

# DPS-4D Transmitter Oscillator Testing and Tuning Procedure

Ryan Hamel, Igor Lisysyan, David Kitrosser, Steve Mendonca, LDI

## Contents

page

1	Introduction .....	1
2	Verify DAC command bytes.....	2
3	Verify DAC proper operation .....	2
4	Prepare programs and schedules for tuning the 61.44 MHz master oscillator .....	4
5	Connect the oscilloscope and prepare for tuning.....	7
6	Changing the backplane with the master oscillator (OCVCXO) .....	9

## Revision Log

This log identifies those portions of this document which have been revised since the original issue. Changes made since the last release will be marked with revision bars within the body of the document, on the right hand side.

Rev.	Date	Description
5.0	4/24/2013	Initial Release after internal LDI review
6.0	3/18/2014	Changed 1 second schedule to 2 second schedule
7.0	5/12/2016	Cleanup of text and slight rewording of procedure
7.1	12/28/2016	Small change to Figure 3
7.2	05/24/2017	Oscillator daughter board, etc.

## 1 Introduction

All the timing and frequency generation in the DPS-4D is derived from a 61.44 MHz oven controlled voltage-controlled crystal oscillator or OCVCXO on the backplane near the front left corner of the chassis. The stability and resolution to which this crystal oscillator can be set is generally better than 1 part in  $10^7$  and possibly on the order of 1 part in  $10^8$ . However, like all quartz crystal oscillators, the frequency drifts due to aging something on the order of 4 parts /  $10^8$  / year and should be re-adjusted yearly. The following procedure details checking the operation of the Digital to Analog Converters on the Transmitter card and the operation of the OCVCXO itself and adjusting or tuning the OCVCXO. The reference for adjusting the OCVCXO frequency is the GPS receiver component of the DPS-4D. The GPS receiver has a 1 pps (pulse per second) output which the DPS-4D uses for time synchronization. This GPS 1 pps is essentially an absolute reference derived from the U. S. Naval Observatory Master Clock. However, there is 50 to 100 nanosecond jitter on the 1 pps signal so the operator performing the following testing and tuning generally has to watch and compare the GPS 1

pps to the 1 pps generated by the DPS-4D and calculate the average drift between the two signals on an oscilloscope. It should be possible to adjust the Digisonde's crystal oscillator so that the drift between the two signals is less than 10 ns per second (1 part in  $10^8$ )

There are two DACs (Digital to Analog Converters) on the Transmitter card. The output of the two DACs are summed which provides one extra bit of resolution in setting the voltage which controls the OCVCXO compared to using one DAC.

## 2 Verify DAC command bytes

The first step is to verify the proper command bytes are being forwarded from DCART to DESC to the transmitter DAC. Once these command bytes are verified to be correct, they do not need to be checked again. **If this is a routine yearly oscillator adjustment skip to section 4.**

2.1 From within DCART, check the *On-line Global Parameters* via *Options / Global Parameters / On-line*.

2.2 From within the *On-line Global Parameters* ensure *cmd1 0x*, and *cmd2 0x* are configured to *03*, and *07* respectively. Resulting values should appear as:

```
cmd1 0x03
```

```
cmd2 0x07
```

note: It is normal that the 0x03 and 0x07 numbers are “grayed out”.

If the values appear as shown above then skip to 3 **Verify DAC proper operation**

If the values **do not** appear as shown above then the *D:\Dispatch\DCART.ini* file must be edited to correct this.

2.3 To edit the *DCART.ini* file place DCART in Manual or Diagnostic mode and then close DCART. Next, open *D:\Dispatch\DCART.ini* in a text editor such as wordpad.

2.4 Locate the parameter *CommandByteOCODAC1* and *CommandByteOCODAC2* and ensure they are configured as follows:

```
CommandByteOCODAC1=3
```

```
CommandByteOCODAC2=7
```

2.5 After making necessary changes to the *D:\Dispatch\DCART.ini* file to reflect the above settings, save and close the file. Please note that the above parameters need not be in any particular order as they exist within the *DCART.ini* file. If the parameters do not exist in the file then create them.

2.6 Restart DCART. Click on the DCART icon on the Desktop. Return to step **2.1** and confirm the command bytes are correct.

## 3 Verify DAC proper operation

After confirming the DAC command bytes are correct, the DAC output should be verified to operate as expected. **If this is a routine yearly oscillator adjustment skip to section 4.** By changing the *Oven Control Oscillator DAC* data values via DCART *On-line Global Parameters* one can adjust both outputs of the DAC on the backplane which are used to control the oscillator's oven; thereby adjusting the oscillator frequency. These values are first commanded to the transmitter card, which then delivers the data serially to a DAC on the backplane. Each data output controls one of two outputs of the DAC. The two outputs are added or combined with equal weights and fed to the oscillator to control tuning of its frequency. Both of the DAC voltage outputs vary from approximately 0 to 5 volts (VDC). The DAC data values are specified hexadecimal and vary from 0x00 to 0xFF corresponding to 0 volts output at 0x00 and 5 volts output at 0xFF. Therefore, if one commands a value of FF (0xFF) to one of the DAC outputs one would expect to see a value very near 5 volts at that output of the DAC.

The output voltages of the DACs for **cmd1** and **cmd2** are verified by measuring the voltages at the **R41** and **R42** resistors on the backplane. The value of cmd1 is measured at R42 and cmd2 at R41. R41 and R42 are located just left of the XMTR card. Measure the voltage at the ends of the surface mounted resistors closest to the card cage. If the backplane has a oscillator daughter board with a 10 MHz quartz crystal, measure this voltage at the header connector with the blue wire.

Once the DAC output voltages are verified to be correct, they do not need to be checked again.

**To verify proper operation of the DAC perform the following procedure:**

- 3.1 Extend the transceiver chassis to its stops and remove its cover.
  - 3.1.1 Measuring the DAC output voltages will require you to work closely to the exhaust cooling fans in the front of the transceiver chassis, next to the card cage. Please be wary of the fans when working near them.
  - 3.1.2 Take proper ESD precautions when working in the transceiver chassis. It is suggested that a grounding ESD wrist strap is used. Static discharge can damage the equipment.
- 3.2 Making changes to the DAC output values requires that DCART be in the advanced mode user interface. To change DCART to advanced mode navigate to the DCART *Options* menu and select *General*. Under *General Appearance and Interface*: click *Advanced Mode*.
- 3.3 (Please remember to change back to *Normal Mode* after completing this procedure.)
- 3.4 Record current DAC commanding values before making changes. From within DCART navigate to *On-line Global Parameters* via *Options / Global Parameters / On-line*. Note the values of *data1 0x\_\_* and *data2 0x\_\_* and record them so they can be re-entered at the end of this procedure if necessary.
- 3.5 From within *On-line Global Parameters*, modify the value of *data2* to be 0x00.
  - Type 00 in the box and then click on the *Apply* button at the bottom of the window.
  - 3.5.1 Note that you must click at least once in both the data1 box and the data2 box before the *Apply* button becomes active (black). The values can be changed one at a time, however.

- 3.6 Using a digital multimeter, check the voltage at the R41 by placing one probe (black) against the transceiver chassis (ground), and the other probe (red) on the side of R41 closer to the card cage. The voltage you measure should be very near 0 volts.
- 3.7 Next via DCART, command *data2* to *0xF0*. Type F0 in the box and click *apply*. Check to ensure the voltage of R41 is near 5 volts, about 4.7 volts.
- 3.8 Next via DCART, command *data2* to *0x7F*. Type 7F in the box and click *apply*. Check to ensure the voltage of R41 is approximately 2.4 volts. Leave 7F in the *data2* box.
- 3.9 Perform the same procedure as in steps 4 through 6 for the *data1* output, measuring the value of R42 with the probe on the side of R42 closer to the card cage and the other on transceiver chassis ground.

*Note that some versions of the Transmitter card generate the data1 output a little differently and the voltages for data1 values of 00 or F0 may not be as described above. The only important setting for data1 is the 0x7F value which should put 2.4 volts on R42. Leave 7F in the data1 box*

## 4 Prepare programs and schedules for tuning the 61.44 MHz master oscillator

Tuning the 61.44 Mhz master oscillator of the DPS-4D system involves using an oscilloscope, observing two signals: the GPS 1pps and the R-Pulse trigger, and changing values of DCART *Oven Control Oscillator DAC* values from within *On-line Global Parameters* in an effort to minimize the observed drift between those two signals.

The GPS 1 pps is used as a reference signal against which the R-Pulse trigger output is to be compared. This R-Pulse trigger signal (the BNC connector labeled TRIG on the front upper right of the transceiver chassis) is only present when the system is transmitting. By creating an appropriate program and schedule the DPS-4D system can be used to produce its own 1 pps (pulse per second) signal (or actually one pulse every 2 seconds, 1/2 pps). That signal will be compared with the GPS 1pps during this procedure.

To tune the oscillator, first it is required to build the proper program and schedule to allow the DPS-4D to produce a 1/2 pps signal. This program may already exist from previous oscillator adjustment in which case check the parameters to ensure they agree with this document. Some parameters may have changed in order to be compatible with the latest version of DCART. The name of the program may not be exactly *Osc Tuning* as suggested below.

- 4.1 Click *STOP* in the upper left to put the system in Manual / Diagnostic mode.

4.2 Within the DCART *EDITED PROGSCHED / Programs* tab create the following *Sounding Mode*, program shown in Figure 1, and name it *Osc Tuning*.

4.2.1 It is important to remember that the goal of this program is to simply **produce a single pulse**. It is possible to create many different program definitions all which produce a single pulse. To this end, many settings of this program do not matter; Fixed frequency, start range, number of samples, Rx Gain, etc all do not affect the program length and so can be set arbitrarily. It is useful to keep that fact in mind when creating such a program.

The screenshot shows the configuration for PROGRAM #020 in Sounding Mode. The interface is divided into several sections:

- FREQUENCY STEPPING:** Freq Stepping Law is set to 'fixed', Fixed Frequency is 2000 [kHz], Fixed Freq Repeats is 1, and Number of Fine Steps is 'none'. Total frequencies: 1.
- SYSTEM SETTINGS:** Constant Gain is 'FULL GAIN Tracker(9) and Antenna Switch(0)', Auto Gain Control is 'fixed', Rx Gain is 'FULL GAIN - 30dB', Wave Form is '66.666... μsec short pulse', and Polarizations is 'O only'. Antennas 1-4 are enabled. Radio Silent is unchecked. Standard polarization is selected.
- RANGE SAMPLING:** Start Range is 80 [km], Number of Samples is 512, and Inter-Pulse Period is 2 [5ms] (checked auto). Range coverage: 80 to 1357.5 / max 1499 km.
- DATA PROCESSING:** RFIM, CCEQ, D-Spike, and ChipComp are checked. Data Reduction includes 'Ionogram Calculation' and 'Clear data below MPA' (checked). A 'View Process Chain' button is present.
- PULSE INTEGRATION:** Number of Integrated Repeats is 1, and Interpulse Phase Switching is 'enabled'. Pulses/freq : CIT : total 1 : 1 : 1.
- OUTPUT FILES:** 'Save product data' is checked, and 'Save raw data' is unchecked. DESC-to-DCART volume 1 packets = 8,304 B.

Figure 1: Single pulse program

4.3 Next, a two second schedule should be created that contains the *Osc Tuning* program. Within the DCART *EDITED PROGSCHED / Schedules* tab create the following two second duration schedule shown in Figure 2, and name this schedule *Osc Tuning*. This schedule may already exist from previous oscillator adjustment in which case check that the duration is set to 2 seconds, not 1 second. The name of the program may not be exactly *Osc Tuning*.



Figure 2: 2 second duration schedule

4.4 Navigate to DCART *EDITED PROGSCHED / SST, Rules, Campaigns* tab and make a record of the currently running schedules and their rules. Next, configure the *Osc Tuning* schedule such that it will run as the day schedule as shown in Figure 3.

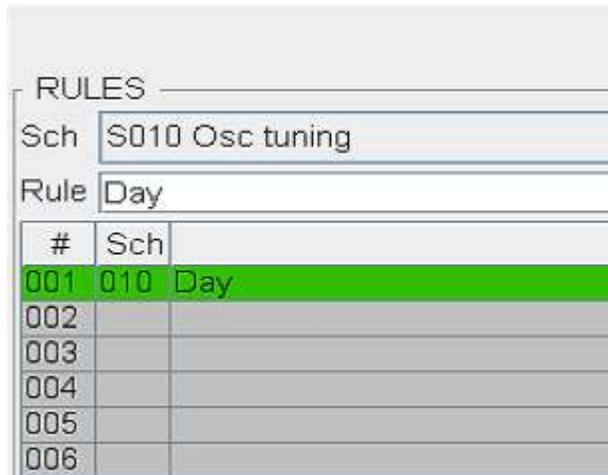


Figure 3: Osc tuning schedule shown to run as day

4.5 Ensure you click on the Upd button to update changes and click Activate changes in the bottom left of the DCART display to transfer the new program and schedule information to DESC. Click the Auto button in upper left of DCART to initiate automatic operations. With the system in Auto mode you should be able to hear an audible click, once every two seconds, emanating from the speaker in the transceiver chassis. Normally, when running a measurement the system will emit a tone as the system is transmitting continuously. Since the system is transmitting only once every two seconds you will only hear noise (a click) once every two seconds.

## 5 Connect the oscilloscope and prepare for tuning

- 5.1 If not done so already, extend the transceiver chassis to its stops and remove the cover. Ensure you take proper ESD precautions when working with an open chassis. It is suggested that a grounding ESD wrist strap be used. There is aging of the quartz crystal oscillator, perhaps both long term and short term. We recommend having the oscillator running under power for a day before making final adjustments. If it is a new backplane (oscillator), letting it run under power for a few days is probably in order.
- 5.2 Ensure your oscilloscope is configured so all channels are set to 1 M $\Omega$  impedance.
- 5.3 Locate where the GPS 1pps signal enters the transceiver chassis in the center rear next to the antenna switch via a BNC bulkhead connector. On the inside of the chassis disconnect the 1pps BNC cable, connect a BNC T connector to the 1pps BNC bulkhead, and reconnect the 1pps cable to the BNC T. Be careful not to drop a cable so that the BNC connector short circuits anything in the chassis. *Note: If the GPS Receiver is the Trimble 360 model (mfg 2017 or later) and the transmitter card is rev. C3 or earlier, there will be a small capacitor (4.7 nf) box in series with the BNC connector on one side or the other of the rear panel. It does not matter which side of this capacitor box you put the T for the oscilloscope.*
- 5.4 Connect a BNC cable from the BNC T to the oscilloscope channel 1 input.
- 5.5 Connect a BNC cable from the TRIG output on the front of the transceiver chassis to the oscilloscope channel 2 input.
- 5.6 Set the oscilloscope trigger source to channel 2 and trigger on the leading edge of the negative going, 2 volt TRIG 1/2 pps signal on channel 2 by adjusting the vertical and horizontal position knobs, and the horizontal scale as necessary. Put the GPS 1pps signal in the center of the oscilloscope display. The leading edge of the negative going 1 pps from the GPS should show up about 7  $\mu$ secs after the leading edge of the negative going 1/2 pps from the TRIG connector on the front panel when synchronization occurs every 17 seconds or sometimes a multiple of 17 seconds, 34, 51 seconds.
- 5.7 It is recommended to start with a horizontal scale of approximately 4  $\mu$ secs per division, and decrease the scale from there as you minimize oscillator drift. With a typical digital oscilloscope it will be possible to “move” the triggering point of the TRIG signal well off to the left of the display and have a horizontal scale of 1  $\mu$ sec per division, then 400 ns per division.
- 5.8 Navigate to DCART [Options / Global Parameters / On-line](#). If this is a routine yearly adjustment, leave data1 set to wherever it is, presumably 0x7F (7F). If this is a new backplane or new hard disk, it would be appropriate to set data1 to 0x7F (7F). If the backplane is new and there is an oscillator daughterboard on it, there should be a sticker on the 10 MHz quarts crystal can with recommended starting values for data1 and data2. Make changes to the data2 values in [Oven Control Oscillator DAC](#) to minimize the observed GPS 1 pps drift on the oscilloscope. If this is a new backplane or new hard disk, it would be appropriate to set data2 to 0x7F (7F) as a starting point. If in the following procedure data 2 gets close to its limits (0x00 or 0xFF) feel free to make a change to data1. Data1 and data2 are summed and have equal weights.
- 5.9 The negative going leading edge of the GPS 1 pps should resynchronize to the TRIG 1/2 pps every 17 seconds so every 17 seconds the leading edge of the GPS signal should jump back to the point

about 7  $\mu$ secs after the TRIG 1/2 pps negative going leading regardless of where it drifted to during the 17 seconds.

- 5.10 Once you have entered a new value in the data2 field, press **Enter** to make “*Apply*” active at the bottom of the window.
- 5.11 Note that **increasing** data2 (or data1) will make the GPS 1 pps drift to the **right** on the screen if you are triggering the oscilloscope with the TRIG 1/2 pps. **Decreasing** data2 will make the GPS 1 pps drift to the **left** on the screen. A change to data2 (or data1) of one unit (one bit, or LSB and do remember that these are hexadecimal values, 0 1 2 3 4 5 6 7 8 9 A B C D E F) is equivalent to approximately a change in the drift between the GPS and R pulses of 7 ns (nanoseconds) /second or 0.1  $\mu$ s per 17 seconds.
- 5.12 The following steps are generally not necessary but once you have the drift down to less than 200 ns / 17 seconds, it might be helpful to watch the drift for a longer period of time, perhaps as long as 4 or 5 minutes in order to get down to the least significant bit of data2. To stop the automatic resynchronizing every 17 seconds, disconnect the 1 pps BNC cable from the BNC Tee which you have temporarily installed in the chassis.
  - 5.12.1 Be careful not to drop the cable so that the BNC connector short circuits anything in the chassis.
- 5.13 After making a change to data2 the GPS pulse will jump well off the screen of the oscilloscope. It will be necessary to reconnect the 1 pps GPS cable back to the BNC Tee for as long as 17 seconds or until resynchronization occurs and the GPS 1 pps signal is back to 7  $\mu$ s after the TRIG 1/2 pps. Then disconnect the cable again and watch the drift for 4 or 5 minutes.
- 5.14 Adjust data2 to achieve minimum drift in either direction. You should be able to get down to the LSB of data2 so that the drift of the GPS 1 pps is very slow in one direction and a change in data 2 of one unit makes the drift very slow in the other direction. This minimum drift should be on the order of 3 or 4 ns (nanoseconds) / second or 1  $\mu$ s in 4 minutes (240 seconds).
- 5.15 It is possible that to achieve the minimum drift data2 would exceed the maximum possible limits for its adjustment, i.e., 00 (0x00) or FF (0xFF). If that is the case it will be necessary to adjust data1 in the same direction you are trying to go with data2. It is suggested to enter 10 (0x10) or F0 (0xF0) for data1 and go back to adjusting data2. Data1 and data2 have equal weights. A change of one LSB in data1 will have the same effect as a change of one LSB in data2.
- 5.16 If it was observed earlier in this procedure that entering 00 or F0 for data1 did not result in the expected 0 volts or 4.7 volts at R42, then it will be necessary to measure the voltage at R42 and to try different values of data1 to adjust that voltage in the direction towards 0 or towards 5 volts as appropriate to allow you to get minimum drift with a value of data2 comfortably between 10 (0x10) and F0 (0xFF).

When done with this tuning procedure change back to “normal” operation. To change DCART back to normal mode, navigate to the DCART *Options* menu and select *General*. Under *General Appearance and Interface*: click *Normal Mode*. Please remember to change back to *Normal Mode* after completing this procedure

## **6 Changing the backplane with the master oscillator (OCVCXO)**

If after the tuning procedure you are still observing oscillator drift that is greater than 30 or 40  $\mu$ s per second, then most likely the 61.44 MHz master oscillator (OCVCXO) is not functioning correctly and the entire system backplane should be removed and replaced with a good one.

Ensure the system is off when removing or replacing the backplane. Take proper ESD precautions when working in the transceiver chassis. It is suggested that a grounding ESD wrist strap is used.

Static discharge can damage the equipment. Removing the backplane first requires you to remove two screws that hold the Data computer hard drive and DVD drive bracket fixed to the transceiver chassis. Once those two screws are removed, slide the hard drive / DVD drive assembly to the right towards the power distribution card. Remove all of the cards from the backplane and place the cards in static bags for safe keeping. Next, remove the 8 screws that mount the backplane to the transceiver card cage, and all cabling to the backplane. Then remove the backplane from the system, tilting it slightly to clear the fans and the disk drives..

Reinstall the backplane carefully reconnecting all the cables as they were. Then repeat the above tuning procedure.