FireFly-II Quick Start Instructions – rev. 1.4

The following is a short description on how to use the FireFly-II GPSDO. A full manual will be provided later.

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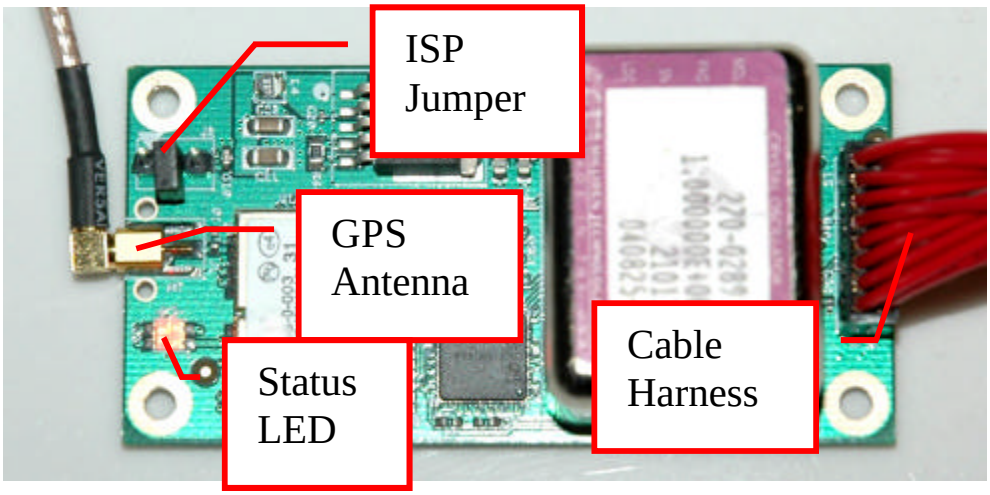
Introduction

The FireFly-II GPSDO includes an extremely high-performance GPS receiver that can acquire and track up to 50 GPS signals down to a state of the art –160dBm, a 32bit processor that runs a Real Time OS, a low-noise CMOS and LVDS 10MHz output, 1PPS UTC synchronized output, RS-232 control interface, and precision voltage references and DACs.

Major connections

The major connections and features of the FireFly-II PCB are shown below:



The following table shows the FireFly-II revision 1.0 hardware connectors:

Ref	Name	Function	Specification	Pinning
J1	Antenna	GPS Antenna	3V Amplified Antenna MMCX connector	Center-RF Input, Shield-GND
J2	ISP/RESET	Reset and ISP	Pull pins 1 and 3 to GND to activate function	3-RESET-IN#, 2-GND, 1-ENTER_ISP#
U18A	10MHz LVDS	10MHz Output A	LVDS, +/-300mV differential	U18.1-10MHz_Pos, U18.2-10MHz_Neg
U18B	10MHz CMOS	10MHz Output B	5Vpp CMOS, open ended or 50 Ohm terminated	U18.13-10MHz, U18.14-GND
U18C	1PPS LVDS	1PPS Output A	LVDS, +/-300mV differential	U18.5-1PPS_Pos, U18.4-1PPS_Neg
U18D	1PPS RS-232	1PPS Output B	RS-232 level	U18.10-1PPS-RS232, U18.12-GND
U18E	1PPS IN	External 1PPS input (optional)	3.3V CMOS, risetime <10ns	U18.11-1PPS-In, U18.12-GND
U18F	Green LED (GPS 1PPS)	Follows status of Green LED	3.3V CMOS	U18.7-LED+, U18.6-GND
U18G	RS-232 SCPI	RS-232 Serial Port	RS-232, 115.2,8N1	U18.9-TX, U18.8-RX, U18.6-GND
U18H	+12V Power	Main Power Input	+11.0V - +14.0V	U18.16-+12V, U18.15-+12V, U18.14-GND, U18.12-GND

Harness Pinning

The following is a table of the cable harness U18 pinout:

PIN	NAME
1	+10MHz LVDS
2	–10MHz LVDS
3	GND
4	–1PPS LVDS
5	+1PPS LVDS
6	GND
7	Green LED Signal
8	RX RS-232
9	TX RS-232
10	1PPS Out RS-232 Level
11	1PPS In CMOS level
12	GND
13	10MHz CMOS Out
14	GND
15	+12V
16	+12V

Harness Connector

The manufacturer for connector U18 is Hirose. A mating housing part number for this connector is available from Digikey, and crimp pins are also available from Digikey for different wire sizes:

http://search.digikey.com/scripts/DkSearch/dksus.dll?Detail&name=H2025-ND

The part number of the connector soldered onto the FireFly-II PCB is:

Hirose DF11-16DP-2DSA01

NOTES:

* The 10MHz CMOS output has a fast rise/fall time of <2ns. Due to this it is essential to keep the 10MHz CMOS wire (pin 13) and it's Ground signal (pin 12 and pin 14) as short as possible, and in close proximity. Typically a thin coax cable using RG-174 cable or similar will be used to connect the 10MHz CMOS output. For best performance and to minimize EMI, the CMOS wire on pin13 should not be longer than ½ inch before it is terminated by a coax cable, or PCB with ground plane.

* The LVDS signals (+/-10MHz, +/-1PPS) should be routed using 100Ohm differential wiring (twisted pair), or two 50Ohm single-ended coaxial cables with the shields being

connected to ground. Terminate these signals with 100Ohm resistors between the positive and the negative wires.

Power

The unit is powered from a +11 .0V to +14.0V DC source, with +12.0V nominal voltage. The current is typically less than 0.28A at 12V. Connect a clean +12V power supply to pins 15 and 16 of the cable harness U18.

Do not reverse the polarity of the power pins, this will damage the unit.

The connector style is a Molex Part Number 22-23-2031 connector.

Connecting the GPS Antenna

Connect the GPS antenna to the BNC to MMCX cable adapter. Caution: use a Lightning Arrestor on your Antenna setup. Use an amplified GPS antenna that is 3V LNA compatible. The FireFly-II GPS receiver is a 50 channel high-sensitivity GPS receiver with very fast lock time. It does not require any self-survey or position-hold mode (auto survey), and thus can be used in mobile platforms.

FireFly-II is capable of generating standard navigation messages (see GPS:GPGGA and GPS:GPRMC RS-232 commands) that are compatible with most GPS based navigation software.

The GPS receiver generates a 1PPS time signal that is phase synchronized to UTC. This 1PPS signal is used to frequency-lock the 10MHz Sine-Wave output of the FireFly-II GPSDO to UTC, thus disciplining the units' 10MHz frequency output to the US Naval master clock for very high frequency accuracy (typically better than 10 digits of frequency accuracy when locked to GPS).

Remote serial control

- The unit is controlled via the Serial port at 115200 baud, 8N1. Other Baud Rates can be set via SCPI commands.
- Connect the RX, TX, and GND pins of the cable harness U18 to a standard RS-232 connector, attaching the FireFly-II unit to your PC's Hyperterminal, or the optional GPSCon software package. An RS-232 level shifter is built into the FireFly-II PCB.

"Help" and command overview

- A listing of the available RS-232 commands can be shown by typing "help?".

- "*IDN?" can be used to see if the connection works. Both commands need to be followed by pressing "Enter".

Loop parameter adjustment

- All loop parameters can be controlled via the RS-232 serial port.
- Loop parameters are optimized for the OCXO on the board, and changing the factory settings may result in the units' performance to deteriorate.

The commands to control the loop parameters are part of the servo? command. See also the **SERVO Subsystem** section below.

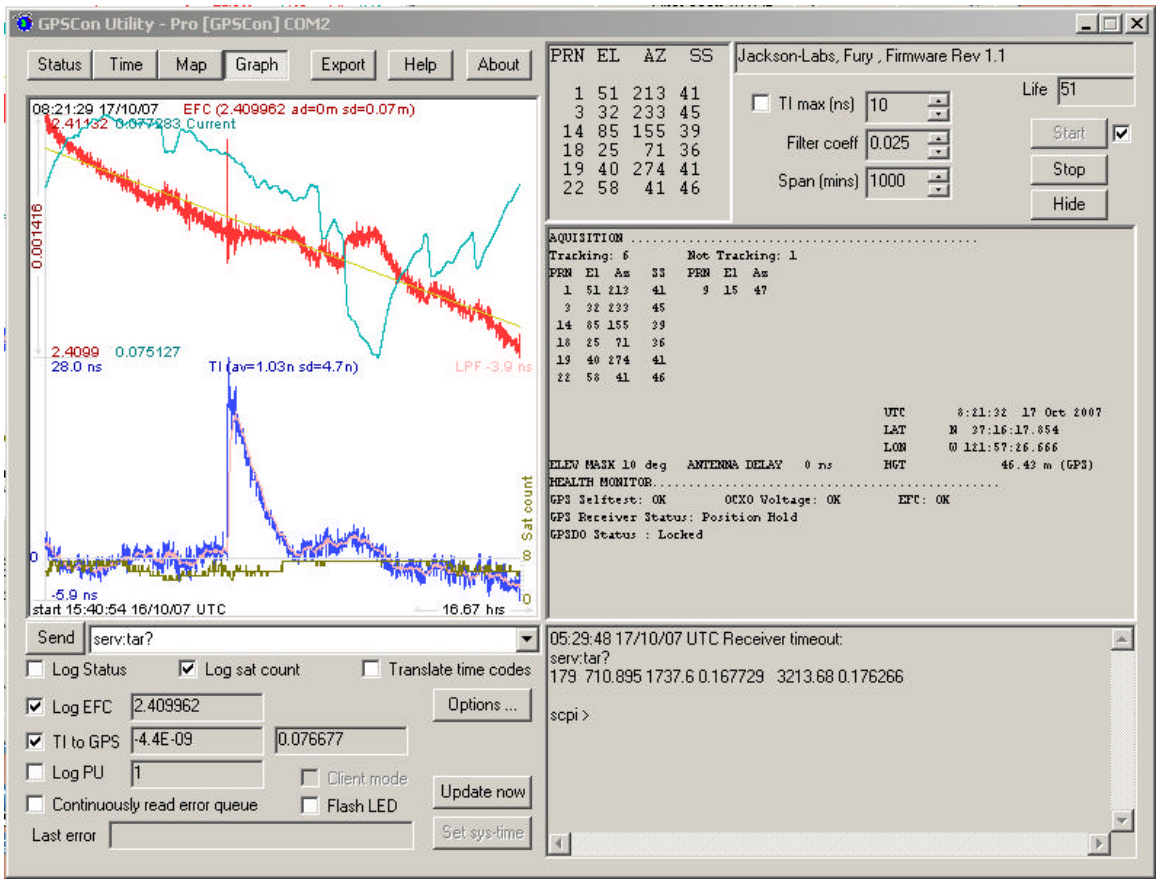
The individual commands are:

EFC Scale: this is the proportional gain of the PID loop. Higher values will give quicker convergence, and faster locking of the GPS time (lower loop time constant), lower values give less noise. Values between 0.7 (good double oven OCXO) and 6.0 (simple single-oven OCXO) are typical.

EFC Damping: overall IIR filter time constant. higher values increase loop time constant. Jackson Labs typically uses values between 10 to 50. Setting this value too high may cause loop instability.

Phase compensation: this is the Integral part of the PID loop. This corrects phase offsets between the FireFly-II 1PPS signal and the UTC 1PPS signal as generated by the GPS receiver. Set higher values for tighter phase-following at the expense of frequency stability. Typical values range from 4 - 30, 25 being the default. Setting this value too high may cause loop instability.

A well-compensated unit will show performance similar to the following plot when experiencing small perturbations:



SCPI-Control Quick Start Instructions

The SCPI subsystem is accessed via the RS-232 interface and a terminal program. By default the terminal settings are 115200, 8N1.

There are a number of commands that can be used as listed below. Most of these are identical or similar to Symmetricom 58503A commands.

GPS Subsystem

Please note that FireFly-II displays antenna height in MSL Meters rather than in GPS Meters on all commands that return antenna height [the legacy Fury GPSDO uses GPS height].

N.B.: firmware version 0.909 and later add a 3D velocity output command: GPS:XYZSPeed.

The GPS subsystem regroups all the commands related to the control and status of the GPS receiver. The list of the commands supported is the following :

GPS:SATellite:TRAcking:COUNt?

GPS:SATellite:VISible:COUNt?

GPS:GPGGA <int> [0,255]

GPS:GGASTat <int> [0,255]

GPS:GPRMC <int> [0,255]

GPS?

GPS:SATellite

This group of commands describe the satellite constellation.

GPS:SATellite:TRAcking:COUNt?

This query returns the number of satellites being tracked.

GPS:SATellite:VISible:COUNt?

This query returns the number of satellites (PRN) that the almanac predicts should be visible, given date, time, and position.

NMEA Support

The following two commands allow the FireFly-II GPSDO to be used as an industry standard navigation GPS receiver. The GPGGA and GPRMC NMEA commands comprise all necessary information about the antenna position, height, velocity, direction, satellite info, fix info, time, date and other information that can be used by standard navigation applications via the FireFly-II RS-232 interface.

Once enabled, FireFly-II will send out information on the RS-232 transmit pin automatically every N seconds. All incomming RS-232 commands are still recognized by FireFly-II since the RS-232 interface transmit and receive lines are completely independent of one another.

Please note that the position, direction, and speed data is delayed by one second from when the GPS receiver internally reported these to the FireFly-II Microprocessor, so the position is valid for the 1PPS pulse previous to the last 1PPS pulse at the time the data is sent (one second delay). The time and date are properly output with correct UTC synchronization to the 1PPS pulse immediately prior to the data being sent.

Once set, the following two commands will be stored in NV memory, and generate output information even after power to the unit has been cycled.

GPS:GPGGA

This command instructs the FireFly-II to send the NMEA standard string $GPGGA every N seconds, with N in the interval [0,255]. The command is disabled during the initial 7 minute OCXO warmup phase.
This command has the following format:

GPS:GPGGA <int> [0,255]

GPGGA shows height in MSL Meters, this is different from traditional GPS receivers that display height in GPS Meters. The difference between MSL and GPS height can be significant, 35m or more are common.

GPS:GGASTat

This command instructs the FireFly-II to send a modified version of the NMEA standard string $GPGGA every N seconds, with N in the interval [0,255]. The command is disabled during the initial 7 minute OCXO warmup phase.
This command has the following format:

GPS:GGASTat <int> [0,255]

This command replaces the regular NMEA GGA validity flag with a decimal number indicating the lock-state of the unit. Please see section **SERVo:TRACe** for a detailed description of the lock state variable. The command allows capture of the position and other information available in the GGA command, as well as tracking the lock state and health of the units' OCXO performance.

GGASTat shows height in MSL Meters, this is different from traditional GPS receivers that display height in GPS Meters. The difference between MSL and GPS height can be significant, 35m or more are common.

GPS:GPRMC

This command instructs the FireFly-II to send the NMEA standard string $GPRMC every N seconds, with N in the interval [0,255]. The command is disabled during the initial 7 minute OCXO warmup phase.
This command has the following format:

GPS:GPRMC <int> [0,255]

GPS:XYZSPeed

Firmware version 0.909 and later add a 3D velocity vector output command. Enabling this command will output a 3 dimensional velocity vector indicating the units' speed in centimeters per second.

X, Y, and Z speed are individually given, and are independent of each other. An accuracy estimate in centimeters per second is also given. The velocity data is time-stamped using the time-of-week with a resolution of milliseconds. Use the following format to generate the velocity vector every N seconds, with N in the interval [0,255]:

GPS:XYZSPeed <int> [0,255]

GPS?

This query displays the configuration, position, speed, height and other relevant data of the GPS receiver in one convenient location.

PTIME Subsystem

The PTIME subsystem regroups all the commands related to the management of the time.The list of the commands supported is the following :

PTIMe:TZONe?

PTIMe:DATE?

PTIMe:TIME?

PTIMe:TIME:STRing?

PTIMe:TINTerval?

PTIME?

PTIMe:TZONe?

Returns the local time zone offset.

PTIMe:DATE?

This query returns the current calendar date. The local calendar date is referenced to UTC time. The year, month, and day are returned.

PTIMe:TIME?

This query returns the current 24-hour time. The local time is referenced to UTC time. The hour, minute, and second is returned.

PTIMe:TIME:STRing?

This query returns the current 24-hour time suitable for display (for example, 13:24:56).

PTIMe:TINTerval?

This query is equivalent to the command SYNChronisation:TINTerval

PTIME?

This query returns at once the result of the four following queries:

PTIME:DATE?

PTIME:TIME?

PTIME:TZONE?

PTIME:TINTerval?

SYNChronization Subsystem

This subsystem regroups the commands related to the synchronization of the FireFly-II with the GPS receiver. The list of the commands supported for this subsystem is the following:

SYNChronization:SOURce:MODE [GPS|EXTernal|AUTO]

SYNChronization:SOURce:STATE?

SYNChronization:HOLDover:DURation?

SYNChronization:TINTerval?

SYNChronization:IMMEdiate

SYNChronization:FEEstimate?

SYNChronization:LOCKed?

SYNChronization?

SYNChronization:HOLDover:DURation?

This query returns the duration of the present or most recent period of operation in the holdover and holdover processes. This is the length of time the reference oscillator was not locked to GPS. The time units are seconds. The first number in the response is the holdover duration. The duration units are seconds, and the resolution is 1 second. If the Receiver is in holdover, the response quantifies the current holdover duration. If the Receiver is not in holdover, the response quantifies the previous holdover. The second number in the response identifies the holdover state. A value of 0 indicates the Receiver is not in holdover; a value of 1 indicates the Receiver is in holdover.

SYNChronization:SOURce:MODE

The Source:Mode command allows an optional external 3.3V level 1PPS input to be connected to the FireFly-II board on connector harness U18. The unit can use this external 1PPS input instead of the internal, GPS generated 1PPS. Switching to the external 1PPS is either done manually with the EXT command option, or automatically with the AUTO command option in case the GPS receiver goes into holdover mode for any reason. The command has the following format:

SYNChronization:SOURce:MODE [GPS|EXTernal|AUTO]

SYNChronization:SOURce:STATE?

This query shows the state of the external 1PPS synchronization option.

SYNChronization:TINTerval?

This query returns the difference or timing shift between the FireFly-II 1 PPS and the GPS 1 PPS signals. The resolution is 1E-10 seconds.

SYNChronization:IMMEdiate

This command initiates a near-instantaneous alignment of the GPS 1 PPS and Receiver output 1 PPS. To be effective, this command has to be issued while not in holdover.

SYNChronization:FEEstimate?

This query returns the Frequency Error Estimate, similar to the Allan Variance using a 1000s measurement interval and comparing the internal 1PPS to GPS 1PPS offset.

Values less than 1E-012 are below the noise floor, and are not significant.

SYNChronization:LOCKed?

This query returns the lock state (0=OFF, 1=ON) of the PLL controlling the OCXO.

SYNChronization?

This query returns the results of these four queries :

SYNChronization:SOURce:MODE?

SYNChronization:SOURce:STATE?

SYNChronization:LOCKed?

SYNChronization:HOLDover:DURation?

SYNChronization:FEEstimate?

SYNChronization:TINTerval?

SYNChronization? Health Status Indicator (firmware 0.913 and later)

The last line in the sync? query is a hexadecimal number indicating the systems health-status. Error flags are encoded in a binary fashion so that each flag occupies one single bit of the binary equivalent of the hexadecimal health-status flag.

The following system parameters are monitored and indicated through the health-status indicator. Individual parameters are ‘ored’ together which results in a single hexadecimal value encoding the following system status information:

If the OCXO coarse-DAC is maxed-out at 255	HEALTH STATUS |= 0x1;
If the OCXO coarse-DAC is mined-out at 0	HEALTH STATUS |= 0x2;
If the phase offset to UTC is >250ns	HEALTH STATUS |= 0x4;
If the run-time is < 300 seconds	HEALTH STATUS |= 0x8;
If the GPS is in holdover > 60s	HEALTH STATUS |= 0x10;
If the Frequency Estimate is out of bounds	HEALTH STATUS |= 0x20;
If the OCXO voltage is too high	HEALTH STATUS |= 0x40;
If the OCXO voltage is too low	HEALTH STATUS |= 0x80;
If the short-term-drift (ADEV @ 100s) > 100ns	HEALTH STATUS |= 0x100;
For the first 7 minutes after a phase-reset, or a coarsedac change:	HEALTH STATUS |= 0x200;

As an example, if the unit is in GPS holdover, and the OCXO voltage is too high, and the UTC phase offset is > 250ns then the following errors would be indicated:

1) UTC phase > 250ns: 0x4
2) OCXO voltage too high: 0x40
3) GPS in holdover: 0x10

'Oring' these values together results in:

0x40 | 0x10 | 0x4 = 0x54

The unit would thus indicate: **HEALTH STATUS: 0x54**

A health status of 0x0 indicates a properly locked, and warmed-up unit that is completely healthy.

DIAGnostic Subsystem

This subsystem regroups the queries related to the diagnostic of the OCXO.The list of the commands supported for this subsystem is as follows:

DIAGnostic:ROSCillator:EFControl:RELative?

DIAGnostic:ROSCillator:EFControl:ABSolute?

DIAGnostic:ROSCillator:EFControl:RELative?

This query returns the Electronic Frequency Control (EFC) output value of the internal reference oscillator. It returns a percentage value between -100% to +100%. :

DIAGnostic:ROSCillator:EFControl:ABSolute?

This query returns the Electronic Frequency Control (EFC) output value of the internal reference oscillator. It returns a value in volts between 0 and 5 V

MEASURE Subsystem

This subsystem regroups the queries related of some parameters that are measured on-board on the FireFly-II. The list of the commands supported for this subsystem is the following:

MEASure:VOLTage?

MEASure:CURRent?

MEASure?

MEASure:VOLTage?

This query returns the power supply voltage applied to the OCXO (ca. 10.45 V)

MEASure:CURRent?

This query returns the current drawn by the OCXO. This current varies in order to keep a stable temperature inside the OCXO.

MEASure?

This query returns the result of the three following queries:

MEASure:VOLTage?

MEASure:CURRent?

SYSTEM Subsystem

This subsystem regroups the commands related to the general configuration of the FireFly-II. The list of the commands supported for this subsystem follows:

SYSTem:COMMunicate:SERial:ECHO <ON | OFF>

SYSTem:COMMunicate:SERial:PROmpt <ON | OFF>

SYSTem:COMMunicate:SERial:BAUD <9600 | 19200 | 38400 | 57600 | 115200>

SYSTem:STATus?

SYSTem:FACToryReset ONCE

SYSTem:COMMunicate

SYSTem:COMMunicate:SERial:ECHO

This command enables/disables echo on RS-232. This command has the following format:

SYSTem:COMMunicate:SERial:ECHO <ON | OFF>

SYSTem:COMMunicate:SERial:PROmpt

This command enables/disables the prompt “scpi>” on the SCPI command lines. The prompt must be enabled when used with the software GPSCon. This command has the following format:

SYSTem:COMMunicate: SERial:PROmpt <ON | OFF>

SYSTem:COMMunicate:SERial:BAUD

This command sets the RS-232 serial speed. The serial configuration is always 8 bit, 1 stop bit, no parity, no HW flow control. Upon Factory reset, the speed is set at 115200 bauds. This command has the following format:

SYSTem:COMMunicate:SERial:BAUD <9600 | 19200 | 38400 | 57600 | 115200>

SYSTem:STATus?

This query returns a full page of GPS status in ASCII format. The output is compatible with GPSCon.

SYSTem:FACToryReset ONCE

This command applies the Factory Reset setting to the EEPROM. All aging, tempco, and user parameters are overwritten with factory default values.

SERVO Subsystem

This subsystem regroups all the commands related to the adjustment of the servo loop:

SERVo:COARSeDac <int> [0,225]
SERVo:DACGain <int> [0.1,10000]
SERVo: EFCScale <float>[0.0 , 500.0]
SERVo:EFCDamping <float>[0.0 , 4000.0]
SERVo:SLOPe <NEG | POS >
SERVo:TEMPCOmpensation <float> [-4000.0, 4000.0]
SERVo:AGINGcompensation <float> [-10.0, 10.0]
SERVo:PHASECOrrection <float> [-100.0, 100.0]
SERVo:1PPSoffset <int> ns
SERVo:QUIet <ON | OFF>
SERVo:TRACe <int > [0,255]
SERVo?

SERVo:COARSeDac

This command sets the coarse Dac that controls the EFC. The FireFly-II control loop automatically adjusts this setting. The user should not have to change this value.

This command has the following format:

SERVo:COARSeDac <int> [0,225]

SERVo:DACGain

This command is used for factory setup.

SERVo: EFCScale

Controls the Proportional part of the PID loop. Typical values are 0.7 (double oven OCXO) to 6.0 (simple single oven OCXO). Larger values increase the loop control at the expense of increased noise while locked. Setting this value too high can cause loop instabilities.

This command has the following format:

SERVo: EFCScale <float>[0.0 , 500.0]

SERVo:EFCDamping

Set's the Low Pass filter effectiveness of the DAC. Values from 2.0 to 50 are typically used. Larger values result in less noise at the expense of phase delay.This command has the following format:

SERVo:EFCDamping <float>[0.0 , 4000.0]

SERVo:SLOPe

The parameter determines the sign of the slope between the EFC and the frequency variation of the OCXO. This parameter should be set to match your OCXO's EFC frequency slope. This command has the following format:

SERVo:SLOPe <NEG | POS >

SERVo:TEMPCOmpensation

This parameter is a coefficient that reflects the correlation between the Current provided to the OCXO and the EFC. This coefficient is automatically computed and adjusted over time by the Jackson-Labs firmware. This command has the following format:

SERVo:TEMPCOmpensation <float> [-4000.0, 4000.0]

SERVo:AGINGcompensation

This parameter is a coefficient that represents the drift of the EFC needed to compensate the natural drift in frequency of the OCXO due to aging. This coefficient is automatically computed and adjusted over time by the Jackson-Labs firmware. This command has the following format:

SERVo:AGINGcompensation <float> [-10.0, 10.0]

SERVo:PHASECOrrection

This parameter sets the Integral part of the PID loop. Loop instability will result if the parameter is set too high. Typical values are 10.0 to 30.0. This command has the following format:

SERVo:PHASECOrrection <float> [-100.0, 100.0]

SERVo:1PPSoffset

This command sets the FireFly-II 1PPS signal's offset to UTC in 16.7ns steps.

Using the SERV:1PPS command results in immediate phase change of the 1PPS output signal.

This command has the following format:

SERVo:1PPSoffset <int> ns

SERVo:TRACe

This command sets the period in seconds for the debug trace. Debug trace data can be used with Ulrich Bangerts' "Plotter" utility to show UTC tracking versus time etc.

This command has the following format:

SERVo:TRACe <int > [0,255]

An example output is described here:

08-07-31 373815 60685 -32.08 -2.22E-11 14 10 6 0x54

[date][1PPS Count][Fine DAC][UTC offset ns][Frequency Error Estimate][Sats Visible][Sats Tracked][Lock State][Health Status]

Please see the **SYNChronization?** command for detailed information on how to decode the health status indicator values.

N.B.: health status information is available with firmware versions 0.913 and later.

The Lock State variable indicates one of the following states:

Value	State
0	OCXO warmup
1	Holdover
2	Locking (OCXO training)
4	[Value not defined]
5	Holdover, but still phase locked (stays in this state for about 100s after GPS lock is lost)
6	Locked, and GPS active

SERVo?

This command returns the result of the following queries:

SERVo:COARSeDac?

SERVo:DACGain?

SERVo: EFCScale?

SERVo:EFCDamping?

SERVo:SLOPe?

SERVo:TEMPCOmpensation?

SERVo:AGINGcompensation?

SERVo:PHASECOrrection?

SERVo:1PPSoffset?

SERVo:TRACe?