Designer Reference and User Guide
SA.22c Rubidium Oscillator

Microsemi
a Microchip company

Contents

1 Revision History

The revision history describes the changes that were implemented in the document. The changes are listed by revision, starting with the most current publication.

1.1 Revision D

Revision D was published in November 2018. In revision D of this document, the Control Register table was updated. For more information, see SA-22c (and x72) Output Control Register (see page 27).

1.2 Revision C

Revision C was published in February 2018. In revision C of this document, the power sequencing was updated to +5 V on first.

1.3 Revision B

Revision B was published in February 2017. The following is a summary of the changes in revision B of this document.

- The SA.22c Dimensions diagram was updated.
- The SA-22c or X72 Refresh Output Control Register table was included.

1.4 Revision A

Revision A was the first publication of this document.

2 Overview

This section describes the SA.22c and lists its typical applications. It provides information on dimensions, performance, and connector pinouts.

The SA.22c is a small form factor, lamp-based Rubidium (Rb) oscillator, as shown in the following figure. This fifth-generation Rb oscillator reflects significant advances in physics miniaturization and integration.

Figure 1 • SA.22c Rubidium Oscillator

The SA.22c design is refined for low-cost mass production and can be integrated into time, frequency, and synchronization systems. It can be directly mounted on a circuit board as a component of a module.

2.1 Applications

The wide operating temperature range of the SA.22c sets a new high-point for this type of atomic reference. Compared with traditional quartz oscillators, the stability of the SA.22c allows it to maintain excellent frequency control, even when the base plate temperature goes above 75 °C. When the host system overheats in fault mode, the SA.22c oscillator continues to produce a stable and accurate time along with a frequency reference.

The SA.22c can be integrated into time and frequency systems, it operates on low power (10 W at 25 °C, operating).

The design is successfully applied as an OEM component in wireless telecom networks such as digital cellular/PCS base stations and SONET/ SDH digital network timing. When linked with a GPS receiver or other external timing reference, the SA.22c provides the necessary timing requirements for CDMA cellular and PCS systems. The low temperature coefficient and frequency stability extends the holdover performance when the GPS signal is lost. Temperature compensated units are available for those special applications that require better temperature performance.

The SA.22c produces a stable frequency with good short and long term stability and phase noise performance.

The microprocessor-based SA.22c allows serial command selection and enables TTL-level digital output frequencies that divide the oscillator output to a number of different frequencies compared to a single fixed output frequency of older oscillators. The ACMOS output frequency is selected at the time of order.

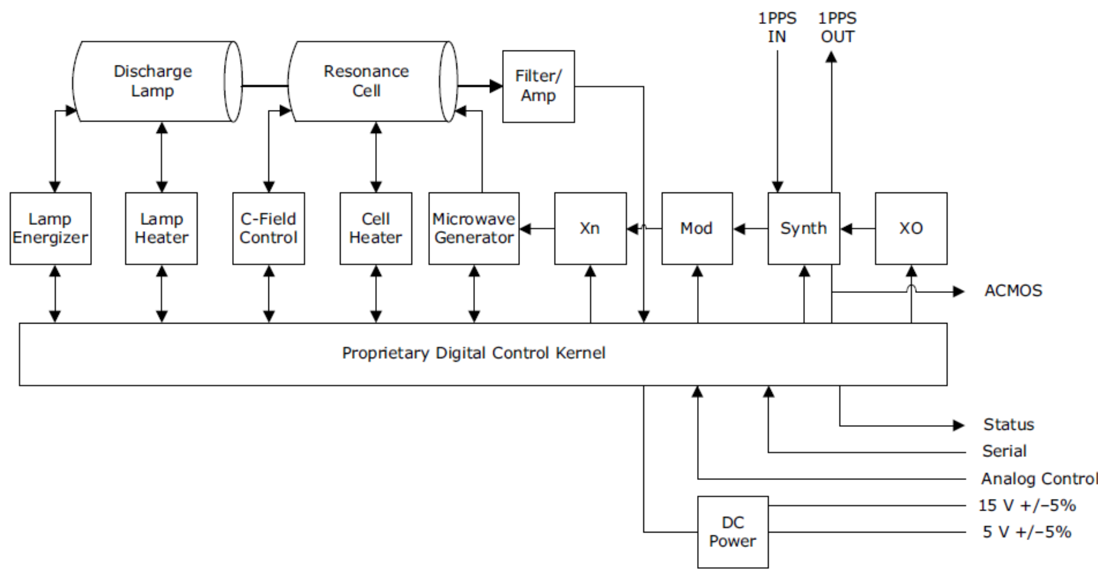
A 1PPS output is an integral part of the design. An optional 1PPS input allows the unit to track GPS or other external reference. For more information, refer to Appendix: One Pulse Per Second Source Connection (see page 30).

For simple applications, the SA.22c provides a 5 V CMOS-compatible built-in self test (BIST) service and a lock alarm signal derived from the basic physics operation. The lock signal indicates when the output frequency is locked to the atomic resonance of rubidium. For more control over the device, an extensive command control status dialog needs to be used.

In addition to controlling the operation of the oscillator, the microprocessor's built-in firmware allows an external host computer to communicate with the embedded controller through a serial port connection. This allows precise frequency control, dynamic frequency selection, enabling and disabling outputs, querying the system's health, initiating a self test, and acquiring information about the unit's serial number, operating temperature, fault history, and other performance indicators. The protocol used is Microsemi Serial Interface Protocol (MSIP).

The following block diagram shows the importance of the digital control in the unit, how it controls and monitors all aspects of operation, such as the heater circuits of the physics package, as well as the selection of outputs.

Figure 2 • SA.22c Rubidium Oscillator Simplified Block Diagram

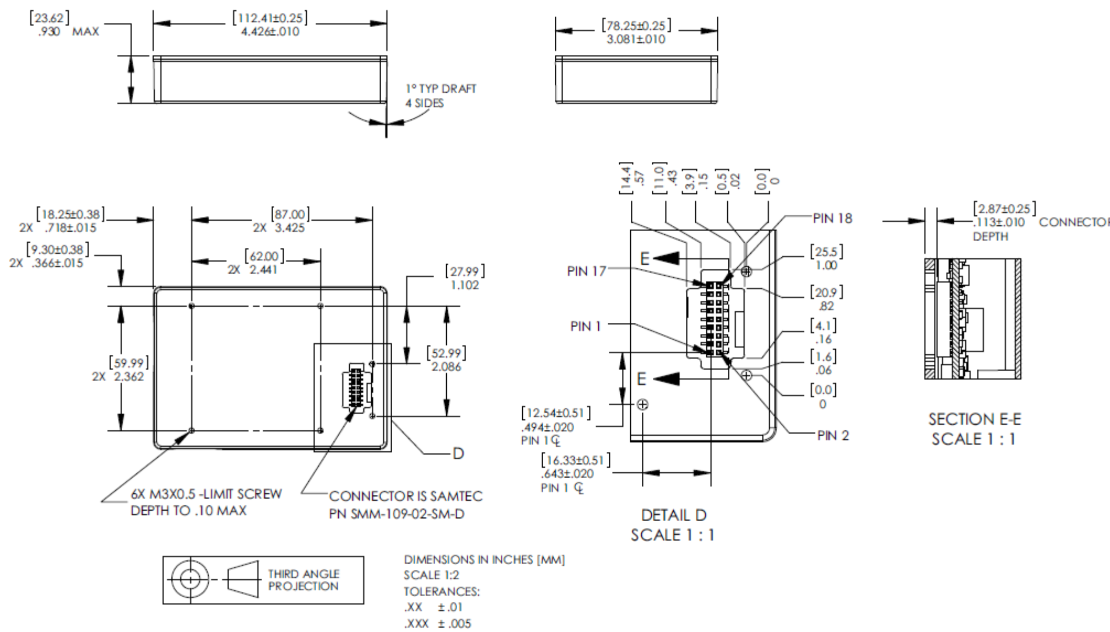


2.2 Specifications

The following figure provides the detailed mechanical specifications of SA.22c.

Note: Datasheet specifications take precedence over this document.

Figure 3 • SA.22c Dimensions



Note: The mating connector is a SAMTEC TMMH-109-01-G-DV-ES-A 2 X 9 shrouded header.

Caution: To avoid damage to the SA.22c, ensure that power and ground are properly connected.

Note: All pins on the I/O connector must be connected.

The following table provides information on the pin assignment and the function chart for SA.22c.

Table 1 • SA.22c Pin Assignment and Function Chart

Pin	Signal	Type	Function
1	VSS	GND	Power and signal return ground (all ground pins must be connected)
2	VDD	PWR	15 Vdc power input (all power pins must be connected)
3	VSS	GND	Power and signal return ground (all ground pins must be connected)
4	VDD	PWR	15 Vdc power input (all power pins must be connected)
5	FREQ CTRL	Analog	Frequency control. Analog input between 0-5 Vdc
6	VCC	PWR	5 Vdc power input
7	1PPS OUT	Output	1PPS output, may be enabled/disabled digitally
8	VSS	GND	Power and signal return ground (all ground pins must be connected)
9	FACMOS	Output	(FACMOS) ACMOS output (frequency selectable at factory)
10	VSS	GND	Power and signal return ground (all ground pins must be connected)
11	VSS	GND	Power and signal return ground (all ground pins must be connected)

Pin	Signal	Type	Function
12	SERVICE	Output	Indicates unit is nearing limits of frequency control and that service is required within months.
13	DIN	Input	UART data in at ACMOS logic levels
14	Lock	Output	If low, indicates Rb oscillator is locked
15	1PPS IN	Input	1PPS input, positive edge triggered
16	DOUT	Output	UART data out at ACMOS logic levels
17	Not available		
18	Not available		

Note: For more information on connector manufacturer's drawings and specifications, see Appendix: Using the Developer’s Kit (see page 16) .

The following table provides information on the absolute maximum ratings for the SA.22c design.

Note: Unit in ambient still air convection (–10 °C to 75 °C).

Table 2 • SA.22c Design Absolute Maximum Ratings

Symbol	Characteristic and Condition		Value	Unit
VDD	Supply relative to ground	15 Vdc Input	±5	%
VCC	Supply relative to ground	5 Vdc Input	±5	%
V_{IN}	Input voltage relative to ground regardless of power supply voltage	DIN and 1PPS IN	–0.25 to 5.25	V
FREQ CTRL	Analog external control	Frequency control	–0.25 to 5.25	V
P_{WU}	**Maximum warm-up power**		<18.5	Watts
P_{Q}	Maximum quiescent power	At –10 °C base plate	9.3	Watts
		At 25 °C base plate	7.2	Watts
		At 75 °C base plate	4.6	Watts
T_{WU}	Maximum warm-up time	Lock time to <1 × 10^{-9} at 25 °C	<7.5	Mins
T_{STG}	**Maximum storage temperature**		–55 to 85	°C
	Vibration (operating)	GR-63-CORE, Issue 4, April 2012, section 4.4.4 and 5.4.2 Opt2: Random Vibration 0.15 grms, unit locked		
	Maximum altitude (powered unit)	With respect to sea level	30,000	Feet
	Maximum altitude (unpowered)	With respect to sea level	50,000	Feet

The following tables provides information on the operating characteristics for SA.22c design.
Note: Unit in ambient still air convection (–10 °C to 75 °C).

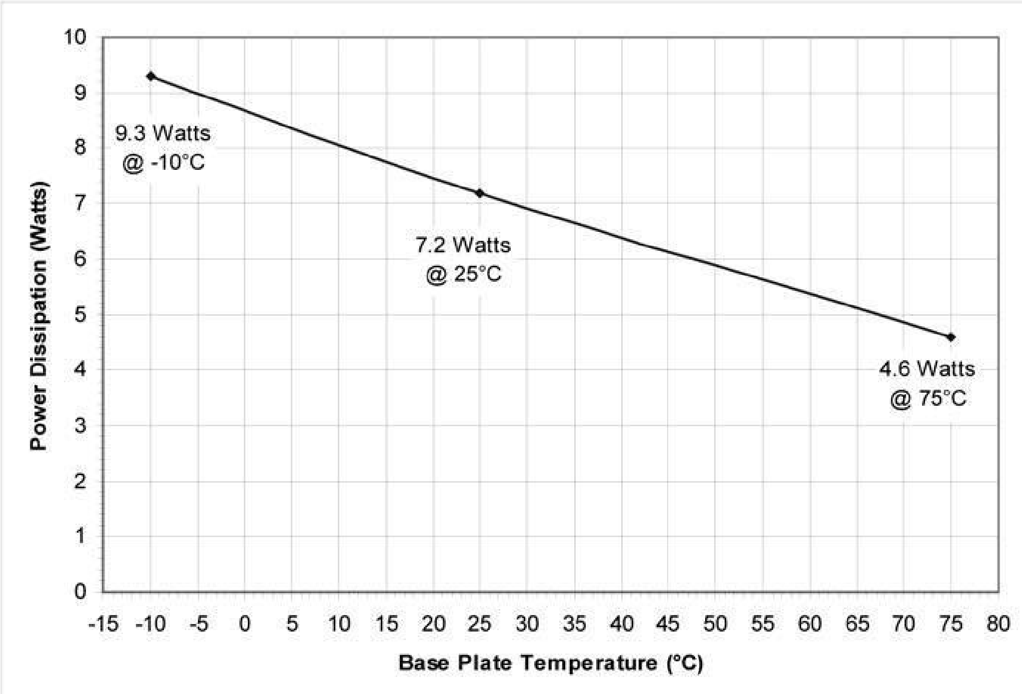
Table 3 • SA.22c Design Operating Characteristics

Symbol	Characteristic and Condition		Minimum	Typical	Maximum	Unit
Digital Inputs/Outputs						
VDD	Supply relative to ground	15 Vdc Input	14.75	15	15.25	V
VCC	Supply relative to ground	5 Vdc Input	4.75	5	5.25	V
V_{IH}	High level input voltage	DIN	2.5	5	5.25	V
		1PPS IN	1.8	5	5.25	V
V_{IL}	Low level input voltage	DIN	0		0.8	V
		1PPSIN	0		0.8	V
V_{OH}	High level input voltage	DOUT, SERVICE, Lock at IOH = –0.33 mA at IOH = 0 mA	3.5	5	5.25	V
		FACMOS,1PPS OUT at IOH = –3.5 mA	3.5	5	5.25	V
V_{OL}	Low level input voltage	DOUT, SERVICE, Lock at IOL = 0.1 mA	0		0.4	V
		FACMOS, 1PPS OUT at IOL = 1.7 mA	0		0.4	V
Analog Inputs/Outputs						
V_{FC}	Frequency control input voltage range	Resolution of 2.0×10^{-12} ΔHz/Hz	0	2.5	5	V
FACMOS	ACMOS frequency output	10 MHz[1]	-5×10^{-11}		$+5 \times 10^{-11}$	ΔHz /Hz
Frequency Control						
$\Delta F/F_R$	Control range	Analog (FREQ CTRL pin) (wide range option)	-1.5×10^{-9} -6.5×10^{-9}		$+1.5 \times 10^{-9}$ $+6.5 \times 10^{-9}$	ΔHz /Hz
		Digital Interface	-1.0×10^{-6}		$+1.0 \times 10^{-6}$	ΔHz /Hz
$\Delta F/F_{RES}$	Frequency control resolution	Digital			2×10^{-12}	ΔHz /Hz

1. Contact the manufacturer for information about other frequencies.

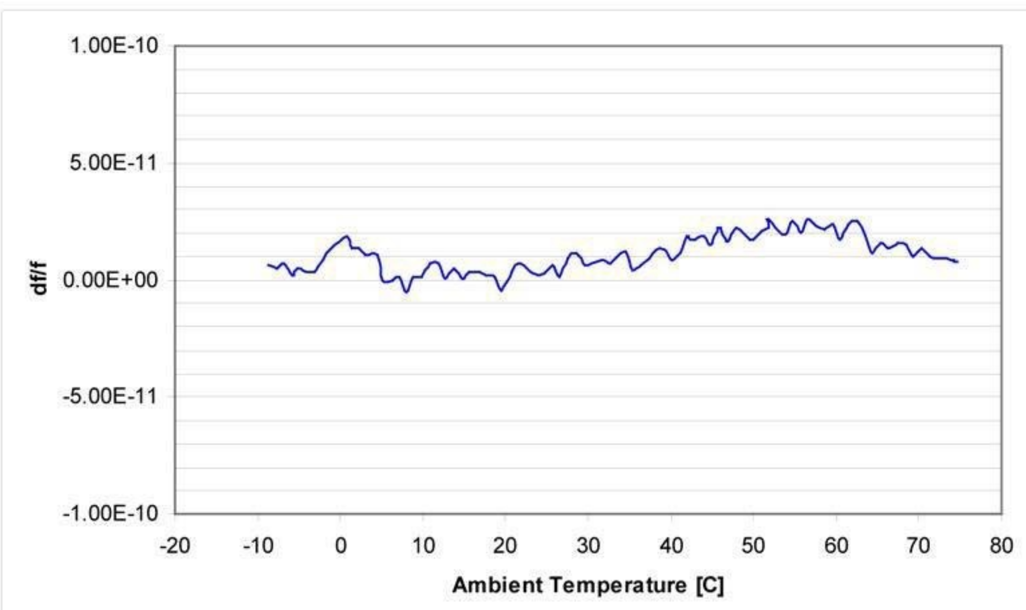
The following figure shows the typical values for total quiescent power dissipation of SA.22c.

Figure 4 • Total SA.22c Quiescent Power Dissipation, Typical (free convection)



The following figure shows the typical API level.

Figure 5 • Typical AP1 Level Tempco (–10 °C to 75 °C Base Plate Temperature)



Note: For more information, see SA.22c Performance Characteristics.

3 Design Integration Considerations

This section provides information on mounting and mating connectors, operating temperature, electrical interface, and noise susceptibility.

3.1 Mechanical Considerations

To mount the SA.22c to a custom-designed circuit board, use the SAMTEC mating connector (see SA.22c Dimensions (see page 4)).

Note: For more information on an adapter test board and designing your own interface circuit board, contact Microsemi sales representatives.

The following figure shows how to mount SA.22c to a circuit board. Mount the SA.22c to the circuit board using six M3 stainless steel screws with a minimum penetration depth of 2 mm and a maximum of 5 mm.

Figure 6 • Mounting an SA.22c to a Circuit Board

3.2 Environmental Considerations

The following sections provide design considerations regarding thermal, humidity, and dust challenges.

3.2.1 Thermal Tape

The base plate of the SA.22c must have good thermal contact to the mounting surface so that the operating base plate temperature can achieve the highest ambient operating temperature. The mounting points of the base plate must maintain uniform temperature. The SA.22c unit normally operates without the thermal tape. However, in some field applications, the tape simplifies the customer system thermal design requirements.

Warning: Attach the SA.22c to a heat sink to prevent it from becoming too hot.

If there is an air flow over the unit's top cover, the SA.22c's maximum operating base plate temperature increases by 1 °C or 2 °C and the power consumption at a given base plate temperature also increases by a few tens of milliwatts. As the base plate temperature continues to increase, the unit eventually loses lock.

Above a base plate temperature of 75 °C, the resonator or lamp heaters get shut down as the control point temperatures are exceeded and the unit temperature coefficients increase to approximately 6×10^{-10} °C.

3.2.2 Water Condensation and Excessive Humidity

Water condensation and excessive humidity condensation of moisture on the electrical components produce frequency spikes or instability until the heat of the operating unit drives out the water vapor.

Condensation does not cause a problem for environments meeting the SA.22c specification, that is, the SA.22c base plate thermal ramp rates are controlled so that they rise at less than 2 °C/minute.

3.2.3 Excessive Dust

Operating the unit in dusty conditions cause unexpected thermal effects, if dust builds up on the top surface. Excessive dust contributes to contamination in the shell of the mating connector and causes intermittent loss of signals.

The SA.22c is shipped in a dust-protected ESD resistant bag. All connectors on any product must be suitably protected, before mating, in a dust-controlled environment.

3.3 External Interfaces and Grounding

SA.22c Dimensions (see page 4) shows the interface circuitry for the 18-pin SAMTEC I/O connector and the mechanical dimensions of the SA.22c. All signals, including power, power return, RF output, signal/chassis ground, and monitor lines are routed through this connector. All voltage supply and ground lines must be connected to the mating connector for the operation of the SA.22c unit.

The SA.22c is constructed with the chassis (unit cover) and signal grounds tied together at multiple points. The power supply return is isolated from both chassis and signal grounds by a ferrite bead. This robust grounding approach offers ESD protection and low spurious emissions, however, it may lead to ground loop issues.

Workarounds commonly used to break DC ground loops at a higher level of integration are:

- Using an RF isolation transformer for the sine RF output
- Floating the transformer secondary winding of the user's power supply

3.4 Electrical Interface

The following sections provide information regarding the main input/output signals of the SA22c.

3.4.1 1PPS Input and Output

The 1PPS output signal of the SA.22c unit is positive-edge triggered and gated with the rising edge of the clock. Its duration for a 10 MHz unit is 400 ns ±10% and the rise/fall time is 4 ns.

3.4.2 Lock Signal

The lock signal indicates that the internal voltage controlled crystal oscillator (VCXO) is locked to the atomic transition. If the lock signal is low after the warm-up is complete, the output frequency is locked to the rubidium atomic clock.

If the lock signal is high, the atomic lock is lost and the SA.22c goes into sweep mode to reacquire lock. The sweep ranges from approximately –21 ppm to 21 ppm in a 20-second period approximately. During the sweep, outputs are maintained but signal accuracy should not be relied upon during sweeping. If the power source to the SA.22c is off, the lock output line is low.

3.4.3 Service Signal

The service signal is valid when the unit is operating and the rubidium oscillator is locked.

The service signal algorithm monitors the health of the rubidium physics package, which includes the Rb lamp bulb and resonator cell and the unit's crystal oscillator that is slaved to the rubidium atomic clock.

The service signal indicates low approximately one month before any of the internal operating parameters are near the end of their tuning or adjustment range.

3.4.4 Frequency Control Signal

The SA.22c frequency control signal is an analog input between 0 Vdc and 5 Vdc that is enabled or disabled at the factory (making it a default setting) or by the customer at a later date (using the MSIP). The service BIT can be selectable high or low.

When in use, the smallest incremental frequency change is 2×10^{-12}. The unit always powers up to the preset free running factory set frequency. Adjustments to the frequency are always relative to the free running frequency of the unit (see also Analog Frequency Control (see page 10)).

3.4.5 ACMOS Output Frequency

The ACMOS output frequency is equal to the internal crystal frequency divided by 2N (N is a number from 1 to 65536). For more information on the list of specific ACMOS output frequencies, contact Microsemi sales representatives.

3.4.6 Analog Frequency Control

Analog frequency adjustment range is $\pm 1.5 \times 10^{-9}$ (0 V–5 V into 5 kΩ). The external frequency control circuitry is designed so that with no voltage applied at Pin 5, the voltage self biases to mid-range or 2.5 V. This input is turned off via the MSIP to eliminate any source of noise. In some versions of the SA.22c, this function is turned off by customer request on power up. If it is to be used later, it must be enabled through the MSIP (refer to Appendix: Microsemi Serial Interface Protocol (see page 25)).

The external analog frequency control is a sampled input with a typical response time constant of 154 ms.

Note: An expanded control range version of SA.22c is also available. It can provide frequency adjustment of $\pm 6.5 \times 10^{-9}$ (0 V–5 V into 5 kΩ).

3.5 Modifiable Unit Settings

SA.22c operation can be modified. See Appendix: Using the Developer's Kit (see page 16) and Appendix: Microsemi Serial Interface Protocol (see page 25) for information on how to use the MSIP to use these functions.

Note: Default power up conditions cannot be altered.

The following table provides the information on the hardware and software items along with its action.

Table 4 • Hardware and Software Selectable Items

Item	Action
Hardware	
1PPS output enable	Turn 1PPS output on or off
Software	
Analog frequency adjust	Enable or disable frequency control function
Adjust frequency[1]	Adjust output frequency from the factory preset value
HELP	Displays the help menu
View control register	Displays current settings of the control register
Set control register	Enable or disable outputs
View unit information	Displays SA.22c information stored in the firmware
View health monitor data	Displays history file of error or fault information

1. Minimum frequency change is 2×10^{-12}. Values less than this are ignored. Maximum frequency change, is not constrained. Setting the frequency outside of its operating limits may render the unit non-functional.

3.6 Susceptibility to Input Noise

For applications where the output spectrum phase noise and spur integrity are crucial, the SA.22c must have a comparatively clean source of DC power (free of spurious current or voltage noise). Connecting fans, heaters, and other switching devices to the DC supply powering the SA.22c results in degraded phase noise and spur performance. Best performance is achieved with only one output turned on and the other frequency outputs turned off.

The Rb atomic frequency source uses a modulation/demodulation scheme with a modulation frequency of approximately 156 Hz. Inherent in this approach is sensitivity to noise at multiples of the modulation frequency. This noise is coupled through both the heater and electronic power lines to cause modulation spurs on the output frequency.

Note: Avoid the modulation frequency and its lower harmonics (roughly up to the tenth harmonic).

3.7 Reliability and Maintenance

The following sections address reliability and maintenance of the SA.22c.

3.7.1 Reliability

The SA.22c is designed with a life of ten years of operation without retuning. To accomplish this, the major mechanisms impacting the need for maintenance were addressed. Thus, each SA.22c is designed to have excess rubidium filled in the lamp to last for the required period, sufficient pulling range for the voltage controlled crystal oscillator, and sufficient dynamic range of the rubidium control loop.

3.7.2 Maintenance

The SA.22c is serviced in the factory only. There is no user service adjustment or maintenance required. A monitor signal is provided to help the user to track indications of pending end-of-life for the unit with sufficient notice to avoid a total and sudden failure of the unit. The key indicator of health is the service indicator that indicates when the rubidium physics package or the on-board quartz oscillator are near to their operating or control limits.

If the lock signal does not indicate a rubidium lock within the specified time, or the service signal indicates that the unit has reached the end of its effective life, remove the unit and return it to Microsemi for service. The service indicator is valid only when the lock signal indicates that the unit is locked.

For information about how to return a unit for service, see Repairs and Support (see page 14).

4 Installation and Operation

This section provides information on details to consider when installing turning on, performance monitoring, operation, and troubleshooting the SA.22c unit.

4.1 Installation

The following sections provide general installation advice.

4.1.1 Site Selection

The SA.22c can be mounted in any orientation. Ensure that the temperature limits are not exceeded for the proper functioning of the SA.22c.

The SA.22c is sensitive to external DC and AC magnetic fields (see, Specifications (see page 4)) and must not be installed in locations subjected to strong magnetic fields from transformers or large power supplies. Avoid using a power source that also provides power to fans or equipment that generates high current pulses.

4.1.2 Turn-On Procedure

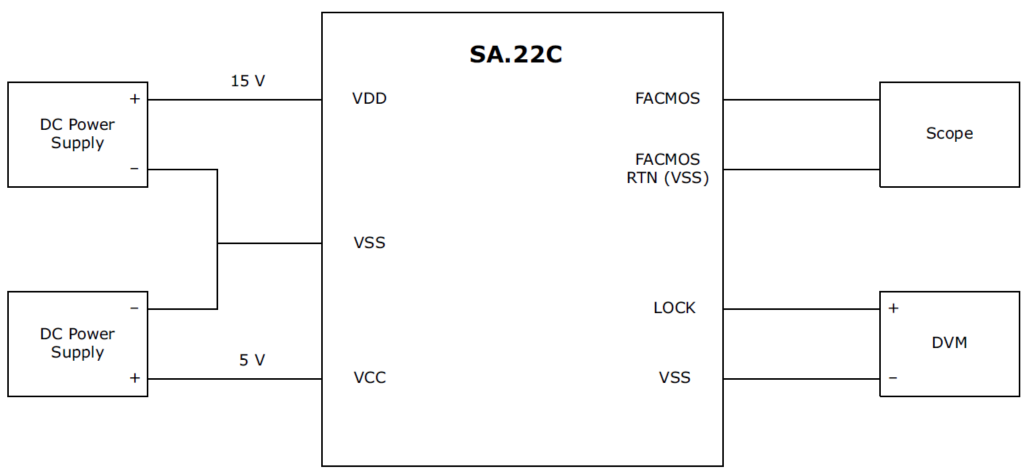
The following steps describe how to power up the SA.22c:

Caution: To avoid damage to the SA.22c, do not apply power to the unit in reverse direction.

1. Verify the SA.22c voltage requirement (see, Appendix: Using the Developer’s Kit (see page 16)).
2. Verify that the power supply is set to the correct voltage and is turned off.
3. Connect the power cable to the SA.22c assembly and turn on the power.

The following block diagram is the suggested connection for turning on the SA.22c.

Figure 7 • Suggested Connections for SA.22c, Initial Turn-on



After the SA.22c starts receiving power, wait until the unit achieves atomic lock (typically 5 minutes). During this period, the monitored lock signal is HIGH. After the unit achieves atomic lock, the lock signal goes LOW.

Depending on the base plate temperature, within several minutes the unit should be within 1×10^{-9} of the center frequency. Thirty minutes after applying power to the SA.22c, the RF output frequency is close to full accuracy (see, Specifications (see page 4)).

Note: The output frequency of the SA.22c is more accurate than most counters. Appropriate measurement equipment can be obtained from Microsemi. Inquire with Microsemi marketing, or your local sales representative, about Microsemi line of test and measurement standards.

4.2 Start-Up Sequence

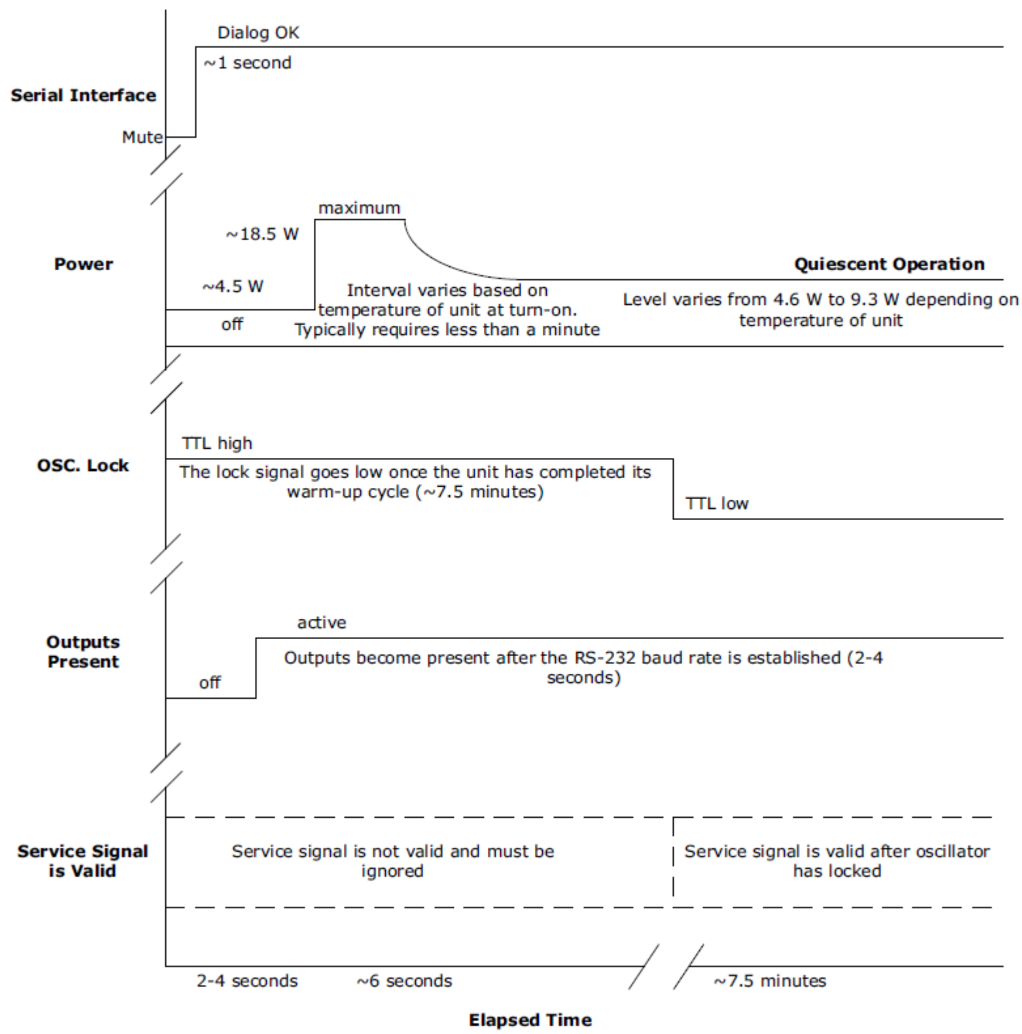
When power is connected, the SA.22c begins its warm-up cycle. After few minutes, the rubidium oscillator reaches a locked condition and its output signals stabilize. The accuracy at shipment is $<\pm 5 \times 10^{-11}$ at 25 °C, typical.

Note: Signals appear at the outputs immediately after power is applied to the unit, but these output signals are not stable until the oscillator is locked.

After 7.5 minutes, the accuracy of the SA.22c oscillator is $<1 \times 10^{-9}$. Performance of the SA.22c unit varies according to the application profile specified at the time of order. For information about application profiles and unit performance, see the SA.22c Product Specification.

To monitor the performance and selectively of the unit, modify using the MSIP firmware included in the unit and connect the unit to the COM port of a PC running Windows.

Figure 8 • Sequence of Start-Up Events



Note: The service signal can be active high or active low depending on the unit configuration.

4.3 Theory of Operation

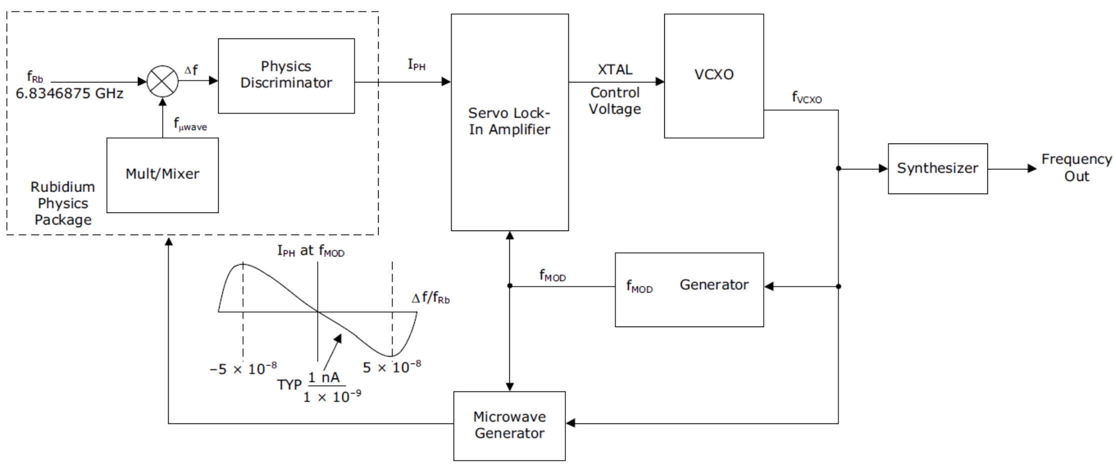
The SA.22c controls the frequency of a quartz crystal oscillator through a frequency-locked loop (FLL) using the atomic resonance property of rubidium (^{87}Rb).

The FLL function block is shown in the following illustration. A microwave signal is derived from a voltage controlled crystal oscillator (VCXO) and is applied to the ^{87}Rb vapor within a glass cell. The light of a rubidium lamp passes through this cell and illuminates a photo detector. When the frequency of the applied RF signal corresponds to the frequency of the ground-state hyperfine transition of the ^{87}Rb atom (an ultra-stable high-Q rubidium atomic resonance), the light is absorbed causing a change (decrease) in photo detector current (IPH).

As the change in current is small, modulation techniques are required to extract the desired signal from the noise background.

The photo detector current generates a control signal with phase and amplitude information, which permits continuous regulation of the VCXO frequency. The servo section converts the photo detector current into a voltage, then amplifies, demodulates, and integrates it for high DC servo loop gain.

Figure 9 • Rb Control Loop Block Diagram



4.4 Troubleshooting

After installation, if the SA.22c unit fails to provide outputs, or the rubidium oscillator fails to achieve lock, check for the following faults:

- External power supply is providing incorrect power
- I/O connector is defective—perform a continuity check

Note: All pins must have a connection in the I/O connector. This is important for the power and ground pins.

- Operating area has excess humidity or moisture
- Ambient temperature is below –10 °C or above 75 °C (the unit may not startup in excessively cold or hot temperatures)

4.5 Repairs and Support

The SA.22c is not field repairable, but some firmware upgrades can be done in the field, as mentioned in Start-Up Sequence (see page 13). If the unit fails, do not remove the cover of the unit and attempt to make repairs.

Note: Unit warranty is void if the cover is removed or if the protective seals covering the two tuning and adjustment holes are torn or removed.

4.5.1 Email

Communicate your technical questions to our email address and receive answers back by email:
For USA, Americas, Asia, and Pacific Rim: ftd.support@microsemi.com
For Europe, Middle East, and Africa (EMEA) Technical Support: ftd.emeasupport@microsemi.com
For EMEA Sales: ftd.emea_sales@microsemi.com

4.5.2 Contact

4.5.2.1 USA, Americas, Asia, and Pacific Rim

Microsemi FTD Services and Support
3870 N, First Street
San Jose, CA 95134
Telephone: 408-428-7907
Toll-free in North America: 1-888-367-7966

4.5.2.2 Europe, Middle East, and Africa (EMEA)

Microsemi FTD Services and Support EMEA
Altlaufstrasse 42
Hoehenkirchen-Siegertsbrunn 85635
Germany
Telephone: +49 700 3288 6435
Fax: +49 8102 8961 533

5 Appendix: Using the Developer's Kit

This appendix provides information about using the SA.22c developer's kit. It includes information about interfacing the adapter test board and the various options for providing power and viewing signals from the SA.22c through the adapter test board.

The SA.22c developer's kit is provided by Microsemi as a design aid and development tool. It allows you to experiment with the Microsemi SA.22c product in various applications and determine how to implement it in the most advantageous manner.

The developer's kit contains a hard copy of this document, the SA.22c unit, the adapter test board, an optional heat sink, application notes, and a CD with electronic files documenting the specifications and performance of the unit.

Note: Contents of the Developer's Kit may change. Consult the packing list for an up-to-date list of materials.

Note: Use a power supply with leads or interface cable to connect the adapter test board to the main power. To avoid potential damage to the adapter test board and the SA.22c, ensure that correct polarity is used.

5.1 Mounting the Unit with the Adapter Test Board

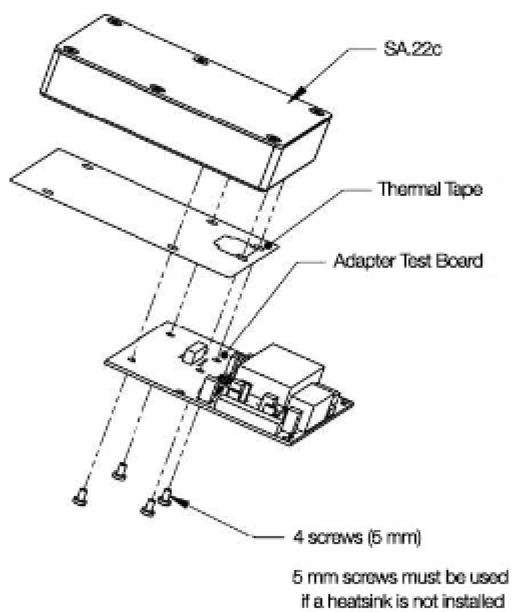
The SA.22c, along with the adapter test board, is designed to mount on a heat-absorbing surface. If a heat-absorbing surface is not available for testing, a suitable heat sink can be ordered as an option.

Note: The mounting screws of the SA.22c are metric (not SAE) and are 3 mm in length with a 0.5 mm thread pitch. They must not penetrate more than 3 mm into the SA.22c base plate.

The following illustration shows the mounting of the SA.22c on the adapter test board. Four 5 mm screws are required to mount the SA.22c on the adapter test board if the optional heat sink is not used.

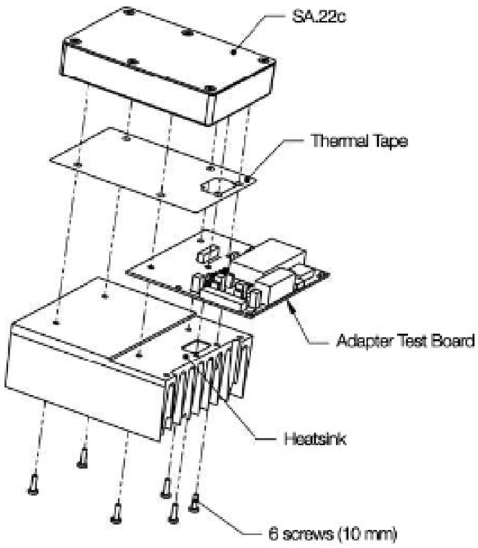
Note: To achieve and maintain the highest level of performance for the SA.22c, Microsemi recommends utilizing a suitable means for heat sinking if you choose not to purchase the optional heat sink.

Figure 10 • SA.22c Developer's Kit without Heatsink Assembly



The following figure shows the mounting of the SA.22c on the adapter test board and to the optional heat sink. Six 10 mm screws are required to properly mount the SA.22c with the adapter test board on the optional heat sink.

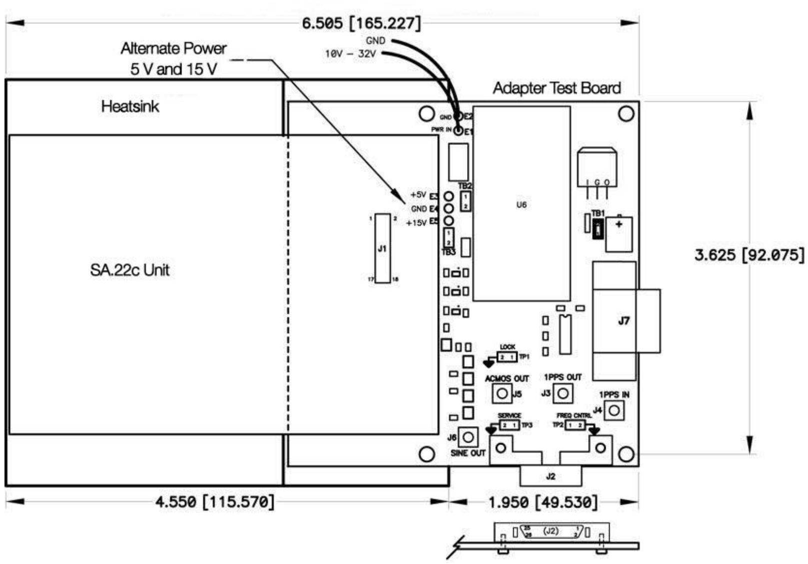
Figure 11 • SA.22c Developer's Kit with Heatsink Assembly



5.2 Interfacing the Adapter Test Board

The adapter test board is designed to deliver power to and retrieve signals from the SA.22c. The adapter test board allows you to electrically integrate the SA.22cto an existing system (via J2). The following illustration shows the top view layout of the adapter test board with SA.22c attached.

Figure 12 • Developer's Kit Interconnect Diagram



J1 on the adapter test board is an 18-pin Samtec 2x9 shrouded I/O header used for electrically connecting the SA.22c to the adapter test board. The following table lists the I/O pin configuration.

The following table provides information on the pin assignment and the function chart for SA.22c.

Table 5 • 18-Pin Samtec I/O Connector (J1)

Pin	Signal	Type	Function
1	VSS	GND	Power and signal return ground (all ground pins must be connected)
2	VDD	PWR	15 Vdc power input (all power pins must be connected)
3	VSS	GND	Power and signal return ground (all ground pins must be connected)
4	VDD	PWR	15 Vdc power input (all power pins must be connected)
5	FREQ CTRL	Analog	Frequency control - analog input between 0 - 5 Vdc
6	VCC	PWR	5 Vdc power input
7	1PPS OUT	Output	1PPS output, may be enabled/disabled digitally
8	VSS	GND	Power and signal return ground (all ground pins must be connected)
9	FSCMOS	Output	(FACMOS) ACMOS output (frequency selectable at factory)
10	VSS	GND	Power and signal return ground (all ground pins must be connected)
11	VSS	GND	Power and signal return ground (all ground pins must be connected)
12	SERVICE	Output	Indicates unit is nearing limits of frequency control and that Service is required within several months.
13	DIN	Input	UART data in at ACMOS logic levels
14	Lock	Output	If low, indicates Rb oscillator is locked
15	1PPS IN	Input	1PPS input, positive edge triggered
16	DOUT	Output	UART data out at ACMOS logic levels
17	Not available		
18	Not available		

J2 is a 26-pin Molex receptacle connector used for delivering power, transmitting/receiving signals, and data to and from the SA.22c. The following table lists the Molex pin configuration.

Table 6 • 26-Pin Molex Connector (J2)

Pin	Signal	Type	Function
1	VINPUT	PWR	Power input 10 Vdc to 32 Vdc (All power pins must be connected)
2	VINPUT	PWR	Power input 10 Vdc to 32 Vdc (All power pins must be connected)
3	VINPUT	PWR	Power input 10 Vdc to 32 Vdc (All power pins must be connected)
4	VINPUT	PWR	Power input 10 Vdc to 32 Vdc (All power pins must be connected)
5	VINPUT	PWR	Power input 10 Vdc to 32 Vdc (All power pins must be connected)
6	VINPUT	PWR	Power input 10 Vdc to 32 Vdc (All power pins must be connected)
7	VINPUT	PWR	Power input 10 Vdc to 32 Vdc (All power pins must be connected)
8	SERVICE	Output	Service required within 30 days based on unit health
9	DOUT	Output	UART data out at ACMOS logic levels
10	DIN	Input	UART data in to SA.22c
11	FREQ CTRL	Analog	Frequency control analog voltage (0 to 5 Vdc)
12	VSS	GND	Indicates unit is nearing limits of frequency control and that service is required within months
13	VSS	GND	Power and signal ground (All ground pins must be connected)
14	VSS	GND	Power and signal ground (All ground pins must be connected)

Pin	Signal	Type	Function
15	VSS	GND	Power and signal ground (All ground pins must be connected)
16	VSS	GND	Power and signal ground (All ground pins must be connected)
17	VSS	GND	Power and signal ground (All ground pins must be connected)
18	VSS	GND	Power and signal ground (All ground pins must be connected)
19	1PPS IN	Input	1PPS input, positive edge triggered
20	1PPS OUT	Output	1PPS output, may be enabled/disabled digitally
21	Lock	Output	If low, then the SA.22c is locked
22	Not available		
23	VSS	GND	Power and signal ground (All ground pins must be connected)
24	FACMOS	Output	Frequency ACMOS signal output
25	VSS	GND	Power and signal ground (All ground pins must be connected)
26	SINE	Output	Sine signal output (50 ?)

J3, J4, J5, and J6 are SMA connectors used for signal outputs (J4 is a signal input) provided by the SA.22c. The following table lists the SMA connectors' signal information.

Table 7 • SMA Connectors' Signal Information

SMA	Signal	Type	Function
J3	1PPS OUT	Output	1PPS output, may be enabled /disabled digitally
J4	1PPS IN	Input	1PPS input, positive edge triggered
J5	FACMOS	Output	Frequency ACMOS signal output
J6	SINE	Output	Sine signal output (50 Ω)

J7 is a 9-pin D-Sub connector used for transmitting/receiving data to and from the SA.22c through the MSIP. The following table lists the D-Sub connector pin configuration.

Warning: When using J3, J4, J5, and J6, it is required that J2 must not be connected. Having J2 connected will cause a loading effect on J3, J4, J5, and J6, which results in degraded signal integrity.

Table 8 • 9 Pin D-Sub Connector (J7)

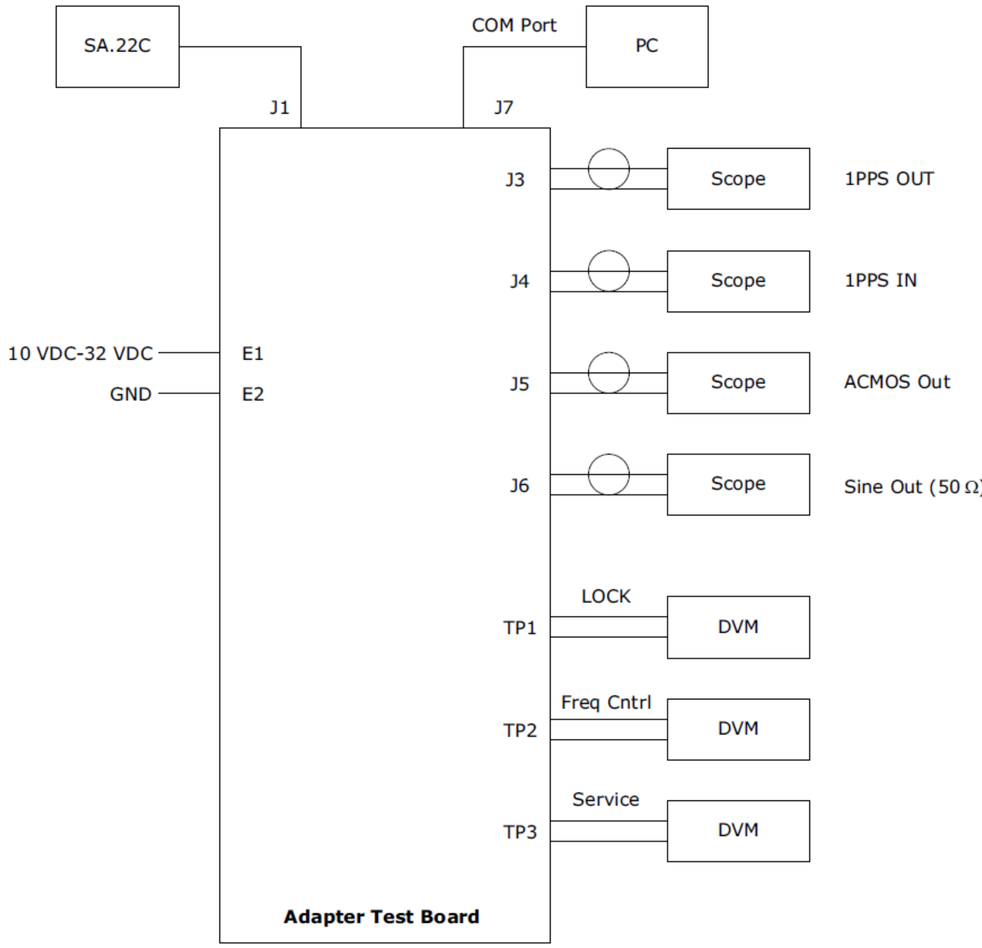
Pin	Signal	Type	Function
1	Not available		
2	DOUT	Output	UART data out at ACMOS logic levels
3	DIN	Input	UART data in to SA.22c
4	Not available		
5	VSS	GND	Signal ground
6	Not available		
7	Not available		
8	Not available		
9	Not available		

5.3 Options for Supplying Power to the Adapter Test Board

The SA.22c adapter test board design allows three power-supplying options.

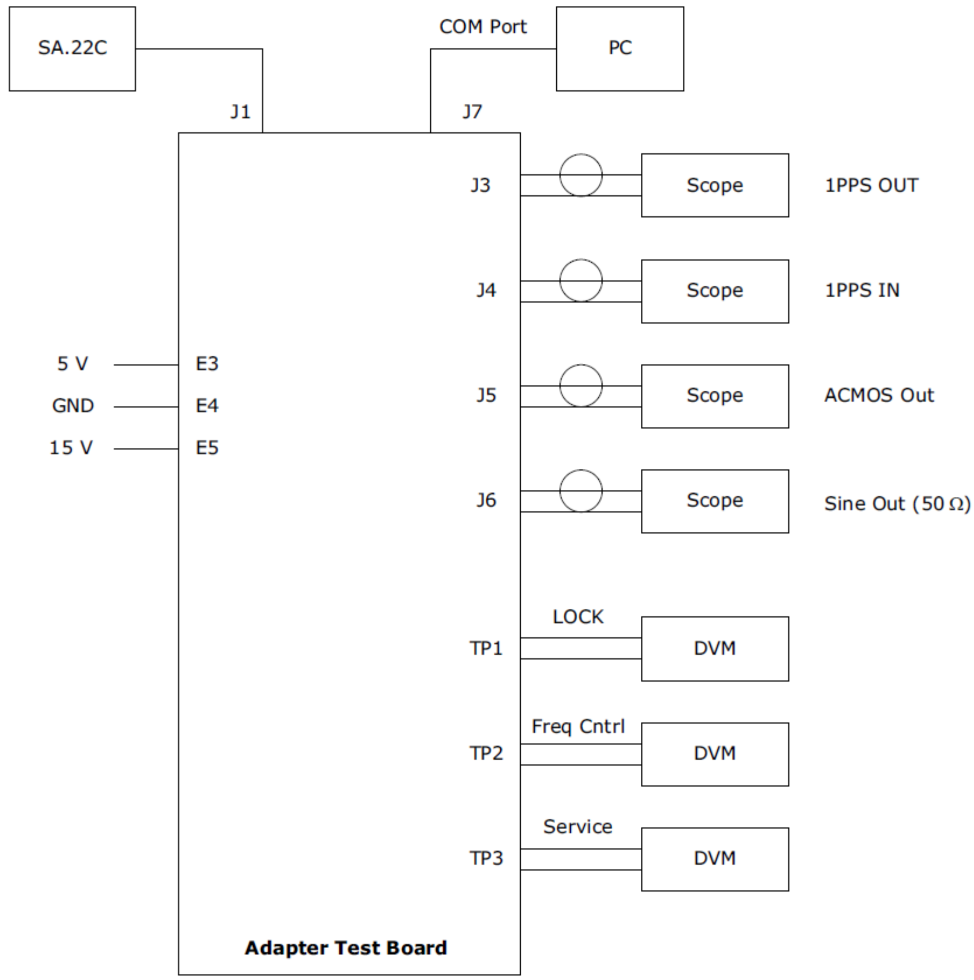
The following figures show the block diagrams of the three different options for powering and setting up the SA.22c with the adapter board. It also shows the connections used to access various inputs and outputs of the SA.22c depending on the option selected.

Figure 13 • Block Diagram of Suggested Test SA.22C Set-up (Option 1)



After the SA.22c unit receives power, wait for a few minutes while the unit achieves atomic lock. During this period, the monitored lock signal must be HIGH. After the unit achieves atomic lock, the lock signal goes LOW.

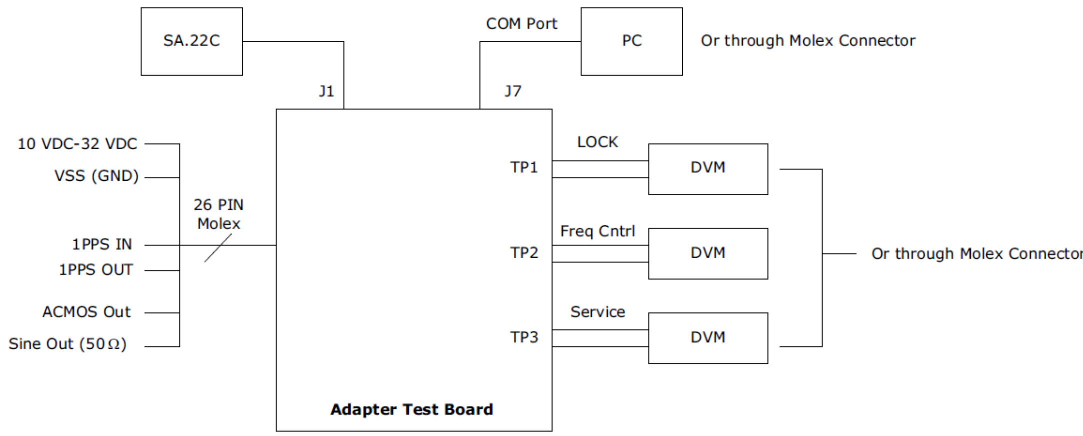
Figure 14 • Block Diagram of Suggested Test SA.22C Set-up (Option 2)



It is recommended to power up 5 V first, or simultaneous with the 15 V supply.

After the SA.22c unit receives power, wait for a few minutes while the unit achieves atomic lock. During this period, the monitored lock signal should be HIGH. After the unit achieves atomic lock, the lock signal goes LOW.

Figure 15 • Block Diagram of Suggested Test SA.22C Set-up (Option 3)

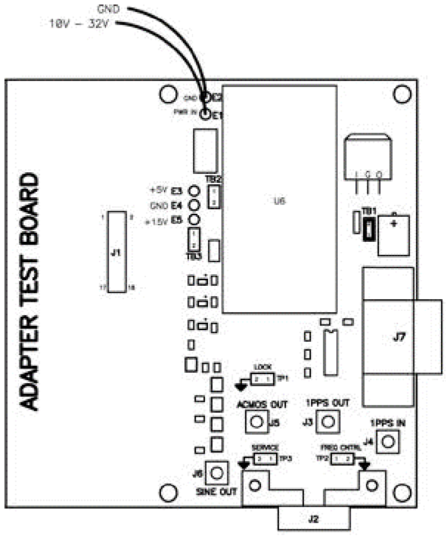


After the SA.22c unit receives power, wait for few a minutes while the unit achieves atomic lock. During this period, the monitored lock signal must be HIGH. After the unit achieves atomic lock, the lock signal goes LOW.

The following figure shows the physical power supply wiring and jumper settings needed for each option.

Warning: Use the power settings and connectors that are appropriate for one particular option at a time. Mixing any combination of these options may result in system failure and may cause damage to the existing circuitry.

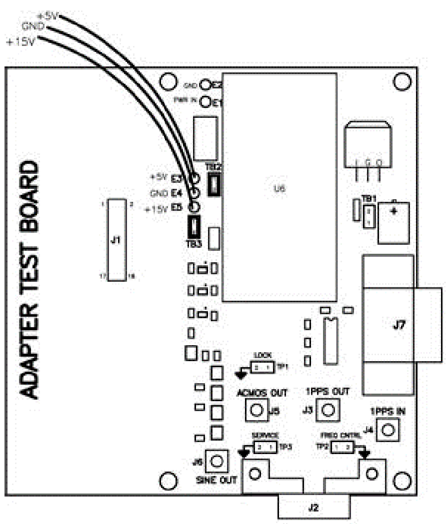
Figure 16 • Power Supply and Output Options



OPTION 1:
10VDC – 32VDC SUPPLIED TO E1
GND SUPPLIED TO E2
TB1 IS INSTALLED
TB2 AND TB3 ARE OPENED

THIS CONFIGURATION GOES THROUGH
DC TO DC CONVERTER AND VOLTAGE REGULATOR
WHICH SUPPLIES +15V AND +5V TO SA.22c

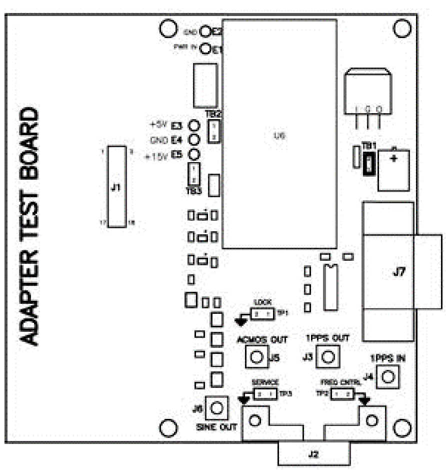
J7 IS CONNECTED TO SERIAL INTERFACE
J3, J5, J6 ARE USED FOR SIGNAL OUTPUTS
J4 IS USED FOR 1PPS INPUT
J2 MUST NOT BE CONNECTED
TB1, TB2, TB3 ARE USED FOR MONITORS AND FREQUENCY CONTROL



OPTION 2:
+5V SUPPLIED TO E3
GND SUPPLIED TO E4
+15V SUPPLIED TO E5
TB2 AND TB3 ARE INSTALLED
TB1 IS OPENED

THIS CONFIGURATION DIRECTLY SUPPLIES
SA.22C WITH +5V AND +15V.

J7 IS CONNECTED TO SERIAL INTERFACE
J3, J5, J6 ARE USED FOR SIGNAL OUTPUTS
J4 IS USED FOR 1PPS INPUT
J2 MUST NOT BE CONNECTED
TB1, TB2, TB3 ARE USED FOR MONITORS AND FREQUENCY CONTROL



OPTION 3:
J2 (26 PIN MOLEX) IS INSTALLED
+10VDC TO +32VDC ARE SUPPLIED THROUGH
PINS 1 THROUGH 7
TB1 IS INSTALLED
TB2 AND TB3 ARE OPENED

THIS CONFIGURATION GOES THROUGH
DC TO DC CONVERTER AND VOLTAGE REGULATOR
WHICH SUPPLIES +15V AND +5V TO SA.22c

J7 IS CONNECTED TO SERIAL INTERFACE (OPTIONAL)
J3, J4, J5, J6 MUST NOT BE CONNECTED
TB1, TB2, TB3 ARE USED FOR MONITORS AND FREQUENCY CONTROL (OPTIONAL)

Option 1 allows you to directly power the adapter test board with 10 Vdc to 32 Vdc supplied to E1 and E2 connected to supply ground. TB1 is installed and TB2 and TB3 are open. In the adapter board, this voltage travels through a DC-to-DC converter and a voltage regulator to supply the SA.22c with 15 Vdc and 5 Vdc for operation. For this option, J7 is used for serial interface communications, J3, J5, and J6 are used for signal outputs, and J4 is used for 1PPS input. TP1 and TP3 are used for lock and service monitor respectively. TP2 is used for providing the analog frequency control if needed. In this option, J2 must not be connected to avoid degraded signal integrity.

Option 2 allows you to directly power the adapter test board with separate 15 Vdc supplied to E5 and 5 Vdc supplied to E3 supplies with E4 connected to supply ground. TB2 and TB3 are installed and TB1 is left open. In the adapter board, these voltages travel directly to the SA.22c for operation (the 5 Vdc must be applied before or simultaneous to the 15 Vdc). For this option, J7 is used for serial interface communications, J3, J5, and J6 are used for signal outputs, and J4 is used for 1PPS input. TP1 and TP3 are used for lock and service monitor respectively and TP2 is used for providing the analog frequency control if needed. In this option, J2 must not be connected to avoid degraded signal integrity.

Option 3 allows you to power the adapter test board with 10 Vdc to 32 Vdc through the 26-pin Molex connector (J2). TB1 is installed and TB2 and TB3 are open. In the adapter board, this voltage travels through a DC-to-DC converter and a voltage regulator to supply the SA.22c with 15 Vdc and 5 Vdc for operation. For this option, J7 or J2 is used for serial interface communications, J2 is also used for input and output signals. TP1 and TP3 are used for lock and service monitor respectively and TP2 is used for providing the analog frequency control if needed; however, J2 can also provide these monitors and frequency control as well (see 26-Pin Molex Connector (J2) (see page 18) for Molex pin configuration). In this option, J3, J4, J5, and J6 must not be connected to avoid degraded signal integrity.

6 Appendix: Microsemi Serial Interface Protocol

This appendix provides information about communicating with the SA.22c through the serial interface connector provided in the developer's kit (see Appendix: Using the Developer's Kit (see page 16)). It includes output examples and a description of commands.

6.1 Using the Microsemi Serial Interface Protocol

The MSIP bridges communication with the SA.22c through the serial port when connected to a host PC. All **developer-mode** commands are a single ASCII letter and require no termination. Out of the eight RUN MODE commands, three require the host to supply data.

6.1.1 Host Terminal Emulator Setup

Set up the comm port of the PC with the following configuration:

- Data rate (baud or B.P.S. – baud rate) of the SA.22c is 57.6K
- No parity
- Eight data bits
- One stop bit
- No local echo (unit echoes)
- No hardware or software flow control

Note: The SA.22c's UART connections are based on 5 Vdc logic levels. However, the developer's kit contains a TTL-to-RS232 converter that allows interfacing to a PC.

6.1.2 Run Mode Data Format (Customer Mode)

SA.22c outputs are all decimal data as ASCII coded hex except for the echoed characters. Do not convert data to decimal when transmitting to the SA.22c. All data are sent to the SA.22c and received back as **ASCII coded hex**. The following example shows how data are encoded.

Note: Flow control is not permitted in **Run Mode**.

The following is an example of the output from the SA.22c after power is supplied to the unit.

```
SA22C by Symmetricom, Inc., Copyright 2006
SA22 Version 6.01C of 7/2006; Loader Version 3
Mode CN01 Flag 0000 [D04D]ok
Unit serial code is 0612SA3763-h, current tuning state is 6
Crystal: 60000000hz, ACMOS: 10000000.0hz, Sine: 10000000.0hz
Ctl Reg: 004C, Res temp off: -1.5410, Lamp temp off: -1.9466
FC: disabled, Srvc: high
Enter Run Mode
FC mode is disabled
1pps mode is disabled
r>
```

Command i: The following example shows the response to the command i to get the serial number and other information on the SA.22c:

```
r>i
SA22C by Symmetricom, Inc., Copyright 2006
SA22 Version 6.01C of 7/2006; Loader Version 3
Mode CN01 Flag 0004
Unit serial code is 0612SA3763-h, current tuning state is 6
Crystal: 3938700hz, ACMOS: 989680.00000000hz, Sine:
```

```
989680.00000000hz
Ctl Reg: 004C, Res temp off: BFC53F7D., Lamp temp off: BFF92B93.
FC: disabled, Srvc: high
```

Command h: The following example shows the response to the command h for the SA.22c help menu:

```
r>h
a: Set FC Mode
f: Adjust DDS Frequency (delta e-11)
i: Info (show program info)
j: Display 1pps Delta Reg
k: Set 1pps TIC
l: Set Service Pin Sense
o: Set ACMOS Output Frequency 'N'
p: Display Control Reg
q: Set Control Reg
t: Save Tuning Data
w: Display Health Data
x: Exit Run Mode
r>
```

Command w: The following example shows the response to the command w for the SA.22c **health data** (wellness):

```
r>w
AData:
SCont: 6012
SerNum: 3B8
PwrHrs: 8A
PwrTicks: E291DB
LHHrs: 85
LHTicks: 16CCE28
RHHrs: 85
RHTicks: 165353C
dMP17: 4156AE53.
dMP5: 3D3C8652.
dHtrVolt: 41852146.
PLmp: 3F7E1248.
Appendix: Microsemi Serial Interface Protocol
097-16313-201 Designer Reference and User Guide Revision B 29
PRes: 3FC3EE0D.
dLVthermC: B8530000.
dRVthermC: B9384000.
dLVolt: 3FA0E4AC.
dMVoutC: C87BD20F.
dTempLo: 412C0000.
dTempHi: 42B50000.
dVoltLo: 416156C8.
dVoltHi: 4185C42A.
iFpgaCtl: 004C
dCurTemp: 42540000.
dLVoutC: 3DF9793A.
dRVoutC: 3DE6A30F.
dMV2demAvg: 3F259383.
```

Note: Values are in hex format.

Command a: The following example shows the response to the command a followed by an integer sets the enable/ disable feature of FC mode. Integer zero followed by <cr> disables FC mode and any nonzero integer followed by <cr> enables the FC mode.

```
r>a
5987717
FC mode enabled
```

Command p: The following example shows the response to the command p for the SA.22c **control register**

```
r>p
Control Reg: 204C
```

Note: For the above example, C corresponds to bits 12-15, 4 corresponds to bits 8-11, 0 corresponds to bits 4-7, and 2 corresponds to bits 0-3 in the following table.

Table 9 • SA-22c (and x72) Output Control Register

Bit	Hex Value	Control	Description	Controlled By
0	1	Lamp switch power boost—internal function	0= Lamp switch off (default during operation) 1= Lamp switch on	Controlled by SDCP, automated function, no user input
1	2	BITE output	0= Unit is locked (default during operation) 1= Unit is not locked	Controlled by SDCP-automated function- no user input
2	4	FXO (crystal output) enable	0= Enables FXO output 1= Disables FXO output	Configuration is set either by entering the control register value during TACO or entering the configuration information into the unit batch list file prior to testing
3	8	1PPS output enable	0= Enables 1PPS output 1 =Disables 1PPS output	Configuration is set either by entering the control register value during TACO or entering the configuration information into the unit batch list file prior to testing
4	1	ACMOS output enable	0= Enables ACMOS output 1= Disables ACMOS output	Configuration is set either by entering the control register value during TACO or entering the configuration information into the unit batch list file prior to testing
5	2	C-field boost	0= Low C-field (default) 1= High C-field	Configuration is set by entering the control register value during TACO. Not configurable in customer firmware
6	4	Sine output enable	0= Enables sine output to 40% of max amplitude 1= Disables sine output	Configuration is set either by entering the control register value during TACO or entering the configuration information into the unit batch list file prior to testing
7	8	Sine output level adjust	0= Zero additional level (default) 1= Adds 15% of max output	Configuration is set by entering the control register value during TACO. Not configurable in customer firmware.
8	1	Sine output level adjust	0= Zero additional level (default) 1= Adds 10% of max output	Configuration is set by entering the control register value during TACO. Not configurable in customer firmware.

Bit	Hex Value	Control	Description	Controlled By
9	2	Sine output level adjust	0= Zero additional level 1= Adds 5% of max output (default)	Configuration is set by entering the control register value during TACO. Not configurable in customer firmware.
10	4	Service	0= Unit is OK 1= Unit requires service	Controlled by SDCP, automated function, no user input
11	8	1PPS locked (sync)	0= No 1PPS sync 1= 1PPS locked to ext 1PPS	Controlled by SDCP, automated function, no user input
12	1	External 1PPS	0= No 1PPS external signal 1= 1PPS external signal present	Controlled by SDCP, automated function, no user input
13	2	FC pin enabled	0= Frequency control pin disabled 1= Frequency control pin enabled	Controlled by SDCP, automated function, no user input
14	4	Reserved not used		
15	8	Reserved not used		

6.1.3 Factory Mode

Data output from the SA.22c in factory mode is not intended for users outside the factory and is not described in this document beyond the table Run Mode Commands (see page 28).

Caution: Using factory mode results in the erasure of firmware on the SA.22c rendering it inoperable and making it necessary to return the unit to the factory for re-programming.

6.1.4 Serial Interface Initialization

The serial interface is initialized as listed in the following tables.

Table 10 • Run Mode Commands

User Output to SA.22c		Response to Host	Command Name and Description
a	Set FC mode Example: a <zero or non-zero integer> <cr>	To be specified	Set analog frequency control mode. This command toggles the analog input pin to the unit **Freq Cntrl** between enable and disable. In factory mode, the default is enabled. During factory test, the default is set to disable for shipping unless the customer ordered the default to be set enabled.
f	Desired frequency change from free running center frequency in parts to 1×10^{-11} Example: for a 100×10^{-11} change: **100<cr>** Example: for a -100×10^{-11} change: **–100<cr>**	To be specified	Adjust frequency. Adjust unit output frequency. Used to discipline the unit. The smallest incremental frequency change is 2×10^{-12} (or **f.2**). Any value less than this will still be allowed, but not executed by the hardware. Maximum value that can be used at one time is 4×10^{-8}. For larger frequency changes, repeated steps equal to or smaller than 4×10^{-8} must be used. Unit always powers up at free running factory set frequency. This command is always relative to the free running frequency.
h		To be specified	Help command. Displays menu.
i		To be specified	Outputs unit information. While dumping data, clock outputs are not guaranteed to meet specifications during the use of this command.

User Output to SA.22c		Response to Host	Command Name and Description
o	N (example of command and data to give 10 MHz for a VCXO of 60 MHz is: **o3**)	To be specified	The default frequency output is 10 MHz[1].
p		To be specified	Displays control register.
q	Hex data to set or reset bits in the control register immediately follows the command (Example: **q3A**)	To be specified	Set control register Allows enabling or disabling of outputs.
t	SAVE command Example: to SAVE changes: **5987717<cr>**	To be specified	Saves all changes made[2].
w		To be specified	Displays health monitor data.

1. Contact the manufacturer for information about other frequencies.
2. If the t command is not used, unit defaults to factory settings at next power up.

Table 11 • Factory Mode Commands

User Output to SA.22c		Response to Host	Command Name and Description
Command	**Data**		
a		a>	Goes to administration mode.
i		Outputs 7 lines of banner (same as power-up information)	Displays unit Information.
r	Run mode	Enter run mode. FC mode is disabled (enabled)	Goes to run mode.

Note: Run mode and admin mode allow the loading of new code, updates, or reconfiguring defaults in the field. It is not a normal operating mode.

Table 12 • SA.22c Administrative Mode Commands

User Output to SA.22c		Response to Host	Command Name and Description
Command	**Data**		
a		Outputs 7 lines of banner (same as power-up information)	Unit information same as the i command in factory mode and run mode.
b	**File** from Microsemi (self-burning)	To be specified	Operating this command without valid file will not overwrite the existing data stored in flash memory.
x	Run mode	x f>	Exit administrative mode to factory mode.
y		Y asks **are you sure?**	Soft reset. Restarts processor.
z		Z asks **are you sure?**	Puts unit into a mode where it will wake only when the power is recycled.

Note: Admin mode allows the loading of new code, updates, or reconfiguring defaults in the field. It is not a normal operating mode.

7 Appendix: One Pulse Per Second Source Connection

This appendix describes how to connect a 1PPS source, such as a commercial GPS receiver, to an SA.22c to achieve long term accuracy and excellent holdover, or flywheeling performance.

7.1 Connection Requirements

The following connections are required for 1PPS setup:

- Power
- GPS antenna/receiver or other 1PPS source reference.
- 1PPS cabling from the source to the SA.22c

No serial port communication is required for initial setup unless the changes are made from the factory default settings. Information on setup, operation, and integration is provided.

7.2 Background

GPS technology has made time and frequency synchronization possible (available) worldwide. Connecting the 1PPS output from a commercial (civilian) GPS receiver to an SA.22c provides a cost effective system that maintains highly accurate time and frequency even when GPS signals are unavailable, for example, during jamming and antenna maintenance.

The GPS system provides 1PPS signals worldwide with good long term stability (that is, $<1\times10^{-12}$ averaged over 24 hours). However, the short term stability of this signal is often compromised by various noise sources, for example, man-made, atmospheric conditions, crosstalk, RF multi-path or inter symbol interference, and GPS receiver oscillator limitations.

Microsemi has pioneered the use of rubidium oscillators in telecommunication applications. Telecommunications applications require long term and short term stability beyond the range of free running quartz oscillators. For example, cellular CDMA systems require 1PPS signals to be synchronized within 2 µs over long periods of time even when GPS signals are not available. To achieve this performance, system designers must combine the benefits of short term stability (from a rubidium or low noise OCXO) with long term stability (from GPS, Loran-C, Glonass, or Cesium). Microsemi is the leader in system products with microprocessor driven circuitry that uses the GPS 1PPS system to steer various oscillators (Cesium, Rubidium, and Quartz). These products make it possible to combine the short term with long term stability. With SA.22c, the solution is more cost effective. The performance level of SA.22c used with a GPS receiver approaches the performance of Cesium oscillators used in telecommunication systems.

7.3 1PPS Functions

The SA.22c can be configured to:

- Generate a rubidium controlled 1PPS signal
- Measure the difference between an incoming 1PPS signal and the SA.22c 1PPS
- Synchronize the SA.22c's frequency and 1PPS output to the incoming 1PPS and provide long holdover times

The following figure shows the SA.22c 1PPS disciplining block diagram.

When an externally generated 1PPS signal is applied to the 1PPS input pin of a properly configured SA. 22c, the unit provides the time interval error difference between the 1PPS input and the 1PPS generated inside the SA.22c (see table 1PPS States Returned with the j Command (see page 33)). The difference is read using the RS232 communications j command. The j command displays the difference between the 1PPS input and the 1PPS generated internally by the SA.22c. The j command generates a number representing the number of TICS in a delta register. If the SA.22c has a 60 MHz crystal, each TIC is 16.7 ns (1.67×10^{-8}). This number is in hex format.

The test bench setup configuration allows the SA.22c to be disciplined by the incoming 1PPS signal. The following figure Test Bench Setup shows the test bench setup. The 1PPS disciplining mode is enabled by default. It can be temporarily disabled by issuing the g command followed by a 1 (see The g Command (see page 34)). Typical performance data for this configuration is shown in Flywheeling Recover with 1PPS offset <1 µsec (see page 35) and Flywheeling Recover with 1PPS offset >1 µsec (see page 36) .

Figure 17 • Time and Frequency Control System

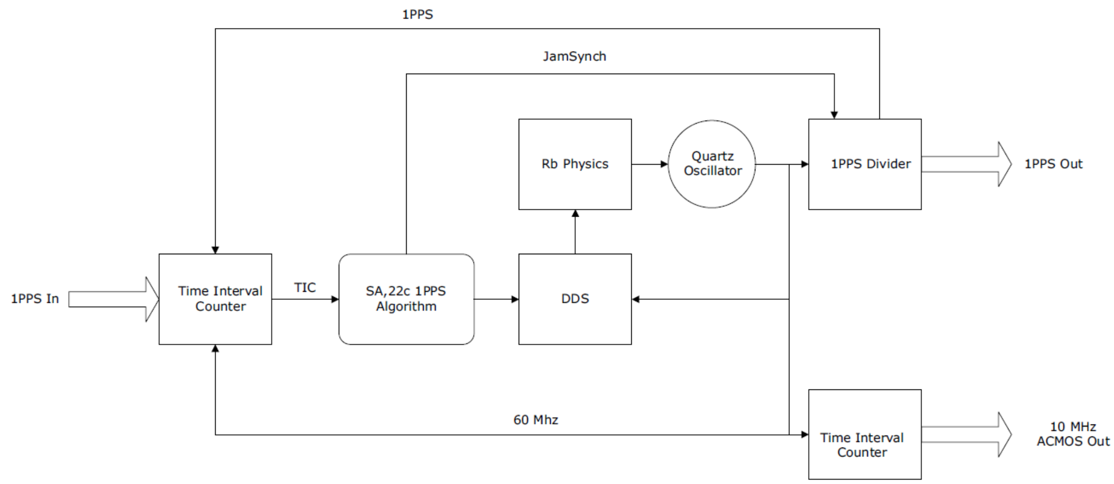
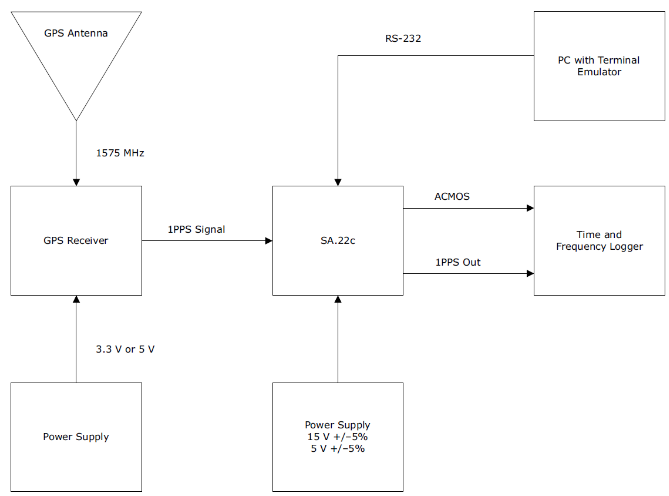


Figure 18 • Test Bench Setup



7.4 System Requirements

The following are the requirements for 1PPS setup and operation:

- SA.22c with 1PPS output enabled
- GPS receiver with less than 300 ns noise

- 1PPS input signals must have repeatable rise time with minimal ringing and must conform to the following:
  - 1PPS input is driven by a standard 3.3 V logic, 5 V CMOS, or 5 V TTL with normal operation at:
    - Input voltage logic high: 2.00 V minimum
    - Input voltage logic high: 5.50 V maximum
    - Input voltage logic low: 0.00 V minimum
    - Input voltage logic low: 0.80 V maximum
  - Maximum DC overshoot must be limited to 5.5 V or 10 mA, whichever is easiest to achieve.
  - Maximum DC undershoot must be limited to –0.5 V or 10 mA, whichever is easiest to achieve.
  - Minimum pulse width (or hold time) of 50 ns.
  - Input impedance >100 KΩ allows you to terminate the 1PPS at the input to the SA.22c with 50 Ω at the SA.22c input pin or drive the SA.22c high impedance directly with a low impedance source such as 50 Ω or any ACMOS gate as long as the input voltage level at the SA.22c pin is met as described above.
- The SA.22c rubidium oscillator subsystem must be locked to achieve synchronization.
- The SA.22c must be set up with the proper time constant and damping factor.
- SA.22c adapter kit is recommended to facilitate setup.
- PC running Microsoft Windows with terminal emulation program. (57600 bps, 8 bits with no parity).

7.5 1PPS Algorithm Operation

There are two parameters that are modified by the user for 1PPS synchronization using the **y** command – damping factor and tau.

Damping factor—determines the relative response time and ringing in response to each step. Values must be between 0.25 and 4. Values less than 0.25 defaults to 0.25 while values over 4 defaults to 4.

Tau (or time constant)—expressed in seconds and determines the time constant of the PLL for following a step in phase for the reference. The range of tau is 5 to 100,000 seconds. Values outside this range cause both the damping factor and tau to change to the factory default settings.

7.5.1 Factory Default

The factory default requires no inputs to the rubidium oscillator. The default value for damping factor is 1 and the default value for tau is 400. These values are a good starting points and work well for most GPS applications.

7.6 Setting the 1PPS Synchronization

The following are the steps for setting 1PPS signal synchronization (SA.22c with 1PPS enabled customer version of firmware at revision 6.05c or higher installed.)

1. Connect the SA.22c to the adapter test board of the developer's kit or to a correctly configured equivalent system. (see Appendix: Using the Developer's Kit (see page 16))
2. Ensure that the terminal emulation program is configured to 57,600 BPS, 8 bits, no parity, no flow control, and the keyboard caps lock is off. All inputs must be in lower case.
3. Power up the system. The header information from the SA.22c is displayed as follows, where the firmware version needs to be confirmed.

```
SA22C by Symmetricom, Inc., Copyright 2006
SA22 Version 6.05C of 7/2006; Loader Version 3
Mode CN03 Flag 0000 [C91F]ok
Unit serial code is 0612SA3763-h, current tuning state is 6
Crystal: 60000000hz, ACMOS: 10000000.0hz, Sine: 10000000.0hz
097-16313-201 Designer Reference and User Guide Revision B 36
Ctl Reg: 0044, Res temp off: -1.5410, Lamp temp off: -1.9466
FC: enabled, Srvc: low
Enter Run Mode
FC mode is enabled
```

```
1pps mode is enabled
r>
```

Note: It is not necessary for the SA.22c to be locked to enter the 1PPS configuration commands, but it must be locked for actual synchronization to occur.

7.6.1 Changing the y Coefficients

Follow the steps to change the y coefficients

1. At the r> prompt, type y, then 1, and press Enter (1 indicates that the damping factor needs to be entered).
2. Enter a value between 0.25 and 4, and press Enter (see Note 3 in The g Command (see page 34) and 1PPS Algorithm Theory of Operation (see page 36)).
3. At the r> prompt, type y, then 2, and press Enter (2 indicates that the time constant needs to be entered).
4. Enter a value between 5 and 100000, and press Enter (see Note 3 in The g Command (see page 34) and 1PPS Algorithm Theory of Operation (see page 36)).
5. At the r> prompt, type z. This saves the 1PPS configuration data to non-volatile memory. If the y coefficients are not saved with the z command, the SA.22c reverts to the previously saved configuration upon restart. The SA.22c responds with the following output (see Note 9 in The g Command (see page 34)):

```
r>z
Saving TData 2, serial number 3BE
1pps Coefs saved
```

7.6.2 The y Coefficients – Factory Default

If the factory default values of damping factor = 1 and tau = 400 are acceptable for the application, no modifications to the y coefficients are required. The SA.22c 1PPS disciplining is enabled at the factory, which allows the unit to work right out of the box. If the y coefficients need to be restored to the factory defaults, enter the value 0 for both the damping factor and tau using the process described in Changing the y Coefficients (see page 33). The SA.22c operates at the factory default damping factor of 1 and tau of 400.

7.6.3 The j Command

Press the j key at any time to return the current value in hex format from the delta register (see Note 1 in The g Command (see page 34)) and the 1PPS state (see Note 2 in The g Command (see page 34) and the following table). The following is the output format:

```
r>j
1pps Delta Reg: 0 ppsState:3
r>.
```

Table 13 • 1PPS States Returned with the j Command

PPS State	Value	Action Performed by SA.22c
INITIALIZE0STATE	0	Start up initialization
INITIALIZE1STATE	1	Start up initialization
INITIALIZE2STATE	2	Start up initialization
HOLDOVERSTATE	3	Seeking usable 1PPS
JAMSYNC1STATE	4	Sync SA.22c output 1PPS to input
JAMSYNC2STATE	5	Sync SA.22c output 1PPS to input
DISCIPLINESTATE	6	Keep SA.22c output 1PPS aligned to input by controlling SA.22c frequency
PIDCALCSTATE	7	Calculations for disciplining algorithm

PPS State	Value	Action Performed by SA.22c
PDATEDDSSTATE	8	Update SA.22c DDS based on PIDCALCSTATE output
ALCSLOPESTATE	9	Calculate slope of incoming 1PPS vs. SA.22c 1PPS during holdover

For more information on 1PPS states, see 1PPS Algorithm Theory of Operation (see page 36).

7.6.4 The g Command

The g command helps to toggle the operation of the SA.22c in any of the three modes mentioned below, which affect the output of the lock pin (pin 14 see Note 10 in The g Command (see page 34)). This 1PPS mode can be changed but cannot be saved. If power is cycled to the unit, it reverts to the factory default. The following are the modes of operation:

- 0 = 1PPS disciplining disabled—Normal rubidium lock pin functionality. Only the rubidium loop needs to be locked to indicate a locked condition on pin 14.
- 1 = 1PPS disciplining enabled—Normal lock pin functionality. Only the rubidium loop needs to be locked to indicate a locked condition on pin 14.
- 2 = 1PPS disciplining enabled—Requires both rubidium loop to be locked and 1PPS synchronization lock to indicate a locked condition on pin 14.

There are two types of 1PPS customer firmware. The 1PPS standard firmware provides an Rb or Rb/1PPS lock indicator at pin 14 and a service indicator on pin 12 of the SA.22c I/O connector. The 1PPS LED firmware uses the same functions for pin 14, but pin 12 is reserved for 1PPS lock indication only. There is no service pin on the 1PPS LED versions. The factory default modes set by the g command for each firmware version are:

- 1PPS standard firmware—Mode 2. Rb lock and 1PPS lock indicated on pin 14.
- 1PPS LED firmware—Mode 1. Rb lock only indicated on pin 14 and 1PPS lock indicated on pin 12.

The key sequence to change the output/lock indicator mode with the g command is as follows:

At the r> prompt, type g, then type either 0, 1, or 2 depending on the desired output mode, and press Enter.

Note: 1 These numbers are in HEX format.

Note: 2 1PPS states: 0 to 2—Initialize; 3, 9—Holdover; 6 to 8—Disciplining.

Note: 3 When connecting to a GPS receiver, the factory default mode is recommended. Start with y1=1 (DF) and Y2=400 TC in seconds). These values work well for most GPS receivers.

Note: 4 Use z command to save your settings.

Note: 5 SA.22c Rubidium system locks approximately 5 minutes after startup.

Note: 6 SA.22c initial frequency must be less than ±3PPB for 1PPS to lock.

Note: 7 Initial 1PPS lock occurs between 3 and 5 minutes after both lock and valid 1PPS are present.

Note: 8 Confirm the firmware version by issuing the i command.

Note: 9 xx is a value returned, which is the hex equivalent of the number of times the table has been written to. TData can be either 1 or 2.

Note: 10 If the J2 Molex connector is used on the adapter test board, then the lock pin is 21 and the service pin is 8.

Note: 11 If the lock and service voltages are measured on the adapter test board, then the lock signal is on TP1 and the service signal is on TP3.

Table 14 • 1PPS Firmware Versions

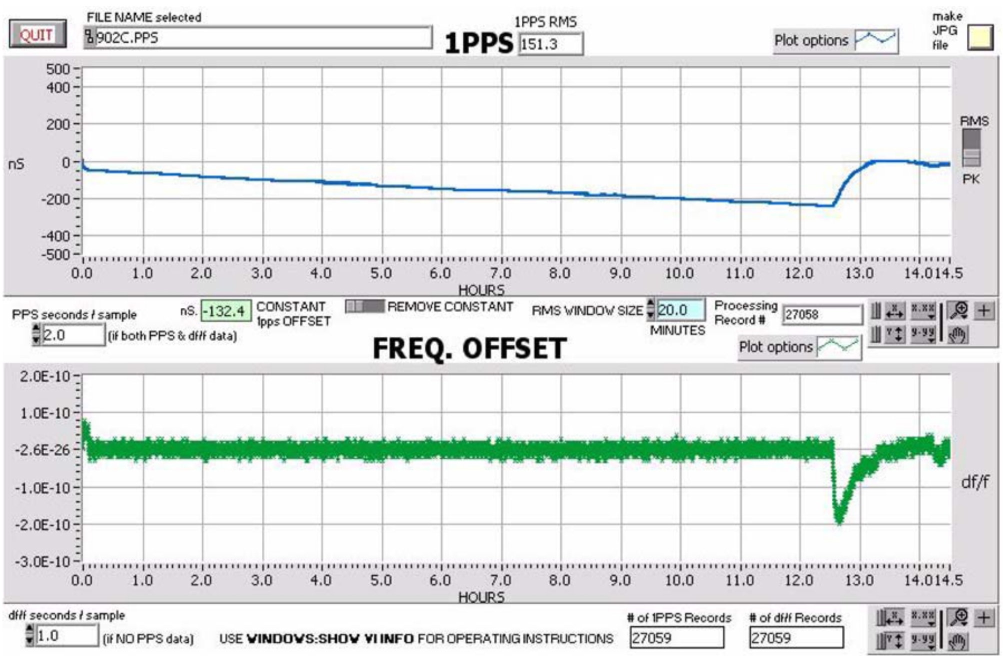
Version	Description
FW6.05c	Pin12 provides service indication
FW6.06c	Pin12 is reserved for 1PPS lock indication only

7.7 Flywheeling Recovery Example–Normal

In this test, the SA.22c is synchronized to 1PPS before the following data set as shown in the following figure. Antenna is removed at 0 hour and reapplied at approximately 12.5 hours. The SA.22c 1PPS output signal reaches an offset of 220 ns.

The subsequent frequency change returns the 1PPS offset to 0 ns.

Figure 19 • Flywheeling Recover with 1PPS offset <1 µsec

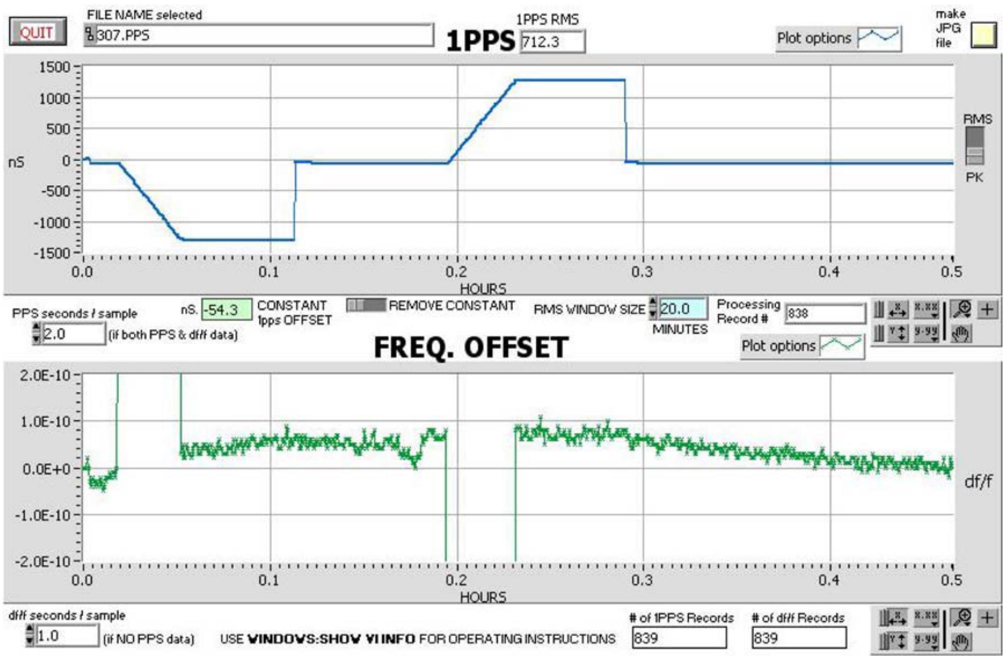


7.8 Recovery with JamSynch

In this test, the antenna to the GPS receiver is removed. The SA.22c is set to an off frequency long enough to induce a 1PPS error over 1 µsec. When the antenna is reapplied, the SA.22c 1PPS recovers by resetting to 1PPS 0 ns (JamSynch). This procedure is repeated to cause both a leading and lagging 1PPS.

Note: This test is performed on a unit started cold that causes the general curve in the frequency data (excluding the intentional offsets).

Figure 20 • Flywheeling Recover with 1PPS offset >1 µsec



7.9 1PPS Algorithm Theory of Operation

SA.22c qualifies 1PPS inputs by analyzing the time difference between the SA.22c's 1PPS output and the external 1PPS input. This is referred to as the holdover state. The SA.22c determines whether the 1PPS input is usable by calculating the rate of change in timing measurements that are taken once per second.

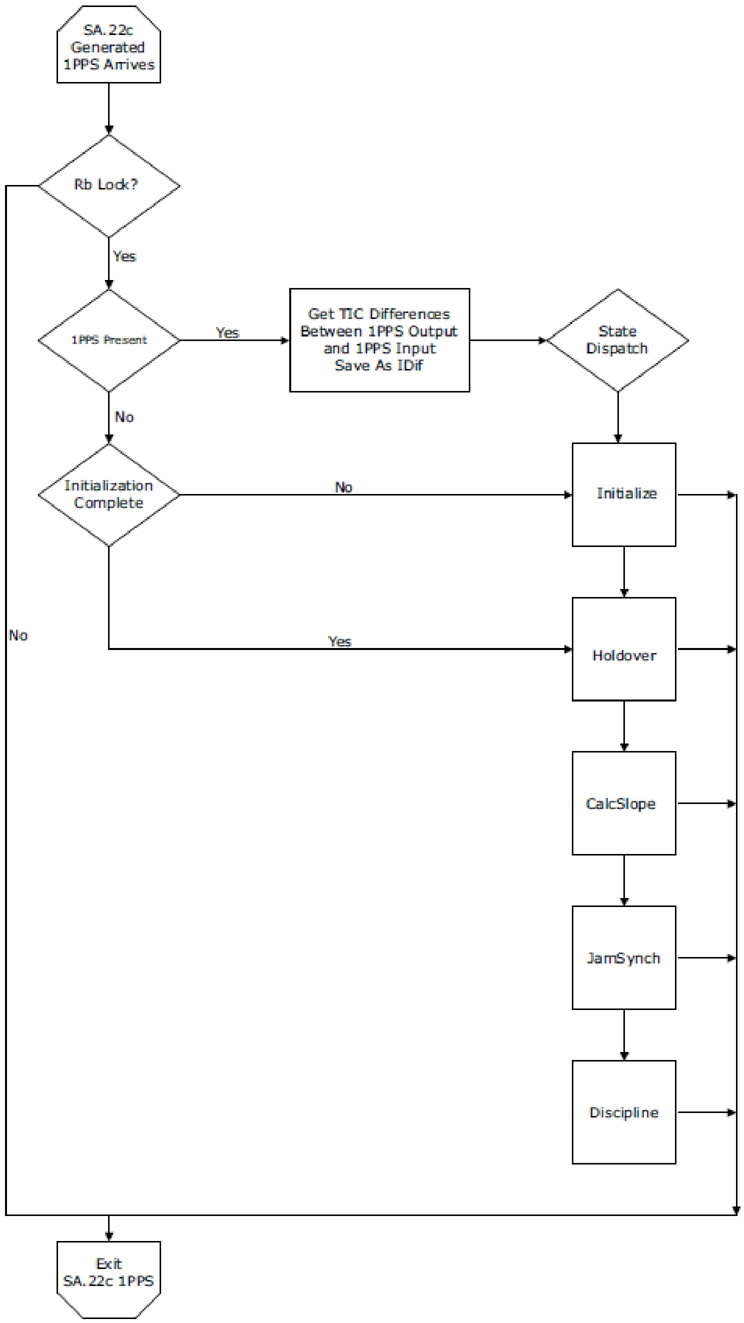
After a 1PPS input is qualified, the SA.22c 1PPS algorithm determines if it is necessary to adjust the counter that produces the 1PPS output (JamSynch state). The algorithm then begins to adjust the output frequency of the SA.22c to keep the 1PPS output aligned with the 1PPS input. This is the disciplining state, and the control method is a proportional integral derivatives (PID) scheme.

The amount of frequency change and the length of time required to reach 1PPS accuracy is adjusted by setting y1 (damping factor) and y2 (time constant) parameters. During this disciplining state, the timing of each 1PPS input is compared to the expected value. If the offset exceeds 333 ns, the algorithm changes to the holdover state and the process begins again. The following figures provide a detailed explanation.

7.9.1 1PPS Algorithm High Level Flow Chart

The following flow chart explains the 1PPS steer algorithm.

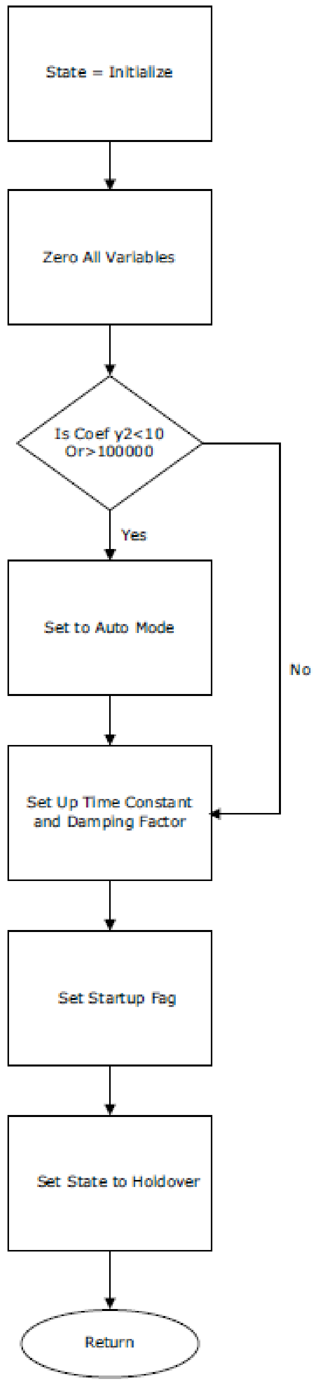
Figure 21 • SA.22c 1PPS Algorithm States



7.9.2 Initialization

During initialization, the algorithm sets up variables based on the time constant (TC) and damping factor (DF). The SA.22c checks for 1PPS input once per second, and if present, it enters the holdover state. Automatic mode is used when the time constant is set to 0. The SA.22c 1PPS is in the initialization state when no 1PPS is applied. The j command shows the 1PPS count.

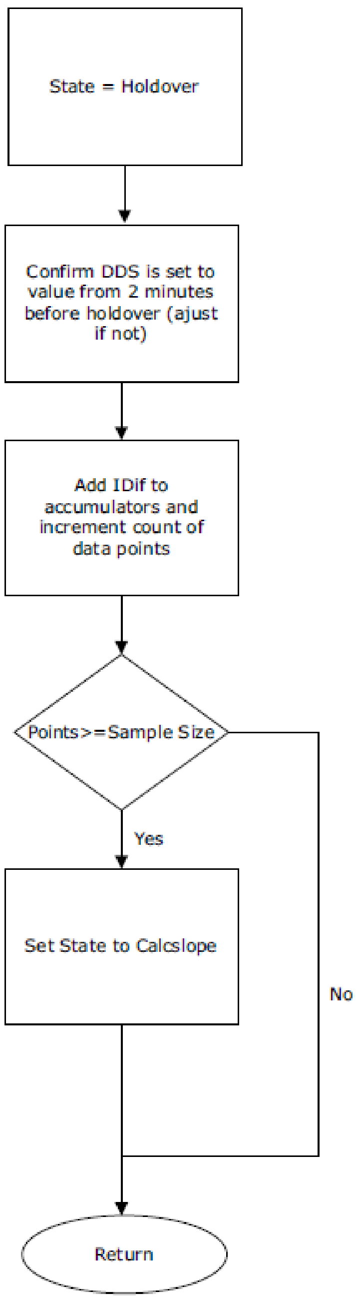
Figure 22 • SA.22c Initialize State



7.9.3 Holdover

During holdover, 1PPS input statistics are accumulated and the results are calculated periodically (CalcSlope State). The sample size is set to 120 data points (120 s).

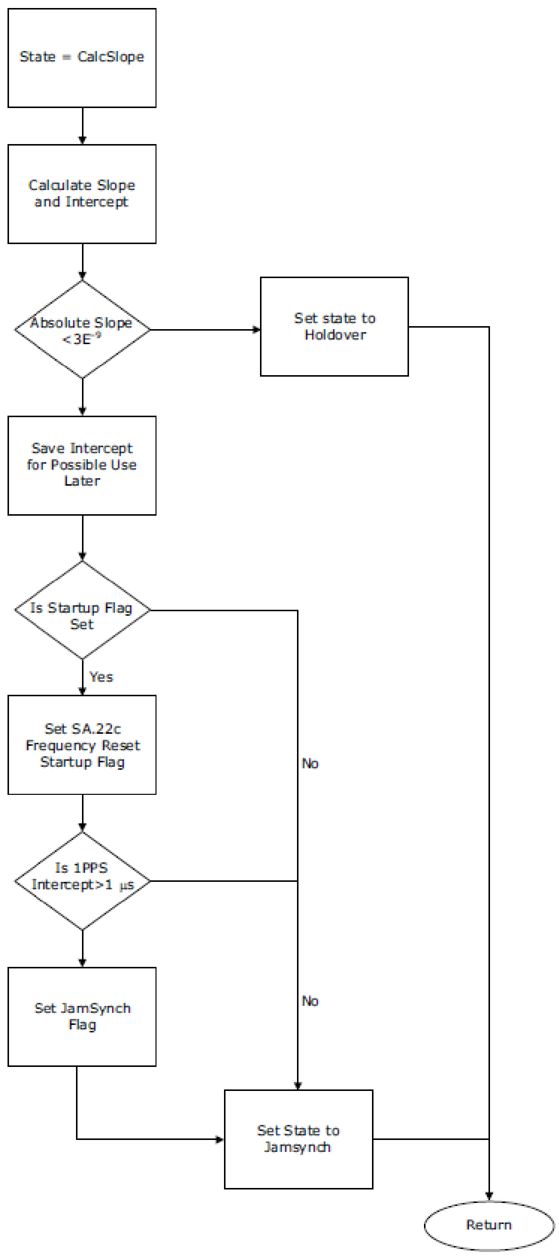
Figure 23 • SA.22c Holdover State



7.9.4 Calcslope

The frequency difference between the SA.22c and the 1PPS source is calculated, and if the difference is $<\pm 3 \times 10^{-9}$, the state changes from holdover to JamSynch. This state executes every 120 s during holdover.

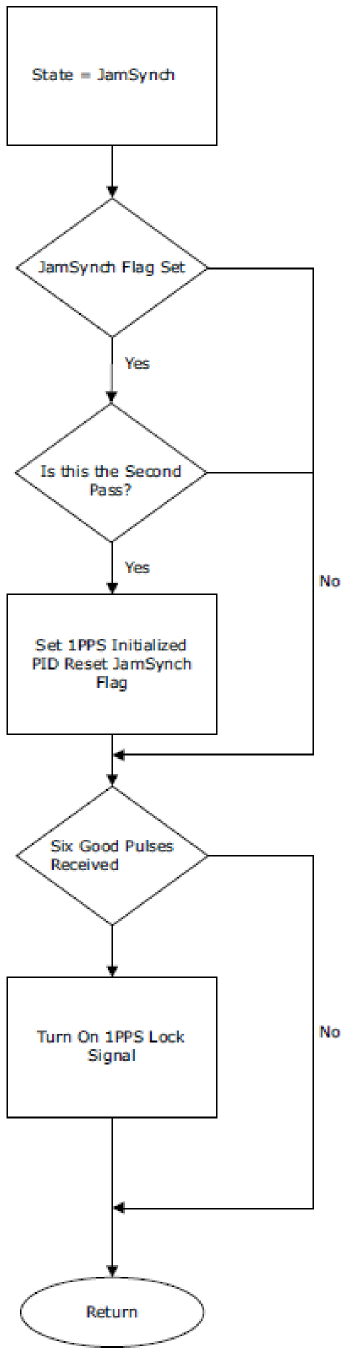
Figure 24 • SA.22c Calcslope State



7.9.5 JamSynch

The SA.22c 1PPS output is compared to the SA.22c 1PPS input, and if the difference is ≥1 µs, the state returns to holdover to collect a second data set. When two consecutive slopes are in range, the SA.22c's 1PPS output is synchronized to its 1PPS input. If the difference is <1 µs, the algorithm waits six more pulses and then advances to the discipline state.

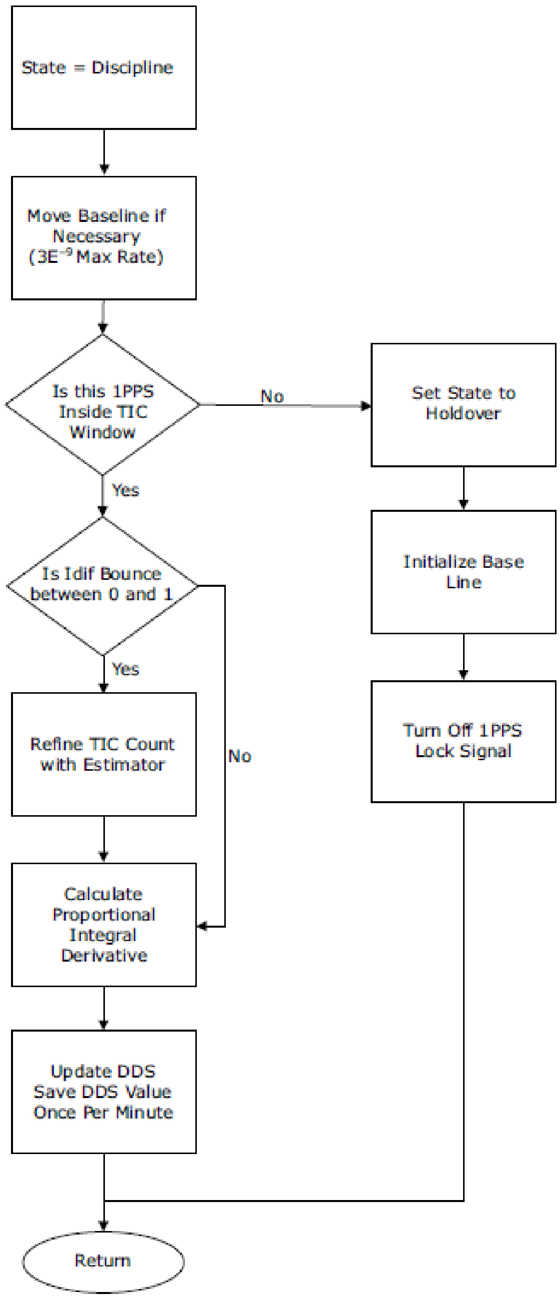
Figure 25 • SA.22c JamSynch State



7.9.6 Discipline

In the discipline state, the SA.22c uses a proportional-integral-derivative (PID) method to steer the 1PPS output. The SA.22c average frequency offset is close to zero. There is some frequency change when recovering from holdover. If at any time a 1PPS input signal is more than 330 ns from its expected value, the 1PPS algorithm returns to holdover state. If the input source is stable, the SA.22c further refines the input estimate to provide a smoother frequency output. Every minute the SA.22c saves the DDS setting in case holdover occurs. Some receivers take a long time to produce 330 ns of error after signal loss; the SA.22c reverts to the DDS value from two periods before the 1PPS becomes invalid.

Figure 26 • SA.22c Discipline State



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