SA.45s CSAC

Chip Scale Atomic Clock

Key Features

- Power consumption <120 mW
- Only 16 cc in volume, 1.6" x 1.39" x 0.45"
- Aging < 3.0E-10/month
- 10 MHz CMOS-compatible output
- 1 PPS output and 1 PPS input for synchronization
- Hermetically sealed
- RS-232 interface for monitoring and control
- Ultra-low power mode for power consumption well below 50 mW

Applications

- Underwater sensor systems
- GPS receivers
- Backpack radios
- Anti-IED jamming systems
- Autonomous sensor networks
- Unmanned vehicles

With an extremely low power consumption of <120 mW and a volume of <16 cc, the Symmetricom® SA.45s Chip Scale Atomic Clock (CSAC) brings the accuracy and stability of an atomic clock to portable applications for the first time.

The SA.45s provides 10 MHz and 1 PPS outputs at standard CMOS levels, with short-term stability (Allan Deviation) of 1.5E-10 @ 1 sec, long-term aging of 3E-10/month, and frequency change over temperature of 5E-10 over an operating range of -10° C to +70° C. The unit can also be ordered with a wider temperature range (Option 002) of -40° C to +85° C, with slightly higher power consumption and a wider frequency change over temperature.

The SA.45s CSAC accepts a 1 PPS input that may be used to synchronize the unit's 1 PPS output to an external reference clock with ±100 ns accuracy. The CSAC can also use the 1 PPS input to discipline its phase and frequency to within 1 ns and 1.0E-12, respectively.

A standard CMOS-level RS-232 serial interface is built in to the SA.45s. This is used to control and calibrate the unit and also to provide a comprehensive set of status monitors. The interface is also used to set and read back the CSAC's internal time-of-day clock.

The SA.45s CSAC can also be programmed to operate in an ultra-low power mode. In this mode, the CSAC's physics package is turned off, and the unit operates as a free-running TCXO. The physics package is then periodically turned back on, and after warm-up (<130 sec), it re-disciplines the TCXO. This operating mode enables average power consumption levels of well below 50 mW.

Quantum™

Symmetricom invented portable atomic timekeeping with QUANTUM™, the world's first family of miniature and chip scale atomic clocks.

Choose QUANTUM™ class for best-in-class stability, size, weight and power consumption.

SA.45s CSAC

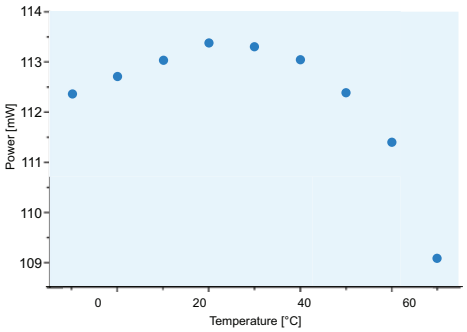
Low Power Consumption By Design

Every part of the SA.45s CSAC has been engineered for low power consumption. It starts with the physics package, shown here in a cutaway view. A vertical-cavity surface-emitting laser (VCSEL) that has been highly optimized for this specific application illuminates the atomic vapor resonance cell, and the light that gets through the cell is then detected by the photodetector. The photodetector output signal drives a feedback loop which is used to achieve atomic resonance using the principles of coherent population trapping (CPT).

The entire physics package has a volume of only 0.35 cm^3, and the actual resonance cell itself has a volume of only 2 mm^3. It is this extremely small size, plus the fact that it is surrounded by a vacuum within the physics package, that allows the entire physics package to be powered by only 10 mW. As the cutaway drawing shows, the only way the physics package connects with the outside world is through a top and bottom polyimide suspension. All signals that need to go to or from the center stack-up are carried on traces that are printed on the suspensions. And because the suspensions are connected to a frame that is engineered to be slightly shorter than the center stack-up, they are in tension and serve to hold the stack-up in place. The result is a very small, highly thermally isolated, and robust physics package with excellent performance. All of the electronics that surround the physics package, and which turn it into a fully functional clock, have also been engineered for low power consumption. Even the CSAC controller's firmware routines have been optimized for low power consumption.

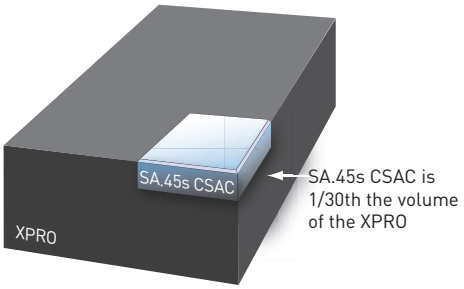
Low Power Is Just The Beginning

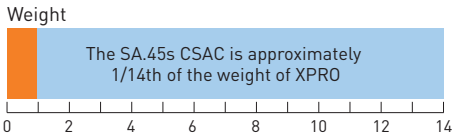
An atomic clock that consumes only 120 mW of power (125 mW for option 002) instead of 10 W or more gives system designers a new and important degree of freedom. But that is just the beginning. Because of its small size and high thermal isolation, the SA.45s CSAC warms up in <130 sec, compared to 8 minutes or more for conventional atomic clocks. Also, power consumption during warm-up is only 140 mW, while conventional atomic clocks will often consume two times their steady-state power during warm-up. Finally, as shown in the graph, the CSAC's power consumption variation vs. temperature is negligible, while other atomic clocks can show variations of 200% or more across their specified temperature range.

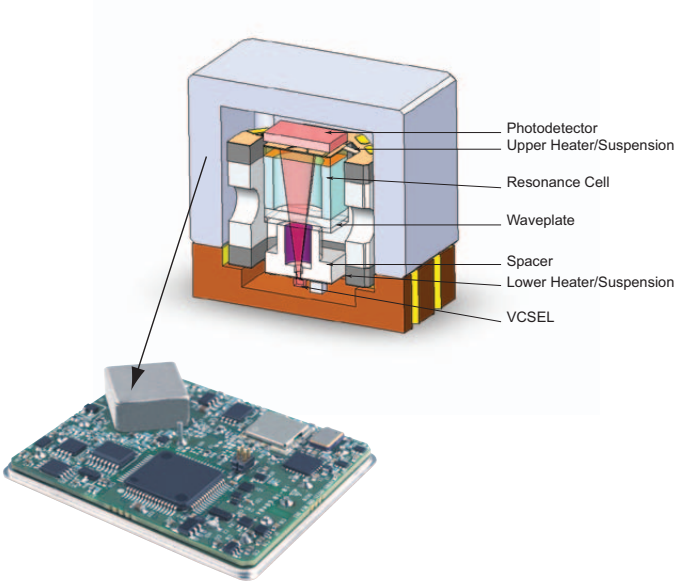


The World's Smallest Atomic Clock

Power consumption and size are both critical to enabling portable applications, and the SA.45s is by far the smallest atomic clock available. For example, the SA.45s CSAC does not quite equal the performance of Symmetricom's XPRO rubidium oscillator, but as shown in the figure, it has approximately 1/30th the volume – and 1/14th the weight – of the XPRO. Conversely, the SA.45s has much higher performance than OCXOs, and still offers a 4x reduction in volume compared to popular OCXO package sizes.





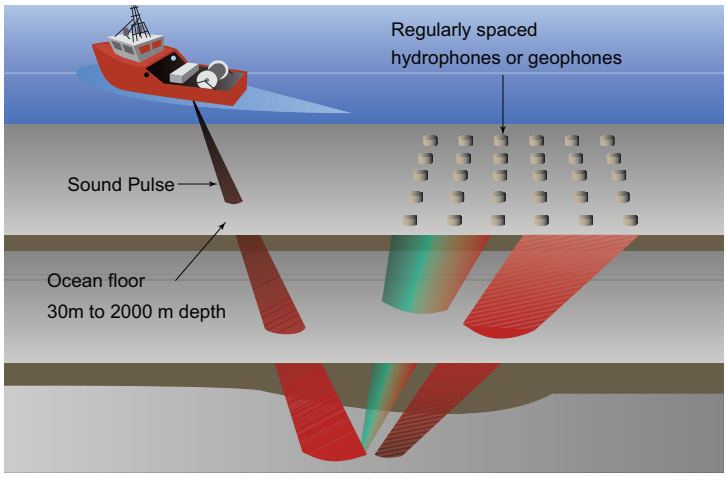


SA.45s CSAC

Underwater Sensor Systems

Underwater sensors are used in seismic research, oil exploration and many other applications. Sensors designed to lie on the ocean floor will typically include a hydrophone, a geophone and a very stable clock to time-stamp the data collected by the sensor. Because GPS signals can't penetrate water, oven-controlled crystal oscillators (OCXO's) have been used to provide the accuracy needed for most time-stamping applications.

But the SA.45s CSAC is a nearly ideal clock for these underwater applications. Because it consumes 1/10th to 1/30th the power of an OCXO, it requires much less battery power, resulting in smaller and lower-cost sensors, or alternatively, sensors with a much longer mission life.



The SA.45s CSAC's aging rate, which can be 1/100th of even a good OCXO, means that time-stamping errors caused by drift are greatly reduced. Finally, the SA.45s CSAC's superior temperature coefficient means that when sensors are calibrated to GPS on a warm boat deck, but then dropped into cold ocean water of several hundred meters depth, the offset error produced by this temperature change is minimized.

For underwater sensor applications requiring even less power consumption, the SA.45s CSAC's ultra-low power mode allows the user to turn off the unit's physics package and let the SA.45s CSAC operate as a free-running TCXO. The physics package is then periodically turned back on to re-discipline the TCXO. This can result in very low power consumption (<50 mW), and in an isothermal environment such as the ocean floor, the errors from the TCXO fluctuation are minimal.

Portable Military Systems

Many advancements in military electronics are aimed at bringing the networked battlefield to the tactical edge, i.e. the individual warfighter. But there are limitations on how many pieces of gear and how much battery weight a warfighter can be expected to carry. This is especially true when operations are carried out in rugged terrain and/or high altitude. The CSAC's small size, light weight, and extremely low power consumption can help in a number of systems:

IED Backpack Jammers: size and weight are always at a premium, so the SA.45s CSAC is an attractive option. Also, power not applied to the timing subsystem is power that can be applied to the jammer itself, or that can be used to extend mission life. The CSAC's precise synchronization is critical to prevent self-jamming, while its ultra-stable holdover is equally vital in GPS-denied environments.

Backpack Radio Systems: the SA.45s CSAC helps to minimize size, weight, and power consumption. At the same time, it provides the high accuracy required by many modern high-bandwidth waveforms, and it provides the stability needed to maintain network synchronization in GPS-denied environments.

GPS Receivers: using the SA.45s CSAC as a timebase, military GPS receivers can achieve greatly reduced Time To Subsequent Fix (TTSF) for 24 hours or more. It also becomes possible to operate with only three satellites in view (instead of the usual 4), a distinct advantage in many urban settings.

SA.45s CSAC

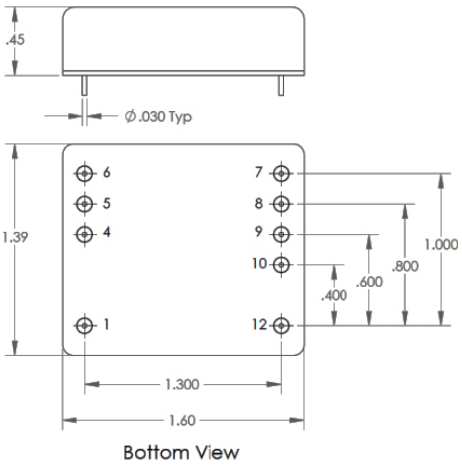
Unmanned Aerial Vehicles

As the number of applications for civil and military umanned aerial vehicles (UAVs) rapidly expands, the suppliers of payloads for these vehicles are being pressured to increase their functionality. In doing so, they find themselves bumping into limitations in size, weight and power.

The SA.45s CSAC can help in all three areas, with a volume of <16 cm^3, a weight of <35 g and power consumption of <125 mW. In fact, in some applications the CSAC is attractive solely because, when compared to conventional rubidium oscillators (~20 W in warm-up, ~10 W in steady state), its low power consumption simplifies thermal management issues.

Many UAV's rely on GPS, and the SA.45s CSAC can be disciplined by the 1 PPS output from a GPS receiver, and provide a stable signal that can be used by C4I or SIGINT payloads. And of course, should GPS be lost due to natural interference or jamming, the SA.45s CSAC provides a stable holdover signal that meets the requirements of even long-endurance missions.

Mechanical Interface



PIN NO.	FUNCTION
1	Tune
2	N/A
3	N/A
4	BITE
5	Tx
6	Rx
7	Vcc
8	GND
9	1 PPS IN
10	1 PPS OUT
11	N/A
12	10 MHz OUT

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Specifications

All specifications at 25°C, 3.3VDC unless otherwise specified

ELECTRICAL SPECIFICATIONS

	-001	-002
RF Outptut		
- Frequency:	10 MHz	10 MHz
- Format:	CMOS	CMOS
- Amplitude:	0-3.3 V	0-3.3 V
- Load Impedance:	1 MΩ	1 MΩ
- Quantity:	1	1
1 PPS Output		
- Rise Time:	< 5 ns	< 5 ns
- Pulse Width:	400 µs	400 µs
- Level:	0-3.3 V	0-3.3 V
- Load Impedance:	1 MΩ	1 MΩ
- Quantity:	1	1
1 PPS Input		
- Format:	Rising edge	Rising edge
- Low Level:	< 0.5 V	< 0.5 V
- High Level	> 2.5 V	> 2.5 V
- Input Impedance:	1 MΩ	1 MΩ
- Quantity:	1	1
Serial Communications		
- Protocol:	RS232	RS232
- Format:	CMOS 0-3.3 V	CMOS 0-3.3 V
- Tx/Rx Impedance:	1 MΩ	1 MΩ
- Baud Rate:	57600	57600
Built-in Test Equipment (BITE) output		
- Format:	CMOS 0-3.3 V	CMOS 0-3.3 V
- Load Impedance:	1 MΩ	1 MΩ
- Logic:	0 = Normal operation 1 = Alarm	
Power Input		
- Operating:	< 120 mW	< 125 mW
- Warmup:	< 140 mW	< 140 mW
- Input Voltage:	3.3 ± 0.1 VDC	3.3 ± 0.1 VDC
- Current:	< 37 mA	< 38 mA

PHYSICAL SPECIFICATIONS

- Size:	1.6" x 1.39" x 0.45"	1.6" x 1.39" x 0.45"
- Weight:	< 35 g	< 35 g
- MTBF:	> 100,000 hours	> 50,000 hours

ENVIRONMENTAL SPECIFICATIONS

Operating:		
- Operating Temperature:	-10 °C to +70 °C	-40 °C to +85 °C
- Frequency Change Over Operating Temp Range: (max. rate of change 0.5 °C/minute):	$\pm 5 \times 10^{-10}$	$\pm 1 \times 10^{-9}$
- Frequency Change Over Allowable Input Voltage Range:	$< 4 \times 10^{-10}$	$< 4 \times 10^{-10}$
- Magnetic Sensitivity: (± 2.0 Gauss):	$< 9 \times 10^{-11}$/Gauss	$< 9 \times 10^{-11}$/Gauss
- Radiated Emissions.	Compliant to FCC part 15, Class B, when mounted in PCB.	Compliant to FCC part 15, Class B, when mounted in PCB.

ENVIRONMENTAL SPECIFICATIONS

- Vibration:	Maintains lock under MIL-STD-810, method 514.5, Procedure 1, 7.7 grms	Maintains lock under MIL-STD-810, method 514.5, Procedure 1, 7.7 grms
- Humidity:	0 to 95% RH per MIL-STD-810, Method 507.4.	0 to 95% RH per MIL-STD-810, Method 507.4
Storage and Transport (non-operating):		
- Temperature:	- 55 °C to +90 °C	- 55 °C to +90 °C
- Shock (1 ms half-sine):	1000 g	1000 g
- Vibration:	Maintains lock under MIL-STD-810, method 514.5, Procedure 1, 7.7 grms	Maintains lock under MIL-STD-810, method 514.5, Procedure 1, 7.7 grms

PERFORMANCE PARAMETERS

	-001	-002
Stability (Allan Deviation)		
	ADEV	**ADEV**
TAU = 1 sec	1.5×10^{-10}	2×10^{-10}
TAU = 10 sec	5×10^{-11}	7×10^{-11}
TAU = 100 sec	1.5×10^{-11}	2×10^{-11}
TAU = 1000 sec	5×10^{-12}	7×10^{-12}
RF Output Phase Noise (SSB)		
1 Hz	< -55 dBc/Hz	< -55 dBc/Hz
10 Hz	< -78 dBc/Hz	< -78 dBc/Hz
100 Hz	< -113 dBc/Hz	< -113 dBc/Hz
1000 Hz	< -128 dBc/Hz	< -128 dBc/Hz
10000 Hz	< -135 dBc/Hz	< -135 dBc/Hz
100,000 Hz	< -140 dBc/Hz	< -140 dBc/Hz
Frequency Accuracy		
- Calibration at shipment:	$\pm 5 \times 10^{-11}$	$\pm 5 \times 10^{-11}$
- Retrace (48 hrs off):	$\pm 5 \times 10^{-11}$	$\pm 5 \times 10^{-11}$
- Aging, monthly:	$<3 \times 10^{-10}$	$<3 \times 10^{-10}$
- Aging, yearly:	$<1 \times 10^{-9}$	$<1 \times 10^{-9}$
- 1 PPS Sync.:	± 100 ns	± 100 ns
Digital Tuning		
- Range:	$\pm 2 \times 10^{-8}$	$\pm 2 \times 10^{-8}$
- Resolution:	1×10^{-12}	1×10^{-12}
Analog Tuning		
- Range:	$\pm 2.2 \times 10^{-8}$	$\pm 2.2 \times 10^{-8}$
- Resolution:	1×10^{-11}	1×10^{-11}
- Input:	0 - 2.5V into 100 kΩ	0 - 2.5V into 100 kΩ
Warm-up Time	< 130 s	< 180 s

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