FireFox Synthesizer
User Manual

FireFox Synthesizer User Manual

Copyright © 2008 Jackson-Labs

Table of Contents

1 Introduction

1.1 Overview

The FireFox synthesizer is a continuous wave (CW), a digital, and a sweeping broadband signal generator with an ultra high-accuracy built-in frequency reference. The unit can generate CW or sweep signals ranging from 0.00001Hz to 1640MHz in 0.00001Hz steps.

It derives its frequency accuracy from an internal GPS receiver that feeds Cesium-quality (long term stability) reference signals to the Synthesizer unit. The unit does not require maintenance as Cesium oscillators do (Cesium references need expensive physics package replacements every 5 years or less), and provides better long-term time-base accuracy than non GPS-disciplined Cesium references.

This manual describes the FireFox GPS disciplined broadband synthesizer module and Desktop unit.

The FireFox GPS Disciplined broadband signal generator is available as a benchtop unit or OEM-module. Both units use a built-in, highly stable GPS-disciplined Oven Controlled Crystal Oscillator (GPSDO). The FireFox Synthesizer for the first time combines sine-wave and digital outputs, and a highly stable frequency reference in one instrument. This combination can generate digital CMOS and LVDS/PECL square waves, and analog RF sine-wave outputs from DC to 1.64GHz with better than 1E-012 long term frequency accuracy.

1.2 Certification

Jackson Labs certifies that this product met its published specifications at time of shipment.

1.2.1 Warranty

This Jackson Labs hardware product is warranted against defects in material and workmanship for a period of 1 (one) year from date of delivery. During the warranty period Jackson Labs will, at its discretion, either repair or replace products that prove to be defective. Jackson Labs does not warrant that the operation for the software, firmware, or hardware shall be uninterrupted or error free even if the product is operated within its specifications.

For warranty service, this product must be returned to Jackson Labs or a service facility designated by Jackson Labs. Customer shall prepay shipping charges (and shall pay all duties and taxes) for products returned to Jackson Labs for warranty service. Except for products returned to Customer from another country, Jackson Labs shall pay for return of products to Customer. If Jackson Labs is unable, within a reasonable time, to repair or replace any product to condition as warranted, the Customer shall be entitled to a refund of the purchase price upon return of the product to Jackson Labs.

1.2.2 Limitation of Warranty

The foregoing warranty shall not apply to defects resulting from improper or inadequate maintenance by the Customer, Customer-supplied software or interfacing, unauthorized modification or misuse, opening of the instruments enclosure or removal of the instruments panels, operation outside of the environmental or electrical specifications for the product, or improper site preparation and maintenance. **JACKSON LABS SPECIFICALLY DISCLAIMS THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. No license, express or implied, by estoppel or otherwise, to any intellectual property rights is granted by this document. Jackson Labs products are not intended for use in medical, life saving, or life sustaining applications.**

1.2.3 Exclusive Remedies

THE REMEDIES PROVIDED HEREIN ARE THE CUSTOMER'S SOLE AND EXCLUSIVE REMEDIES. JACKSON LABS SHALL NOT BE LIABLE FOR ANY DIRECT, INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES, WHETHER BASED ON CONTRACT, TORT, OR ANY OTHER LEGAL THEORY.

1.2.4 Safety Summary

The following general safety precautions must be observed during all phases of operation of this instrument. Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards of design manufacture, and intended use of the instrument. Jackson Labs assumes no liability for the customer's failure to comply with these requirements.

1.3 General

1.3.1 Environmental Conditions

This instrument is intended for indoor use. It is designed to operate at a maximum relative non-condensing humidity of 95% and at altitudes of up to 4000 meters. Refer to the specifications tables for the ac mains voltage requirements and ambient operating temperature range.

1.3.2 Line Power and Grounding

The FireFox Desktop unit operates on a 100V to 220V, 43Hz to 65Hz AC power input with typically less than 20W power consumption. The FireFox OEM unit operates on a 12.0V regulated DC input with typically less than 1A input current. Both units are designed to be continuously powered to keep the GPS receiver and OCXO warmed-up and locked.

The FireFox desktop unit requires a three-pronged AC power plug with proper grounding to prevent electrocution hazards. All BNC and SMA connector shields are grounded, and should not be connected to any voltage sources. To minimize shock hazard, the instrument chassis and cabinet must be connected to an electrical ground. The instrument must be connected to the ac power supply mains through a three-conductor power cable, with the third wire firmly connected to an electrical ground (safety ground) at the power outlet. Any interruption of the protective (grounding) conductor or disconnection of the protective earth terminal will cause a potential shock hazard that could result in personal injury. If the instrument is to be energized via an external autotransformer for voltage reduction, be certain that the autotransformer common terminal is connected to the neutral (earthed pole) of the ac power lines (supply mains).

1.3.3 Line Fuse

Fuses are internal to the instrument and are not user-serviceable. All repairs should be referred to a qualified service technician. The FireFox OEM module uses a self-resettable Polyfuse that will correct itself once the fault or overload condition is removed.

1.3.4 Do not operate the Instrument in an Explosive Atmosphere

Do not operate the instrument in the presence of flammable gases or fumes. The instrument contains mechanical switches and relays that could cause sparks and thus ignition of flammable gases or fumes.

1.3.5 Keep away from Live Circuits

Operating personnel must not remove instrument covers. Component replacement and internal adjustments must be made by qualified service personnel. Do not replace components with power cable connected. Under certain conditions, dangerous voltages may exist even with the power cable

removed. To avoid injuries, always disconnect power, discharge circuits and remove external voltage sources before touching components.

1.3.6 Do not Service or Adjust alone

Do not attempt internal service or adjustment unless another person, capable of rendering first aid and resuscitation, is present.

1.3.7 Do not exceed Ratings

This instrument is equipped with a line filter to reduce electromagnetic interference and must be connected to a properly grounded receptacle to minimize electric shock hazard. Operation at line voltages or frequencies in excess of those stated on the data plate may cause unsafe leakage currents.

1.3.8 Do not substitute parts or modify the Instrument

Do not install substitute parts or perform any unauthorized modifications to the instrument. Return the instrument to Jackson Labs for service and repair to ensure that safety features are maintained. Instruments that appear damaged or defective should be made inoperative and secured against unintended operation until they can be repaired by qualified service personnel.

1.3.9 Operational Warning

Do not operate the FireFox desktop unit without its covers in place. Life line voltages are present inside the case, and could cause bodily harm or death when the unit is operated without its covers in place.

1.4 Quick Start Instructions

The following paragraphs describe the basic operational procedures to use the FireFox unit. The user interface for the FireFox OEM board and the FireFox Desktop unit are essentially identical.

Figure 1.1   FireFox Desktop Unit Front Panel

1.4.1 Connecting the instrument

Connect the AC power cord to the rear panel power connector. The unit will operate from 100V to 240V AC. See Figure 1.6 for the FireFox rear-panel connectors. Connect the factory-supplied GPS antenna to the GPS BNC connector on the rear panel. By default, the unit is configured to supply 5V to the GPS antenna. Jumper JP4 inside the unit can be used to select 3.3V antenna interfaces. Please note that opening the unit will void the factory warranty.

1.4.2 Initializing the GPS

Every time the FireFox unit is moved, it is recommended to enable the GPS Automatic Site Survey mode (or AutoSurvey) in order to reacquire its exact new position. The autosurvey algorithm averages a total of 10000 valid position fixes and typically takes about 2-3 hours to finish. Once the position is surveyed, the GPS will automatically enter the Position-Hold mode. In Position-Hold mode, the GPS receiver no longer solves for position and only one satellite is required to accurately determine time.

The Autosurvey activation is located in the *SETUP->GPS* menu section.

For a better position accuracy, it is also recommended to setup the Antenna Cable Delay in the GPS Config menu.

Caveat: the unit contains an internal maintenance-free rechargable battery that will keep the time, date, position, and GPS almanac alive inside the GPS receiver for ca. 3 hour long power failures.

After a certain time, the voltage on the battery will drop to a level at which the GPS real time clock ceases to run. The GPS unit will continue to hold the data in its memory for several days after this happens, but the time and date will not be updated anymore. This may cause the unit to turn on with an internal time/date that is stale (old by several days), causing the GPS receiver to search for a satellite constellation that presently does not exist. This may cause the GPS receiver to require a significantly longer time to first fix (TTFF) than if the battery was completely discharged. It may take up to 12 hours for the GPS receiver to start the Auto-Survey process under this fault condition.

To speed up the TTFF in this condition, the user may configure the unit to be remotely controlled (*Communication->GPS->Remote*). To do this, connect a PC to the GPS-Serial connector on the back of the unit, and use WinOncore12 to set the time and date of the GPS receiver. WinOncore12 has a configuration wizard for this purpose (see the FAQ/GPS section on www.jackson-labs.com for information on where to download WinOncore12).

1.4.3 Setting up the GPS

1.4.3.1 GPS Time Offset

The FireFox Signal Generator requires the user to set the political time offset to GMT time. Enter the *SETUP->GPS->GPS TIME OFFSET* menu and select between -12 to +12 hours of time offset to Greenwich Mean Time (GMT)

1.4.3.2 Selecting Metric/US Mode

The unit may display GPS height, time, and date in either Metric or US mode. Select the *SETUP->TIME->US/METRIC* menu to change the setting of the relevant GPS data in the LCD Display.

1.4.3.3 GPS Auto Survey

Enter the *SETUP->GPS->AUTO SURVEY* menu to start the GPS Auto Survey mode. This will initiate the GPS receiver to build an average position using 10,000 position readings, and to store this average position in its' memory to improve the timing accuracy. Operating with the averaged position is called Position Hold mode. Pressing the *enter* key in this menu will re-initiate the Auto Survey mode. The FireFox will indicate the Auto Survey mode by displaying "AS" in the main frequency setting window above the "STAT" indicator. Operating in Position Hold mode is indicated by an "OK" display above the "STAT" indicator.

1.4.4 Setting the Frequency

Figure 1.1 shows the front panel LCD and keys used to change the output frequency of the FireFox Signal Generator. The LCD shows either the frequency setting mode, or the menu mode. The frequency setting mode is the default mode after power up. Press the menu key until the unit shows the frequency setting mode if the unit is in any of the sub-menus. The left and right keys now control the cursor which can be moved onto any of the frequency triplets, or onto the RF output power setting. The cursor will wrap-around the display automatically.

Use the up and down keys to change the frequency triplet. You may also press and hold the up or down keys to automatically scan through the frequency range. The speed of the scan will increase after a short time interval.

When scanning the frequency using the down key, the display will show 0Hz after some time if the selected frequency triplet has been reduced to 0Hz. Release the down key, then press and hold the down key again to start scanning the frequency triplet below the one originally selected. The frequency scanning in this mode will then start at 999....Hz.

As an example, set the frequency to 10.0MHz. Now place the cursor onto the 0 digit of the 10MHz triplet (the single-MHz digit). Press and hold the down key, and the frequency will scan through 9, 8, 7.... 0 MHz. The display will now show "Uncal! 0MHz". Release the down key, and press and hold it again. The cursor will now be automatically placed onto the 1KHz digit, and down-scanning of the frequency will commence at 999KHz.

A menu item for the upper frequency limit can be set to limit the highest frequency the unit can generate. This item is accessible in the *SETUP->OUTPUTS->FREQ-LIMIT* menu. You may select any frequency as the upper limit in this menu, and the unit will then not allow higher frequencies to be selected from the front panel. Check the frequency limit setting if you are not able to configure the unit to generate signals up to the 1.64GHz maximum frequency.

1.4.5 Setting the RF Amplitude

The unit has an analog RF output connector that will provide a sine wave for 50 Ohm terminated loads. The RF output is enabled for frequencies from 2MHz to 1640MHz. The VALID LED next to the RF-OUT BNC connector indicates if the selected frequency is within the range of the RF-OUT connector. The power level of the output sine wave may be controlled via the front panel keypad. The unit has two output level selecting modes:

• Relative output level ranging from 0% to 100%

• Calibrated absolute output level from -40dBm to +10dBm.

Select the mode in *SETUP->OUTPUT->POWER UNIT*

The relative output mode allows the unit to produce its maximum output power which may range from +7dBm to over +18dBm depending on the frequency. The absolute output power mode will generate a calibrated output power into a resistive 50 Ohm load connected directly at the RF output connector on the front of the unit with typically better than +-0.2dBm accuracy and 0.02dBm resolution.

Move the cursor onto the RF amplitude digits in the frequency setting mode. Press the up or down keys to change the output power.

The unit also has a power limit menu similar to the frequency limit menu explained in paragraph 1.4.4 . Please check the power limit in the *SETUP->OUTPUT->POWER LIMIT* menu if you are unable to select a desired power level up to 100% or +10dBm.

1.4.6 Using the CMOS and LVDS outputs

The FireFox unit is unique in that it can produce both analog (sine wave) outputs, and digital outputs simultaneously. Four front panel digital outputs are available. All four outputs on the front panel are driven in parallel, within their respective output frequency ranges as indicated by the VALID LED's.

Please note that the LVDS outputs have an under-range from 2-10MHz. The outputs are driven in this under-range, but are not guaranteed to be jitter-free. The CMOS output is usable from 0Hz to 350MHz, with an over-range up to 390MHz in which the output is driven and usable but not guaranteed to be jitter-free.

1.4.6.1 Connecting a cable to the LVDS Outputs

Two differential, complementary LVDS signals are available on SMA connectors on the front panel of the FireFox unit. Typically LVDS signals are connected to 50 Ohm transmission lines (cables) and differentially end-terminated with a 100 Ohm termination resistor between the Positive and Negative LVDS signals. The user may also end-terminate the signals individually to Ground using 50 Ohm end-terminators. The output voltage levels will change slightly when terminating to Ground.

By using 50 Ohm ground terminated cables it may be possible to drive PECL inputs. A series capacitor may also be used to remove the LVDS DC-Offset present on the LVDS SMA connectors. The signal swing on the two LVDS connectors is approximately 300mV peak on each output, and this may be used to drive two independent analog inputs with ca. -7dBm level when connected via AC-coupling.

1.4.6.2 Connecting a cable to the CMOS Output

The FireFox CMOS output is designed to drive a 50 Ohm transmission line or cable without any end-termination (open-ended cable). Voltage levels are up to 5Vpp when using open-ended cables.

The FireFox CMOS output may also drive 50 Ohm end-terminated cables without damage and with a slightly more than 50% reduction on the high-level output voltage. The rise and fall times of the FireFox CMOS output are on the order of 1V/ns or faster.

Please note that the CMOS output is low-pass filtered for output frequencies below 30MHz to reduce DDS-generated spurs above 30MHz, and thus to reduce the output jitter. The CMOS output provides the output signal with the least spurs present for output frequencies below 30MHz of all of the FireFox front-panel outputs.

1.4.6.3 Selecting the Front Panel CMOS Output Voltage

The Front Panel CMOS peak-to-peak output voltage is selectable via a switch on the back panel of the FireFox Desktop unit, and via a Jumper on the FireFox OEM PCB. The switch is visible in the upper left hand corner of Figure 1.6. Use JP12 located close to the CMOS output BNC connector to select the CMOS output voltage when using the FireFox OEM PCB.

The CMOS output voltage can be selected to be either 0V to 3.3V, or 0V to 5.0V when driving un-terminated transmission lines. This voltage level will be reduced by slightly more than 50% when driving an end-terminated 50 Ohm transmission line.

1.4.7 Setting up the DDS

Enter the menu *SETUP->DDS* to control the internal settings of the FireFox Signal Generator RF DDS (Digital Direct Signal Generator).

1.4.7.1 Setting the Phase Offset

Enter the *SETUP->DDS->PHASE OFFSET* menu item to control the output Frequencies' phase in relation to the rear panel 10MHz time base output. The user can select the phase in small increments from -180 Degrees to +180 Degrees.

1.4.7.2 Mixer ON/OFF

The FireFox Signal Generator has a general-purpose, non-dedicated 2GHz Bandwidth mixer built-in, accessible through the front panel BNC connectors.

This mixer can be turned ON or OFF via the *SETUP->DDS->MIXER* menu.

Turning off the mixer may help prevent some spurs, and may be usefull when debugging IF and AGC circuitry etc.

1.4.7.3 FRACT ON/OFF

The menu item *SETUP->DDS->FRACT ON/OFF* determines the mode of the FireFox Signal Generator Fractional-N DDS to be used or to be disabled. This setting determines the FireFox Signal Generator resolution, and also affects the output phase noise and frequency drift. Select FRACT ON to set the DDS to 48-bit Frequency mode, or FRACT OFF to turn off the Fractional-N mode, and set the unit to 32-bit Frequency mode.

See Section 3.6.6 for an in-depth discussion of the Fractional-N operating mode.

1.4.7.4 Noise/Spur Optimization

The menu item *SETUP->DDS->NOISE/SPUR OPT* allows the internal FireFox PLLs' to be setup for either best-noise performance (Spur optimization turned to OFF) or best-spur performance (Spur optimization turned to ON). This setting will affect the PLL charge currents of the internal PLLs' and place these either in the best operating mode for Phase Noise performance, or for least-Spur performance.

Set this item to OFF for typical operations that require low phase-noise signals.

1.4.8 Setting up the Output

The following settings affect the FireFox maximum frequency that can be generated, as well as the analog front panel RF Output power.

1.4.8.1 Frequency Limit

In the *SETUP->OUTPUT->FREQ LIMIT* menu the user may limit the maximum possible frequency that can be set via the front panel keys in the frequency setting menu. This setting will also affect sweep modes, and memory recall modes.

The unit will not generate Frequencies above the limit Frequency selected in this menu item.

The limit Frequency will be stored in non-volatile memory until changed in this menu item.

1.4.8.2 Power Unit

In the *SETUP->OUTPUT->POWER UNIT* menu the user may select either a relative power output ranging from 0% to 100% of the units' power output capability, or an absolute output power selected in dBm (between -40dBm to +10dBm).

Setting relative mode is useful if the maximum power output at any given frequency is desired from the analog RF Output BNC connector on the front panel. The maximum output power in relative mode can range from +5dBm to over +18dBm depending on the output frequency.

Setting absolute mode will allow the unit to generate RF signals with high level-accuracy (typically within +-0.2dBm at an output power of 0dBm). The range of the output power is limited to -40dBm to +10dBm in absolute mode.

This setting only affects the analog RF Output BNC connector on the front panel. All other signal outputs remain unaffected by this setting.

1.4.8.3 Power Limit

In the *SETUP->OUTPUT->POWER LIMIT* menu the user may limit the maximum possible analog RF Output Power that can be set via the front panel keys in the frequency setting menu. This setting will also affect sweep modes, and memory recall modes.

The unit will not generate Power levels above the limit Frequency selected in this menu item on the analog RF Output BNC front panel connector.

The limit Power will be stored in non-volatile memory until changed in this menu item.

This setting only affects the analog RF Output BNC connector on the front panel. All other signal outputs remain unaffected by this setting.

1.4.9 Setting up Frequency Sweeps

The unit can be used as a sweeping signal generator. The following parameters are selectable through the keypad menu:

- frequency start (F1, from 0 to 1.64 Ghz)
- frequency stop (F2, from 0 to 1.64 Ghz). The stop frequency has to be different to the start frequency and may be selected to be lower than the start frequency.
- duration (D) of the sweep from 0.1s to 1000s with a resolution of 0.1s.
- sweep spacing (pace): linear or logarithmic
- sweep mode:
    - from F1 to F2, single sweep only
    - from F1 to F2 and back from F2 to F1, single sweep only. In this case the total duration of the sweep time is doubled.
    - from F1 to F2 continuously sweeping until the Right key is pressed. Every sweep from F1 to F2 will have a duration D, and the unit will restart at F1 once F2 has been reached.

- from F1 to F2 back and forth from F2 to F1 continuously sweeping until the Right key is pressed. Every sweep from F1 to F2 or F2 to F1 will have a duration D.

The sweep settings are accessible directly from the main menu *SWEEP*.

1.4.10 Monitoring the Instrument Status

1.4.10.1 OCXO Status

The FireFox Signal Generator allows its internal status to be monitored via the *STATUS/OCXO* menu item. The OCXO temperature, the OCXO EFC DAC value, the estimated 30 minute Allan Deviation, and the GPS pulse number can be monitored when accessing this menu item.

The EFC status shows the value of the present DAC setting from 0% to 100%. This value is typically between 50% and 60%, and should only change slowly over time.

The *Freq Est* number displayed shows the estimated Allan Deviation for a measurement interval of 30 minutes (1800s). This number is calculated by taking the phase offset measurement between the GPS 1PPS output, and the internal OCXO 1PPS signal, waiting 30 minutes, then comparing this value to the present phase offset and calculating the error in one minute updates.

The OCXO temperature shown is measured at the outside of the metal cage of the OCXO, and should typically be between 45 and 65 Degrees Celsius.

The 1PPS pulse count shows how many 1PPS pulses have been received from the GPS timing receiver. At least 3600 pulses need to be received for the *Freq Est* to be calculated correctly.

1.4.10.2 GPS Status

The GPS status menu item will display the stored GPS hold-mode position and altitude. The GPS receiver firmware version can also be checked in this menu item.

The GPS status is also displayed in the LCD main frequency setting menu, on the right hand side above the "SAT" and "STAT" indicator. The meaning of these indicators is as follows:

LCD STAT indicator	Meaning
OK	The unit is receiving at least one Satellite, and is locked to better than 15E-011 to UTC
AQ	The unit is searching for Satellites (Acquiring)
AS	The unit is receiving at least 4 Satellites, and is in Auto Survey mode
2D, 3D	The unit is receiving at least 3 to 4 Satellites, and Position Hold Mode has been de-selected, or the unit is entering Auto Survey mode

Table 1-1: GPS Status Indicator Abbreviations

LCD STAT indicator	Meaning
UL	The OCXO is not locked to UTC (Unlocked)
BG	The unit is receiving sufficient Satellites for Auto Survey mode, but the Satellite Geometry is bad and the present Satellites cannot be used (Bad Geometry)

Table 1-1: GPS Status Indicator Abbreviations

1.4.10.3 Sys Config

This menu item will show various FireFox system parameters.

The first item in the LCD is the FireFox Signal Generator Firmware version. SCPI commands are available with Firmware Version 3.0 or later.

The GPS type is displayed. The M12+ or M12M receivers are used in the FireFox Signal Generator.

The MTI OCXO version is displayed in this menu item. The single oven default OCXO is MTI230-0827. The double oven OCXO option is MTI270-0269

The last display item is DDS Resolution. The DDS resolution is the internal resolution limit due to the 48 bit DDS setup. The smallest DDS step size is 1.7764microhertz, and the highest step size is 14.2109microhertz, depending on the output frequency. The system will generate an output frequency closest to the desired frequency, with a step size displayed in the LCD.

1.4.11 Using the External Mixer

The FireFox Signal Generator includes a general purpose mixer accessible from the front panel. A mixer is used to generate a signal consisting of the difference of two input signals. Mixers can be used to shift high-frequency signals into lower frequency bands, or vice versa.

As an example, the FireFox Signal Generator can be used to modulate baseband video signals to RF channel frequencies. Analog or Digital signals such as DVB-T baseband signals can be upconverted to RF frequencies up to about 400MHz. To RF modulate an I/Q baseband DVB-T video signal to an RF carrier of 61.25MHz, simply set the RF output of the FireFox Signal Generator to 61.25MHz, feed the RF output into the LO Mixer input (set the RF output amplitude to 0dBm, making sure not to exceed the Mixer input damage level of +10dBm), and feed the DVB-T baseband signal into the mixers RF input. The Mixer output will now contain a DVB-T modulated signal with a 61.25MHz carrier. A VSB filter may have to be used to properly format the signal.

The mixer is also useful when trying to receive high frequency signals; see the following example:

An FM modulated signal at 1.40GHz is to be received using the FireFox and a standard FM radio. The input signal has to be transformed from 1.40GHz to 100MHz to be receivable by the FM Radio.

For this example, we will select a Local Oscillator (LO) Frequency of 1.50GHz. The LO input is simply driven by the FireFox RF output signal via a BNC jumper cable, so the FireFox is set to generate the 1.5GHz. The received RF input signal is then connected to the RF input. Mixing the 1.5GHz LO frequency with the 1.4GHz RF signal will generate a 100MHz mixing product (the Intermediate Frequency, or IF signal), which is basically the RF signal shifted to 100MHz. The IF output can now be connected to the FM radio tuned to 100MHz. The received signal will now be audible by the radio.

Typical signal levels at the mixer inputs are -20dBm to 5 dBm for the RF input, and 0dbm for the LO input. Care must be exercised to avoid driving the Mixer RF and LO inputs above 10dbm. Driving the inputs above this level could damage the mixer.

The mixer can be disabled in the menu settings to reduce potential interference.

1.4.12 Storing and Recalling Setups

The FireFox unit can store up to 10 independent setups in its internal Non Volatile memory. To store, recall, and erase setups, enter the Memory menu by pressing *MEMORY->RECALL/SAVE/ERASE*.

Once inside the SAVE or RECALL menu items, press the UP or DOWN key to select a memory position to save to, or recall from. Positions 0 to 9 are selectable.

An empty memory position is indicated by a "-" sign, an occupied position is indicated by a "*" sign.

Save a memory setup by pressing the ENTER key in the SAVE menu. You may exit the save menu by pressing the EXIT/MENU key.

Recall a memory location by pressing the ENTER key in the RECALL menu. You can exit without recalling by pressing the EXIT/MENU key.

The user may erase only the entire memory. This is useful if all memory locations have been filled-up, and the older data is no longer useful.

Erase all memory positions by pressing ENTER in the ERASE menu. Exit the erase menu without erasing any data by pressing the EXIT/MENU button.

All FireFox settings such as Maximum Frequency, Power settings, the Frequency, Power Unit, output power and other settings are saved in these memory locations.

Please note that GPS relevant data such as the GPS position in Position Hold mode, the GPS GMT time offset, etc. are not maintained in these memory locations, but rather inside the GPS itself.

1.4.13 Using the GPS and OCXO Reference Outputs

1.4.13.1 GPS Receiver 1PPS Output

The FireFox Signal Generator provides a highly stable 1PPS CMOS 3.3V compatible output pulse on its' rear panel 1PPS BNC connector. This pulse is derived from the Motorola M12+ GPS Timing receiver. It does exhibit the typical M12+ sawtooth waveform, which may be compensated by using the Motorola Clock Granularity Message available on the rear panel GPS RS-232 port. See the Motorola M12+ documentation about details of how to use these two outputs.

The rear panel 1PPS output is buffered by a high-speed, 3.3Vpp CMOS output, and this output should typically drive an open-ended 50 Ohm transmission line/cable. Terminating the output with a 50 Ohm resistor will not damage the output, but will significantly reduce its output voltage swing.

The CMOS buffer adds ca. 6ns of Tpd propagation delay to the GPS receivers' 1PPS output signal; this delay may be compensated in the receiver by using the Antenna Cable Delay setting available when connecting the WinOncore12 software to the GPS receiver. See section 1.4.14.3 and section 3.5.3 for details about the WinOncore12 software.

1.4.13.2 OCXO Timing Reference Output

The rear panel 10MHz time-base reference output is highly accurate, and disciplined by the GPS receiver. This output is driven by a high-speed CMOS driver with 3.3Vpp output drive voltage. This output may either drive a non-terminated 50 Ohm transmission line/cable, or it may drive an end-terminated cable. The output voltage will be reduced by 50% if the BNC cable is end terminated with a 50 Ohm resistor. See Figure 1.2 for typical stability data for this 10MHz output signal.

The unit will require between 3 to 10 hours to stabilize fully when turned on from a cold-start. The OCXO crystal may take up to one week to fully stabilize and to have periodic frequency shifts seize to appear, especially if the unit has recently been moved, shipped, or has experienced significant thermal changes.

The 30 minute Allan Deviation Estimate of this output is available in the FREQ EST display item when entering the *STATUS->OCXO* menu item. This estimation is calculated by measuring the internal OCXO generated 1PPS signal phase shift to the GPS generated 1PPS signal, and comparing the momentary value to the value calculated 30 minutes previously. The deviation is then calculated, and displayed in the LCD. Typical deviation numbers when the unit has been locked and operating for several weeks are <+-5E-010 for the default OCXO option, and <+-5E-011 for the Double Oven Ultra High Stability OCXO option.

1.4.14 Advanced GPS Setup

1.4.14.1 Factory Reset

Pressing the enter button in the *SETUP->GPS->FACTORY RESET* menu will initiate a GPS receiver Factory Reset, and reset all of the stored settings of the FireFox Signal Generator. Please power cycle the unit after initiating this command.

This command requires the user to re-initiate all of the settings such as Power Unit, GPS Time Offset, Maximum Frequency and Maximum Power etc.

It is recommended that a Factory Reset is only initiated if the unit stops responding correctly to user commands.

1.4.14.2 GPS TRAIM Filter

The GPS receiver can operate with an internal TRAIM (Time Receiver Autonomous Integrity Monitoring) algorithm to ensure that data from bad Satellites will not corrupt the FireFox Signal Generator Time Base accuracy. The receiver requires at least 4 Satellites to be received and to be in good status when entering the *SETUP->GPS->GPS TRAIM FILTER* menu and selecting *GPS 1PPS FILTER ON*. Any Satellite solutions with less than 4 Sats being received, or with any one Sat exceeding 300ns deviation from the others will be considered stale by the GPS firmware when this option is set to ON.

Jackson Labs recommends maintaining this setting in the OFF position when using the default FireFox Signal Generator OCXO, and only setting this option to ON when using the ultra-high-stability double-oven OCXO option with a GPS Antenna that has a clear view of the sky.

1.4.14.3 Controlling the M12+ GPS Receiver using a PC

You may use Motorola's WinOncore12 Windows(tm) program to check the Motorola M12+ GPS Timing receiver status, and to modify advanced settings of the GPS receiver such as Satellite Mask Angles etc. Please see the GPS FAQs on the Jackson Labs website (www.jackson-labs.com) for pointers where to download the WinOncore12 utility.

Follow these steps in order to be able to control the internal M12+ GPS receiver via WinOncore12:

1) Connect the RS-232 cable supplied with your FireFox Signal Generator to your PC's COM:1 or COM:2 serial port, and to the FireFox Signal Generators' back panel RS-232 port labeled "RS-232 GPS" - see Figure 1.6.

2) Go to the FireFox menu *SETUP->COMMUNICATION->GPS* and choose *REMOTE.* You must stay in the *REMOTE* menu in order to have external access to the GPS receiver. Leaving the *REMOTE* menu will disable external access to the GPS receiver.

3) Download, install and start the WinOncore12 program on your PC, and setup the communication port under the *OPTIONS->COMMUNICATIONS->PC-COMMUNICATIONS* WinOncore12 menu. Set the port you choose, and select 9600 Baud communications.

4) You should now see Satellite status information and be able to control the receiver with the WinOncore12 program. Settings such as Satellite Mask Angles etc. will be stored in the internal GPS receiver battery-backed NV memory.

1.4.15 Entering the Calibration Mode

The FireFox Signal Generator does not need to be frequency calibrated, it continuously calibrates its internal time base using the built-in GPS receiver.

The analog RF Output BNC connector on the front panel does need periodic calibration to achieve the specified level accuracy when in absolute (dBm) mode.

Press the *SETUP->CALIBRATION* menu button to enter calibration mode. Please see Chapter 4 for an in-depth discussion about the requirements for executing a self-calibration of the RF amplitude levels.

1.4.16 Entering SCPI Remote Control Mode

Beginning with Firmware Revision 3.0 and later, the FireFox Signal Generator may be controlled via its rear panel RS-232 connector using the SCPI-99 industry standard communication protocol. See Chapter 2 for a list of supported SCPI commands.

The user can manually enter the SCPI remote control mode by pressing *SETUP->COMMUNICATION->SCPI-MODE* in the menu.

The user may select the SCPI RS-232 communication BAUD rate via the *SETUP->COMMUNICATION->SERIAL SPEED* menu.

1.5 FireFox Desktop Typical Specifications

1.5.1 Specification Summary

Item	Description	Specification
Frequency	Range Resolution Accuracy measured over 30 minutes Settling time	DC - 1640MHz 10 micro Hertz <+-5E-010 <<10ms
Frequency Sweeping	Start and Stop Frequency Frequency update rate Sweep Mode Sweep Time Repetition RF output power	Arbitrary, from 0Hz to 1640MHz 500 updates per Second Linear and Logarithmic 0.1 - 1000s F1->F2, or F1->F2->F1 Leveled, between -40dBm and +10dBm, better than 1dBm level accuracy
Time Base	Stability Aging Warm-up time from cold boot @ 20 Degree Celsius Lock time with GPS reception	See Figure 1.2 for typical Allan Deviation Fully corrected by GPS <1 hour <5 hours
GPS Receiver	1PPS timing offset to UTC, 1-Sigma 1PPS timing offset to UTC, 6-Sigma Recommended antenna	<10ns <20ns >18dB gain, 3.3V or 5V
Phase Noise	At 250MHz carrier, 0dBm RF output 1KHz Offset 10KHz Offset 100KHz Offset 1MHz Offset	 <-90dBc/Hz <-110dBc/Hz <-140dBc/Hz <-150dBc/Hz

Table 1-2: FireFox Key Specifications (Typical)

Item	Description	Specification
Spurs	Typical worst case spurs <150MHz carrier 150MHz - 400MHz carrier 400MHz - 800MHz carrier 800MHz - 1640MHz carrier	 <-45dBc/Hz <-48dBc/Hz <-56dBc/Hz <-65dBc/Hz
Phase adjustment	<390MHz 390MHz - 775MHz 775MHz - 1640MHz	0.1 Degree steps 0.2 Degree steps 0.4 Degree steps
CMOS Output	BNC front-panel connector DC to 390MHz into open-ended 50 Ohm cable into 50 Ohm end-terminated cable	 0-3.3V or 0-5V <1/2 open-ended output voltage
RF Output	BNC front-panel connector relative mode (0% - 100%) absolute mode power absolute mode accuracy at 0dBm output	 up to +18dBm -40dBm to +10dBm better than 0.5dBm typically
LVDS Output	Common mode voltage (100 Ohm terminated SMA to SMA connector) Differential Output Voltage Magnitude into 100 Ohms	1.2V 340mV
RF Mixer Panel	General-purpose, non-dedicated mixer available via BNC front-panel connectors. RF and LO input range Filtered IF output bandwidth LO input sensitivity RF input sensitivity Damage level.	 <4.5MHz to 2GHz <4.5MHz to >350MHz <-10dBm <-10dBm +14dBm
RS-232 Ports	GPS RS-232 System RS-232 (Firmware Rev. 3.0 and later)	Motorola WinOncore12 compatible SCPI-99 compatible

Table 1-2: FireFox Key Specifications (Typical)

Item	Description	Specification
1PPS GPS Port	CMOS compatible BNC output on rear panel. Rising edge synchronized to UTC. Do not terminate, use a 50 Ohm open-ended cable. Rising edge can be shifted in 1ns steps via WinOncore12 software to compensate for antenna cable delay.	0-3.3V
Power Consumption	100V - 230V, 43Hz - 65Hz AC, steady state	<20W
	12.0V input option, steady state	7.5W - 8.5W

Table 1-2: FireFox Key Specifications (Typical)

1.5.2 Typical Allan Deviation Plots
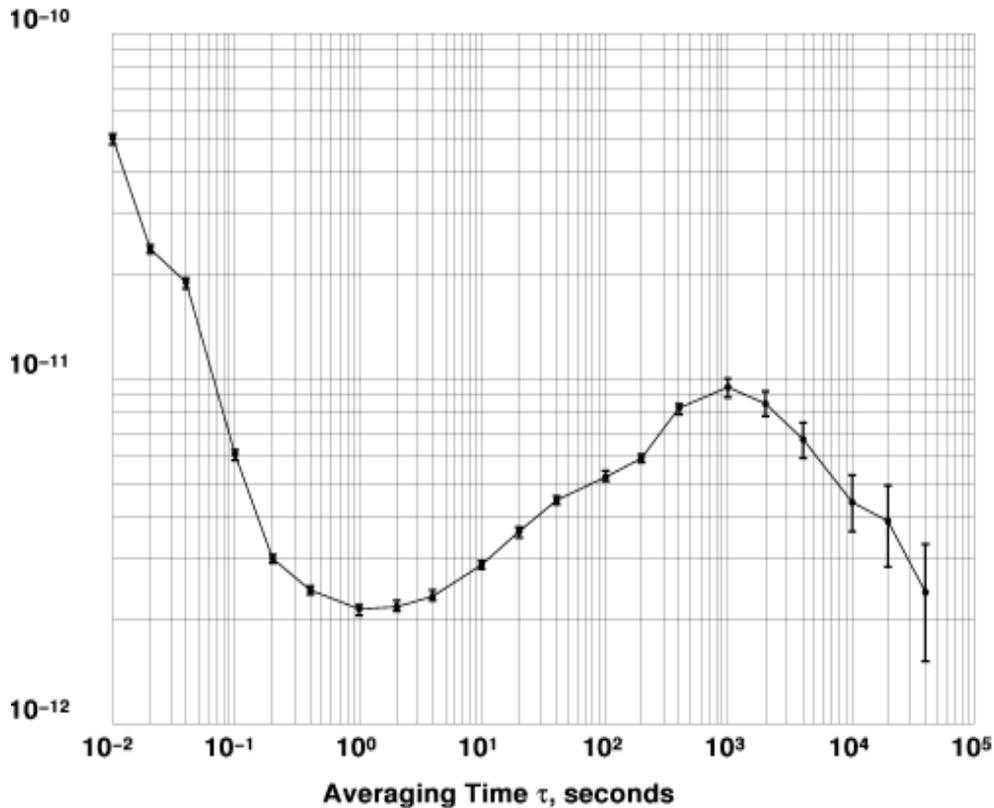
Figure 1.2   Typical Allan Deviation of 5MHz front panel output with default OCXO

The FireFox Allan Deviation in Figure 1.2 was measured by an internationally recognized independent test lab using a Hydrogen Maser as a reference compared to the FireFox Signal Generator front-panel RF output set to 5.0MHz at +7dbm. Measurements were done using a TSC 5110A Time Interval Analyzer.

Figure 1.3 shows the typical Allan Deviation when using the optional, ultra-high-stability double-oven OCXO. Note the significant stability improvement for time periods above 1s measurement intervals when using the double-oven OCXO option as compared to the standard OCXO
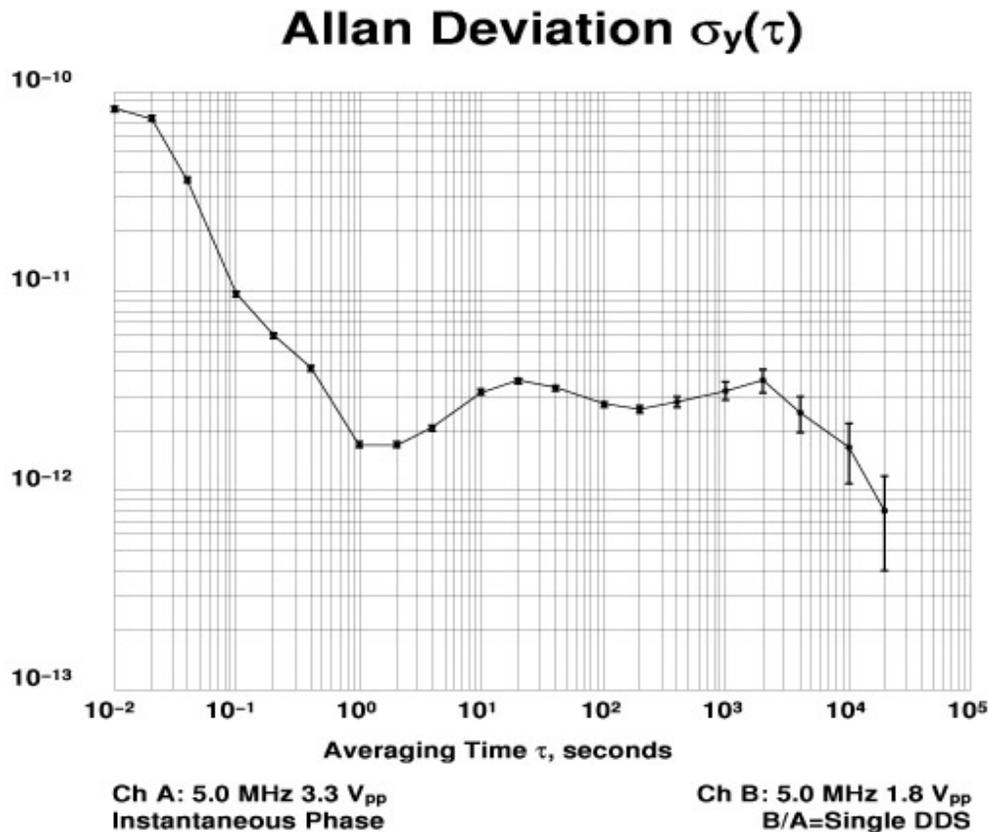
Figure 1.3   Typical Allan Deviation of 5MHz front panel output with double-oven Ultra-High-Stability OCXO option

It can be clearly seen from Figure 1.3 that the FireFox Signal Generator equipped with the ultra-high-stability OCXO option achieves better than 1E-12 timing stability in less than 10 hour measurement intervals when locked to GPS.

The rear panel 1PPS output of the FireFox Signal Generator is driven by the Motorola M12+ GPS timing receiver. The 1PPS BNC output is only active when the unit is locked to at least one satellite. See Figure 1.4 for a typical Frequency Stability measurement of the FireFox 1PPS output when compared to an ultra-high-stability reference. It can be seen that the FireFox 1PPS output can achieve about 1E-12 timing stability in less than 24 hour measurement intervals when locked to GPS. The FireFox Signal Generator already achieves this excellent stability with the default OCXO.
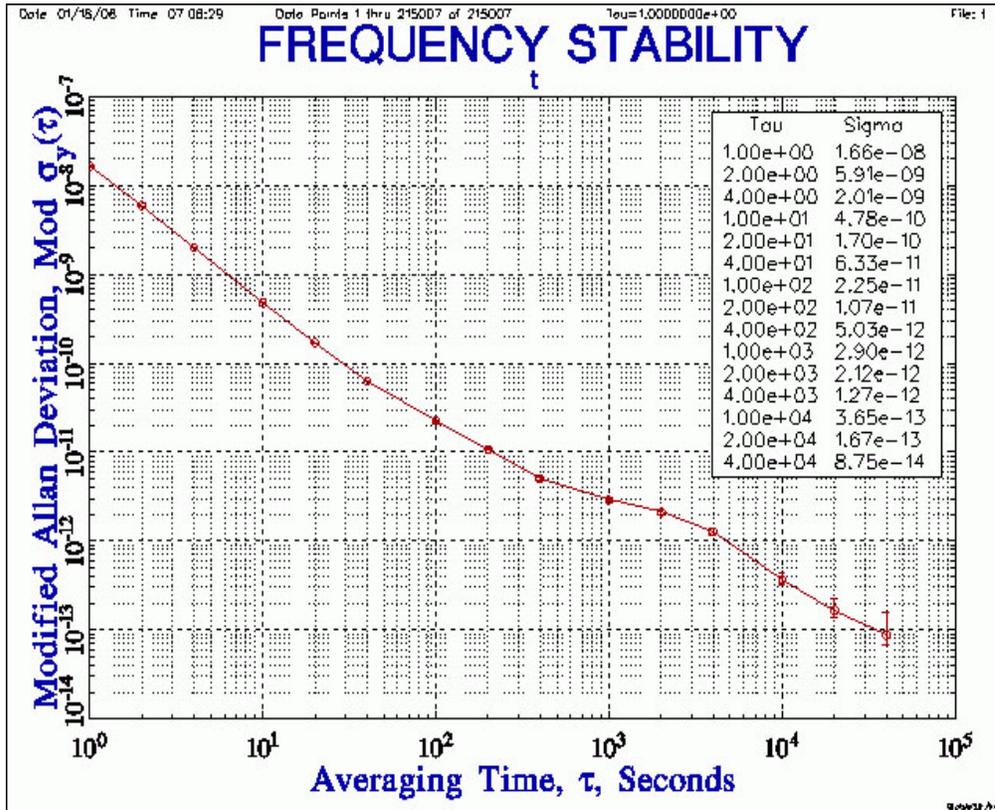
Figure 1.4   Rear Panel 1PPS output Stability when locked to GPS

1.5.3 Block Diagram

The FireFox built-in GPSDO feeds a Direct Digital Synthesizer (DDS) which allows Continuous-Wave (CW) frequencies from DC to 1.64GHz to be generated with 10µHz (15 digit) resolution over a 1.64GHz range. With the help of its internal GPS timing receiver, the built-in 10MHz OCXO reference achieves a better than 10^{-12} (Stratum-1) long term accuracy. The short term accuracy when locked to GPS is typically better than $+-5 \times 10^{-10}$ when measured in 30 minute intervals, see Figure 1.2. Please note that this Allan Deviation plot represents typical values under optimum conditions, and there is typically a fairly large unit-to-unit spread when measuring Allan Deviation, especially at measurement intervals of less than 2000 seconds.

Figure 1.5 shows a block diagram of the FireFox synthesizer:
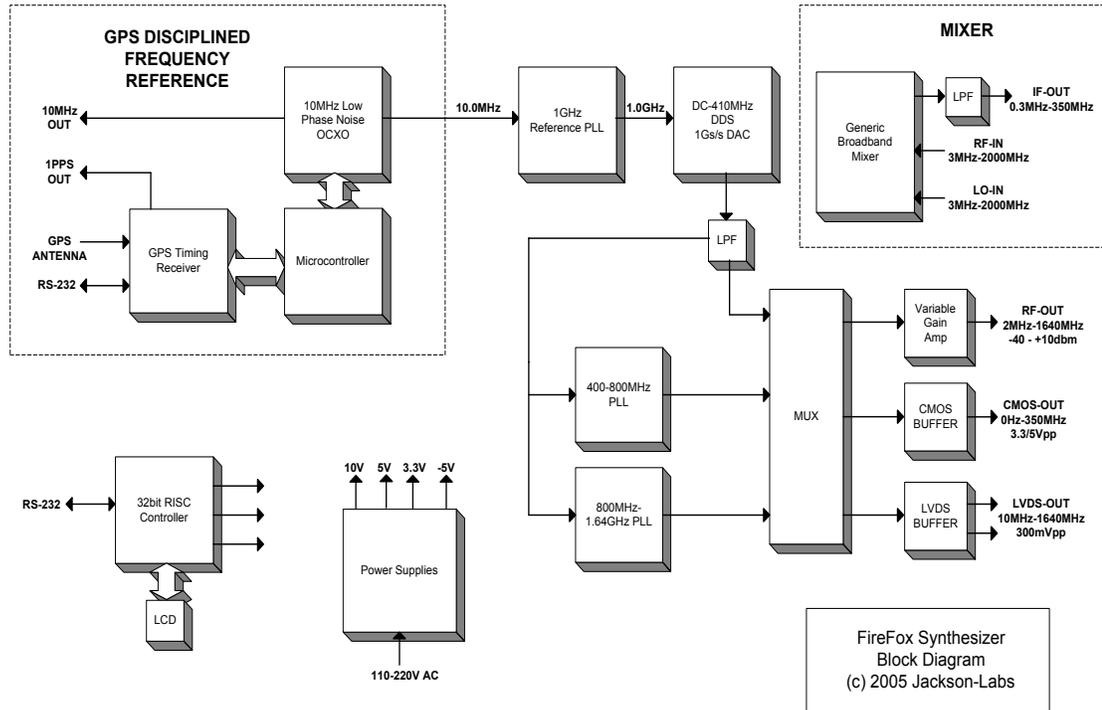
Figure 1.5   FireFox Synthesizer Block Diagram

1.6 Detailed Overview

The following paragraphs provide an in-depth overview of the features, applications and capabilities of the FireFox Signal Generators.

1.6.1 Applications

The FireFox Synthesizer has five outputs to provide signals to applications that require a low-noise, low jitter, accurate and stable frequency signal. All outputs are driven in parallel, limited to their respective frequency operating ranges as indicated by their "VALID" LED's which are located adjacent to their respective outputs. Any variety of outputs may be used independently of each other.

Applications include generating arbitrary frequencies with high accuracy and low noise for calibrating instruments, operating as an in-house frequency and time standard, design and development of digital circuits, VLSI chips, memory interfaces, and microprocessors, designing and debugging PLL circuits, and driving mixers and other RF equipments' local oscillator inputs. With the frequency sweep features it is possible to use the FireFox synthesizer to design Microwave equipment, to measure S11 and S12 performance of filters, cables, and amplifiers etc. The units can also be used as HAM frequency generators, and for any other application where arbitrary highly precise and accurate, and non-standard frequencies must be generated.

The FireFox synthesizer is particularly well suited for the following applications due to its high accuracy and resolution. These types of applications were previously difficult to achieve with conventional equipment:

* Combining two FireFox units, and running them at slightly different frequencies (frequency offsets as low as 10µHz can be achieved between two FireFox units) to test for equipment behavior and failure when two slowly drifting oscillators are driving the system. This is helpful in Telecom type applications.

* High-speed research applications in which two geographically separate locations require precisely synchronized timing and frequency references. Precise signal synchronization anywhere on the globe is possible due to the units' worldwide GPS reception, and its synchronization to UTC.

* Test & measurement applications in production environments.

* Moon-bounce type research where signals with low phase noise and extremely high frequency accuracy are required due to the very low level of the reflected RF signal.

* Generating, and measuring the effects of Audio/Video drift in broadcast applications such as Digital TV distribution, IPTV, video-on demand etc.

* Measuring long-term drift and noise on Rubidium, Cesium, and Crystal Oscillators.

* Measuring performance of RF receivers in the presence of arbitrary jamming signals. These jamming signals could be generated with 10µHz resolution and up to +10dbm output power by the FireFox signal generator.

* The output phase can be controlled in 0.1 degree steps from -180 to +180 degrees, allowing very precise alignment of signals for quadrature type applications.

* The frequency, the amplitude, and most other internal settings can be controlled via an RS-232 serial port under host-PC control, allowing automated test setups (SCPI compatible RS-232 control firmware upgrade available Q2/2006).

1.6.2 Signal Generator Outputs

The following output signals are available on the FireFox unit:

   * **CMOS OUTPUT** - 3.3Vpp or 5Vpp (user selectable via back-panel switch)

   A best-in-class, extremely high-speed generic CMOS compatible output can generate frequencies from 0Hz to 350MHz, with an overrange of up to 390MHz. This output is typically used to clock digital circuits such as microprocessors, FPGAs, DDR SDRAM memories, and ASICs. The output is typically fed into a 50 Ohm transmission line or coax cable, and left unterminated at the receiver. Using a 50 Ohm termination resistor at the receiver will cause a ca. 50% reduced voltage output swing. End termination is not recommended, but will not harm the output.

   * **RF OUTPUT** - 50Ohms, 2MHz to 1640MHz range, -40dbm to +10dbm (typ.)

   Can be used as the local oscillator for any RF type application. Maximum power typically ranges from +10dbm to +15dbm depending on the frequency. Has leveled output capability, with output power selected via keypad. This output can be used as the local oscillator source for the built-in generic Mixer (use +10dbm output max to avoid mixer damage). The RF output requires 50 Ohm end-termination.

   * **LVDS OUTPUT** - 50Ohms DC coupled 10MHz to 1640MHz 300mVpp (with a 2MHz to 10MHz underrange)

a standard positive DC-biased differential LVDS output is available on two SMA connectors. These signals are typically used to drive ultra high speed digital signals into FPGA's, ASICs, backplanes, or memories. For LVDS compatible signals, two 100Ohm differentially terminated transmission lines or coax cables are typically connected to these outputs, with the 100Ohm resistor connecting the two differential signals together. The two transmission lines may also be terminated independently to ground through two 50 Ohm termination resistors yielding PECL compatible signal levels. LVDS signals are 300mVpp voltage swing, and can be used to drive LVDS, PECL, ECL, SSTL and other differential, low-voltage swing applications through simple termination resistor/capacitor matching circuits. These two outputs can also be used as two -7dbm RF LO signals with 180 Degree phase offset to each other when AC coupled and 50 Ohm end-terminated.

* **10MHz FREQUENCY REFERENCE OUTPUT** - unterminated CMOS 3.3Vpp

A GPS disciplined low phase-noise OCXO drives this CMOS output. This signal may be used as a very high accuracy in-house frequency reference due to its constant drift calibration via GPS satellites. An unterminated 50Ohm coax cable is typically connected to this output. The quality of this output signal approaches that of Rubidium atomic clock reference standards. The long term frequency accuracy of this output exceeds that of non-GPS disciplined Cesium atomic frequency standards.

* **GPS 1PPS OUTPUT** - unterminated CMOS 3.3Vpp

A 1PPS signal (positive edge active) that is accurate to within 20ns of UTC is available on this connector. Typically an unterminated 50Ohm coax cable is used to provide this signal to optional external Caesium or Rubidium atomic frequency references for disciplining purposes. A GPS timing receiver with Auto-Survey position-averaging, position-hold mode and T-RAIM signal quality assurance algorithm provides this signal.

1.6.3 GPS Disciplined OCXO Reference

The FireFox ultra-low phase noise internal 10MHz OCXO is constantly drift-corrected by comparing its output frequency to the Caesium based GPS satellite timing signals. The GPS satellites are maintained by the U.S. Naval Observatory (for more information see also: *http://tycho.usno.navy.mil/)*. The GPS signals are received by a specialized high-end Motorola GPS timing receiver that has a better than 20ns accuracy per second to UTC on its 1PPS output signal. This receiver is housed in its own metal enclosure to improve its immunity to thermal changes and external interferences. Maintaining frequency synchronization between the internal OCXO and the average GPS UTC time signal allows the FireFox synthesizer to achieve its excellent frequency accuracy without ever requiring calibration.

NIST traceability of the GPS timing reference is available at: *http://tf.nist.gov/service/gpscal.htm*. The FireFox synthesizer 1PPS output can be used to discipline external Cesium or Rubidium references with NIST traceability. A complete USNO test report of the GPS timing receiver performance is available upon request. The USNO report shows a measured overall offset to the USNO master timing reference 1PPS signal of typically only 2ns after 300 hours of operation. Figure 1.6 shows the GPS antenna connection, the 1PPS output, and the 10MHz OCXO reference output of the FireFox synthesizer desktop unit.

Figure 1.6   FireFox Desktop Unit Rear Panel

1.6.4 DDS Synthesizer

The FireFox variable output frequency is generated by a Direct Digital Synthesizer with 48bit resolution. Figure 1.5shows the block diagram of the FireFox synthesizer, with the DDS module visible on the upper part of the image. The DDS generates sine wave signals ranging from 10μHz to 410MHz using a 10bit DAC and a 1GHz reference input. A 400MHz low pass reconstruction filter is used at the output of the DDS to reduce aliasing and improve spurious performance. The output signal of the DDS drives a PLL module that multiplies the output frequency of the DDS up to 1.64GHz for output signals above 400MHz. The DDS phase accumulator may be controlled by the user via the keypad to shift the output signal phase arbitrarily from -180 to +180 degrees with 0.1 degree resolution.

1.6.5 RF Output Buffer

The FireFox synthesizer has multiple digital outputs and one analog RF signal output. This RF output is factory-calibrated and leveled, and the amplitude is adjustable via the keypad. The output is a pure sine wave with low phase noise, and low spurs and harmonics. A buffer and variable-gain amplifier allow signal levels above +10dbm typ. with a control range down to -40dbm typ. The user can either select a calibrated leveled output signal (indicated in dBm) or a relative output level (0-100%) via the keypad. The maximum relative output level varies with frequency. The RF output can be periodically calibrated using an Agilent E4418B or E4419B power meter and an Agilent 8482A power sensor connected to the FireFox synthesizer. Calibration is fully automatic, and can include user cabling and amplifiers etc. to compensate for cable losses.

1.6.6 User Interface

A 5-key keypad is used to control the settings of the FireFox synthesizer. Status is displayed on a 20x4 character LCD display. The keypad is used to select frequency, amplitude, and menu settings that control the GPS receiver, internal memory settings, the DDS, sweep features, and the status information display.

Frequency and amplitude settings are controlled via UP/DOWN and LEFT/RIGHT keys by simply selecting the sub range with the LEFT/RIGHT keys, and then setting the desired value by pressing and holding the UP/DOWN key. See Figure 1.1 showing the front panel of the FireFox desktop unit.

1.6.7 NV-memory

All user selections including up to 10 user profiles are stored in non volatile memory. The GPS receiver stores its satellite almanac, the present position, and time/date information in battery-backed SRAM. GPS settings can be maintained for several days typically without an external power source, while all other settings are stored indefinitely in the NV memory even when power is removed from the system.

1.6.8 Frequency Sweeping

The unit can be used for arbitrary frequency sweeping with linear or logarithmic sweep modes. Start, Stop, and sweep speed settings are entered into the FireFox synthesizer via the keypad. Sweeps can be repetitive, or single-shot. The RF output is leveled during sweeping.

1.6.9 Differences between Desktop unit and OEM module

The FireFox OEM module is identical to the circuit board used in the FireFox desktop unit. The desktop unit adds a power supply, and a high-quality metal enclosure with keypad, LCD, and connectors to the FireFox OEM module allowing the unit to be used on a lab bench with easy access to all IO connections. The FireFox OEM module allows integration of the unit in space-constrained applications where control via the serial ports or fixed-frequency settings are required. The FireFox OEM module operates from a single +12.0V DC power supply and consumes less than 8W of power, while the FireFox desktop unit can operate from 110V to 240V AC. An optional +12.0V power connector can be added to the FireFox desktop unit by the factory to allow mobile, battery-powered operation. See figure Figure 1.7 and Figure 1.8 of the FireFox OEM module.

Figure 1.7   FireFox OEM Module System Board Bottom
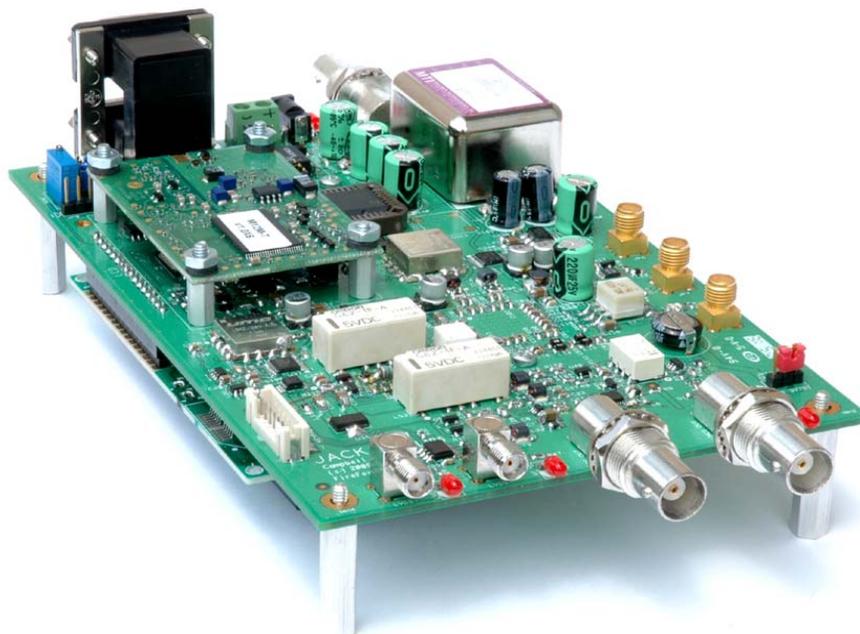
Figure 1.8   FireFox OEM Module System Board Top

1.6.10 Generic Mixer

The FireFox synthesizer includes a generic broadband mixer that is accessible via three SMA connectors (FireFox OEM module) or three BNC connectors (FireFox desktop unit). The mixer can be disabled via the front panel keypad for power savings and interference reduction.

The FireFox mixer is completely independent of any other function of the FireFox unit, and can be operated independently of other signals on the FireFox synthesizer. Typical applications of the FireFox mixer however would use the FireFox analog RF output as the Local Oscillator (LO) driver of the FireFox mixer. The RF input of the mixer could then be connected to an external LNA buffer and band-select filter. The Intermediate Frequency (IF) output of the mixer can then be connected to IF demodulators etc.

Using the FireFox RF output as an LO signal source for the mixer allows frequencies up to 2GHz to be mixed down to the 350MHz bandwidth of the mixer output. Care must be exercised to avoid driving the mixer input above +10dbm because this would cause damage to the mixer input. The RF output of the FireFox synthesizer is easily capable of generating damaging signal levels above the +10dbm damage-level of the Mixer inputs.

2 SCPI Remote Control

2.1 RS-232 SCPI Remote Control

Beginning with Firmware Release 3.0, the FireFox Signal Generator can be controlled remotely through a serial RS-232 connection via the built-in *System* RS-232 port located on the back-panel. The supported commands are compatible with the industry standard SCPI-99 protocol. The SCPI protocol originated from HP and the later IEEE GPIB standard commands, and is widely used in the industry to control instruments similar to the FireFox.

The FireFox SCPI implementation adheres to the SCPI-99 standard, and achieves compatibility with popular competitive Signal Generators and their typical command sets. This assures an effortless transition of user-installed legacy software, with most software implementations working out-of-the-box without any modification at all.

2.2 SCPI Introduction

Additional information regarding the SCPI protocol syntax can be found on the following web site: *http://www.scpiconsortium.org*. Please refer to the document *SCPI-99.pdf* for details regarding individual SCPI command definitions.

A basic familiarity with the SCPI protocol is recommended when reading this chapter.

The FireFox belongs to the SCPI-defined instrument Class "RF & Microwave Sources" and implements all the commands necessary to control the output frequency, phase, power and the sweep functionality.

2.3 Initiating SCPI Control Mode

The FireFox Signal Generator is controlled by the front-panel keypad by default. The remote control mode using the SCPI commands is disabled by default, and needs to be initiated via manual key commands. The FireFox SCPI remote control is activated by setting the *SCPI Mode* tag located under the *SETUP/COMMUNICATION* menu option. The user can access this menu option by using the front-panel keypad. The FireFox Signal Generator will remain in SCPI mode until the key *Menu* is pressed on the keypad.

By entering the SCPI mode, the SCPI command **RST* is automatically executed, thus initiating the unit into a default state.

2.4 Serial Communication Setup

The RS-232 serial configuration used in the FireFox Signal Generator is 8-bit word-length, no parity, 1 stop-bit. A Windows Hyper-Terminal is sufficient to transfer commands into the FireFox Signal Generator (turn *echo* on as described in section 2.5.8.1.2 .to see your typing).

2.5 Support for IEEE488.2 Mandated Commands

The SCPI standard requires several commands to be implemented for full standard compliance. The following list describes these mandated commands. These commands are not required for the operation of the FireFox Signal Generator, they are only provided for standard compliance.

*IDN?

This commands identifies the Firefox and will display the following string:

Jackson-Labs, FireFox Synthesizer, Firmware Rev [x].[x]

*RST

This command sets back the default values of the Frequency and Sweep subsystem. No signal is being generated.

Power is set to the minimum of -40dBm and the phase offset is set to 0 Degrees. The serial speed and echo status remain unchanged after a *RST command.

*ESR?

This command queries the contents of the Standard Event Status register (SESR) as defined by IEEE488.2

Only the followings bits are managed:

- bit 4: Execute error. This bit is set whenever an error occurred in the execution of a command.
- bit 5: Command error. This bit set whenever a command with a wrong syntax is received
- bit 7: Power On. This bit is set at all time.

*ESE

This command sets the contents of the register Standard Event Status Enable register. It is a mask specifying which bit of the Standard Event Status register should be displayed in the ESR register.

*ESE?

This command queries the value of the register SESE.

*CLS

This command clears the register OPER, SESR and ESE.

OPER?

This command is the query of the OPERation status register. Only bit3 (Sweeping) is actually currently managed. All the other bits are set to zero.

2.5.1 Frequency Subsystem

The FireFox Signal Generator has two output operating modes: Continuous Wave (CW) and Sweeping Mode. The Frequency sub-system gives the user the capability to program the front-panel static output frequency when the unit is in Continuous Wave (CW) mode, and allows the selection of sweep parameters when in sweep mode. In sweep mode, the unit may generate a frequency sweep between any two arbitrary frequencies ranging from 0Hz to 1640MHz.

Two commands exist to control frequency sweeping: **SOURCE:FREQUENCY** and **SOURCE:SWEEP**

2.5.1.1 [SOURce]:FREQuency

The supported options are:
- [:CW|:FIXed] <numeric_value> <unit>
- :MODE <CW|FIXed|SWEep>
- :CENTer <numeric_value> <unit>
- :SPAN <numeric_value> <unit>
- :STARt <numeric_value> <unit>
- :STOP <numeric_value> <unit>

2.5.1.1.1 [SOURce]:FREQuency:CW

The Continuous Wave or FIXed node is used to select a single output frequency. This node is optional. The units supported are "Ghz", "Mhz", "Khz", "Hz", "uHz".

By default, when no units are specified, the value is considered to be in Hertz.

If the output state is turned on as described in section 2.5.5.1 and the frequency mode is CW, the frequency output will be changed immediately upon reception of the command.

This command is an alias of the command FIXed.

2.5.1.1.2 [SOURce]:FREQuency:MODE

This command changes the FireFox mode. Only two modes are supported: Sweep or CW. The FIXed mode is an alias of the CW mode.

2.5.1.1.3 [SOURce]:FREQuency:CENTer <numeric_value>

This command sets the Center frequency. The change of this value will affect Start and Stop frequency in the following way:
- Start = Center – Span/2
- Stop = Center + Span/2

The numeric value is interpreted as in the command *CW.*

On **RST*, the CENTer frequency is set to 1.64Ghz/2 = 820.0Mhz

2.5.1.1.4 [SOURce]:FREQuency:SPAN <numeric_value>

This command sets the range for the frequency sweep. Changing this value will affect the Start and Stop frequency in the following way:

- Start = Center – Span/2
- Stop = Center + Span/2

The numeric value is interpreted as in the command *CW.*

On **RST*, the SPAN value is set to 1.64Ghz

2.5.1.1.5 [SOURce]:FREQuency:STARt <numeric_value>

This command sets the Start frequency for the sweep configuration. The change of this value will affect Center and Span in the following way:

- Center = |Stop -Start|/2
- Span   = | Stop – Start |

The numeric value is interpreted as in the command *CW.*

On **RST*, the STARt value is set to 0Hz

2.5.1.1.6 [SOURce]:FREQuency:STOP <numeric_value>

This command sets the Stop frequency for the sweep configuration. Changing this value will affect Center and Span in the following way:

- Center = |Stop -Start|/2
- Span   = |Stop – Start|

The numeric value is interpreted as in the command *CW.*

On **RST*, the STOP value is set to 1.64Ghz.

2.5.2 Sweep subsystem

The SWEEP subsystem commands allow more detailed control of the FireFox sweep functionality than the FREQUENCY subsystem commands provide.

The FireFox Signal Generator can be used as an SCPI controlled or manually controlled RF sweeping signal generator with leveled output. The output signal level is highly accurate (within +/-1dBm) and the frequency update rate is in excess of 500 updates/s in Software controlled mode, and 125Mupdates/s in Hardware controlled mode. Sweeps can range from 0Hz to 1640MHz, and several sweep modes are available including single sweeps and repetitive sweeps.

2.5.2.1 [SOURce]:SWEep

:MODE   < HW | SW>

: DWELl   <numeric value>

: POINTs <numeric value>

:TIME <numeric value>

:STEP?

:GENeration   <ANALog | STEPped>

: SPACing <LINear | LOGarithmic>

: DIRection <UP | DOWN| UPDOWN>

:COUNt <numeric value>

This command controls the Frequency sweep functionality of the FireFox. The RF output power is leveled during frequency sweeping, and the output level is set by the power command described in Section 2.5.3.1 . Leveling the RF output power allows the frequency sweeping mode to be used to measure frequency responses of filters, amplifiers, cables, etc. with a very high level of accuracy. FireFox sweeps can also be used with Spectrum Analyzers and Directional Couplers to provide full Network Analyzer functionality.

2.5.2.2 [SOURce]:SWEep:MODE <HW | SW>

This command selects between the Software-Controlled sweeping mode and the Hardware-Controlled sweeping mode.

Sweeps will affect the LVDS, CMOS, and RF outputs of the FireFox simultaneously.

In the Software-Controlled sweeping mode the microcontroller controls the frequency of the DDS and changes it incrementally at high speed thereby sweeping the output frequency between the Start and Stop frequencies. This mode has the advantage that the RF level of the output is calibrated throughout the sweep. Sweeping in software mode is available throughout the entire FireFox frequency range [0Hz to 1640MHz]

The Hardware-Controlled mode uses the DDS circuitry directly by automatically incrementing hardware counters inside the DDS chips. This mode allows extremely fast sweeps with frequency update rates of up to 125Mupdates/s with a limited frequency range of [2Mhz to 390Mhz]. The output RF power is not calibrated in HW sweep mode.

Upon *RST, the Sweep MODE is set to SW

2.5.2.3 [SOURce]:SWEep:DWELl <numeric value>

This command controls the amount of time in seconds spent at each point during a sweep.

In Software-Controlled sweeping mode, this value must be in the range [0.001, 1000] with a resolution of 0.001 s.

In Hardware-Controlled sweeping mode, this value must be in the range [8.e-9, 5.2428 e-4] with a resolution of 8ns

.

Upon *RST, this value is 0.001 s.

2.5.2.4 [SOURce]:SWEep:POINTs <numeric value>

The number of points in a stepped sweep. This parameter is not used if GENeration is ANALog.

In a linear sweep, this value is coupled to sweep step by the equation: STEP = SPAN/(POINts-1). If POINts are changed, STEP will also be changed, but not SPAN. In a logarithmic sweep, POINts will determine the number of points/decade of sweep by the equation: POINts/DECADE = (POINts-1)/SPAN (in decades)

Upon *RST, this value is set to 2.

2.5.2.5 [SOURce]:SWEep:TIME <numeric value | AUTO>

This command controls the duration of the frequency sweep when the command INITiate:IMMEdiate has been issued. This command can be issued at any time during a sweep but it will only be activated after the next trigger event. The time unit is in seconds.

If AUTO is selected, the sweep duration is the result of the equation :

duration = (POINts -1) * DWELl

In Hardware-Controlled sweeping mode, only AUTO can be used.

Upon *RST, the default TIME is set to 10 seconds.

2.5.2.6 [SOURce]:SWEep:STEP?

This command can only be queried on the FireFox. This value is hard coupled to SPAN and POINts by the equation: STEP=SPAN/(POINts-1)

2.5.2.7 [SOURce]:SWEep:GENeration < ANALog | STEPped >

Selects between an analog or stepped sweep :

STEPped: A stepped sweep is selected, and the points are controlled by the SWEep:POINts and FREQ:SPAN

ANALog: The sweep is contiguous. This is in fact the fastest sweep possible. This mode is only supported in Software-Controlled sweeping mode.

Upon *RST, the sweep GENeration is ANALog.

2.5.2.8 [SOURce]:SWEep:SPACing <LINear | LOGarithmic>

This command controls the pace of the sweep functionality. The logarithmic spacing is only available on Software-Controlled sweeping mode.

Upon *RST, this value is set to LINear.

2.5.2.9 [SOURce]:SWEep:DIRection <UP | DOWN| UPDOWN>

This command controls the direction of the sweep. If the direction is UP (DOWN), the sweep frequency will vary from the selected STARt (STOP) frequency to the STOP (START) frequency. The direction UPDOWN is a proprietary setting that allows the sweep to go up from the STARt frequency to the STOP frequency and decrease in the opposite direction. In this case, the total duration of the sweep is doubled.

Upon *RST, the direction is set to UP.

2.5.2.10 [SOURce]:SWEep:COUNt <numeric value>

This command determines the number of sweeps which are enabled by a single trigger event. This command has no effect if the Continuous trigger is used.

Upon *RST, this value is set to 1.

2.5.2.11 Software-Controlled Sweep configuration example

Complete command syntax style:
SOURce:FREQuency:MODE SWEep
SOURce:FREQuency:STARt 100 Mhz
SOURce:FREQuency:STOP 1 Ghz
SOURce:POWer 2
SOURce:SWEep:MODE SW
SOURce:SWEep:SPACing LOGarithmic
SOURce:SWEep:TIME 30
SOURce:SWEep:GENeration ANALog
OUTPut ON
INITiate:IMME

Alternative abbreviated style resulting in the same output sweep:
FREQ:MODE SWE; STAR 100Mhz;STOP 1Ghz
POW 2
SWE:MODE SW;SPAC LOG;TIME 30;GEN ANAL;COUNt 1

OUTP 1

INIT:IMME

Both command formats will initiate a software-controlled sweep with logarithmic frequency update rate from 100Mhz to 1GHz with an RF output amplitude of +2dBm. The total duration of the sweep will be 30 seconds.

2.5.2.12 Hardware-Controlled Sweep configuration example

Complete command syntax style:

SOURce:FREQuency:MODE SWEep

SOURce:FREQuency:STARt 10 Mhz

SOURce:FREQuency:STOP 390 Mhz

SOURce:POWer 2

SOURce:SWEep:MODE HW

SOURce:SWEep:GENeration STEPped

SOURce:SWEep:POINTs 3801

SOURce:SWEep:DWELl 1.e-6

SOURce:COUNt 10

OUTPut ON

INITiate:IMMe

Alternative abbreviated style resulting in the same output sweep:

FREQ:MODE SWE; STAR 10Mhz;STOP 390Ghz

POW 2

SWE:MODE HW;GEN STEP;POINTs 3801;DWELl 1.e-6;COUNt 10

OUTP 1

INIT:IMME

This command setup will initiate a hardware-controlled stepped sweep with linear frequency update rate from 10Mhz to 390 GHz with an RF output amplitude of +2dBm. Each frequency step will be of (390 – 10)Mhz/(3801-1) = 100 Khz and will last 1 microsecond. The sweep duration will last 3.8 ms and will be repeated a total of 10 times.

2.5.3 Power Subsystem

The Power Subsystem controls the output power of the FireFox RF output BNC connector.

2.5.3.1 [SOURce]:POWer[:LEVel] [IMMEdiate][:AMPLitude] <numeric_value>

This command sets the actual magnitude of the output signal in SWEEP and CW mode. The unit is defined in dBm. On *RST*, the power magnitude is set to the minimum of -40dBm.

2.5.4 Phase Subsystem

The FireFox DDS provides a 14-bit internal phase control. The phase can be changed in relation to the back panel GPSDO 10MHz reference output. The phase can be controlled over the a complete 360 degrees cycle.

2.5.4.1 [SOURce]:PHASe[:ADJUST]   <numeric_value> <unit>

This command controls the phase offset value relative to the GPS Disciplined OCXO (GPSDO) reference. The phase value can be expressed in radians (no suffix) or in degrees (suffix DEG), and should be defined in the interval [-PI,PI] radians or [-180, 180] Degrees.

On *RST*, this value is set to 0.

2.5.5 Output Subsystem

This command controls the RF output connector of the FireFox Signal Generator.

2.5.5.1 OUTPut[:STATe]   <ON | OFF>

This command controls the RF output of the Firefox. At *RST, the output state is OFF. The output state has to be ON for CW and SWEEP to generate a signal on the RF port.

2.5.6 Initiate Subsystem

The Initiate Subsystem controls the sweep functionality of the FireFox Signal Generator.

2.5.6.1 INITiate:

The supported options for this command are:
- :CONTinuous[:ALL]   <ON | OFF>
- :IMMEdiate

The INITiate subsystem is used to control the initiation of the Sweep subsystem.

INITiate:CONTinuous[:ALL]   <ON | OFF>

This command puts the Sweep subsystem in continuous mode. If the output is ON and the Frequency mode is SWEep, the sweep is going to start and will continue until an Initiate:Continuous OFF command is issued.

On *RST, INITiate:CONTinuous is set to OFF.

INITiate:IMMEdiate

This command issues a trigger event and will start the frequency sweep only if the following conditions are met:

- the output is ON
- the Frequency mode is set to sweep

If the conditions are not met at the time of the trigger, the command is simply ignored. The sweeping will stop when the STOP frequency is reached.

2.5.7 Measure Subsystem

Only the Temperature query of the Measure subsystem is implemented.

2.5.7.1 MEASure:TEMPerature

This command is used only to query the temperature of the OCXO.

- MEASure:TEMPerature? <cr>

2.5.8 System Subsystem

Only the Communicate command of the System subsystem is implemented.

2.5.8.1 SYSTem:COMMunicate:SERial

The supported options for this command are:

- BAUD <numeric_value>
- ECHo ON | OFF

2.5.8.1.1 SYSTem:COMMunicate:SERial:BAUD <numeric_value>

This command sets the speed of the RS232. The supported Baud rates are 9600,19200, 38400,57600 and 115200 bits/s. The Baud rate changes immediately upon reception of this command. The serial speed can also be queried' or changed through the keypad interface

This value is not affected on *RST and it is stored in the non-volatile EEPROM. Please check this setting in the menu if communication to the FireFox Signals Generator is not possible, the Baud Rate may have been set and stored at an incorrect value.

2.5.8.1.2 SYSTem:COMMunicate:SERial:ECHO ON|OFF

This command enables the echo functionality on the RS-232 port. This option is convenient when the FireFox is directly controlled via a VT100-like terminal. When the ECHO functionality is on, the <backspace> character is recognized and correctly managed.

This value is not affected on *RST.

2.5.9 Miscellaneous proprietary commands

In order to facilitate use of the SCPI commands, the following proprietary commands have been added.

2.5.9.1 HELP?

This command give a summary of all the SCPI commands available on the FireFox Signal Generator.

2.5.9.2 SOURCE?

This command displays the setting of the entire source subsystem.

2.6 SCPI Command Examples

The following examples showcase how the SCPI interface commands may be used to operate the FireFox Signal Generator.

2.6.1 Setting the FireFox into Continuous Wave Mode

Complete command syntax style:
- SOURce:FREQuency:CW 123.456 Mhz <cr>
- OUTPut   ON
- POWer   0

Alternative abbreviated style:
- FREQ 123456000 <cr>
- OUTP 1<cr>
- POW 0 <cr>

Both command formats will configure the FireFox Signal Generator to output the Frequency 123.456MHz with an amplitude of 0dBm

2.6.2 Configuration and Settings Query

Most commands can be queried by using the question mark (?) symbol behind the command.
- pow?

would return the output power value to the RS-232 port.
- freq?

would return the frequency.

The complete command syntax may also be used in compliance to the SCPI standard:

- SOURce:POWer?

3 FAQs

3.1 Overview

The following pages try to answer commonly asked questions. Please refer to the online FAQ at www.jackson-labs.com for the most recent FAQs.

3.2 General FAQs

General FAQs discuss topics of general interest related to the FireFox operation.

3.2.1 How can the FireFox Synthesizers offer such high performance for such a low price?

From the outset the FireFox synthesizers were designed for the lowest cost possible while still beating competitive units in quality. They eliminate unnecessary features the competition may offer, yet focus on providing the best quality essential features that customers need. The FireFox synthesizers use the latest RF chips, Microprocessors, FPGA's and discrete components available on the market to significantly reduce the component count and thus cost, while simultaneously increasing the units' reliability. Only standard, off-the-shelf components are used to guarantee a long life and support time of the unit. Other reasons are that Jackson Labs offers and supports these units directly from the factory, and does not have to maintain a high administrative, or advertising overhead.

3.2.2 How did you decide what features to include in the FireFox synthesizers?

A team of engineers each with decades of development experience designed the FireFox synthesizers. The engineers asked themselves what features they would like to see and use on a laboratory bench-top instrument most. The requirements' documents were thus designed with real-life applications in mind, and not with a focus on making marketing documents look good. Extensive customer feedback was then incorporated to fine-tune the instruments' performance, features, and firmware. Feel free to contact Jackson Labs to offer your feedback, requirements, suggestions, and questions.

3.2.3 How long does the FireFox system take to warm up?

The FireFox system typically warms up to within 10-8 within 15 minutes. Its specified operating parameters and GPS lock are typically achieved in less than 5 hours from a cold start when receiving satellites in position hold mode.

3.2.4 Why is there no power switch on the FireFox?

The FireFox is designed for permanent power-on to achieve its rated accuracy. Cold power-on requires ca. 5 hours of operation to achieve UTC lock, and the unit is kept operating to avoid this initial delay. In order to stay locked to UTC, the OCXO oscillator receives constant drift corrections from the GPS timing receiver. Over time the drift errors of the OCXO and the GPS receiver will decrease, and the system errors that need to be corrected will thus decrease as well. The unit only has to lock to UTC once after power-up, and will remain locked as long as GPS signals are received and power is supplied. Power consumption is typically low at 18W when operating from 110V AC, and less than 10W when running from a 12V DC supply.

3.3 Application/Usage FAQs

The following FAQs give useful hints in operating the FireFox Signal Generators.

3.3.1 What is the difference between the FireFox Desktop unit and the FireFox OEM PCB?

The FireFox Desktop unit uses the same FireFox OEM board that is also sold separately. The desktop unit includes a Swiss-made enclosure, a power supply, an LCD Display, a Keypad, and external connectors for all the I/O connections available on the FireFox OEM board. The FireFox OEM board is typically installed into a user enclosure, and statically set to a fixed frequency, or controlled via the built-in RS-232 serial port.

3.3.2 What applications is the FireFox Synthesizer designed for?

The FireFox synthesizer has five independent outputs to allow it to be used in almost any application that requires a highly stable and accurate analog sine-wave signal, or digital clock signal. It combines a function generator, signal generator, and GPS Disciplined frequency reference into one small unit. As a bonus, the unit also includes a generic, non-dedicated 2GHz mixer usable for building receivers, or up/down-converters.

The units' outputs are optimized for the following uses:

* High-power HCMOS 3.3V/5Vpp digital output signal, DC to 390MHz. This signal is a typical CMOS output signal that can drive an un-terminated 50 Ohm transmission line at either 5V or 3.3V peak (selectable via switch on the back panel). The output driver is strong enough to also drive 50 Ohm resistor end-terminated transmission lines up to 2.4V (5Vpp setting), which is enough signal-level to switch typical 3.3V CMOS logic or TTL inputs. The rise and fall times of this output are typically less than 1ns. The output can typically provide 32mA of drive current. This signal can

be used in any digital logic application up to 390MHz, far outperforming competitive solutions allowing it to be used in SDR, DDR, QDR memory interfaces, or as CPU master clock drivers.

* 50 Ohm AC-coupled spectrally pure RF sine-wave output from 2MHz to 1640MHz. Used in any type of communication applications that require a low phase-noise, spectrally pure output signal. Adjustable from typically less than -40dbm to up to +18dbm depending on the frequency (in relative output mode, when setting 0% to 100% output power).

* LVDS digital differential, 50 Ohm signal on two SMA connectors. Typically terminated by a 100 Ohm resistor between the two signals. This signal is used in modern high-speed interfaces such as LCD panels, FPGAs, memories etc. These signals can also be used as standard RF signals when connected via an AC coupler (output at ca. -3 to -5dbm), or as PECL differential signals when terminated to ground via two 50 Ohm resistors. The signal is being driven from 10MHz to 1640MHz, with an under-range down to 2MHz.

* BNC connector with a 10MHz very low phase-noise Reference clock output, digital CMOS 3.3V level. This signal in combination with a CMOS 3.3V level 1PPS output is similar to other frequency references on the market, and may be used as an in-house frequency standard to drive other instruments for better than 10^{-12} long term performance.

* Broadband 2GHz analog mixer. A general-purpose broadband mixer with over 350MHz bandwidth is available on the front panel. This can be used in receiver, transmitter, or transponder applications. Any RF signal up to 2GHz may be mixed with an LO signal up to 2GHz, and produce a 350MHz bandwidth IF signal. The RF signal input can be driven by a -20dbm to +10dbm signal. The LO input can typically be driven by the Synthesizers' own RF-type output (see above) at 0dbm. To avoid damage, a signal amplitude maximum of +10dbm should not be exceeded on the RF and LO inputs.

3.3.3 Can the FireFox system keypad be locked?

Yes, the FireFox keypad can be locked with jumper JP11 located on the FireFox main PCB.

3.3.4 How come the Frequency Display doesn't let me select the exact Frequency I need?

You probably have turned off Fractional-N mode (see also "Resolution" FAQ under Performance section). With fractional-N mode disabled, the frequency granularity that can be generated is 1/65536 of the granularity when the fractional-N mode is enabled.

A warning message in the LCD display shows "FractOff" to indicate that the fractional-N mode is turned off.

When the fractional-N mode is turned off, the frequency will still be increased or decreased in 10µHz steps when pressing the UP/DOWN buttons, but the display will show the actual frequency that can be generated by the DDS (closest match to the desired frequency) once the button is released.

The advantage of turning off the fractional-N mode is that the system generates an exact mathematically deterministic frequency without residual, fractional errors that are present in fractional-N mode.

3.3.5 How come the display shows "UNCAL" below 1Hz?

The DDS system resolution below 2MHz output frequencies is about 1.7764µHz. The output frequency of the FireFox can be set by the user with 10µHz resolution. This step size when combined with the DDS internal resolution of 1.7764µHz creates an average residual output error of about +-0.8882µHz.

This error becomes more pronounced as the output frequency goes below 1Hz, with a worst-case performance when selecting an output frequency of 10µHz, which is actually generated as 10.6584µHz. The worst-case error at 10µHz output is thus a significant 6.58%.

With an output frequency of say 100Hz, the error due to the DDS resolution is about $+-9 \times 10^{-9}$, which is typically negligible, but still above the FireFox OCXO accuracy when the system is locked to GPS.

An external CMOS, TTL, or PLD divider is recommended if extreme accuracy for frequencies below 100Hz is required. This divider will allow the FireFox system to run the DDS at a frequency of 100Hz or higher, preventing the residual DDS error from becoming significant.

3.3.6 What do the LED's in the front panel indicate?

The front panel outputs have frequency range limits at which their outputs are valid. The green LED's indicate when a particular output is valid and usable. The CMOS and RF outputs are disabled outside of their operating ranges. The LVDS outputs are active below their respective lower operating limit (10MHz) in an under-scan mode. Operation of the LVDS outputs in under-scan mode cannot be guaranteed, and the LVDS LED is thus turned off. The CMOS output is driven in over-scan mode between 350MHz and 390390MHz, and the CMOS LED is thus turned off in this frequency range.

3.3.7 What do I have to do to move the FireFox unit to a different location?

The FireFox unit is location sensitive due to the GPS receiver operating in location-hold mode. When factory new, the receiver averages ten thousand GPS readings to establish its permanent new location. This operation is done only once for every new location, or whenever the receiver has been turned-off long enough to discharge its internal backup batteries. It uses this location as a reference point for receiving the timing solution. Establishing a permanent position is called Auto-Survey mode, and operating with this location data is called position-hold mode.

For the FireFox unit to operate properly and within specification, the unit should be placed into Auto Survey mode any time its antenna is moved more than 30 feet (10m). This has to be done only once every time the receiver antenna is moved.

Placing the unit into Auto Survey mode also requires the antenna to have an unobstructed view of the sky for as long as it takes to receive the ten thousand 3D readings that are required to establish the final position data. After the receiver has established its permanent position, only one GPS satellite is required for synchronizing the internal OCXO, thus greatly relaxing the placement requirements of the GPS antenna (please note that the receiver requires at least 4 satellites to be operational when the T-RAIM timing mode is turned on).

3.3.8 What happens to the FireFox settings when the power is turned off?

The FireFox units have non-volatile memory that stores settings such as the frequency, amplitude, and menu options. This non-volatile memory does not require any battery backup. The unit will thus power-up with the last frequency and amplitude setting used prior to power-down.

Several important settings are stored in the GPS receiver and are backed up by a rechargeable battery that has a life span of typically several days when the unit is powered off. These settings are the position established by the Auto-Survey function and used for position-hold mode, the time offset from GMT, and the receiver operating-mode.

3.3.9 How accurate is the output power on the RF output connector?

The FireFox units offer two output modes on the RF BNC connectors, relative and absolute output mode. The operating mode is selected in the "SETUP" menu. Relative mode allows controlling the output power from 0% to 100% of the units' capability, with the actual output power level varying with the frequency. This mode allows the user to harvest the maximum possible output power the unit can generate at any given frequency. Maximum power levels in relative mode typically range from +8dBm to +18dBm depending on the output frequency.

Absolute mode is used when highly accurate power levels are required. Absolute mode sets the output power to factory-calibrated levels ranging from -40dBm to +10dBm. The output power at the RF BNC connector is accurate to within +-1dBm of the value displayed in the LCD over the units' frequency range (+-0.2dbm typical accuracy).

3.4 Hardware FAQs

These FAQs describe the hardware implementation and connectivity requirements of the FireFox Signal Generators.

3.4.1 The rear panel says: "Do not terminate CMOS outputs". Can the outputs drive 50 Ohm end-terminated cables?

The FireFox uses high speed, strong CMOS drivers to drive the rear 1PPS output, the 10MHz output, and the front CMOS output. These outputs are designed to drive unterminated (open-ended) 50 Ohm cables as well as 50 Ohm end-terminated cables. The outputs can drive a minimum of +24mA. Using unterminated cables yields 3.3V logic levels, while using 50 Ohm end-terminators will reduce the output amplitude by ca. 50% making them non TTL compatible; thus the warning label.

The CMOS output drivers used in the FireFox provide both very low jitter and a very small 1PPS delay (in the order of a couple of nanoseconds). They can drive both AC coupled, sine-wave 50 Ohm inputs as well as digital TTL/CMOS inputs and thus provide more flexibility than traditional sine-wave outputs.

3.4.2 Can the FireFox system be powered by a battery?

The FireFox system requires a regulated 12.0V power supply to operate properly. A power source such as a Lead Acid type battery will have an output voltage ranging between 11V (discharged) to over 14V (charging), and is thus not suitable for powering the FireFox board.

A 12.0V pre-regulator with over-voltage protection can be used to drive the FireFox system from a vehicle power system.

Contact Jackson Labs for modification of the FireFox desktop unit if a 12V DC input is required.

3.4.3 What are the mixer connections on the front panel used for?

The FireFox unit includes a general purpose mixer accessible from the front panel. A mixer is used to generate a signal consisting of the difference of two input signals. Mixers can be used to shift high-frequency signals into lower frequency bands. This is useful when trying to receive high frequency signals; see the following example:

An FM modulated signal at 1.40GHz is to be received using the FireFox and a standard FM radio. The input signal has to be transformed from 1.40GHz to 100MHz to be receivable by the FM Radio.

For this example, we will select a Local Oscillator (LO) Frequency of 1.50GHz. The LO input is simply driven by the FireFox RF output signal via a BNC jumper cable, so the FireFox is set to generate the 1.5GHz. The received RF input signal is then connected to the RF input. Mixing the 1.5GHz LO frequency with the 1.4GHz RF signal will generate a 100MHz mixing product (the Intermediate Frequency, or IF signal), which is basically the RF signal shifted to 100MHz. The IF output can now be connected to the FM radio tuned to 100MHz. The received signal will now be audible by the radio.

Typical signal levels at the mixer inputs are -20dBm to 5 dBm for the RF input, and 0dbm for the LO input. Care must be exercised to avoid driving the Mixer RF and LO inputs above 10dbm. Driving the inputs above this level could damage the mixer.

The mixer can be disabled in the menu settings to reduce potential interference.

3.4.4 How can I calibrate the FireFox Signal Generator?

The FireFox Signal Generator never needs frequency calibration, it automatically and continuously calibrates itself using the GPS signals.

The RF analog signal output level is calibrated at the factory, and it is recommended that the user calibrates the unit annually to maintain output amplitude accuracy in absolute power mode (when using the dBm indicator in the LCD). The unit has sophisticated calibration software built in, and it can automatically calibrate itself completely without user interaction.

You will need the following equipment to calibrate the FireFox:

1) Agilent E4418B or E4419B power meter with DB-9, RS-232 serial port option

2) Agilent 8482A power sensor (or any other Agilent power sensor with -30 dBm to 10 dBm and 2MHz to 1.64GHz range

3) Short BNC to N type adapter to connect the power sensor to the FireFox BNC RF output connector

4) RS-232 DB-9 Null Modem cable

To calibrate the FireFox RF output follow these steps after letting the equipment warm up for at least 30 minutes:

1) Connect an Agilent E4418B power meter via its RS-232 serial port to the FireFox "System" RS-232 port using a (female to female) DB-9 NULL-MODEM cable.

2) Use an Agilent 8482A power sensor, and calibrate it using the power meters' "CAL" output. Make sure to manually program the sensor correction factors into the E4418B power meter (see the power meters' and sensors' user manuals).

3) Connect the 8482A power sensor to the FireFox RF analog output through a short BNC to N type adapter. Do not use a cable to connect the sensor to the FireFox, the cable would reduce the calibration accuracy.

4) Start the calibration program in the "MENU/SETUP/CALIBRATION/SETUP" menu. You should immediately see the power meter display show varying readings and frequencies in its LCD display (the display should update once every second or so). The FireFox LCD display will also show varying power, frequency, and DAC readings.

5) After several hours, the unit will display a "power cycle now" message after the calibration has finished. Make sure to power-cycle the unit when prompted to do so, and do not interrupt the power calibration cycle.

During step 4) the unit will auto-calibrate itself - this process will take several hours to complete. The calibration parameters are stored in its internal Flash memory after the calibration process completes.

3.5 GPS Receiver FAQs

These FAQs discuss the GPS sub-section (the GPS Disciplined Oscillator or GPSDO) of the FireFox synthesizer

3.5.1 Why did you include a GPS receiver in the FireFox synthesizers?

Before FireFox, customers had to purchase a separate GPS disciplined Cesium or Rubidium frequency reference, and a synthesizer unit and connect these together to get both accuracy, and resolution. The cost of these units easily exceeds $5000, and leaves the user with two power-hungry, clunky units that have to be connected to each other.

FireFox uses an internal very high-end Motorola M12 timing receiver, which is specialized for reference timing applications. The GPS timing receiver provides the best available timing reference signal on the market by compensating for the receivers' location, thus providing a timing signal that is synchronized to within 20ns of UTC anywhere in the world. This timing signal is used to synchronize a high-end, low-noise 10MHz OCXO to UTC which itself provides the reference signal to all FireFox PLLs and the DDS. Combining both the GPS disciplined Frequency reference and the Synthesizer functionality into one unit allows exceptional accuracy (the frequency accuracy is much better than 10^{-12} long term for the 10MHz internal OCXO reference) while at the same time reducing the size, cost, power consumption, and failure rate of the units.

3.5.2 How does the FireFox handle GPS hold-over mode?

Other commercially available reference-timing receivers boast of their long hold-over circuitry performance when not being able to receive any satellites. The FireFox synthesizer uses a slightly different approach.

Instead of hoping for the best and designing circuitry for hold-over mode when the receiver cannot receive GPS satellites due to jamming or due to the low sensitivity of competitive receivers, the FireFox uses an optimized design and the best receiver available on the market to avoid any GPS receiver drop-outs in the first place. Once the receiver has established its position and is in position-hold mode, only one satellite needs to be seen by the receiver for the FireFox synthesizer to work properly. The sensitivity and jamming immunity of the FireFox GPS receiver is absolutely exceptional. Thus long hold-over periods will likely never occur even if the antenna is just placed in a window sill.

3.5.3 Can the internal GPS receiver be connected to a PC?

The FireFox internal microprocessor controls and configures the GPS receiver with default settings during power-on. A menu option allows access to the GPS serial signals via an RS-232 connector on the back panel to override these default settings. This connector may be used to optionally control the GPS receiver setup via Motorola's WinOncore12 PC software.

All features of the internal Motorola M12+ receiver can be checked and controlled via a simple null-modem serial cable. Antenna cable offset, satellite mask angles, timing information, satellite health information as well as GPS vs. UTC time-base settings are some of the parameters that may be controlled and checked via the PC software, overriding the FireFox default settings.

3.5.4 I can connect to the GPS receiver from my PC, but cannot change any settings?

The FireFox GPS receiver is controlled by its internal microprocessor by default. You can monitor all GPS parameters via WinOncore12 but you cannot change its settings in the default mode. To change the receiver settings, go to "MENU/SETTINGS/COMMUNICATION/GPS CONTROL" and change the item to "REMOTE". You must stay in this menu item for as long as you want to change the receiver settings via WinOncore12. Exiting this menu item will return the receiver to "LOCAL" control, and you will again only be able to monitor the receiver parameters without being able to change them.

3.5.5 What is the GPS Auto-Survey Mode?

The FireFox system uses a specialized GPS timing receiver. Instead of calculating the geographic position, this receiver uses a fixed geographic position setting to achieve a very high timing accuracy. When the present position is unknown (such as when the receiver was moved) the satellite receiver will measure and average ten thousand position measurements to achieve a position average with very high accuracy. This measurement mode is called Auto Survey Mode. The satellite receiver locks into its final position-hold mode within 2.5-5 hours, after which it will receive the position-corrected timing information from the GPS receivers. The Auto Survey mode settings are saved in NV

memory, and the mode will not have to be invoked again unless the unit is turned off for longer than 2 days (typically) or the units' antenna is moved more than 30 feet.

3.5.6 What is the T-RAIM mode in the GPS receiver?

The FireFox GPS receiver includes an optional Motorola Time RAIM (Time-Receiver Autonomous Integrity Monitoring) algorithm for checking the timing solution integrity. This mode is invoked via the front-panel menu, and allows the GPS receiver to check the quality of a satellite receivers' signal. It will mask off signals from Satellites that indicate any fault conditions, or if the particular GPS signal is outside certain limits compared to three or more other satellite signals. This Algorithm prevents faulty satellites, or adverse atmospheric conditions from affecting the precision of the FireFox synthesizer. T-RAIM is unique to the FireFox system and its' Motorola GPS timing receiver.

3.5.7 Why did you not use a cheap, standard GPS receiver?

Competitive products use standard GPS receivers to save cost, or because they were designed prior to GPS timing receivers becoming available. These receivers are optimized for navigational purposes, and do not include the benefits of position-hold mode and T-RAIM (see above). Their tracking filters need to be very wide to allow for speed and directional changes, translating into much larger inaccuracies in the timing reference output. The timing receiver is typically stationary, and thus allows for much smaller bandwidth tracking filters, increasing the timing solution accuracy significantly. Comparable navigational receivers have a typical accuracy of 100ns rms, whereas the receiver used in the FireFox units has a down to 10ns or better 1-Sigma timing resolution due to its optimized small bandwidth tracking filters (2ns solutions are possible when using optional sawtooth correction). The FireFox units further increase the accuracy of the timing solution and the receiver sensitivity by enclosing the receiver into a shielded metal can to mitigate the effects of temperature changes and EMI, and by rigorously filtering all power supply voltages prior to entering the timing receiver.

3.5.8 What types of GPS antennae are supported?

The FireFox system supports both 3.3V and 5V GPS antennae via a standard BNC connector. Jumper JP4 on the PCB can be set for either 3.3V or 5V output. Many 5V rated antennae will also work with a 3.3V setting. Jackson Labs recommends mounting any outdoor antennae with proper lightning precautions.

3.5.9 What do the SAT and STAT items in the LCD display indicate?

The SAT number indicates the number of satellites that are presently being received and used for the timing solution. The STAT item is a status indicator, having the following meaning:

BG - Bad Geometry. This indicates that the satellite positions are not differentiated enough to be usable in Auto-Survey mode.

AQ - Acquiring. This indicates that the unit is looking for satellites to track.

UL - Unlocked. The unit is receiving satellite timing information, but has not finished locking the OCXO to UTC yet.

AS, 3D, 2D - Position fixes. The unit is receiving 3D or 2D position fixes when in Auto Survey mode. Ten thousand readings are required to finish Auto Survey mode.

OK - Position hold mode with locked OCXO. The unit has locked the OCXO to UTC, and sufficient satellites are being received to maintain lock.

3.6 Performance FAQs

The following FAQs describe the performance of the FireFox Signal Generators, and it's features.

3.6.1 How does the FireFox Synthesizer offer such wide bandwidth?

The FireFox synthesizers' internal circuitry divides the output bandwidth into four bands, with each band optimized to reduce noise, spurs, and to offer the best linearity possible. The frequency bands are: DC (0.00001Hz) to 30MHz, 30MHz to 390MHz, 390MHz to 770MHz, and 770MHz to 1.64GHz. These bands are switched seamlessly in the background. A Direct Digital Synthesizer (DDS) with a 10-bit DAC and 1GHz sample rate generates the first two bands (DC to 390MHz). Frequencies above 390MHz are generated by a very low phase noise PLL controlled VCO phase-locked to the internal DDS.

3.6.2 How can spur performance be increased even further?

An LC-type output filter can be used to reduce out-of-band spurs. These filters can be designed with public-domain software (see for example "Elsie", an easy to use filter designer available at www.tonnesoftware.com), or these can be purchased off-the-shelf. Mini Circuits (www.minicircuits.com) offers such filters as small inexpensive ceramic components in their LFCN and HFCN series filters.

3.6.3 Does the FireFox need calibration?

The FireFox system never needs frequency calibration; it is constantly being calibrated by the GPS timing signal. The FireFox RF output amplitude has been calibrated at the factory, and it is recommended that the unit is returned to Jackson Labs once a year for amplitude calibration. The user may also self-calibrate the FireFox units using an Agilent power meter; see the hardware FAQ.

3.6.4 There is a Frequency Estimate display in the menus. What is this number?

The FireFox system constantly measures the internal OCXO offset to the GPS 1PPS signal. This measurement is done in 10ns steps (100MHz sampling). The firmware then adjusts the OCXO steering voltage (Electronic Frequency Control - EFC) to compensate for any drift between the OCXO and UTC. The timing differences between the OCXO and the 1PPS signal are stored in memory once per minute over a 30-minute period. The momentary difference is then compared to the difference that was measured 30 minutes ago, and a drift is calculated from these two values. Thus an

estimate of the overall time base drift over the last 30 minutes can be established. This drift is typically less than +5x10^-11 over a thirty-minute period when locked to the GPS signal.

As an example, let's assume the Frequency Estimate display indicates 1.6 x10^-11. At 100MHz output frequency we can calculate the estimated accuracy of the output signal to be:

100MHz * 1.6 x10^-11 = 0.0016Hz

Thus the absolute frequency error of the output (to the UTC atomic reference) is estimated to be 1.6mHz, and the output frequency is thus estimated as 100,000,000.0016Hz.

3.6.5 There is a Resolution number displayed in the menus. What is this number?

This value shows the minimum step resolution that the DDS can generate in the particular frequency band it is operating in.

The DDS system has 32bit integer accuracy with an additional 16bit fractional component. The resolution is applied to three frequency ranges (DC-390, 390-770, 770-1640MHz). The effective frequency resolution is thus over 48bits.

This resolution determines the smallest frequency step size that can be generated by the DDS system, and thus determines the residual mathematical error of the system. The smallest fractional frequency step that can be generated in Fractional-N mode is smaller than the 10µHz step size of the FireFox system, and the value displayed in the LCD can thus be used to estimate the frequency error at any particular frequency.

See also the Fractional-N mode FAQ.

3.6.6 There is an option to turn Fractional-N mode on/off. What is this used for?

This setting option allows exact, cycle-accurate coarse frequencies to be generated (32bit integer mode), or frequencies with a much finer resolution (48bit fractional mode) but with a very small fractional residual uncertainty.

Consider the following explanation:

the DDS has a 32bit integer component. This integer component alongside the 1Gs/s sample rate allows 2^32 individual frequencies to be generated without any residual error according to the following formula:

Fout = (32bit Tuning Word * 1GHz)/ 2^32

This formula is accurate for output signals from 2MHz to 390MHz. Use the following formulas to determine the resolution of the output signal for the remaining frequency bands:

DC to 2MHz: Fout = (32bit Tuning Word * 0.5GHz)/ 2^32

390 to 770MHz: Fout = (32bit Tuning Word * 2GHz)/ 2^32

770MHz to 1640MHz: Fout = (32bit Tuning Word * 4GHz)/ 2^32

The frequencies generated with fractional-N mode turned off are thus cycle-accurate without any slipped cycles or residual frequency error. As an example, consider the following example of generating a 10MHz frequency with a tuning word of 4294967296:

10.0MHz = (4294967296 * 1GHz)/ 2^32

The advantage of integer mode is thus that this particular tuning word generates a cycle-accurate, phase-drift-free 10MHz signal without any cycle slipping, or residual. The phase angle to the internal 10MHz OCXO is fixed, and remains drift free. The disadvantage of this mode is its granularity, which is limited by the 32bit tuning word.

The frequency granularity with fractional mode turned off, and an output frequency ranging from 2MHz to 390MHz is thus exactly 0.2328306436538696 2890625Hz. Keep in mind that the absolute accuracy of the output signal is limited by the accuracy of the 10MHz reference signal from the OCXO.

To improve the frequency granularity of the output signal, a fractional-N mode can be enabled that increases the frequency resolution by an additional 16bits. The disadvantage of this mode is that it is not mathematically deterministic; there is a frequency uncertainty of about 1/2LSB that prevents this mode from being cycle accurate.

By increasing the DDS resolution, the DDS residual is made very small (about 1GHz / 2^48 at a 10MHz output frequency). The frequency resolution with fractional-N mode turned on is thus 3.55µHz for an output ranging from 2MHz to 390MHz.

This DDS resolution is typically less than the systems' minimum resolution of 10µHz. The system attempts to match the user selected 10µHz step setting to the closest frequency that the DDS can generate. The frequency difference between the desired setting (selectable in 10µHz steps), and the actual frequency being generated causes a very small error.

4 Auto Calibration

4.1 Introduction

The FireFox Synthesizer does not require frequency calibration, it continuously self-calibrates its internal OCXO by using the GPS timing receiver.

The FireFox Synthesizer RF output level is factory calibrated, and it is suggested that the user re-calibrates the RF output once a year to maintain an accurate output level. The unit can auto-calibrate itself using an external power meter. It contains firmware to drive an Agilent E4418B or E4419B power meter connected to an Agilent 8482A power sensor.

The following paragraphs describe how to connect the power meter to the FireFox and initiate the auto-calibration procedure.

4.2 Power Meter Setup

The power meter and FireFox synthesizer have to be warmed-up for one to two hours before the auto-calibration is started. Plug in, and turn on the power meter, and plug in the FireFox synthesizer into the wall power outlet.

After warm-up, and prior to starting the auto-calibration, the Agilent power meter needs to be properly prepared to reduce the calibration error.

4.2.1 Updating the Agilent Sensor Cal Table

The Agilent 8482A sensor has a sensor calibration table placed on its bottom. The data from this calibration table needs to be entered into, and enabled in the Agilent power meter by hand (it is then stored inside the power meter). Please follow the Agilent user manual to enter, and enable the sensor cal table data into the power meter. The power meter is not accurate without properly typing in, and enabling the calibration table in the power meter.

4.2.2 Using alternate Power Sensors, Power Meters

Other Agilent power sensors may be used if they have at least a -30dBm to +10dBm power sensing range and 100KHz to 1.7GHz frequency range.

E4418B specific control codes are sent to the Agilent power meter via the RS-232 serial port in SCPI format, so power meters that are not E4418B RS-232 SCPI compatible will not function with the FireFox auto calibration procedure.

4.2.3 Calibrating the Power Sensor

The Agilent power meter has a Power Reference output that is used to calibrate the power sensor at 50MHz. Plug-in the 8482A power sensor into the *Power Ref* output of the power meter (see Figure 4.1). Press the ZERO/CAL button on the front of the power meter, and follow the instructions in the LCD display to zero, and calibrate the sensor.

Figure 4.1   Calibrating the Agilent power sensor

The power meter is now properly prepared. Agilent recommends to recalibrate the sensor every 24 hours, or if the ambient temperature changes.

4.3 Calibration Setup

Prior to starting the auto-calibration procedure, the user must connect the two instruments to each other. Follow the procedures below to setup the calibration.

4.3.1 Sensor Connection

Connect the power sensor to the FireFox *RF Output*. See Figure 4.2. Use a BNC to N-F adapter between the power sensor and the FireFox synthesizer.

Figure 4.2   Connecting the power sensor to the FireFox RF output

Figure 4.3 shows how to connect the sensor and BNC to N adapter in detail.

Figure 4.3   Power sensor connection detail

The sensor may also be connected using a short cable, but this will affect output linearity due to cable to connector VSWR mismatch.

4.3.2 Serial Cable Connection

The power meter is controlled by the FireFox system controller via a serial port. Use a standard RS-232 Null-Modem cable with DB-9 female connectors (a suitable RS-232 cable is shipped with the FireFox Synthesizer). Connect the FireFox *System* RS-232 output to the Agilent power meters' RS-232 port. See Figure 4.4 for details on how to connect the two instruments to each other.

Figure 4.4   Power Meter Serial Communication connection

The Calibration setup is now ready to start the actual calibration procedure.

4.4 Initiating Calibration

The calibration procedure is started by the FireFox front panel keypad.
Make sure the two units are connected correctly, and follow the procedure below:

1) Press the *Menu* button to enter the menu mode
2) Scroll down and enter the *Setup* sub menu
(Continued)

Figure 4.5   Entering the Calibration sub-menu

3) Scroll down to the *Calibration* sub menu. Please note that the Calibration sub menu is on the sixth level, and thus not visible in the LCD display until you scroll above the top menu item, or below the bottom most menu item. See Figure 4.5 on how to enter the Calibration sub menu.
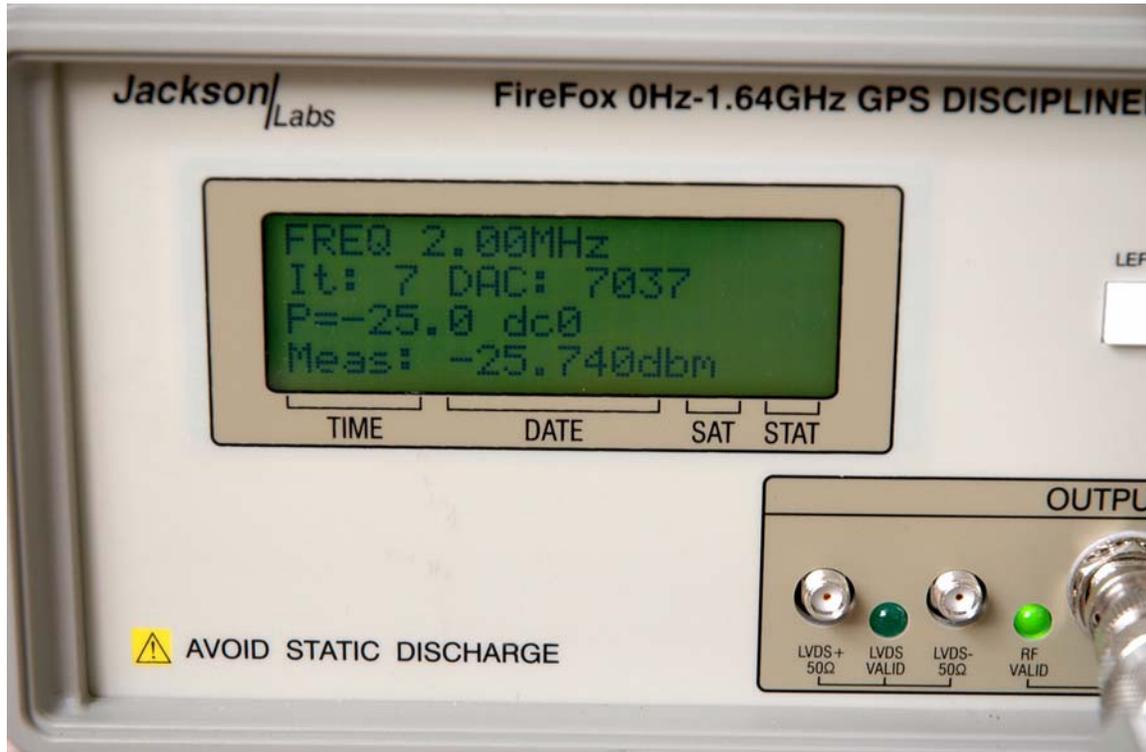
(continued)
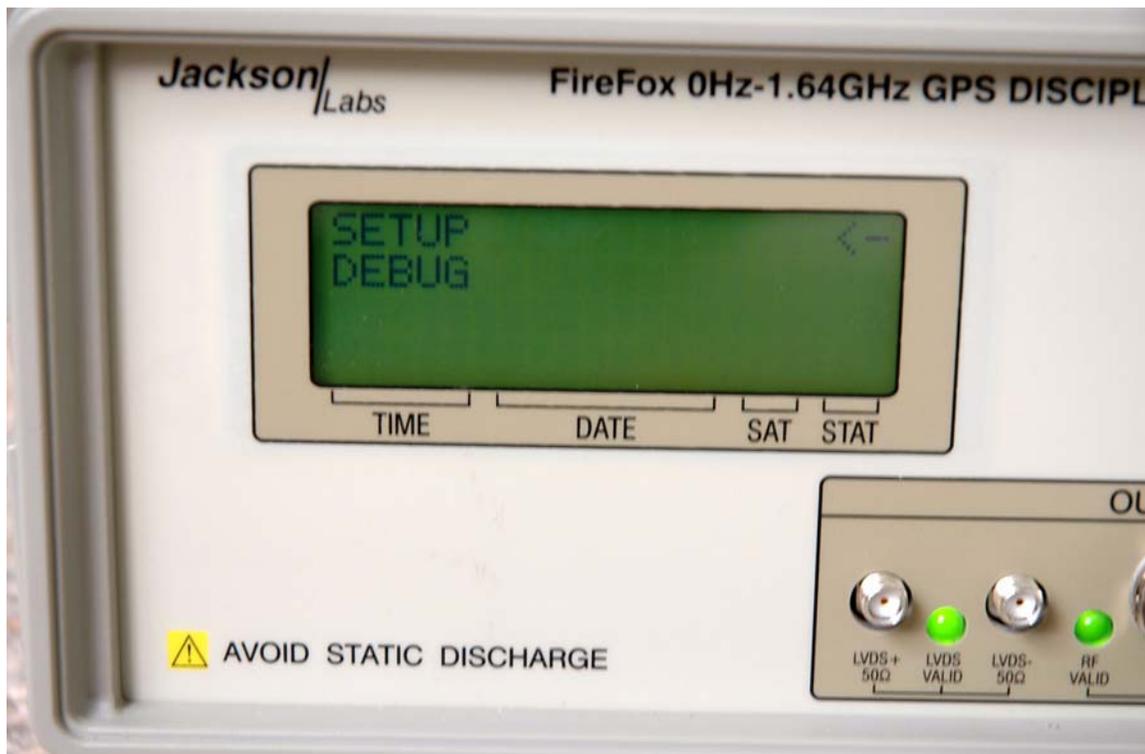
Figure 4.6   Starting the Calibration procedure

4) Enter the *Calibration* sub menu

5) Two menu items are shown (see Figure 4.6): *Setup* and *Debug.* Entering Setup will start the actual calibration procedure. Debug is used for factory testing.

(Continued)

Figure 4.7   LCD Display during calibration procedure

6) Enter Setup and verify that the LCD displays information similar to Figure 4.7

The auto-calibration procedure will take several hours to finish. **To avoid calibration errors, do not disconnect any of the cables or touch any of the buttons on either unit during the calibration procedure.**

Figure 4.8   Agilent power meter display during calibration

During calibration, the Agilent power meter will display the momentary frequency and level of the output signal being measured. The frequency will vary from 2MHz to 1640MHz (see Figure 4.8)

Please note that the Power meter has been turned into remote mode by the FireFox (*RMT* is displayed in the LCD) and the unit is communicating as evidenced by the *RX/TX* indicators. The Power meter may sometimes also display the *ERR* indicator, this indicator can be disregarded.

Please note that the power meter indicates that it is using sensor calibration table 2 with the *(2)* indication in the LCD display under the frequency. You must enter and enable the calibration table properly to avoid calibration errors.

Figure 4.9   Successful Calibration results

The unit will display a message as shown in Figure 4.9 when the calibration is finished successfully. Calibration data is only stored in Flash memory at the end of the calibration when this message is displayed.

N.B.: TO USE THE FIREFOX, YOU MUST UNPLUG THE UNITS' POWER AFTER AND ONLY AFTER THE CALIBRATION IS FINISHED AND YOU SEE THE MESSAGE IN Figure 4.9

You can verify proper operation of the FireFox RF output using the power meter as it is connected for calibration. The FireFox output power from -30dBm to +5dBm should be within +-1dBm, and are typically within +-0.2dBm after calibration when measured with the setup describe above, and if the power meter is set to the proper frequency using its *Frequency* button.