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SA.22c Rubidium Oscillator

Designer's Reference and User's Guide

Revision A – May 2007

Part Number 097-16313-201

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How to Use This Guide

This section describes the format, layout, and purpose of this guide.

In This Preface

- Purpose of This Guide
- Who Should Read This Guide
- Structure of This Guide
- Conventions Used in This Guide
- Warnings, Cautions, Recommendations, and Notes
- Related Documents and Information
- Where to Find Answers to Product and Document Questions
- What's New In This Guide

Purpose of This Guide

The *SA.22c Designer's Reference and User's Guide* provides basic recommendations for designing products to use Symmetricom's SA.22c Rubidium Oscillator. The guidelines in this user guide are generic because specific product requirements vary from application to application.

This material consists of a brief description of SA.22c design supported by block diagrams, description of environmental issues, installation guidelines, required mating connectors, and unit operation.

Who Should Read This Guide

This document is intended for engineers and telecommunications professionals who are designing, installing, operating or maintaining time, frequency, and synchronization systems having a requirement for a low profile and highly precise frequency generator.

To use this document effectively, you should have a good understanding of digital telecommunications technologies and analog frequency generation and synthesis techniques.

Structure of This Guide

This guide contains the following sections:

Chapter, Title	Description
Chapter 1, Description	This section contains a description of the SA.22c and lists its typical applications. It provides information on dimensions, performance, and connector pinouts.
Chapter 2, Design Integration Considerations	This section contains mechanical issues pertaining to SA.22c mounting and mating recommendations, including thermal and EMI considerations, external interfaces and grounding, frequency control, susceptibility to noise, and reliability goal.
Chapter 3, Installation and Operation	This section contains the information necessary to properly install and operate the SA.22c unit including a simplified theory of operation, and maintenance and warranty.
Appendix A, Using the Developer's Kit	This appendix describes the SA.22c developer's kit hardware.
Appendix B, Symmetricom Serial Interface Protocol	This appendix describes use of the external communications link software.

Chapter, Title	Description
Appendix C, One Pulse Per Second Source Connection	This appendix describes how to connect a one pulse per second (1PPS) source to an SA.22c.
Index	Provides references to individual topics within this guide.

Conventions Used in This Guide

This guide uses the following conventions:

- **Acronyms and Abbreviations** – Terms are spelled out the first time they appear in text. Thereafter, only the acronym or abbreviation is used.
- **Revision Control** – The title page lists the printing date and versions of the product this guide describes.
- **Typographical Conventions** – This guide uses the typographical conventions described in the table below.

When text appears this way...	... it means:
TimeProvider User's Guide	The title of a document.
LOCK	An operating mode, alarm state, status, or chassis label.
Press **Enter**	A named keyboard key. The key name is shown as it appears on the keyboard. An explanation of the key's acronym or function immediately follows the first reference to the key, if required.
`FC mode enabled`	Text in a source file or a system prompt or other text that appears on a screen.
`r>w` `r>a`	A command you enter at a system prompt or text you enter in response to a program prompt. You must enter commands for case-sensitive operating systems exactly as shown.
Lock-in	A word or term being emphasized.
Symmetricom ***does not*** recommend...	A word or term given special emphasis.

Warnings, Cautions, Recommendations, and Notes

Warnings, Cautions, Recommendations, and Notes attract attention to essential or critical information in this guide. The types of information included in each are explained in the following examples.



Warning: To avoid serious personal injury or death, *do not* disregard warnings. All warnings use this symbol. Warnings are installation, operation, or maintenance procedures, practices, or statements, that if not strictly observed, may result in serious personal injury or even death.



Caution: To avoid personal injury, *do not* disregard cautions. All cautions use this symbol. Cautions are installation, operation, or maintenance procedures, practices, conditions, or statements, that if not strictly observed, may result in damage to, or destruction of, the equipment. Cautions are also used to indicate a long-term health hazard.



ESD Caution: To avoid personal injury and electrostatic discharge (ESD) damage to equipment, *do not* disregard ESD cautions. All ESD cautions use this symbol. ESD cautions are installation, operation, or maintenance procedures, practices, conditions, or statements that if not strictly observed, may result in possible personal injury, electrostatic discharge damage to, or destruction of, static-sensitive components of the equipment.



Electrical Shock Caution: To avoid electrical shock and possible personal injury, do not disregard electrical shock cautions. All electrical shock cautions use this symbol. Electrical shock cautions are practices, procedures, or statements, that if not strictly observed, may result in possible personal injury, electrical shock damage to, or destruction of components of the equipment.



Recommendation: All recommendations use this symbol. Recommendations indicate manufacturer-tested methods or known functionality. Recommendations contain installation, operation, or maintenance procedures, practices, conditions, or statements, that provide important information for optimum performance results.



Note: All notes use this symbol. Notes contain installation, operation, or maintenance procedures, practices, conditions, or statements, that alert you to important information, which may make your task easier or increase your understanding.

Related Documents and Information

See your Symmetricom representative or sales office for a complete list of available documentation.



Note: Symmetricom offers training courses designed to enhance your knowledge of the SA.22c Rubidium Oscillator. Contact your local representative or sales office for a complete list of courses and outlines.

Where to Find Answers to Product and Document Questions

For additional information about the products described in this guide, please contact your Symmetricom representative or your local sales office. You can also contact us on the web at www.symmetricom.com.

What's New In This Guide

This is the initial release of this User's Guide.

Chapter 1 Description

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

In This Chapter

- Overview
- Typical Applications
- Specifications

Overview

The SA.22c rubidium (Rb) oscillator is the newest of Symmetricom's family of precision frequency generator components. This fifth generation Rb oscillator reflects significant advances in physics miniaturization and integration.



Figure 1-1. SA.22c Rubidium Oscillator

Drawing on over 30 years of experience, the SA.22c design has been refined for low cost mass production and can be easily integrated into time, frequency and synchronization systems. It can be mounted directly onto a circuit board as a component of a module. It offers the high reliability and accuracy of a rubidium oscillator in a new design concept benefiting from the many years of experience Symmetricom has gained in fielding tens of thousands of rubidium oscillators.

Typical Applications

The elevated 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. Even if the host system overheats in fault mode, the SA.22c oscillator continues to produce a stable and accurate time or frequency reference.

The SA.22c is easily integrated into time and frequency systems because of its low profile. The unit operates with a low power requirement (+15V ±5%, +5V ±5%).

This design is being successfully applied as an OEM component in wireless telecom networks such as digital cellular/PCS base stations and SONET/ SDH digital network timing. 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 excellent frequency stability extend holdover performance when the GPS signal is not available. Temperature compensated units are available for those special applications requiring even better temperature performance.

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

The microprocessor-based SA.22c is a more cost-effective system design that allows serial command selection and enabling of TTL-level digital output frequencies. This allows the oscillator output to be divided to a number of different frequencies, as opposed to older oscillators with a single fixed output frequency. 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 a GPS or other external reference. For more information, refer to Appendix C, One Pulse Per Second Source Connection.

For simple applications the SA.22c provides a 5V CMOS-compatible Built-in Self Test (BIST) Service and a **LOCK** alarm signal derived from the basic physics operation. This lock signal indicates when the output frequency is locked to the atomic resonance of rubidium. When more control over the device is desired, an extensive command control status dialog is available.

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, the dynamic frequency selection, the ability to enable and disable outputs, to query the system's health, and acquire information about the unit's serial number, operating temperature, fault history, initiate a self test, and other performance indicators. The protocol used is Symmetricom's proprietary Symmetricom Serial Interface Protocol, or SSIP.

The simplified block diagram below 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.

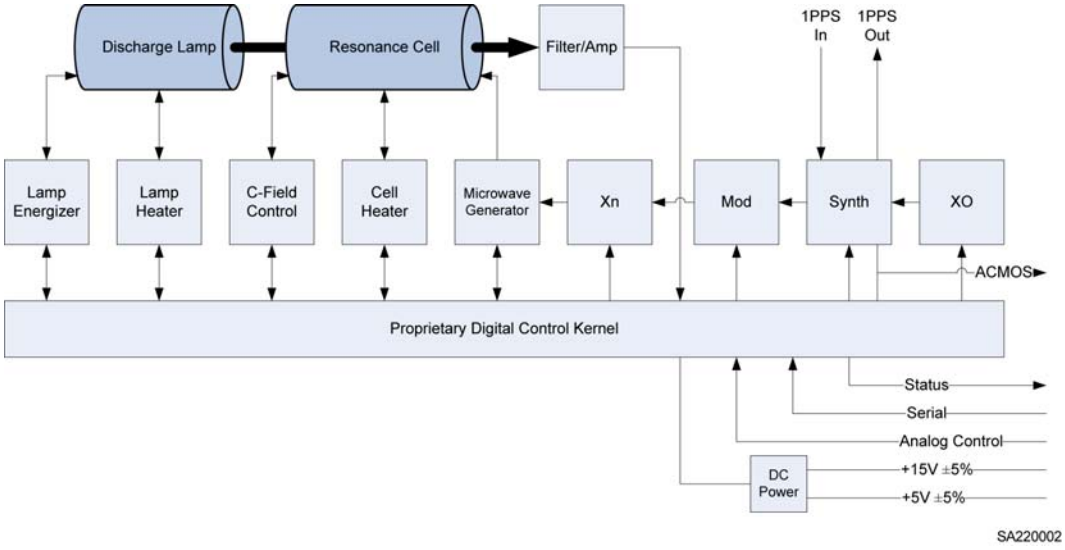


Figure 1-2. SA.22c Rubidium Oscillator Simplified Block Diagram

Specifications

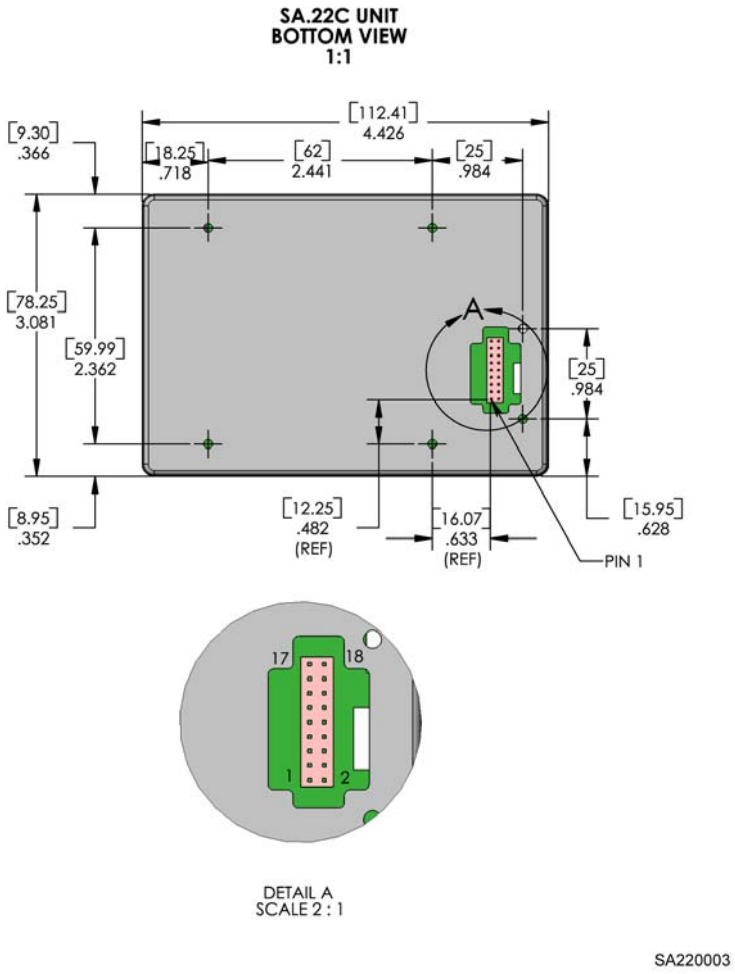


Figure 1-3. SA.22c Dimensions

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.

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

Pin Number	Signal Name	Type 1	Signal Function
1	VSS	GND	Power and signal return ground (all ground pins must be connected)
2	VDD	PWR	+15Vdc 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	+15Vdc power input (all power pins must be connected)
5	FREQ CTRL	Analog	Frequency control - analog input between 0 - 5Vdc.
6	VCC	PWR	+5Vdc 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)
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	N/A	N/A	N/A
18	N/A	N/A	N/A



Note: Refer to Appendix A, Using the Developer's Kit for the connector manufacturer's drawings and specifications.

Table 1-2. SA.22c Design Absolute Maximum Ratings

Symbol	Characteristic (Unit in ambient still air – convection)		– 10° C to 75° C Base-plate	Units
VDD	Supply relative to ground	+15Vdc Input	±5	%
VCC	Supply relative to ground	+5Vdc 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}	**Max Warm Up Power**		<18.5	Watts
P_Q	Max quiescent power	– 10° C base plate	9.3	Watts
		25° C base plate	7.2	Watts
		75° C base plate	4.6	Watts
T_{WU}	Maximum warm-up time	Lock time to < $1E^{-9}$ @ 25° C	<7.5	Mins
T_{STG}	**Maximum Storage Temperature**		– 55 to 85	° C
	Vibration (operating)	GR-CORE-63, 4.4.4 and 5.4.3 up to 1.5 g		
	Maximum altitude (powered unit)	With respect to sea level	30,000	Feet
	Maximum altitude (unpowered)	With respect to sea level	50,000	Feet

Table 1-3. SA.22c Design Operating Characteristics

Symbol	Characteristic (Unit in ambient still air – convection)		– 10° C to 75° C Base-plate Min - Max - Typ	Units
Digital Inputs/Outputs				
V_{DD}	Supply relative to ground	+15Vdc input	14.75 15.25 15	V
V_{CC}	Supply relative to ground	+5Vdc input	4.75 5.25 5	V

Table 1-3. SA.22c Design Operating Characteristics (Continued)

Symbol	Characteristic (Unit in ambient still air – convection)		– 10° C to 75° C Base-plate Min - Max - Typ	Units
V_{IH}	High level input voltage	DIN	2.5 5.25 5	V
		1PPS IN	1.8 5.25 5	V
V_{IL}	Low level input voltage	DIN	0 0.8	V
		1PPSIN	0 0.8	V
V_{OH}	High level output voltage	DOUT, SERVICE, LOCK@IOH = – 0.33mA@IOH = 0mA	3.5 5.25 5	
		FACMOS,1PPS OUT@IOH = – 3.5mA	3.5 5.25 5	V
V_{OL}	Low level output voltage	DOUT, SERVICE, LOCK@IOL = 0.1mA	0 0.4	V
		FACMOS, 1PPS OUT@ IOL = 1.7mA	0 0.4	V
Analog Inputs/Outputs				
V_{FC}	Frequency control input voltage range	Range of ± 1.5E $^{-9}$ with resolution of 2.0E $^{-12}$ or ± 6.5E $^{-9}$	0 5 2.5	V
FACMOS	ACMOS Frequency Output	10MHz (Consult factory for optional ACMOS frequencies)	– 5E $^{-11}$ + 5E $^{-11}$	ΔHz/Hz
Frequency Control				
$\Delta F/F_R$	Control Range	Analog (FREQ CTRL pin)	– 1.5E $^{-9}$ + 1.5E $^{-9}$ – 6.5E $^{-9}$ + 6.5E $^{-9}$ (wide range)	ΔHz/Hz
		Digital Interface	– 1.0E $^{-6}$ + 1.0E $^{-6}$	ΔHz/Hz
$\Delta F/F_{RES}$	Frequency Control Resolution		2.04	E $^{-12}$ ΔHz/Hz

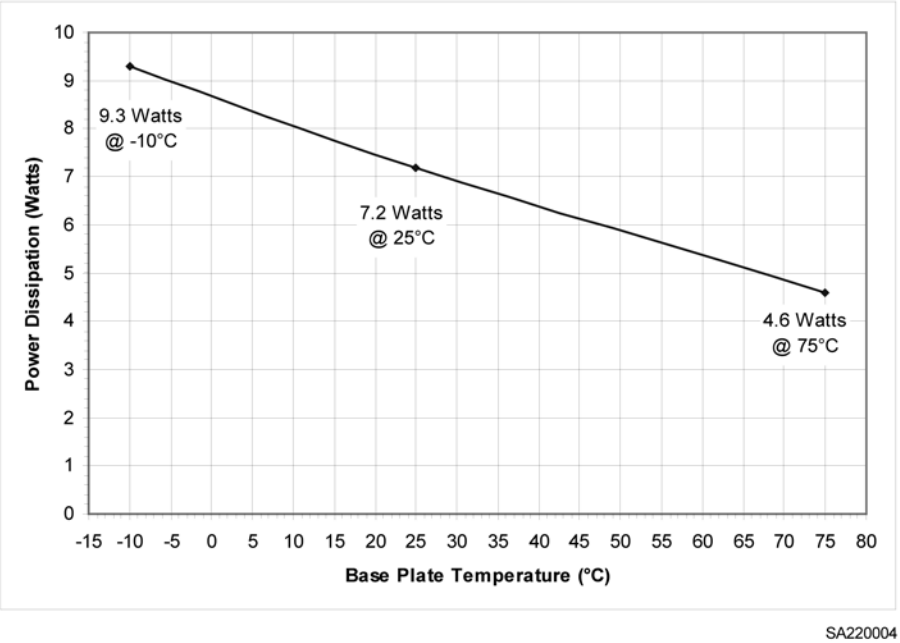


Figure 1-4. Total SA.22c Quiescent Power Dissipation, Typical (free convection)

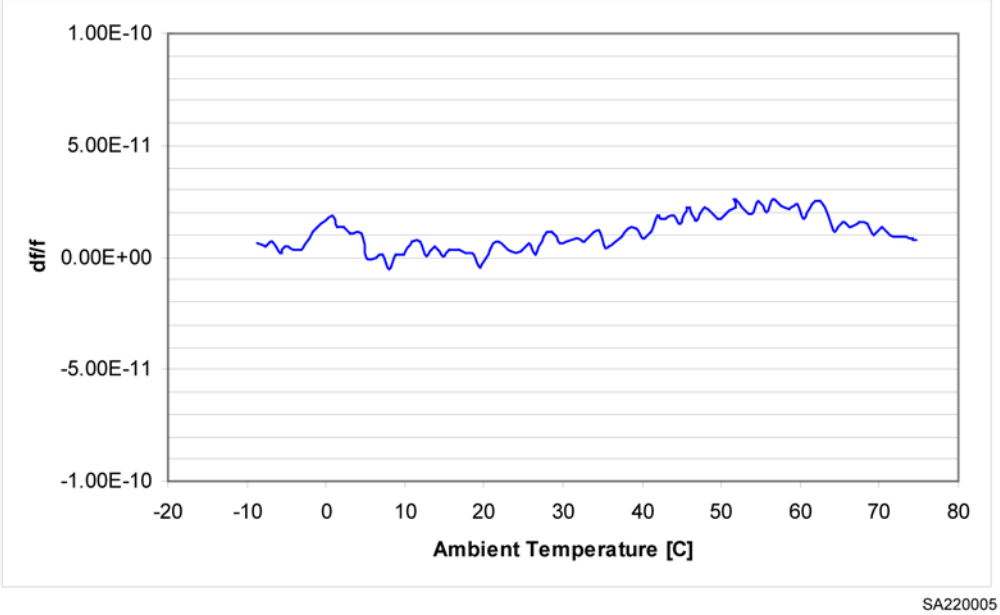


Figure 1-5. Typical AP1 Level TEMPCO [-10º C to 75º C Base Plate Temperature]

Note: Refer to the SA.22c Performance Characteristics document for more detailed information.

Chapter 2 Design Integration Considerations

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

In This Chapter

- Mechanical Considerations
- Thermal Considerations
- External Interfaces and Grounding
- Electrical Interface
- Frequency Control Analog
- Modifiable Unit Settings
- Susceptibility to Input Noise
- Reliability and Maintenance

Mechanical Considerations

Mounting Recommendations

To mount the SA.22c to a custom-designed circuit card, use the SAMTEC mating connector (see Figure 1-3). Use the six mounting holes located on the base plate.

Note: Contact Symmetricom for information on an adapter test board and for information on designing your own interface circuit board.

Figure 2-1 shows how to mount an SA.22c to a circuit board.

Use six M3 stainless steel screws with a minimum penetration depth of 2 mm and a maximum of 5 mm.



Figure 2-1. Mounting an SA.22c to a Circuit Board

Thermal Considerations

Thermal Tape

In order to achieve the highest ambient operating temperature for the SA.22c operating base plate temperature Symmetricom recommends that the bottom (“base plate”) of the SA.22c have good thermal contact to the mounting surface. It is also very important to maintain a uniform temperature into the base plate of the SA.22c through its mounting points. The SA.22c unit operates normally without thermal tape. In some field applications the tape may simplify customer system thermal design requirements.



Warning: To avoid personal injury, attach the SA.22c to a heat sink to prevent it from becoming too hot to touch.

If there is air flow over the unit's top cover, the SA.22c's maximum operating base plate temperature increases by 1 or 2° C and its 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 shut down as control point temperatures are exceeded and the unit temperature coefficients increase to approximately $6E^{-10}$ °C.

Water Condensation and Excessive Humidity

Condensation of moisture from the air onto electrical components produces frequency spikes or instability until the heat of the operating unit drives out the water vapor.

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

Excessive Dust

Operating the unit in dusty conditions may cause unexpected thermal effects if dust builds up on the top surface. Excessive dust will also contribute to contamination in the shell of the mating connector and could cause 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.

External Interfaces and Grounding

Figure 1-3 shows the interface circuitry for the 18-pin SAMTEC I/O connector and mechanical dimensions. 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 at the mating connector for the SA.22c unit to operate properly.

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

Workarounds commonly used to break DC ground loops at a higher level of integration are to use an rf isolation transformer for the sine rf output, and/or float the transformer secondary winding of the user's power supply.

Electrical Interface

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%. Rise/fall time is 4 ns.

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 once warm-up is completed, the output frequency is locked to the Rb atomic clock.

If the LOCK signal is high, atomic lock has been lost and the SA.22c goes into sweep mode to reacquire lock. The sweep ranges from approximately –21 ppm to +21 ppm in approximately a 20 second period. During the sweep, outputs are maintained but you should not rely on signal accuracy during sweeping. If the power source to the SA.22c is OFF, the lock output line is low.

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 Rb physics package, which includes the Rb lamp bulb and resonator cell, and the unit’s crystal oscillator that is slaved to the Rb atomic clock.

The Service Signal indicates low when any of the internal operating parameters are near the end of their tuning or adjustment range, providing approximately one month's notice of this situation.

Frequency Control Signal

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

When in use, the smallest incremental frequency change is $2E^{-12}$ (or f.2). 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 Frequency Control Analog, on page 31).

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). Consult the factory for a list of specific ACMOS output frequencies.

Frequency Control Analog

Greater Than $\pm 1E^{-9}$ Internal or External Control

The external frequency control circuitry is designed so that with no voltage applied at Pin 5, the voltage will self bias to mid-range, or 2.5V. This input can also be turned off via the SSIP to eliminate any source of noise. In some versions of the SA.22c, this function can be turned off by customer request on power up. If it is to be used later it must be enabled through the SSIP (refer to Appendix B, Symmetricom Serial Interface Protocol).

Time Response of External Frequency Control

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

Modifiable Unit Settings

SA.22c operation is modifiable by the customer. Refer to Appendix A, Using the Developer's Kit and Appendix B, Symmetricom Serial Interface Protocol for information on how to use the SSIP to use these functions.



Note: You cannot alter the default power up conditions.

Table 2-1. 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 firmware
View Health Monitor Data	Displays history file of error or fault information

Note:

1 Minimum frequency change is $2E^{-12}$ (or "f.2"). Values less than this are ignored. Maximum frequency charge, is not constrained. Setting the frequency outside of its operating limits may render the unit non-functional.

Susceptibility to Input Noise

If you have an application where the output spectrum phase noise and spur integrity is 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 can result 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).

Reliability and Maintenance

Reliability

The SA.22c is designed with a goal of ten years of operation without retuning. To accomplish this, the major mechanisms impacting the need for maintenance were addressed. Thus, each SA.22c has been designed to have excess rubidium fill 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.

Maintenance

User Maintenance

The SA.22c is considered to be factory serviceable only. There is no user service adjustment or maintenance required.

A monitor signal is provided to allow 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 Rb physics package or on-board quartz oscillator are near their operating or control limits.

If the Lock signal does not indicate a Rb 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 to Symmetricom for service. The Service indicator is valid only when the Lock signal indicates that the unit is locked.

For information on how to return a unit for service, see Repairs, on page 40.

Chapter 3 Installation and Operation

This section provides information on details to consider when installing the SA.22c and the procedure to follow when turning on the unit. There is an explanation of the start-up sequence, monitoring performance, and theory of operation. It also contains a troubleshooting guide, customer support information, and warranty information.

In This Chapter

- Installation
- Start-up Sequence
- Theory of Operation
- Troubleshooting
- Repairs

Installation

Site Selection

The SA.22c can be mounted in any orientation. In environments that approach the operating limits of the SA.22c, ensure that the temperature limits are not exceeded.

The SA.22c is sensitive to external dc and ac magnetic fields (refer to specification) and should not be installed in locations subjected to strong magnetic fields from transformers or large power supplies.

A Rb frequency standard is a very precise component and you should employ optimum practices for its use. Avoid using a power source that is also providing power to fans or equipment that generates high current pulses.

Turn-on Procedure

Use the following steps to power up the SA.22c.

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

1. Verify the SA.22c voltage requirement (refer to Appendix A, Using the Developer's Kit).
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.
4. Turn on power.

Refer to Figure 3-1 for a block diagram of a suggested hook-up.

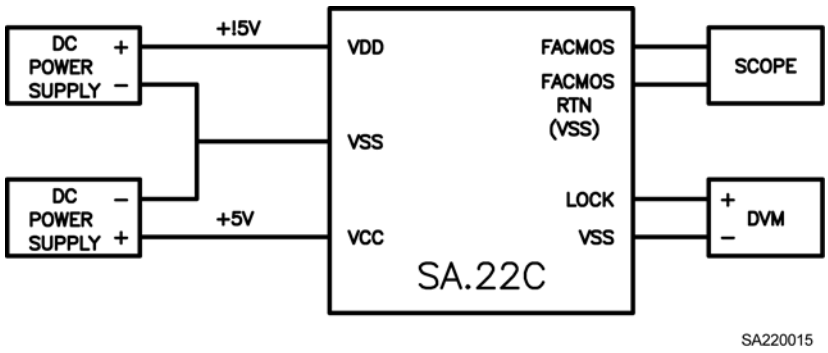


Figure 3-1. Suggested Connections for SA.22c, Initial Turn-on.

Once the SA.22c is plugged in and is receiving power, wait five minutes while the unit achieves atomic lock. During this period, the monitored LOCK signal should be HIGH. Once the unit achieves atomic lock, the LOCK signal goes LOW.

Depending on base plate temperature, within five to less than seven minutes the unit should be within $1E^{-9}$ of center frequency. Thirty minutes after applying power to the SA.22c the rf output frequency will be very close to full accuracy (refer to SA.22c specifications).



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

Start-up Sequence

When power is connected, the SA.22c begins its warm-up cycle. After five minutes the rubidium oscillator reaches a locked condition and its output signals will stabilize. The accuracy at shipment is $<\pm 5E^{-11}$ 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 after the oscillator has locked.

After 7.5 minutes the accuracy of the SA.22c oscillator is $<1E^{-9}$. Performance of the SA.22c unit varies according to the application profile specified by the customer at time of order. Refer to the SA.22c product specification for information on application profiles and unit performance.

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

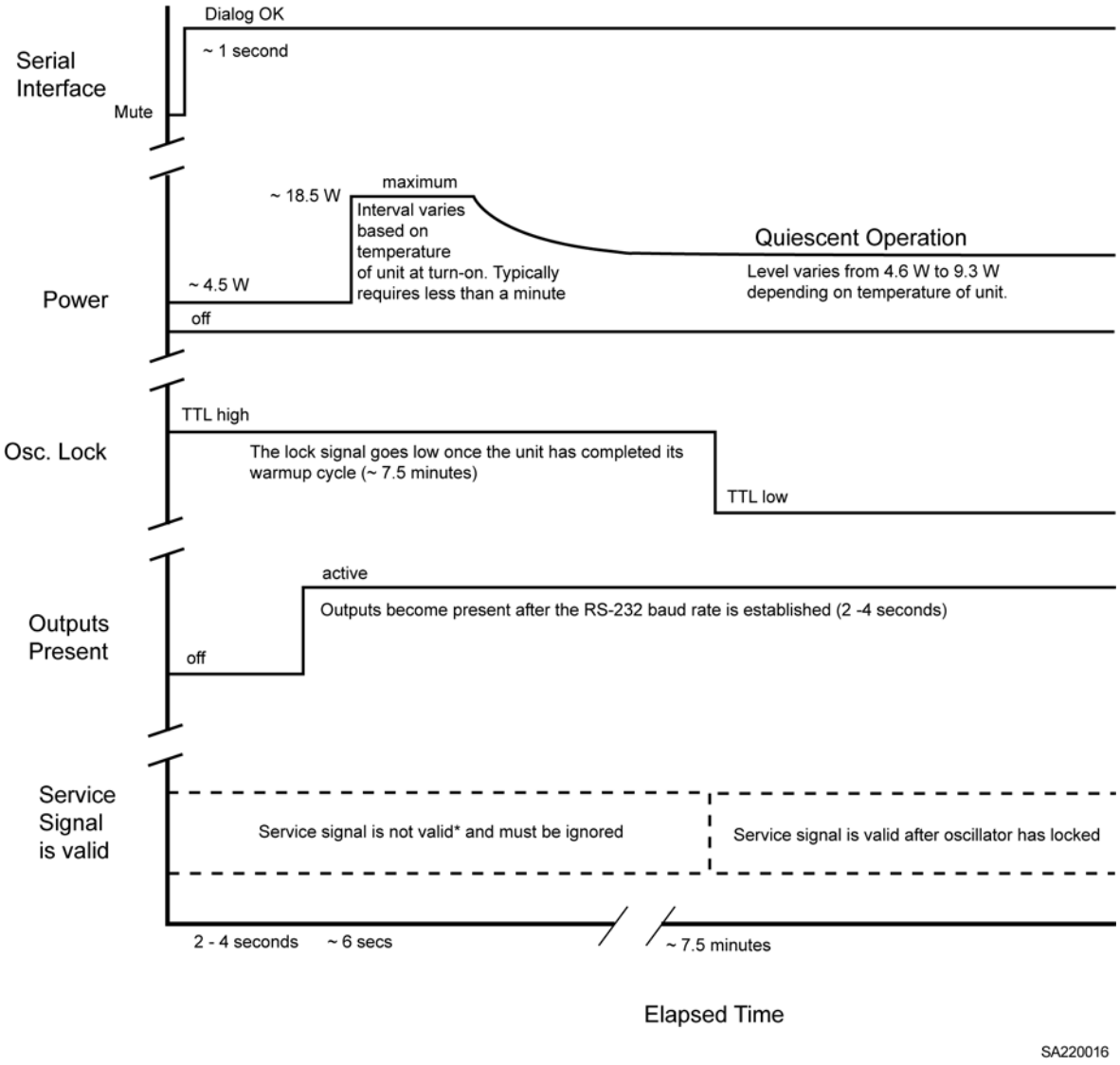


Figure 3-2. Sequence of Start-up Events

Note: The Service signal can be Active High or Active Low depending on the unit configuration.

Theory of Operation

The Model SA.22c makes use of the atomic resonance property of rubidium (^{87}Rb) to control the frequency of a quartz crystal oscillator via a frequency-locked loop (FLL).

The FLL function block is shown in Figure 3-3. A microwave signal is derived from a voltage-controlled crystal oscillator (VCXO) and applied to the ^{87}Rb vapor within a glass cell. The light of a rubidium lamp also 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), light is absorbed causing a change (decrease) in photo detector current (I_{PH}).

As the change in current is small, modulation techniques are required to be able to extract the desired signal out of the noise background.

The photo detector current is used to generate 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.

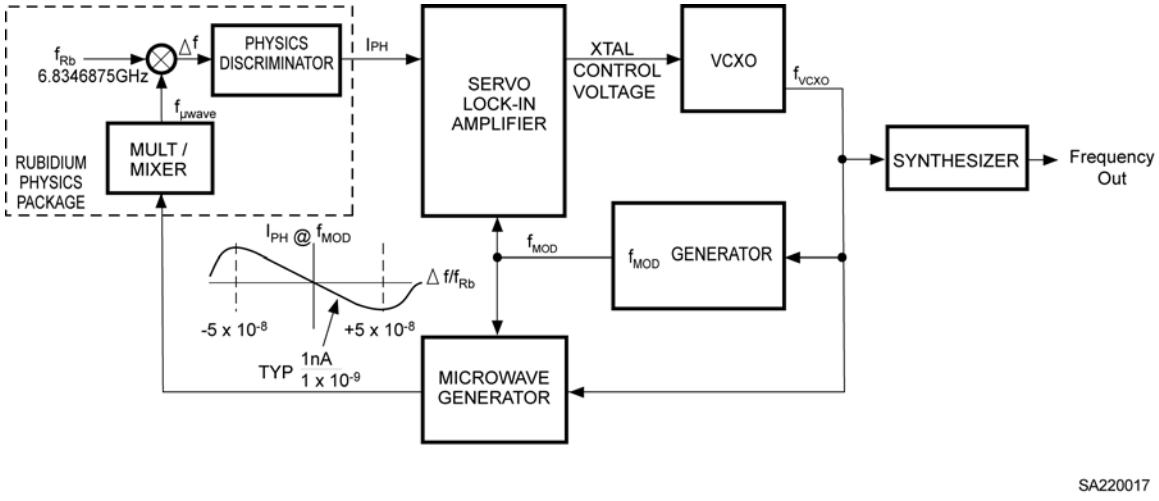


Figure 3-3. Rb Control Loop Block Diagram

Troubleshooting

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

- The external power supply is providing power
- The external power supply is providing the correct power
- The I/O connector may be defective – perform a continuity check



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

- Is there excess humidity or moisture inside the operating area
- Is the ambient temperature below –10° C or above +75° C (the unit will not startup properly in excessively cold or hot temperatures)

Repairs

The SA.22c is not field repairable, but some firmware upgrades can be done in the field, as noted in Start-up Sequence, on page 37. 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.

If the unit no longer operates properly, or if it has reached the end of its effective life, please visit Symmetricom's web site at www.symmetricom.com and click the support, warranty and repair link. You can also use the following link: www.symmetricom.com/support/warranty_and_repair/repair_form.aspx?prodtype=TSD.

Once you submit your form through the Internet, a confirmation will be sent back to you. Requests are processed within 24 to 48 hours. Once processed, you will receive an e-mail from the Repair Administration group that provides your RMA number, warranty information or repair cost if applicable, and the address of where to send the unit for repair.

If you have questions regarding the status of your RMA you may reach our Repair Administration department at 888 367 7966, option 3. You may also e-mail your requests or queries to TSDRMA@Symmetricom.com. Our fax number is 559 961 5175.

Appendix A Using the Developer's Kit

This appendix provides information on using the SA.22c Developer's Kit. It includes information on interfacing the Adapter Test Board as well as information on the various options for providing power and viewing signals from the SA.22c through the Adapter Test Board.

In This Appendix

- Introduction
- Mounting the Unit with the Adapter Test Board
- Interfacing of the Adapter Test Board
- Options for Supplying Power to the Adapter Test Board

Introduction

The SA.22c Developer's Kit is provided by Symmetricom as a design aid and development tool. It permits a design engineer to experiment with Symmetricom's SA.22c product in various applications and to determine how to implement it in the most advantageous manner.

The developer's kit contains a hardcopy 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: Users must supply a power supply with leads or interface cable in order to connect the Adapter Test Board to main power. Users must observe proper polarity of the Adapter Test Board in order to avoid potentially damaging the Adapter Test Board as well as the SA.22c.

Mounting the Unit with the Adapter Test Board

The SA.22c, along with the adapter test board, is designed to mount onto a heat-absorbing surface using the six mounting holes. During demonstration testing if a heat-absorbing surface is not available, 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 should penetrate no more than 3 mm into the SA.22c base plate.

Figure A-1 shows the mounting of the SA.22c onto the adapter test board. Four 5 mm length screws are needed to properly mount the SA.22c onto 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, Symmetricom strongly recommends utilizing a suitable means for heat sinking if the user chooses not to purchase the optional heat sink.

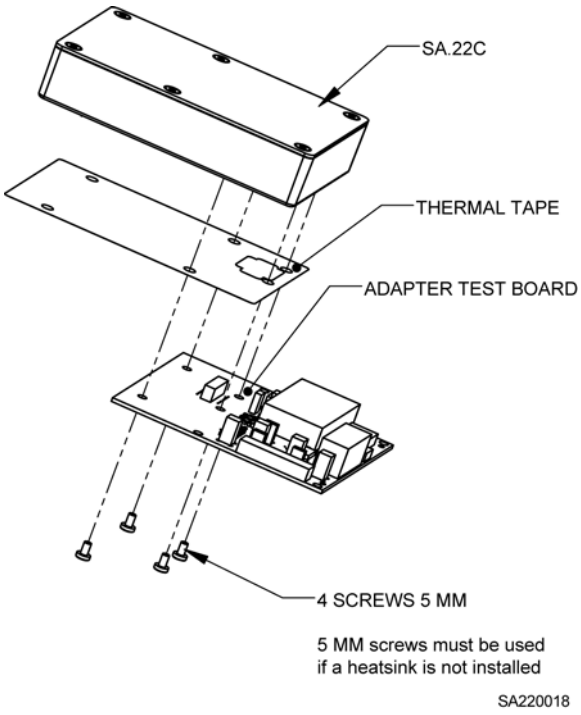


Figure A-1. SA.22c Developer's Kit Without Heatsink Assembly

Figure A-2 shows the mounting of the SA.22c onto the adapter test board and to the optional heat sink. Six 10 mm length screws are needed to properly mount the SA.22c with the adapter test board onto the optional heat sink.

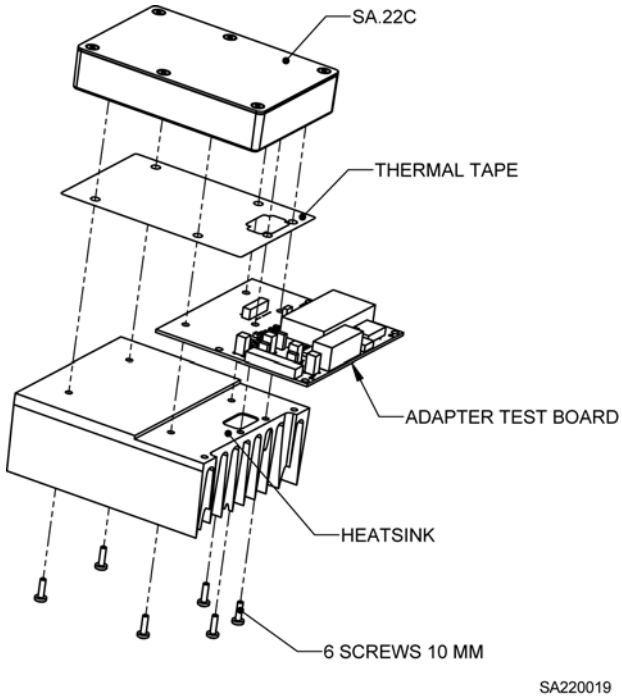


Figure A-2. SA.22c Developer's Kit With Heatsink Assembly

Interfacing of the Adapter Test Board

The adapter test board was designed to allow the user a flexible means of delivering power to and retrieving signals from the SA.22c. Additionally, the Adapter Test Board also allows the user to electrically integrate the SA.22c into an existing system (via J2). Figure A-3 shows the top view layout of the Adapter Test Board with SA.22c attached.

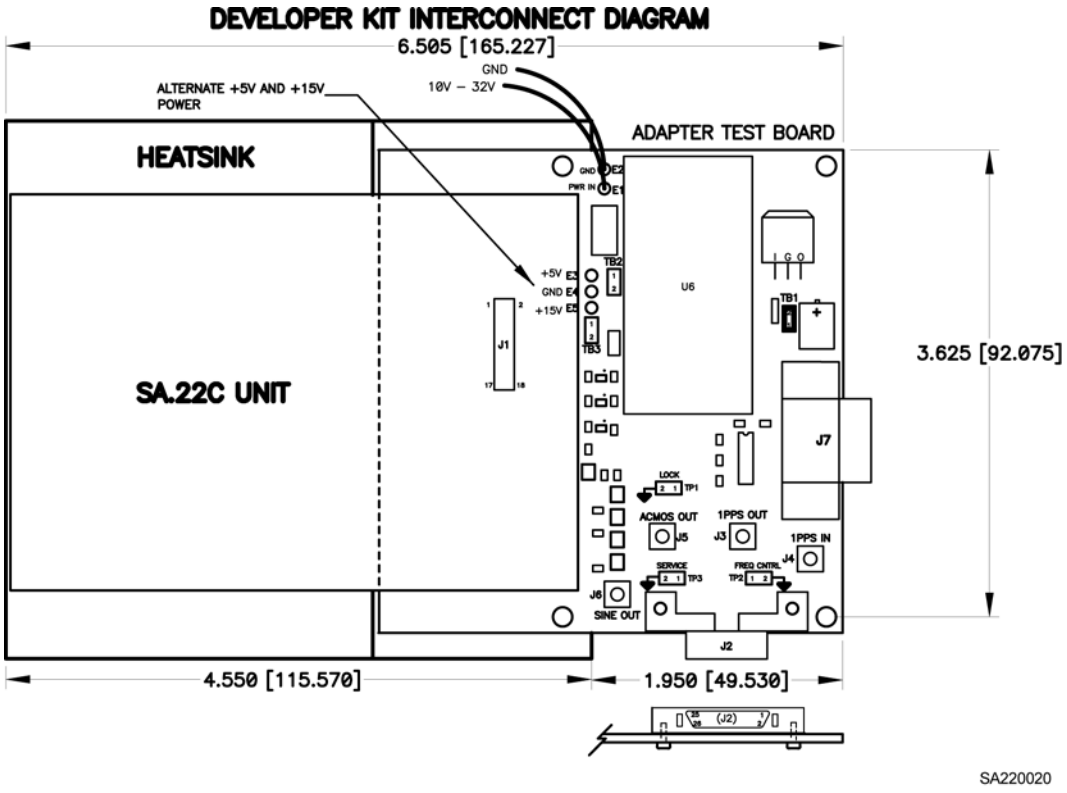


Figure A-3. Developer's Kit Interconnect Diagram

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. See Table A-1 for the I/O pin configuration.

Table A-1. 18-Pin Samtec I/O Connector (J1)

Pin	Signal Name	Type	Signal Function
1	VSS	GND	Power and signal ground (All ground pins must be connected)
2	VDD	PWR	Power Input +15Vdc (All power pins must be connected)

Table A-1. 18-Pin Samtec I/O Connector (J1) (Continued)

Pin	Signal Name	Type	Signal Function
3	VSS	GND	Power and signal ground (All ground pins must be connected)
4	VDD	PWR	Power Input +15Vdc (All power pins must be connected)
5	FREQ CTRL	Analog	Frequency control analog voltage (0 to +5Vdc)
6	VCC	PWR	Power Input +5Vdc
7	1PPS OUT	Output	1PPS output, may be enabled/disabled digitally
8	VSS	GND	Power and signal ground (All ground pins must be connected)
9	FACMOS	Output	Frequency ACMOS signal output
10	VSS	GND	Power and signal ground (All ground pins must be connected)
11	VSS	GND	Power and signal ground (All ground pins must be connected)
12	SERVICE	Output	Service required within 30 days based on unit health
13	DIN	Input	UART data in to SA.22c
14	LOCK	Output	If low, then the SA.22c is locked
15	1PPS IN	Input	1PPS input, positive edge triggered
16	DOUT	Output	UART data out at ACMOS logic levels
17	N/A	N/A	N/A
18	N/A	N/A	N/A

J2 is a 26-pin Molex receptacle connector used for delivering power and transmitting/receiving signals and data to and from the SA.22c all from one connector. See Table A-2 for the Molex pin configuration.

Table A-2. 26-Pin Molex Connector (J2)

Pin	Signal Name	Type	Signal Function
1	VINPUT	PWR	Power Input +10Vdc to +32Vdc (All power pins must be connected)
2	VINPUT	PWR	Power Input +10Vdc to +32Vdc (All power pins must be connected)

Table A-2. 26-Pin Molex Connector (J2) (Continued)

Pin	Signal Name	Type	Signal Function
3	VINPUT	PWR	Power Input +10Vdc to +32Vdc (All power pins must be connected)
4	VINPUT	PWR	Power Input +10Vdc to +32Vdc (All power pins must be connected)
5	VINPUT	PWR	Power Input +10Vdc to +32Vdc (All power pins must be connected)
6	VINPUT	PWR	Power Input +10Vdc to +32Vdc (All power pins must be connected)
7	VINPUT	PWR	Power Input +10Vdc to +32Vdc (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 +5Vdc)
12	VSS	GND	Power and signal ground (All ground pins must be connected)
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)
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

Table A-2. 26-Pin Molex Connector (J2) (Continued)

Pin	Signal Name	Type	Signal Function
22	N/A	N/A	N/A
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 ohm)

J3, J4, J5, and J6 are SMA connectors used for signal outputs (J4 is a signal input) provided by the SA.22c. See Table A-3 for the SMA connectors' signal information.

Table A-3. SMA Connectors' Signal Information

SMA	Signal Name	Type	Signal 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 ohm)

J7 is a 9-pin D-Sub connector used for transmitting/receiving data to and from the SA.22c via the Symmetricom Serial Interface Protocol (SSIP). See Table A-4 for the D-Sub connector pin configuration.



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

Table A-4. 9-Pin D-Sub Connector (J7)

Pin	Signal Name	Type	Signal Function
1	N/A	N/A	N/A
2	DOUT	Output	UART data out at ACMOS logic levels

Table A-4. 9-Pin D-Sub Connector (J7) (Continued)

Pin	Signal Name	Type	Signal Function
3	DIN	Input	UART data in to SA.22c
4	N/A	N/A	N/A
5	VSS	GND	Signal Ground
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	N/A	N/A	N/A
9	N/A	N/A	N/A

Options for Supplying Power to the Adapter Test Board

The SA.22c adapter test board design allows three power-supplying options to accommodate the users needs.

Figure A-4 shows block diagrams of the three options for powering and setting up the SA.22c with the adapter board. It also show which connections are used to access the various inputs and outputs of the SA.22c depending on which option you use.

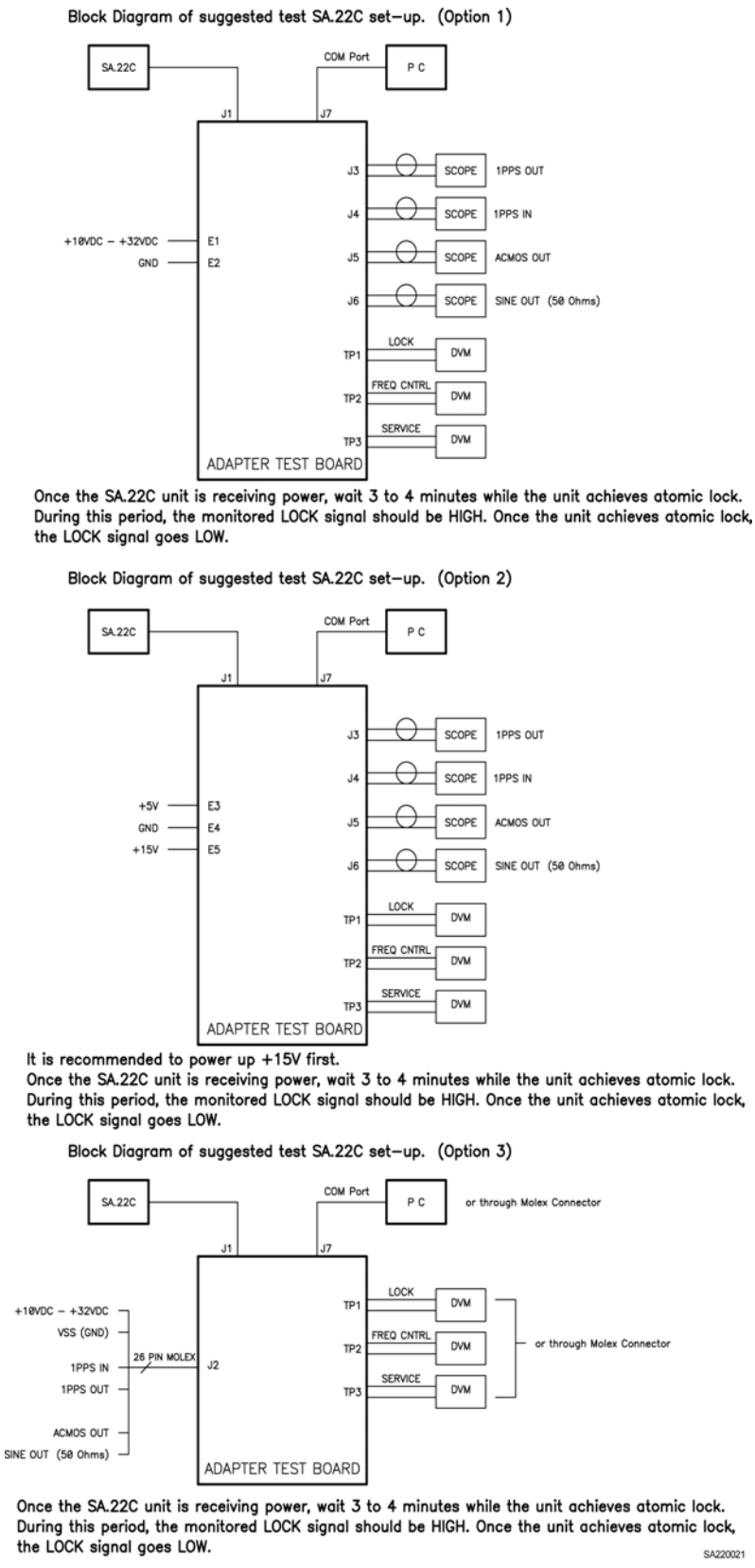


Figure A-4. Block diagram of suggested Test Setup

Figure A-5 shows the physical power supply wiring and jumper settings needed for each option.

Warning: Users need to 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 a system failure and possibly cause damage to the existing circuitry.

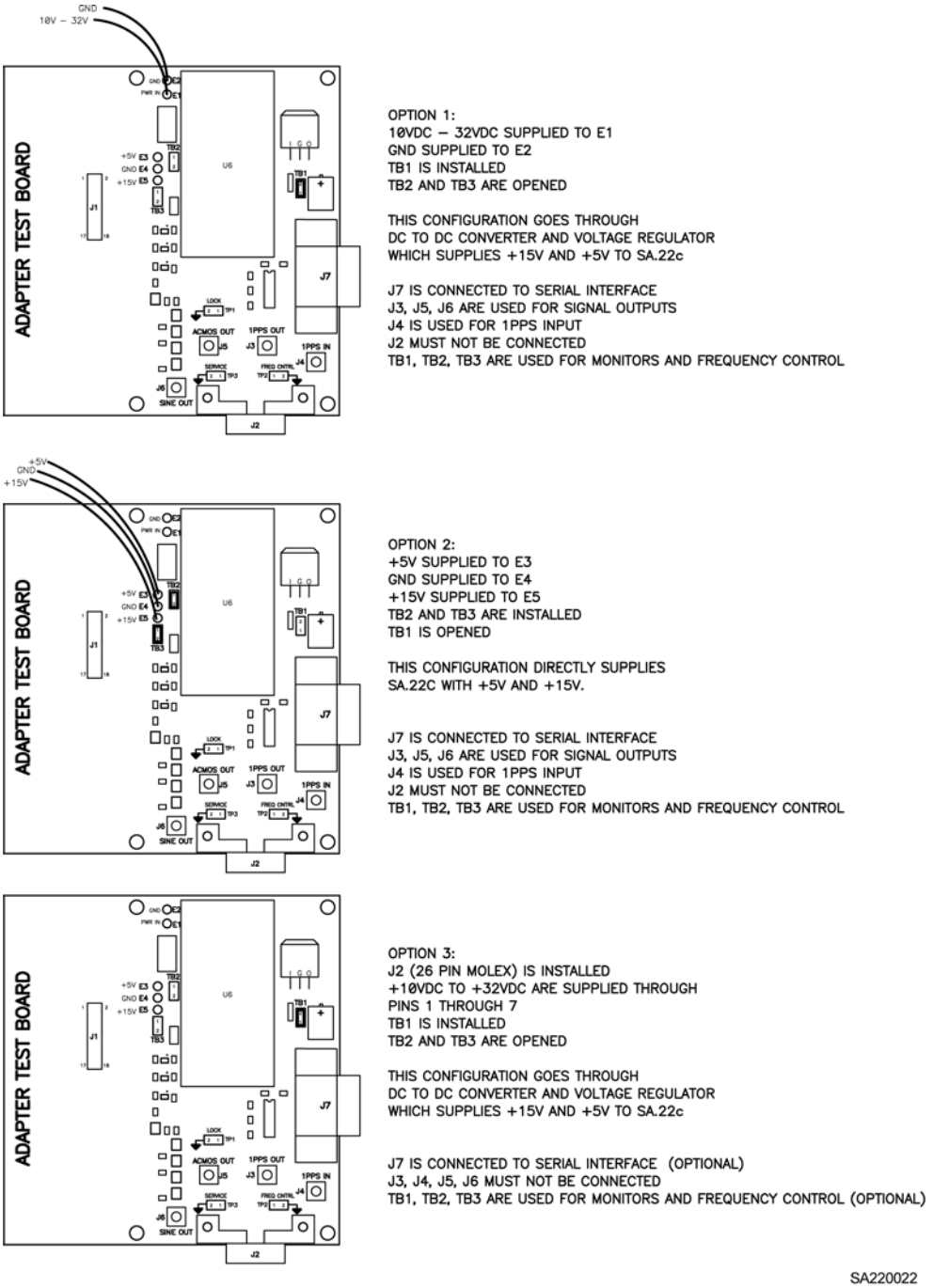


Figure A-5. Power Supply and Output Options

Option 1 allows the user to directly power the adapter test board with +10Vdc to +32Vdc going to E1 with E2 connected to supply ground. Also, TB1 needs to be installed while TB2 and TB3 need to be uninstalled. In the adapter board, this voltage travels through a DC-to-DC converter and a voltage regulator to supply the SA.22c with the +15Vdc and the +5Vdc it needs to operate. For this option, J7 is used for serial interface communications. J3, J5, and J6 are used for signal outputs while 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 in order to avoid degraded signal integrity.

Option 2 allows the user to directly power the adapter test board with separate +15Vdc going to E5 and +5Vdc going to E3 supplies with E4 connected to supply ground. Also, TB2 and TB3 need to be installed while TB1 needs to be uninstalled. In the adapter board, these voltages travel directly to the SA.22c for operation (the +15Vdc should be applied before the +5Vdc). For this option, J7 is used for serial interface communications. J3, J5, and J6 are used for signal outputs while 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 in order to avoid degraded signal integrity.

Option 3 allows the user to power the adapter test board with +10Vdc to 32Vdc through the 26-pin Molex connector (J2). Also, TB1 needs to be installed while TB2 and TB3 need to be uninstalled. In the adapter board, this voltage travels through a DC-to-DC converter and a voltage regulator to supply the SA.22c with the +15Vdc and the +5Vdc it needs to operate. For this option, J7 is used for serial interface communications; however, J2 also can be used for serial interface communications if the user would rather do so. 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 Table A-2 for Molex pin configuration). In this option, J3, J4, J5, and J6 must not be connected in order to avoid degraded signal integrity.

Appendix B Symmetricom Serial Interface Protocol

This appendix provides information on communicating with the SA.22c through the serial interface connector as provided in the Developer's Kit (see Appendix A, Using the Developer's Kit). It includes output examples and a description of commands.

In This Appendix

- Using the Symmetricom Serial Interface Protocol

Using the Symmetricom Serial Interface Protocol

The Symmetricom Serial Interface protocol (SSIP) provides 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. Of the eight RUN MODE commands, three require the host to supply data.

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
- 8 data bits
- 1 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.

Data Format

Run Mode Data Format (Customer Mode)

SA.22c outputs are all decimal data as “ASCII Coded Hex” except for 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”.

Data sent to the SA.22c in run mode should not be encoded.

The following is an example of output from the SA.22c after power is applied 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>
```

The following is an example of the response one gets by entering the letter “i” to get serial number and other facts of “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
```

The following is an example of entering the letter “h” to get the “help menu” from the SA.22c:

```
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>
```

The following print out shows the response to the command for “w” for 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.
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.
```

The following print out shows how entering the letter “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
```

The following print out shows the “*control register*” contents by entering the letter “p”:

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

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 Table B-1.



Caution: Using factory mode can result 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.

Serial Interface Initialization

The serial interface is initialized as follows:

Table B-1 defines the SA.22c's Run Mode Commands.

Table B-2 defines the bit functions of the factory mode commands of the SA.22c.

Table B-3 defines the administrative mode commands.

Table B-1. Run Mode Commands

User Output to SA.22c		Response to Host	Command Name and Description
Command	DATA		
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 Cntl' 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 E^{-11} Example: for a $+100E^{-11}$ change: "100<cr>" Example: for a $-100E^{-11}$ change: "–100<cr>"	To be Specified	Adjust Frequency Adjust Unit output frequency. Used to discipline the unit. The smallest incremental frequency change is $2E^{-12}$ (or "f.2"). Any value less than this will still be used. Max value that can be used at one time is $4E^{-8}$. For larger frequency changes, repeated steps equal to or smaller than $4E^{-8}$ should be used. Unit always powers up at free running factory set frequency. This command is always relative to the free running frequency.
h	None	To be Specified	HELP command Displays menu.
i	None	To be Specified	Outputs Unit information While dumping data, clock outputs are not guaranteed to meet specifications during the use of this command.
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. Consult factory for other frequency options.

Table B-1. Run Mode Commands (Continued)

User Output to SA.22c		Response to Host	Command Name and Description
p	None	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. **Note:** if the "t" command is not used, unit defaults to factory settings at next power up,
w	None	To be Specified	Displays Health Monitor data

Table B-2. Factory Mode Commands

User Output to SA.22c		Response to Host	Command Name and Description
Command	DATA		
a	None	a>	Goes to Administration mode
i	None	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: This mode and ADMIN mode allow the loading of new code or updates, or reconfiguring defaults in the field. It is not a normal operating mode.

Table B-3. SA.22c Administrative Mode Commands

User Output to SA.22c		Response to Host	Command Name and Description
Command	DATA		
a	None	Outputs 7 lines of banner – same as power-up	Unit Information Same as the "i" command in FACTORY mode and RUN mode.
b	"File" from Symmetricom (self-burning)	To be Specified	Operating this command without valid "file" will not overwrite the existing data stored in FLASH memory.
x	None	x f>	EXIT Administrative mode to FACTORY mode
y	None	Y asks "are you sure?"	Soft reset. Restarts processor.
z	None	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 or updates, or reconfiguring defaults in the field. It is not a normal operating mode.

Appendix C One Pulse Per Second Source Connection

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

In This Appendix

- Connection Requirements
- Background
- 1PPS Functions
- System Requirements
- 1PPS Algorithm Operation
- Setting the 1PPS Synchronization
- 1PPS Firmware Versions
- Flywheeling Recovery – Normal
- Recovery with JamSynch
- 1PPS Algorithm Theory of Operation

Connection Requirements

The following connections are required for 1PPS setup:

- Power
- GPS antenna
- 1PPS from the source to the SA.22c

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

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 become unavailable, for example, during jamming and antenna maintenance.

The GPS system provides worldwide 1PPS signals with extremely good long term stability (i.e., < $1E^{-12}$ 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 intersymbol interference, and GPS receiver oscillator limitations.

Symmetricom has pioneered the use of rubidium oscillators in telecommunications applications. Telecommunications applications often require long term and short term stability beyond the range of free running quartz oscillators. For example, cellular CDMA systems often require 1PPS signals to be synchronized within 2 µs over very 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). Symmetricom 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. Now, with SA.22c, the solution can be even more cost effective. When used with a GPS receiver the SA.22c provides telecommunications system performance levels that rival levels obtained using Cesium oscillators.

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 very long holdover times

Figure C-1 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 can provide the time interval error difference between the 1PPS input and the 1PPS generated inside the SA.22c (see Table C-1). 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 produces 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 ($1.67E^{-8}$). Note that this number is in hex format.

A more convenient configuration is to allow the SA.22c to be disciplined by the incoming 1PPS signal. Figure C-2 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, on page 68). Typical performance data for this configuration is shown in Figure C-3 and Figure C-4.

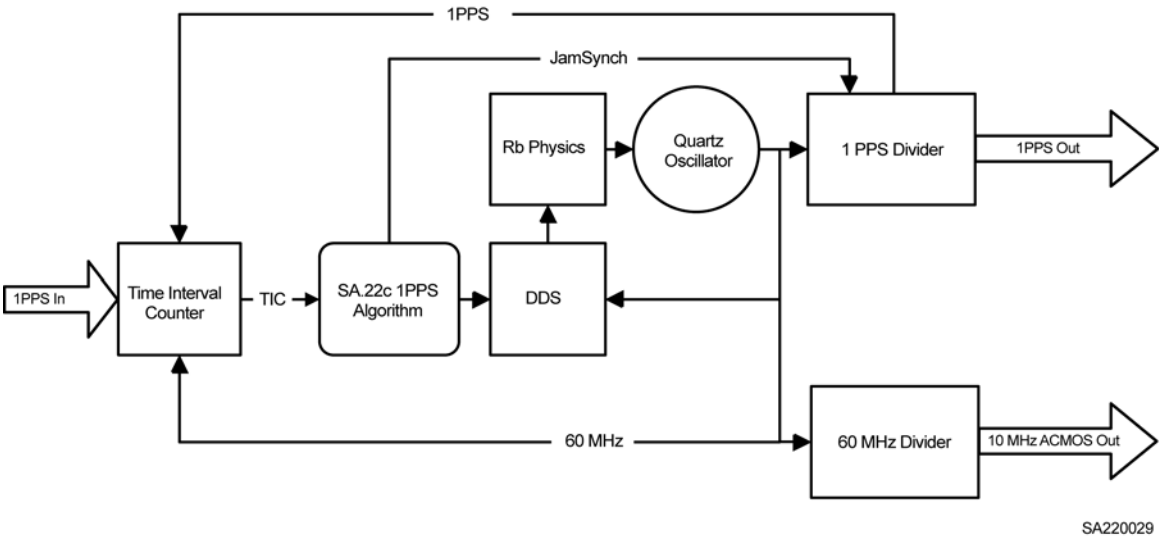


Figure C-1. Time and Frequency Control System

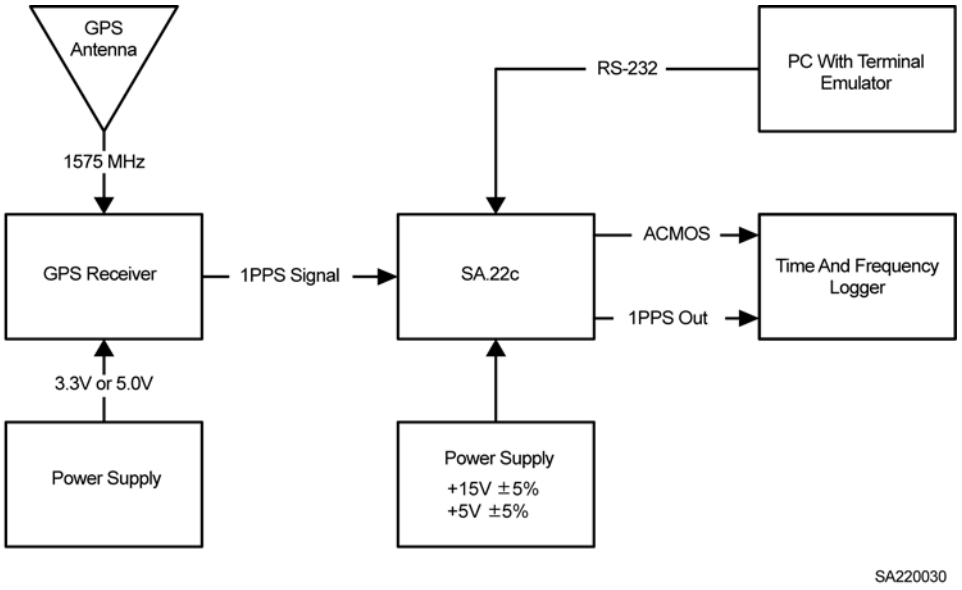


Figure C-2. Test Bench setup

System Requirements

The following information lists the requirements for 1PPS setup and operation:

- SA.22c with 1PPS output enabled.
- GPS receiver with less than 300 ns noise.
- One pulse per second input signals must have repeatable rise time with minimal ringing and must conform to the following:
  - 1PPS input can be driven by a standard 3.3 volt logic, 5 volt CMOS, or 5 volt TTL with normal operation at:

    Input voltage logic high: 2.00V minimum

    Input voltage logic high: 5.50V maximum

    Input voltage logic low: 0.00V minimum

    Input voltage logic low: 0.80V maximum
  - Maximum DC overshoot must be limited to 5.5V or 10mA, whichever is easiest to achieve.
  - Maximum DC undershoot must be limited to –0.5V or 10mA, whichever is easiest to achieve.
  - Minimum pulse width (or hold time) of 50 ns.

  - Input impedance is >100K Ω allowing the user 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 (see Table C-3 for part numbers).
- PC running Microsoft Windows with terminal emulation program. (57600bps, 8 bits with no parity).

1PPS Algorithm Operation

There are two parameters that can be 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 should be between 0.25 and 4. Values less than 0.25 will default to 0.25 while values over 4 will default 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 will cause both the Damping Factor and Tau to change to the factory default settings.

Factory Default

The factory default requires no inputs to the rubidium oscillator from the user. The default value for Damping Factor is 1 and the default Tau is 400. These values are a good starting point and will work well for most GPS applications.

Setting the 1PPS Synchronization

The following assumes the SA.22c has a 1PPS enabled Customer version of firmware at revision 6.05c or higher installed.

- Connect the SA.22c to the Adaptor Test Board of the Developer’s Kit or to a correctly configured equivalent system. (See Appendix A, Using the Developer’s Kit)
- Ensure the terminal emulation program is configured to 57,600 BPS, 8 bits, no parity, no flow control and that the keyboard caps lock is off. All input should be lower case.

- Apply power to the system. You will see header information from the SA.22c displayed similar to the following where you should confirm the firmware version.

```
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
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.

Changing the "y" Coefficients

- At the `r>` prompt, type **y**, then **1**, then **Enter** (1 indicates that you wish to enter the Damping Factor).
- Enter a value between 0.25 and 4 and press **Enter** (see Note 3, on page 69 and 1PPS Algorithm Theory of Operation, on page 72).
- At the `r>` prompt, type **y**, then **2**, then **Enter** (2 indicates that you wish to enter the Time Constant).
- Enter a value between 5 and 100000 and press **Enter** (see Note 3, on page 69 and 1PPS Algorithm Theory of Operation, on page 72.
- 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, on page 69):

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

The “y” Coefficients – Factory Default

If the factory default values of Damping Factor = 1 and Tau = 400 are acceptable for your application, no modifications to the y coefficients are required. The SA.22c 1PPS disciplining is enabled at the factory allowing the unit to work right out of the box. If you wish to return the y coefficients to the factory defaults, enter the value 0 for both the Damping Factor and Tau using the process described in Changing the “y” Coefficients, on page 66. This causes the SA.22c to operate at the factory default Damping Factor of 1 and Tau of 400.

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, on page 69) as well as the 1PPS state (see Note 2, on page 69 and Table C-1). The output format appears similar to the following:

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

Table C-1. 1PPS States Returned with the j Command

Description	Expected Values	Action Being Performed
INITIALIZE0STATE	0	Start up initialization
INITIALIZE1STATE	1	Start up initialization
INITIALIZE2STATE	2	Start up initialization
HOLDOVERSTATE	3	Seeking usable 1PPS
JAMSYNC1STATE	4	Synch SA.22c output 1PPS to input
JAMSYNC2STATE	5	Synch 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
PDATEDDSSTATE	8	Update SA.22c DDS based on PIDCALCSTATE output.
ALCSLOPESTATE	9	Calculate slope of incoming 1PPS vs. SA.22c 1PPS during holdover.

See 1PPS Algorithm Theory of Operation, on page 72 for additional information on 1PPS states.

The “g” Command

The “g” command allows you to change the SA.22c to operate in any of three modes which affect the output of the Lock Pin (pin 14 see Note 10, on page 69). Note that this 1PPS mode can be changed by the user but cannot be saved. If power is cycled to the unit it reverts to the factory default. The modes are:

0 = 1PPS Disciplining Disabled – Normal Rb Lock Pin functionality. Only the Rb loop needs to be locked to indicate a locked condition on pin 14.

1 = 1PPS Disciplining Enabled – Normal Lock Pin functionality. Only the Rb loop needs to be locked to indicate a locked condition on pin 14.

2 = 1PPS Disciplining Enabled – Requires both Rb loop to be locked AND 1PPS synchronization lock to indicate a locked condition on pin 14.

Note that 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 mode set by the g command for each firmware version is:

- 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**.

Notes:

1. These numbers are in HEX format.
2. 1ppsStates: 0 to 2 – Initialize; 3, 9 – Holdover; 6 to 8 – Disciplining.
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.
4. Use “z” command to save your settings.
5. SA.22c Rubidium system locks approx. 5 minutes after startup.
6. SA.22c initial frequency must be less than ± 3PPB for 1PPS to lock.
7. Initial 1PPS lock occurs between 3 and 5 minutes after both lock and valid 1PPS are present.
8. Confirm the firmware version by issuing the “i” command.
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.
10. If using the J2 Molex connector on the Adapter Test Board, then the Lock pin is 21 and the Service pin is 8.
11. If measuring the Lock and Service voltages on the Adapter Test Board, then the Lock signal is on TP1 and the Service signal is on TP3.

Table C-2. 1PPS Firmware Versions

Customer Standard	Customer LED
6.05c	6.06c

Flywheeling Recovery – Normal

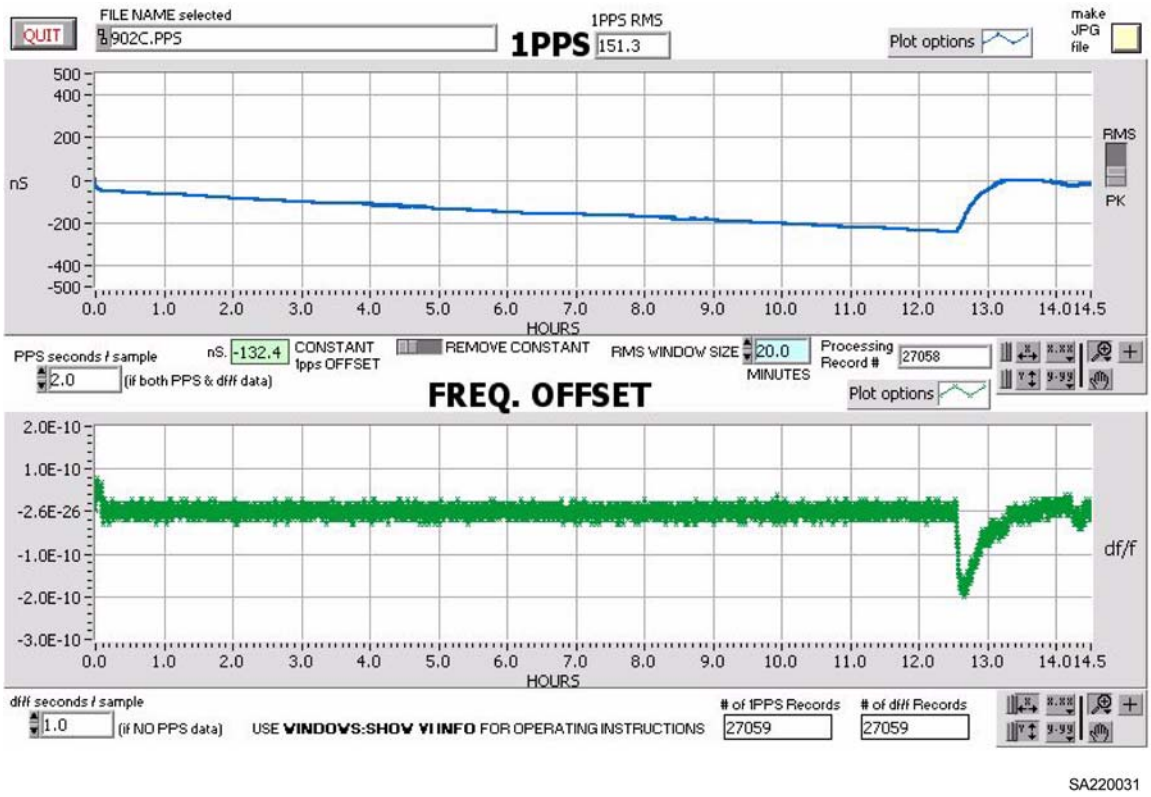


Figure C-3. Flywheeling Recover with 1PPS offset < 1µsec

In this test, the SA.22c was synchronized to 1PPS before this data set. Antenna is removed at hour 0 and reapplied at approximately hour 12.5. The SA.22c 1PPS output signal had reached an offset of 220 nanoseconds.

The subsequent frequency change is what returns the 1PPS offset to 0 nanoseconds.

Recovery with JamSynch

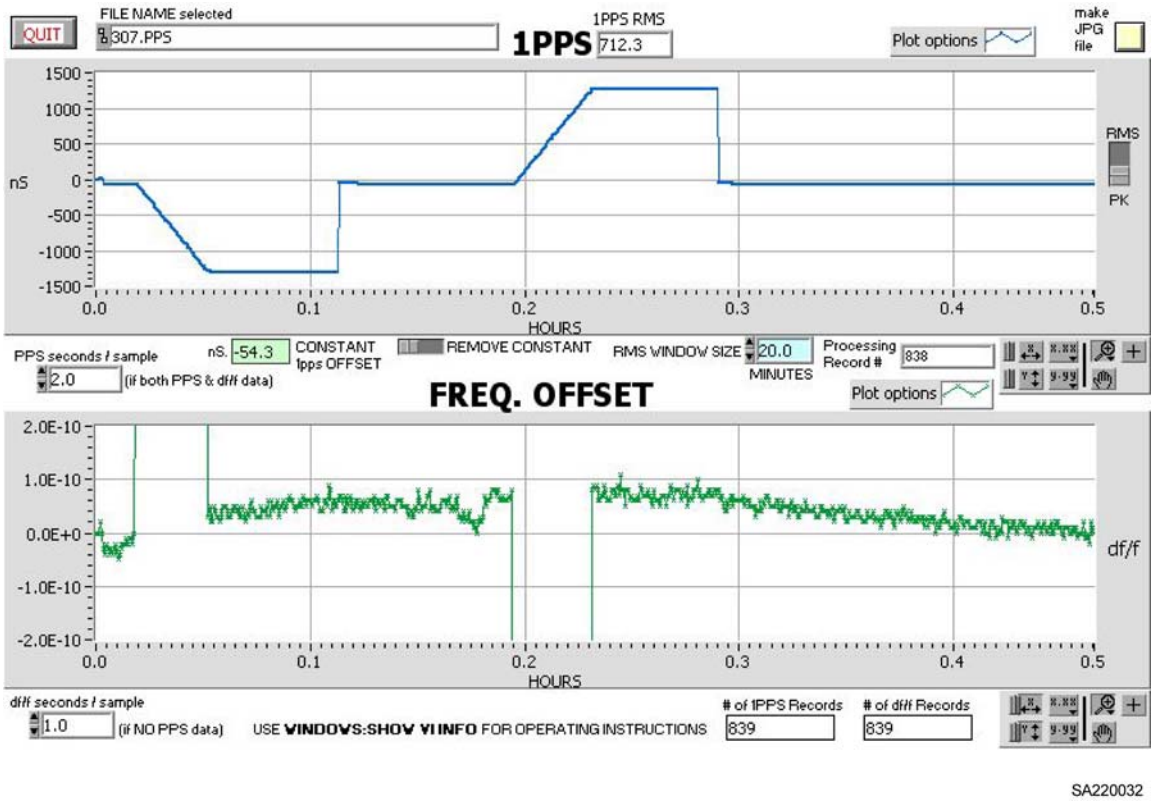


Figure C-4. Flywheeling Recover with 1PPS offset > 1µsec

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

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

1PPS Algorithm Theory of Operation

SA.22c qualifies 1 pulse per second (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.

Once 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 can be 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 nanoseconds, the algorithm changes to the HoldOver state and the process begins again. Refer to the following figures for additional details.

1PPS Algorithm High Level Flow Chart

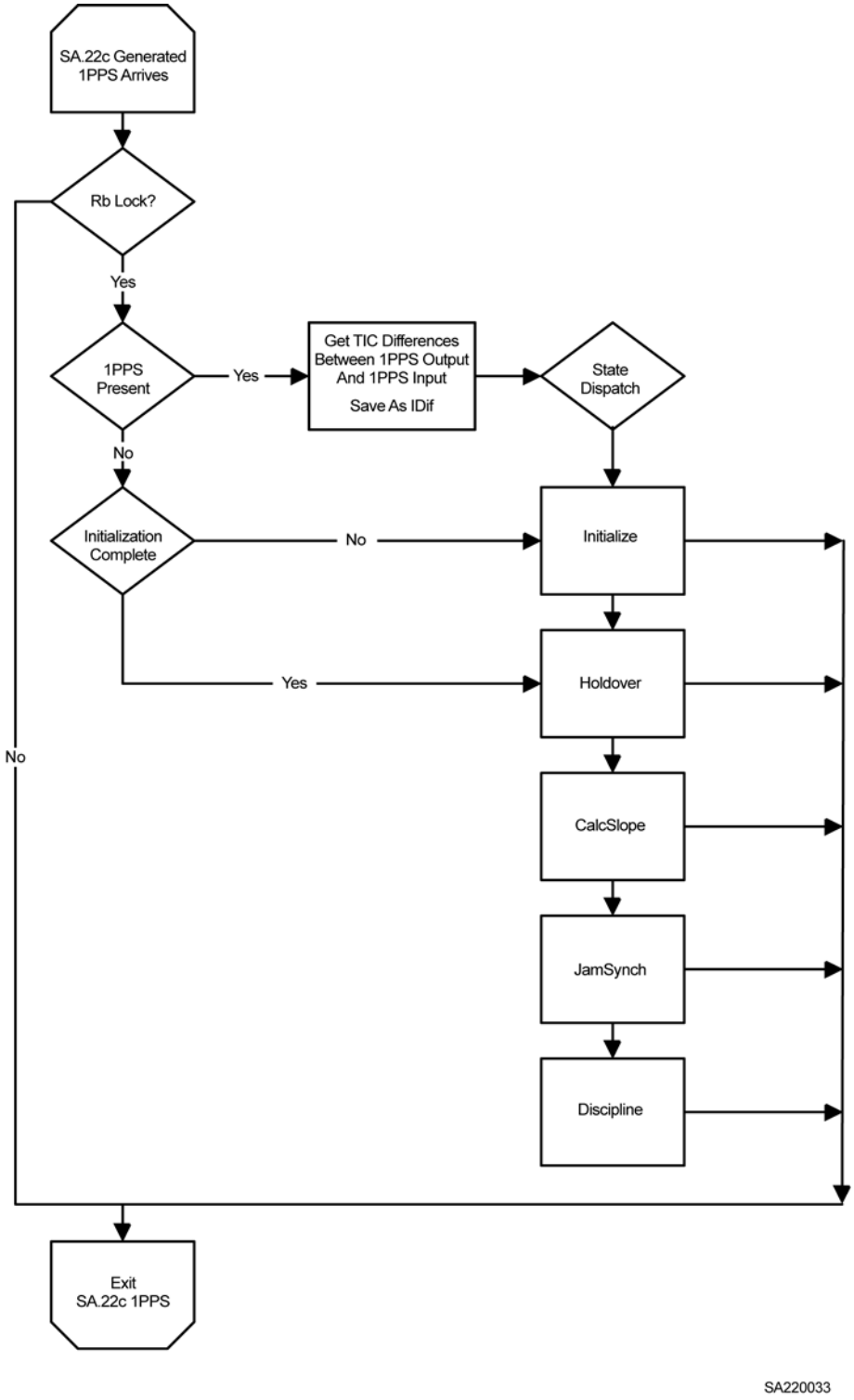


Figure C-5. SA.22c 1PPS Algorithm States

Initialization

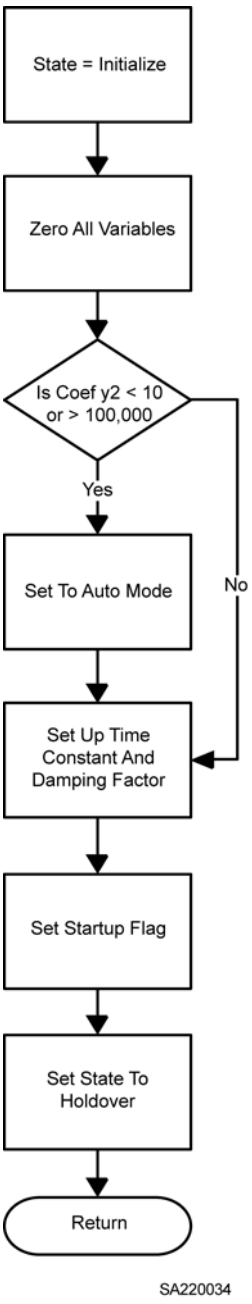


Figure C-6. SA.22c Initialize State

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 there is no 1PPS applied.

The “j” command shows the 1PPS count.

Holdover

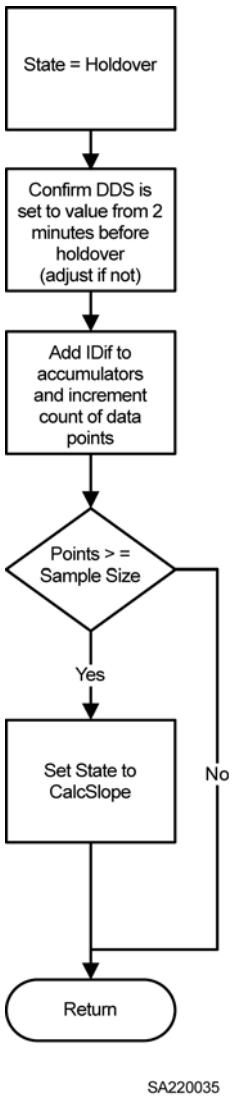
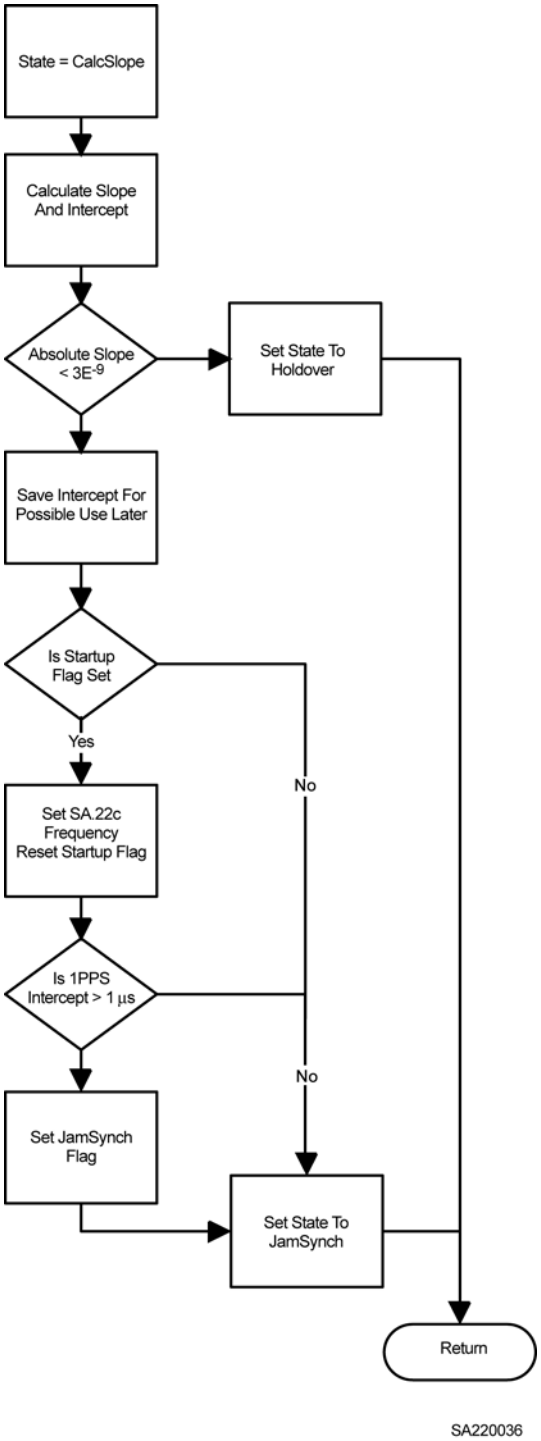


Figure C-7. SA.22c Holdover State

During holdover, 1PPS input statistics are accumulated and periodically the results are calculated (CalcSlope State).

The sample size is set to 120 data points (120 seconds).

Calcslope



When the frequency difference between the SA.22c and the 1PPS source is calculated, if the difference is < ±3E $^{-9}$ the state changes from holdover to JamSynch.

This state executes every 120 seconds during holdover.

Figure C-8. SA.22c Calcslope State

JamSynch

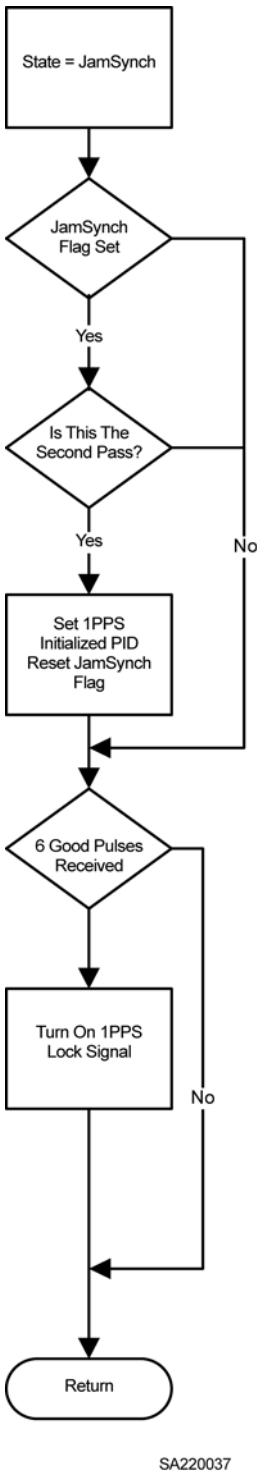


Figure C-9. SA.22c JamSynch State

When the SA.22c 1PPS output is compared to the SA.22c 1PPS Input, if the difference is ≥ 1 µsec. 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 µsec. the algorithm waits 6 more pulses and then advances to the Discipline state.

Discipline

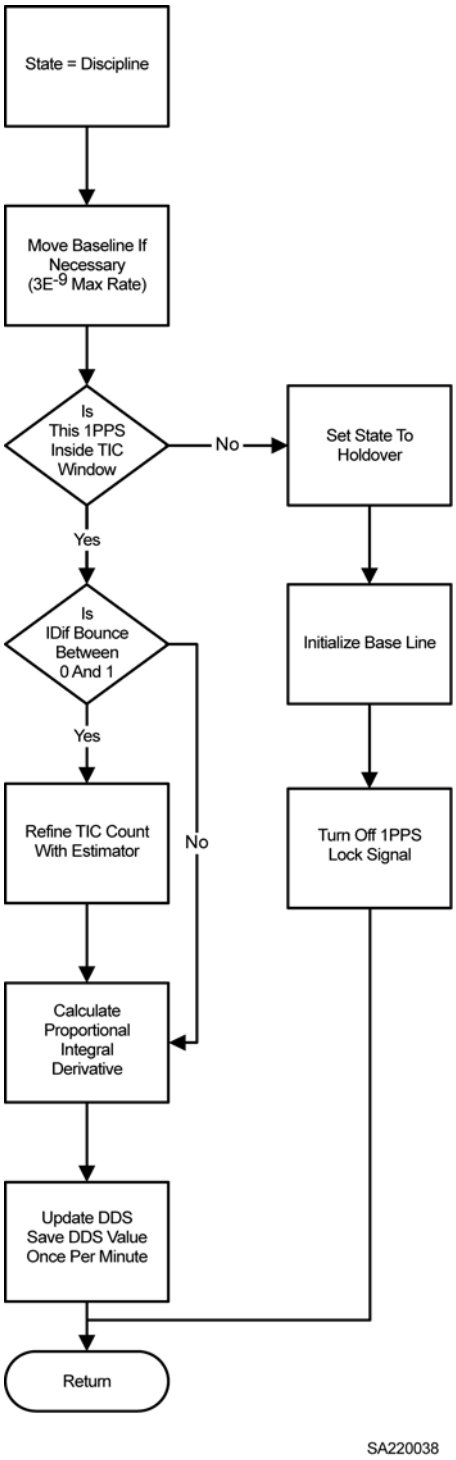


Figure C-10. SA.22c Discipline State

In the Discipline State, the SA.22c uses a PID (proportional-integral-derivative) method to steer the 1PPS output of the SA.22c. This method means the SA.22c average frequency offset is close to zero. You can expect to see some frequency change when recovering from holdover.

If at any time a 1PPS input signal is more than 330 nanoseconds from its expected value the 1PPS algorithm returns to holdover state.

If the input source is very 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. Since some receivers take a long time to produce 330 nanoseconds of error after signal loss, the SA.22c reverts to the DDS value from 2 periods before the 1PPS becomes invalid.

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