Updated 07/07/07

DDSv4 VFO Owner's Guide

The DDSV4 VFO is a new oscillator based on the Analog Devices AD9859 DDS numerical oscillator and an Atmel ATMEGA16 microcontroller.

Specifications

Power Req.	Backlight off = 6 to 7VDC, 170mA Backlight on = 6 to 7VDC, 250mA		Drift	30 – 40 Hz @ 10MHz for 5 min. warm-up, nil afterwards
Output Freq.	0 – 100 MHz		Clock Reference Freq.	25 MHz, multiplied X14 internally to 350MHz by the DDS
Output Power	800 mV into 50 Ohms (except at 50MHz or higher – see amplitude)		Size	1" X 2" (DDS Board) 1.5" X 3" (Display).
Harmonics	Down 45dB (see also Spurs)		Construction	Surface Mount
Freq. Control	Rotary Encoder – User selectable 1Hz, 10Hz, 100Hz or higher step size.		Additional Controls	Band, Fast Step (5kHz default)

Features

User selectable modes – Ham, SWL, Sig Gen or Audio Oscillator. Ham band mode is the default.
User selectable IF shift (offset) frequency. No IF shift is the default.
Above Offset can be high or low side injection.
User selectable step size – 1Hz, 10Hz, 100Hz and up in 100Hz increments.
100Hz step and 5kHz fast step is the default for Ham band mode.
Digital outputs to automatically connect RF filters
SMA RF output connector
2X16 Backlit display standard. Backlight can be disabled to reduce current.
Display provides information on frequency, mode, step size and offset frequency.
Modular platform – user can change display, pushbuttons or encoder.

DEFAULTS:

	Ham	SWL	SigGen	Audio
Step	100	5000	5000	100
Fast Step	5k	5k	5k	5k

Operation

When power is applied to the unit, the Atmel microcontroller sends commands to the DDS chip to set initial registers and start oscillation at 1.8 MHz. After that sequence, the micro looks for a signal from the "Fast Step" pushbutton and the rotary encoder. If nothing is seen there, then it looks for an actuation of the Band pushbutton. If no input is found, it returns to look for a rotary encoder input. Once the unit is turned off and back on the process begins at 1.8 MHz again. The "Band" pushbutton is provided to jump between bands.

Built onboard is a buffer stage to beef up the output enough to drive passive mixers. This is followed by a high-cut (low pass) "T" filter. This reduces the output by-products of the oscillator.

The microcontroller/DDS board rides piggy-back on a display module. The display provides a continuous update of frequency.

Hook-up

Hook up is very easy. The unit will start to oscillate with just the application of power and ground. The complete hookup is shown on the next page. A small board is also provided with the unit. It combines the functions of two pushbuttons and a rotary encoder. One pushbutton is to step through the bands and the other is for Fast Step. This design is modular so that user can reconfigure the pieces later to suit their own use.

1. The DDS board is plugged into a display – this can be changed later to a different type – most have the same pinout.
2. A different rotary encoder can be used – I have shown the pinout on the next page.

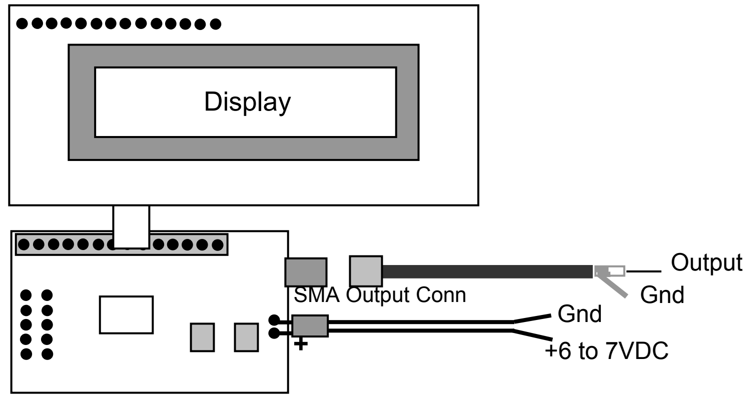
Calibration

Each unit is calibrated before shipment. This is done after a 10 minute warm-up, with input voltage set at 6.5V. The output frequency is adjusted to be within 10Hz above the indicated frequency at 10MHz. Note that the error will be proportionally higher at higher frequencies, but still reasonably accurate I think.

Front Side View

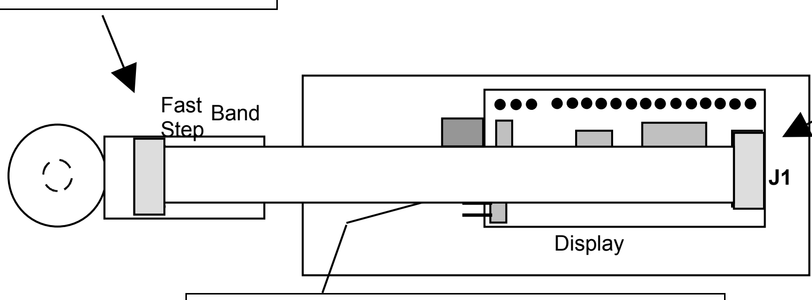
HOOK-UP

1. Plug the oscillator board into the 16 pin connector on the back side of the display board.
2. Carefully plug in the power cable insuring that **Positive is at the corner**.
3. Plug in the RF coax cable
4. Plug the ribbon cable into J1 connector as shown below and the other end into the back side of the pushbutton board, oriented as shown.
6. This completes the connections. When power is applied the display should read 1800000 and there should be a 1.8 MHz sine wave at the coax cable.



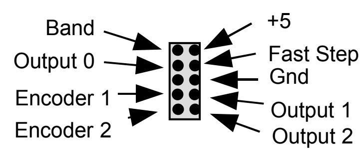
Back Side View

Pushbutton board –
PB1 = Band
PB2 = Fast Step

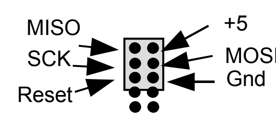


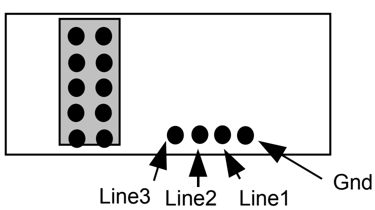
Note that there is a large via marked G and two vias marked O. These can be used as an addition location for output – a small coax cable can be soldered here in case no SMA cable is available. See the layout drawing for more detail on the locations.

Connector J1 Pinout (Board view)



Connector J1 Pinout (Board view) for programming. Note this is the standard 6-pin AVR program interface.





Bottom view of pushbutton board.
- 10-pin cable pinout is same as J1 on mainboard.
- Gnd and lines 1 – 3 are outputs for filters.

Rotary Encoder – types tested
1. DigiKey CT3001, CTS 288T232R161A1 (currently what comes with the unit)
2. DigiKey P12334, Panasonic
3. DigiKey P10859, Panasonic

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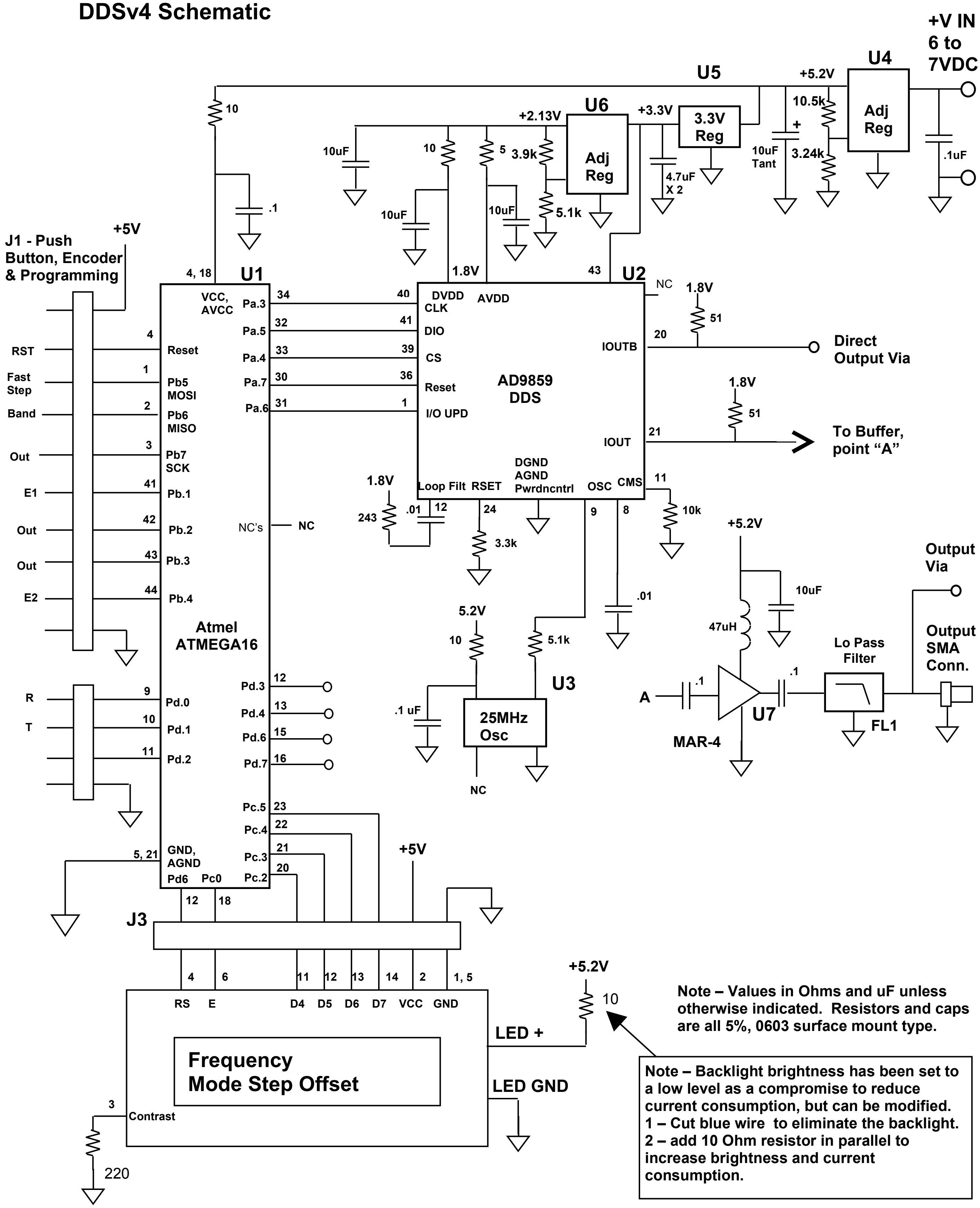
DDSv4 Schematic



Note – Values in Ohms and uF unless otherwise indicated. Resistors and caps are all 5%, 0603 surface mount type.

Note – Backlight brightness has been set to a low level as a compromise to reduce current consumption, but can be modified.
1 – Cut blue wire to eliminate the backlight.
2 – add 10 Ohm resistor in parallel to increase brightness and current consumption.

DDSv4 Bill Of Material

U1 – Microcontroller, Atmel ATMEGA16, TQFP, (Digi-Key ATMEGA16-16AU-ND)
U2 – DDS, 400MHz, Analog Devices AD9859 (DK AD9859YSVZ-ND)
U3 – 25MHz Oscillator (DK 300-7216-1-ND)
U4 – Adjustable Linear Regulator, SOIC-8 Micrel MIC39102 DK 576-1175-ND
U5 - 3.3V Linear Regulator, SOIC-8 Micrel MIC39101-3.3
U6 - Adjustable Linear Regulator, SOT-23-5 TI TPS73201DBVR
U7 – MiniCircuits MAR-4
Cable, 10 pos., 2X5 conn. – Digikey M3AAA-1006J-ND
Display – 2 Lines X 16 Characters, Electronix Express LCM1602A-FL-GBS
FL1 – Low Pass Filter, Miller EMI220T-RC, DK M9936CT-ND
Rotary Encoder CTS 288T232R161A1 (DK CT3001-ND)
J1– Header, 2X 5, .100" c-c, straight
J3 – Header, 1 X 16, .100" c-c, straight
Resistors and Caps are mostly 0603 or 0805 SMD type, values as shown on the schematic

Spur Discussion

On an oscilloscope, the fundamental DDS output appears as a nice clean sine wave. However in any DDS design there will be some other frequency by-products. There are a number of reasons that these can occur such as DDS system clock feed-though, clock oscillator feed-through, and images of the output freq and the system freq. (Nyquist sampling theorem). Considerable effort was made to reduce all of these. In most applications the output spurs will be sufficiently low, however if a cleaner output is desired, then an additional low pass (high cut) filter can be added. The MAR-4 output is 50 Ohms impedance so any of the 50 Ohm filter designs will work.

Spur Measurements (Advantest 3GHz Spectrum Analyzer, with 50Ohm load at DDS output).

Freq	Close Spur	Spur Level	Note
3.5MHz	7MHz	-45dB	
7 MHz	14MHz	-45dB	
20MHz	40MHz	-48dB	Next spur 330MHz (-45dB)
30MHz	60MHz	-50dB	Next spur 320MHxz (-50dB)
50MHz	100MHz	-50dB	Next spur 300MHz (-35dB*), then at 400MHz (-42dB*)

*these spurs can be significantly reduced with more output filtering or the addition of 22pF or 33pF cap between output and closest ground.

Software features

To get into the user selectable features, hold down the left "Band" AND right "FastStep" buttons for one second anytime the unit is powered. When you see "Main Setup Menu" you have entered setup mode – quickly release the buttons. The display will now slowly cycle through the following – Step Size Select, Mode Select, Offset Freq Select and back again. When the option you want to access is being displayed, push the left button again. To exit setup menu push the right button and go back to normal operation.

Step Size Select – the display will indicate "Sel. Step Size" and the current step size. Rotate the encoder to change step size to desired value. You will see that below 100Hz you can select 10Hz or 1Hz which is the minimum. NOTE – this is the only mode where the value will not be saved when you turn off the unit. Push the right side button to go back to previous menu.

Mode Select – the display will now cycle through **Ham, SWL, SigGen** and **Audio Osc**. Push the left side button to select. The display will indicate that the mode was selected and go back to the original cycle. You can go on to other selections from there.

- In Ham mode the band step button are set for 1.8----50.1 MHz, with step size 100Hz and fast step 5kHz
- In SWL mode the band step buttons are set for 1.8---25.6 MHz, with step size 1kHz, fast step 5kHz.
- In SigGen mode the band step buttons are set for 1.0 – 100 MHz, with step size 1kHz, fast step 5kHz.

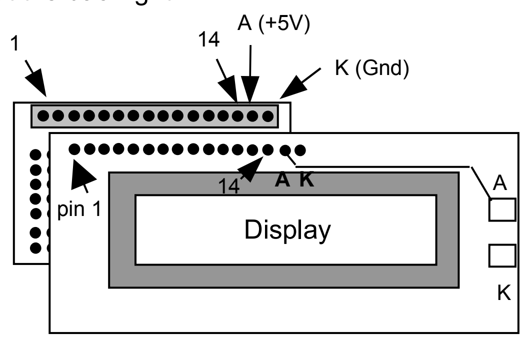
- In Audio oscillator mode the step buttons are set for 880 Hz – 6kHz, with step size of 100 Hz.

Offset Select – the display indicates “Sel Offset Freq” and the current offset frequency. Push the Band button and/or rotate the encoder to select the offset frequency. As you push the button you will notice that the display will eventually cycle through negative numbers. These are to set up low side injection. For example an offset of 455000 means that the output frequency will be 455kHz above the displayed frequency. An offset of -455000 means that the output frequency will be 455kHz below the displayed frequency. Push the right side button to return to setup mode, push twice to go back to normal operation.

Display Options

The display interface is configured for the supplied display which includes a backlight. You can use other displays, however attention needs to be paid to the pinout as some are slightly different.

The supplied Electronix Express display has the backlight connector pins at the right hand end of the row and will need to be plugged in as shown below. The row of pins is at the upper edge of the board. There are other displays that have the backlight connector at the opposite end and also at the bottom edge, so care must be taken when substituting displays. This layout will also support non-backlit displays that have similar pinout but without the backlight.



The pinout used in this layout will support the following displays.

Lumex displays are available at Digi-Key.
Hantronix displays are available at Mouser.

Lumex LCM-S01602DSF/A (backlit)

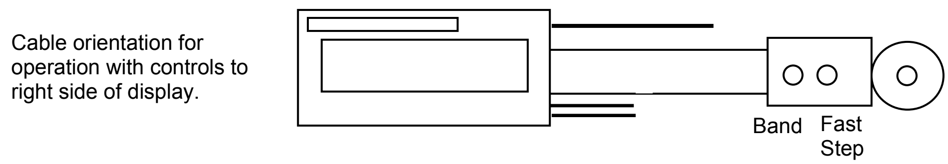
Hantronix HDM16216L-5-L3OS (backlit)

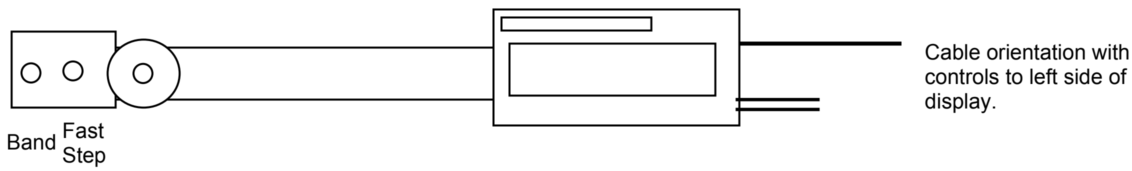
Hantronix HDM16216H-5-S00S (no backlight)

To use a different display module you’ll need to also get a 1 X 16, .1’ ctr-ctr receptacle (or 1 X 14 if there is no backlight). I use Digi-Key 929850-01-36-ND, made by 3M. This is a 36 pin style which I cut into lengths as needed. You could also use the precut version from the same 929850 series in the Digi-Key catalog. There are other suppliers of receptacles, however some of them do not have pin retention as good as the 3M part, so I’ve stuck with this one.

Cable Orientation

I have found the examples below useful. The cable can be folded at 90 degree angles for other orientations.





Output Amplitude

The DDSv4 is designed to provide enough output to drive a passive mixer – 800mV minimum. No control for is provided at this time as I figured this amount or higher would be desired in any case. Amplitude can be reduced easily with in-line resistors if necessary. DDS oscillators drop off in amplitude at higher frequencies, so the exception to the above design goal is at 50MHz or higher. Currently the highest I can coax out is 400mV at 50MHz and 200 - 300mV at 100MHz, both into 50Ohm load.

Operation at audio frequencies.

I have provided capability to use this as an audio oscillator, however the final amplifier configuration is designed for RF and severely attenuates audio frequencies. For operation at the audio range I suggest soldering a small wire to the "Direct Output" via shown in the layout drawing.

Source Code

! will be glad to provide source code. The code is written in BASIC and is easy to follow. I use the BASCOM BASIC compiler to generate hex code which I then load into the micro through the standard 6-pin avl ISP port. I highly recommend this compiler – it has many features which make code development much easier and faster.

Experimentation

I would encourage you to experiment with the DDSv4. Of course the original intention is that it be used as a local oscillator for a receiver, or as the frequency source for a transmitter. Some ideas are below.

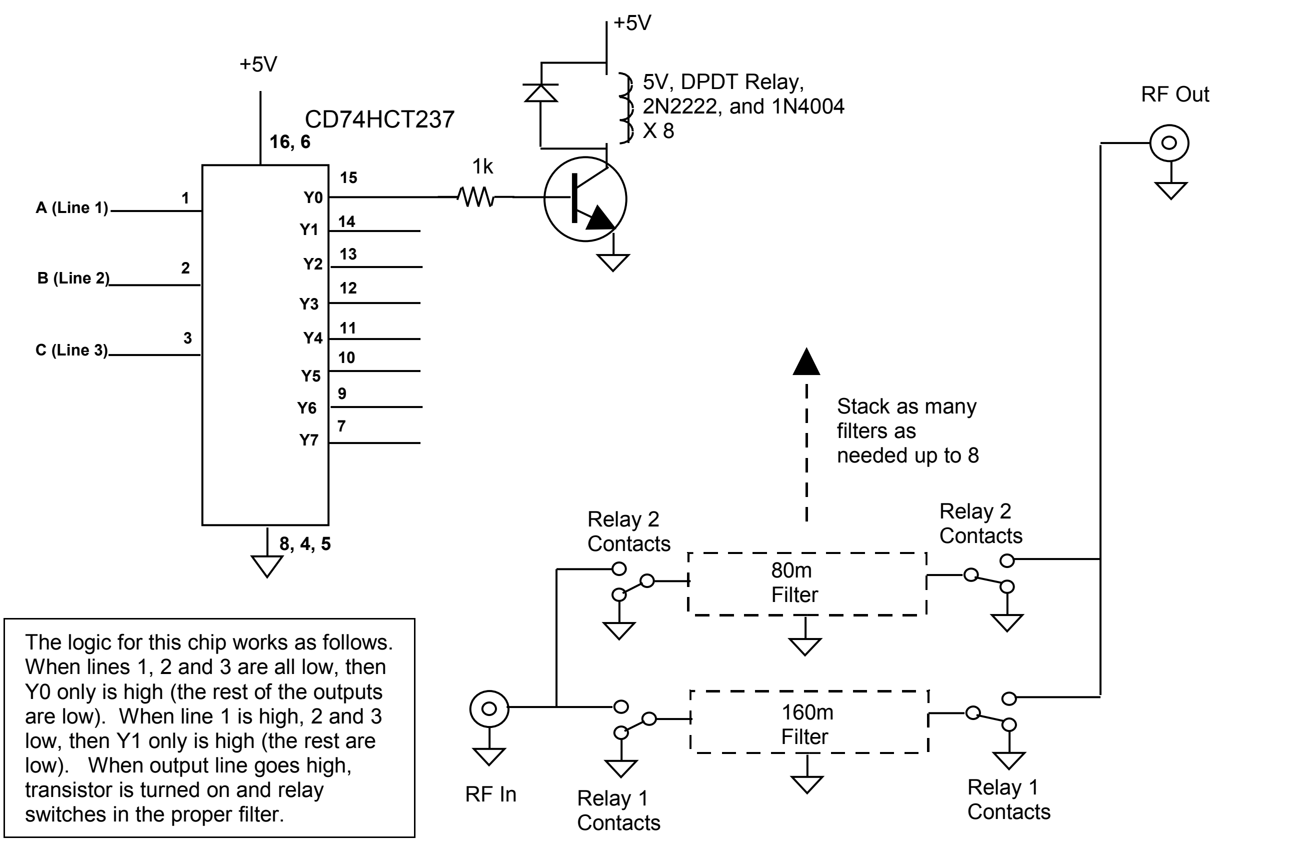
1. Set up a new push-button arrangement.
2. Try higher quality encoders.
3. Use different displays.
4. Build the unit into a small box with a battery and make a miniature portable signal generator.
5. For the really daring you can modify the source code to add new band stop frequencies, create a unit designed for a specific band, etc.

Outputs for RF Filters

The current implementation has three output lines to be used for receive (or output) filters. Note that I expanded the frequency range for each output setting to allow use of wider range receive filters for SWL use. This should not affect use for ham filters. The table below lists the output line status vs. frequency.

Ham Band (MHz)	SWL Band (MHz)	DDS Output Freq.	Line 3	Line 2	Line 1	Dec Val
	Broadcast (.54 – 1.7)	<1.8	0	0	0	0
160m (1.8–2.0)	120m (2.3 - 2.495)	>=1.8 to <2.8	0	0	1	1
80m (3.5–4.0)	90m (3.2 - 3.4) 75m (3.9 - 4.0) 60m (4.75 - 5.06) 49m (5.8 - 6.2)	>=2.8 to <6.2	0	1	0	2
40m (7.0 – 7.3)	41m (7.1 – 7.5)	>=6.2 to <9.5	0	1	1	3
30m (10.1 – 10.15)	31m (9.5 – 9.905) 25m (11.65 – 12.05)	>=9.5 to <14.0	1	0	0	4
20m (14.0 – 14.35)	19m (15.1 – 15.6) 16m (17.55 – 17.9)	>=14.0 to <18.0	1	0	1	5
17m (18.068-18.168) 15m (21.0 – 21.45)	13m (21.45 – 21.85)	>=18.0 to <24.0	1	1	0	6
12m (24.89 – 24.99) 10m (28.0 – 29.7)	11m (25.6 – 26.1)	>=24.0	1	1	1	7

The outputs for RF filtering are provided on the pushbutton board. There are three lines and will need to be decoded to provide filter capabilities. The logic condition will be true anytime the output frequency is within the band shown above. Any of the 3-to-8 line decoder/demultiplexers such as SN74LV138 and CD74HCT237, etc. should work for this application. I worked up an example schematic below using the HCT237 which I found easier to set up since the logic is non-inverted.



Step Frequencies

The table below lists the step frequencies for the four available modes.

Step \ Mode	Ham (MHz)	SWL (MHz)	Sig Gen (MHz)	Audio Osc. (Hz)
1	1.8	2.3	.1	880
2	3.5	3.2	.2	1000
3	7.0	3.9	.5	1500
4	10.1	4.75	1.0	2000
5	14.0	5.8	2.0	2500
6	18.068	7.1	5.0	3000
7	21.0	9.5	10.0	3500
8	24.890	11.65	15.0	4000
9	28.0	15.1	20.0	4500
10	28.3	17.55	30.0	5000
11	50.0	21.45	50.0	5500
12	50.1	25.6	100.0	6000

Misc. Notes

1. I use ExpressPCB as the board supplier. Recently they went RoHS compliant on the min-board Pcbs which means that instead of being tin/lead plated they are silver plated. I find this harder to solder to and thus the solder joints don't look as nice to me as before. I apologize for this, but I have no choice at this time.

2. You will see some pads in layout where there are no components. I frequently create places for extra bypass caps for example, but sometimes they are not needed. So don't be concerned if you see places with "missing" components.

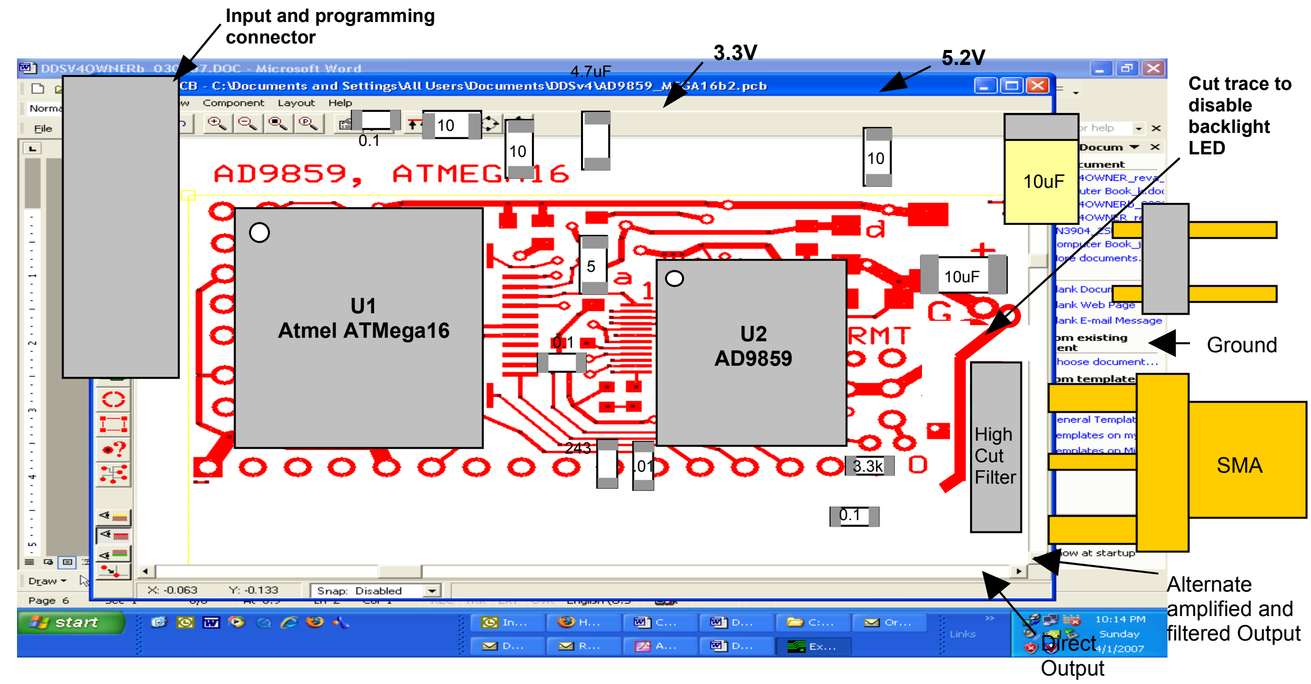
3. The U4 regulator is a robust device and should withstand a fair amount of abuse. It is also the first place where input voltage is regulated to 5.2VDC. Since it is a linear regulator, the difference between input voltage and 5.2V is converted to heat. With the backlight on and with the input at 10V, you can see that the device would get quite hot (10V – 5.2V) = 4.8V X .27A = 1.3 Watts. For this reason I suggest running the unit at 6 to 7 volts. The Micrel MIC39102 has a dropout spec of only about 200mV in the range we're using it so it will run happily in regulation with a supply of 6V.

4. Why the odd 5.2V? This is a long story. During development I went to a fair amount of trouble to reduce output spurs. I discovered the MAR-4 created a significant spur at two times the fundamental frequency if its operating voltage was at 5V or less (have to also allow for the drop across the 47uH choke). So I boosted the supply voltage to 5.2 volts which solved the problem.

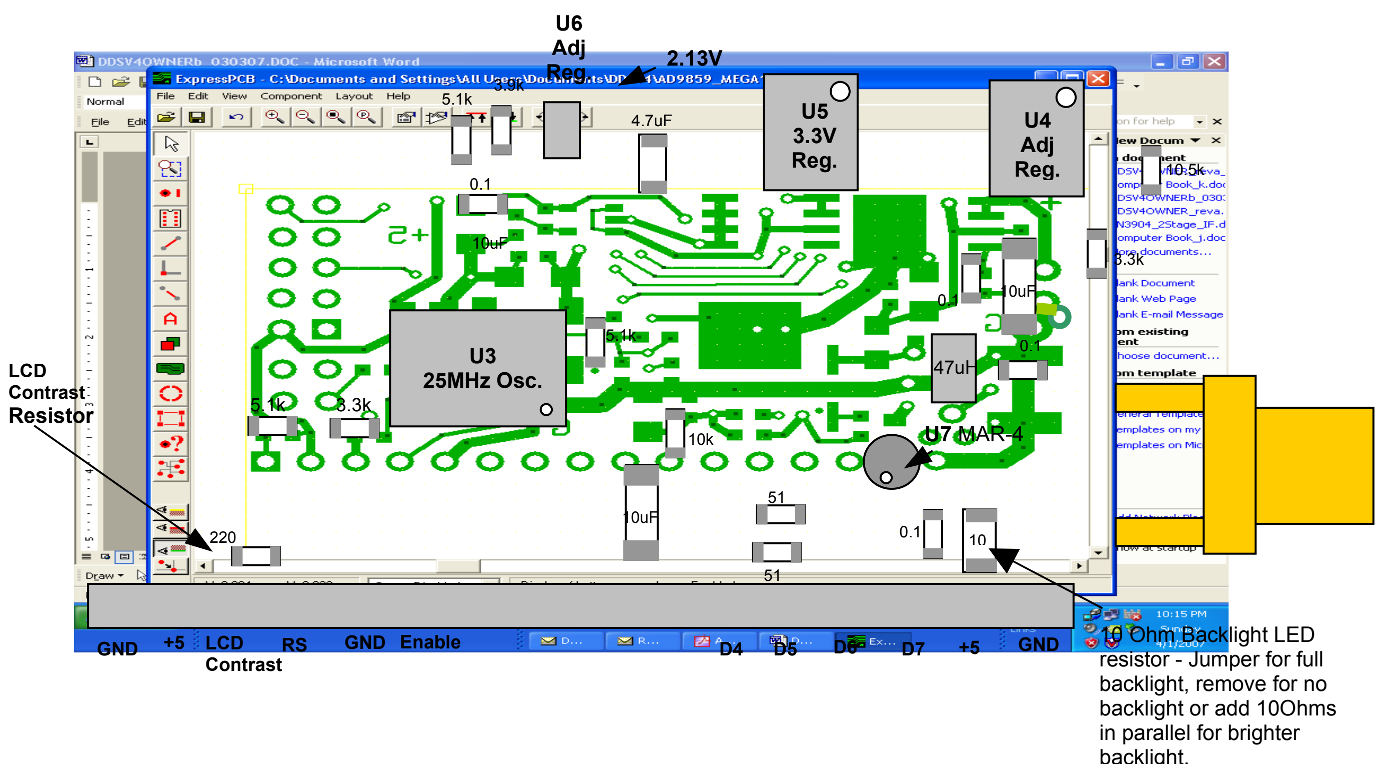
5. I'd really like to encourage experimentation. One area I plan to work on is different PA options. The MAR-4 is EOL at Minicircuits so I need to find another alternative.

6. To keep program size down I haven't put in code to prevent the user from doing something crazy like trying to set frequency below 0 or same for step size. If you accidentally do that I have no idea what the unit will do. Generally you should be able to recover from anything by restarting the unit.

Top Side Layout



Bottom side layout



Note that this bottom side layout is as if you are looking through a clear board from the top side.

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Troubleshooting:

You shouldn't have much in the way of difficulties but here are a few notes just in case.

1. If one of the parameters, like step size, gets corrupted just go into setup mode and re-select the operating mode you're interested in (like Ham). This will reset the step size.

2. If you get proper display but no RF output, first thing to do would be to probe the two small output vias shown on the previous page. If there is RF output there, then the DDS is working OK, but the MAR-4 PA section has a problem. I would then check for 5.2 V at the 47uH inductor and almost the same at the MAR-4. Check the entire section for broken components or open solder joints.

3. If there is no display backlight check the 10 Ohm resistor connected to the display at pin 15 and the blue wire.

4. For total no-op condition:
   - Check 5.3V, 3.3V and 2.13V supply voltages
   - Check current consumption – should be about 230 – 250mA with display connected and backlight on.
   - Check for 25MHz oscillation at U3 and at both sides of 5.1K resistor.