completed press the encoder button for longer than 1 second and release.
12. The DDS VFO will then store the values in non-volatile memory and return to normal operation.

8 INSTALLING IN A MST

8.1 FRONT PANEL

The DDS VFO is simply screwed to the inside of the front panel of the MST. The DDS VFO PCB is set back from the panel using threaded spacers to allow room for the LCD. If you use the LCD supplied in the kit the distance will be 22mm. This can be made up of a 10mm spacer and 12mm spacer or a single 22mm spacer or a long screw and nuts.

A countersink screw is used on the front panel to provide a flush surface for the front panel label to sit. If preferred round head screws can be used which means that holes need to be made in the label and also the heads will be visible from the front.

If a LCD is used that does not incorporate a backlight it will not be as high and so the length of the screws and spacers need to be reduced accordingly.

The general mounting arrangement is shown in Figure 5.

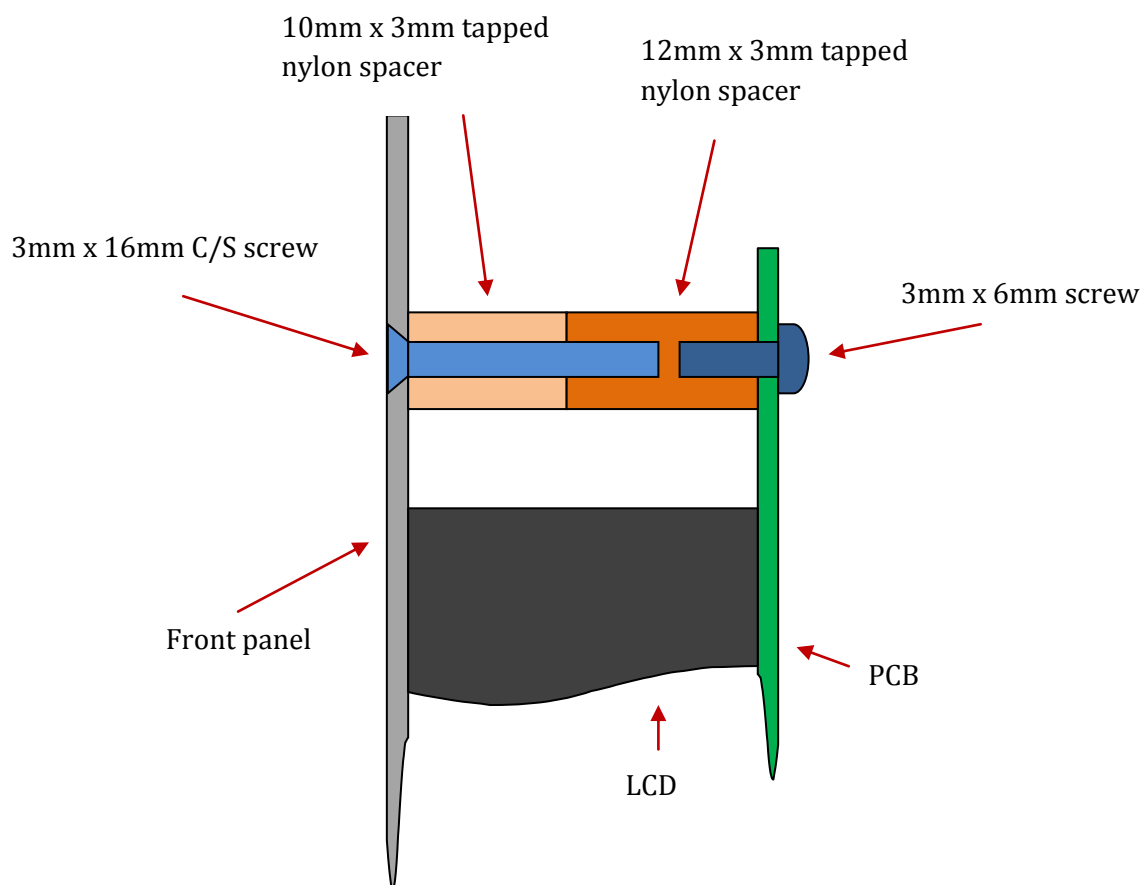


Figure 5 Installing in a MST

8.2 WIRING

8.3 POWER

The DDS VFO is connected to the MST3 via a 4 wire cable. The MST3 end is terminated with a 6 pin plug, with only 4 pins used.

The DDS VFO end is terminated in a 4 pin plug. The connections are shown in Figure 6.

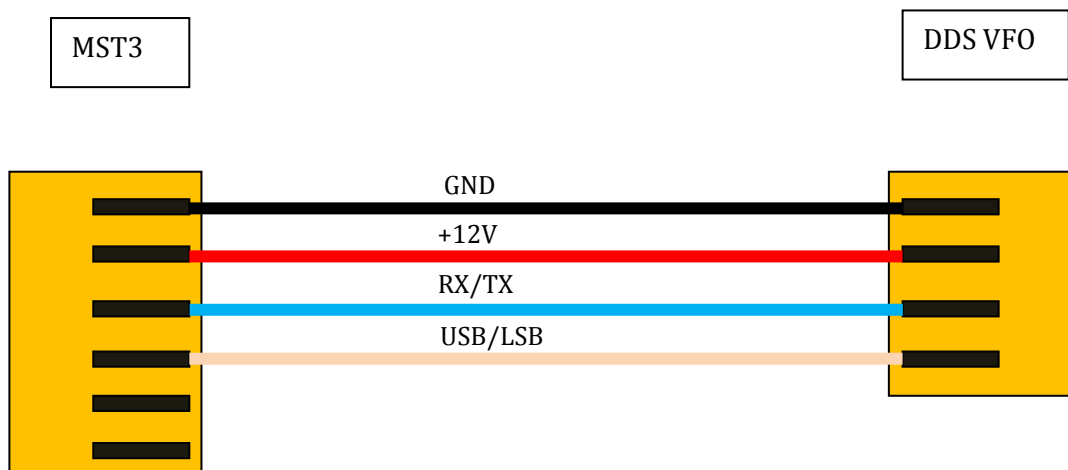


Figure 6 MST3 cable

8.4 OUTPUT

The DDS VFO output is via a 2 pin connector. The ground pin is indicated with a 'G' on the PCB overlay.

9 OPERATION

9.1 POWER ON

When the DDS VFO is powered on the version number is displayed briefly. This is followed by the operating display shown in Figure 7. Note that RIT is only displayed when RIT is enabled.

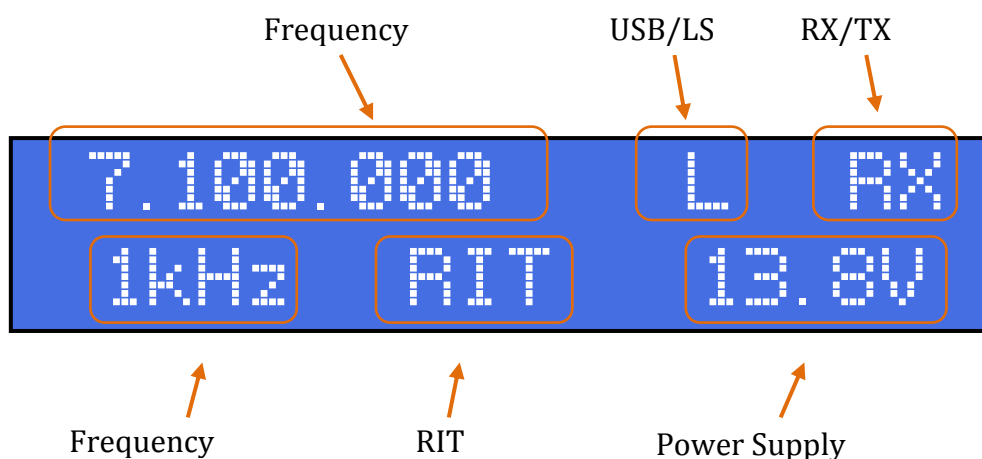


Figure 7 LCD operating display

9.2 TUNING

To tune the DDS VFO rotate the encoder clockwise to raise the frequency and counter-clockwise to lower the frequency. The frequency will change by an amount equal to the Step value.

9.3 FREQUENCY STEPS

To change the current frequency step press the encoder push button for less than 1 second and release. Each press cycles through the available steps which are 10KHz, 1KHz, 100Hz and 10Hz.

9.4 RIT

In receive mode press the button down for longer than 1 second. RIT will be displayed on the bottom line. The frequency can now be adjusted independent of the transmit frequency.

When switching to transmit mode the DDS will revert to the transmit frequency.

To exit RIT, press the encoder push button for longer than 1 second. The RIT message will disappear and the receive frequency will equal the transmit frequency.

9.5 VOLTAGE DISPLAY

The power supply voltage is displayed in the lower right hand side of the LCD. This is updated every 500mS. If the voltage falls below 8V a low voltage warning message is displayed to indicate the power supply is too low for proper operation.

9.6 FREQUENCY CALIBRATION

1. Measure the actual DDS output frequency and compare this to the frequency displayed on the LCD. Note the difference.
2. If the DDS output frequency is less than the displayed frequency, the difference needs to be subtracted in the Freq Calibrate configuration.
3. If the DDS output frequency is greater than the displayed frequency, the difference needs to be added in the Freq Calibrate configuration.
4. Pressing the encoder button for less than 1 second will toggle the sign indicator.
5. Rotating the encoder will increase or decrease the difference value.
6. Once set press the encoder button for longer than 1 second.

9.7 VOLTAGE DISPLAY CALIBRATION

1. Measure the power supply voltage and compare this to the voltage displayed on the LCD. Note the difference.
2. If the power supply voltage is less than the displayed voltage, the difference needs to be subtracted in the Volts Calibrate configuration.
3. If the power supply voltage is greater than the displayed frequency, the difference needs to be added in the Volts Calibrate configuration.
4. Pressing the encoder button for less than 1 second will toggle the sign indicator.
5. Rotating the encoder will increase or decrease the difference value.
6. Once set press the encoder button for longer than 1 second.

10 NOTES

10.1 OVERCLOCKING

The AD9834 has been shown to operate effectively at clock rates much higher than the manufacturer's specifications. The Firmware allows for 50MHz, 80MHz and 100MHz master oscillator frequencies and can be selected in configuration.



- 1. While experiments show that the DDS chip can operate at higher clock rates, they are outside the manufacturers published specifications and any resulting problems are the responsibility of the kit builder.**
- 2. If the master clock is changed on the PCB and the configuration is not updated the output frequency will be different to the displayed frequency.**
- 3. If an output frequency of greater than 10MHz is desired the output LPF will need component changes.**

10.2 DDS OUTPUT

The output of the DDS LPF is DC coupled and does not include a series capacitor. If using the DDS VFO other than with the MST you may need to use a series coupling capacitor between the DDS VFO LPF and input of the other circuit.

10.3 FREQUENCY RANGE

The DDS VFO was designed to be used as digital VFO. The minimum range allowed by the current firmware is 10KHz. The upper frequency range is not limited by the firmware, but there is a practical limit set by the hardware. The AD9834 is clocked by a 50MHz master clock and the maximum usable frequency is 1/4 of this or 12.5MHz. Also the DDS VFO hardware incorporates a LPF with a 10MHz cutoff frequency and any frequencies higher than this will be greatly attenuated.



The DDS VFO does not limit operation beyond the amateur bands. It is up to the user to ensure they do not transmit outside their frequency band allocation.

10.4 LCD

The DDS VFO operates best with a backlit display. The characters are bright and clear and readable in dim environments. The backlight does consume extra current and if minimizing current consumption is a priority then a non-backlit type can be substituted for the supplied LCD. In this case resistor R9 can be left off the board, although leaving it in will not cause any issues. If an LCD with backlight is used, but is not the same as supplied in the kit, the backlight may require a different value of current limiting resistor. Check the LCD data sheet before applying power to determine the correct resistor value and change R9 if needed.

A non-backlit display will also not be as deep and this needs to be taken into account when mounting to the front panel.

10.5 FIRMWARE UPGRADES

The PCB contains a functioning 6 pin ISP header to allow future firmware upgrades.