Arduino Mega 2560 & DDS-60 WSPR/QRSS Controller W3PM


```
10,140.060 KHz  GPS
16:23:29 UTC    W3PM
EM64 34N 086W sat=04
QRSS Transmit 10 mW
```
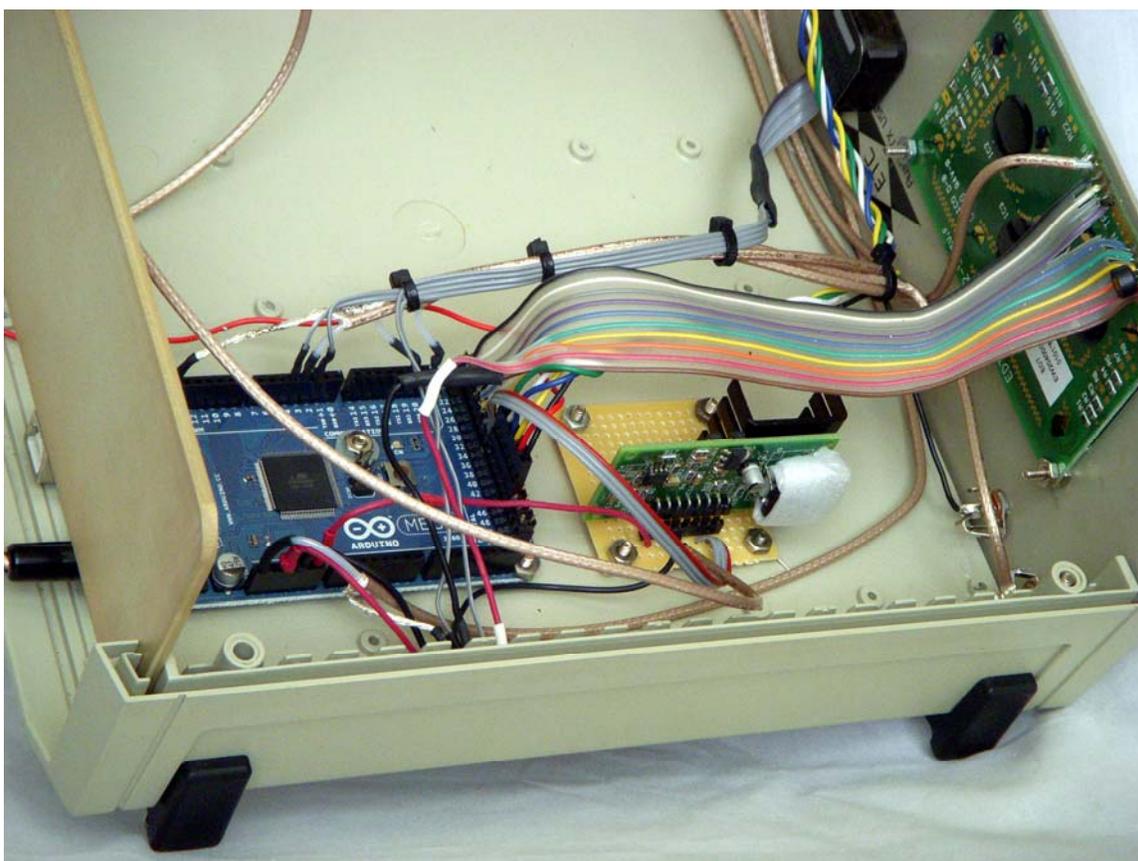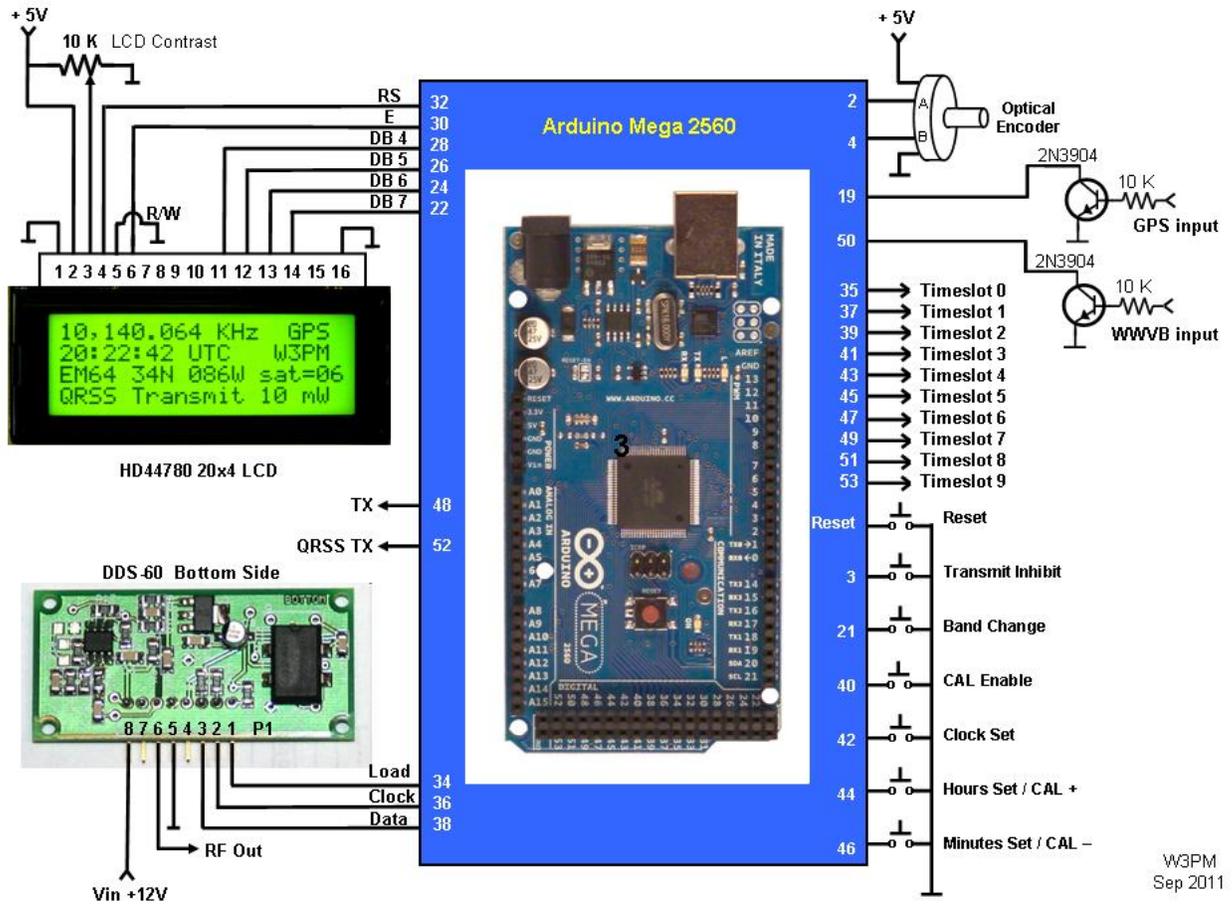
Arduino Mega 2560 & DDS-60 WSPR/QRSS Signal Source v2.0

This Arduino Mega 2560 & DDS-60 project provides a collection of features to use as a foundation to build a WSPR/QRSS beacon.

- NMEA GPS, WWVB or independent timing for UTC synchronization of WSPR and QRSS transmissions.

- On chip generation of WSPR message.

- 'On-the-fly' GPS generation of grid square location for portable WSPR operation.

- 6 thru 160 meter operation with VFO control.

- Individual WSPR power level allocation for each band.

- Single band operation or coordinated frequency hopping for multi-band WSPR transmissions.

- 20x4 LCD display of frequency, time, transmission mode, timing source, callsign, grid-square, power, latitude, longitude, and WWVB pulse width.

- Flexible control of band selection, mode of operation, and power level.

- QRSS Morse FSK plus 12 graphical pattern options

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Arduino Mega 2560 / DDS-60 Schematic

+ 5V
10 K LCD Contrast
RS 32
E 30
DB 4 28
DB 5 26
DB 6 24
DB 7 22
R/W
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

```
10,140.064 KHz  GPS
20:22:42 UTC    W3PM
EM64 34N 086W sat=06
QRSS Transmit 10 mW
```
HD44780 20x4 LCD

Arduino Mega 2560

+ 5V
Optical Encoder
A
B
2N3904 10 K
19 GPS input
50
2N3904 10 K
WWVB input

35 Timeslot 0
37 Timeslot 1
39 Timeslot 2
41 Timeslot 3
43 Timeslot 4
45 Timeslot 5
47 Timeslot 6
49 Timeslot 7
51 Timeslot 8
53 Timeslot 9

TX 48
QRSS TX 52

DDS-60 Bottom Side

8 7 6 5 4 3 2 1 P1

Load 34
Clock 36
Data 38

RF Out
Vin +12V

Reset Reset
3 Transmit Inhibit
21 Band Change
40 CAL Enable
42 Clock Set
44 Hours Set / CAL +
46 Minutes Set / CAL –

W3PM
Sep 2011

Introduction

The Arduino Mega 2560 & DDS-60 provides a "Swiss Army Knife" collection of
features to use as a foundation to build a complete WSPR/QRSS beacon.

The DDS-60 is not intended to be used as a stand alone transmitter. Spectral purity
regulations within your country may require the use of appropriate output filtering. The
Mega 2560 provides for external amplifier on/off control and timeslot switched outputs
for external filter control.

Acknowledgements

The on chip generation of the WSPR message algorithm is the work of Andy Talbot, G4JNT. His excellent paper 'The WSPR Coding Process' provides a simple description of the encoding protocol. Portions of the GPS receive code were influenced by Igor Gonzalez Martin's Arduino tutorial.

Initial Setup

Open "Mega_DDS60_v2_0.pde" into the Arduino development environment and customize the script to personalize your station information. The station information is found near the beginning of the script. Only change the data highlighted in red. Do not change any other data. Be sure to remember to save your changes and upload the file into the Mega 2560.

WSPR Data Setup:
```
//_____
// ENTER WSPR CALLSIGN AND GRID SQUARE DATA:
char call[7] = "W3PM";
char locator[5] = "EM64"; // Use 4 character locator e.g. "EM64"
//_____
```

Note:
- Upper or lower case characters are acceptable.
- The callsign is a maximum of 6 characters. Do not use special characters such as "/".
- Use only 4 characters for the grid locator.

WSPR and QRSS Control Setup:
```
//_____
// ENTER TIME SLOT DATA:
// column 1 = frequency; Column 2 = mode; Column 3 = power
// frequency: Hz
// mode: ( 0=idle, 1=transmit WSPR, 2=transmit QRSS )
// power: Min = 0 dBm, Max = 43 dBm, steps 0,3,7,10,13,17,20,23,27,30,33,37,40,43
// Note: Ensure QRSS message length does not exceed QRSS allocated transmit window(s)
unsigned long timeslot_array [10] [3] = {

 { // timeslot 0  00,20,40 minutes after hour
   1838100,0,20    }
 ,
 { // timeslot 1  02,22,42 minutes after hour
   3594100,2,20    }
 ,
 { // timeslot 2  04,24.44 minutes after hour
   50294500,2,10    }
 ,
 { // timeslot 3  06,26,46 minutes after hour
   7040100,2,17    }
 ,
 { // timeslot 4  08,28,48 minutes after hour
   10140200,1,3    }
 ,
 { // timeslot 5  10,30,50 minutes after hour
   14097100,1,7    }
 ,
 { // timeslot 6  12,32,52 minutes after hour
```

```
        18106100,1,17    }
,
{ // timeslot 7  14,34,54 minutes after hour
   21096100,1,23    }
,
{ // timeslot 8  16,36,56 minutes after hour
   24926100,1,33    }
,
{ // timeslot 9  18,38,58 minutes after hour
   28126100,1,37    }
};
```

Note:

- Column 1 frequency is in Hz.

- Column 2 transmit mode (0=idle, 1=WSPR, 2=QRSS)

- Column 3 power in dBm (e.g. 37 = 5 watts).

- Timeslot 2 is normally loaded with a 60 meter transmit frequency. I loaded this timeslot with a 6 meter frequency because FCC regulations prohibit 60 meter WSPR transmissions in the USA.

QRSS Setup:

```
//_____
// ENTER QRSS DATA:

// QRSS frequency (Hz)
unsigned long QRSSfreq = 10140060;

// QRSS message
// A "space" should be added at the end of message to
// separate message when looping
const char QRSSmsg[ ] = "W3PM ";

// QRSS frequency shift in Hz
const byte QRSSshift = 4;

// QRSS dot length in seconds
const byte QRSSdot = 3;

// QRSS patterns:
// 0 = ID loop; 1 = sinewave; 2 = interrupted sinewave; 3 = sawtooth
// 4 = waves; 5 = hills; 6 = herringbone; 7 = upramp ; 8 = downramp
// 9 = upramp sawtooth; 10 = downramp sawtooth; 11 = M's; 12 = W's
const byte Pattern = 4;
};
```
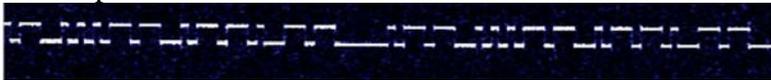
(0) ID Loop

(1) Sinewave

(2) Interrupted Sinewave

(3) Sawtooth

(4) Waves

(5) Hills

(6) Herringbone

(7) Up ramp

(8) Down ramp

(9) Up sawtooth

(10)   Down sawtooth


(11)   M's

(12)   W's

Notes:
- Frequency is in Hz
- The QRSS frequency may be within any band 6 through 160 meters.

- The QRSS message may be a callsign or callsign with a short message separated by a space (e.g. "W3PM EM64 ").
- Always end the message with a space. This separates the message when looping.
- Ensure that a sufficient number of sequential 2 minute time slots are allocated to QRSS to complete the message.
- Use only characters A-Z and numbers. Special characters such as "/" are not supported.
- If exclusive QRSS operation is desired using GPS or WWVB timing be sure to configure at least one time slot to zero "0" (transmitter off) to allow for time updates.

Frequency Calibration:
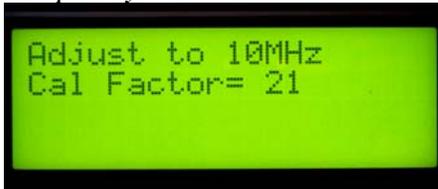
The DDS-60 requires frequency calibration unless you are using a GPS disciplined oscillator or other high precision frequency source for the 30 MHz oscillator.

A software calibration routine is provided as follows:
- Connect a frequency counter to the DDS-60 RF output.
- Access the calibration routine by depressing and holding the "CAL enable" pushbutton while resetting the Mega 2560.
- While holding the "CAL enable" pushbutton depress the appropriate "CAL +" or "CAL – " pushbutton to set the frequency counter to 10 MHz.
- Release the "CAL enable" pushbutton to store the calibration factor into EEPROM memory.

Time Synchronization

Three methods of time synchronization are provided…GPS timing, WWVB timing, and independent internal clock timing. Reset the Mega 2560 before implementing GPS or WWVB timing. The software cannot automatically switch from GPS to WWVB timing or vice-versa.

I prefer to use external WWVB and GPS receivers and use an NPN transistor buffer at the input ports. Internal pull-up resistors are implemented in software at Mega pins 19 and 50. The receiver may be directly connected to the Mega by disabling the pull-ups in the software and connecting a <u>negative</u> going pulse data stream.

GPS Timing:

NMEA GPS is the preferred method of timing. It is available worldwide and will provide automatic "on-the-fly" calculation of the grid square location. It will also provide a LCD display of latitude and longitude and the number of satellites within range.

To enable GPS timing, connect a 5V peak-to-peak positive going NMEA $GPGGA 4800 baud data stream to the GPS input 10K resistor. When the software detects GPS data the updated time will be displayed first. (Note: The displayed time may be scrambled and overwrite other portions of the LCD when the GPS receiver is first turned on and not locked on to any satellites.) The software will then wait for a valid GPS flag (normally 4 satellites in range). When a valid GPS data flag is detected the software will wait until the next active transmit timeslot before turning the transmitter on. At this time "GPS" will be displayed in the upper right hand corner of the display along with updated grid-square, latitude, longitude, and satellites-in-view data on row 3 of the display.

GPS timing is not active during transmit times due to software interrupt conflicts. During transmit times the internal time clock keeps track of time until the GPS timing is turned back on between WSPR transmissions. If the system is used only for QRSS be sure to configure at least one timeslot to zero "0" (transmitter off). This is necessary to allow for GPS time updates.

WWVB Timing:

WWVB timing should only be used if you can reliably receive WWVB during daylight hours. Sparkfun < http://www.sparkfun.com/products/10060> and Digi-Key < http://search.digikey.com/scripts/DkSearch/dksus.dll?Detail&name=561-1014-ND> at one time sold a CMMR-6P-60 receiver and antenna for less than $11 US. Unfortunately, they are out of stock at the time of this writing. A WWVB receiver and antenna scavenged from an "Atomic" clock will work.

To enable WWVB timing, connect a 5V peak-to-peak positive going data stream to the WWVB input 10K resistor. When the software detects WWVB data, the data pulse width will be displayed on the LCD. Look for pulse widths of 200, 500, and 800 milliseconds plus or minus a few counts. Periodic counts of less than 100 milliseconds indicate the presence of noise and will not allow the internal clock to synchronize to WWVB time. I

mounted my receiver and antenna away from the Mega 2560 and other noise sources to provide consistent daytime reception of WWVB data.

The time display will update to UTC time after a few minutes provided you are receiving steady time pulses. The software will then wait until the next active transmit timeslot before turning the transmitter on. At this time "WWVB" will be displayed in the upper right hand corner of the display.

Important note: WWVB timing is not active during transmit times due to software interrupt conflicts. During transmit times the internal time clock keeps track of time. Because WWVB updates take more than a minute under optimal conditions, one or more sequential timeslots must be set to zero "0" (transmitter off) to allow sufficient time for WWVB time updates.

Independent Timing;

The internal time clock may be used to synchronize transmission times over a period of a few hours. The time must first be manually set to an accurate time source.

Depress and hold the "Clock Set" pushbutton while resetting the Mega 2650 to enter the time set routine. While holding the "Clock Set" button, depress the "Hours" and "Minutes" pushbuttons to set the time. Releasing the "Clock Set" pushbutton will start the clock.

Internal time keeping is dependent upon the accuracy of the Mega 2650's 16 MHz crystal clock. If you plan to use the internal clock over a long period of time, the OCR1A variable for timer1 may be changed to provide more accurate timing. The value is nominally 62500 but is set to 62487 with the correction factor for my Mega 2650. If the internal clock runs fast increase this value, if slow decrease the value. A few iterations may be required to get the timing accurately set.

Transmit Inhibit

```
50,294.500 KHz    GPS
16:35:35 UTC    W3PM
EM64 34N 086W sat=07
TX OFF          10 mW
```

The transmitter may be put into a standby mode by depressing the Transmit Inhibit pushbutton. Depress again for normal operation. The GPS or WWVB receiver will remain on for time updates during standby periods.

Single Band WSPR Operation

Single band operation is normally set by entering the appropriate configuration in the *WSPR and QRSS Control Setup* described earlier. An alternate method of selecting single band WSPR operation is provided when using the Mega in a multi-band configuration.

```
21,096.120 KHz *GPS
16:34:36 UTC    W3PM
EM64 34N 086W sat=07
WSPR Transmit 10 mW
```

Pushbutton method:
- Depress the "Transmit Inhibit" pushbutton to turn off the transmitter.
- Select the desired band of operation with the "Band Change" pushbutton.
- Depress and hold the "CAL Enable" button then depress the "Band Change" pushbutton. An asterisk will appear to the left of mode of operation display on the LCD to indicate single band operation.
- Depress the "Transmit Inhibit" pushbutton to return to normal operation. The controller will begin a WSPR transmission in the corresponding frequency time slot.

VFO Operation

The VFO is only operational during non-transmit periods. Frequency changes made with the VFO are not stored in EEPROM and will be lost upon reset or power down. Update the *WSPR and QRSS Control Setup* if permanent frequency changes are desired.

The optical encoder rate of change may be varied by changing the maximum value of the variable *ii* in the "void doEncoder()" section of the software.

I have not tried using a mechanical encoder. Use of a mechanical encoder would probably require software modification including a de-bounce routine.

External Amplifier and Filter Switching

Ten timeslot outputs corresponding to the ten *WSPR and QRSS Control Setup* timeslots are provided for external filter switching. A TX output is provided for external amplifier switching. The TX output is active when the unit is in either QRSS or WSPR transmit mode.

The QRSS TX is only active when the unit is in QRSS transmit mode. This output may be used to control an external QRSS amplifier and/or filter.

Hardware Options

The builder may wish to customize the system for his/her use and exclude unnecessary hardware.

I found that after using the system I seldom used the rotary encoder to make frequency adjustments. If I built a second system, I would consider excluding the encoder.

A simplified system could be built excluding all the hardware (except the Mega 2650 and DDS-60 of course) and use GPS or WWVB for time synchronization. LEDs could be connected to the TX line and Band Select outputs to monitor system operation.

Reducing DDS-60 Frequency Drift

The DDS-60 VFO is a self-contained functional module that generates a good-quality RF signal from 1-60 MHz by using a small pc board to contain just the bare DDS essentials – an Analog Devices AD9851 DDS chip, a clock oscillator, a 5th-order elliptic filter and an adjustable-level RF amplifier. Additional information for this board may be found at: http://amqrp.org/kits/dds60/index.html.

The board is designed with the 30 MHz reference oscillator chip mounted on the opposite side of board from the AD9851 DDS chip. The heat generated by the DDS chip tends to affect frequency stability. I reduced thermal related frequency drift by mounting the oscillator about 0.25 in. above the board using wire leads as standoffs. A small jacket of Polystyrene was used to further thermally isolate the oscillator. A small heat sink attached to the AD9851 with epoxy glue further reduced the drift problem to acceptable levels. An external 30 MHz precision reference oscillator would provide the best solution to this problem. It would also eliminate the requirement to provide a frequency correction factor.

I may be contacted at   w3pm at amsat dot org   for any questions or comments.