FS752 GNSS Disciplined Time and Frequency Reference

User Manual

SRS Stanford Research Systems

Distribution in the UK & Ireland

Lambda

Characterisation, Measurement & Analysis

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Revision 1.00

Certification

Stanford Research Systems certifies that this product met its published specifications at the time of shipment.

Warranty

This Stanford Research Systems product is warranted against defects in materials and workmanship for a period of one (1) year from the date of shipment.

Service

For warranty service or repair, this product must be returned to a Stanford Research Systems authorized service facility. Contact Stanford Research Systems or an authorized representative before returning this product for repair.

Information in this document is subject to change without notice.

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Contents

Revisions

Rev	Date	Changes
1.00	1/1/19	First release

Safety and Preparation for Use

Line Voltage

The instruments operate from a 90 to 132 V_{AC} or 175 to 264 V_{AC} power source having a line frequency between 47 and 63 Hz. Power consumption is less than 80 VA total. This instrument is intended to be powered at all times. Therefore, there is no power switch. Power is applied to the instrument as soon as the line cord is plugged in.

Power Entry Module

A power entry module, labeled AC POWER on the back panel of the instrument, provides connection to the power source and to a protective ground.

Power Cord

The unit is shipped with a detachable, three-wire power cord for connection to the power source and protective ground.

The exposed metal parts of the box are connected to the power ground to protect against electrical shock. Always use an outlet which has a properly connected protective ground. Consult with an electrician if necessary.

Grounding

BNC shields are connected to the chassis ground and the AC power source ground via the power cord. Do not apply any voltage to the shield.

Line Fuse

The line fuse is internal to the instrument and may not be serviced by the user.

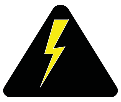
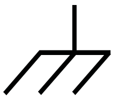
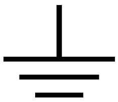
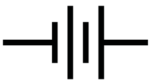
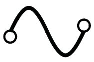
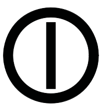
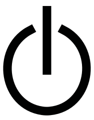
Operate Only with Covers in Place

To avoid personal injury, do not remove the product covers or panels. Do not operate the product without all covers and panels in place.

Serviceable Parts

There are no user serviceable parts. Refer service to a qualified technician.

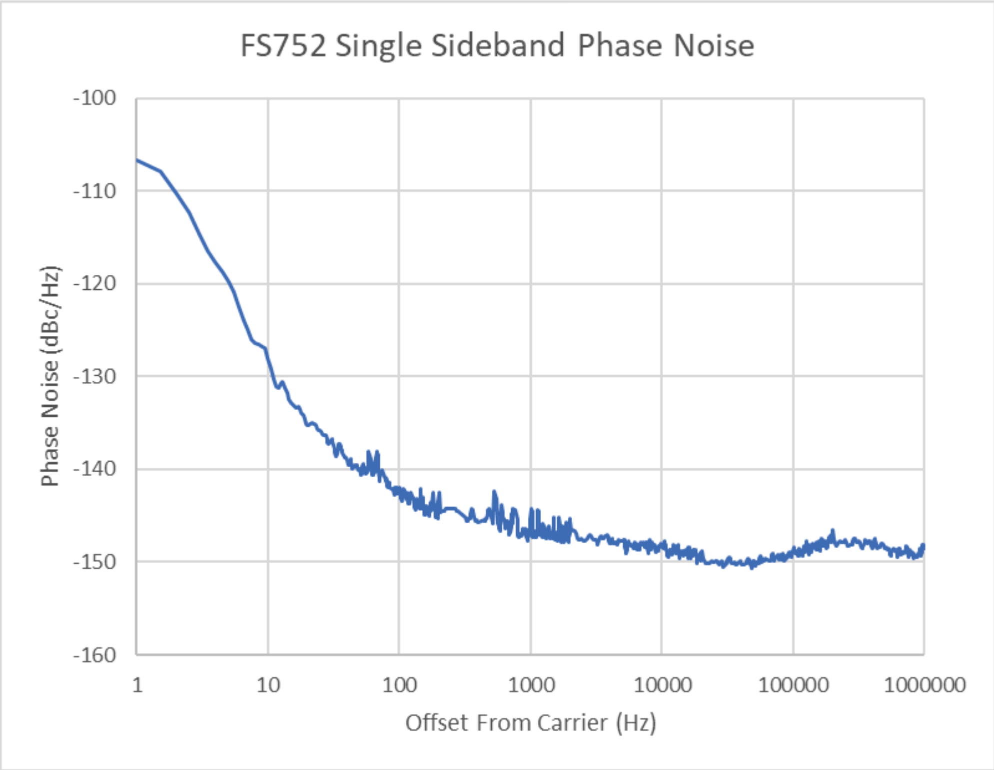
Symbols You May Find on SRS Products

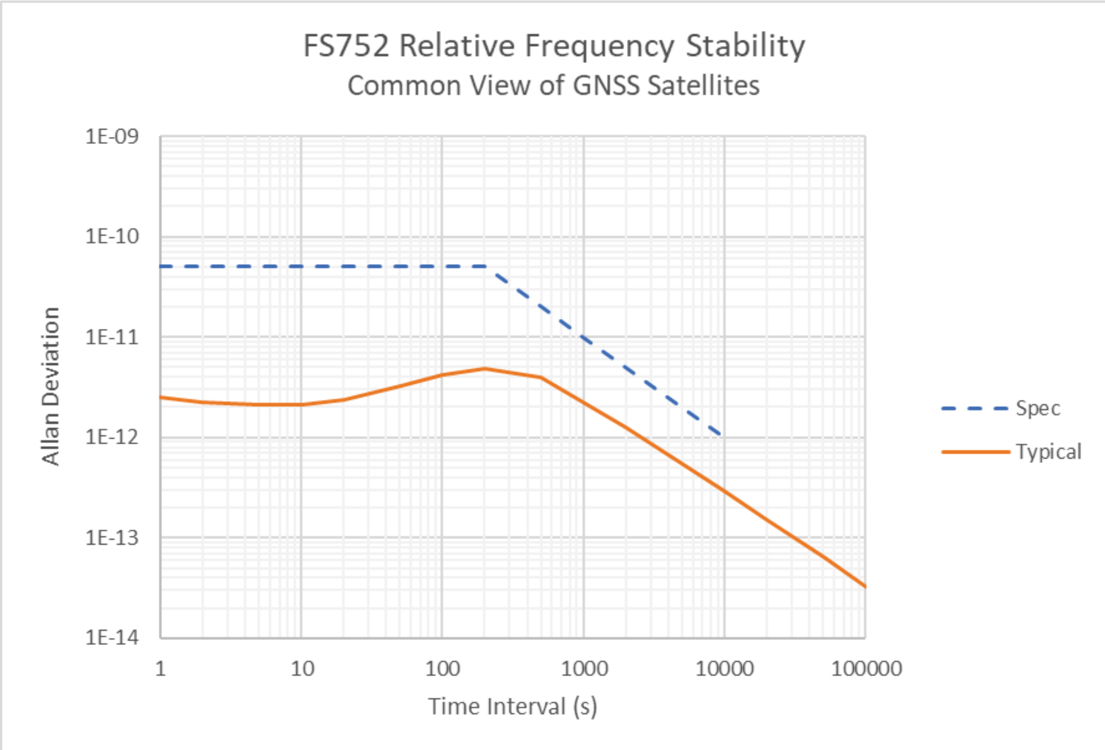
Symbol	Description
	Alternating Current
	Caution – risk of electrical shock
	Frame or Chassis terminal
	Caution – refer to accompanying document
	Earth (ground) terminal
	Battery
	Fuse
	Power On
	Power Off
	Power Standby

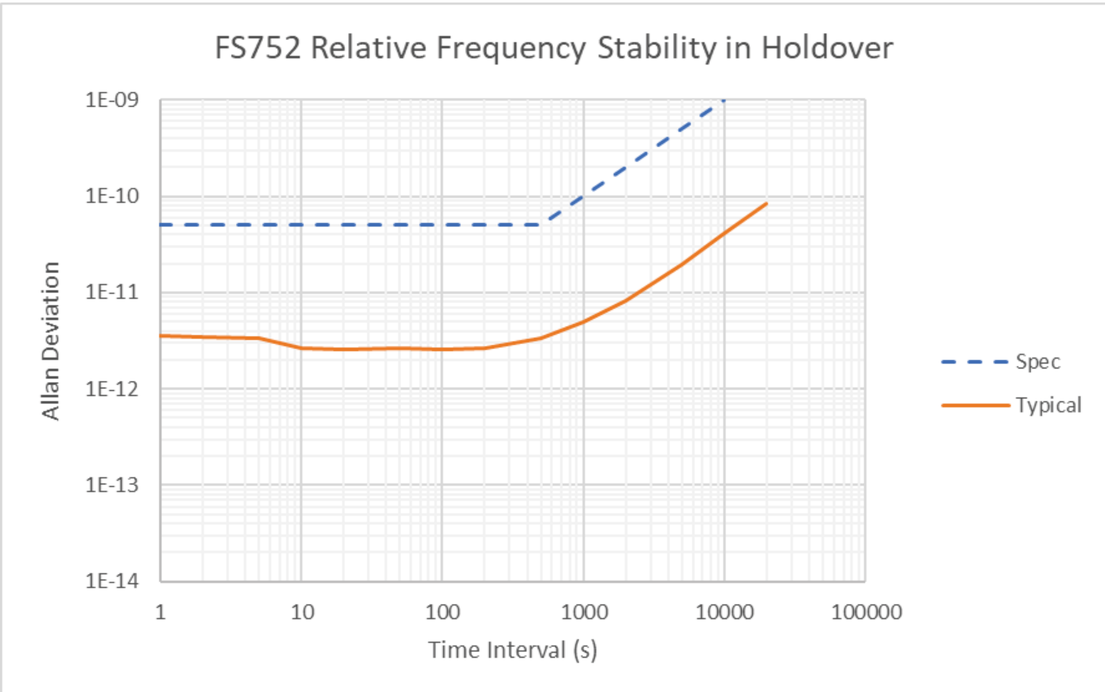
Specifications

OCXO Timebase

Oscillator type	Double oven controlled
Temperature stability	<1×10^{-9} (20 to 30°C)
Aging (undisciplined to GNSS)	<0.05 ppm/year
Phase noise (SSB)	<−125 dBc/Hz at 10 Hz offset
Stability	<5×10^{-11} (1 second) See graphs next page
Holdover	<40 µs / 24 hr




FS752 Relative Frequency Stability
Common View of GNSS Satellites
Allan Deviation
1E-09
1E-10
1E-11
1E-12
1E-13
1E-14
1
10
100
1000
10000
100000
Time Interval (s)
Spec
Typical


FS752 Relative Frequency Stability in Holdover
Allan Deviation
1E-09
1E-10
1E-11
1E-12
1E-13
1E-14
1
10
100
1000
10000
100000
Time Interval (s)
Spec
Typical

GNSS Receiver

Model	u-blox, NEO-M8T
Power on to satellite acquistion	<1 minute (typical)
Time to acquire almanac	~15 minutes when continuously tracking satellites
Optimized for static applications	Over determined clock mode enables receiver to use all satellites for timing.
Accuracy of UTC	< 100 ns
Timing wander	< 20 ns rms, clear sky < 500 ns rms, indoor
Antenna delay correction range	± 0.1 s

1 pps Output

Period	1 s
Width	10 µs
Phase accuracy to internal reference	<2 ns
Jitter	<50 ps (rms)
Level	+5 V CMOS logic
Transition time	<2 ns
Source impedance	50 Ω
Reverse protection	±5 V_{DC}

10 MHz Output (50 Ω load)

Amplitude	13 dBm
Amplitude accuracy	±1 dB
Harmonics	<–40 dBc
Spurious	<–90 dBc (100 kHz BW)
Phase settability	Phase can not be adjusted.
Output coupling	DC, 50 Ω ±2 %
User load	50 Ω
Reverse protection	±5 V_{DC}

Computer Interfaces (standard)

USB	Virtual COM port with FTDI drivers 115.2k baud, 8 bits, no parity, 1 stop bit, RTS/CTS flow

Option A: 10 MHz Distribution

Number of outputs	4
Specifications	Same as standard 10MHz output

Option B: 1 PPS Distribution

Number of outputs	4
Specifications	Same as standard 1 PPS outputs

General

Line power	<30 W, 90 to 264 V_{AC}, 47 to 63 Hz with PFC
EMI compliance	FCC Part 15 (Class B), CISPR-22 (Class B)
Case dimensions	17” × 2” × 12” (W × H × D)
Weight	<10 lbs
Warranty	One year on parts and labor

Remote Interface Commands

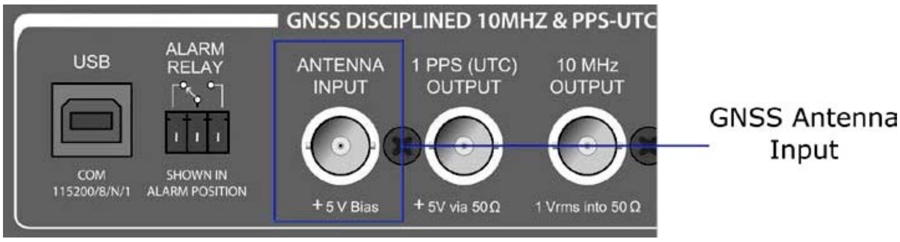
Quick Start Instructions

Installing the FS752

To setup and install the FS752 follow these steps:

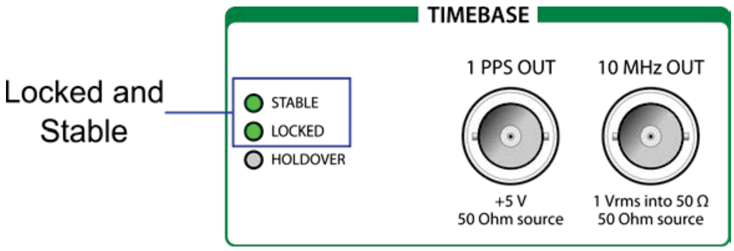
1. Install the GPS antenna in a location that has a clear view of the sky, such as the roof of a building. See below for details.

2. Connect the cable from the antenna to the rear panel input of the FS752 labeled ANTENNA INPUT.



3. Power on the FS752 by plugging in the AC power cord.

If you don't care about the absolute accuracy of the FS752's phase relative to UTC then setup is complete (otherwise, see section Configuration). The FS752 will automatically search for the GNSS satellites and lock its internal timebase to them. Once locked, the FS752 may take up to 1 hour or more to fully stabilize. When the FS752 is fully stabilized the front panel locked and stable LEDs should be on.



Installing the Antenna

Selecting a Location for the Antenna

The signals broadcast by the GNSS satellites are extremely weak and difficult to detect. Generally speaking, you will get best results if the antenna has a clear unobstructed view of the sky. This is commonly on the roof of the building within which the FS752 is located. If this is not possible, the user can try locating the antenna at a window. Doing so, however, may degrade the quality and reliability of the GPS signal as fewer satellites will typically be visible and with less SNR. This can degrade the long-term stability of the FS752 by a factor of three.

Antennas Offered by SRS

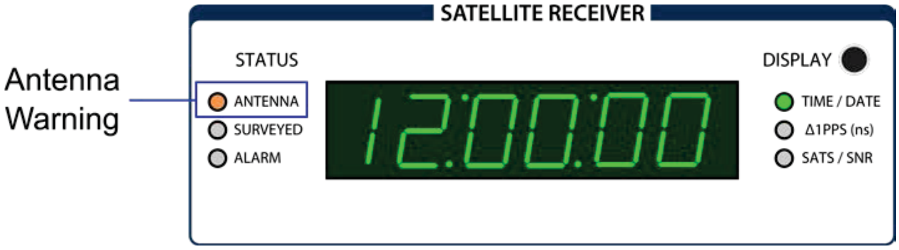
SRS offers two antenna solutions, an indoor antenna and an outdoor antenna. The indoor antenna includes the antenna and 23 feet of RG58 cable to connect the antenna directly to the FS752. The outdoor solution includes the antenna, 75 feet of low loss cable, and a complete solution for protecting the equipment from lightning strikes. The outdoor kit is described in detail below.

Active Antenna Required

The antennas provided by SRS are active antennas. An active antenna is required with the FS752 to ensure sufficient signal is available at the receiver input. The FS752 supplies 5 VDC to the antenna cable to power the active antenna. Active antennas typically have more gain and improved signal detection capability over passive antennas. They also help to overcome the signal loss introduced by long antenna cables and, therefore, are necessary.

Antenna Warning LED

The orange LED on the front panel labeled ANTENNA warns if the FS752 detects that the antenna input is either an open or short circuit. It typically goes off when the antenna is properly connected to the FS752.



The state of the LED, however, is based solely on the DC current draw on the antenna cable, not on measured signal levels. If the current draw is less than 5 mA, the FS752 will warn of an open circuit. If the current draw is greater than 75 mA, the FS752 will warn of a short circuit. The total current draw for the antenna is limited to 300 mA. Please note that the performance of the FS752 is not impacted at all if the power draw of your antenna falls outside this range, The FS752's GPS receiver will continuously search for GPS satellites regardless of the current draw on the antenna. The warning LED is merely meant to be a helpful diagnostic to consider when troubleshooting a lack of signal for the most common installations.

Antenna Delay Correction

The FS752's estimate of UTC is based on when the receiver detects the signal, not when the signal arrives at the antenna. If a long cable is needed to connect the antenna to the FS752, this delay can be significant. The typical delay for most BNC cables is 1.5417 ns per foot. Thus, for a 30 ft cable, the delay would be $1.5417\times30 = 46.25$ ns. If uncorrected, the FS752's estimate of UTC would be 46.25 ns later than a properly calibrated unit. See section Configuration for details on how to incorporate this correction into the instrument operation.

GNSS-Outdoor Antenna Kit (Model O740ANT2)

The GNSS-Outdoor Antenna Kit consists of components for the construction of a robust GPS/GLONASS antenna system. The kit includes a Trimble Bullet III GNSS omnidirectional antenna with LNA and TNC connector on a short aluminum mast. The mast has a cable access slot, silicone weather plug, and a grounding lug for lightning protection. The cap at the bottom of the mast is tapped for ¼”-20 and bolted to a magnetic mount which has a 90 lbs. (40 kg) pull rating.

The magnetic mount may be removed to allow for mounting to a shelf, bracket or cabinet. The included die cast aluminum bracket allows mounting to a wall or pole. A lightning surge arrestor and 100’ (30 m) of 10 AWG copper wire is provided for lightning protection. Two lengths (25’ and 50’) of low loss, 0.400” diameter, 50 Ω TNC extension cables (male-female, *not* RP), and a TNC to BNC adapter to connect to the SRS GNSS receiver are included.

The +32 dBi gain antenna will provide a +20 dBi signal to the receiver, allowing for up to 12 dB of cable loss. The 0.400” cables allow cable lengths up to 200’ (60 m). Inline GPS amplifiers are available from third party vendors if the antenna is more than 200’ from the receiver.

Outdoor Antenna Kit Contents

The contents of the outdoor antenna kit are detailed in Table 1. The main components are pictured in Figure 1.

Table 1: Outdoor antenna contents

Quantity in Kit	Description
	Antenna
1	Assembled antenna mast with magnetic base
1	TNC (M) to BNC (M) adapter to connect to FS752 ***
1	3/16" Allan key to remove magnetic mount ***
	Alternate mounting arm
1	Die cast aluminum mounting bracket
4	SS Wood screws (#10 x 1.5”) for mounting bracket ***
4	#10 Flat washer for mounting bracket ***
	Cables
1	LMR400, TNC (M-F), 25’ (1.4 dB loss)
1	LMR400, TNC (M-F), 50’ (4.2 dB loss)
1	100’, #10 AWG, solid, green insulation
1	Silicone tape wrap for water proofing
20	Black cable ties, UV protected, 7.5”, 50 lb. ***
	Lightening arrestor
1	10 kA lightning surge suppressor, TNC (M-F) with copper ground lug ***
2	Self-tapping #8x1/2” SS metal screws to mount arrestor ***
1	Original lug and screw for lightning arrestor ground ***

*** Hardware item is located in polybag.

Figure 1: Outdoor antenna kit

Design Considerations

There are many considerations for the design of an outdoor GNSS antenna, including:

1. An unobstructed view of the sky. If obstructions are unavoidable, a clear view of the southern sky is preferred. Also, avoid antenna placement with multipath opportunities (reflections from other structures).

2. Use of cable types and lengths with less than 12 dB of loss at 1.6 GHz between the antenna and the timing receiver. (The cables included with the kit have a total loss of 5.6 dB.)

3. Sufficient height so that the antenna will not be buried by more than 1 foot of snow.

4. Strategies to avoid lightning strikes. Avoid being the highest metal object (which, unfortunately, conflicts with a clear sky view and avoiding multipath).

5. A strategy to handle a lightning strike. This is a complicated and important topic which must be addressed to insure the safety of personnel and reduce equipment damage. The antenna mast and inline lightning surge arrestor, included with the antenna kit, must be attached to a grounded structure, or connected to earth ground via a grounding rod.

6. Compliance with local building and electrical codes.

7. Compliance with building lease term and easements.

When designing the outdoor GNSS antenna system, site specific designs and the use of other materials will be required. If additional cables are needed they should have a TNC male on one end and a TNC female connector on the other, so that they may be used as extension cables without coax barrels. These are *not* RP cables (which reverse the pin and socket of conventional connectors). The cables sold by SRS are not plenum rated. For additional TNC cables we suggest part number 28-463-050 (a 50’ cable with a typical loss of 4.2 dB) available from http://www.showmecables.com/

Mounting the Antenna

The required connections for installing the antenna are highlighted in Figure 2. The simplest semi-permanent installation uses the magnetic antenna mount placed on top of a HVAC unit on the roof. If HVAC placement is not available, the magnetic mount can be attached to a 10 lbs. weight (barbell weights work well for this purpose) and placed on the roof.

Alternatively, the magnetic mount can be removed allowing the antenna to mount to a wall or pole using the included mounting arm. The antenna may also be mounted to any horizontal surface or brace which has a ¼” diameter hole. A 3/16” hex wrench is included in the kit to remove the magnetic mount from the antenna mast. The hardware, including fiber washers to break galvanic contact, should be reused.

To connect the antenna to the coax cable, first remove the antenna from the mast. Observing the gender of both ends of the cable, thread the male end of the cable through the oval slot in the antenna mast. Remove the plastic protector from the antenna connector. Screw the cable on to the antenna connector finger tight. Push the cable down into the mast and screw the antenna onto the mast. (The TNC connector is free to rotate, and the direction of rotation will not cause the TNC to loosen.)

Lightning Protection

There are two important components for lightning protection: A ground wire attached directly to the aluminum antenna mast, and a lightning arrestor/surge absorber located where the coax cable enters the building. The arrestor has a TNC male connector on one end and a TNC female on the other and a lug for earth ground in the center. Both the antenna mast ground and the lightning arrestor must be separately connected to earth ground with #10 AWG copper wire (included with kit). All outdoor TNC connectors, including those attached to the lightning arrestor, should be protected from weather and sunlight exposure with the included silicone tape wrap.

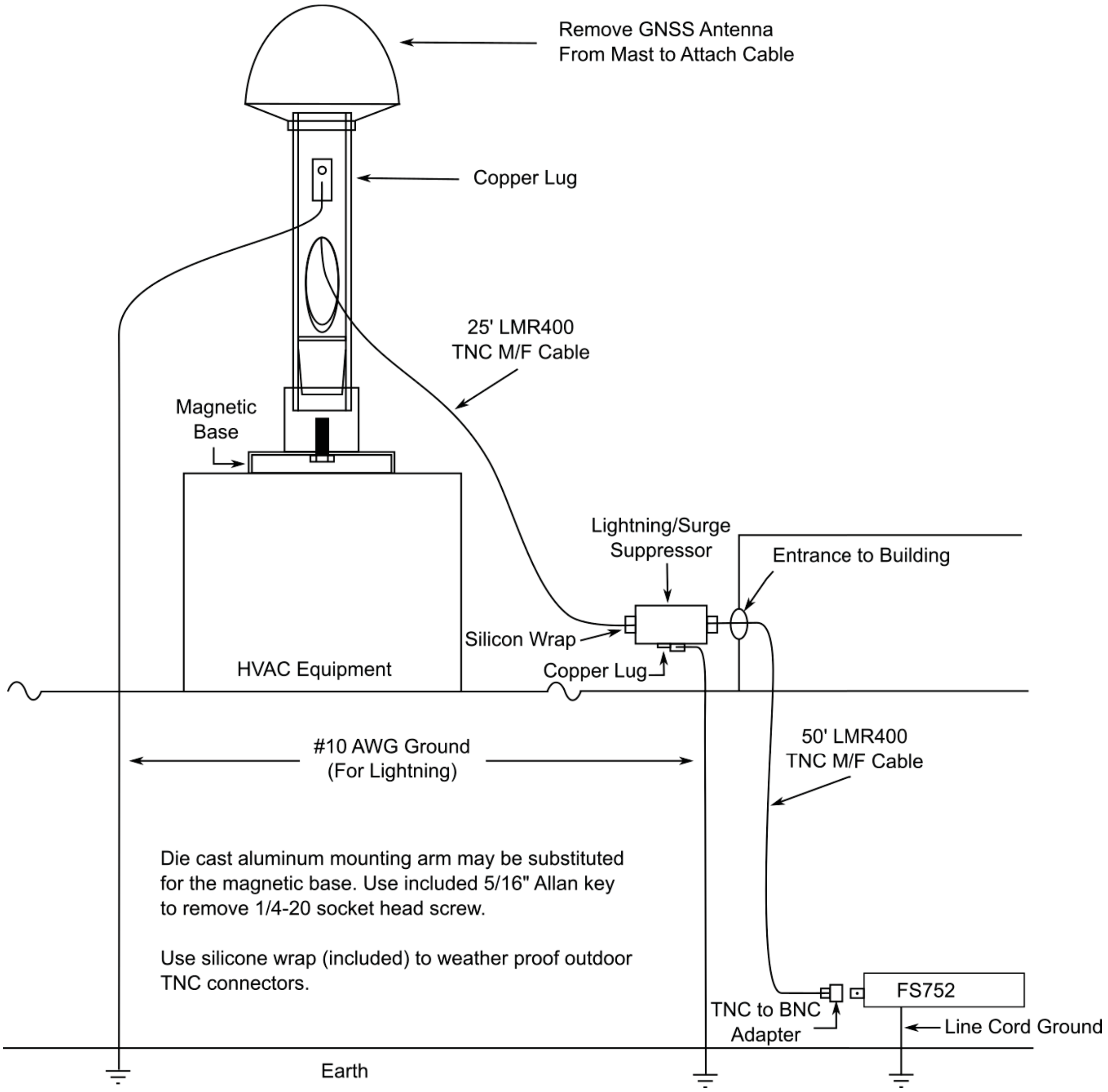


Figure 2: Antenna installation

Troubleshooting

Symptom	Solution
No satellites found, or stuck searching for GPS.	Most likely caused by low SNR due to a poorly positioned antenna. Verify that the connection to the antenna is good. Then try moving the antenna to a location with a clear view of the sky to see if this improves the situation. For good results, the unit should have an SNR > 40 once satellites are found.
Instrument is tracking satellites but reports “no pps”.	When locked to only GPS satellites, the receiver may take up to 12.5 minutes to receive the information needed to align the 1 PPS pulse output to UTC. Until the UTC information is received, the receiver will hold off generating the 1 PPS timing pulses. This is generally not a problem when simultaneously locked to GLONASS satellites as their timing is already aligned to UTC.

Global Navigation for Timing

FS752 Feature Overview

The FS752 GNSS Disciplined Time and Frequency Reference is designed to provide continuously calibrated time and frequency distribution to a local laboratory. Calibration is maintained by locking its internal reference to the time-of-day signals broadcast by one of the various GNSS constellations of satellites. The satellites which make up the GNSS network are equipped with rubidium and cesium clocks which are monitored and controlled by government agencies to ensure that the system maintains synchronicity with UTC. The FS752's GNSS receiver can track any of the four major GNSS constellations: GPS, GLONASS, BEIDOU, or GALILEO. In fact, two constellations can be tracked simultaneously. By default, the FS752 is configured to track both GPS and GLONASS. Simultaneous tracking improves quality and reliability by increasing redundancy and enabling the receiver to incorporate independent timing solutions into its estimate of UTC.

The FS752's receiver is also specifically designed to generate precise timing. It achieves this by performing an extended survey of its position. Once the position is accurately known, all satellite information may then be dedicated toward improving the timing solution. This not only improves the quality of the timing, but also improves overall robustness by enabling the receiver to generate timing pulses with as little as 1 satellite in view. The FS752 can align its 1 PPS to UTC provided by the receiver with a relative precision of 50 ps, an RMS deviation of less than 15 ns and an absolute accuracy of 100 ns.

The FS752 provides five buffered 10 MHz outputs and two buffered 1 PPS digital outputs aligned to UTC. The 10 MHz outputs generate 1 V_{rms} into 50 Ω and may be used as frequency references for laboratory equipment. The 1 PPS outputs generate 10 µs pulses, with 5 V CMOS logic and rising edges aligned to UTC. The 1 PPS outputs can be arbitrarily advanced or delayed (as a group) to account for cable delays if desired.

Still more distribution may be installed with the purchase of one or two distribution boards, with four additional outputs each. Option A provides four 10MHz outputs. Option B provides four 1 PPS outputs. Any combination of option boards may be installed to better match customer application requirements. A unit with two Option A boards installed will have the ability to distribute thirteen buffered copies of the 10 MHz: five standard copies, and eight additional copies included on the two option boards.

Theory of Operation

Global Navigation Systems

Global navigation systems are satellite-based systems designed to provide a user with inexpensive, yet precise, position and timing information. There are four major constellations in operation today as detailed in Table 2.

Table 2: GNSS Navigation Systems

GNSS System	Controlling Governments
GPS	United States
GLONASS	Russia
BEIDOU	China
GALILEO	European Union

GPS was the first navigation system deployed in 1995. It is the oldest and most mature navigation system in operation today. Russia soon followed with GLONASS. More recently, China's BEIDOU and the European Union's GALILEO navigation systems are coming online.

How Does GPS Work

All four systems have similar performance and specifications. While the details between the various systems differ, the basic theory of operation is the same. For simplicity of presentation, we will highlight the various components that make up the GPS system. However, the basic concepts apply to other systems as well.

The Global Positioning System, or GPS, is a radio-navigation system which allows users with a clear view of the sky to identify their current position and time of day from any location around the globe. The system was originally designed for the military, but has been used for a wide variety of civil applications since its deployment, particularly in automobile and marine navigation. The system is managed and controlled by the United States Air Force (USAF). It consists of three parts: a space segment, a ground-based control segment, and the user segment.

The space segment consists of 24 satellites orbiting earth in 12-hour orbits at an altitude of approximately 20,200 km. The satellites are arranged into 6 equally spaced orbital planes with 4 satellites allocated to each plane. The organization is designed so that a user will always be able to view at least 4 satellites from virtually any location around the world. Atomic clocks on board the satellites maintain precise time of day information. The satellites then broadcast ephemeris and time of day information to the user segment. A user with a view of at least 4 satellites can use this information to triangulate their position and time.

The control segment monitors the health of the satellites and uploads corrections and updates to the navigational information stored in the satellites. It is also in charge of decommissioning satellites when they have reached end of life, and the commissioning of new satellites to replace them. It consists of a master control station and a number of antennas and monitoring sites spread throughout the world.

The user segment consists of an antenna and a receiver which extracts the signals broadcast by the satellites. If the user can track at least 4 satellites, it has enough information to triangulate its position (latitude, longitude, height), and time of day.

If the receiver has an accurate clock, it can compute the distance to a known satellite by comparing the time of day broadcast by the satellite to its own clock. The difference between the two clocks represents the amount of time it took for the radio signals to travel from the satellite to the receiver. Since radio signals are known to travel at the speed of light, the distance to the satellite is computed simply by multiplying the time difference by the speed of light. By computing the distance to three different satellites, the receiver can infer its own position by finding the intersection of three spheres centered at the location of each satellite with radii equal to the computed distance to the given satellite.

Unfortunately, most receivers do not have sufficiently accurate clocks to make this measurement possible. The satellites, on the other hand, do have accurate clocks on board. By tracking a fourth independent satellite, therefore, the receiver can extract the correct time of day needed in the computation of its position. In the end, the signals from four independent satellites describe four equations which enables one to solve for four unknowns: latitude, longitude, altitude, and time. If still more satellites are visible and tracked, more information can be incorporated into the solution and the overall error is correspondingly reduced.

Using GPS Satellites for Timing

While most people are aware of the positioning benefits of GPS, it is really precise timing that makes the whole endeavor possible. GPS time is monitored and maintained by a network of atomic clocks on the ground and aboard the satellites which are collectively steered to follow universal coordinated time (UTC) as maintained by the United States Naval Observatory (USNO).

For the FS752, it is this last point which is of significant importance. By locking its internal timebase to GPS or any of the other GNSS constellations, the FS752 can provide long term frequency stability on par with the best time keeping instrumentation in world, but at a fraction of the cost.

Position Survey for Improved Timing

Further improvements in timing can be achieved if the receiver is located at a fixed position and is not expected to move. This is assumed to be the typical case for users of the FS752. In this scenario, the timing produced by the receiver can be improved by performing an extended survey of its position. Once the position is accurately known, the receiver need not compute its position any longer. Rather, it can supply its known position into the equations and use all available satellites toward improving the timing solution. This not only improves the quality of the timing, but also improves overall robustness by enabling the receiver to generate timing pulses with as little as 1 satellite in view.

Locking to GNSS Satellites

Phase Lock Loop Design

When the FS752's GNSS receiver starts tracking satellites it outputs a 1 PPS aligned to UTC. The FS752 uses a sophisticated phase lock loop to lock its OCXO timebase to that signal. The basic loop design can be described by the diagram in Figure 3.

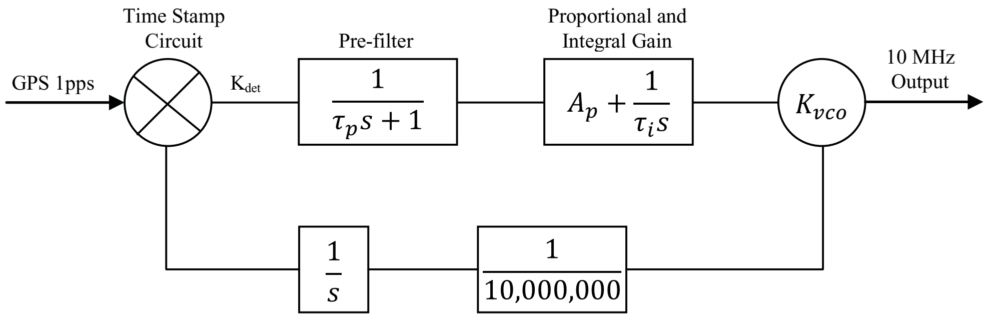


Figure 3: GPS phase lock loop

The symbols in the diagram have the following definitions:

s	Laplace frequency
A_p	Proportional gain
τ_i	Integral time constant
τ_p	Pre-filter time constant
K_{det}	Phase detector gain
K_{vco}	VCO gain

The basic architecture is that of a 2nd order phase lock loop with proportional and integral gain. This basic loop is then augmented with the insertion of a pre-filter designed to reduce the loop's sensitivity to the broadband noise of GPS. Given the definitions above, we define the natural loop time constant, τ_n, and use it to compute the following variables in the phase lock loop:

$$A_p = \frac{2}{K_{det} K_{vco} \tau_n}$$

$$\tau_i = {\tau_n}^2 K_{det} K_{vco}$$

$$\tau_p = \frac{\tau_n}{6}$$

Given these definitions and ignoring the pre-filter for the moment, the loop would have the following response to a step in frequency and phase:

$$\Delta T(t) = t[F_0 - \Delta T(0)/\tau_n] e^{-\frac{t}{\tau_n}} + \Delta T(0) e^{-\frac{t}{\tau_n}}$$

with the following symbol definitions:

t	Time
$\Delta T(t)$	The phase deviation as a function of time

$\Delta T(0)$ The initial phase deviation at time t = 0
F_0 The initial frequency offset at time t = 0
τ_n The natural loop time constant for the phase lock loop

Graphically, the step responses for phase and frequency are shown in Figure 4. One can see that it takes about one to two time constants before the bulk of the error is corrected. It takes five to six time constants before the phase to stabilized. The insertion of the pre-filter perturbs this solution slightly, but the overall response is very similar.

The speed of the phase lock loop is controlled by the natural loop time constant, τ_n. Shorter time constants enable the loop to follow the reference more faithfully, including its broadband noise. Longer time constants will follow the reference more loosely and may provide better performance, particularly if the local reference is more stable in the short term. The goal is to select a time constant that reflects the best balance between short-term and long-term performance for the loop.

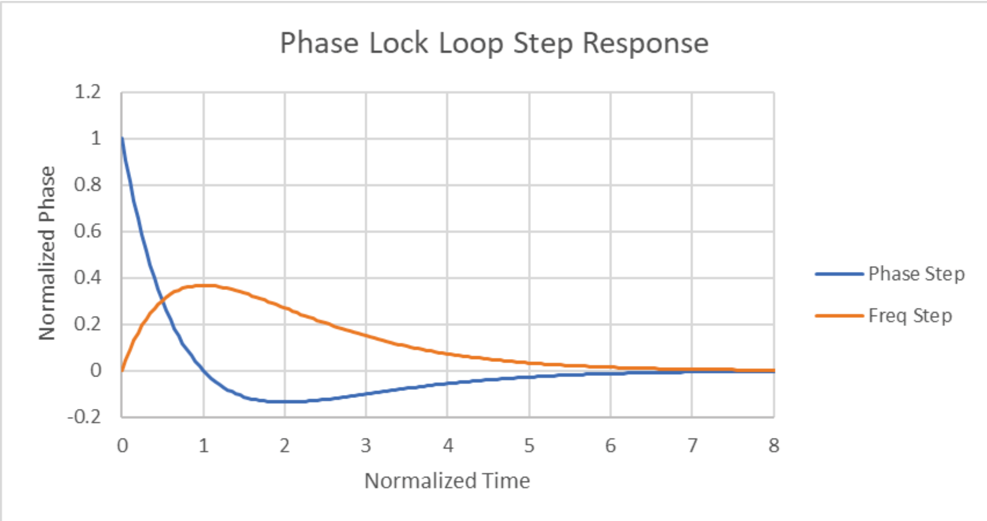


Figure 4: Phase lock loop step response

Predictive Filtering

The superior short-term stability of the FS752's OCXO enable the usage of predictive filtering to improve the stability of the FS752 even further over traditional methods. Predictive filtering uses state space methods to predict the phase of the local timebase relative to GPS. The technique is quite similar to Kalman filtering. The benefit is that the FS752 can average the GPS signal more effectively, resulting in a significantly more stable signal with a shorter time constant than would be possible with traditional filtering.

Timebase Stability

While the long-term stability of GPS is excellent, its short-term stability is rather poor in comparison to modern oscillators. The FS752 incorporates an ovenized crystal oscillator with a short-term stability that out performs GPS for time intervals up 100 seconds or so. Figure 5 shows the typical measured stability of the FS752 locked to GPS at various time intervals. The stability of GPS is also shown for comparison purposes. Notice that at intervals of 1 second, the stability of the FS752's OCXO is nearly 100 times better than that of GPS. Out at intervals beyond 1000 seconds, however, GPS is clearly better. By locking the OCXO to GPS with an appropriate time constant, we gain the best of both worlds: superior short-term stability and matched long-term stability.

TODO: ADD STABILITY GRAPH FOR FS752

Figure 5: Frequency stability of FS752 with different timebases installed.

Adaptive Bandwidth

The FS752 is designed to provide the best overall trade-off between short-term and long-term performance, once its timebase has warmed up and stabilized. At start-up, however, the timebase is cold and its frequency is changing rapidly. In an effort to provide decent timing as soon as possible, the time constant of the loop is shortened up significantly so that it can follow the GPS signal in spite of its changing frequency. When the instrument detects that the timebase has fully warmed up and stabilized, it will gradually increase the time constant to its optimum value. This may take an hour or more.

Losing Lock to GNSS

With a well-placed antenna that has a clear view of sky, the receiver should rarely lose lock to the GNSS satellites. A poorly placed antenna, on the other hand, will potentially degrade the stability of FS752 in addition to making it more vulnerable to losing lock to the GNSS signals altogether. Therefore, careful consideration should be given to antenna placement during the installation of the FS752. However, since ideal antenna placement is not always possible, it is important that the timebase be designed to handle unlock events gracefully.

Monitoring Lock to GNSS

The FS752 uses a finite state machine (FSM) to continuously monitor the GNSS receiver and the PLL. The basic operation of the FSM is illustrated in Figure 6

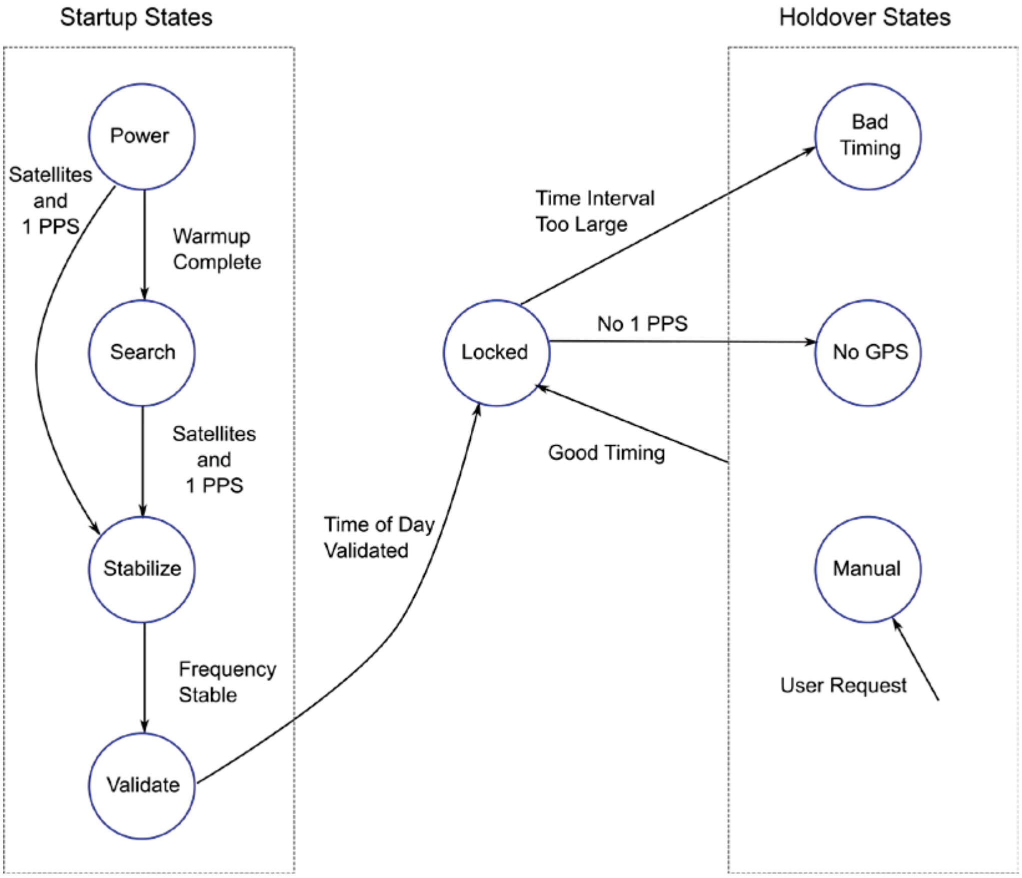


Figure 6: A simplified timebase state diagram showing the most common transitions.

The FS752 starts out in the power on state. It then progresses through a number of startup states towards its goal of extracting time of day information from the GNSS satellites and locking its timebase to the 1 PPS generated by the receiver. Once locked the FS752 continuously monitors the quality of the 1 PPS and transitions to a holdover state if problems are detected. When good timing is recovered, the FS752 will transition back to the locked state and lock its timebase to the 1 PPS generated by the receiver.

FSM States

More detailed information on each of the FSM states is provided below.

Power On

The FS752 always starts out in the power on state. There is no battery back up for maintaining a real time clock, so the FS752 has no estimate for the current date and time. Furthermore, the timebase and electronic components may be cold and their frequencies will be significantly off until the electronics and the timebase warm up. During this time all instrument initialization is performed and the receiver is configured to start searching for GNSS satellites.

Search

Once initialization is complete, the FS752's receiver will start searching for GNSS satellites. This is the first step towards discovering the time of day. If the antenna has a reasonably clear view of the sky, it should be able to discover satellites within about 1 minute. The receiver will initiate its position survey as soon as it is able to compute a position fix. This generally requires that the receiver be tracking a minimum of 4 satellites. When the position survey completes, the receiver will automatically switch to over-determined clock mode and dedicate all satellite signals toward a better timing solution. In this mode, the receiver need only track 1 satellite to generate precise timing.

In order to transition out of the 'Search' state, the receiver must be generating an accurate 1 PPS. As mentioned above, this requires tracking at least 4 satellites (at least initially). However, in order to generate an accurate 1 PPS aligned to UTC (the default), the receiver must also download from the satellites, the corrections needed to align the pulse to UTC. Normally, this will happen quickly if the receiver is tracking both GPS and GLONASS satellites (the default). On the other hand, if the user configures the receiver to only track GPS, the download of UTC corrections may take up to 12 minutes.

Stabilize

Once the receiver is generating an accurate 1 PPS, the FS752 will attempt to lock its timebase to it. However, it takes a few minutes for the ovenized oscillator to warm up to its target temperature. During this time its frequency will be changing too quickly for it to lock to the GNSS timing pulses. In the 'Stabilize' state the F752 is monitoring its own frequency and waiting for it to settle and stabilize enough for it to successfully lock to the GNSS satellites.

Validate

When the frequency has sufficiently stabilized, the FS752 will validate the consistency of the time of day reported by the receiver. If the reported time of day proves to be consistent for 10 seconds, the FS752 will set its time to that reported by the receiver and initiate the phase lock loop to lock the timebase to the 1 PPS generated by the receiver. At this point, the F752 will begin displaying the correct date and time of UTC.

Lock

Initially, the time constant of the PLL will be very short so that the timebase can successfully track GNSS time even as it continues to finish warming up and settle down. As the timebase frequency starts to settle the time constant for the loop will be gradually increased to the optimum loop time constant for maximum stability. This may take an hour or more to complete. When it does, the locked and stable LEDs on the front panel will be highlighted as shown in Figure 7.

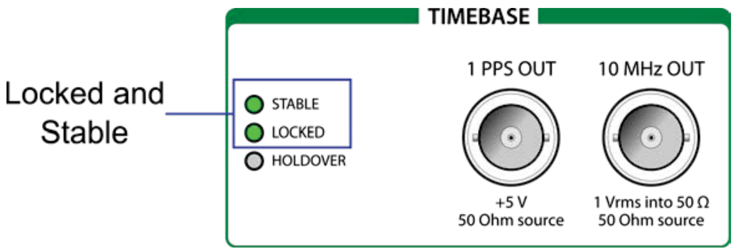


Figure 7: The stable LED is highlighted when the PLL reaches its optimum configuration.

While locked to the GNSS 1 PPS, the FS752 will continuously monitor the PLL and adjust its configuration, if necessary to maintain lock. In particular, if the 1 PPS appears to be 'walking away,' the loop time constant will be reduced to regain good alignment. If this is not possible the FS752 will transition to one of the holdover states.

Holdover States

The FS752 transitions to one of the holdover states whenever it loses lock to the GNSS satellites. While in holdover, the FS752 will hold its frequency steady at the last value it had before losing lock. It will also continuously monitor GNSS time in hopes of relocking to it, using the same validation criteria used at startup to initiate lock. The FS752 will enter holdover for one of three reason: no 1 PPS, a bad 1 PPS, or by user request.

No GPS

The most common reason for entering holdover is losing track of the GNSS satellites. In this scenario, the receiver will stop generating a 1 PPS, and the FS752 has no choice but to wait for the 1 PPS to return when satellites are recovered.

Bad Timing

The second reason for entering holdover is for bad timing. Bad timing is defined to be a discrepancy between the FS752's estimate of UTC and the GNSS estimate of UTC that exceeds a preset configuration threshold, which is 1 μs (by default). Under normal circumstances, this should never occur, so when it is encountered, the FS752 assumes that something must be wrong and enters holdover.

Manual Holdover

The last way of entering holdover is by user request. This can only be done over the remote interface, and so will not happen in normal operation.

Recovering From Holdover

Once the FS752 enters holdover it will continue to monitor the 1 PPS generated by the receiver in hopes of re-locking to the signal. It uses the same criteria used at startup for assessing when it can initiate lock again except for one detail. At startup the FS752 will jump the phase of its 1 PPS to match that of the GNSS 1 PPS to get good alignment immediately. This is also the method used to recover from bad timing. However, for the case when the discrepancy between the FS752 and the GNSS 1 PPS is less than 1 μs, the FS752 will not jump phase, but rather slew the phase by adjusting the frequency to gradually bring the 1 PPS back into alignment using the standard PLL. In this case, there will be no phase discontinuity in the 1 PPS at the time of re-lock, but the timebase will necessarily run off frequency for a while in order to bring the phase back into alignment. The 1 μs threshold between good and bad timing is a configuration parameter which can be adjusted by the user over the remote interface via the GpsDO application if desired. See the chapter on Configuration.

System Alarm

The FS752 includes a SPDT switch on its rear panel which can be used to switch external instrumentation based upon the state of timebase. A front panel LED in the blue STATUS section of front panel indicates the current state of the alarm. By default, the alarm asserts whenever the FS725 is not locked to the GNSS 1 PPS. The conditions under which the alarm is asserted may be configured over the remote interface via the GpsDO application to better meet the user's application if desired. See the chapter on Configuration.

Timebase Events

The FS752 automatically captures each time the state of the timebase changes as an event. Every time the timebase either locks or unlocks from GPS, for instance, the event will be recorded, identifying what happened and when it happened. Events may be viewed and cleared one by one with the GpsDO application. The FS752 has room to store up to 10 events. If more than 10 events occur, the oldest event is discarded to make room.

The event queue provides the user with automatic self-monitoring capability. The user need not continually query the state of the timebase. Rather, he or she can view the event log to see if anything happened over the time period of interest. By comparing time stamps, one can easily deduce how long the timebase spent in each state.

Instrument Operation

Front-Panel

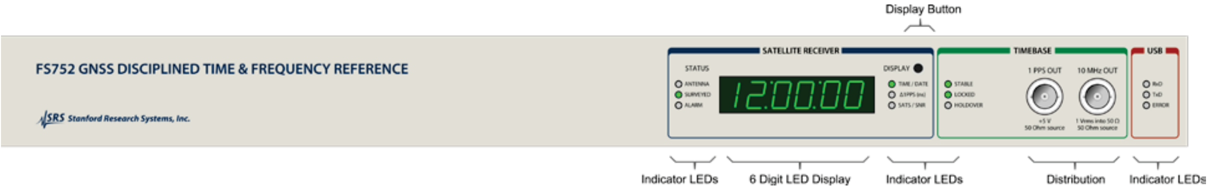


Figure 8: The FS752 front panel

Display

The FS752 front panel consists of a 6-digit LED display, four columns of indicator LEDs, two distribution outputs, and one button. The location of each of these items is highlighted in Figure 8. The display is divided into three sections: satellite receiver, timebase, and USB. Each section is color coded to assist the user in identifying related functionality and status. The display button, located in the receiver section enables the user to toggle between five displays: time, date, 1pps offset, number of satellites tracked, and average SNR. Under the display button are three indicator LEDs to highlight the information currently being displayed. The remaining LEDs provide dedicated status information about the state of the receiver, timebase, or USB remote interface.

Rear-Panel

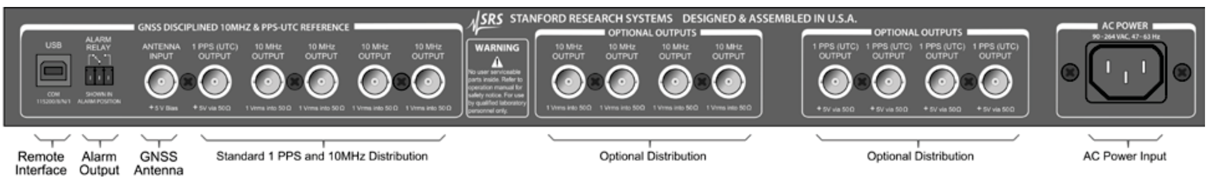


Figure 9: The FS752 rear panel

The rear panel provides connectors for remote interface communication via USB, a switch tied to the system alarm, a GPS antenna input, distribution of the 10 MHz and 1 PPS outputs and AC power. Space is available for the installation of two optional distribution boards, each with four connectors a piece. Two types of option boards are available: one for extra 10 MHz distribution, and on for extra 1 PPS distribution. The customer may install whatever combination best fits his or her application needs. The location of all these components is highlighted in Figure 9.

AC Power

Connect the unit to a power source through the power cord provided with the instrument. The center pin is connected to the chassis so that the entire box is earth grounded. The unit will operate with an AC input from 90 to 264 V, and with a frequency of 47 to 63 Hz. The instrument requires 30 W and implements power factor correction. Connect only to a properly grounded outlet. Consult an electrician if necessary. There is no power on/off switch, as the FS752 is intended to be operated continuously.

USB

The USB port accepts a USB Type B connector for interfacing to a host computer. The FS752 will enumerate as an FTDI virtual COM port with the following configuration: 115,200 baud, 8 data bits, 1 stop bit, no parity, and RTS/CTS hardware flow control. Drivers for the port should install automatically on modern Windows computers.

Alarm Relay

This connector is tied to a 3A, SPDT switch, with normally open and normally closed connections. By default, the alarm will assert when the receiver loses lock to the GNSS satellites. However, the conditions under which it asserts may be configured by the user.

Antenna Input

In order to lock to GPS, the FS752 must be connected to a GPS antenna. The FS752 provides 5V power on the antenna input to support active antennas with more gain. The FS752 tries to detect fault conditions related to the antenna to alert the user of potential problems. If the current draw is too large, an antenna short fault is reported. Alternately, if the current draw is too small, an antenna open fault is reported.

1 PPS and 10 MHz Distribution

Standard Distribution

The FS752 provides distribution for both 1 PPS and 10 MHz. The base instrument includes two 1 PPS outputs of distribution: one on the front panel, and one on the rear panel. The phase of the 1 PPS outputs is aligned to UTC. If desired, the phase of the 1 PPS may be adjusted to account for cable delays when attempting to synchronize with external instrumentation. However, since the 1 PPS distribution consists of buffered copies of a single signal, any phase adjustment will affect all 1 PPS outputs equally.

The base instrument also includes five 10 MHz outputs of distribution: one on the front panel and four on the rear panel. The phase of the 10 MHz is NOT correlated with UTC in any way, and cannot be adjusted either. The 10 MHz distribution is intended to be used as a frequency reference to synchronize laboratory equipment.

Optional Distribution

The rear panel has space for the installation of up to two option boards for expanded distribution. Two different types of option boards are offered: 10 MHz distribution, and 1 PPS distribution. Each board provides four buffered outputs of the desired signal. The user may mix and match the installed options to meet application needs.

Front Panel Operation

Installation and Power

In order for the FS752 to find GNSS satellites, it must be connected to a suitable GNSS antenna and plugged into an AC power source. Connectors for the antenna and AC power are available on the rear panel. For best results the GNSS antenna should be installed in a location with a clear view of the sky. Please refer to the Quick Start Instructions on page 1 for detailed instructions.

Apply power to the rear panel AC power input. Once power is applied, the FS752 will show the model number (752) and the version of firmware executing. Operation then commences immediately. There is no on/off switch on the FS752 as it is intended to be operated continuously.

Navigating the Display

The FS752 has one button on the front panel for navigating between displays and three indicator LEDs for identifying what information is being displayed in the 6-digit LED display.

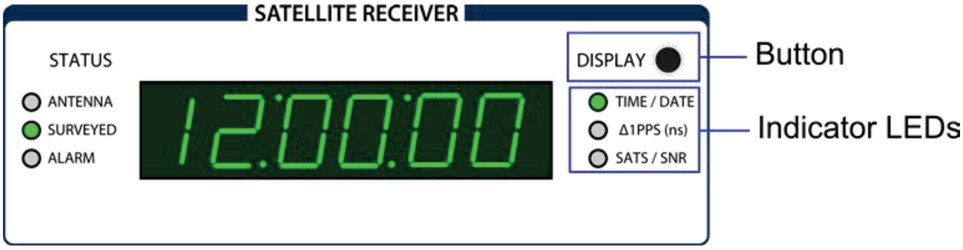


Figure 10: The FS752 display button and indicator LEDs.

There are five main displays: time, date, delta 1 PPS, number of satellites, and average SNR. Navigation between displays is simple. Briefly pressing the display button advances the display to the next sequential option. The indicator LEDs help to identify the information being displayed.

Main Displays

TIME / DATE

UTC time is displayed in the form HH:MM:SS, where HH is hours, MM is minutes, and SS is seconds. Hours is displayed in 24-hour format with midnight represented as 00:00:00, and the second before midnight as 23:59:59.

When the UTC date is displayed, the year will be presented briefly, followed by the month and day. The displayed month is the common three letter abbreviation for the month, such as “Jan” for January and “Feb” for February.

Note that time and date will not be displayed until the FS752 has successfully aligned its output with UTC.

Δ1 PPS

The Δ1 PPS display shows the difference (delta) between the FS752's output 1 PPS and the 1 PPS produced by the GNSS receiver in nanoseconds. When the FS752 is locked to GNSS satellites, the phase lock loop is working to make the average of this difference zero.

Note that the Δ1 PPS display will not be shown until the FS752 has successfully aligned its output with UTC and its absolute offset is less than 1 μs.

SATS / SNR

The last two displays provide diagnostic information. SAT shows the number of satellites being tracked. SNR shows the average detected signal to noise ratio of the 4 strongest satellite signals. SNR is particularly helpful when verifying good placement of the GNSS antenna. For best results, the SNR should be above 40, though the FS752 will continue to operate with the SNR as low as 20.

Alternate Displays

In addition to the main displays, there are 3 alternate displays. Alternate displays are accessed by pressing and holding the front panel display button for longer than 2 seconds. While the button is pressed the display will cycle between the three options. Release the button to select the desired alternative display.

Position

Select position to view latitude, longitude, altitude, and survey progress. Latitude is displayed first. Press the display button briefly to move successively to each parameter. Once survey is viewed, the display will revert back to the previous main display.

Latitude is displayed in degrees with positive values referring to locations north of the equator and negative values referring to locations south of the equator. Longitude is also displayed in degrees, but with positive values referring to locations east of the prime meridian and negative values referring to locations west of the prime meridian. Due to lack of display space, values shown are rounded to the second digit after the decimal. Many more digits are available over the remote interface via the GpsDO application.

Altitude is shown in meters above the GPS reference ellipsoid (WGS 84). Note that the reference ellipsoid may deviate by up to 100 m from the more conventional definition of altitude as the height above mean sea level. Bear this in mind when trying to interpret altitude values reported by the receiver relative to those shown on printed maps.

The last position parameter shown is survey progress. Survey progress is shown as a percentage from 0 to 100. When the survey is complete, the unit will display "done." And the "SURVEYED" LED in the STATUS section of the front panel will turn on.

Alarm

The alternate display for alarm identifies the cause of an alarm assertion. When an alarm asserts, the rear panel SPDT switch asserts and the front panel ALARM LED in the status section of the front panel highlights as shown in Figure 11. For the example shown in the figure, the display indicates that the alarm is being asserted because the timebase is in holdover.

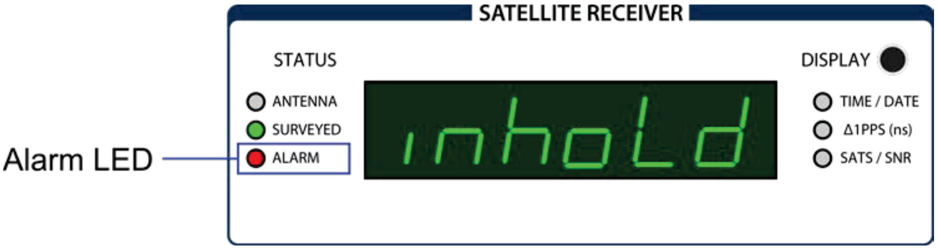


Figure 11: An example alternate display for alarm.

The alarm display will identify the cause of any alarm assertion as detailed in Table 3.

Table 3: Alarm Displays

Alarm Display	Cause
None	No alarm is being asserted
No tm	Time and date has not been set by GNSS satellites
In hold	In holdover. Timebase lost lock to GNSS 1 PPS
Offset	Timebase deviates from UTC by more than the configured amount (1 µs by default).

By default, the FS752 is configured to track the current state of the timebase and assert the alarm if time is not set by GNSS or the timebase is in holdover. The FS752 also supports the latching of alarm conditions. In this case, the alarm will assert until the user explicitly clears the alarm. The user clears an alarm by pressing the display button while viewing the cause of the alarm. The alarm will only clear, of course, if the condition which caused the alarm is no longer true. See section Configuration for instructions on how to change the alarm configuration.

Timebase

The timebase display provides information on the current state of the timebase and whether it is locked to the GNSS satellites. The possible timebase displays and their meaning is detailed in Table 4.

Table 4: Timebase Displays

Timebase Display	Meaning
Search	The GNSS receiver is searching for satellites
No PPS	Satellites have been found but the receiver is still unable to generate an accurate 1 PPS
Verify	The unit is verifying that its timebase has stabilized and that the timing generated by the receiver is good.
Good	The timebase is locked to the 1 PPS generated by the GNSS receiver
Holdover no PPS	The timebase has lost lock to the GNSS satellites and is currently in holdover because no 1 PPS is being generated.
Holdover bad PPS	The timebase has lost lock to the GNSS satellites and is currently in holdover because the 1 PPS being generated is either unstable or exceeds the 1 µs (default) threshold.
Holdover Forced	The user has manually requested the FS752 to unlock from GNSS via the remote interface.

The first three timebase displays (search, no PPS, and verify) are only possible at startup. Once the FS752 has set its time, and locked to the GNSS satellites, the timebase will only toggle between locked (good) and one of the holdover states.

Startup Displays

At startup, the FS752 briefly shows the model number (752) followed by the version of firmware executing. Initially, the main displays for time, date, and Δ1 PPS will not be shown because these values are undefined until the FS752 is able to locate GNSS satellites and lock to them. Until this happens, the timebase alternate display is shown instead. The user may still view the number of satellites tracked and the average SNR.

Timebase Status

Under normal operation the state of the timebase can be assessed directly from the status of the LEDs located in the green TIMEBASE section of the front panel.

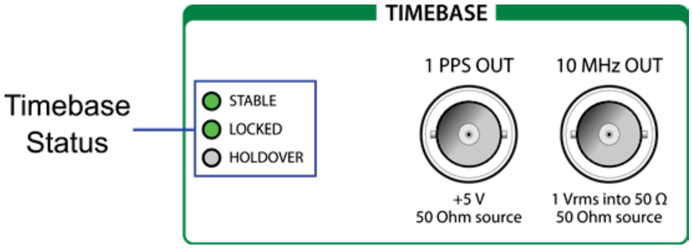


Figure 12: Dedicated LEDs for indicating timebase status.

At startup all LEDs will be off. When the FS752 first locks to the GNSS 1 PPS, the LOCKED LED will turn on. Thereafter, whenever lock is lost the LOCKED LED will turn off and the red HOLDOVER LED will turn on. The STABLE LED will only turn on when the timebase has been locked for some time, the 1 PPS is in good alignment with UTC as generated by the GNSS receiver, and the loop time constant for the PLL is at the optimum value for the timebase. This may take up to an hour or more.

USB Status

The FS752 can be controlled and queried over a virtual RS-232 communications interface created by the USB drivers for the instrument. No communication is required for normal operation. However, if communication is attempted, the front panel LEDs in the USB section of the front panel may aid in diagnosing communication issues.

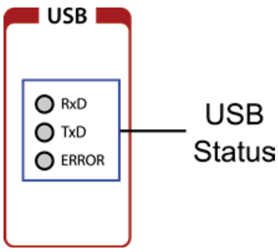


Figure 13: Dedicated LEDs for indicating USB communication status.

The RxD and TxD LEDs flash whenever the instrument receives or transmits data respectively. If an illegal command is parsed or executed, the ERROR LED will turn on.

Error Reporting

Whenever an illegal command is parsed or executed, the specific cause of the error will be shown on the front panel as an error number. See section Error Codes on page 81 for details on the interpretation of error codes. Once an error is generated, the user must dismiss the error by pressing the front panel display button before the normal front panel display operation commences.

GpsDO Application

In addition to the front panel interface, the FS752 provides a remote interface over which full status information may be queried. The available command set is quite extensive and it provides the user with detailed control over the operation of the FS752. However, the user need not invest time in learning the commands that can be executed. The GpsDO application, available from the SRS website, makes sending commands, viewing status, and changing the configuration of the FS752 over the remote interface easy.

The application queries the state of the FS752 over a virtual COM port created by the USB device drivers. It then aggregates the information into groups and graphs that are much easier to comprehend and interpret.

Installation Requirements and Setup

The GpsDO application should run on any 64-bit Windows computer. No installation is required. The application is actually written in Python, but it has been wrapped up into a single executable with no library dependencies.

Before running the application, connect the USB cable from the FS752 to the host computer. The host computer should be able to locate the FTDI device drivers automatically via Windows Update. The device drivers will create a virtual RS-232 COM port for communicating with the FS752.

Once the device drivers are installed, run the GpsDO application. Connecting to the FS752 via the application is easy. Merely select the appropriate communications port and click Connect. The application will only display available COM ports, so it should be relatively easy to identify the correct one.

Instrument Status

If all goes well, the Instrument Status page will be filled in with the current state of the instrument similar to that shown in Figure 14. The application shows data for position, tracked satellites, timebase status, events, warnings, and alarms. The data is continuously updated as long as the connection is maintained.

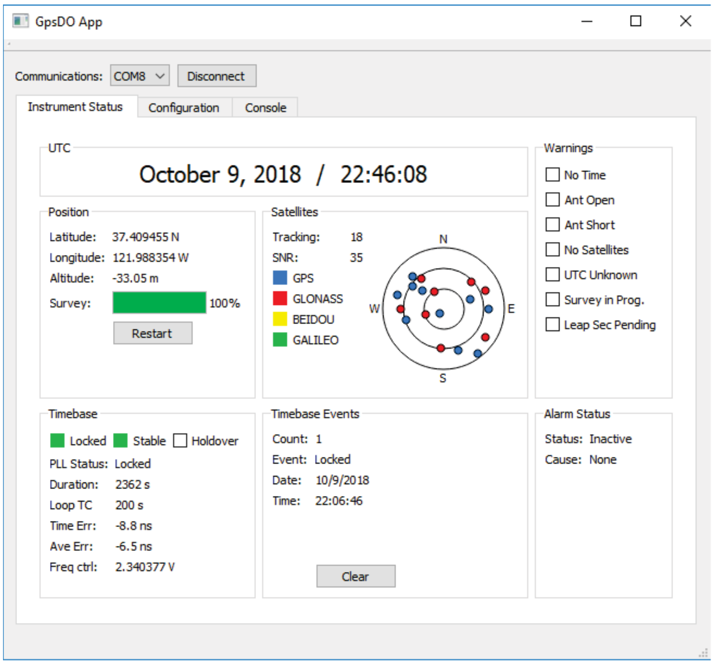


Figure 14: Example instrument status page for the GpsDO application.

Configuration

The FS752 configuration options will be discussed in detail in the next chapter. While the expectation is that most users will rarely need to change the default configuration, the GpsDO application provides an easy method of doing so. The second tab, labeled Configuration, is dedicated to controlling the FS752 configuration. Merely click on the tab heading to activate the tab. A sample configuration page is shown in Figure 15

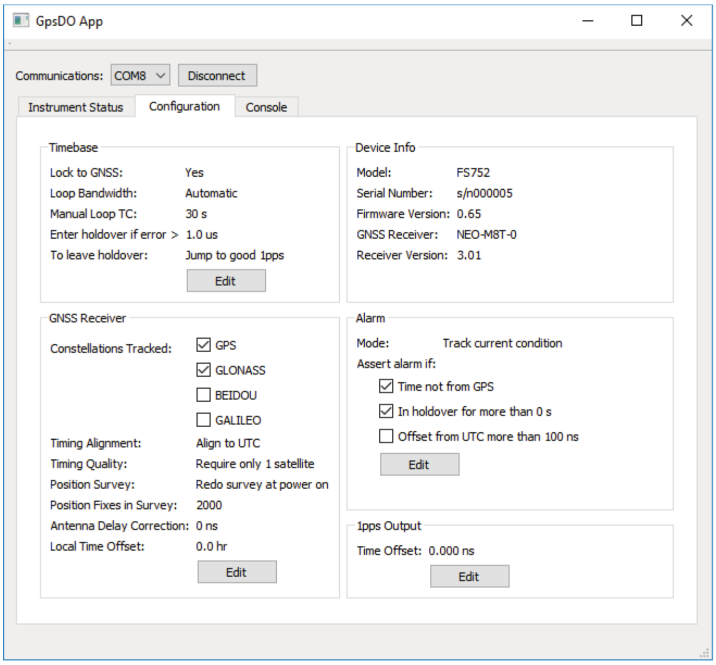


Figure 15: Example configuration page for the GpsDO application.

Console

Lastly, if the user wants to explore manually sending commands to the instrument, the GpsDO application provides a console for doing that. The console is activated by clicking on the tab heading labeled Console. A sample console page is shown in Figure 16.

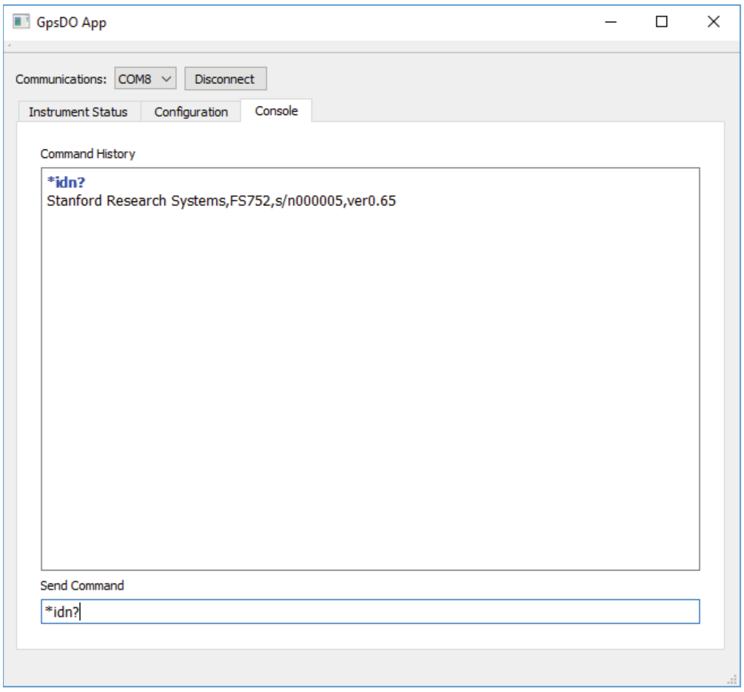


Figure 16: Example console page for the GpsDO application.

Commands are sent by typing in the command at the bottom and then completing the command by pressing Enter on the keyboard. The command is sent to the FS752 and recorded in the command history window in blue. The response to the command, if any, will be displayed in black.

As commands are entered successively, they will be appended to the command history window. It is possible to recall previously sent commands by using the up and down arrows.

Configuration

Aside from possibly correcting UTC for antenna cable delays, the expectation is that the user should rarely need to change the configuration of the FS752. In most cases installing the antenna in a location with a clear view of the sky, attaching the antenna to the rear panel, and apply power is all that is necessary. In the rare case when the user would like to change the configuration, it must be done through the remote interface via USB. The GpsDO application, available on the SRS website, greatly simplifies the process, and is the recommended way for modifying the FS752 configuration.

Using the GpsDO application to modify the configuration is easy. The user connects to the instrument on the appropriate COM port, selects the Configuration tab, and clicks on one of the Edit buttons. A dialog box of user options will be displayed. The user makes the desired modifications and clicks OK.

The configuration options are divided into four main categories: timebase, GNSS receiver, alarm, and 1 PPS output. Each category will be discussed in detail below.

Timebase Configuration

In the GpsDO application, refer to the Timebase pane of the Configuration page. This pane enables the user to modify how the FS752 timebase locks to the GNSS satellites. The user can modify the bandwidth of the phase lock loop as well as the criteria for entering and leaving holdover.

Lock to GNSS

This option controls whether or not the FS752 will try to lock its timebase to the GNSS satellites when they are being tracked.

Selecting Yes (the default) directs the FS752 to lock its timebase to the GNSS satellites as soon as they are located and tracked.

Selecting No will force the FS752 to unlock from the GNSS satellites and enter manual holdover. The frequency will be held at the last frequency control setting indefinitely. The FS752 will not attempt to re-lock to the GNSS satellites until this setting is changed back to Yes.

Related Commands

`TBASe:CONFig:LOCK`

Loop Bandwidth

This option controls how the bandwidth of the phase lock loop is adjusted as the FS752 attempts to lock its timebase to the GNSS satellites.

Selecting Automatic (the default) directs the FS752 to automatically throttle the bandwidth of the phase lock loop with which it locks to the GNSS satellites in order to maintain good phase alignment. When good phase alignment has been achieved and the timebase frequency is stable, the FS752 will automatically reduce the bandwidth of the loop to its optimum setting for the best overall frequency stability. Conversely, if good phase alignment is lost, the bandwidth of the loop will be automatically increased until good alignment is regained.

Selecting Manual directs the FS752 to use the specified manual loop time constant (see below). The bandwidth of the PLL will be fixed at that setting. Advanced users may want to specify loop time constant with which the FS752 locks to GNSS to optimize the FS752 frequency stability for their application.

Related Commands

`TBASe:CONFig:BWIDth`

Manual Loop TC

This option enables the user to set the manual time constant of the phase lock loop. The manual loop time constant only applies when the Loop Bandwidth option discussed above is set to Manual. The time constant controls how tightly the PLL locks the FS752 timebase to the GNSS satellites. The time constant may be set to values ranging from 3 seconds to 1 million seconds.

Short time constants enable the FS752 to better follow any corrections in the GNSS timing. However, since the short-term stability of the FS752's timebase is better than the stability of the GNSS satellites, choosing a short time constant will generally degrade the short-term stability of the FS752.

Conversely, choosing a time constant that is too long will degrade the long-term stability of the FS752 by inhibiting its ability to correct its frequency wander and aging. This will also lead to larger phase wander about UTC.

The optimum time constant for the FS752's timebase when everything is warmed up and settled is approximately 200 seconds (the default).

Related Commands

`TBASe:TCONstant`

Criteria to Enter Holdover

This option defines the threshold (1 µs by default) for categorizing a 1 PPS pulse from the GNSS receiver as bad. Whenever the difference between the FS752's estimate of UTC and that of the GNSS receiver exceeds this threshold, the FS752 will reject the pulse as 'bad' and refuse to continue locking to it. If the FS752 receives 10 'bad' pulses in a row, it will abandon lock and enter holdover.

Bear in mind that this option only applies to one possible cause for entering holdover. The most common cause for entering holdover is that the receiver has lost track of all satellites and is no longer generating any 1 PPS at all. When no 1 PPS is being generated, the FS752 will enter holdover, regardless of the value of the threshold.

However, the threshold for bad timing can have an impact on how the FS752 leaves holdover. For more details on this, see the next section.

Related Commands

`TBASe:CONFig:TINTerval:LIMit`

Criteria to Leave Holdover

The FS752 may enter holdover for a number of reasons, the most common of which is that the receiver lost the GNSS signal and there is no 1 PPS being generated to which it can lock. When the receiver locates satellites again and starts generating the 1 PPS again, how should the FS752 respond? This configuration parameter provides three choices: wait for good 1 PPS, jump to good 1 PPS, and slew to good 1 PPS.

Wait for Good 1 PPS

With this option, the FS752 will only re-lock if the 1 PPS pulses generated by the receiver are 'good' as defined by the threshold set in the previous section. If the pulses are good according to the given threshold, the FS752 will simply turn on the phase lock loop and gradually slew the phase back into alignment as if it had never lost lock.

The danger of selecting this option is that if the FS752 loses the satellite signal for an extended period of time, its timebase will be forced to free-run until the signal is regained. If, during that time, the phase of the FS752 drifts beyond the threshold for 'bad' pulses, the FS752 may never be able to re-lock to GNSS time, because it is incorrectly categorizing them as 'bad' pulses. As a result, this is probably not the best option for most applications.

Jump to Good 1 PPS

With this option (the default), the FS752 remains in holdover until satellites are recovered and the receiver is generating a 1 PPS again. At this point there are two possibilities. The first possibility is that the recovered 1 PPS pulses are judged to be 'good' according to the threshold set in the previous section. In this case the FS752 will simply turn on the phase lock loop and gradually slew the phase back into alignment as if it had never lost lock.

The second possibility is that the recovered 1 PPS pulses are judged to be 'bad' according to the threshold set in the previous section. In this case, the FS752 will jump its phase to regain good alignment between it and the GNSS signal and turn on the phase lock loop again.

Slew to Good 1 PPS

With this option, the FS752 remains in holdover until satellites are recovered and the receiver is generating a 1 PPS again. At this point the FS752 will simply turn on the phase lock loop and gradually slew the phase back into alignment as if it had never lost lock. Unlike the previous option, no distinction is made between 'good' and 'bad' pulses. Until the 1 PPS comes into good alignment, all pulses are considered to be 'good' pulses.

Choose this option if your application cannot handle sudden jumps in phase in the 1 PPS output.

Related Commands

`TBASe:CONFig:HMODe`

GNSS Receiver Configuration

In the GpsDO application, refer to the GNSS Receiver pane of the Configuration page. This pane enables the user to modify how the GNSS receiver is configured and the characteristics of the 1 PPS pulse it generates. The user can configure which constellations of satellites are tracked, the alignment of the 1 PPS pulse, the position survey, antenna delay corrections, and local time offsets.

Constellations Tracked

There are four major constellations of GNSS satellites in operation today: GPS, GLONASS, BEIDOU, and GALILEO. The GPS and GLONASS systems are the most mature and currently provide the most coverage. The others are also operational, however, and will improve their coverage in the coming years. The FS752's GNSS receiver is capable of tracking any of the four types of satellites. In fact, it can track more than one constellation of satellites, simultaneously.

This option identifies which constellations of satellites should be tracked by the FS752's GNSS receiver. The default is to track both GPS and GLONASS satellites. The user may choose the desired combination of satellites, but be aware that not all combinations are supported. The selections are limited by available channels and tuning frequencies. If a selected combination is rejected the receiver will merely remain at its previous setting.

If the combination of satellites is changed, the receiver will be forced to reset. This means that all currently tracked satellites will be lost and the receiver will be forced to search for them anew as if it were powering up for the first time.

Related Commands

GPS:CONFig:CONStellation

Timing Alignment

This option enables the user to configure the timing alignment of the 1 PPS output. By default, time is aligned to Coordinated Universal Time (UTC). However, time may alternatively be aligned to any one of the GNSS standards: GPS, GLONASS, BEIDOU, or GALILEO. Although, all of the standards are based on networks of cesium atomic standards, there are some important differences between them.

First, the UTC and GLONASS standards are synchronized to mean solar time. Synchronization is achieved with the occasional insertion of leap seconds. When a leap second is inserted, the last minute of that day will have 61 seconds instead of the normal 60 seconds. These corrections ensure that the time of sunrise and sunset do not shift over time.

The other timing standards (GPS, BEIDOU, and GALILEO) are strictly atomic time scales and are not corrected with the insertion of leap seconds. This means that the time of day reported by GPS, for instance, differs from UTC by an integer number of seconds. As of January 2017, GPS time was 18 seconds ahead of UTC. This difference is called the UTC offset.

Furthermore, even when you correct for the UTC offset, the time reported by GPS will differ slightly from UTC. This is because it is an independent clock and therefore its phase will deviate from that of UTC. This phase is continuously monitored by the ground control segment of GPS, however, and they can (and do) steer GPS time to ensure that the phase of GPS does not deviate by more than 1 μs from UTC (USNO). In practice, the deviation is usually less than 10 ns. Both the current UTC offset and the current UTC to GPS phase deviation are broadcast by the GPS satellites as part of the almanac. This is particularly relevant at startup, because it may take up to 12 minutes for the receiver to download the almanac.

Similarly, each of the particular GNSS constellation also have their own version of UTC. Thus, UTC as presented by GPS satellites will differ slightly from the UTC presented by GLONASS satellites. When tracking more than one constellation, the receiver will automatically choose an appropriate standard to follow. If it is important that timing be aligned with a particular version of UTC, configure the receiver to only follow that single constellation

The displayed time of day on the front panel and the physical phase of the FS752 1 PPS will reflect the selected timing alignment. When aligned to GPS, for example, the time of day displayed by the front panel will be 18 seconds ahead of UTC.

When choosing to align time with a particular GNSS constellation, it follows that the receiver must also be configured to track that constellation.

Related Commands

```
GPS:CONFig:ALIGnment
GPS:UTC:OFFSet?
```

Timing Quality

Normally, GNSS receivers must track at least 4 satellites before they can generate a position and timing fix. This stems from the fact that there are 4 unknowns to be solved: latitude, longitude, altitude, and time. 4 equations are required to solve for 4 unknowns. However, if the receiver is not moving, then it need not re-compute its position each time. Rather, it can use the position computed from before, since it is not changing. In this case only 1 satellite is needed to compute time.

In normal operation, the FS752 will automatically survey its position for 2000 seconds to accurately determine its position. After that, the receiver will enter over determined clock mode and all satellites will be dedicated to generating the best possible timing. Only one satellite is required to generate a solution. However, the quality of such a solution increases as more satellites are incorporated into it.

There is a tradeoff to consider. Should the receiver generate potentially noisy timing pulses when tracking just one satellite (the default)? Or should it wait until it is tracking at least three satellites before generating timing pulses. The quality of the timing may be significantly better for three satellites, but it also increases the likelihood that the FS752 will be forced into holdover. Noisier timing may be preferred to no timing at all.

Related Commands

```
GPS:CONFig:QUALity
```

Survey

The FS752's GPS receiver provides the best timing performance when the antenna is stationary and not moving. It gets enhanced performance by surveying its position for a time and then using that position to improve the timing. The FS752 support three modes of operation: disabled, redo at power on and remember previous survey.

Disabled

This option prevents the receiver from going into over-determined clock mode. Instead the receiver will always compute its current position in addition to time of day each second. It is the appropriate choice if the position of the antenna may move.

Redo Survey at Power On

This option (the default) causes the receiver to perform a position survey after each power cycle and then go into overdetermined clock mode. It is the appropriate choice if the antenna will be stationary once power is applied to the FS752.

Remember Survey Results

This option causes the receiver to perform the position survey only once. The results of the survey are then stored in nonvolatile memory. Thereafter, the FS752 will enter over determined clock mode immediately after power on, relying instead on the position stored in nonvolatile memory. This option is most appropriate when the antenna is installed in a static location and then never moved, even when power is lost.

Related Commands

`GPS:CONFig:SURVey:Mode`

Position Fixes in Survey

The FS752 position survey is designed to accurately identify the receiver's current position by averaging together the position fixes computed when the receiver is not moving. By default, the survey will average together 2,000 position fixes to obtain its surveyed position. If desired, the user may change the number of fixes included in the survey.

Related Commands

`GPS:CONFig:SURVey:FIXes`

Antenna Corrections

This option can be used for correcting the phase of the 1 PPS output relative to absolute UTC. Look at the 1 PPS time offset setting on page 36 for an alternate method that may be preferable for some users.

The FS752's GPS receiver computes position and time based on the position of the antenna. However, the antenna signal must travel through a potentially long cable before it reaches the GPS receiver input on the FS752. Thus, the signal reaching the receiver is delayed compared to the case where the antenna is attached directly to the receiver with no intervening cable. The typical delay for most BNC cables is 1.5417 ns per foot. For a 30 ft cable, the delay would be $1.5417 \times 30 = 46.25$ ns. If uncorrected, the FS752's estimate of UTC would be 46.25 ns later than a properly calibrated unit.

The user may correct for this delay, however, by entering a negative antenna cable delay correction. The user would correct for a 30 ft cable by entering a correction of −46.25 ns.

Related Commands

`GPS:CONFig:ADELay`

Local Time Offset

The user may prefer to have the local time of day displayed, rather than UTC. To display local time, the user must enter the offset in hours between UTC and the local time. If the offset is zero, UTC or GNSS time will be displayed according to the selected timing alignment. When the offset is nonzero, the local version of UTC or GNSS time will be displayed.

Related Commands

`SYSTem:TIMe:LOFFset`

Alarm

In the GpsDO application, refer to the Alarm pane of the Configuration page. This pane enables the user to configure the conditions under which the system alarm is asserted. The rear panel of the FS752 contains screw terminals to a SPDT switch actuated by the system alarm. The system alarm may be controlled manually, or it may be configured to assert in response to anomalous conditions, such as detecting the timebase is in holdover, or has drifted more than 100 ns from UTC.

Related Commands

```
SYSTem:ALARm?
SYSTem:ALARm:CONDition?
SYSTem:ALARm:EVENt?
SYSTem:ALARm:CLEar
SYSTem:ALARm:FORCe:STATe
```

Alarm Mode

The system alarm can operate in one of three modes: tracking, latching, or manual.

Tracking Current Condition

In tracking mode (the default), the alarm is asserted when a configured condition is true, and de-asserted when the configured condition is false. The user cannot forcibly clear the alarm except by removing the alarm condition.

Latch Alarm Condition

In latching mode, the alarm is asserted when a configured condition is true. Unlike tracking mode, however, it is not de-asserted when the configured condition becomes false. Rather, it remains asserted until the user explicitly clears the alarm. The user can clear the alarm from the front panel by viewing the alarm condition and pressing the display button to clear it (see page 22). The user will not succeed in clearing the alarm if the configured condition is still true because it will merely be reasserted. In this case the alarm can only cleared by removing the condition.

Manually Set State

In manual mode, the user explicitly sets the state of the alarm. The state can be toggled by pressing the display button while view the alarm state (see page 22).

Related Commands

```
SYSTem:ALARm:MODe
SYSTem:ALARm:FORCe:STATe
```

Alarm Conditions

When the system alarm is in tracking or latching mode, the user must specify the conditions which will trigger the alarm. The default is to assert the alarm when the receiver is not locked to the GNSS satellites. The user also has the option to assert the alarm if the FS752's estimate of UTC differs from the GNSS satellites by more than the given amount.

Related Commands

```
SYSTem:ALARm:ENABle
SYSTem:ALARm:GPS:TINTerval
SYSTem:ALARm:HOLDover:Duration
```

1 PPS Output

In the GpsDO application, refer to the 1pps Output of the Configuration page. This pane enables the user to configure the output delay of the 1 PPS outputs relative to UTC.

Time Offset

The FS752 is calibrated so that the zero crossing or rising edge of the output at the BNC corresponds to UTC. However, the user's equipment may be located some distance away from the FS752. Thus, it may be desirable to advance or delay the signal so that rising edge of the output coincides with UTC at the input to the user's equipment. Enter a negative value to advance the signal. Enter a positive value to retard the signal. The phase can be adjusted by up to 1 second.

The 1 PPS time offset adjustment has a similar effect as the antenna delay correction discussed on page 34. The difference is that the antenna delay correction is applied directly to the receiver, where as this correction is applied to the output driver for the 1 PPS output. Corrections applied to the output directly can be implemented immediately without disturbing the phase lock loop locking the FS752 to the GNSS satellites. In contrast, when the correction is applied directly to the receiver, it will appear to the FS752 as a step in phase of the reference 1 PPS that the phase lock loop must follow. If the phase step is reasonably small the phase lock loop will gradually pull the FS752 to the new phase reference by running off frequency. If the phase step is large, the FS752 may lose lock and enter holdover before realigning with the new phase reference.

Note that this time offset value applies to all distributed copies of the 1 PPS output as a group. Individual adjustment of the phase of a single output independent of the other outputs is not possible.

Related Commands

`SOURce:PHASe:SYNChronize:TDELay`

Factory Default Settings

The factory default settings for the FS752 are shown in Table 5.

Table 5: Factory default settings

Parameter	Value	Set by *RST
Display	Time of day	✓
Timebase GPS lock	Enabled	
Timebase holdover mode	Jump to good 1pps timing	
Timebase bandwidth mode	Auto bandwidth control	
Timebase time interval limit	1 µs	
Timebase manual time constant	200 s	
GNSS timing alignment	UTC	
GNSS timing quality	Require 1 satellite	
GNSS survey mode	Redo survey at power-on	
GNSS position fixes in survey	2000	
GNSS antenna cable delay	0 ns	
Local time offset	0 hr	
System alarm mode	Track timebase state	
System alarm manual state	Off	
System alarm holdover duration limit	0 s	
System alarm timing error limit	100 ns	
1 PPS output time delay	0 ns	

Forcing Instrument Settings to Factory Defaults

Occasionally it may be useful to force ALL instrument settings to their factory default state. This may be necessary, for example, when transferring a unit from a secure location. Perform the following procedure to wipe the instrument of all user settings and force all system settings to their factory default values:

1. Unplug the power cord to the FS752.
2. Press and hold the front panel display button.

3. While pressing the display button, re-plug in the power cord to the FS752.
4. Continue pressing the display button until the display reads ‘reset’.
5. Release the display button to initiate the reset.

Related Commands

`SYSTem:SECurity:IMMediate`

Remote Programming

Introduction

The FS752 may be programmed via the USB remote interface. Any host computer interfaced to the instrument can easily control and monitor its operation.

USB

The FTDI drivers for the USB remote interface should be downloaded automatically by Windows Update. The drivers will automatically create a virtual RS-232 COM port for communicating with the FS752.

Virtual RS-232 COM Port

In order to communicate properly over the virtual RS-232 COM port, the instrument and the host computer both must be configured to use the same settings. Use the following setup when attempting to communicate: 115200 baud, 8 data bits, 1 stop bit, no parity, and RTS/CTS hardware flow control.

Front-Panel Indicators

To assist in programming, there are three front panel indicators located under the USB section of the front panel: RxD, TxD, and ERROR. See Figure 17.

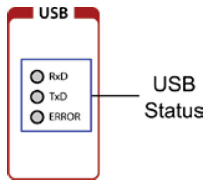


Figure 17: Communications indicator LEDs.

The RxD and TxD LEDs flash every time a character is received or transmitted, respectively. This is useful when troubleshooting connections because it clearly indicates when the FS752 successfully received and responded to a command.

The ERROR LED will be highlighted when a remote command fails to execute due to illegal syntax or invalid parameters. Once highlighted, the LED will remain lit until the error queue is cleared. Errors codes will be automatically displayed on the 6-digit LED display whenever they occur. See section Error Codes on page 81, for details on interpreting them. They can be cleared by pressing the front panel display button. When all error codes have been cleared, the ERROR LED will turn off.

SCPI Command Language

The FS752 uses the SCPI (Standard Commands for Programmable Instruments) language for controlling the instrument over a remote interface. The SCPI language is an ASCII based command language that organizes functions into a hierarchical tree of commands with branches of the tree separated by colons.

SubSystems

The base or root of the tree represents a subsystem of the instrument. Each succeeding branch of the tree subdivides the subsystem into related categories of functionality. The final branch of the tree identifies a command related to the subsystem that can be executed by the FS752. This structure facilitates understanding of the functions carried out by commands. As an example, consider the subset of the STATus subsystem shown below.

```
STATus:
    GPS:
        CONDition?
        ENABle
        ENABle?
        [:EVENt]?
    OPERation:
        CONDition?
        ENABle
        ENABle?
        [:EVENt]?
```

STATus is a subsystem of the FS752 and it is at the root of the tree. At the next level down, the STATus subsystem is divided into two branches: GPS and OPERation. Each of these categories is then further subdivided into four virtually identical commands: CONDition, ENABle, ENABle?, and [:EVENt]?. However, because of the hierarchical structure of the language, we can infer that the commands listed under the GPS branch refer to GPS receiver status, while those listed under OPERation carry out the same functions but refer to OPERation status rather than GPS status. Thus, the hierarchical structure of the commands aids the user in interpreting the operations carried out by the individual commands.

Understanding Command Syntax

SCPI commands often take one or more parameters which modify or identify the numerical value a variable should take. Some parameters are required. Others may be optional. Furthermore, the data types for each parameter may differ. Thus, for brevity, we need a set of conventions for defining commands which clearly identifies all the valid variations of the command without having the list each possibility separately. These conventions are set forth here.

An example command is illustrated below:

```
SOURce:PHASe[:ADJust] {<phase>|MINimum|MAXimum|DEFault}
```

Keyword Case

Keywords are defined with a mixture of upper-case and lower-case letters. The upper-case letters indicate the short or abbreviated version of the keyword. This is usually the first 3 or 4 letters of the keyword. The user may send either the short version or the entire long version of the keyword in their programs. The case of the letters sent to the FS752 does not matter. It is only used here to succinctly identify the two versions of the keyword. Thus, SOUR, source, and Sour are all acceptable forms of the keyword. Other forms, such as SOU, or SOURC, are not. Given the definition above, the following commands are all identical:

```
SOUR:PHAS MIN
SOURCE:PHASE MINIMUM
SOUR:PHASE MIN
```

Punctuation Used in Definitions

The following punctuation is used to identify variations and options for the command:

- Braces ({ }) enclose different parameter choices. The braces, themselves, are not sent with the command
- A vertical bar (|) separates alternative parameter choices for the command. In the example above, the choices are a <phase> or one of the keywords: MINimum, MAXimum, or DEFault. The vertical bar is not sent with the command.
- Triangle brackets (< >) indicate that you must specify a numerical value. In the example above, <phase> would be specified as a number with optional units. Thus, one could set the phase using the following command: SOUR:PHAS 1.253 ns. The triangle brackets are not sent with the command.
- Square brackets identify optional keywords or parameters in the command. Optional items may be omitted if desired. In such case a default value is normally substituted for the parameter. In the example above, the keyword `ADJust` is optional and may be omitted. Thus, the command `SOUR:PHAS:ADJ 125 ns` is identical to the command that omits the keyword: `SOUR:PHAS 125 ns`.

Examples

Putting it all together, all of the following commands are valid given the example definition presented above.

```
SOUR:PHAS MIN
SOUR:PHAS DEFAULT
SOURCE:PHASE 125e-9
SOURCE:PHASE 125 ns
SOURCE:PHAS MAXIMUM
```

Queries

Command queries are usually formed by appending a question mark (?) to the command. To query the current phase of the 1 PPS output, we use the following command: SOUR:PHAS?

Separators

As mentioned above, a colon (:) separates the different keywords that make up a command. If a command takes a parameter, a space MUST separate the last keyword of a command and the first parameter of that command. If a command takes multiple parameters, they are separated from each other with a comma (,). Finally, a semicolon (;) is used to separate multiple commands on the same line. If the following command is in the same subsystem as the preceding command then the subsystem is not repeated for the second command. Otherwise the command must be fully specified and preceded by a colon. Given the example command tree presented in section SubSystems above, the following commands are valid:

```
STAT:GPS:ENAB 1; EVENT?
STAT:GPS:COND?; :STAT:OPER:COND?
```

In the first line, both ENABle and EVENt are in the same subsystem, STAT:GPS, so that portion of the command is omitted for the EVENt? query. However, the two condition queries are in different subsystems, so the operational condition query is preceded by a colon and fully specified on the command line.

When multiple queries, separated by semicolons, are made in a single command line, the responses from the individual queries are separated by a semicolon as well.

IEEE 488.2 Common Commands

The IEEE 488.2 standard defines several common commands that nearly all instruments support. Common commands start with an asterisk (*) followed by three letters. Like with SCPI commands, a space MUST separate the command and any parameters which follow. Multiple common commands may executed in a single line by separating the commands with a semicolon (;). An example is given below.

```
*RST; *OPC?
```

Parameter Types

The SCPI language supports several different data types for use with command parameters.

Numeric Values

Parameters that take numeric values accept all common decimal representations of numbers, including optional signs, decimal points, or scientific notation. Hexadecimal values specified with a prefix of 0x prefix as used in the C language are also accepted. If only certain values are allowed, numeric entries will be rounded to the nearest allowed value. The following examples are all valid numeric entries:

```
100
-123.456
+1.23456e2
-.456
0x64
```

The last example, 0x64, is the hexadecimal representation for the decimal number 100.

Many commands that take numeric parameters will also accept the keywords MINimum, MAXimum, or DEFault to set the parameter to the requested value for that parameter.

Units

Some numeric values may be followed with a unit designation. The most common engineering prefixes are also accepted. For example, the antenna delay may be set to 10 ns with the command GPS:CONF:ADEL 10 ns.

Discrete Parameters

Some parameters take one of a small list of allowed keywords. They often have a short form and a long form, just like command keywords. In the command definition, the uppercase letters indicate the short form. Either case may be used when sending the short or long form of the value to the instrument. Queries will always return the short form. Consider the following command definitions:

```
TBASe:CONFig:BWIDth [{ AUTo | MANual }]
TBASe:CONFig:BWIDth?
```

The user may specify auto bandwidth control by sending the command `TBAS:CONF:BWID AUTO`. The query will return `AUT`, which is the short form of the value.

String Parameters

Quoted string parameters allow one to send almost any sequence of characters, including characters that are normally reserved as separator characters, such as a comma, semicolon, or colon. The string must begin and end with the same quote character: either a single quote, or a double quote. The quote delimiter may itself be included in the string if it is typed twice without any characters in between.

Command Termination

Commands should be terminated with a line feed <LF>. They may optionally be terminated with a carriage return <CR> followed by a line feed <LF>. As previously noted, multiple commands may be sent in a single line if they are separated by a semicolon (;). Commands are executed in the order received and execution commences once the command separator or terminator is received.

Status Reporting

Architecture

The FS752 reports on its status via a hierarchy of status registers. Instrument status is stored in three 16-bit registers: the questionable status register, the operational status register, and the GPS receiver status register. Parsing and command execution status is reported via the standard event register (*ESR?). Summaries of all these registers are reported as bits in the serial poll status byte for the instrument (*STB?). Although not supported on the FS752, GPIB-like remote interfaces may be configured to generate a request for service when a given bit in the serial poll status byte is set. This scheme enables the user to be notified when events of interest occur, and to ignore events that are not of interest. Detailed status is always available in the source registers. However, with proper configuration, these registers need not be queried until an event of interest actually occurs.

Each instrument status register has three associated status words: a condition register, an event register and an enable register. The relationship of these three registers is depicted in Figure 18.

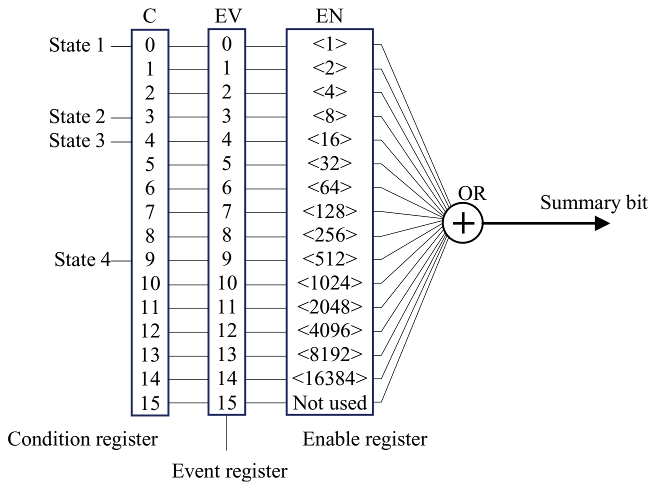


Figure 18: Organization of status registers

Condition Register

The condition register reports on the current state of the instrument. At the far left of Figure 18 are listed four items of state which feed into four different bit locations of the condition register. When the instrument is in the given state, then the corresponding bit in the condition register is set. When the instrument leaves the given state, the corresponding bit is cleared. Bits in the condition register which are set indicate items of state that are true at the time of the query. Bits in the condition register which are clear indicate items of state that are false at the time of the query. Querying the condition register does not alter the bits in the register. Only changes in the actual instrument state alter the bits of the condition register.

When the condition register is queried, only one number is returned which is the binary sum of all bits in the register which are set. The binary weight of each bit in the register is shown in the enable register at the far right of Figure 18. The binary weight increases by a factor of two for each bit. Bit 0 has a weight of 1. Bit 1 has a weight of 2. Bit 2 has a weight of 4, and so on, up to bit 14 which has a weight of 16384. The number returned by a query of the condition register is the sum of weights of the bits which are set.

For example, in Figure 18, State 1 feeds into bit 0 and State 2 feeds into bit 3. If both State 1 and State 2 are true, then both bits 0 and 3 will be set. If all other states are false, then the number returned by a query of the condition register will be the binary sum of bit 0 and bit 3, which is 1 + 8 = 9. If only State 2 is true, then only bit 3 will be set and a query of the condition register will return 8. Similarly, if only State 1 is true, then only bit 0 will be set and the query will return 1. Finally, if none of the states is true, the query will return 0.

Event Register

Bits from the condition register feed into corresponding bits in the event register. The event register differs from the condition register, however, in that the bits are sticky. Once a bit is set, it remains set until explicitly cleared by a query of the event register. The event register, therefore, enables the user to capture all events that have occurred since the previous query of the register, even if the states in question are short lived and not true at the moment of the query.

Like the condition register, a query of the event register returns a single number which is the binary sum of all bits in the register which are set. (See the discussion of the condition register above for a detailed explanation of this process.)

Unlike the condition register, a query of the event register clears any bits which were previously set. Executing the *CLS command will also clear this register. Bear in mind that if the corresponding bits in the condition register are still set, these bits will immediately be set again after the clear from the query.

Enable Register

The enable register is a mask register that controls which bits from the event register will set the overall summary bit. If a bit in the enable register is set, then the corresponding bit in the event register will be combined with other enabled bits of the event register via a logical OR operation to create an overall summary bit.

The user sets the enable register with a single number which is the binary sum of all bits in the register which should be set. (See the discussion of the condition register above for a detailed explanation of this process.) Continuing with the example from Figure 18, If the enable register is set to 9 = 1 + 8, then the summary bit will be set if either bit 0 or bit 3 of the event register is set. Therefore, if the user detects that the summary bit is set, he can infer that either State 1 or State 2 or both were at least momentarily true since the last query of the event register.

Enable bits are set via a command. They are not cleared by a query or the execution of the *CLS command. To clear enabled bits, the user must send another set command with those bits set to zero. Sending the number zero will clear all bits of the enable register and prevent the summary bit from ever being set.

FS752 Status

The FS752 status is reported through the standard event register and three instrument status registers. The organization and hierarchy of these registers is depicted in Figure 19. There are three instrument status registers: GPS receiver status, questionable status, and operational status. These are all 16-bit registers which report on the status of the instrument and its operation. The 8-bit standard event register reports on the status of command parsing and execution. The summary bits from each of these registers feed into a single, 8-bit condition register called the serial poll status byte (*STB). Summary bits for the error queue and the output buffer also feed into this status byte. The serial poll status byte, therefore, provides summary status for the entire instrument.

The serial poll enable register (*SRE) can be used to combine all the summary bits in the serial poll status byte (*STB) into a single summary bit, also in the serial poll status byte located at bit 6. In this way, summary status for the entire instrument may be condensed down to a single bit. Although not supported on the virtual RS-232 remote interface included with the FS752, this bit is often used to generate request-for-service interrupts on GPIB-like remote interfaces.

Serial Poll Status Byte

The serial poll status byte provides summary status for the instrument as a whole. The interpretation for bits in the serial poll status byte is shown in Table 6.

Table 6: Interpretation of serial poll status bits

Bit	Name	Meaning
0		
1	GPS	An unmasked bit in the GPS receiver status has been set.
2	ERR	There is at least one error in the error queue. Query the error with the command SYST:ERR?
3	QUES	An unmasked bit in the QUES status register has been set.
4	MAV	The interface output buffer has at least one character in it. Perform a read of instrument to retrieve it.
5	ESR	An unmasked bit in the standard event status register (*ESR) has been set.
6	MSS	Master summary bit. Indicates that the instrument is requesting service because an unmasked bit in this register has been set.
7	OPER	An unmasked bit in the OPER status register has been set.

The serial poll status byte may be queried with the *STB? command. The service request enable register (*SRE) may be used to control when the instrument asserts a request-for-service on interfaces where that is supported.

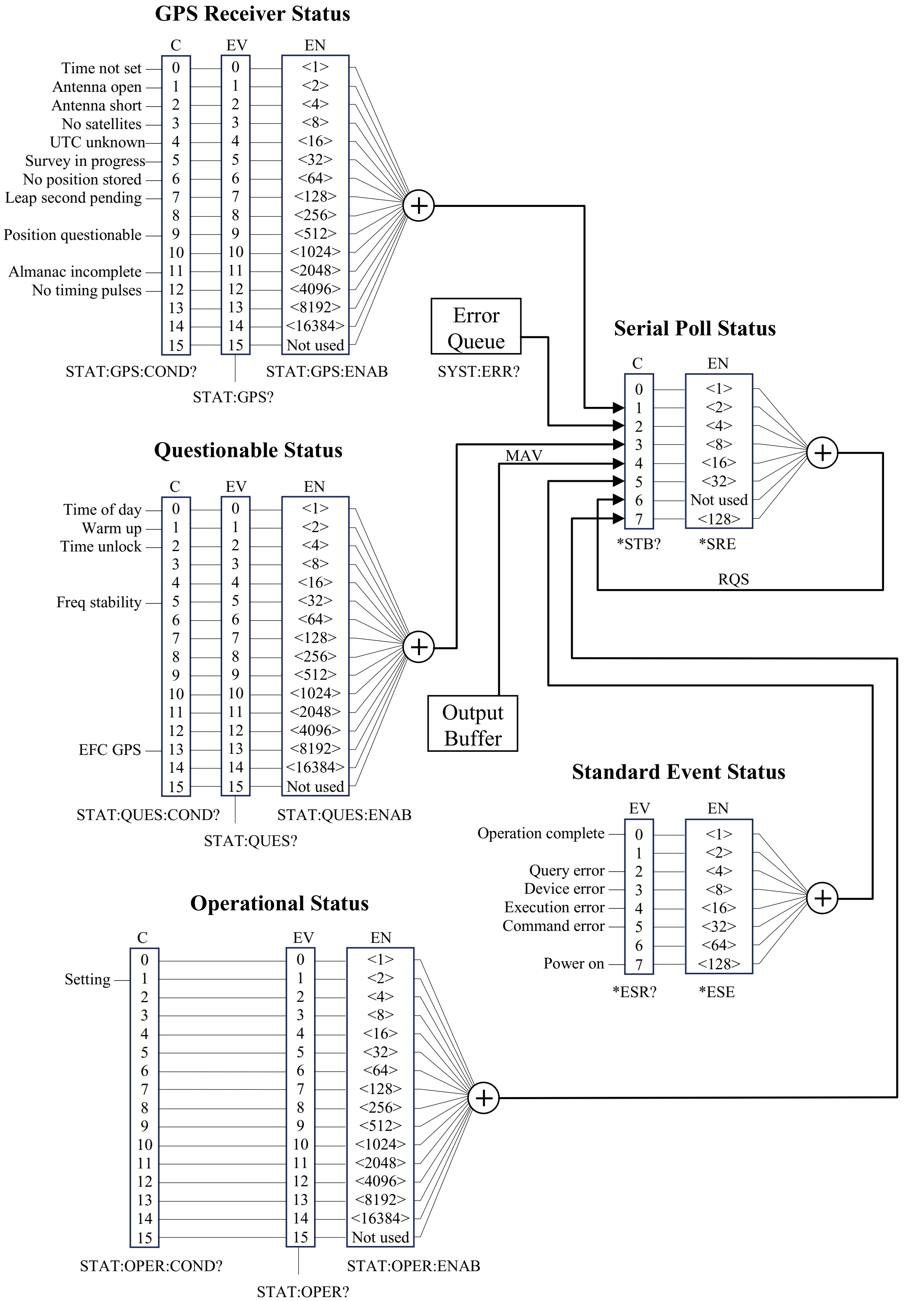


Figure 19: FS752 Status reporting

Standard Event Status Register

The standard event register provides status information on command parsing and execution. The interpretation for bits in the standard event status register is shown in Table 7.

Table 7: Interpretation of standard event status bits

Bit	Name	Meaning
0	OPC	Operation complete. All previous commands have completed. See command *OPC.
1		
2	QYE	Query error occurred.
3	DDE	Device dependent error occurred.
4	EXE	Execution error. A command failed to execute correctly because a parameter was invalid.
5	CME	Command error. The parser detected a syntax error.
6		
7	PON	Power on. The unit has been power cycled.

The standard event status register may be queried with the *ESR? command. The standard event status enable register (*ESE) may be used to control the setting of the ESR summary bit in the serial poll status byte (*STB).

Questionable Status

Bits in the questionable status register warn the user when the validity of some instrument function is in question. For example, bit 0 of the questionable status register will be set until the GPS receiver has successfully decoded the time of day from the GPS satellites. Until this happens, all time of day information reported by the FS752 is invalid. Other bits in the questionable status register provide information on the frequency stability of the timebase.

The interpretation for bits in the questionable status register is shown in Table 8

Table 8: Interpretation of questionable status bits

Bit	Name	Meaning
0	Time of day	Instrument time of day has not been set by the GPS receiver. Absolute time measurements are invalid.
1	Warm up	The timebase is still warming up. Frequency drift will be much larger than normal.
2	Time unlock	The timebase is not locked to GPS. Time and frequency stability may be degraded.
3		
4		
5	Freq stability	The timebase has not been locked to GPS long enough to reach optimum frequency stability.
6		
7		
8		
9		
10		
11		
12		
13	EFC GPS	Indicates that the frequency control for the installed timebase is saturated. This might indicate a large timing error.
14		
15		

The condition, event, and enable registers for questionable status are queried using the following commands, respectively.

```
STAT:QUES:COND?
STAT:QUES?
STAT:QUES:ENAB?
```

Operation Status

Bits in the operational status register provide information on the operation of the instrument. For example, bit 1 of the operational status register indicates that a hardware setting in the FS752 has changed. Most settings change quickly, so this bit will normally only be detected via the event register.

The interpretation for bits in the operational status register is shown in Table 9

Table 9: Interpretation of operation status bits

Bit	Name	Meaning
0		
1	Setting	Hardware instrument settings are changing
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

The condition, event, and enable registers for operational status are queried using the following commands, respectively.

```
STAT:OPER:COND?
STAT:OPER?
STAT:OPER:ENAB?
```

GPS Receiver Status

Bits in the GPS receiver status register provide information on the status of the GNSS receiver and its ability to track satellites.

The interpretation for bits in the GPS receiver status register is shown in Table 10

Table 10: Interpretation of GPS receiver status bits

Bit	Name	Meaning
0	Time not set	Time of day information has not been received from the satellites, yet.
1	Antenna open	The GNSS antenna does not appear to be connected to the receiver input.
2	Antenna short	The receiver input appears to be shorted.
3	No satellites	No GNS satellites have been found
4	UTC unknown	The UTC offset from GPS is unknown. The offset is recorded in the almanac which can take up to 15 minutes to download from the satellites.
5	Survey in progress	A position survey is in progress.
6	No position stored	No surveyed position has been stored in nonvolatile memory.
7	Leap second pending	A leap second is pending. When pending, they are normally scheduled for the end of the day on June 30th or December 31st.
8		
9	Position questionable	The stored position does not appear to be correct according to data now being collected. A new survey may need to be collected.
10		
11	Almanac incomplete	A complete almanac has not been downloaded from the GPS satellites, yet. It can take up to 15 minutes of continuous tracking of satellites to download the almanac.
12	No timing pulses	Timing pulses are not being generated by the receiver. Timing pulses must be generated in order for the FS752 to lock its timebase to the GNSS satellites.
13		
14		
15		

The condition, event, and enable registers for GPS receiver status are queried using the following commands, respectively.

```
STAT:GPS:COND?
STAT:GPS?
STAT:GPS:ENAB?
```

Common IEEE-488.2 Commands

***CLS** **Clear Status**

Syntax

```
*CLS
```

Description

This command immediately clears all status registers as well as the SYST:ERR queue.

***ESE** **Standard Event Status Enable**

Syntax

```
*ESE <value>
*ESE?
```

Description

Set the Standard Event Status Enable register to <value>. The value may range from 0 to 255. Bits set in this register cause ESR (in *STB) to be set when the corresponding bit is set in the *ESR register. The query returns the current value of the enable register. Definitions for the bits in the standard event register are given on page 48.

Example

```
*ESE 1
```

Enable bit 0 so that an operation complete event will set the ESR bit in the serial poll status byte.

***ESR?** **Standard Event Status Register**

Syntax

```
*ESR?
```

Description

Query the Standard Event Status Register. After the query, the returned bits of the *ESR register are cleared. The bits in the ESR register have the following meaning:

Bit	Meaning
0	OPC – operation complete
1	Reserved
2	QYE – query error
3	DDE – device dependent error
4	EXE – execution error
5	CME – command error
6	Reserved
7	PON – power-on

See page 48 for more detailed information on the event status register.

Example

```
*ESR?
```

A return of ‘176’ would indicate that PON, CME, and EXE are set.

*IDN? Identification String

Syntax

```
*IDN?
```

Description

Query the instrument identification string.

Example

```
*IDN?
```

Returns a string similar to 'Stanford Research Systems,FS752,s/n001025,ver1.00'

*OPC Operation Complete

Syntax

```
*OPC
*OPC?
```

Description

The set form sets the OPC flag in the *ESR register when all prior commands have completed. The query form returns '1' when all prior commands have completed, but does not affect the *ESR register.

*OPT? Options

Syntax

```
*OPT?
```

Description

The query returns a comma separated list of the two possible installed options in the following order: left rear panel board, and right rear panel board. They may take on the following values:

Option	Value
10 MHz distribution	A
1 PPS distribution	B
Not installed	X

Example

```
*OPT?
```

The query returns the current installed options. A return of "A,X" would indicate that one 10 MHz distribution board is installed in the left slot. The right slot is empty.

*PSC Power-on Status Clear

Syntax

```
*PSC <value>
*PSC?
```

Description

Set the Power-on Status Clear flag to <value>. The Power-on Status Clear flag is stored in nonvolatile memory in the unit, and thus, maintains its value through power-cycle events.

If the value of the flag is 0, then the Service Request Enable and Standard Event Status Enable Registers (*SRE, *ESE) are stored in non-volatile memory, and retain their values through power-cycle events. If the value of the flag is 1, then these two registers are cleared upon power-cycle.

Example

Use the following commands to set power on status clear to 1 and then query the setting.

```
*PSC 1
*PSC?
```

*RCL Recall Instrument Settings

Syntax

```
*RCL <location>
```

Description

Recall instrument settings from <location>. The <location> may range from 0 to 9. Locations 1 to 9 are for arbitrary use. Location 0 is reserved for the recall of default instrument settings. Note that this command primarily affects the display, not the overall instrument configuration.

Example

```
*RCL 3
```

Recall instruments settings from location 3.

*RST Reset Instrument

Syntax

```
*RST
```

Description

Reset the instrument to default settings. This is equivalent to *RCL 0. See Factory Default Settings on page 37 for a list of default settings.

*SAV Save Instrument Settings

Syntax

```
*SAV <location>
```

Description

Save instrument settings to <location>. The <location> may range from 0 to 9. However, location 0 is reserved for current instrument settings. It will be overwritten after each front panel key press. Note that this command primarily affects the display, not the overall instrument configuration.

Example

```
*SAV 3
```

Save current instrument settings to location 3.

*SRE — Service Request Enable

Syntax

```
*SRE <value>
*SRE?
```

Description

Set the Service Request Enable register to <value>. Bits set in this register cause the FS752 to set the summary status bit when the corresponding bit is set in the serial poll status register, *STB.

Example

```
*SRE 16
```

Set bit 4 of the enable register. This will cause the master summary bit of the serial poll status register to be set when the FS752 has bytes in its output buffer ready to be read. Definitions for the bits in the serial poll status byte are given on page 46.

*STB? — Status Byte

Syntax

```
*STB?
```

Description

Query the standard IEEE 488.2 serial poll status byte. The bits in the STB register have the following meaning:

Bit	Meaning
0	Reserved
1	GPS status summary bit
2	Error queue is not empty
3	Questionable status summary bit
4	Message available, MAV.
5	ESR status summary bit
6	MSS – master summary bit
7	Operational status summary bit

See page 46 for more detailed information on the serial poll status byte.

Example

```
*STB?
```

A return of ‘114’ would indicate that GPS, MAV, ESR, and MSS are set. GPS indicates that an enabled bit in STAT:GPS is set. MAV indicates that a message is available in the output queue. ESR indicates that an enabled bit in the *ESR is set. MSS reflects the fact that at least one of the summary enable bits is set and the instrument is requesting service.

*WAI Wait for Command Execution

Syntax

```
*WAI
```

Description

The instrument will not process further commands until all prior commands including this one have completed.

Example

```
*WAI
```

Wait for all prior commands to execute before continuing.

GPS Subsystem

Commands in the GPS Subsystem enable configuration of the GNSS receiver and report on its operation.

GPS:CONFig:CONStellation — GPS Configure Constellation

Syntax

```
GPS:CONFig:CONStellation <constellation mask>
GPS:CONFig:CONStellation?
```

Description

The first definition enables the user to set the combination of satellites tracked. The second definition queries the current combination of satellites being tracked. The constellation mask is a single number from 1 to 15 whose binary bits identify the combination of satellites that should be tracked as identified in Table 11. The default constellation mask is 3, which has bits 0 and 1 set, meaning GPS and GLONASS will be tracked. The user must execute the command GPS:CONF:SAVE to save the current values to nonvolatile memory. Note that not all combinations are supported. If an unsupported combination is requested, the command will be ignored without reporting an error.

Table 11: Constellation bit definitions

Bit	Constellation
0	GPS
1	GLONASS
2	BEIDOU
3	GALILEO

Example

```
GPS:CONF:CONS 3
```

Configure the GNSS receiver to track GPS and GLONASS.

GPS:CONFig:MODe — GPS Configure Mode

Syntax

```
GPS:CONFig:MODe <anti-jamming>, <elevation mask>, <signal mask>
GPS:CONFig:MODe?
```

Description

The first definition enables the user to set anti-jamming mode, the elevation mask and the signal mask. The second definition queries the current values for these parameters. <Anti-jamming> is a Boolean value which enables or disables anti-jamming in the receiver. The factory default is enabled. <Elevation mask> is the elevation angle in radians, below which satellites are ignored in over determined clock mode. It can range from 0 to $\pi/2$. <Signal mask> is the minimum signal level in dbHz, below which satellites are ignored in over determined clock mode. It can range from 0 to 55 dBHz. The default value for both masks is 0. The user must execute the command GPS:CONF:SAVE to save the current values to nonvolatile memory.

Example

```
GPS:CONF:MODE 1,0.2618,10
```

Enable anti-jamming. Set elevation mask to 15 degrees = 0.2618 radians. Set the minimum signal level to 10 dbHz.

GPS:CONFig:SAVe — GPS Configure Save

Syntax

```
GPS:CONFig:SAVe
```

Description

The user uses commands in the GPS:CONFIG subsystem to configure the operation of the receiver. The configuration is lost, however, if the power is cycled unless this command is executed. It saves the current GPS receiver configuration to nonvolatile memory, so that it may be automatically recalled when the power is cycled.

Example

```
GPS:CONF:SAV
```

Save the current GPS receiver configuration to nonvolatile memory.

GPS:CONFig:SURVey:Mode — GPS Configure Survey Mode

Syntax

```
GPS:CONFig:SURVey[:MODe] [{DISabled|REDo|REMember}]
GPS:CONFig:SURVey[:MODe]?
```

Description

The first definition sets the GPS survey mode to the given configuration. If mode is omitted, the default mode is REDo. The second definition queries the current GPS survey mode. When DISabled is selected no survey is carried out. This mode is appropriate in mobile environments. REDo causes the survey to be repeated each time the instrument is power cycled. REMember causes the results of the survey to be saved in nonvolatile memory. When the instrument is power cycled, the surveyed position is recalled from memory and the survey is not repeated. The user must execute the command GPS:CONF:SAVE to save the current value to nonvolatile memory.

Example

```
GPS:CONF:SURV REM
```

Configure the GPS receiver to do a survey at startup the first time, but to remember the results of the first survey from then on rather than repeating the survey.

GPS:CONFig:SURVey:FIXes — GPS Configure Survey Fixes

Syntax

```
GPS:CONFig:SURVey:FIXes [<fixes>]
GPS:CONFig:SURVey:FIXes?
```

Description

The first definition sets the number of position fixes in the survey. If <fixes> is omitted, the default number is 2000. The second definition queries the current number of position fixes in the position survey. This is the number of position fixes that get averaged together to define the GPS antennas location. Once the position is well known, the receiver can be put into over determined clock mode and the receiver can provide improved timing by dedicating the signal from all satellites to timing.

The user must execute the command GPS:CONF:SAVE to save the current value to nonvolatile memory.

Example

```
GPS:CONF:SURV:FIX 3000
```

Configure the GPS receiver to include 3000 position fixes in the position survey.

GPS:CONFig:ALIGnment — GPS Configure Timing Alignment

Syntax

```
GPS:CONFig[:TIMing]:ALIGnment [{UTC|GPS|GLONass|BEIDou|GALileo}]
GPS:CONFig[:TIMing]:ALIGnment?
```

Description

The first definition sets the 1pps alignment. If alignment is omitted, the default alignment is UTC. The second definition queries the current 1pps alignment. When UTC is selected, all timing is aligned to UTC. The other options align timing to the given navigation system. Any selection other than UTC requires that that constellation be tracked as well. The user must execute the command GPS:CONF:SAVE to save the current value to nonvolatile memory.

Example

```
GPS:CONF:ALIG UTC
```

Alignment of the 1pps output is to UTC.

GPS:CONFig:QUALity — GPS Configure Timing Quality

Syntax

```
GPS:CONFig[:TIMing]:QUALity [{1SAT|3SAT}]
GPS:CONFig[:TIMing]:QUALity?
```

Description

The first definition sets the minimum number of satellites the receiver must track before outputting a hardware 1pps pulse. If omitted, the default quality is 1 satellite. The second definition queries the current timing quality. Timing quality generally increases as the number of satellites increases. However, the user must also consider reliability and holdover performance. Degraded performance may be preferred over no timing whatsoever. The user must execute the command GPS:CONF:SAVE to save the current value to nonvolatile memory.

Example

```
GPS:CONF:QUAL 3SAT
```

Require the GPS receiver to track 3 satellites before outputting a hardware 1pps pulse for the timebase to track.

GPS:CONFig:ADELay — GPS Configure Timing Antenna Delay

Syntax

```
GPS:CONFig[:TIMing]:ADELay <delay>
GPS:CONFig[:TIMing]:ADELay?
```

Description

The first definition sets the antenna delay to <delay> in seconds. The second definition queries the current antenna delay in seconds. The <delay> may range from −0.1 s to +0.1 s. Note that the user should enter a negative number here to compensate for the length of their antenna cable. It affects the timing of all inputs and outputs. The user must execute the command GPS:CONF:SAVE to save the current value to nonvolatile memory.

Example

```
GPS:CONF:ADEL -100ns
```

Set delay to −100 ns. This advances the timing generated by the GNSS receiver by 100 ns.

GPS:POSition? — GPS Position

Syntax

```
GPS:POSition?
```

Description

Query the GPS position. This routine returns the surveyed average position of the receiver in latitude, longitude, and altitude. Latitude is specified in radians, with positive values indicating north, and negative values indicating south. Longitude is specified in radians, with positive values indicating east, and negative values indicating west. Altitude is specified in meters above the reference ellipsoid (WGS84).

Example

```
GPS:POS?
```

Query the current surveyed position of the GPS receiver.

GPS:POSition:HOLD:STATe? — GPS Position Hold State

Syntax

```
GPS:POSition:HOLD:STATe?
```

Description

Query whether the GPS receiver is in over-determined clock mode where all satellites are being used for maximum timing performance. The query will return 1 if the receiver is in over-determined clock mode, otherwise 0. The receiver typically enters over-determined clock mode once the position survey is complete.

Example

```
GPS:POS:HOLD:STAT?
```

Query whether the GPS receiver has entered over-determined clock mode.

GPS:POSition:SURVey — Set GPS Position Survey

Syntax

```
GPS:POSition:SURVey <latitude>,<longitude>,<altitude>
```

Description

Specify the surveyed position to be <latitude>, <longitude>, and <altitude>. The FS752 will take the supplied values as the current surveyed position and enter over-determined clock mode. <Latitude> and <longitude> should be specified in radians and <altitude> in meters. For <latitude>, use positive values for north and negative values for south. For <longitude> use positive values for east and negative values for west. The altitude refers to the height above the reference ellipsoid (WGS84). Note that this is not the same as mean sea level.

Example

```
GPS:POS:SURV 0.652917714322,-2.1290993165,-26
```

Set the position for the position survey and go to over-determined clock mode.

GPS:POSition:SURVey:DELete — GPS Position Survey Delete

Syntax

```
GPS:POSition:SURVey:DELete
```

Description

Delete the surveyed position stored in nonvolatile memory, if any.

Example

```
GPS:POS:SURV:DEL
```

Delete the current stored position in nonvolatile memory.

GPS:POSition:SURVey:PROGress? — GPS Position Survey Progress

Syntax

```
GPS:POSition:SURVey:PROGress?
```

Description

Query how much of the position survey has completed. The FS752 will return an integer between 0 and 100 %.

Example

```
GPS:POS:SURV:PROG?
```

Query the progress of the position survey by the GNSS receiver.

GPS:POSition:SURVey:SAVe — GPS Position Survey Save

Syntax

```
GPS:POSition:SURVey:SAVe
```

Description

Save the current position in nonvolatile memory. The receiver will subsequently use it to enter over-determined clock mode where all satellites are used for maximum timing performance.

Example

```
GPS:POS:SURV:SAV
```

Save the current position in nonvolatile memory.

GPS:POSition:SURVey:STARt — GPS Position Survey Start

Syntax

```
GPS:POSition:SURVey:STARt
```

Description

Restart the GNSS receiver's position survey. Note that previously saved results are not deleted by this command.

Example

```
GPS:POS:SURV:STAR
```

Restart the GPS receiver's position survey.

GPS:POSition:SURVey:STATe? — GPS Position Survey State

Syntax

```
GPS:POSition:SURVey:STATe?
```

Description

Query whether a position survey is in progress or not. The query returns 1 if the survey is in progress, otherwise 0.

Example

```
GPS:POS:SURV:STAT
```

Query whether a position survey is in progress.

GPS:SATellite:TRACking? — GPS Satellite Tracking

Syntax

```
GPS:SATellite:TRACking?
```

Description

Query which GNSS satellites are being tracked by the receiver. The query returns the number of satellites being tracked, followed by the IDs of the satellites as a comma (,) separated list.

Example

```
GPS:SAT:TRAC?
```

Query the number and IDs of the satellites being tracked by the receiver.

GPS:SATellite:TRACking:STATus? — GPS Satellite Tracking Status

Syntax

```
GPS:SATellite:TRACking:STATus?
```

Description

The receiver has 20 channels for tracking satellites. This command returns the information shown in Table 12 for each channel, successively:

Table 12: Satellite tracking information

Index	Parameter
0	Satellite ID number
1	Acquired
2	Ephemeris
3	Reserved
4	Signal level in dbHz
5	Elevation in degrees
6	Azimuth in degrees
7	Space vehicle type

If a channel is not tracking a satellite, it will return zero for all parameters. In all, $20 \times 8 = 160$ parameters are returned as a comma (,) separated list.

Example

```
GPS:SAT:TRAC:STAT?
```

Return tracking information on all satellites being followed.

GPS:UTC:OFFSet? — GPS UTC Offset

Syntax

```
GPS:UTC:OFFSet?
```

Description

Query the current offset between UTC and GPS in seconds. As of January 1, 2017, UTC, which has leap seconds inserted intermittently, is 18 seconds behind GPS which does not have leap seconds inserted. Note that this command will return 0 until the time of day has been set properly.

Example

```
GPS:UTC:OFFS?
```

Query the current offset between UTC and GPS in seconds.

Source Subsystem

The Source Subsystem enables users to configure the phase of the 1 PPS output.

SOURce:PHASe — Source Phase Adjust

Syntax

```
SOURce[{1|2|3}]:PHASe[:ADJust] {<phase>|MINimum|MAXimum|DEFault}
SOURce[{1|2|3}]:PHASe[:ADJust]? [{MINimum|MAXimum}]
```

Description

The first definition adjusts the phase of the selected output to <phase> or one of the keyword values. The second definition queries the current phase for the selected output. <Phase> is specified in seconds. Positive values of <phase> cause the phase to lead the reference. Negative values of <phase> cause the phase to lag the reference.

Example

```
SOUR:PHAS:SYNC
SOUR:PHAS -10e-9
```

Synchronize the phase for the 1 PPS output to UTC. Advance the phase by 10 ns.

SOURce:PHASe:SYNChronize — Source Phase Synchronize

Syntax

```
SOURce:PHASe:SYNChronize
```

Description

Adjust the phase for the 1 PPS output to align with UTC, if possible. If UTC is not yet known, then phase is aligned to a common internal reference. The is aligned on the next second boundary of UTC.

Example

```
SOUR:PHAS:SYNC
```

Synchronize the phase for the Sine output to UTC.

SOURce:PHASe:SYNChronize:TDELay — Source Phase Synchronize Time Delay

Syntax

```
SOURce[{1|2|3}]:PHASe:SYNChronize:TDELay {<delay>|MINiumum|MAXimum|DEFault}
SOURce[{1|2|3}]:PHASe:SYNChronize:TDELay?
```

Description

This command enables the user to control alignment of the signal of an output relative to UTC. The first definition sets the time delay to <delay> or the given limit. The second definition queries the current value of the time delay. The <delay> can range from −1.0 to +1.0 seconds. Negative delays advance the phase of the signal. Positive delays retard the phase of the signal. This command is useful for correcting insertion delays of cables used to get signals from the FS752 to application equipment. The factory default is 0.0 seconds. This is a system setting which is unaffected by a *RST command or a recall of default settings. The setting is stored in nonvolatile memory and automatically restored at power on.

Example

```
SOUR:PHAS:SYNC:TDEL -100 ns
```

Advance the phase of the 1 PPS output by 100 ns. This will correct for several feet of cable delay in getting the signal to application equipment.

Status Subsystem

Commands in the Status Subsystem report on instrument status. Each element of status has 3 registers associated with it: a condition register, an event register, and an enable register. For a detailed discussion of these registers and how they are related see Status Reporting on page 44.

STATus:GPS:CONDition? — Status GPS Condition

Syntax

```
STATus:GPS:CONDition?
```

Description

Query the current condition of the GPS receiver. See section GPS Receiver Status on page 51 for detailed information on the interpretation of GPS receiver status. See Status Reporting on page 44 for more information on condition registers.

Example

```
STAT:GPS:COND?
```

Query the current condition of the GPS receiver status register.

STATus:GPS:ENABle Status GPS Enable

Syntax

```
STATus:GPS:ENABle <mask>
STATus:GPS:ENABle?
```

Description

The first definition sets the mask for combining GPS receiver status bits into the summary bit located in the serial poll status byte. The second definition queries the current mask. See section GPS Receiver Status on page 51 for detailed information on the interpretation of GPS receiver status. See section Status Reporting on page 44 for more information about enable registers.

Example

```
STAT:GPS:ENAB 1
```

Set the summary bit in the serial poll status byte if the time of day of the instrument has not been set by the GPS receiver.

STATus:GPS:EVENt? Status GPS Event

Syntax

```
STATus:GPS[:EVENt]?
```

Description

Query the GPS receiver status event register. See section GPS Receiver Status on page 51 for detailed information on the interpretation of GPS receiver status. See Status Reporting on page 44 for more information on event registers.

Example

```
STAT:GPS?
```

Query the event register for GPS receiver status. This returns all bits that have been set since the previous query. The query then clears all bits.

STATus:OPERation:CONDition? Status Operation Condition

Syntax

```
STATus:OPERation:CONDition?
```

Description

Query the current condition of operational status for the FS752. See section Operation Status on page 50 for detailed information on the interpretation of the operation status bits. See Status Reporting on page 44 for more information on condition registers.

Example

```
STAT:OPER:COND?
```

Query the current condition of operational status for the FS752.

STATus:OPERation:ENABle — Status Operation Enable

Syntax

```
STATus:OPERation:ENABle <mask>
STATus:OPERation:ENABle?
```

Description

The first definition sets the mask for combining operational status bits into the summary bit located in the serial poll status byte. The second definition returns the current mask. See section Operation Status on page 50 for detailed information on the interpretation of operational status bits. See section Status Reporting on page 44 for more information about enable registers.

Example

```
STAT:OPER:ENAB 2
```

Set the summary bit in the serial poll status byte if instrument settings changed since the previous query of the event register.

STATus:OPERation:EVENt? — Status Operation Event

Syntax

```
STATus:OPERation[:EVENt]?
```

Description

Query the event register of operational status for the FS752. See section Operation Status on page 50 for detailed information on the interpretation of the operation status bits. See Status Reporting on page 44 for more information on event registers.

Example

```
STAT:OPER?
```

Query the event register for operational status. This returns all bits that have been set since the previous query. The query then clears all bits.

STATus:QUEStionable:CONDition? — Status Questionable Condition

Syntax

```
STATus:QUEStionable:CONDition?
```

Description

Query the current condition of questionable status for the FS752. See section Questionable Status on page 49 for detailed information on the interpretation of the questionable status bits. See Status Reporting on page 44 for more information on condition registers.

Example

```
STAT:QUES:COND?
```

Query the current condition of questionable status for the FS752.

STATus:QUEStionable:ENABle — Status Questionable Enable

Syntax

```
STATus:QUEStionable:ENABle <mask>
STATus:QUEStionable:ENABle?
```

Description

The first definition sets the mask for combining questionable status bits into the summary bit located in the serial poll status byte. The second definition returns the current mask. See section Questionable Status on page 49 for detailed information on the interpretation of questionable status bits. See section Status Reporting on page 44 for more information about enable registers.

Example

```
STAT:QUES:ENAB 32
```

Set the summary bit in the serial poll status byte if the timebase was not at optimum frequency stability since the previous query of the event register.

STATus:QUEStionable:EVENt? — Status Questionable Event

Syntax

```
STATus:QUEStionable[:EVENt]?
```

Description

Query the event register of questionable status for the FS752. See section Questionable Status on page 49 for detailed information on the interpretation of the questionable status bits. See Status Reporting on page 44 for more information on event registers.

Example

```
STAT:QUES?
```

Query the event register for questionable status. This returns all bits that have been set since the previous query. The query then clears all bits.

System Subsystem

Commands in the System Subsystem control overall system behavior. System settings are typically not affected by a *RST and are stored in nonvolatile memory so that they may be recalled automatically when the power is cycled.

SYSTem:ALARm? — System Alarm

Syntax

```
SYSTem:ALARm?
```

Description

Query the current state of the system alarm. The FS752 will return 1 if the alarm is asserted, otherwise 0.

Example

```
SYST:ALAR?
```

Query the current state of the system alarm.

SYSTem:ALARm:CLEar System Alarm Clear

Syntax

```
SYSTem:ALARm:CLEar
```

Description

Clear the event register for the system alarm. When the current mode for command SYST:ALARm:MODe is LATCh, this will clear the alarm assuming current limits are not being exceeded.

Example

```
SYST:ALAR:CLE
```

Clear the event register for the system alarm.

SYSTem:ALARm:CONDition? System Alarm Condition

Syntax

```
SYSTem:ALARm:CONDition?
```

Description

Query the condition register for the system alarm. This register indicates which of the possible alarm conditions are currently true. The system alarm will only be asserted if a condition is true and it is enabled in the enable register.

Example

```
SYST:ALAR:COND?
```

Query the condition register for the system alarm.

SYSTem:ALARm:ENABle System Alarm Enable

Syntax

```
SYSTem:ALARm:ENABle <mask>
SYSTem:ALARm:ENABle?
```

Description

Mask possible alarm conditions so that only those that are enabled here can cause the system alarm to be asserted. When the current mode for command SYST:ALARm:MODe is TRACk, this register masks the condition register for the system alarm, SYST:ALARm:CONDition. When the current mode for command SYST:ALARm:MODe is LATCh, this register masks the event register for the system alarm, SYST:ALARm:EVENt.

Example

```
SYST:ALAR:ENAB 1
```

Enable alarm if the time of day has not been set by GPS.

SYSTem:ALARm:EVENt? System Alarm Event

Syntax

```
SYSTem:ALARm:EVENt?
```

Description

Query the event register for the system alarm. This register indicates which of the possible alarm conditions that have been latched since the last time the event register was cleared. When the current mode for command SYST:ALARm:MODe is LATCh the system alarm will be asserted if an event condition is true AND it is enabled in the enable register. Note that unlike the event registers in the Status Subsystem, reading this register does not clear it. It must be explicitly cleared with the SYSTem:ALARm:CLEar command.

Example

```
SYST:ALAR:EVENt?
```

Query the condition register for the system alarm.

SYSTem:ALARm:FORCe:STATe System Alarm Force State

Syntax

```
SYSTem:ALARm:FORCe[:STATe] {1|ON|0|OFF}
SYSTem:ALARm:FORCe[:STATe]?
```

Description

The first definition sets the forced state of the alarm. The second definition queries the current forced state of the alarm. This value only has significance if the current mode for command SYST:ALARm:MODe is FORCe.

Example

```
SYST:ALAR:FORC ON
```

Assert the alarm if the alarm mode is FORCe.

SYSTem:ALARm:MODe System Alarm Mode

Syntax

```
SYSTem:ALARm:MODe {TRACk|LATCh|FORCe}
SYSTem:ALARm:MODe?
```

Description

The first definition sets the alarm mode to one of three options: track, latch, or force. The second definition queries the current alarm mode.

Tracking mode causes the alarm to follow current conditions. The alarm is asserted when current limits are exceeded. The alarm is de-asserted when current limits are no longer exceeded.

Latching mode causes the alarm to be asserted when current limits are exceeded. However, the alarm will not be de-asserted until explicitly requested to do so and the limit is no longer exceeded.

In force mode, the user manually sets the state of the alarm.

Example

```
SYST:ALAR:MODe
```

Query the current mode for the system alarm.

SYSTem:ALARm:GPS:TINTerval — System Alarm GPS Time Interval

Syntax

```
SYSTem:ALARm[:GPS]:TINTerval {<time error>|MINimum|MAXimum|DEFault}
SYSTem:ALARm[:GPS]:TINTerval?
```

Description

The first definition sets the time interval between GPS and the internal timebase that must be exceeded before the alarm condition for a timing error is asserted. The <time error> may range from 50 ns to 1 s. The default is 100 ns. The second definition queries the current value for the time interval.

Example

```
SYST:ALAR:TINT 1 us
```

Set the timing error limit to 1 µs. This means that the alarm condition for timing errors will not be set unless the measured time interval between GPS and the internal timebase exceeds 1 µs. Note that the system alarm will not actually be asserted unless this condition is also enabled with the SYST:ALARm:ENABle command.

SYSTem:ALARm:HOLDover:Duration — System Alarm Holdover Duration

Syntax

```
SYSTem:ALARm[:HOLDover]:DURation {<duration>|MINimum|MAXimum|DEFault}
SYSTem:ALARm[:HOLDover]:DURation?
```

Description

The first definition sets the amount of time in seconds that the FS752 must be in holdover before the alarm condition for holdover is asserted. The <duration> may be any 32 bit unsigned integer. The default is 0. The second definition queries the current value for the duration.

Example

```
SYST:ALAR:DUR 100
```

Set the holdover duration to 100 seconds. This means that the alarm condition for holdover will not be set unless the FS752 is in holdover for more than 100 seconds. Note that the alarm will not actually be asserted unless this condition is also enabled with the SYST:ALARm:ENABle command.

SYSTem:COMMunicate:SERial:BAUD — System Communicate Serial Baudrate

Syntax

```
SYSTem:COMMunicate:SERial:BAUD {4800|9600|19200|38400|57600|115200}
SYSTem:COMMunicate:SERial:BAUD?
```

Description

The first definition configures the RS-232 port to operate at the selected baud rate. The second definition queries the current baud rate. Note that the new configuration does not take effect until the port is reset via a SYSTem:COMMunicate:SERial:RESet command or the power is cycled.

Example

```
SYST:COMM:SER:BAUD 115200
```

```
SYST:COMM:SER:RESET
```

Set the serial port baud rate to 115200 baud. Then reset the port so that the new baud rate becomes active.

SYSTem:COMMunicate:SERial:RESet — System Communicate Serial Reset

Syntax

```
SYSTem:COMMunicate:SERial:RESet
```

Description

Reset the serial port and activate it using the current configured baud rate

Example

```
SYST:COMM:SER:BAUD 115200
SYST:COMM:SER:RESET
```

Set the serial port baud rate to 115200 baud. Then reset the port so that the new baud rate becomes active.

SYSTem:COMMunicate:LOCK? — System Communicate Lock

Syntax

```
SYSTem:COMMunicate:LOCK?
```

Description

Request an exclusive lock on communication with the FS752. The FS752 will return 1 if the request is granted, otherwise 0. When an interface has an exclusive lock on communication with the FS752, other remote interfaces as well as the front panel are prevented from changing the instrument state. The user should call the command SYSTem:COMMunicate:UNLock command to release the exclusive lock when it is no longer needed.

Example

```
SYST:COMM:LOCK?
SOUR:FREQ 5 MHz
SOUR2:FREQ 1 MHz
SYST:COMM:UNL?
```

Request a communications lock. If all is well, the FS752 will return 1, indicating it has granted the lock. Set the frequency for the Sine output to 5 MHz. Set the frequency for the Aux output to 1 MHz. Finally, release the communications lock.

SYSTem:COMMunicate:UNLock? — System Communicate Unlock

Syntax

```
SYSTem:COMMunicate:UNLock?
```

Description

Release an exclusive lock on communication with the FS752 that was previously granted with the SYSTem:COMMunicate:LOCK command. The FS752 will return 1 if the lock was released, otherwise 0.

Example

```
SYST:COMM:LOCK?
```

```
SOUR:FREQ 5 MHz
SOUR2:FREQ 1 MHz
SYST:COMM:UNL?
```

Request a communications lock. If all is well, the FS752 will return 1, indicating it has granted the lock. Set the frequency for the Sine output to 5 MHz. Set the frequency for the Aux output to 1 MHz. Finally, release the communications lock.

SYSTem:DATe System Date

Syntax

```
SYSTem:DATe <year>,<month>,<day>
SYSTem:DATe?
```

Description

The first definition sets the FS752 date if it has not been set by the GNSS receiver. If the date has already been set, error −221, “Settings conflict,” will be generated and the requested date ignored. The second definition queries the current date. It returns the year, month, and day as a comma (,) separated list.

Example

```
SYST:DATE 2016,12,15
```

Set the current date for the FS752 to December 15, 2016, if the date has not already been set by the GNSS receiver.

SYSTem:DISPlay:SCReen System Display Screen

Syntax

```
SYSTem:DISPlay[:SCReen] [{TIMe|DATe|DELTa|SATellites|SNR]
SYSTem:DISPlay[:SCReen]?
```

Description

The first definition sets the display. This is equivalent to pressing one of the 8 keys located in the right hand portion of the front panel display. Allowed values are detailed in Table 13. If omitted the display defaults to timebase status and configuration. The second definition queries the current display setting.

Table 13: Allowed display settings

Keyword	Display setting
TIMe	Current time of day
DATe	Current date
DELTa	Delta between FS752 1 PPS and receiver’s 1 PPS
SATellites	Number of satellites tracked
SNR	Average signal to noise ratio of tracked satellites

Example

```
SYST:DISP SYST
```

Set the display to system settings.

SYSTem:ERRor? System Error

Syntax

```
SYSTem:ERRor[:NEXT]?
```

Description

Query the next error at the front of the error queue and then remove it. The error queue can store up to 10 errors. If the error queue overflows, the last error in the queue will be replaced with the error: −350, “Error queue overflow.”

Example

```
SYST:ERR?
```

Query the next error in the error queue. If no error is in the queue, then 0, “No error,” is returned.

SYSTem:SECurity:IMMediate System Security Immediate

Syntax

```
SYSTem:SECurity:IMMediate
```

Description

This command wipes the instrument of user settings and restores the unit to factory default settings. All settings stored in nonvolatile memory will be erased except for firmware and calibration data. This includes configuration settings for the GNSS receiver and all the remote interfaces. All system configuration settings will be replaced with factory defaults. Execution of this command is not recommended in normal use, as system configuration settings will be lost. However, it may be required when removing the instrument from a secure area. This command may take up to 10 seconds to complete. It should not generally be executed frequently. Use *RST for general use.

Example

```
SYST:SEC:IMM
```

Wipe the instrument of user settings and restore instrument to factory default settings.

SYSTem:TIMe System Time

Syntax

```
SYSTem:TIMe <hour>,<minute>,<second>
SYSTem:TIMe?
```

Description

The first definition sets the FS752 time of day if it has not been set by the GNSS receiver. If the time has already been set, error −221, “Settings conflict,” will be generated and the requested time ignored. The second definition queries the current time of day. It returns the hour, minute, and second as a comma (,) separated list of integers. The second field will be returned as a decimal fraction with 10 ns of resolution representing the precise time that the query was executed.

Example

```
SYST:TIM 16,23,43
```

Set the current time to 16:23:43, if the time has not already been set by GPS.

SYSTem:TIMe:LOFFset System Time Local Offset

Syntax

```
SYSTem:TIMe:LOFFset <offset>
SYSTem:TIMe:LOFFset?
```

Description

The first definition sets the local offset from UTC to local time in seconds. The second definition queries the current local offset in seconds. This setting is not affected by a *RST command. Its value is stored in nonvolatile memory and will be automatically restored when the power is cycled.

Example

```
SYST:TIM:LOFF -3600
```

Set the local time offset to −1 hour. With this offset in effect, times reported by the FS752 will be 1 hour earlier than UTC.

SYSTem:TIMe:POWeron — System Time Power On

Syntax

```
SYSTem:TIMe:POWeron?
```

Description

Query the date and time at which the FS752 was powered on. The FS752 returns the year, month, day, hour, minute, and second as a comma (,) separated list. Until the date and time are set by the GNSS receiver this command will report power on to be midnight, January 6, 1980, which is the start date of GPS. Once time has been set by GPS, the true date and time of power on will be returned.

Example

```
SYST:TIM:POW?
```

Query the date and time at which the FS752 was powered on.

Timebase Subsystem

Commands in the Timebase Subsystem control the operation of the internal timebase, including whether it locks to the GNSS receiver, when it comes unlocked from the GNSS receiver, and how it recovers from the unlocked state. Note that commands in this subsystem are not affected by a *RST. They control system configuration and are automatically saved to nonvolatile memory.

TBASe:CONFig:BWIDth — Timebase Configure Bandwidth

Syntax

```
TBASe:CONFig:BWIDth [{AUTo|MANual}]
TBASe:CONFig:BWIDth?
```

Description

The first definition sets the desired bandwidth control. The second definition queries the current value for bandwidth control. When AUTo is selected, the bandwidth with which the timebase follows the GNSS receiver is automatically adjusted based on the measured timing errors. When the timing error is large bandwidth is increased. Conversely, when timing errors are small bandwidth is decreased. When MANual is selected, the bandwidth is fixed and the time constant of the phase lock loop is governed by the value set with the TBASe:TCONstant command. When the parameter is omitted, the value is assumed to be AUTo.

Example

```
TBAS:CONF:BWID AUT
```

Configure the timebase to automatically increase bandwidth when timing errors are large and then gradually narrow the bandwidth when lock is stable.

TBASe:CONFig:HMODe — Timebase Configure Holdover Mode

Syntax

```
TBASe:CONFig:HMODe [{WAIT|JUMP|SLEW}]
TBASe:CONFig:HMODe?
```

Description

The first definition controls how the timebase leaves holdover mode when timing offsets are larger than allowed. The second definition queries the current behavior for leaving holdover mode. When WAIT is selected, the timebase will wait for the timing offsets to improve before leaving holdover mode. If JUMP is selected, the timebase will leave holdover by jumping from its current phase to that of the GNSS receiver to correct the offset immediately. If SLEW is selected the timebase will leave holdover by slewing its phase from its current value to that of the GNSS receiver to correct the offset.

Example

```
TBAS:CONF:HMOD JUMP
```

Configure the timebase to leave holdover by jumping its phase to that of the GNSS receiver if the current timing error exceeds the configured limit.

TBASe:CONFig:LOCK — Timebase Configure Lock

Syntax

```
TBASe:CONFig:LOCK [{1|ON|0|OFF}]
TBASe:CONFig:LOCK?
```

Description

The first definition controls whether the timebase locks to the GNSS receiver or not. When set to 1 or ON, the timebase will lock to the GNSS receiver if it is generating timing pulses. When set to 0 or OFF, the timebase will not lock to the GNSS receiver. If the parameter is omitted, it is assumed to be ON. The second definition queries the current setting.

Example

```
TBAS:CONF:LOCK 1
```

Configure the timebase to lock to the GNSS receiver when possible.

TBASe:CONFig:TINTerval:LIMit — Timebase Configure Time Interval Limit

Syntax

```
TBASe:CONFig[:TINTerval]:LIMit <time error>
TBASe:CONFig[:TINTerval]:LIMit?
```

Description

The first definition sets the limit for timing errors to <time error> in seconds. The second definition queries the current limit. The <time error> may range from 50 ns to 1.0 s. The factory default value is 1 μs. When the measured timing error of the timebase relative to the GNSS receiver exceeds this limit, the timebase will unlock from the GNSS receiver and enter holdover.

Example

```
TBAS:CONF:LIM 100 ns
```

Configure the timebase to unlock from the GNSS receiver if the time interval error exceeds 100 ns.

TBASe:EVENt:CLEar — Timebase Event Clear

Syntax

```
TBASe:EVENt:CLEar
```

Description

Discard all events in the timebase event queue

Example

```
TBAS:EVEN:CLE
```

Discard all events in the timebase event queue.

TBASe:EVENt:COUNt — Timebase Event Count

Syntax

```
TBASe:EVENt:COUNt?
```

Description

Query the number of events in the timebase event queue.

Example

```
TBAS:EVEN:COUN?
```

Query the number of events in the timebase event queue.

TBASe:EVENt:NEXT? — Timebase Event Next

Syntax

```
TBASe:EVENt[:NEXT]?
```

Description

Query the queue of timebase events for the next event. The command returns the name of the event, followed by the year, month, day, hour, minute, and second that the event occurred as a comma (,) separated list. Then the event is removed from the queue and discarded. If no event has occurred, then NONe is returned with the current time. Allowed events are detailed in Table 14.

Table 14: Possible timebase events

Event	Name	Meaning
NONe	None	No events in the queue
POWerup	Power up	Time at which FS752 powered up
SEARch	Searching for GPS	Searching for GNSS satellites
STABilize	Stabilizing	Waiting for timebase frequency to stabilize
VTIMe	Validate time	Validating time of day before setting it.

LOCK	Lock	Locked to GNSS receiver
MANual	Manual holdover	Entered holdover at user request
NGPS	No GPS	Entered holdover because timing pulses are not being generated by the GNSS receiver.
BGPS	Bad GPS	Entered holdover because the timing error of the timebase relative to the GNSS receiver exceeds the limit specified in the command TBAS:CONF:LIM.

Example

```
TBAS:EVEN?
```

Query the queue of timebase events for the next event.

TBASe:FCONtrol — Timebase Frequency Control

Syntax

```
TBASe:FCONtrol <fc>
TBASe:FCONtrol?
```

Description

The first definition sets the frequency control value for the timebase to <fc>. The second definition returns the current frequency control value. Valid values may range from 0 to 4.096. Error −221, "Settings conflict," is generated if the user tries to manually set the frequency control value when the timebase is locked to the GNSS receiver. This setting is not automatically saved to nonvolatile memory. It must be explicitly saved with the TBASe:FCONtrol:SAVe command if desired.

Example

```
TBAS:FCON 2.0
```

Set the frequency control for the timebase to 2.0.

TBASe:FCONtrol:SAVe — Timebase Frequency Control Save

Syntax

```
TBASe:FCONtrol:SAVe
```

Description

Save the current frequency control value to nonvolatile memory. This value will be restored when the FS752 is power cycled. It will control the frequency of the timebase until it locks to the GNSS receiver again.

Example

```
TBAS:FCON:SAV
```

Save the current frequency control value to nonvolatile memory.

TBASe:STATe? — Timebase State

Syntax

```
TBASe[:STATe]?
```

Description

Query the current state of the timebase. Allowed states for the timebase are detailed in Table 15.

Table 15: Allowed states for the timebase

State	Meaning
POWerup	Instrument has been recently powered up
SEARch	GNSS receiver is searching for satellites
STABilize	Waiting for frequency of the timebase to stabilize
VTIMe	Validating time of day reported by GNSS receiver
LOCK	Locked to GNSS receiver
MANual	Manual: in holdover at the request of the user
NGPS	In holdover because timing pulses are not being generated by the GNSS receiver.
BGPS	In holdover because timing error of the timebase relative to the GNSS receiver exceeds the limit specified in the command TBAS:CONF:LIM.

Example

```
TBAS?
```

Query the current state of the timebase.

TBASe:STATe:HOLDover:DURation? Timebase Holdover Duration

Syntax

```
TBASe[:STATe]:HOLDover[:DURation]?
```

Description

Query the length of time in seconds the FS752 has been in holdover. If the FS752 is not currently in holdover, it returns 0.

Example

```
TBAS:HOLD?
```

Query the holdover duration.

TBASe:STATe:LOCK:DURation? Timebase Lock Duration

Syntax

```
TBASe[:STATe]:LOCK[:DURation]?
```

Description

Query the length of time the FS752 has been locked to the GNSS receiver. If the FS752 is not currently locked to the GNSS receiver, it will return 0.

Example

```
TBAS:LOCK?
```

Query the timebase lock duration.

TBASe:STATe:WARMup:DURation? Timebase Warm Up Duration

Syntax

```
TBASe[:STATe]:WARMup[:DURation]?
```

Description

Query the time in seconds that passed between when the FS752 was powered on and it first locked to the GNSS receiver. If it has not successfully locked to the GNSS receiver, then it returns the time in seconds since power on.

Example

```
TBAS:WARM?
```

Query the warm up duration.

TBASe:TCONstant — Timebase Time Constant

Syntax

```
TBASe:TCONstant <time constant>
TBASe:TCONstant? [{CURRent|TARGet|MANual}]
```

Description

The first definition sets the time constant for the phase lock loop that locks the timebase to the GNSS receiver when MANual is selected for the command TBASe:CONFig:BWIDth. The second definition queries one of three different time constants: the current time constant, the target time constant, and the manual time constant set with the first definition above. If the parameter is omitted, the current time constant is returned. If the timebase is configured for automatic bandwidth control (the default), the current time constant may vary from 3 s up to the target time constant for the installed timebase. The target time constant is a factory setting which identifies the optimum time constant for the installed timebase that should be used when the timebase has fully stabilized and timing errors are small.

Example

```
TBAS:TCON 40
TBAS:TCON?
TBAS:TCON? MAN
```

Set the manual time constant to 40 s. Query the current time constant. Query the manual time constant set above. It should be 40.

TBASe:TINTerval — Timebase Time Interval

Syntax

```
TBASe:TINTerval? [{CURRent|AVERage}]
```

Description

Query the current or average measured time interval in seconds between the internal timebase and the GNSS receiver. If the parameter is omitted, the current time interval is returned. The current time interval is the measured time interval between the internal timebase and the latest GNSS timing pulse. The average time interval reported is an exponential average of the current time interval with a time constant equal to 1/6 of the time constant of the phase lock loop. See the TBASe:TCONstant command. Positive values indicate the internal timebase is lagging GNSS time. Negative values indicate the internal timebase is leading GNSS time. If time of day has not yet been set by the GNSS receiver, this command generates error −230, "Data corrupt or stale." Alternatively, if GNSS lock is lost after time has been set, this command returns the last known time interval as the current time interval and zero for the average time interval.

Example

```
TBAS:TINT?
```

Query the current time interval between the internal timebase and GPS.

Error Codes

The instrument contains an error buffer that may store up to 10 error codes associated with errors encountered during power-on self tests, command parsing, or command execution. The ERR LED will be highlighted when a remote command fails for any reason. The errors in the buffer may be read one by one by executing successive SYST:ERR commands. The user may also view the errors from the front panel by navigating to Communication > Activity. Press CLEAR to discard the error. Errors are displayed in the order in which they occurred. The ERR LED will go off when all errors have been discarded.

The meaning of each of the error codes is described below.

Command Errors

−100 Command Error
A nonspecific command error occurred.

−104 Data type error
A parameter has the wrong data type.

−108 Parameter not allowed
A parameter was supplied that is not allowed.

−109 Missing parameter
A required parameter was missing.

−113 Undefined header
The supplied command is undefined.

−114 Header suffix out of range
A numeric suffix for one of the command keywords was out of range.

−120 Numeric data error
A numeric value was supplied that could not be represented internally. This can happen if a number with an exponent larger than ±43 is supplied.

−131 Invalid suffix
A supplied parameter contained invalid units.

−141 Invalid character data
A supplied character data keyword was invalid or undefined.

−148 Character data not allowed
The character data keyword supplied is defined but not allowed.

−151 Invalid string data
The supplied string did not contain matched quotes.

−190 Command buffer overflow

The supplied command exceeded 256 characters and the command buffer overflowed.

Execution Errors

−200 Execution error

A nonspecific execution error occurred.

−213 Init ignored

An INITiate command was received but a measurement was already in progress, so the command was ignored.

−221 Settings conflict

A valid command was received, but it cannot be executed because current settings of the instrument are incompatible with the command. This may occur, for example, if one tries to manually set the frequency of the timebase when it is locked to GPS.

−222 Data out of range

A supplied parameter is out of range.

−230 Data corrupt or stale

An attempt to read data failed because it is already been discarded, corrupted, or lost.

Device Specific Errors

−300 Device specific error

A device specific error occurred.

−314 Save/recall memory lost

A *SAV or *RCL command failed because the settings stored in nonvolatile memory were corrupted or lost.

−350 Error queue overflow

More have errors occurred, but they were discarded because the error queue overflowed.

−360 Communications error

A framing or parity error occurred on the communications interface.

−363 Input buffer overrun

The input buffer for the communications interface overflowed. All data was flushed and the communications interface reset.

−365 Time out error

The instrument timed out waiting for data over the remote interface.

Query Errors

−400 Query error

A nonspecific query error occurred.

−410 Query INTERRUPTED

A new command was received before the previous query was read by the remote interface. The old query will be discarded.

−450 Query lost data

The output buffer for the communications interface overflowed. The query result was discarded.

−451 Query no data

The query resulted in no data.

Instrument Errors

500 GNSS time out error

A command was sent to the GNSS receiver, but the instrument timed out waiting for a response.

501 GNSS failed

A command was sent to the GNSS receiver, but the receiver rejected it as invalid.

514 Not allowed

A command was received, but rejected as not allowed because another remote interface has an exclusive lock on the instrument.

800 EEPROM read/write failed

A read or write to nonvolatile EEPROM failed.

900 Self test failed

The instrument self-test failed.

FS752 Circuit Description

Overview

The FS752 provides a 10 MHz frequency reference which is disciplined by GNSS with a long term stability of better than $1:10^{13}$. The instrument can also time tag external events with respect to UTC or GNSS and measure the frequency of user inputs. The instrument also has DDS synthesized frequency outputs, adjustable rate (and width) pulse outputs, and an AUX output for arbitrary waveforms including an IRIG-B timecode output. A GUI (graphical user interface) allows the user to configure the instrument and see the results of time and frequency measurements.

The performance of the 10 MHz output depends on the installed timebase. The standard timebase provides $1:10^{9}$ short term frequency stability and phase noise of less than −100 dBc/Hz at 10 Hz offset. An optional OCXO (ovenized crystal oscillator) timebase provides $1:10^{11}$ short term frequency stability and phase noise of less than −130 dBc/Hz at 10 Hz offset. An optional rubidium timebase provides $1:10^{12}$ short term frequency stability, phase noise of less than −130 dBc/Hz at 10 Hz offset, and a long term holdover (lost GNSS signal) of better than 1 μs/day.

Either optional timebase (OCXO or rubidium) provides a dramatic improvement in the holdover characteristics, a 30 dB reduction in the phase noise and a tenfold reduction in the TDEV. There are some users who would not need this performance improvement. For example, users who only need time tags with 1μs accuracy or frequency measurements with $1:10^{8}$ accuracy could use the standard timebase.

The FS752 provides bias for a remote active GNSS antenna. The unit's GNSS receiver tracks up to 12 satellites, will automatically survey and fix its position, then use all received signals to optimize its timing solution. The FS752 time-tags the 1 pps output from the receiver, corrects the result for the receiver's sawtooth error, then phase locks the timebase to the GNSS 1 pps with an adjustable time constant between 10 seconds and 4000 s. The TDEV (rms timing deviation) between two instruments is a few nanoseconds.

If the GNSS signal is lost, the timebase is left at the last locked frequency value. The timebase will age or drift in frequency by up to ±2 ppm (for the standard timebase), ±0.05 ppm/year and ±0.002 ppm (0 to 45^{o}C) for the OCXO, and ±0.001 ppm/year and ±0.0001 ppm (0 to 45^{o}C) for the rubidium timebase.

There are two user inputs (one on the front, one on the rear panel) for frequency and time tag events. The inputs have adjustable thresholds and slopes. Frequencies are measured with a precision of $1:10^{11}$ in 1 s, $1:10^{12}$ in 10 s, and $1:10^{13}$ in 100 s. Time tags are reported with 1 ps resolution commensurate with the short term stability of the OCXO and rubidium timebases. Time tags will have an error of about 10 ns rms with respect to UTC or GNSS time.

The FS752 has a rear panel low phase noise 10 MHz sine output with an amplitude of 1 Vrms. Up to 15 additional copies of the 10MHz output are available via optional rear panel outputs.

The FS752 has front and rear panel sine outputs which provide sine outputs from 1 mHz to 30.1 MHz with 1 μHz resolution, or a fixed 100 MHz, with adjustable amplitude from 100 mV to 1.2 V rms. Up to 15 additional copies of the sine outputs are available via optional rear panel outputs.

The FS752 has front and rear panel pulse outputs which can provide low jitter pulses from 1 mHz to 25 MHz. The pulse outputs have adjustable phase with respect to UTC and the pulse width can be set as narrow as 5 ns, or as wide as the entire pulse period minus 5 ns, with 1 ps resolution. Up to 15 additional copies of the pulse outputs are available via optional rear panel outputs.

The FS752 has front and rear panel auxiliary (aux) output which can generate standard or arbitrary waveforms (sine, ramp, triangle, etc.) The aux output can also provide an AM modulated IRIG-B timecode output. Up to 15 additional copies of the aux output are available via optional rear panel outputs.

A rear panel alarm relay is set if power is lost or under user defined conditions including: timebase fault, loss of GNSS reception, or any failure to maintain phase lock between the timebase and GNSS. The relay has both normally open and closed outputs.

Optional distribution amplifiers, each providing five additional rear panel outputs for the 10 MHz, SINE, PULSE, AUX or IRIG-B outputs, can be installed. Up to three distribution amplifiers can be installed and configured from the front panel. Each output has its own driver which provides high isolation between outputs.

The instrument may be used without GNSS. The (optional) rubidium timebase has a lifetime aging of only a few parts per billion, and can serve as an autonomous laboratory timebase in many applications.

Appendix A: Parts List

Front Display (Assembly 746)

Ref	Value	Description	SRS P/N
C102	100000P	Capacitor, 0603, X7R	5-00764
C103	100000P	Capacitor, 0603, X7R	5-00764
C104	100000P	Capacitor, 0603, X7R	5-00764
C105	100000P	Capacitor, 0603, X7R	5-00764
C106	100000P	Capacitor, 0603, X7R	5-00764
C107	100000P	Capacitor, 0603, X7R	5-00764
C108	100000P	Capacitor, 0603, X7R	5-00764
C109	100000P	Capacitor, 0603, X7R	5-00764
C110	100000P	Capacitor, 0603, X7R	5-00764
C111	100000P	Capacitor, 0603, X7R	5-00764
C112	100000P	Capacitor, 0603, X7R	5-00764
C113	100000P	Capacitor, 0603, X7R	5-00764
C114	100000P	Capacitor, 0603, X7R	5-00764
C115	100000P	Capacitor, 0603, X7R	5-00764
C116	100000P	Capacitor, 0603, X7R	5-00764
C121	4.7UF / 50V X5R	Ceramic, 16V, X5R	5-00807
C122	100000P	Capacitor, 0603, X7R	5-00764
C123	100000P	Capacitor, 0603, X7R	5-00764
C124	1000P / X7R	Capacitor	5-00911
C125	100000P	Capacitor, 0603, X7R	5-00764
C126	5.6P	Capacitor, 0603, NPO	5-00684
C130	100000P	Capacitor, 0603, X7R	5-00764
C131	15U/T35	Cap, Tantalum, SMT	5-00518
C201	100000P	Capacitor, 0603, X7R	5-00764
C204	1UF 16V /0603	Ceramic, 16V, X5R	5-00661
C205	100000P	Capacitor, 0603, X7R	5-00764
C206	10UF / X5R	Capacitor, Ceramic Or Mylar	5-00910
C207	1UF 16V /0603	Ceramic, 16V, X5R	5-00661
C208	0.01UF / 16V	Ceramic, 16V, X5R	5-00604
C209	100000P	Capacitor, 0603, X7R	5-00764
C210	10UF / X5R	Capacitor, Ceramic Or Mylar	5-00910
C211	100000P	Capacitor, 0603, X7R	5-00764
C212	1UF 16V /0603	Ceramic, 16V, X5R	5-00661
C213	47P / X7R	Capacitor, Ceramic Disc	5-00912
C214	47P / X7R	Capacitor, Ceramic Disc	5-00912
C301	100000P	Capacitor, 0603, X7R	5-00764
C302	100000P	Capacitor, 0603, X7R	5-00764
C303	100000P	Capacitor, 0603, X7R	5-00764
C304	100000P	Capacitor, 0603, X7R	5-00764
C305	100000P	Capacitor, 0603, X7R	5-00764
C306	100000P	Capacitor, 0603, X7R	5-00764
C307	100000P	Capacitor, 0603, X7R	5-00764
C308	100000P	Capacitor, 0603, X7R	5-00764
C309	100000P	Capacitor, 0603, X7R	5-00764
C310	100000P	Capacitor, 0603, X7R	5-00764
C311	100000P	Capacitor, 0603, X7R	5-00764
C312	100000P	Capacitor, 0603, X7R	5-00764
C313	100000P	Capacitor, 0603, X7R	5-00764
C314	100000P	Capacitor, 0603, X7R	5-00764
D102	GREEN	LED, T-3/4	3-00424
D105	SMV1213	Integrated Circuit	3-02392
D201	MBRX160-TP	Diode, SMT	3-01701
J101	20 PIN DI	Connector	1-00008
J201	TSW-108-07-F-D	Connector	1-01423
J202	TSW-105-07-F-D	Connector	1-01424
J203	USB_MICRO	Connector	1-01395
J204	40-pin FLEX	Connector	1-01425
J205	6-pin MOLEX	Connector	1-01426
J206	8 PIN DI TSW 07	Connector	1-00290
L102	2506031517Y0	Ferrite bead, SMT	6-00759
L103	2506031517Y0	Ferrite bead, SMT	6-00759
L104	2506031517Y0	Ferrite bead, SMT	6-00759
L105	2506031517Y0	Ferrite bead, SMT	6-00759
L106	2506031517Y0	Ferrite bead, SMT	6-00759
L107	SRF0504-152Y	Choke, Misc.	6-01127
L201	2506031517Y0	Ferrite bead, SMT	6-00759
L202	2506031517Y0	Ferrite bead, SMT	6-00759
L203	15uH/ 1210	Fixed inductor	6-01128
L204	2506031517Y0	Ferrite bead, SMT	6-00759
L205	2506031517Y0	Ferrite bead, SMT	6-00759
L301	2506031517Y0	Ferrite bead, SMT	6-00759
L302	2506031517Y0	Ferrite bead, SMT	6-00759
L303	2506031517Y0	Ferrite bead, SMT	6-00759
PCB0	FS752 Display P	Fabricated component	7-02460
R102	470	Resistor, 0603, Thick Film	4-01861
R111	10K	Resistor, 0603, Thick Film	4-01893
R112	10K	Resistor, 0603, Thick Film	4-01893
R113	10K	Resistor, 0603, Thick Film	4-01893
R114	7.5K	Resistor, 0603, Thick Film	4-01890
R115	100K	Resistor, 0603, Thick Film	4-01917
R116	1.00K	Resistor, 0603, Thin Film	4-02157
R201	10K	Resistor, 0603, Thick Film	4-01893
R205	10K	Resistor, 0603, Thick Film	4-01893
R206	910K	Resistor, 0603, Thick Film	4-01940
R207	5.1	Resistor, 0603, Thick Film	4-01814
R208	27K	Resistor, 0603, Thick Film	4-01903
R211	33	Resistor, 0603, Thick Film	4-01833
R212	33	Resistor, 0603, Thick Film	4-01833
R213	10K	Resistor, 0603, Thick Film	4-01893
R216	10K	Resistor, 0603, Thick Film	4-01893
R217	10K	Resistor, 0603, Thick Film	4-01893
R224	100	Resistor, 0603, Thick Film	4-01845
R301	10K	Resistor, 0603, Thick Film	4-01893
R302	10K	Resistor, 0603, Thick Film	4-01893
RN101	10KX4D	Resistor network	4-00912
SW101	SW-SMT	Switch, Momentary	2-00075
SW102	SW-SMT	Switch, Momentary	2-00075
U102	74LVC3G04DCTR	Integrated Circuit	3-01999
U103	DS1816R-20	Integrated Circuit	3-02084
U104	74hct1g86	Integrated Circuit	3-02403
U105	32bit-ARM-Corte	Integrated Circuit	3-02397
U106	LM2937ESX-3.3	Integrated Circuit	3-02404
U201	65LVDS2DBV	Integrated Circuit	3-01770
U202	74LVC1G3157	Integrated Circuit	3-02046
U203	74LVC1G3157	Integrated Circuit	3-02046
U204	U_REG_40V-20mA	Integrated Circuit	3-02389
U205	FT230XQ	Integrated Circuit	3-02314
U301	FLASH 256MBit	Integrated Circuit	3-02400
U302	SDRAM 256MBit	Integrated Circuit	3-02399
Y101	12MHz	Crystal	6-01126
Z	CMT-1603	Misc. Components	6-00793
Z	SIM-PCB S/N	Label	9-01570

Front Keypad (Assembly 741)

Ref	Value	Description	SRS P/N
C101	100000P	Capacitor, 0603, X7R	5-00764
C102	100000P	Capacitor, 0603, X7R	5-00764
C103	100000P	Capacitor, 0603, X7R	5-00764
C104	100000P	Capacitor, 0603, X7R	5-00764
D101	GREEN	LED, T-3/4	3-00424
D102	GREEN	LED, T-3/4	3-00424
D103	RED	LED, T-3/4	3-00425
D104	YELLOW	LED, T-3/4	3-00426
D105	YELLOW	LED, T-3/4	3-00426
D106	YELLOW	LED, T-3/4	3-00426
D107	GREEN	LED, T-3/4	3-00424
D108	RED	LED, T-3/4	3-00425
D109	YELLOW	LED, T-3/4	3-00426
D110	GREEN	LED, T-3/4	3-00424
D111	RED	LED, T-3/4	3-00425
D112	RED	LED, T-3/4	3-00425
D113	GREEN	LED, T-3/4	3-00424
D114	GREEN	LED, T-3/4	3-00424
J101	8 PIN DI TSW 07	Connector	1-00290

PC1	FS752 PCB	Fabricated component	7-02461
R101	49.9K	Resistor, 0603, Thin Film	4-02320
R102	20.0K	Resistor, 0603, Thin Film	4-02282
R103	499	Resistor, 0603, Thin Film	4-02128
R104	499	Resistor, 0603, Thin Film	4-02128
RN101	8X100	Resistor, Misc.	4-02497
RN102	8X100	Resistor, Misc.	4-02497
RN103	10KX4	Resistor network	4-01789
RN104	10KX4	Resistor network	4-01789
SW101	B3F-1052	Switch, Momentary	2-00053
SW102	B3F-1052	Switch, Momentary	2-00053
SW103	B3F-1052	Switch, Momentary	2-00053
SW104	B3F-1052	Switch, Momentary	2-00053
SW105	B3F-1052	Switch, Momentary	2-00053
SW106	B3F-1052	Switch, Momentary	2-00053
SW107	B3F-1052	Switch, Momentary	2-00053
SW108	B3F-1052	Switch, Momentary	2-00053
U101	74LVC2G04	Integrated Circuit	3-01968
U102	74HC165	Integrated Circuit	3-01969
U103	74LVC1G125DBV	Integrated Circuit	3-01886
U104	74HC595ADT	Integrated Circuit	3-00672
U105	74HC595ADT	Integrated Circuit	3-00672
U106	74LVC2G08DCT	Integrated Circuit	3-01656
U107	ADCMP371	Integrated Circuit	3-01970
Z	BUTTON CAP	Hardware	0-00996

10	4.7	Resistor, 0603, Thick Film	4-01813
R11	45.3	Resistor, Thin Film, MELF	4-00988
R12	150	Resistor, 0603, Thin Film	4-02078
R13	150	Resistor, 0603, Thin Film	4-02078
R2	1.00K	Resistor, 0603, Thin Film	4-02157
R3	45.3	Resistor, Thin Film, MELF	4-00988
R4	4.7	Resistor, 0603, Thick Film	4-01813
R5	45.3	Resistor, Thin Film, MELF	4-00988
R6	4.7	Resistor, 0603, Thick Film	4-01813
R7	45.3	Resistor, Thin Film, MELF	4-00988
R8	4.7	Resistor, 0603, Thick Film	4-01813
R9	45.3	Resistor, Thin Film, MELF	4-00988
U1	74LVC3G34DCTR	Integrated Circuit	3-01852
U2	74LVC3G34DCTR	Integrated Circuit	3-01852
U3	65LVDS2DBV	Integrated Circuit	3-01770
U4	74LVC3G34DCTR	Integrated Circuit	3-01852
U5	74LVC1G125DBV	Integrated Circuit	3-01886
U6	74LVC1G04	Integrated Circuit	3-02070
U7	74LVC3G34DCTR	Integrated Circuit	3-01852
U8	74LVC3G34DCTR	Integrated Circuit	3-01852
U9	74LVC3G34DCTR	Integrated Circuit	3-01852
Z	1/2" CUSTOM	Hardware	0-01259
Z	FS752 BNC Block	Fabricated component	7-02463
Z	SIM-PCB S/N	Label	9-01570

Option Timebase Adapter (Assembly 605)

Ref	Value	Description	SRS P/N
J1	SSW-107-01-S-S	Connector	1-01078
J3	09-52-3101	Connector	1-01058
PC1	CG635 TIMEBASE	Fabricated component	7-01586
R1	3.01K	Resistor, Metal Film	4-00176
R2	2.00K	Resistor, Metal Film	4-00158
R3	3.01K	Resistor, Metal Film	4-00176
R4	12.1K	Resistor, Metal Film	4-00148
U1	LM358	Integrated Circuit	3-00508
Z	6-32 KEP	Hardware	0-00048
Z	4-40X1/4PP	Hardware	0-00187
Z	8-32X1/4PF	Hardware	0-00416
Z	3403	Hardware	0-01090
Z	26-48-1101	Connector	1-01057
Z	SC10-24V - CG	Oscillator	6-00079
Z	CG635, OPT	Fabricated component	7-01614

Appendix B: Schematic Diagrams

Schematic 1: Front Panel Display 1
Schematic 19: Timebase Option Adapter