

DDS VFO



CONSTRUCTION MANUAL

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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 is designed as a companion for the MST transceiver board although it could be used with most 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 1MHz to 10MHz.
5. Selectable 1KHz, 100Hz or 10Hz frequency steps.
6. Tuning lock control.
7. Displays power supply voltage.
8. Programmable IF frequency. Ensures the displayed frequency is the same as the transmitted frequency.
9. Programmable IF offsets:
 - Minus – DDS output frequency is the IF frequency minus the displayed frequency.
 - Plus - DDS output frequency is the IF frequency plus the displayed frequency.
 - Rev - DDS output frequency is the displayed frequency minus the IF frequency.
 - None – DDS output frequency is the same as the displayed frequency. Used for frequency generator applications or with Direct Conversion receivers.
10. Programmable option to save the current frequency and step value into memory. These are re-loaded at power up.
11. Draws only around 50mA at 13.8V DC (with LCD backlight).
12. Spurious outputs at least -45dB.
13. Typically 300mV pk-pk sine wave output (200 ohms).
14. High quality double sided PCB with ground plane, plated through holes, solder mask and silk screen.
15. 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 ATmega8 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 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. Two other inputs, one analog (A) and the second digital (D), have been included in the PCB layout but are not implemented in the current software release. 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 testing 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 10MHz Butterworth low pass filter to attenuate unwanted high frequency components.

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

3 PARTS LIST

Quantity	Comment	Designator
Capacitors		
2	47pF 50V disc ceramic	C15, C17
1	150pF 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
5	10K 1/4W 1% resistor	R2, R4, R6, R7, R10
3	30K 1/4W 1% resistor	R1, R3, R5
1	10K horizontal trimpot	VR1
Semiconductors		
1	ATmega328 - 28pin DIP	U1
1	AD9834BRUZ 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	28 pin DIP narrow IC socket	
1	3 pin x 2 row 2.54mm pitch header	HDR1 (ISP)
1	11mm Rotary Encoder.	RE1
1	4 pin 2.54mm pitch header RA	SK1 (PWR)
1	2 pin 2.54mm pitch header RA	SK2 (OUT)
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	

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 10MHz carrier (BFO) signal and mixes this with the audio signal when you speak. The output of the balanced modulator is 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 DSBSC or Double Sideband Suppressed Carrier modulation. The DSBSC 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, IF offset of Minus and display frequency of 7.100MHz. The DDS VFO firmware computes that actual DDS VFO output frequency.

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

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

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 the following: IF frequency of 10.0003MHz , IF offset of Minus and display frequency of 7.100MHz .

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 10.0003MHz (suppressed carrier) - $2.9003\text{MHz} = 7.100\text{MHz}$.

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 2 when installing the components.

Step 1: Resistors

If in doubt check the values with a multimeter before soldering. Pass the pigtailed 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. R14 is not used.

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.

6 TESTING

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 8 and 15V DC. If the power supply has current limiting set this to about 200mA.

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. 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 Transmit frequency of 7.1MHz and a 1KHz Step. The default IF frequency is 10MHz with a Minus offset so using an oscilloscope or a frequency counter verify that the DDS is outputting a 2.9MHz sine wave signal of around 300mV pk-pk.

7 CONFIGURATION

7.1 UNDERSTANDING OPTIONS

IF offset

Consider a transmitter using a Superhet mixing arrangement. The transmit frequency is a result of the IF frequency being mixed with a VFO frequency. If for example the IF carrier frequency is 10MHz and the desired transmit frequency is 7.1MHz then the VFO frequency can be either:

1. $10 - 7.1 = 2.9\text{MHz}$ using a Minus offset
2. $10 + 7.1 = 17.1\text{MHz}$ using a Plus offset

It is important to understand that when the DDS VFO is configured with an IF offset the frequency displayed on the LCD is not equal to the DDS output frequency.

If, however, the VFO DDS is to be used as a general purpose signal generator or with a Direct Conversion receiver, the IF offset can be disabled. In this case the displayed frequency will be the same as the DDS output frequency.

TX frequency

The TX (Transmit) frequency is the initial frequency displayed on the LCD at power up. The VFO DDS firmware uses this value and the IF carrier frequency as well as the IF offset to compute the actual DDS output frequency.

IF frequency

To generate an accurate output frequency using the equations above, the IF carrier frequency must be measured and the value entered at configuration. If not the displayed frequency may not match the transmit frequency.

30 second frequency save

This option enables the automatic saving of the current frequency and step in EEPROM so that it is recalled the next time the DDS VFO is powered on. This overrides the programmed TX frequency. 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.

7.2 PROCEDURE

To program the DDS VFO:

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 IF offset screen will be displayed. Pressing the encoder button for less than 1 second will toggle through the options. Once completed press the encoder button for longer than 1 second and release.
4. The IF frequency screen 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. **Note that if the IF offset has been disabled this screen will be bypassed as it becomes irrelevant.**
5. The Transmit frequency screen 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 30 second save frequency screen 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.
7. The DDS VFO will then store the values in non-volatile memory and return to normal operation.

8 INSTALLING IN A MST

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 3.

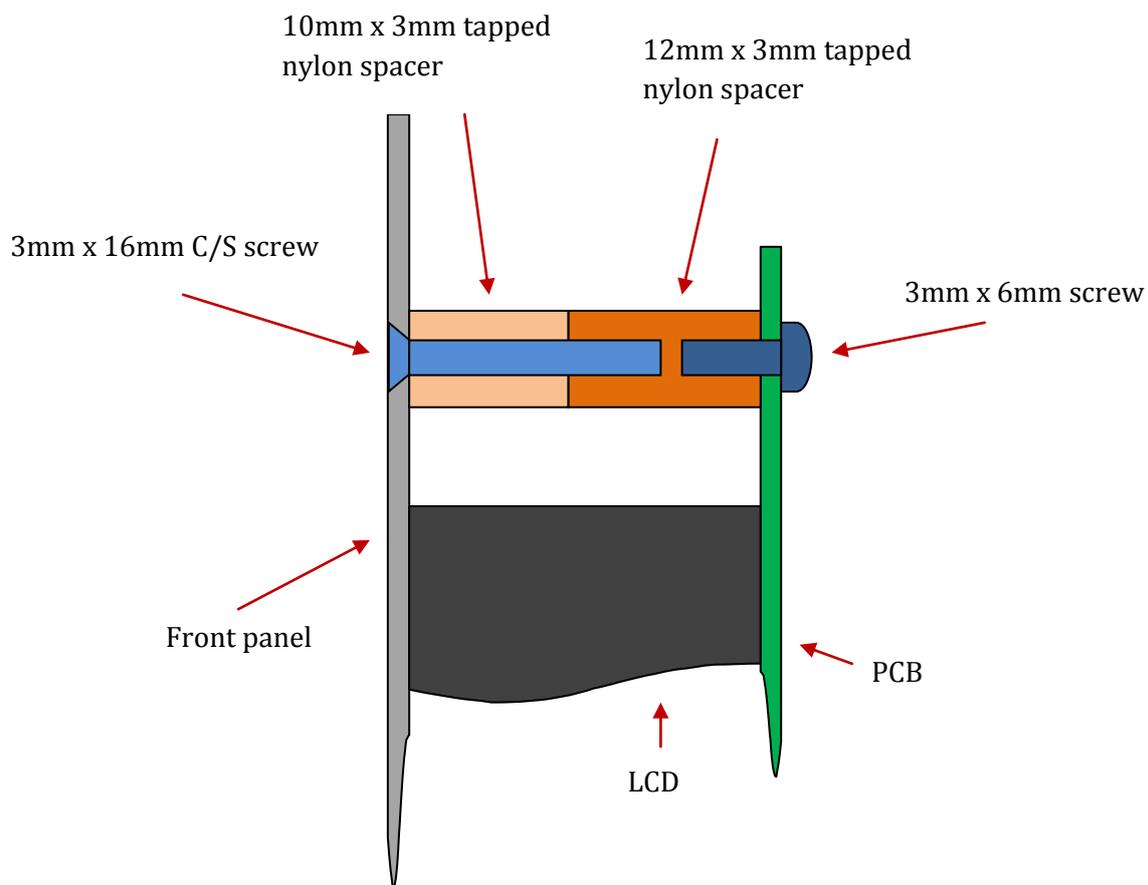


Figure 3 Installing in a MST

9 OPERATION

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 4.

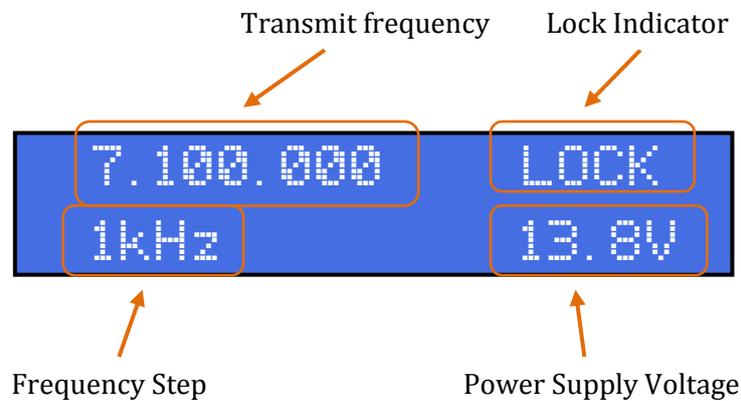


Figure 4 Typical LCD operating display

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.

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 1KHz, 100HZ and 10Hz.

Tuning Lock

To lock the encoder from changing frequency press the encoder push button for more than 1 second. A lock message will be displayed on the upper right of the LCD.

To unlock press the encoder push button for less than 1 second.

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.

10 NOTES

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.

Frequency range

The DDS VFO was designed to be used as digital VFO. As such the minimum range allowed by the current firmware is 1MHz. Attempting to program a frequency lower than this will result in an error message on the LCD. 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.

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.

Additional inputs

The PCB includes two additional inputs. One is intended to measure an analog voltage and the other is configured as a digital input. Both are able to handle a voltage between 0 and 20V DC maximum. The current firmware release does not utilize these inputs and so when making the 4 pin power cable these pins can be left un-terminated.

Firmware upgrades

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