

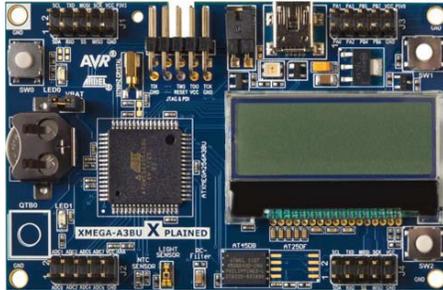
# Open Source AD9850 DDS VFO controller firmware for the ATMEL

## XMEGA-A3BU Xplained evaluation board

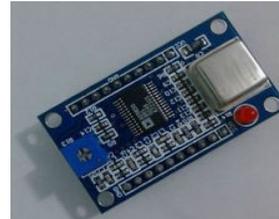
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*XMEGA-A3BU BOARD by ATMEL*



*Cheap AD9850 board from China*

The ATMEL XMEGA-A3BU evaluation board makes a convenient platform for controlling an inexpensive AD9850 DDS module. New firmware can be loaded via a simple USB connection. The factory assembled board is just a little larger than a credit card, making it a reasonable size to mount on a small front panel. The board is available from ATMEL distributors such as Mouser and Digi-Key for about \$30.00.

The AD9850 module is available direct from China via a number of sellers on e-bay for between \$5 and \$10.00. I would pick one with a SMT clock oscillator mounted, rather than the large through hole can some have. I got one of those and the clock oscillator was defective.

The firmware is designed to replace the existing analog VFO of a QRP rig or as the VFO in a new receiver, transmitter or transceiver project. It could also be used just as a signal generator. It's amazing the number of different ways Hams want to use a Digital VFO. I have tried to make the firmware flexible and programmable enough that it should cover most possible uses. The great thing about this easily reprogrammed controller is that additional features and operating modes can be added as time and need dictate.

### **DDS Controller functions:**

- 0 to 40 MHz output with 125 MHz reference clock, programmable
- 1 Hz to 100 kHz tuning steps
- Rotary tuned
- Built in Iambic "B" mode keyer with three message memories. Separate Audio Mute and transmitter keying outputs and side tone generation.
- Pre-programmed HF ham band QRP frequencies, 160 to 10 meters. BCD band outputs for selecting filters when implementing multi band rig.
- Programmable offset frequency to match your IF
- Reference clock calibration

### **Operation:**

The VFO is controlled by five switches and a rotary encoder. Most switches have different uses depending on what menu function is active at the time.

S1 – MENU function select  
S2 – Keyer message 1  
S3 – Keyer message 2  
S4 – Keyer message 3  
S5 – RIT on/off  
Encoder – tuning functions

### **Switch function descriptions:**

#### **Tuning:**

The rotary encoder is used for tuning the main operating frequency and is used to select a number of the options.

#### **Tuning Limits:**

The output frequency is limited from between 0.000,000 and 40.000,000 MHz under all tuning conditions. The output frequency must remain less than 1/3d of the DDS reference clock for best spectral purity.

Tuning limits for ham bands are enabled when a band is loaded from memory. This keeps you from straying outside of the band by accident. However, the limits can be disabled should out of band tuning be desired. Just beware that the transmitter is not disabled while out of band so care must be taken not to transmit where your not suppose to and probably cause damage to your transmitter.

### **PUSH BUTTON SWITCHES:**

**S1 – Menu** : Set tuning rate | set keyer code speed | select band | Turn limits on/off | Enter message memory |

Functions are selected by holding the menu switch closed until the desired function shows up on the LCD in the lower left corner of the display. Release the switch to activate the displayed function. These cycle at a rate of about 1 a second.

#### **Tuning rate: display message - none**

- "push and release" (less than 1 second) of the Menu switch will activate this function.
- The symbol " ^ " is used as a cursor to indicate the current tuning rate decade. Use the encoder to move the cursor to the desired decade.
- Tap the MENU switch to exit to normal tuning mode.

#### **Keyer code speed: display [ CSxx ]** where xx is the current keyer speed

- Push and Hold the MENU switch closed for at least 1 second, but less than 2.
- Use the encoder to change the speed up or down in 1 wpm increments, 5 to 40 wpm. Tuning will stop at upper and lower selections.
- Tap the MENU switch to exit.

#### **Select band: display message [BAND]**

- Push and Hold the MENU switch closed for at least 2 second, but less than 3
- Use the encoder to select the band, 160 to 10 meters. Tuning will stop at the upper and lower selection limits.
- Tap the MENU switch to exit

- This function can be hidden for single band rigs.

### **Turn tuning limits on or off: display message [TLON] or [TLOF]**

- Turn the encoder counter clock wise to turn off [TLON] --> [TLOF]
- The status LED above the display will turn from green to red when the limits are off.
- Turn the encoder clock wise to turn on [TLOF] --> [TLON]
- Tap MENU to exit

If you turn the tuning limits back on while out of band, you will be able to only tune up or only able to tune down, depending on which side of the limits you are at the time. And remember not to transmit out of band.

### **Keyer Memory: display message [KMEM]**

This mode allows entering Morse messages via the paddle. There are three message locations of up to 63 characters in length (word spaces are characters). Letters, numbers and most available Morse punctuation and special ascii characters are decoded and displayed on the top line of the display. This helps ensure proper entry of the messages. A back space function is available to erase mistakes.

- Hold the MENU switch closed for at least 3 seconds.
- The display will change when this mode is activated
- The frequency reading is cleared
- "ENTER MSG" appears on the 2d line.
- S2, S3 and S4 have new functions in this mode. The functions are labeled on the bottom line of the display as such: [ KMEM X RM BS -- ]
  - X = S2 = escape mode at any time
  - RM = S3 = Review message
  - BS = S4 = Back Space
  - -- = no function.
- When you start to enter a message, the Morse characters are decoded and displayed on the top line. When the line fills up the characters will start to scrawl.
- A word space is shown a ":" to let you know when and where the space has been inserted.
- "X" switch – exit (S1, Menu) Exit this mode at any time prior to storing a message.
- "BS" switch (S3) – Back Space. Allows you to delete an entry or word space.
- "RM" switch (S2) – review message.
- If you try to exceed 63 characters, [MEM FULL] will appear on the display. If this happens, you have three options.
  1. Store the message as is.
  2. Back space to remove some letters or words. Note, the mem full message will not be erased, even though the memory is no longer full.
  3. Exit the memory entry mode and start again.

When you've finished keying in your message, push the "RM" switch. The message will play so you can decide if you like the way it sounds or not before actually storing it. If you want to start over, push the MENU button [X] Other wise, push one the the switches now labeled M1, M2 or M3 to store the message in one of those locations.

- Push the [M1] S2, [M2] S3 or [M3] S4 switch to store the message in location 1, 2 or 3. The display and control will return to normal operation.

### **Sending messages:**

- Push S2 for memory location 1
- Push S3 for memory location 2
- Push S4 for memory location 3
- Once a message has started sending, it can be terminated by closing the DOT paddle. If a character is being sent, the message will terminate when that character has completed sending.

### **S5 – RIT:**

Pushing S5 will toggle RIT on and off. This control can be combined with the tuning encoder by using an encoder with a built in push button switch.

RIT is displayed as the delta frequency from the current receive frequency, displayed under the corresponding digits of the frequency display [ -0.000] and the RIT label written below "MHz". The tuning step is set to the 10 Hz decade for fine tuning. The original tuning step will be restored when RIT is exited. The tuning step can be changed if desired.

The encoder will now tune the receiver frequency and leave the transmit frequency set where it was when RIT was enabled. Although the display only indicates a delta of up to +/- 9.999 kHz, there is actually no limit to how far you can tune, but it is recommended you stay below 10 kHz. There really shouldn't be any need to go any farther.

#### Checking the base frequency for activity when RIT is enabled:

Pressing the MENU (S1) switch for 1 second will restore the base frequency to the receiver as long as the switch is held closed. The message [SPOT] will appear on the display while this is active. This provides a means of checking for activity on your transmit frequency.

### **Rx/Tx toggle pin input:**

It may be desirable to switch between the DDS frequency between receive and transmit independently of the built in keyer. This pin is effectively the "straight key" input. In addition to switching between Rx and Tx, it operates the Audio Mute, Side tone and transmitter keying outputs as the keyer would. See the pin chart for the location of this input. Voltage on this pin must not exceed 3.3V, so use isolation to drive it, like a 2N7000 mosfet.

### **Set up:**

Default set up values can be changed in this mode. The default values are:

- 125.000,000 MHz DDS reference frequency – used to calculate the DDS output frequency
- 40.000,000 MHz upper frequency limit.
- 0.000,000 Hz offset frequency
- Multi-band selection enabled
- Direct transmit frequency enabled
- 20 wpm code speed
- 100 Hz tuning decade
- 160 meter band loaded on power up

Before entering the set up mode, set the band, code speed and tuning step to the values you

would like to have on power up. These settings will be saved when the set up mode is exited.

### **Entering SET UP mode:**

- Press and hold the switch labeled "SW1" on the evaluation board for 5 seconds. This ensures you really want to enter this mode.
- When the set up mode is activated, [CALR] will appear in the message space at the bottom left. Release the switch and then the current reference oscillator frequency will be written on the frequency display line.

### **[CALR] – adjust DDS reference frequency.**

- The frequency display line now shows the current DDS reference frequency, which initially will be 125.000,000 MHz
- The DDS frequency output is set to 10.000,000 MHz so that it can be measured or compared to an accurate 10 MHz reference.
- Adjust the reference frequency as needed to set the DDS output to exactly 10.000,000 MHz.
- The tuning rate is set to 10 Hz for fine tuning, but can be changed to faster rates if desired by pressing the MENU button to activate the tuning rate selection mode.
- If a reference frequency other than 125 MHz is needed, adjust as required to set the display to the desired frequency. Note that due to leading zero suppression, 100 MHz will display as 1 0.000,000 MHz, missing the 10 MHz zero.
- Push SW1 on the board to advance to the High frequency limit mode.

### **[HLMT] High frequency Limit:**

The highest frequency the DDS should be allowed to produce is about 1/3d the reference clock. If the clock frequency is changed to a significantly different value from 125 MHz, the high frequency limit should be changed accordingly. One might also want to extend the frequency range a bit to cover 6 meters, but one needs to be careful about a spur which will occur at about 75 MHz and may not be very well filtered out.

- The frequency line will display the current high frequency tuning limit, initially the default value of 40.000,000 MHz.
- Use the tuning encoder to set the desired limit frequency.
- Press SW1 to advance to setting the offset frequency.

### **[OSET] Setting the Offset:**

The offset frequency is added or subtracted to the displayed frequency to generate the required LO (local oscillator) frequency when used as the VFO in a super heterodyne receiver or transceiver. This will typically be the IF frequency of the rig. The offset will produce low side injection unless the result is negative, then high side injection will be produced. This ensures the output frequency is always within the range which can be produced by the DDS chip. As the displayed frequency approaches the offset frequency, the LO produced will approach and then become zero when the frequencies are equal.

While in this mode, the offset frequency will be outputted via the DDS chip. If the DDS is installed into a rig, this allows you to hear the signal and peak it in the pass band of the receivers crystal filter and adjust the BFO for the proper receiver beat note.

- The current offset frequency is displayed on the frequency line.

- Use the encoder to tune to the desired offset frequency. Tuning rate can be set as needed.
- Push SW1 to advance to next setting when done.

### **[MBON] or [MBOF] Multi-band on or off.**

If the VFO is used in a single band rig, there is no need to be able to select other bands which would just cause trouble if done.

- Display message : [MBON] or [MBOF]
- toggle between on and off using the MENU (S1) switch.
- Push SW1 on board to advance to next setting

### **[ DIR ] or [ HET ] Heterodyne or direct transmit frequency output:**

Most transceivers mix the VFO frequency with the IF BFO oscillator to produce the actual transmit frequency. Therefore, when switching between transmit and receive, the VFO frequency does not change unless RIT is enabled. In this case, the HET or heterodyne mode is required.

However, due to the frequency agility of the DDS VFO, it is possible to eliminate the transmit VFO/BFO mixer and produce the transmit frequency directly. This simplifies the design of a transmitter as the mixer and band pass filter can be eliminated. This also generally results in a cleaner signal as mixer products don't have to be filtered out. When building a multi-band rig, having direct transmit frequency output greatly simplifies the design, as not only does it eliminate the transmit mixer, but multiple crystal oscillators, band pass filters and all the required switching.

Unfortunately, this mode is only suitable for CW transmitters. Transmitters which require modulation is done at the IF frequency and must be heterodyned to the transmit frequency.

- Display message : [ DIR ] or [ HET ] Direct is the "factory" default.
- Toggle with MENU switch
- Push SW1 on board to advance to next setting

### **[ STAE ] or [STEO] Side tone mode:**

Side tone is required independent of the transmitter when entering in keyer messages. It may not be desired if the transmitter also produces side tone. Therefore, it can be programmed to operate only for enunciation when entering messages or enabled when keying the transmitter. "Always enabled" is useful for HB rigs with direct transmit frequency output or Direct conversion rigs as in this case, the receiver does not "hear" the transmitter in order to generate internal side tone.

- Display message [STAE] (always enabled) or [STEO] enunciation only. Always enabled is the "factory" default.
- Toggle with MENU switch
- Push SW1 on board to advance to next setting.

### **Side tone output signal:**

The side tone is set to 600 Hz and is some what filtered at the header pin. It can be heard with just a small 8 ohm speaker connected to the pin, but barely. To be useful, it should be additionally filtered and the amplitude reduced to a suitable level to input into the receivers audio amplifier. It will need to be capacitively coupled to an audio amplifiers input. In many QRP transceivers which use a LM386 audio amp, one of the two inputs are not used and the side tone can be injected into the unused pin for volume control independent level.

### **[X4OF] or [X4ON] X4 output frequency for SDR:**

Turning X4 on will multiply the output frequency by a factor of 4. Most SDR designs require this type of frequency scaling for the I/Q output mixers. When enabled, the display frequency will be limited to a maximum of 10.500 MHz so that the output remains below the 40 MHz upper limit.

- Use the Menu switch to toggle between X4 off – normal operation, [X4OF] and [X4ON] X4 output enabled.
- Push SW1 to save and exit the settings mode.

## **Programming the board with the controller firmware:**

You will need to download and install a programmer called "FLIP" from the Atmel web site. [Http://www.atmel.com](http://www.atmel.com) Search for 'FLIP' in the search box to locate the download page. Be sure to download the instructions too!

Next you will need the .hex file with the controller firmware. Download the zip file which also contains the source code here : <http://kd1jv.qrpradio.com/XMEGA/AD9850controller.zip>

Be sure to check back once in a while to see if there are any updates to the firmware, either to fix bugs (which I hope there are none, but it's hard to think of every possible combination of events to test) or additions to the program.

Unzip the folder to a folder in a location you can find such as "My Documents".

After you install the FLIP program, you can plug the eval board into your PC with an USB cable. The **SW0** switch on the board must be closed while you plug in the cable to invoke the Boot loader program in the XMEGA processor.

A new hardware found dialog will open and you will need to find the driver to install. This needs to be done manually, following the directions from Atmel. Once the USB driver is installed you can open the FLIP program. Some set up is required.

- Select the device to be programmed, XMEGA256A3BU
- Locate the hex file to be loaded, AD9850controller.hex
- Click on the download icon in the tool bar.
- Click the release button to reset the board and start the application.

That's all there is to it!

The source code is written directly in assembly because I can't make heads or tails of a C/C++ listing. Plus it forces me to learn all the nitty gritty details of making the part work. The source code can be opened with any word processor. If you want to tinker with the code, you will need to download and install "Studio 6" from Atmel. It is a free download, but you do need to register and it's a very big file.

With 256K of program memory available and only a fraction of the first bank of 64K is being currently used, so many more features could be added to the firmware.

### **Possible firmware additions are:**

- 1, S meter display using one of the A/D input channels
- 2, Battery voltage monitoring
- 3, Transmitter power output display
- 4, Real time clock with battery back up.
- 5, Keyboard keyer
- 6, USB control
- 7, PSK beacon generator
- 8, QRSS beacon transmitter
- 9, Additional message memories
- 10, User frequency memories.
- 11, Short wave broadcast bands.

## Off board connections:

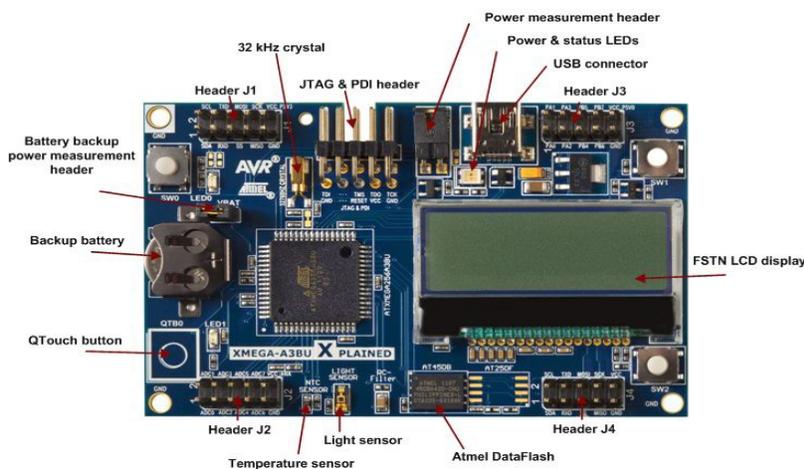
A number of off board connections are required which are available on the various SIP header pins located along the edge of the eval board. Unfortunately, these pins stick up from the top of the board. Even if nothing is plugged into them, the board has to be spaced from a front panel far enough that the display is set back a significant distance, making even harder to read than it already is with the little characters it displays. The situation is unacceptable if using a plug to connect to the pins, as this would require spacing the board even farther from the front panel.

The simplest solution is to clip the pins short, leaving just enough to solder a wire to. If you have good de-soldering tools and abilities, removing the SIP pins and relocating them so they stick out the back side would be the neatest option. This is generally best done by removing the plastic base and then removing the pins one at a time. The base can be slid off the top of the pins by using a small screw driver to work it up from the board. Then replace with new pins after cleaning out the pad holes of solder. Doing it this way reduces the risk of damaging the plated through hole.

Off board connections are thus:

- DDS power, enable, data and clock
- Paddle Dot and Dash inputs
- Keyer output - transmitter key, audio Mute and side tone.
- Encoder
- Push buttons

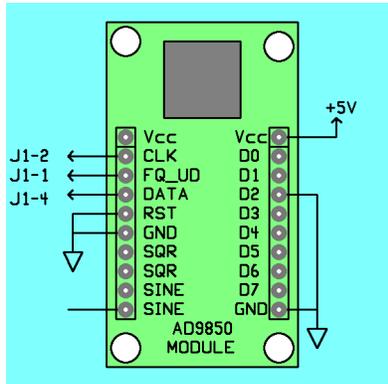
Pin number	J1	J2	J3	J4
1	DDS CS (FQ_update)	Band BCD 1		Encoder CH A
2	DDS Clock	Band BCD 2		Encoder CH B
3	External Rx/Tx keying input	Band BCD 4	Side tone out	
4	DDS Data	Band BCD 8		
5	Paddle in, DOT	SW1 - MENU		
6	Paddle in DASH	SW2 - Mem 1		
7	Keyer MUTE out (active high)	SW3 - Mem 2		SW5 - RIT
8	Keyer KEY out (active high)	SW4 - Mem 3		
9	Ground	Ground	Ground	Ground
10	+ 3.3V		Ext + 5 volts in	Vcc (5V) to DDS



Header locations are shown in picture to the left. The battery back up is currently not used, so the battery and/or shorting jumper can be removed.

The board SW1 switch is above the display to the right and the SW2 switch is below the display.

## AD9850 module pin out



Pin out of the common Chinese 9850 module. There are several versions available. Ones with a SMT clock instead of the through hole metal can might be better. The module I got had a defective clock oscillator, which was the metal can type.

If a different style module is obtained, you will have to determine the pin out if not supplied. D0 and D1 must be pulled high and D2 connected to ground in order to enable serial loading. Data comes in on the D7 pin. D0 and D1 may have pull up resistors installed on the board, which is the case with the module shown, but D2 must be wired to ground. These modules might also need a better output filter to clean up the output signal. The one supplied on the module might have too high a roll off frequency.

## Power supply:

The XMEGA board is set up to get it's power from the USB cable. For stand alone use in a rig, a 5 volt supply must be connected to the board. An external +5 volts source can be connected to Pin 10 of J3 or pin 10 of J4. J3 is preferred as it is closer to the 3.3V board regulator.

The external 5V source will need at least a 200 ma capacity to have some head room. Most of this current goes to powering the 125 MHz clock oscillator. Although the 5 volts to power the DDS board can be taken off one of the pins on the XMEGA board, it should be wired directly to the 5 volt source, typically a 7805 or 78M05 regulator with suitable heat sink.

The AD9850 can run on the 3.3 volt supply, the only question is will the clock oscillator supplied on the board? It would be worth a try as powering the AD9850 with the lower voltage will reduce it's current consumption. Worst case, the reference oscillator could be replaced with a 3.3V version. They are not all that expensive.

The 3.3V regulator on the XMEGA board can handle input voltages up to 14V and output up to 1000 ma, but since it is not heat sunked very well, the power dissipation should be kept low by powering it with a 5V source.

## Keyer output buffering:

The transmitter keying and audio Mute outputs from the board must be buffered before connecting to external circuits. **Keep in mind that the ports on the XMEGA chip run at 3.3V so some kind of level shifter is needed to connect to external circuits.** The outputs are active high which allow directly driving the gate of a MOSFET like a 2N7000 to produce the active low output most transmitter keying and mute circuits require. An NPN transistor could be used instead, but a base resistor must be used. A value between 2.2 K and 10 K will likely work in most cases, depending on how much current it has to sink.

## Selecting encoder and Push button switches to use:

Pretty much any mechanical encoder can be used. One with a built in switch is handy to use as the RIT on/off switch. Look for one with about 20 counts per rev and a metal bushing on the shaft for long life.

TACT push button switches are preferred as they have minimal contact bounce. They are also inexpensive and come with a verity of actuator lengths. One disadvantage is they need to be mounted to some kind of board, as they are designed to be pcb mounted.