

An Audio/RF DDS Signal Generator (1Hz to 30MHz)

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A combined Audio/RF Signal Generator capable of generating stable sine wave signals from 1Hz to 30MHz with a 1Hz resolution and a known, constant output level is presented. A Direct Digital Synthesizer (DDS), a rotary encoder and a large 8-digit Liquid Crystal Display under control of a PIC16F628A micro controller together with analogue components provide a versatile test instrument.

Features

- 1Hz to 30MHz output frequency
- Audio Section with 600Ω impedance from 1Hz to 100kHz
- RF Section with 50Ω impedance from 100kHz to 30MHz
- Constant and known output levels across frequency (RF=0dBm \pm 1.5dB)
- Calibrated by using a standard Digital Volt Meter (DVM)
- Easy one button, one knob operation
- Large, easy readable 8 digit display
- Pure Sine wave generated by Direct Digital Synthesis (DDS)

Introduction

One of the ways to prove that one knows and understands a subject is to actually teach that subject to others. A successful student will continue building on this acquired knowledge to invent or create his own new designs. The foundation therefore needs to be sound.

One of the ways to understand test equipment and its application is to construct one's own test equipment. Some of the interested readers may be fascinated by the idea of building one's own test equipment and then using these to develop and test one's own antennas, receivers, transmitters and the like. This facet of amateur radio can be stimulated by this project as it includes elements of digital, audio, RF and analogue design.

The project described in this article is aimed at those enthusiasts who require a more accurate, stable and known reference signal source than the traditional free running oscillator versions. Most of the older generation signal generators cover either the audio or RF spectrum, but seldom both. Examples such as the Leader LSG-15 (RF) and the Heathkit ISG-72 (Audio) generators which are shown in Figure 1 have found a home in many ham radio shacks.



Figure 1 : Leader LSG-15 (RF) (left) and Heathkit ISG-72 (Audio) (right)

Their frequency coverage is usually split into bands and some of the higher bands rely on frequency doublers/triplers which introduce harmonics.

Applications

A stable Audio/RF source of known frequency is often required to test receiver front ends, mixers, RF/IF amplifiers and audio amplifiers which typically forms part of a radio frequency receiver.

The DDS Signal Generator described here, can also be used as a replacement Local Oscillator for Variable Frequency Oscillators (VFO's) and crystal oscillators in older HF radio equipment. The audio section of the DDS signal generator may be used to test audio amplifiers as well as sound card frequency responses where sound cards are being used with modern Software Defined Radios (SDR's).

The known and calibrated output level available on a second small signal output having a level of -73dBm into 50Ω which is equal to S9 on a Signal Strength Meter, allows the radio amateur to compare S-meter calibrations between different bands and different manufacturers of receivers and transceivers. Refer to Greg Ordys (W8WWW) article about the "S-meter blues" [1]

Antenna analysis can be performed by connecting the output of the DDS Signal Generator to a Return Loss Bridge which allows reflection measurements to be made across frequency. The bridge is a 3-port network that has an input, an unknown port and a 50Ω detector port. The DDS Signal generator is connected to the input port. An antenna can be connected to the output port and a home built detector with an analogue panel meter can be connected to the detector port. The frequency is varied across the band of interest and the reflection from the load, which is present on the detector port, can be charted across frequency. The setup is calibrated by connecting a 50Ω dummy load to the unknown port. Subsequent measurements can then be made and the VSWR calculated. This technique is described in [2]

Future expansions are planned to include software updates to enable an automatic sweep mode, with user selectable start, stop and step values. A saw tooth generator output which is synchronized with the frequency values is planned. This could be used on the X-axis of an oscilloscope with an RF detector as described above connected to the Y-axis. This arrangement will then allow an oscilloscope which is set in the X-Y mode to display the reflection levels in real-time.

Many other applications can be found for this easy to build Audio/RF DDS Signal Generator. It is not intended to be an arbitrary wave form generator and generates only sine wave outputs. External circuitry could however be added to generate square wave outputs.

Functions of the Main Components

The block diagram of the DDS signal generator is shown in Figure 2.

The Analog Devices™ AD9834 complete DDS is capable of generating sine wave output signals across multiple octaves of which the output frequency is set by a 28-bit digital programming word.

A PICMicro™ 16F628A manufactured by Microchip™ is used to calculate and send the programming commands to the DDS. This microprocessor is also used to display

the frequency and handle other functions such as the frequency adjustments from the rotary encoder and tuning step changes.

The readout consists of 2 x 4 character 7-segment displays of which the digits are 12.7mm high, mounted side-by-side. These are connected to 2 x AY-0438 32-segment display drivers (IC1, IC2) also manufactured by Microchip™. This provides a large, easily readable display. A 2 x 16 type display could also be integrated (future). The code snippets to program and use these LCD's are available on the Internet but has not been included in this design and will require the use of a few additional output ports of the PIC.

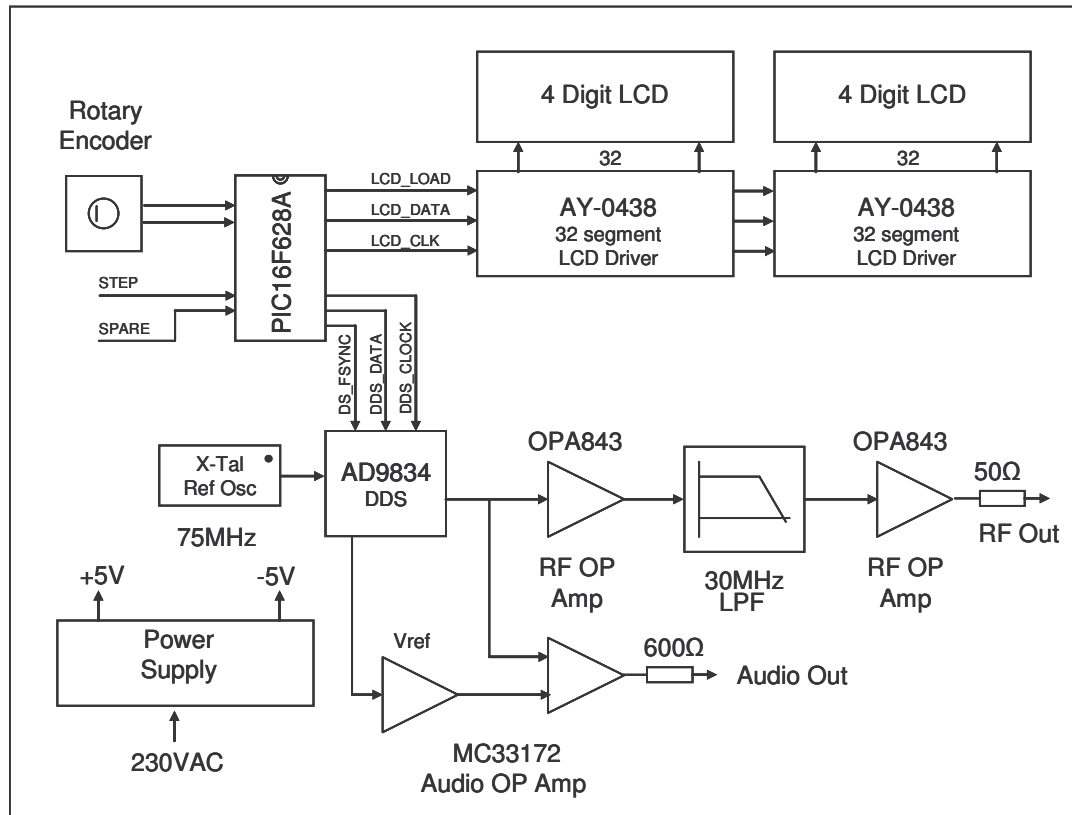


Figure 2 : DDS Signal Generator – Block Diagram

A rotary encoder allows increment/decrement of the selected digit. A separate “STEP” change button is used to select the step increment (1Hz to 1MHz). Certain rotary encoders have an integrated pushbutton and the author found these useful when one hand operation is required. Both types can be used with this design.

The frequency range has been split into an Audio and RF band which are routed via different output amplifiers to obtain the correct output level and impedance. Audio signals (1Hz to 100kHz) are available at the 600Ω unbalanced output connector while the RF output (100.001kHz to 30MHz) is available at the 50Ω unbalanced output connector.

Although actual audio frequencies does not extend up to 100kHz the sound card inputs as used by SDR's extend beyond the normal audible frequency range. The output level of the audio section will decrease (roll off) as the frequency increases to within the RF band. The output level of the RF section will decrease at frequencies

below 100kHz due to the DC blocking capacitors in the final stage. The circuits are not switched at the cross over of 100kHz. This is intentional and is to enable calibration of the RF section at 55Hz using a normal Digital Volt Meter (DVM) as later described in the Calibration section.

A separate power supply PCB is part of the design. This power supply generates the +5V and -5V used by the PIC and the OP amps as well as the +3.3V power required by the Master Clock Oscillator (MCO). The 75MHz MCO is only available in +3.3V versions and although the DDS can also operate from +5V it was decided to use +3.3V for the DDS as well. This will reduce noise that can be induced from the digital circuits operating from the +5V supply rail.

DDS description

A modern DDS generates a very clean output if the clock frequency is at least eight times higher than the output frequency. In this application the AD9834 (IC4) is clocked by a 75MHz clock oscillator.

At the higher frequency limit of 30MHz the clock frequency is just over 2 times the output frequency and spurious signals appear in the spectrum. A low pass filter is required at the output of the DDS to ensure a spectrally clean signal.

The DDS uses a crystal oscillator as the Master Clock Oscillator (FCLK). The output of the DDS is calculated based on this reference frequency and the programming word in the following relationship:

$$F_{OUT} = (F_{CLK} \times FREQ)/(2^{28}) \text{ where } FREQ \text{ is the 28-bit digital word.} \quad [3]$$

The Digital to Analogue Converter (DAC) in the DDS consists of a current source with a maximum output level which is determined by the value of RSET (R8) and the formula :

$$I_{FSD} = (18 \times V_{REF})/RSET \text{ where } V_{REF}=1.2V \text{ and } RSET =6k8 \quad [4]$$

When this current is terminated in a resistive load, a voltage which is equal to $V_{DDS} = I_{FSD} \times R_{12}$ is generated. For an AC signal this is the peak-to-peak value (with DC offset) and is independent of the output frequency. It is this useful property that is exploited to perform the calibration function.

What the PIC does

The PIC (IC3) has a few tasks that it needs to perform, almost at the same time, but independent of each other (not strictly multi-tasking):

1. Check frequency limits
2. Check Step Change input and change the step size if the push button switch has been pressed
3. Check for changes in the Rotary Encoder (increment or decrement)
4. Calculate and look up the 7 segment values of the digits and send them to the display
5. Calculate the DDS word and send it to the DDS IC.

The DDS word is only calculated and sent to the DDS IC when the frequency has changed. When no user input is active, the DDS and display retains the previous generated frequency. This avoids additional output spurious signals.

The frequency limits for the Audio and RF ranges are set in the program code to ensure no out-of-range signals are possible. The display flashes to indicate when the lower or higher limit is reached.

Display

The numeric display has 8 digits and can therefore display a maximum value of up to 99.999 999MHz. In this application the maximum frequency is 30MHz which will be displayed as 30.000000. Frequencies above 1MHz has a decimal point eg. 7.020000 and frequencies below 1MHz are displayed in Hz eg. 125kHz is displayed as 125000. The minimum frequency of 1Hz only uses the far right digit.

The 8 digit display is built using 2 x 4 digit displays next to each other. Each are driven by a 32 segment display driver (IC1,2). The reason for this is that LCD glass with 8 digits have smaller digit height and are difficult to plug in/remove from the display socket. They also break easily. The 4-digit version are more readily available.

The display driver use a 3-wire interface to the PIC. The LCD_CLOCK, LCD_DATA and LCD_LOAD line signals are generated by the PIC. The LCD_LOAD signal allows a new display value to be loaded into the buffers of IC1,2 while displaying the old value. When LCD_LOAD goes to a logic high, the new value is instantantly displayed. This removes any scrolling/flickering effects that appear with the relatively slow 2 x 16 LCD modules.

The displays and drivers are hosted on a separate PCB and are connected to the main section via a header HD1.

Audio Output Section

The output voltage from the DDS (IC4, pin 19) is not centered around 0V and the usual technique of adding a decoupling capacitor can not be used at frequencies as low as 1Hz as it will require a bipolar capacitor of about 10,000uF which is not practical for this design and will introduce a reactive component in the output impedance.

The audio section uses a dual OP Amp (IC7) to perform level shifting and amplification of the DDS output signal to a known level without any DC offset. The reference signal from the DDS is buffered by IC 7A to ensure that the Vref output is not loaded. Vref is used by the DAC inside the DDS and affects the DAC linearity.

IC 7B is configured in a differential amplifier configuration and subtracts this known level from the DDS output signal, while at the same time adding gain. This results in a signal which swings symmetrical around 0V. This section requires adjustment of VR1 to ensure that there is no DC offset present. This is done using a common DVM set to DC and the signal generator set to a frequency of 50Hz. DVM's are calibrated to work at 50Hz and can measure DC offsets present on an AC signal by setting the meter to DC. The values of R20, R21, R21 are chosen such that if VR1 is set for 0V DC at the output, the gain results in a 2.2Vp-p signal into a 600R termination. This is equal to 0dBm or 0VU on a VU meter.

A low level signal output is derived from this by R28 and R29 and provides a -65dBm signal on pin 3 of header HD6. This low level signal can be used for sound card testing as mentioned earlier.

RF Output Section

The output of the DDS is terminated in the “load” generated by IC5. The output of the RF OP Amp (IC5, pin 6) is a low impedance point. The input impedance as viewed from the DDS output (IC4, pin 19) is $R11//R12 = 180\Omega$.

The low impedance output is connected in series with a 51Ω resistor to present a 50Ω source impedance to the low pass filter.

An Elliptic 5th order 0.1dB pass band ripple filter is used to perform the low pass filtering of the DDS output signal. The filter cut-off frequency is 30MHz with the stop band frequency at 45MHz. The 45MHz stop band frequency is calculated such that the mixing products from the 75MHz clock with the DDS output frequency which occurs around 37.5MHz are suppressed. ($75\text{MHz}/2 = 37.5\text{MHz}$, $37.5\text{MHz} - 30\text{MHz} = 7.5\text{MHz}$, $30\text{MHz} + 2 \times 7.5\text{MHz} = 45\text{MHz}$)

The filter provides 45dB attenuation at 45MHz which is acceptable for this application. The filter response is shown in Figure 3 :

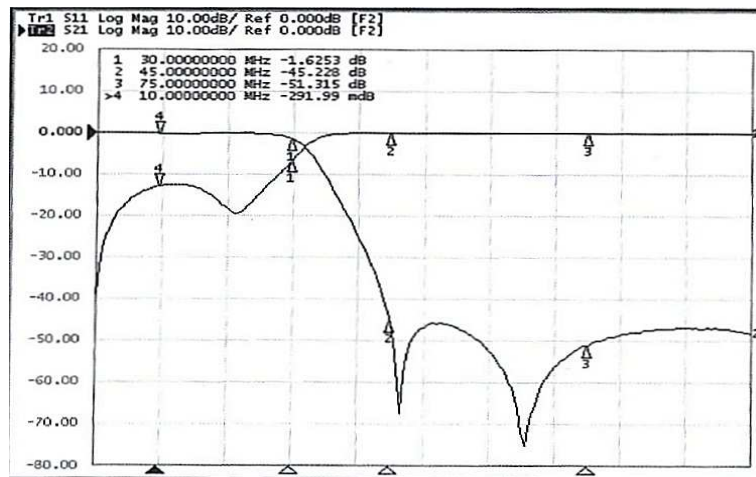


Figure 3 : Low Pass Filter Response

The second RF OP Amp (IC6) is configured as an inverting amplifier. The DC offset of the signal, which is still present after the low pass filter is removed with de-coupling capacitors (C23, C24). The values of R16 and R17 has been chosen to obtain a 0dBm output into 50Ω (available power) at the output header (pin1 of HD5). DC de-coupling is done at the output of the OP Amp (IC6, pin 6) to avoid DC being connected to the input of the spectrum analyzer that was used to characterize the frequency response of the signal generator. Most spectrum analyzers have a very strict 0V DC input specification which can result in serious damage.

A low level signal is derived from the output by means of a 73dB attenuator connected to R19. -73dBm into 50Ω is equal to an S-meter reading of S9. This low level signal can be used for receiver S-meter testing and comparisons, even between

different bands as this level is constant to within 1.5dB across the 30MHz band. The same result can be achieved by connecting an external step attenuator between the output and the antenna connector of the receiver that needs to be tested.

The 0dBm and -73dBm outputs can be used at the same time without mutual influence.

Power Supply

The power supply consists of a small 230V to 6-0-6 VAC transformer. The rectifier (B1) and C34 and C37 provides DC to the three regulators on the power supply PCB. The 78M05 1A, 5V regulator (IC9) provides the +5V output while a 79L05 100mA -5V regulator (IC10) provides the -5V output.

The 3.3V output required by the Master Clock and used by the DDS is generated by the MCP1702 low drop out voltage regulator (IC5) from Microchip™. This regulator is mounted on the Analogue board and is supplied by the +5V rail to minimize the voltage drop across the regulator and subsequent heat generation.

Operating the Signal Generator

Operation is really simple and intuitive. After power-on the output signal which matches the displayed frequency is immediately available on the respective Audio or RF port.

The user sets the required frequency by first selecting the most significant (1MHz) digit and then turning the rotary encoder to set the digit to 0,1 or 2. Thereafter the user selects the 100kHz digit and sets the value to the desired frequency. Continue in this way until the desired frequency is entered.

The step size is changed by pressing the STEP button. The default step size is 1kHz. The step size cycles through 10MHz ⇒ 1MHz ⇒ 100kHz ⇒ 10kHz ⇒ 1kHz ⇒ 100Hz ⇒ 10Hz ⇒ 1Hz ⇒ 10MHz etc.

The author has found that for coarse tuning, the 100kHz step is most often used as the complete 100kHz to 30MHz range can be covered at a rapid rate. For tests within a band the 1kHz setting is used most often, while for fine settings the 100, 10 and 1 Hz digits are used.

Availability of Components

Components are available from the device manufacturers directly (Analog devices ships free samples of the AD9834CRUZ) at no cost to the constructor, but requires registration on their web site. Most web based suppliers stock the required components. A few components are only available in SMD and if kits are compiled the analogue PCB will be supplied with the SMD components already fitted.

The resistors, capacitors, IC sockets and headers are readily available. The two inductors can either be moulded choke inductors, or can easily be hand wound using 0.51mm (24AWG) enamelled copper wire. It consists of 11 turns which are tightly wound around the smooth end of a on a 4mm drill bit.

Printed Circuit Boards

The signal generator consists of three printed circuit boards. The Display and Analogue boards are double sided, while the Power Supply board is single sided. A fourth, optional board which contains a 73dB attenuator can be fitted if the -73dBm (S9) output level is required.

The PCB layouts were done using the Freeware version of the Eagle layout editor available from <http://www.cadsoft.de/>. The freeware version is fully functional, but has a board size limitation of 100mm x 80mm. The Display and Analogue boards measure 130mm x 45mm and to overcome the size limitation of the software, the author split the boards across two layout files which were joined using “magic tape” after printing.

Care was taken to place the components such that the number of vias is limited. Most of the vias are implemented by soldering the components leads on both the top and bottom layer. If a kit is to be compiled, a professionally made PCB will not require soldering both sides and the construction will be simplified.

The Display board which holds the 4-digit LCD's, the display driver IC's and the rotary encoder is shown in Figure 4. The rotary encoder has been placed to the left of the display on purpose. The author is right handed and found it useful to change frequency steps using the left hand while writing down results with the right hand. The rotary encoder can however be mounted separate from the display board at any convenient orientation.

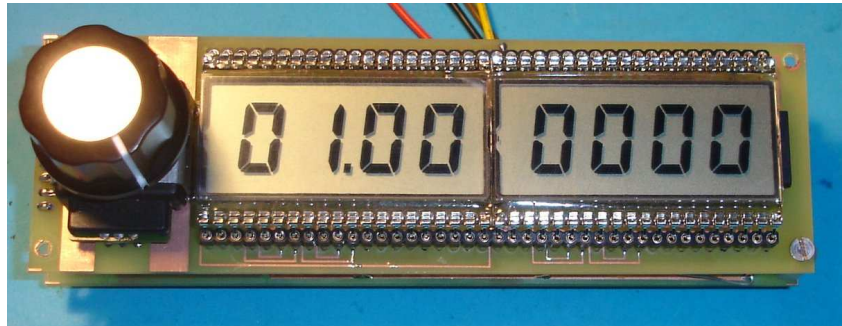


Figure 4 : Display Board prototype showing 1MHz

The Analogue board, although not strictly only analogue, holds the PIC, DDS and the analogue output circuitry.

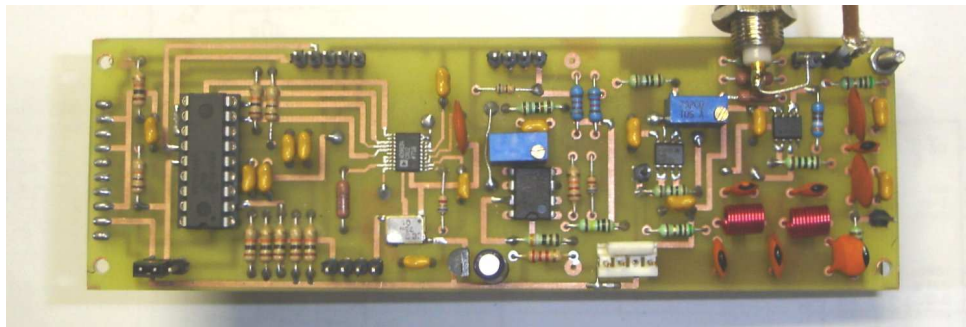


Figure 5 : Analogue Board - prototype

The power supply board is complete with its transformer, bridge rectifier and capacitors as well as the +5V and -5V regulators.

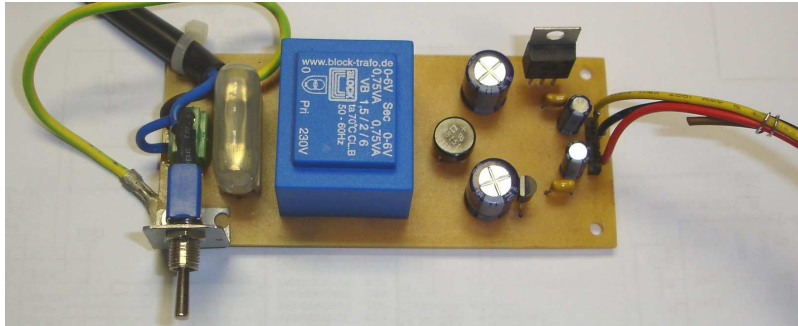


Figure 6 : Power Supply – prototype board

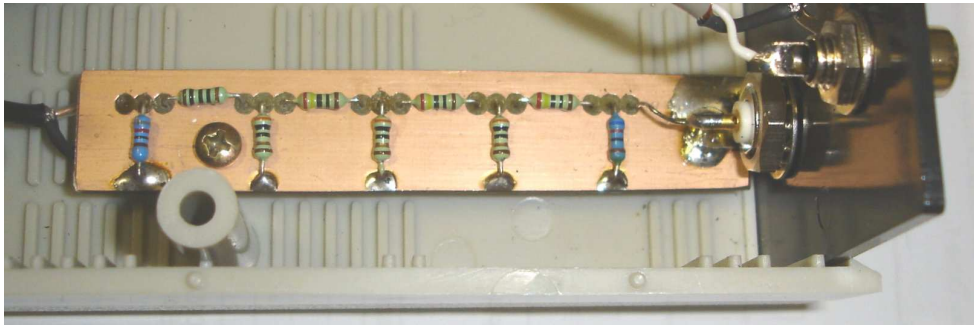


Figure 7 : 73dB Attenuator board

Construction

Populating the boards with its components require intermediate skills and the constructor should be familiar with soldering and handling of electrostatic sensitive components. Care should be taken in all steps and the author's motto is : "rather an extra step than starting all over again".

1. Display

C1 to C4 are mounted first. Then the 40 pin single in line sockets which hosts the LCD's are mounted. Now mount the 10 way single in line header pin strip by inserting it from the bottom of the board (HD1). Carefully bend the 40 pin LCD drivers' (IC1, IC2) pins close to each other to match the PCB spacing. Antistatic and proper grounding practises should be followed. Note the orientation and insert the IC's and solder all pins. No IC sockets can be used for these IC's as their height will be too high for the LCD's to fit across them.

Insert the 2 LCD's, by carefully inserting their pins into the SIL sockets, noting the orientation. Turn the complete display upside down and gently press on the back of the PCB until the LCD snaps into place. Do not use excessive force as this may damage the LCD.

Insert the rotary encoder and ensure the height of the body is not lower than the LCD glass. Solder into place.

The display board is now ready and will be connected to the Analogue board after it has been constructed.

2. Analogue Board

The analogue board contains 4 surface mount components which will be supplied pre-mounted as part of the kit. This is to enable constructors having no surface mount soldering experience or equipment to also enjoy building this project.

Start by soldering the IC socket for the PIC (IC 3). Then install the resistors (R12 to R29) ensuring that the correct values are placed at the correct positions. Continue by installing all the capacitors (C5 to C33). Most capacitors are 100nF decoupling capacitors, but the capacitors at the low pass filter and RF output section have different values. Note that C16 at the DDS has a value of 10nF.

L1 and L2 can be wound using 11 tightly wound (side-by-side) turns of 24AWG wire around the smooth end of a 4mm drill bit. The ends must be tinned and the coils mounted in place. Ensure that the windings are not spread apart as this will drastically affect the inductance and disturb the low pass filter response. Kits will be supplied with 270nH moulded coils which are mounted in the same way as the resistors. Insert and solder the inductors in place.

Insert and solder the 2 x 5 single in line socket (SK1) from the bottom of the PCB. SK1 must meet with HD1 when the display and analogue boards are joined.

Insert and solder the header pins HD2 to HD6. HD4 need not be mounted unless the constructor is interested in using In-Circuit-Serial-Programming (ICSP) to modify the PIC firmware. More information about ICSP is described later in this article.

Use a multi-meter which is set to the 2k Ω setting to adjust the multi-turn trim pots VR1 and VR2 to their centre positions. Continue construction by mounting VR1 and VR2.

Insert and solder the 3.3V regulator (IC5) into place taking care of the orientation according to the component layout.

The building should now be complete i.e. no remaining parts from the kit. Cleaning of all solder joints using flux remover is recommended.

The display and analogue boards can now be joined together. Insert the spacers that separate the boards at the mounting holes. Fit the M2.5 x 30mm screws that secure the boards together.

Connect a push-to-make, release-to-break push button (S1) to pin 3 and 4 of HD2. This is the STEP button which will change the frequency step size.

Insert the programmed PIC taking care of the orientation. Ensure that JP1 is set to the Operate mode (Link pin 2 & 3).

3. Power Supply

Building the power supply is reasonably easy. Start by mounting the input edge connector and the output header. Then mount the bridge rectifier (B1) and capacitors (C34 to C39). Mount the fuse holder (F1) and insert the PCB mount transformer (TRF1). Lastly install the regulator IC's (IC9 and IC10) taking care of their orientation. Insert the 250mA fuse in the fuse holder.

Clean the board using flux remover.

In general, using PCB mount transformers are attractive from the point of view that they allow a self contained power supply to be constructed. The downside is that the board onto which they are mounted can become a dangerous and lethal item.

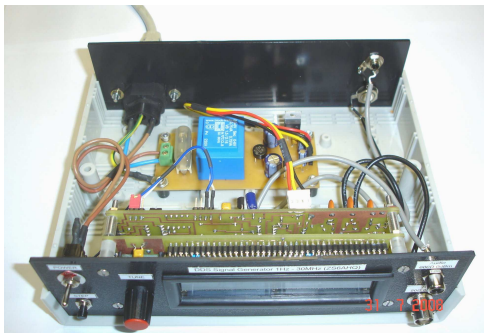
For safety it is strongly recommended to mount the power supply board onto a temporary non-conductive piece of material, such as wood or Perspex to avoid any accidental contact with the 230V AC present at the primary side at the bottom of the board. Remember that by now, the work bench may have many cut off resistor and capacitor leads lying around.

The anticipation of testing the project may override the urgency to perform this safety precaution and will undoubtedly have disastrous effects should one of the off-cut component leads short the 230V AC on the main side. Remember: "rather an extra step than starting all over again", or in this case, maybe not be able to start again at all..!

As a minimum precaution, the primary side of the bottom of the PCB should be covered with insulation tape, which will keep conductors away, but is no guarantee for future shorts which can occur should the insulation tape wear through.

Enclosure

The DDS Signal Generator was built into a split type box. The display and analogue board were mounted directly on the front panel together with the power switch, STEP push button and the 0dBm outputs. The power input connector and the low level signal outputs were mounted on the rear of the unit. The completed unit is shown below.



Any enclosure can be used as long as the safety precautions for mounting the power supply PCB is followed.



Figure 8 : Completed DDS Signal Generator

Testing and Calibration

The power supply needs to be tested first. Ensure that the mains connection to the PSU board is isolated and safe. Apply power. Use a multi-meter to measure the +5 and -5V lines on HD7 (pin 1=+5V. pin 3=-5V)

Connect the power supply to the Analogue board (HD3). Now, this is the moment..!

Watch the display and apply power. The display should show the welcome screen : "ddS Sig" "gEn v01". This indicates that the display and the PIC are working correctly. Press the STEP push button. The 1MHz digit will be selected and the rotary encoder can now be turned. The displayed frequency should change as the rotary encoder is turned. When pressing the STEP change push button the selected digit should blink on the display. Refer to the section about operation to become familiar with the frequency setting.

Set the frequency to 55Hz. (The author found that interference from the 50Hz mains (or 60Hz in certain countries) which is induced in the DVM leads introduces measurement errors.

The audio section alignment will be performed first. Connect a DVM between , the audio output (pin 1 HD6) and ground. Set the DVM range to measure 0 to 2V DC. Adjust VR1 slowly until the meter reads 0V. This setting adjusts the DC value of the difference amplifier (IC8A).

Now set the DVM to measure AC in the same 0 to 2V range. The reading should show : 1.562V ($\pm 50\text{mV}$). This will result in a 0dB output level when terminated with a 600 ohm load. If an oscilloscope is available, the peak-to-peak voltage should read 4.4V.

No other adjustments need to be made as the frequency response of the audio section (IC8) is flat up to 100kHz. The -3dB Bandwidth is at 200kHz and the output level reduces further as frequency increases into the RF range.

Set the multi-meter to the 0 to 2 V AC range again. Connect the meter between ground and test point 1 (TP1) which is located at the node of R15, C22, R23, C24, L2

and C20. Set VR2 until the meter reads 212mVrms (600mV peak-to-peak using a scope).

The output is now calibrated to be 0dBm at frequencies from 100kHz to 30MHz. It's that simple. No specialized RF test equipment is needed.

To verify that the calibration is correct, an oscilloscope can be connected to the 0dBm 50Ω output (pin 1 HD5). Set the frequency of the signal generator to 1MHz. Ensure that the scope is calibrated against it's internal test oscillator. The output should be 1.14V peak-to-peak with no load connected. The -73dBm output is automatically calibrated when the 0dBm calibration has been done.

Results

1. RF Section : 0dBm output

The RF section performs better than the requirement of having a 0dBm output signal level within $\pm 1.5\text{dB}$ ($3\text{dB} = \frac{1}{2}$ a S-point) across the frequency range from 100kHz to 30MHz. The output level vs frequency is shown in Figure 9.

This measurement was taking by a calibrated HP8562A Spectrum Analyser (9kHz to 22GHz). The max hold function was used and the signal generator was stepped in 100kHz steps while the measurements were automatically taken.

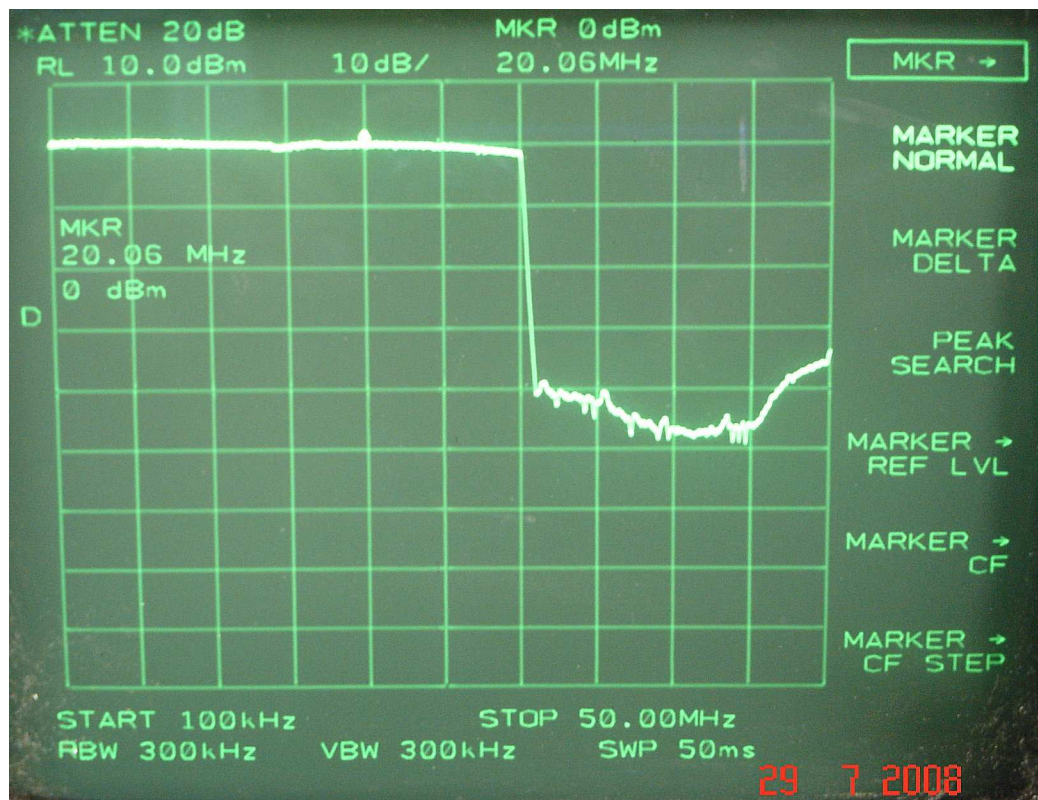


Figure 9 : - Output level across frequency : RF Section

The spurious levels which are inherent to the DDS mechanism of frequency generation were found to be below 45dB which is considered adequate for amateur radio use, especially in view of the fact that amateur radio equipment operates in bands which are selected with front end filters. These spurious signals are out of band for most "wide band" software defined radios which typically covers 50KHz bandwidth.

Results are shown for 1, 20 and 30MHz in the figures below. Each division represents 10dB while the second line from the top is 0dBm.

The phase noise was measured at 10MHz as : -103dB/Hz at 10kHz away from the carrier with a 300Hz resolution bandwidth. The phase noise is determined by the master clock oscillator which is very good. The measurement was limited by the capability of the instrument.

The frequency accuracy is determined by the accuracy and drift of the master clock oscillation as well as the ratio of the output frequency relative to the frequency of the master clock. The 75MHz clock oscillator has a 100parts-per-million (ppm) drift coefficient which results in a drift of 30ppm at 30MHz with better values as the frequency decreases.

The frequency resolution, which is the smallest possible increment in frequency is 0.280Hz according to equation [3]. This is constant and it therefore means that the higher the frequency, the less the effect of the frequency resolution. E.g a displayed frequency of 1Hz will actually yield an output 1.117Hz, while 10Hz will yield 10.058Hz. The frequency resolution is therefore for all practical purposes set by the minimum display increment of 1Hz.

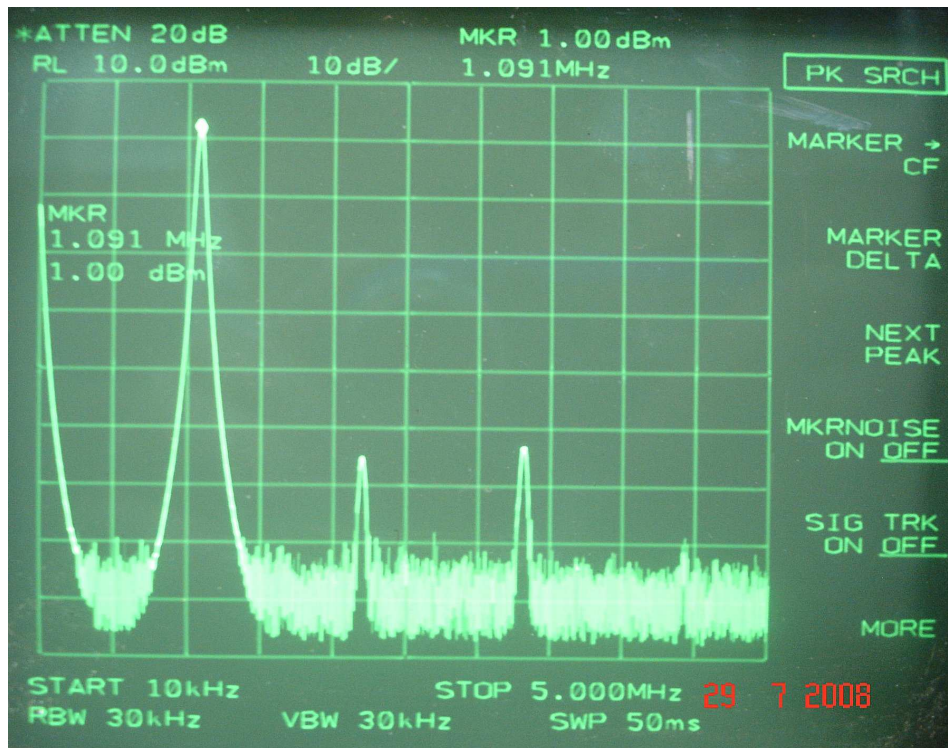


Figure 10 : Output frequency = 1MHz

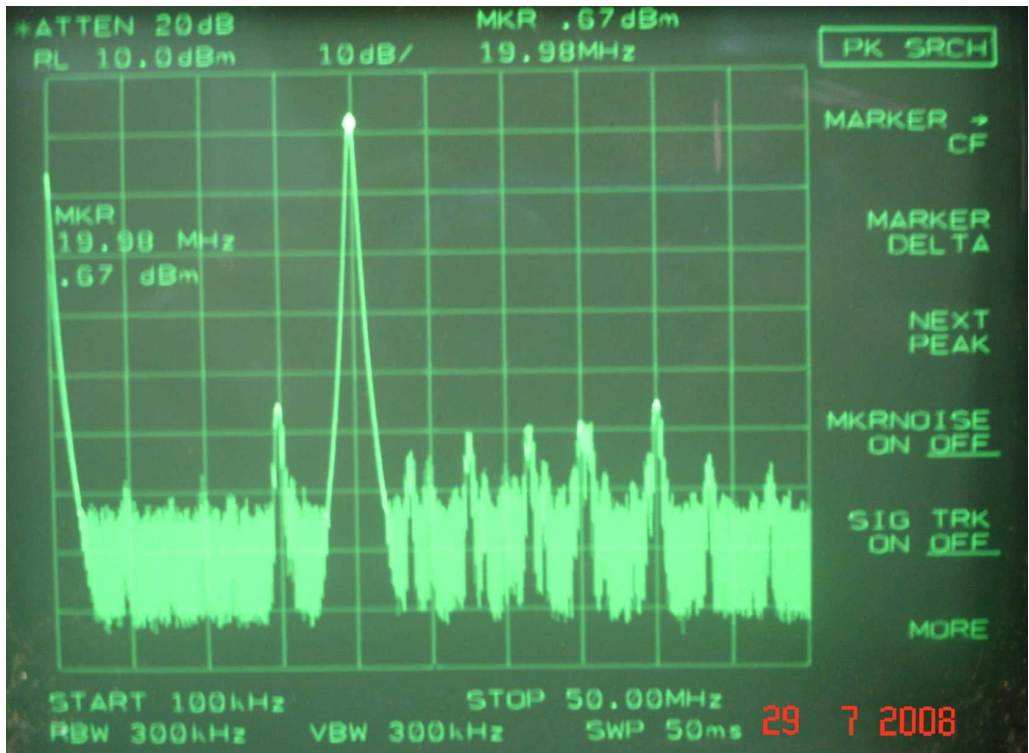


Figure 11 : Output Frequency = 20MHz

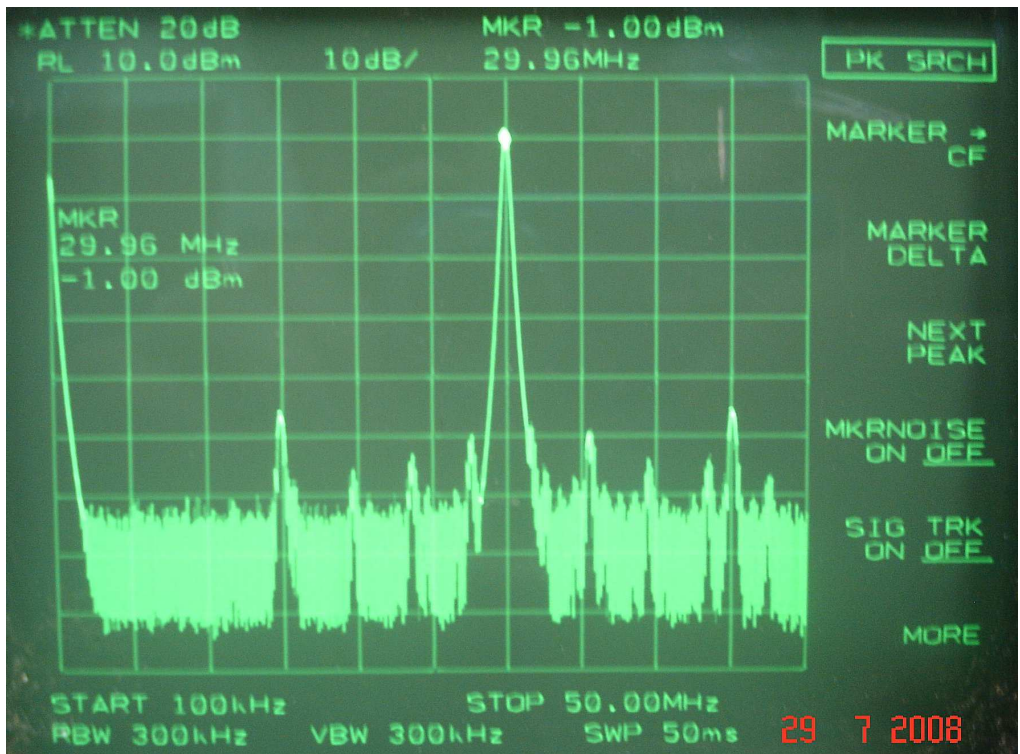


Figure 12 : Output frequency = 30MHz

2. RF Section : -73dBm Output

The 73dB attenuator board was tested on a vector network analyser and the S-parameter S21 was measured as -72.9dB up to about 80MHz. (This instrument measures to better than 0.1dB..!) The return loss (S11 and S22 was measured as -38dB and -35dB respectively, which represents very good input and output matching into a 50Ω system.

The -73dBm output which is equal to a S-9 reading into a receiver with a 50Ω input impedance was tested connected to a ICOM-706 HF transceiver. The mode was set to CW and the S-meter reading was observed to be S-9 on all the ham bands from 80m to 10m. The S-meter evaluation application has therefore been proven to work well.

3. Audio Section

The Audio section was evaluated using a 20MHz analogue oscilloscope. The peak-to-peak value of the 0dBm output signal at the output (pin3 of HD6) was checked. No DC offset is present and the output amplitude of 2.2Vp-p is constant up from 1Hz to 100kHz. The amplitude drops as frequency increases and the -3dB point is around 200kHz which is well into the lower RF band.

The -60dBm low level output signal was connected to the line input of a PC sound card (AC97). The Software Defined Radio (SDR) software of M0KKGK was run on the PC. The frequency was set to 7,056MHz and the DDS signal generator was varied across a frequency of 1kHz to 20kHz. Refer to Figure 13. The frequency response of the sound card was observed and can be plotted across frequency. This method can be used to evaluate the frequency response of various sound cards.

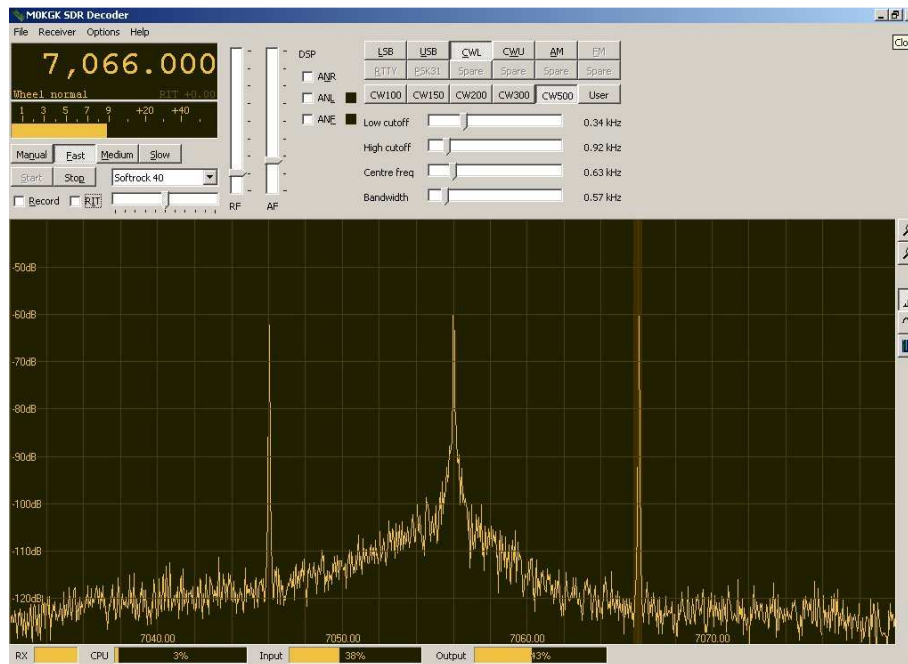


Figure 13 : -60dBm Audio Signal received on SDR

Software

The code for the PIC16F628A was developed by the author in assembly language. A few public domain routines for 32-bit addition, subtraction and Binary to Binary Coded Decimal (BCD) conversion were used and the authors are credited for this. The source code (.asm) and compiled .hex file are available at no charge. Programmed PIC16F628A devices can be supplied with each kit.

A detailed description of the program flow and execution is beyond the scope of this article. Interested reader could refer to the source code listing [6], which has been generously commented.

The analogue board, which hosts the PIC micro has been fitted with an In Circuit Serial Programming (ICSP) header (HD4). ICSP allows the PIC programmer to be connected to the PIC while it is still mounted "in the circuit". JP1 needs to be set to programming mode and a PIC programmer which has an ICSP mode and cable needs to be connected. ICSP is mostly used during the development phase of the firmware, or where the PIC is soldered directly onto the PCB without using an IC socket. This allows software updates to be programmed into the onboard flash memory, without removing the IC.

Future Improvements

The signal generator performs well. The following future improvements can be considered.

1. A 600R balanced output can be a useful addition.
2. The software update for a sweep function, which allows the user to set a start/stop and sweep time will add a "wobulator" functionality to the unit.

Summary

This DDS signal generator will prove to be a valuable piece of test equipment for any radio amateur and audio/RF homebrew enthusiast.

The fact that a calibrated wide frequency range audio and RF source can be home constructed at a cost which is far less than commercial equipment is attractive.

References

- [1] S-meter blues by Greg Ordy (W8WWW)
<http://www.seed-solutions.com/gregordy/Amateur%20Radio/Experimentation/SMeterBlues.htm>
- [2] ARRL Handbook 1999, Chapter 7, Test Equipment and Accessories, p. 154, Figure 36.
- [3,4] Analog Devices Data Sheet for AD9834 Complete DDS
- [5] Microchip Data Sheet for PIC MICRO 16F628A, In Circuit Serial Programming, Section 14-11, p 112.
- [6] DDS Signal Generator source code listing : 1 30 DDS v10.asm dated 31 July 2008.