Quartzlock

PRE-PRINT
FOR EFTF & ARMMS 2012

Concise Catalogue

Precise Frequency & Time Control Products

New Active & Passive Hydrogen Masers
Ultra Low Noise Signal Stability Analyser
New Ultra Low Noise **Distribution Amplifiers**
New Very Low Noise **Sub-Miniature Rubidium Oscillators** & Instruments
New range of **Miniature Rubidium Components** and Instruments
Very Low Noise GPS Time & Frequency References
Active Noise Filters
Timing Module

www.quartzlock.com

Business values

Team

Very skilled and experienced people in R&D, production, production test, calibration, QA, QC and business management. Our component suppliers, specialist sub-contractors, assembly services, software experts plus many others who make running Quartzlock a pleasure and make an important contribution to the highest quality and performance electronic products we design and build.

IPR

Quartzlock's Intellectual Property is in our designs, technology and techniques. We invest a large percentage of our revenue on R&D to keep ahead of our few competitors. Quartzlock's list of standard solutions to frequency control and active noise filtering, DDS, DPLL, synthesizers and other low noise "tools" such as our new CPT physics package, optics, laser and light modulation techniques enable us to meet demanding requests for even higher performance, in smaller, lighter, lower power products.

Brand

Some 50 years of close to market R&D, high quality manufacturing and test, has painted the Quartzlock brand with an excellent reputation for reliability and high performance.

Active and Passive Hydrogen Maser Laboratory

Quartzlock's maser based laboratory, commercially unique in the EU, and with very few exceptions elsewhere in the world, give our team the tools needed to do the measurement science essential for the high level of performance our products, R&D and production test require.

Product Line

Quartzlock specializes in Precise Time and Frequency Control. Quartzlock has the widest range of highest specification Hydrogen Masers, to the lowest cost Rubidium and GPS Disciplined Oscillators.

Continuous improvement

Our product specialization means that stability (AVAR), drift, spurii and phase noise will all be improved in current and future products. Quartzlock products outperform our competitors. More than a third of the products in this catalogue are new.

Warranties

Quartzlock have a standard three year warranty on Rubidium products (E10-MRX/A10-MRO have two years until end 2012 then change to three years). This level of confidence in reliability / MTBF is unique to Quartzlock.

Future

Tomorrows products will be even more stable and with lower power and phase noise characteristics at lower cost. Larger market sectors will be entered. Export sales increased. Customer defined products will sit alongside our "industry standard's".

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Index

Oven Controlled Crystal Oscillators

Time and Frequency Distribution

OEM Timing Products and Signal ‘Clean-up’ (Board level)

Active Noise Filter

Test and Measurement

GPS Time and Frequency References

OEM Rubidium Oscillators

Atomic Time and Frequency References

New Products

CH1-75A
Active Hydrogen Maser **page 70**

CH1-76A
Passive Hydrogen Maser **page 74**

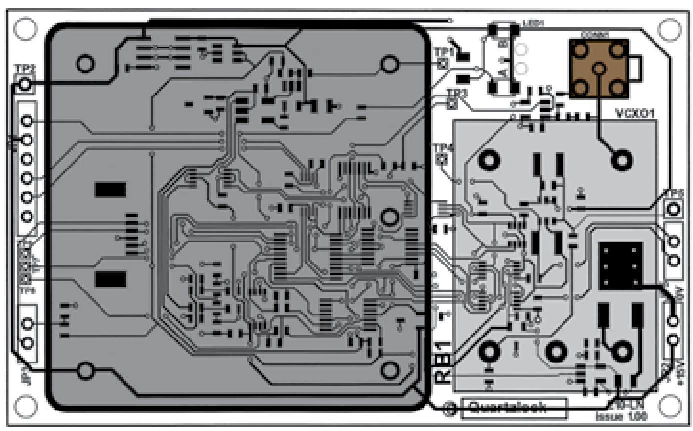
A7-MX using A10-MX as reference

A10-MX Rubidium Frequency Reference **page 54**

A5-8 Ultra Low Noise, High Isolation Primary Reference Distribution Amplifier **page 8**

E10-Y Series Desktop Rubidium Frequency Reference **page 68**

E10-MRX Sub Miniature Atomic Clock OCXO sized Rubidium Oscillator **page 60**



Actual size

E10-LN Very Low Noise Rubidium Oscillator Module – 91 x 55mm **page 48**

E1000 Low Noise 1U 19” Rack Mount Rubidium Frequency Reference **page 58**

E8000 GPS Disciplined Low Noise OCXO Time and Frequency Reference **page 42**

Quartzlock's Journey

1964 Saw the first Clive Green & Roger Davis production-run products in RF & microwave frequency "down convertors" and RF VHF sources. These were followed by CW & AM radio transmitters, 600 Watt HF SSB Passive Grid Linear Amplifiers with exceptionally low, cross and inter-modulation products.

1970 High power VHF & UHF RF sources for MoD plasma research. RF Test equipment. An SSB, AM, CW TX 1000W single box test solution with SSB power measurement.

1980 True RMS RF power meter with dynamic range from 10mW to 1000W (linear scale), Worlds First TTL Synthesized Signal Generator (Peter Broadbent) helped keep UK Sonar ahead. A 100MHz Synthesized Signal Generator (Toby Holland under PB) Manual & Automatic modulation meters with phase mod capability. The most compact single portable 230V / 12V dc radiotelephone test set (John Lake, John Bloice, PB, CRG, Peter Ward and others)

1990 Exploited early LF Off Air Frequency Standard design with rapid R&D to an industry standard product selling low 1,000's (PB… Colin Desborough…Graham McCloud/Dr Cosmo Little)

2000 Consolidating Rubidium Technology and joined the Hydrogen Maser radio-technology originators and world leaders IEM Kvarz. Subsequently sold some 50 Active & Passive H Masers around the world with Quartzlock's own A5 Ultra Low Noise Distribution Amplifiers & A6 Frequency Convertors. The Quartzlock A7-MX Signal Stability Analyzer production began (CL, WK) A5, A6, A7 early A10 Rb, A5000, A8 GPS line followed (Dr Wolfgang Klisch, Hadwin Kramer).

2010 New A5000, E1000, E8000, E8010, E8-X, E8-Y, include new A6-CPS technology for low noise & clean technology. 1PPS timing module introduced.

2012 The introduction of completely new sub-miniature Rb components & Rb instruments with Ultra Low Noise versions available. The E10-MRX Rb is lowest cost & power, OCXO size with 150g mass. A NMI level E5 Signal Distribution Amplifier (replaces E5) is introduced.

Radio telephone test set *1980*

10mW–1000W RMS Power Meter

Modulation meter *1975*

World's first TTL synthesized signal generator *1970s*

Contact Quartzlock

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SC Cut Oven-controlled Quartz Oscillator

- Phase noise -110dBc/Hz @ 1Hz (10MHz)
- Phase noise -123dBc/Hz @ 1Hz (5MHz)
- Stability $2x10^{-12}$/s ($8x10^{-13}$/s in benign environment) (10MHz)
- Stability $5x10^{-13}$/s (5MHz)

Features

- Very low phase noise
- High stability (AVAR)

Benefits

- Improves considerably instrument noise and stability specifications
- The basic internal quartz reference

Applications

- One of the key components in Quartzlock's Very Low Noise instruments

Specification

Frequency	5 & 10MHz, other frequencies in range 4–20MHz by request		
Output	Sine wave 7dBm (±2dBm)		
Frequency Ageing	Rate per day, at dispatch <$5x10^{-10}$		
Projected Ageing	Rate per year <$5x10^{-8}$		
Operating Temperature Range	Standard -20°C to +70°C, (other options possible from -40°C)		
Temperature Stability	<$1x10^{-8}$ over -20°C to +70°C		
Stability With Supply Voltage	<$1x10^{-9}$ for 10% change		
Stability With Load Change	<$1x10^{-9}$ for 10% change from 50ohms		
Short Term Stability (1 sec)	<$2x10^{-12}$		
Phase Noise (data for 10MHz quoted)	**Offset**	**10MHz Typical values**	**5MHz Typical values**
	1Hz	<-110dBc/Hz	<-123dBc/Hz
	10Hz	<-125dBc/Hz	<-140dBc/Hz
	100Hz	<-135dBc/Hz	<-145dBc/Hz
	1kHz	<-150dBc/Hz	<-150dBc/Hz
	10kHz	<-155dBc/Hz	<-155dBc/Hz
	50kHz	<-160dBc/Hz	<-163dBc/Hz
Warm-Up Error	±$1x10^{-8}$ of final frequency after <8 minutes at 25°C		
Frequency Adjustment (electrical only)	+0.5 to +7.0V, stabilised output provided. Suitable for 10+ years life, 15 years typical ±0.5ppm minimum, positive slope		
Power Supply	+12V DC standard. +15 & +18V options		
Power Consumption	5W max. at switch on. Typically 1.2W when stabilised at +25°C		
Harmonics	<-30dB wrt carrier		
Dimensions (max)	36.1mm long, 27.2mm wide		
	19.4mm high		
Shock	IEC 68-2-27 Test Ea, 50G for 11mS		
Vibration	IEC 68-2-06 Test Fc, 10-55Hz, 1.5mm , 55-500Hz, 10G		
Storage Temperature	-40 to +90°C		
Humidity	>90% non-condensing, solder sealed package		

1...100MHz
Distribution Amplifier

□ Exhibits low 1/f AM & PM noise

The Quartzlock A5-8 Distribution Amplifier is a precision distribution amplifier for use with Frequency Standards or other signals where a need for multiple outputs from a single generator is required. Available in 8 outputs. The A5-8 replaces previous A5 models; the specification has improved isolation and other parametrics. *NB This specification is provisional at time of going to press, final specification due June 2012, ask Quartzlock.*

Features

- High Isolation between inputs and outputs
- Ultra low phase noise
- Ultra high stability
- Very low harmonic distortion
- Bipolar Junction Amplifiers 24Vdc BBU &/or 90 ... 240Vac operation

Benefits

- Hydrogen Maser compatible performance
- Retains original input signal characteristics
- 8 outputs
- May be supplied with two or three channel inputs
- No cross channel interference between outputs for mission critical applications

Applications

- Frequency Distribution where the highest levels of stability and lowest levels of phase noise are required
- National Standards Laboratories
- Calibration Laboratories
- Research and Development
- Production Test

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Typical Characteristics *

No of outputs	8
No of inputs	1 to 4 (Note mixed frequencies are permitted in one unit)
Input characteristics Impedance: Level: Input SWR:	 50 Ohm nominal 0dBm to +13dBm adjustable, sine wave <1.2:1 at 10MHz <1.5:1 at 100MHz
Output Characteristics Impedance: Level: Output SWR:	 50 Ohm nominal 13dBm nominal into 50 Ohms (1 volt RMS) <1.2:1 d) Maximum Output: 17dBm at 10MHz typical
Frequency Response	2MHz to 100 MHz +/-1.5dB 500kHz to 100MHz+/-3dB
Harmonics	(at nominal output, 10MHz) (Source harmonics less than -60dBc) Second Harmonic <-50dBc Third Harmonic <-40dBc
Isolation a) Output to output: b) Output to input: c) Input to input (crosstalk):	 >90dB(adjacent outputs) at 10MHz 130dB at 5MHz (non adjacent outputs) typ. >70dB (adjacent outputs) at 100MHz Typically >110dB at 10MHz and >90dBm at 100MHz >110dB at 10MHz >90dB at 100 MHz >90dB at 5MHz >80dB at 10MHz >55dB at 100MHz
Phase Noise @ 10MHz 1Hz 10Hz >100Hz	dBc/Hz -140 -150 -165
Short term stability @ 10MHz 1s 10s 100s	 <10^{-13} <$3x10^{-14}$ <10^{-14}
Spurious Outputs	< -110dBc (above 1MHz) (typically <-120dBc) (Spurious outputs are exclusively from the switch mode power supply)
Broadband Noise	<-148dBm/Hz
Delay match between outputs	<2ns (within group of 4 outputs <0.3ns)
Temp stability of delay	10ps/deg C
Phase change at output	Due to open or short at any other output (Calculated from isolation): 0.5ps (at 10MHz)
Output Failure Alarm	LED on each output + common active low logic output

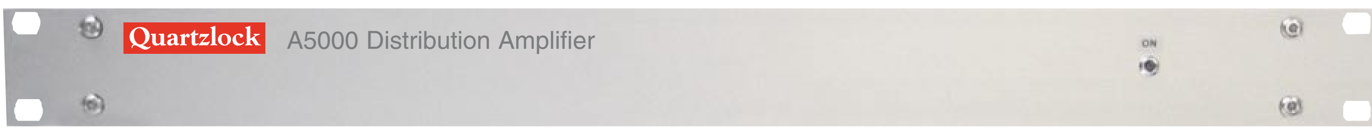
Measurement Results *

Input characteristics Impedance: Level: Level max:	 50 ohm +13dBm, 1V RMS 1.2VRMS, 5MHz
Output characteristics Impedance: Level: Maximum:	 50 ohm 1V into 50 Ohms (RMS) 1.1V into 50 Ohms
Frequency Response	800kHz – 100MHz ± 1dB
Harmonics	5MHz source harmonics less than -60dBc
Isolation Output to output: Non-adjacent o/p typ @ 5MHz: Output to Input:	 >110dB 5–60MHz 130dB >70dB 70–100MHz
Stability AVAR	1s tba
Phase noise (5MHz) offset 1Hz 10Hz 1kHz Noise Floor	 -170dBc
Phase stability	10ps/°C (5MHz)
Supply	90 ... 240Vac &/or 24Vdc BBU Battery Input
Size	International 2U Rack Mount
Warranty	1 year (ask Quartzlock about low cost extended warranty)

*** Provisional Specification**
(Final spec due June 2012, contact Quartzlock)

A Fully Specified, 1–20MHz Low Cost Distribution Amplifier

- Comprehensive Specification
- Excellent Short Term Stability & Phase Noise
- 1MHz – 20MHz Bandwidth



The E5000 Distribution Amplifier is a 1U Rack Mount unit. The E5000 allows a cost and space efficient way to distribute reference frequencies throughout a system or lab with virtually no signal degradation. The standard E5000 accepts input frequencies of 1MHz to 20MHz and provides twelve outputs of the same frequency.

Features

- Compact design
- -115dBc/Hz @ 1Hz phase noise
- 90dB @ 10MHz Isolation

Benefits

- Unity Gain
- 0dBm to 10dBm input
- High Stability
- High Isolation
- Low Distortion

Applications

- Industrial Calibration Laboratories
- Telecoms
- Test Solutions
- RF Test Bench
- Production Test

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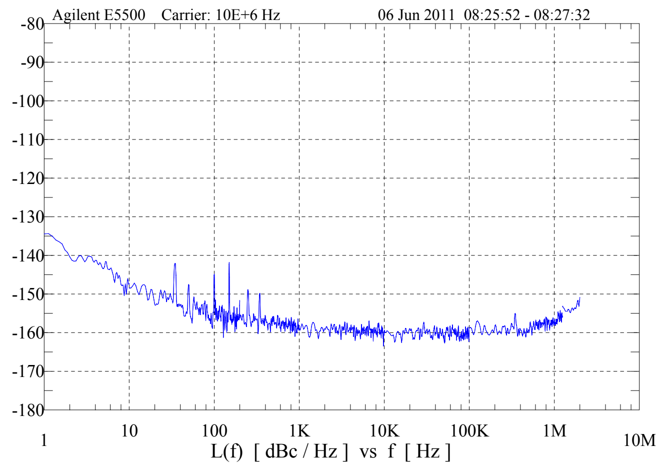
Specification

No of Outputs	12	
No of Inputs	1	
Input characteristics	Impedance Level Input SWR	50 ohm nominal +10dBm nominal <1.2 :1 at 10 MHz
Output characteristics	Impedance Rated output	50 ohm nominal at 10MHz 12dBm into 50 ohms (@ +13dBm max, distortion will occur)
	Output SWR	<1.2:1
	Maximum output	13dBm into 50 ohms at 10MHz typical
Frequency response	1MHz to 20MHz +/-1.0dB	
Harmonics	(at rated output,10MHz) (source harmonics less than -60dBc) Second harmonic < -50dBc Third harmonic < -50dBc	
Isolation	**Output to output** (adjacent outputs) >60dB at 10 MHz **Output to output** (non adjacent) >70dB at 10MHz Output to input >90db at 10MHz	
Short term stability (at 10MHz)	2×10^{-13} tau=1sec 2×10^{-14} tau=10sec 5×10^{-15} tau=100sec	
Phase Noise (10 MHz)	Offset	Typical phase noise,dBc/Hz
	1Hz	-132
	10Hz	-145
	100Hz	-152
	1kHz	-158
	10kHz & Noise floor	-160
Spurious outputs	< -100dBc	
Broadband noise	< -155 dBc/Hz	

Delay match between outputs	< 1 ns
Delay input to output	< 6ns
Supply	85 ... 240V ac
Size	1U 19" 44 x 483 x 240mm

Phase Noise



Typical Output to Output Stability

Measured in 200Hz bandwidth

Tau	Allan Variance
1ms	5×10^{-11}
10ms	8×10^{-12}
100ms	8×10^{-13}
1s	2×10^{-13}
5s	2×10^{-14}
10s	1.5×10^{-14}
100s	3×10^{-15}
1,000s	1×10^{-15}
10,000s	$\times 10^{-16}$

Ask Quartzlock for plots

Fully Specified, Low Cost, Desktop **Distribution Amplifier**

- Compact Desktop
- 1MHz–20MHz Bandwidth
- Comprehensive Specification
- Excellent Short Term Stability & Phase Noise

Approx actual size

Features

- Very Low Cost & Very Small Size
- 1MHz–20MHz Bandwidth
- Comprehensive Specification
- Excellent Short Term Stability & Phase Noise
- 6 outputs

Benefits

- +13dBm Output Level
- +6dBm to +12dBm
- High Stability
- Low Distortion
- High Isolation

Applications

- Industrial Calibration Laboratories
- Telecoms
- Test Solutions
- RF Test Bench
- Production Test

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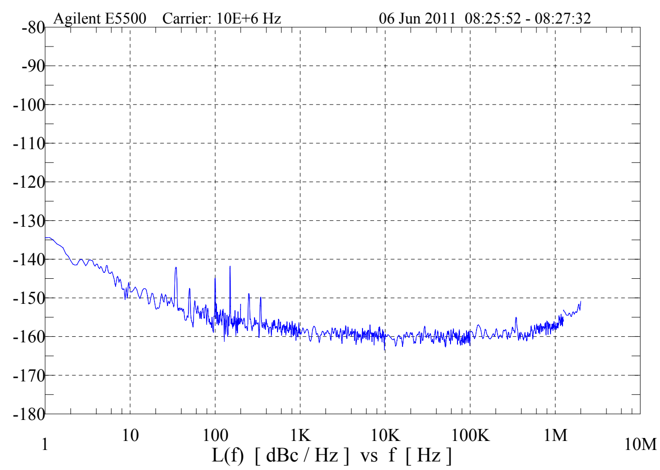
Specifications

No of outputs	6
No of inputs	1
Input characteristics	**Impedance** 50 ohm nominal **Level** +10dBm nominal +6 dBm to +12 dBm **Input SWR** <1.2 :1 at 10 MHz
Output characteristics	**Impedance** 50 ohm nominal **Rated output** at 10MHz 12dBm into 50 ohms (@ +13dBm max, distortion will occur) **Output SWR** <1.2:1 **Maximum output** 13dBm into 50 ohms at 10MHz typical
Frequency response	1MHz to 20MHz +/-1.0dB
Harmonics	(at rated output,10MHz) (source harmonics less than -60dBc) Second harmonic < -50dBc Third harmonic < -50dBc
Isolation	**Output to output** (adjacent outputs) >50dB at 10 MHz typically >60dB **Output to output** (non adjacent) Ask Quartzlock **Output to input** >90db at 10MHz
Short term stability (at 10MHz)	2 x 10^{-13} tau=1sec 2 x 10^{-14} tau=10sec 5 x 10^{-15} tau=100sec
Phase noise (10MHz)	**Offset** / **Typical phase noise, dBc/Hz** 1Hz -132 10Hz -145 100Hz -152 1kHz -158 10kHz -160 100kHz -160
Spurious outputs	< -100dBc
Broadband noise	< -155 dBc/Hz
Delay match between outputs	< 1ns
Delay input to output	< 6ns
Supply	12V dc. E5-X6 is supplied with 85... 240V ac supply
Size	105 x 30 x 125mm

Phase Noise



Typical Output to Output Stability

Measured in 200Hz bandwidth

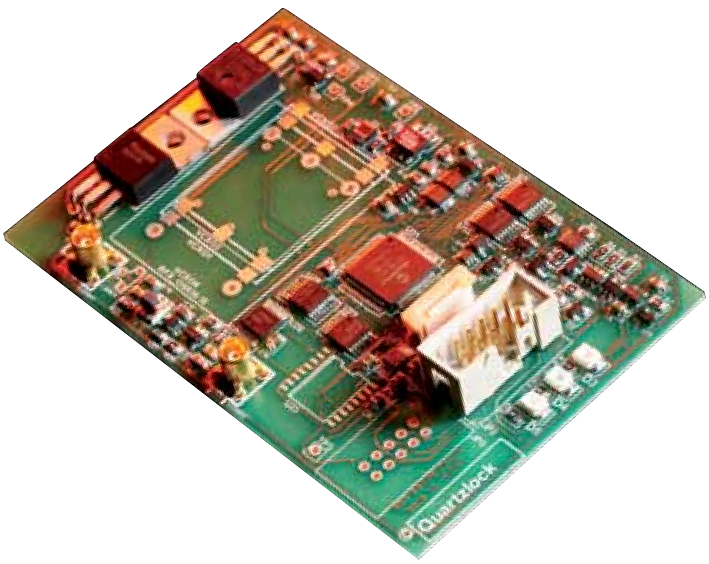
Tau	Allan Variance
1ms	5x10^{-11}
10ms	8x10^{-12}
100ms	8x10^{-13}
1s	2x10^{-13}
5s	2x10^{-14}
10s	1.5x10^{-14}
100s	3x10^{-15}
1,000s	1x10^{-15}
10,000s	8x10^{-16}

Output to Output Stability

Ask Quartzlock for plots. Typically x10-14/s

OEM 1PPS Timing Module

- Compact form factor
- License available
- Very fast lock to GPS



STOP PRESS Now available as a complete instrument

This is a PCB level product to control an OCXO or Rubidium oscillator from an external 1PPS. The A6-1PPS uses a 3 state Kalman filter algorithm to measure & correct the frequency offset of the oscillator with respect to the 1PPS input. Time-tagged 1PPS to 200ps resolution & <1ns jitter.

Features

- 1PPS output
- 10MHz output
- Self calibrating internal clock analogue interpolator.
- 1PPS time tag resolution of 200ps,
- <1ns rms jitter

Benefits

- Holdover mode is initiated by failure of the 1PPS input
- Reduced 1PPS jitter
- Fast lock to high accuracy from raw GPS 1PPS

Applications

- Defence timing
- WiMAX Base stations
- 3G Base stations (WCDMA, CDMA2000)
- LTE 4G
- Digital Video Broadcast
- General Timing and Synchronization

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A locking module for timing

This module is designed to lock a 10MHz stable oscillator, either OCXO or rubidium, to the 1PPS time mark signal generated from a GPS receiver. The module can be programmed for a wide range of controlled oscillator parameters, and GPS receivers. The controlled oscillator can be either on or off the board. A stable 1PPS time mark is generated from the controlled oscillator. This can be adjusted to any offset from the GPS 1PPS in 1ns steps.

The control algorithm used is designed to give optimum control results and the fastest possible acquisition from switch on.

Design strategy

This module is designed to lock a 10MHz stable oscillator, either an OCXO or a rubidium, to the 1PPS time mark signal generated from a GPS receiver.

There are a number of challenging problems involved in this, as the data rate by definition is only one measurement per second. In order to get sufficient frequency resolution to correct the oscillator, a very long averaging time would be required.

Because the 1PPS time mark is a fast rise time logic signal, the only measurement that is feasible is to time tag the incoming 1PPS edge relative to a local clock driven by the controlled oscillator. By calculating the rate of change of the arrival time over a suitable averaging period, the frequency offset of the controlled oscillator can be calculated. **An alternative strategy** would be to set the time of the first 1PPS arrival as the zero phase of a phase detector with a range of +/- 0.5s. This is equivalent to +/- Pi radians. A phase lock loop would then provide a very slow control of the oscillator.

In both systems the timing accuracy and resolution of the incoming 1PPS is important. Modern GPS receivers provide a 1PPS output jitter of between 1us RMS for a navigation receiver, to less than 7ns RMS for a special timing receiver operating in position hold mode. It is desirable that the timing resolution of the module should be better than this, as otherwise quantization noise would enter the averaging process and degrade the performance of the system. It would only be possible to compensate for this by increasing the averaging time. A suitable specification for time resolution is +/- 1ns.

To achieve this directly would need a 1GHz clock. A much more suitable method is an analog time interval expander. This device has been used in many designs of frequency counter starting with the Racal 1992. The principle is that an error pulse is generated which has a width equal to the time between the incoming edge to be timed, and the next clock pulse. For example, with a 100ns clock, the error pulse will have a width of between 0 and 100ns. This error pulse is then used to charge a capacitor or integrator. The capacitor or integrator is then discharges at a much slower rate, say 1/1000 of the rate. The resulting stretched pulse is then measured using the available clock pulses. The improvement in resolution equals the ratio of the discharge to charge rate. For the example above the resolution will be 100ps.

The next thing to consider is the choice of the control algorithm. This must provide an appropriate control bandwidth so the short term stability of the controlled oscillator (Allen variance) is optimised over a wide range. The ideal bandwidth will vary considerably between a low cost OCXO, and a rubidium.

One option is to use a simple phase lock loop. This would be a type 2 second order loop (ie with an integrator in the loop filter) with a zero to give suitable phase margins for optimum dynamic performance. **However** one problem with a phase lock loop is that it must reduce the initial phase error to zero by changing the frequency of the VCO. With the very long loop time constant necessary to remove the effect of the GPS time jitter, the eventual settling of the loop could take several days. It is also difficult to extract measures of performance from the loop, for example it is difficult to estimate the current frequency error of the VCO. **It was felt that a frequency control loop would settle quicker.** For a frequency standard we do not mind operating with a fixed phase offset, and there is no need to reduce this to zero.

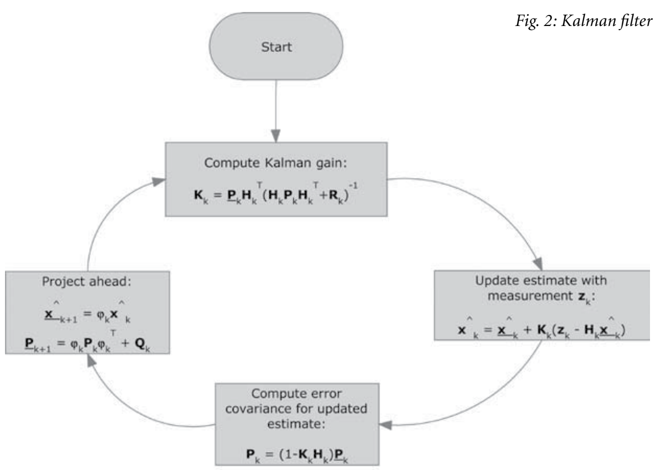
→

One possible method of extracting frequency offset from phase data is a quadratic least squares fit on a block of data. This is a standard method for extracting phase offset, frequency offset, and frequency drift from phase difference information. Having extracted the offset frequency, we can then make a correction to the controlled oscillator to remove the offset. If the control constant was known exactly, there would be no under or overshoot. The problem with this method is that we do not know how large to make the block of data that we analyse. The reliability of the fit is given by the correlation coefficient, and ideally this should be monitored on a continuous basis. What is required is a continuous least squares process. This is of course, a Kalman filter, and this was the eventual method selected for implementing the control algorithm.

The Kalman filter will be briefly described in general in a (hopefully) simple way, and then the specific implementation for our problem will be described in more detail.

A block diagram of a Kalman filter is given in figure 1. It is basically a recursive estimation, based on noisy measurements, of the future "state" of a system . The system is defined as a "state vector" and a "state transition matrix". The system in our case would be the controlled oscillator that we wish to predict, and the state vector would contain the phase offset, frequency offset, and frequency drift variables. The "state transition matrix" defines the differential

Fig. 2: Kalman filter



The system is modelled as follows:

$$\mathbf{x}_{k+1} = \varphi_k \mathbf{x}_k + \mathbf{w}_k$$

The measurement of the system occurs at discrete times:

$$\mathbf{z}_k = \mathbf{H}_k \mathbf{x}_k + \mathbf{v}_k$$

$\mathbf{x}_k$ = (n x 1) process state vector at time t_k
φ_k = (n x n) state transition matrix
$\mathbf{w}_k$ = (n x 1) vector sampled white gaussian noise
zk = (m x 1) vector measurement at time tk
$\mathbf{H}_k$ = (m x n) matrix giving the connection between the measurement and the state vector at time t_k

$\mathbf{v}_k$ = (m x 1) measurement error (sampled white gaussian noise)

$\mathbf{e}_k = \mathbf{x}_k - \hat{\mathbf{x}}_k$ Estimation error

$\mathbf{P}_k$ = (n x n) Estimation error covariance matrix
$\mathbf{Q}_k$ = (n x n) system covariance matrix

$\mathbf{R}_k$ = (m x m) measurement noise covariance matrix

relationship that exists between the state variables over one time increment. The concept of a system driven by noise processes is important here. If our Rb had absolutely constant drift, its output phase would be known for all time once the initial drift , frequency offset and phase offset had been determined. Data gathered a year ago would have as much validity as data an hour old. If the Kalman filter is given this model of the Rb, the results are identical to the least squares fit of all the data. Of course the quadratic least squares fit assumes that the Rb can be modelled by three constants.

A more realistic physical model would allow the drift to vary. If this varied in a deterministic way, we should add a further term to the state vector to reflect this deterministic process. However if the variation was random, we can tell the Kalman filter that this is so. Note that the filter is only optimum for white gaussian noise processes. However in our case we can model the noise of the Rb oscillator more accurately by adding white gaussian noise to each term in the state vector. If we add some uncorrelated noise to each term in the state vector, we end up with white phase noise, white FM noise, and random walk FM noise due to the single and double integration in the model. This is shown in figure 2.

The measurements are also assumed to be contaminated with gaussian white noise. In our case we only have one measurement, that is phase offset. We do not know that the main contributer to measurement noise, the GPS receiver, is either white or gaussian. However this is a limitation of the simple Kalman filter that we intend to use. If we are sure of the characteristics of the measurement noise, we can include this knowledge by adding more terms to the state vector. We are then essentially including the known aspects of the measurement in the system model.

As well as the state vector, the Kalman filter maintains a matrix that gives the current variances (mean square error) of the quantities in the state vector. These give us current estimates of the likely errors in the state vector, in our case variances of phase offset, frequency offset, and frequency drift. These will be very useful for display to the user. They also have another use, which will be demonstrated later. In effect they control the "bandwidth" of the filter. As more data comes in, the variances decrease, and the filter gives more weight to the current estimate(which represents the complete history of the data), and less to the current measurement. The measurement variance, which we have to tell the filter, also affects the "bandwidth". If we tell the filter that the measurement is noisy, it reduces the bandwidth.

So far we have considered the Kalman filter as a device for analysing the incoming data in an optimum way. **However we need to control the Rb oscillator, and reduce the frequency offset to zero.** An elementary method would be to write periodic corrections to the Rb control DAC, and wait for the Kalman filter to track out the resulting discontinuity in the measurements.However there is a much better way. If we adjust the frequency offset term in the state vector at the same time that we correct the Rb , the filter will ignore the correction, and no extra settling time will be required. In effect we are defining the model of the Rb to have a frequency discontinuity at

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a particular time, and provided the real Rb has that discontinuity, the Kalman filter will see no difference between the model, and what the measurements are telling it about the real system.

Using this technique, we can correct the Rb as often as we like. However if we are uncertain as to the exact value of the control constant, then the correction will undershoot or overshoot the model. Another trick that can be useful is if we know that there is a measurement discontinuity, but we do not know how large it is. An example would be if the GPS signal disappears for any reason. When satellites were reacquired, there could be a phase discontinuity between the GPS 1PPS and the locking module internal clock. Although we cannot tell the filter the amount or direction of the discontinuity, we can tell it that its current estimate of phase is completely unreliable. We do this by adding a large number to the appropriate term of the error covariance matrix. The filter then gives maximum weight to the measurements to reacquire the phase as quickly as possible, however as it thinks its frequency is still accurate, it does not give excessive weight to the rate of change of phase measurement, and the frequency covariance hardly rises.

The Kalman filter can predict ahead if measurement data fails. In this case both the state vector and the error covariance matrix will be updated. The previously estimated value of drift will update the frequency offset automatically. Frequency corrections can be made in the usual way.The error covariances will rise to reflect the lower confidence in the predictions as time passes. When measurements resume, the filter will automatically recover and the error covariances will start to fall. Thus the user is always aware of the reliability of the frequency output. If an unknown phase step is expected on resumption of measurements, then the phase variance should be augmented as previously described.

Technical details of design

The design is based around a PIC18F6723 microcontroller. This is a high end controller with 5 capture/compare modules and 4 timer/counters. The time interval expander is tightly integrated with the processor internal peripherals to produce an economical design. The basic timing resolution is 400ns (one processor cycle at a 10MHz clock frequency). The time interval expander extends the resolution by 2000 times. In order to avoid the problems of expanding a pulse of zero width, one cycle of the 10MHz clock (100ns) is added to the time error pulse. This gives an unexpanded pulse width of 100ns to 500ns. After expansion, the pulse is 200us to 1ms. This is timed by the 400ns clock to give a basic +/-200ps resolution.

A time interval expander must be calibrated as otherwise a glitch will be produced when the time error pulse rolls over from 500ns to 100ns, and vice versa. This is caused by the expansion ratio not being exactly the expected 2000 times. The expansion ratio may drift with time and temperature.

As the incoming 1PPS only needs measuring once per second, the dead time is used to calibrate the time expander. The hardware generates exact pulses of 100ns and 500ns by gating from the 10MHz clock. These are expanded and measured. The calculated end points of the expanded pulse are used to correct the real measurement of the incoming 1PPS. This auto calibration operates continuously.

The control of the OCXO or other controlled oscillator uses a precision tuning voltage derived from DtoA convertors . Two 16 bit DACs are used, with the output of the fine tune DAC divided by 256 and added to the output of the coarse tune DAC. This gives effectively 24 bit resolution with an overlap between the coarse and fine tune DACs. A software normalisation process ensures that the fine tune DAC is used for tuning most of the time. Only when the controlled oscillator has drifted out of range of the fine tune DAC would the coarse tune DAC need adjusting, with the chance of a very small glitch in the tuning voltage. A precision, low noise, voltage reference is used to supply the DACs.

The microcontroller is provided with an RS232 interface. A simple set of control codes enable monitoring and set up of the controlled oscillator parameters to accomodate a wide range of controlled oscillators. A Windows front end program will use the control codes to enable the operation of the PLL to be monitored with real time graphs of performance measures.

Software design

In normal operation the auto calibration performs calibration cycles every 20ms. The approximate time of arrival of the next 1PPS input pulse is known, so the calibration cycles are paused while the 1PPS is measured. The raw measurement of the arrival time is corrected for the actual expansion ratio and is scaled to lie in the range -500.000000 to +499999999 ns relative to the internal clock.

The first valid 1PPS edge to arrive after reset is used to zero the internal clock. This makes the arrival time initially close to zero, and avoids problems with lack of precision in the floating point calculations which follow.

The corrected time tag is sent to the Kalman filter routine which runs once every second. The estimate of the controlled oscillator phase, fractional frequency offset, and drift (the state variables) is updated by the new measurement. Also updated is the error covariance matrix which provides an indication of the accuracy of the estimate of the state variables.

After update of the filter, the frequency correction for the controlled oscillator is calculated. This is done by scaling the Kalman frequency offset estimate by the known (programmed) tuning slope of the oscillator. The correction is then added to the frequency control register of the oscillator.

The tuning voltage is divided between the coarse and fine tune DACs as follows: When normalisation is performed, the fine tune DAC most significant 8 bits are set to mid point (80h). The least significant 8 bits of the fine tune DAC are set to the least significant →

8 bits of the tuning word. The coarse tune DAC is then set to provide the final tuning voltage. During all subsequent tuning, only the fine tune DAC is used over its 16 bit range. If the range is exceeded, the normalisation procedure is repeated.

A state machine provides control of locking. After reset the last value of the frequency control register, which has been stored in EEPROM on a regular basis, is restored. This will retune the controlled oscillator to very nearly the correct frequency. The Kalman update is disabled and the software waits for the following all to occur (state 0):

a) Rubidium reference warm up input to go low or OCXO supply current to drop below a threshold showing the Rubidium/OCXO has warmed up

b) A 1PPS input capture has occured

The sofware then requests a reset of the internal clock (state 1). This will normally occur on the next 1PPS to be received.

Once a clock reset has occured, the Kalman filter tracking is started, however frequency corrections are not made to the controlled oscillator. (state 2) Each capture must be within 50us of the first capture, otherwise the reset state is reentered. After 100 successful captures, state3 is entered provided the performance monitor, MEANFREQERROR is below a threshold.

The performance monitor, MEANFREQERROR is calculated as follows:

The mean of the Kalman frequency offset estimate is calculated by means of a 5th order exponential filter. (In the pre lock state the mean may not be near zero, ie there may be a constant offset between the controlled oscillator and GPS time)

After each iteration of the Kalman filter, the current deviation is calculated by subtracting the current frequency offset estimate from the running mean. This value is squared, and divided by the predicted variance from the error covariance matrix that is maintained by the filter. This normalises the actual deviation that is seen by the predicted deviation from the filter. (The predicted deviation only depends upon the system and measurement noise parameters NOT on the actual behaviour of the system.)

The normalised deviation in then filtered in a 4th order exponential filter. During warmup the performance measure will be high, indicating that the controlled oscillator is still drifting fast, relative to its predicted steady state performance. When the controlled oscillator is stable, and the Kalman filter has settled, the performance measure will drop below a threshold. At this point frequency corrections will be started. (state 3)

In state 3 corrections are made to the controlled oscillator. The filter and oscillator will continue to settle, until the performance monitor falls below a second threshold. At this point the lock indicator is switched off. (state 4)

The following parameters set up the Kalman filter to match the controlled oscillator:

a) Oscillator noise parameters:

S1 variance of random walk FM noise

S2 variance of white FM noise

S3 variance of white phase noise

OC1 oscillator tuning constant in fractional frequency/volt

OC2 maximum oscillator tuning voltage in volts, assuming 0V minimum

b) 1PPS noise root variance (a function of the GPS receiver used)

R measurement noise root variance in seconds

These parameters are programmed over the RS232 interface, and are stored in non volatile memory.

The oscillator noise parameters may be obtained from a measured Allen variance curve using a MathCad modelling program.

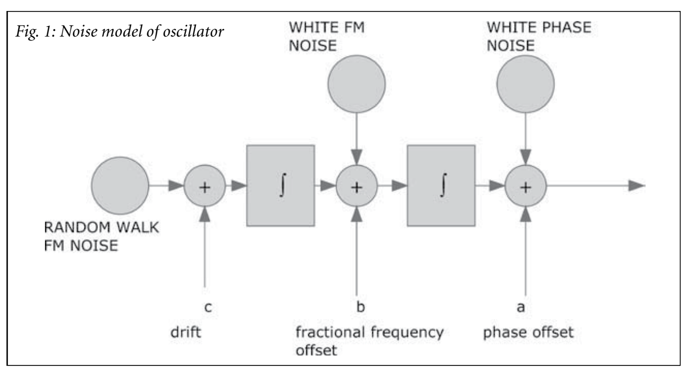
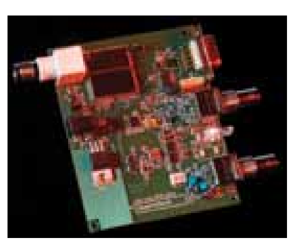


Fig. 1: Noise model of oscillator



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Specification

Frequency	10MHz
Input Level	100mv Pp to 5Vpp (Oscillator off board)
1PPS Input Impedance:	500 Ohms
Output Level	13+/-2 dBm (Oscillator on board)
1PPS Input Level	5V TTL/Cmos positive edge
Width	10us Minimum
Input Impedance	1000 Ohms
1PPS Output Level	5V TTL/Cmos positive edge
Width	10ms
Preset Offset Of 1PPS Output	-500000000 To +499999999 Ns in 1ns Steps
Timing Baseline	Selectable between fixed (minimum jitter) or kalman phase estimate (maximum accuracy)
External Tune Voltage	0 to span, where span is software adjustable between 5.8V and 10V
Lock Indicator	**On** Not Locked **Off** Locked, Low Phase Error **Short Flash Every Second** Locked, High Phase Error
Interface	See separate document
Interface Codes	See separate document
Performance	The control performance depends very much on the quality of the controlled oscillator and the source of the 1PPS synchronizing signal. For these reasons it is difficult to quote absolute performance figures.
Power Supply	14 to 30V (On board OCXO is used) An external OCXO or Rubidium may be used. 12 To 30V (No on-board OCXO)

The Following Cases Are Typical Controlled Oscillator: Rubidium	
1PPS Source	Passive Hydrogen Maser (Essentially no 1PPS Jitter) Result: Allen Variance 100s $1x10^{-12}$ 1000s $3x10^{-13}$ 10,000s $1x10^{-13}$
Controlled Oscillator: Rubidium	
1PPS Source	Quartzlock E8-Y/E8000 GPS Receiver in Position Hold Mode Result: Allen Variance 100s $1x10^{-12}$ 1000s $1x10^{-12}$ 10,000s $8x10^{-13}$
Current Consumption	150mA Typical (On-board OCXO)
Size	25 x 25 x 5mm (Without OCXO)

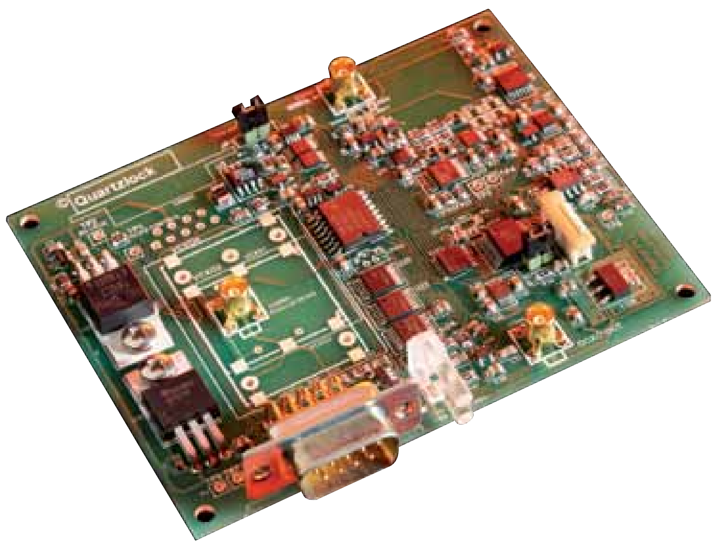
The Quartzlock A3 series of SC cut OCXO's are ideal for use on the A6-1PPS design-in board product. The oscillator performance defines the 1PPS accuracy.

A3 specification is typically:

Short term stability AVAR $8x10^{-13}$/second PN -110dBc/Hz @ 1Hz

DPLL, DDS Active Noise Filter

- 1MHz to 40MHz output frequency
- 4mHz to 500mHz PLL bandwidths
- Compact OEM board for a wide range of applications



The A6-CPS digital phase locked loop (PLL) provides an low noise, very high short term stability filtered output which can be customised to a specific application.
The A6-CPS digital PLL may be fitted into the Quartzlock A6 frequency convertor with BVA OCXO, rubidium, GPS or other options.

Features

- RS232 monitor and control
- Pre-defined user bandwidths
- Wide range of OCXO supported

Benefits

- Improved phase noise
- Improved short term stability
- Low cost solution to upgrade existing designs and references
- Quick and simple to use and integrate

Applications

- Time and frequency reference for satellite communication ground stations, CDMA, LTE, DTV & DAB
- Frequency referencing of interception and monitoring receivers
- Wired and Wireless network synchronization
- Secure communications, C4, defence and R&D
- Radar & navigation systems
- Higher definition in MRI imaging systems

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Technical Description

This module is designed to overcome the disadvantages of narrow band width analog phase lock loops used to lock relatively stable oscillators together, or to generate arbitrary frequencies from a 10MHz reference with good phase noise, freedom from non harmonically related spurii, and good short term stability.

When locking a low noise OCXO to a rubidium reference, for example, the ideal PLL bandwidth will be very much less than 1Hz, probably in the region of 10 to 100mHz.

An analog loop will have a very long time constant integrator, leading to thermal drift, capacitor dielectric absorption, and operational amplifier offset drift. In addition, acquisition time of the loop will be very long, and if there is any frequency error, acquisition may not occur at all. There is also a problem of providing an effective "in lock" indicator to the user, or for use with associated equipment.

The digital loop overcomes all these problems. The long time constant integrator is replaced by a digital integrator that does not drift at all. A combination of an analog phase detector for low noise, and an extended range phase/frequency detector for certain acquisition can be used. The loop bandwidth can be set to maximum for acquisition, followed by glitch free reduction to the working bandwidth when the phase error becomes small. In addition performance measures related to the phase error in the loop, and the frequency error can easily be derived and used to indicate lock and bandwidth control. As an additional benefit a hold over mode that keeps the controlled oscillator tuning voltage constant if there should be a reference failure can be easily provided.

In order to generate arbitrary frequencies from a 10MHz reference, a DDS synthesiser is used. This has 36 bit resolution and is clocked at 10MHz from the reference. Output frequencies of 1.8MHz to 3.6MHz are available

as the reference input to the digital PLL. This enables the controlled oscillator (OCXO) to have a frequency range of 1.8MHz to 28.8MHz. The resolution at 10MHz output will be 1.45x10-11.

Technical details of design

The design uses mixer type phase detectors operating at frequencies between 1.8MHz and 10MHz. A dual phase detector is used with quadrature square wave inputs from the controlled oscillator. The main input , which is split between the quadrature phase detectors, is a sine wave input at a level between 0 and 13dBm, and is link selected to either come from the 10MHz reference input, or the output of the DDS synthesiser.

The sine wave signal from the controlled oscillator is converted to a square wave using a fast comparator. It is then divided by 2, 4 or 8 using digital dividers. A link selects direct, 2,4, or 8 divided signals.

The output from the dividers forms the "Q" reference signal to the Q phase detector. A quadrature "I" reference is generated by passing the Q signal through a programmable delay line, which may be set to delays from 10ns to 137ns, in steps of 0.5ns. This enables quadrature references to be generated for phase detector frequencies between 1.8MHz and 25MHz.

The outputs from the phase detectors are filtered and amplified by DC amplifiers with gain control using digital potentiometers. The gain is controlled by a software AGC system which tries to keep the input to the ADCs at optimum levels. The phase detector outputs are sampled by two channels of the 10bit AtoD convertor internal to the PIC 16F689 microcontroller. All other functions of the PLL are carried out by software.

The control of the OCXO or other controlled oscillator uses a precision tuning voltage derived from DtoA convertors . Two 16 bit DACs are used, with the output of the fine tune DAC divided by 256 and added to the output of the coarse tune DAC. This gives effectively 24 bit resolution with an overlap between the coarse and fine tune DACs. A software normalisation process ensures that the fine tune DAC is used for tuning most of the time. Only when the controlled oscillator has drifted out of range of the fine tune DAC would the coarse tune DAC need adjusting, with the chance of a very small glitch in the tuning voltage. A precision, low noise, voltage reference is used to supply the DACs.

The microcontroller is provided with an RS232 interface. A simple set of control codes enable monitoring and set up of the digital PLL parameters to accomodate a wide range of controlled oscillators. A Windows front end program will use the control codes to enable the operation of the PLL to be monitored with real time graphs of performance measures.

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Software design

The input to the software is the sampled I and Q signals from the phase detectors. These are sampled at a 1kHz rate. As the final bandwidth of the PLL will be less than 1Hz, this oversampling enables prefiltering to be used which extends the resolution and reduces noise in the 10bit AtoD convertor internal to the microcontroller. Single pole digital filters are used on both the I and Q channels. These are implemented as exponential filters which have a 3dB band width which is a function of the "order" of the filter. Filter orders between 0 (no filter) and 15 are provided. This gives bandwidths between 114Hz for order 1, and 4.8mHz for order 15. The filter order is varied as the user selected PLL bandwidth is varied.

After prefiltering, the I and Q channels, now at 16 bit resolution, are subsampled at a rate between 15.625 s/s, and 1.953 s/s depending on the user bandwidth and lock state of the PLL. The "Q" sample is now divided by the "I" sample (after checking that I>Q) to give a binary fraction. This is used to look up the phase value in a TAN-1 look up table. The look up table is used to synthesise two types of phase detector:

a) A phase detector with 16 bit resolution between Pi/2 and -Pi/2.

b) A phase/ frequency detector with 16 bit resolution between 2Pi and -2Pi. This phase detector is equivalent to the well known digital phase/frequency detector. This rolls over between 2Pi and 0 for positive cycle slips, and between -2Pi and 0 for negative cycle slips, and will always provide reliable lock if there is a initial frequency error.

The output of the selected phase detector now has digital gain applied, selectable between 1/256 and 128. After digital gain, the phase value is added into the integrator, which is 32 bits wide.

In order to make the loop stable, by providing a phase lead, the phase value has proportional term gain applied, also selectable between 1/256 and 128. This value is added to the upper 3 bytes of the integrator to give the tuning voltage (24 bits)

The tuning voltage is divided between the coarse and fine tune DACs as follows: When normalisation is performed, the fine tune DAC most significant 8 bits are set to mid point (80h). The least significant 8 bits of the fine tune DAC are set to the least significant 8 bits of the tuning word. The coarse tune DAC is then set to provide the final tuning voltage. During all subsequent tuning, only the fine tune DAC is used over its 16 bit range. If the range is exceeded, the normalisation procedure is repeated. A state machine provides control of locking. After reset the last value of the integrator, which has been stored in EEPROM on a regular basis, is restored. This will retune the controlled oscillator to very nearly the correct frequency. The loop is then opened and the software waits for the following all to occur (state 0):

a) Rubidium reference warm up input to go high.

b) OCXO supply current to drop below a threshold showing the OCXO has warmed up

c) A measure |I|+|Q| which is an approximate measure of the signal level at the phase detector to rise above a threshold.

When these conditions are fulfilled, the software attempts to lock the loop (state 1) by selecting the phase frequency detector, maximum bandwidth, and maximum subsample rate. It then closes the loop and waits for another measure, which is |phaseresult|, to drop below a threshold. The measure |phaseresult| is the modulus of each phase calculation filtered in an 8th order exponential filter, the bandwidth of which, for the 15.625 s/s subsample rate, equals 9.7mHz.

Once the lock threshold for |phaseresult| is reached, the lock state (state 2) is entered. The bandwidth is switched to the users selected bandwidth, which has been maintained in EEPROM, and the phase detector is switched over to the narrow band phase detector (Pi/2 to -Pi/2). All the time during normal operation , |phaseresult| is being compared to a lower threshold than the lock threshold. If it exceeds this threshold, state 3 is entered which provides a brief flash of the lock LED to warn the user that the selected bandwidth may be too narrow for the PLL to track the drift of the controlled oscillator fast enough. This low threshold is currently set at 480ps maximum phase error.

In extreme cases the lock threshold (4.8ns phase error) may be exceeded, in which case the software assumes lock is lost and re-enters state 1. A further performance measure is calculated, which is available over the interface. This is the first difference of the phase error, filtered in an 8th order exponential filter. It is corrected for subsample rate, and has a constant sensitivity of 5.8x10-15 per bit. (at 10MHz phase detector frequency)

This performance measure gives the mean fractional frequency difference between the controlled oscillator and the reference, and is useful for setting up the optimum bandwidth of the PLL.

The band width and damping of the PLL is controlled by 4 parameters, integrator digital gain, proportional digital gain, prefilter order, and subsample rate. These are preset for 8 values of user selected bandwidth, and can only be changed by modifying the software. It is possible to temporarily adjust the four individual parameters as part of a test procedure carried out over the RS232 interface. The selection of the 4 parameters has been optimised using a mathematical model of the PLL modelled as a MATHCAD spreadsheet. This could be made available to customers who wished to readjust the PLL parameters.

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Specification

Reference Input		
Frequency	10MHz	(DDS used)
	1MHz to 10 MHz	(no DDS)
Level	100mVPP to 5VPP	(DDS used)
	1VPP to 5VPP	(no DDS)
Input Impediance	1000 OHMs	
Controlled Oscillator		
Frequency	1MHz to 40MHz	(no DDS)
	1.8MHz to 28.8MHz	(DDS used)
Level (external oscillator)	100mVPP to 5VPP	
	High end options	**Typical option**
Phase Noise	-130dBc/Hz @ 1Hz offset	-110dBc/Hz
	-178dBc/Hz @ 10kHz offset	-160dBc/Hz
Stability Allan Variance	$8x10^{-14}$/s	$x10^{-13}$/s
Input Impediance	500 Ohms	
External Tune Voltage	0 to SPAN, where SPAN is software adjustable between 5.8V and 10V	
	Notes: a) If DDS is not used, controlled oscillator must be k times higher frequency than refeence, where k is link adjusted to 1,2,4,8 b) Either reference or controlled oscillator must be 10MHz to provide microcontroller clock	
Power Supply	14 to 30V	on board OCXO is used
	12 to 30V	no on board OCXO
Current Consumption	150mA typical	on board OCXO
	50mA	typical (no on board OCXO)
PLL Bandwidths	4mHz to 500mHz typical in 8 binary increments	
Frequency Pull in	Up to 7Hz initial frequency error	
Lock Indicator	On	Not locked
	Off	Locked, low phase error
	Short flash every second	Locked, high phase error
	Long flash, short flash	No processor clock
Interface	9.6kbaud, RS232, PC compatible, Windows front end program or USB	
Interface Codes	Ask Quartzlock for separate document	
PCB Size	94 x 75mm (may be substantially reduced in customised version). OCXO may mount off PCB.	

Active Noise Filter
Atomic Clock Clean up Oscillator

- 1MHz to 40MHz output frequency
- 4mHz to 500mHz PLL bandwidths
- Primary reference compatible

The A6-ANF Active Noise Filter has an Ultra Low Noise SC OCXO oven-controlled quartz oscillator which is used in Quartzlock's Active Noise Filter Clean Technology to filter input reference signals. The A6-ANF provides an ultra low noise, very high short term stability filtered output to make a significant improvement in Rubidium or Ceasium frequency reference.

Features

- RS232/USB monitor and control
- Pre-defined user bandwidths
- Comprehensive range of phase noise and STS options

Benefits

- Improved phase noise
- Improved short term stability
- Low cost solution to upgrade existing references
- Quick and simple to use and install

Applications

- Improved primary reference phase noise
- Improved primary reference short term stability

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b) A phase/ frequency detector with 16 bit resolution between 2Pi and -2Pi. This phase detector is equivalent to the well known digital phase/frequency detector. This rolls over between 2Pi and 0 for positive cycle slips, and between -2Pi and 0 for negative cycle slips, and will always provide reliable lock if there is a initial frequency error.

The output of the selected phase detector now has digital gain applied, selectable between 1/256 and 128. After digital gain, the phase value is added into the integrator, which is 32 bits wide.

In order to make the loop stable, by providing a phase lead, the phase value has proportional term gain applied, also selectable between 1/256 and 128. This value is added to the upper 3 bytes of the integrator to give the tuning voltage (24 bits)

The tuning voltage is divided between the coarse and fine tune DACs as follows: When normalisation is performed, the fine tune DAC most significant 8 bits are set to mid point (80h). The least significant 8 bits of the fine tune DAC are set to the least significant 8 bits of the tuning word. The coarse tune DAC is then set to provide the final tuning voltage. During all subsequent tuning, only the fine tune DAC is used over its 16 bit range. If the range is exceeded, the normalisation procedure is repeated. A state machine provides control of locking. After reset the last value of the integrator, which has been stored in EEPROM on a regular basis, is restored. This will retune the controlled oscillator to very nearly the correct frequency. The loop is then opened and the software waits for the following all to occur (state 0):

a) Rubidium reference warm up input to go high.

b) OCXO supply current to drop below a threshold showing the OCXO has warmed up

c) A measure |I|+|Q| which is an approximate measure of the signal level at the phase detector to rise above a threshold.

When these conditions are fulfilled, the software attempts to lock the loop (state 1) by selecting the phase frequency detector, maximum bandwidth, and maximum subsample rate. It then closes the loop and waits for another measure, which is |phaseresult|, to drop below a threshold. The measure |phaseresult| is the modulus of each phase calculation filtered in an 8th order exponential filter, the bandwidth of which, for the 15.625 s/s subsample rate, equals 9.7mHz.

Once the lock threshold for |phaseresult| is reached, the lock state (state 2) is entered. The bandwidth is switched to the users selected bandwidth, which has been maintained in EEPROM, and the phase detector is switched over to the narrow band phase detector (Pi/2 to -Pi/2). All the time during normal operation, |phaseresult| is being compared to a lower threshold than the lock threshold. If it exceeds this threshold, state 3 is entered which provides a brief flash of the lock LED to warn the user that the selected bandwidth may be too narrow for the PLL to track the drift of the controlled oscillator fast enough. This low threshold is currently set at 480ps maximum phase error.

In extreme cases the lock threshold (4.8ns phase error) may be exceeded, in which case the software assumes lock is lost and re-enters state 1. A further performance measure is calculated, which is available over the interface. This is the first difference of the phase error, filtered in an 8th order exponential filter. It is corrected for subsample rate, and has a constant sensitivity of 5.8x10-15 per bit. (at 10MHz phase detector frequency)

This performance measure gives the mean fractional frequency difference between the controlled oscillator and the reference, and is useful for setting up the optimum bandwidth of the PLL.

The band width and damping of the PLL is controlled by 4 parameters, integrator digital gain, proportional digital gain, prefilter order, and subsample rate. These are preset for 8 values of user selected bandwidth, and can only be changed by modifying the software. It is possible to temporarily adjust the four individual parameters as part of a test procedure carried out over the RS232 interface. The selection of the 4 parameters has been optimised using a mathematical model of the PLL modelled as a MATHCAD spreadsheet. This could be made available to customers who wished to readjust the PLL parameters.

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A6-ANF Typical Stability, Phase Noise and Spurii

Frequency Stability	**5 or 10MHz outputs**
1 to 30s	$5x10^{-13}$ (options available from 1 ... $2.5x10^{-13}$)
100s	$4x10^{-13}$
1 hour	$5x10^{-13}$
1day	$x10^{-12}$
Long Term Stability	**5 or 10MHz outputs**
1 day	$5x10^{-13}$
1 month	$4x10^{-11}$
1 year	$4x10^{-10}$

Phase Noise dBc/Hz in 1Hz BW	10MHz output	ULN option	5MHz output	ULN option
1Hz	-115	-122	-123	-130
10Hz	-146	-137	-145	-145
100Hz	-156	-143	-150	-153
1kHz	-163	-145	-155	-156
10kHz	-168	-145	-158	-156

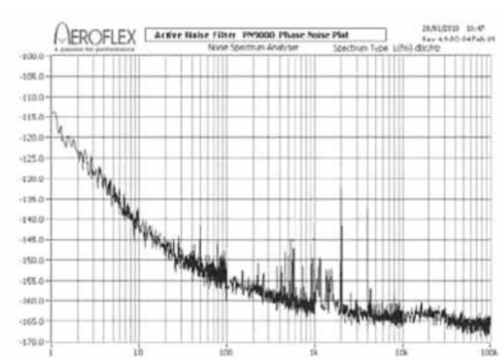
Harmonics	<40dBc
Spurious	<80dBc
Warm Time to $1x10^{-9}$	5min
Reference Input	
Frequency	10MHz (DDS used) 1MHz to 10MHz (no DDS)
Level	100mVpp to 5Vpp (DDS used) 1VPP to 5Vpp (no DDS)
Input Impedance	1000 OHMs
Controlled Oscillator	
Frequency	1MHz to 40MHz (no DDS) 1.8MHz to 28.8MHz (DDS used)
Level (external oscillator)	100mVPP to 5Vpp
External Tune Voltage	0 to SPAN, where SPAN is software adjustable between 5.8V and 10V

Notes: a) If DDS is not used, controlled oscillator must be k/m times higher frequency than reference, where k is link adjusted to 1,2,4,8 (where k is link adjusted to 1,2,4,8 and m adjusted to 2. This allows 5MHz reference. b) Either reference or controlled oscillator must be 10MHz to provide microcontroller clock

PLL Bandwidths	4mHz to 500mHz typical in 8 binary increments	
Frequency Pull-in	Up to 7Hz initial frequency error	
Lock Indicator	on	not locked
	off	locked, low phase error
	short flash every second	locked, high phase error
	long flash, short flash	no processor clock

Typical Characteristics

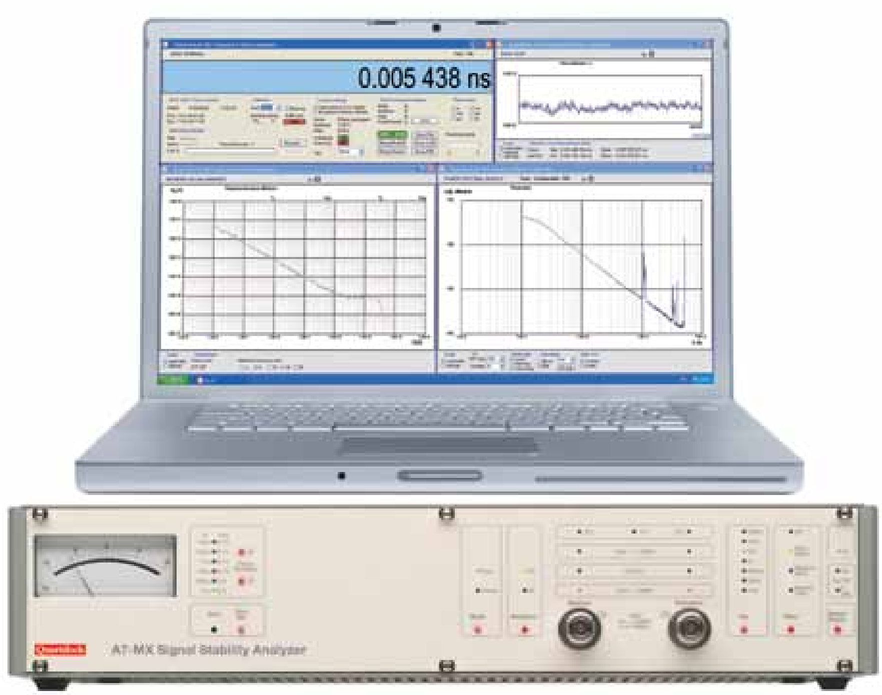
Input signals	2.048, 5MHz, 10MHz, 100MHz: 0.5Vrms sine, 50Ω
Output signals	5MHz, 10MHz or 100MHz, 0.5Vrms sine, 50Ω
Holdover performance	Long term stability: $2x10^{-11}$/day, $4x10^{-9}$/year ($4x10^{-10}$/year option);
Temperature stability	$<2x10^{-10}$ (-5C to +55C)
Management	RS-232C or USB
Environmental Characteristics	Operational: -5C to +55C
	Storage: -40C to +85C
	Humidity: 95% non-condensing
Power Supply	100–240Vac battery back-up option
Physical Dimensions	H x W x D (mm): 89 x 483 x 280 (3.5”x19”x11”)
Options	External Battery Back-up Ultra Low Noise Distribution Amplifier (E5) Choice of input and output frequencies



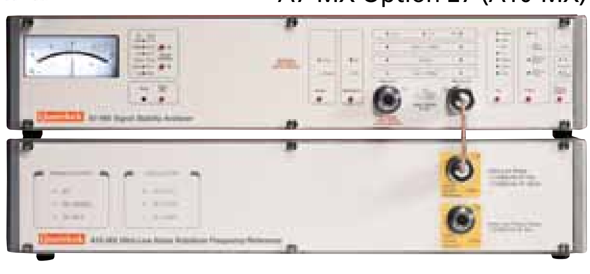
Example of ‘clean’ performance (2010)

Signal Stability Analyzer

- Very high resolution: <50fs single shot (5 and 10MHz)
- Very low noise floor: <5x10^{-14} @ 1s
- Selectable filters, resolutions and tau
- Ultra-fast measurement time



A7-MX Option 27 (A10-MX)



The A7-MX is a bench or rack mount instrument which interfaces with most notebook or desktop PCs, using an RS232 or USB interface on the computer.

The instrument includes a differential multiply and mix chain, and a 2 channel digital phase comparator. An analog meter shows frequency offset or phase difference. The A7-MX has a close-in phase noise personality 500mHz to 500Hz.

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Features

- Broadband 50kHz–65MHz input with high resolution 5 or 10MHz input
- Large digital display of phase / relative & absolute frequency
- Block storage of data files enables offline analysis
- 32,768 data point storage
- Crash proof with 24Vdc Battery Back Up
- On screen Allan variance and phase noise plots in real time
- Measurement error fully specified
- Plot print and save functions

Benefits

- Unskilled operation
- Unequalled performance
- External PC enables low cost 2-3 year upgrades
- Flexible and easy to use
- Saves up to 40% of oscillator R&D time

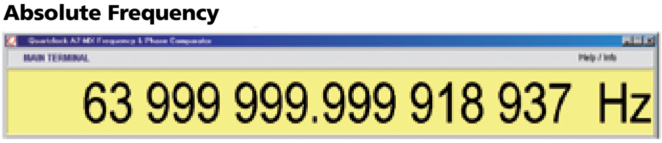
Applications

- Stability analysis of oscillators
- Close-in Phase noise analysis
- Atomic frequency standard calibration
- Active & passive component phase stability measurement
- ADEV, Modified ADEV, TVAR, MTIE etc (with stable 32)
- Temperature & Phase testing
- Relative & Absolute counter display of Frequency & Phase difference
- Precision product characterisation
- "National Measurement" level metrology & analysis

Outstanding Features

The A7-MX is invaluable in the design of low noise oscillators, atomic frequency standards and passive devices where close in phase noise, freedom from spurii, and phase stability are essential design objectives. The A7-MX is unique in its ability to measure time domain stability at averaging times from 1ms to weeks, and phase noise from mHz to 500Hz. Discrete spurii can be measured close to the carrier at levels down to -120dBc. The high resolution input operates at 5 or 10MHz. The reference is also at 5 or 10MHz.
A lower resolution input is provided which will measure at frequencies between 50kHz and 65MHz. The A7-MX is not limited to research and development. The real time digital display of fractional frequency offset combined with the high resolution analogue meter makes the production setting of all types of frequency standard a simple and rapid operation.

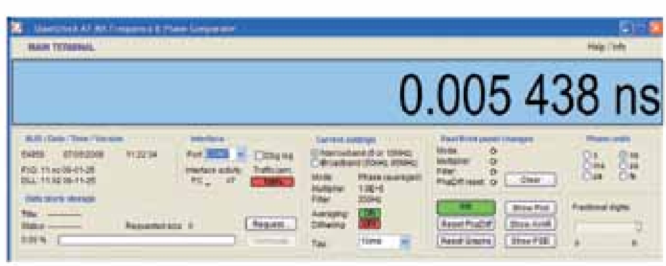
Absolute Frequency



Statistics: Max • Min • Mean • Standard Deviation

Fractional Frequency Difference

Phase Difference fs • ps • ns • µs • ms • s



Narrowband / High Resolution Mode

Inputs		
a) Reference	5 or 10MHz sine wave	$\pm 5x10^{-5}$
b) Measurement (3 measurement inputs - see non standard options = A7-MY)	5 or 10MHz sine wave	$\pm 5x10^{-5}$
	+0dBm to +13dBm into 50Ω	
c) Input levels:	Low multiplier	$\pm 1x10^{-5}$
d) Max Freq difference (Filter off):	High multiplier	$\pm 1x10^{-7}$
Connectors	N Type, Front Panel	
Outputs	100kHz square wave CMOS/TTL (frequency mode)	
a) Counter A channel	10us pulse CMOS/TTL (phase difference mode)	
b) Counter B channel	10us pulse CMOS/TTL (phase difference mode)	
c) Counter external reference	10MHz CMOS/TTL	
Filter	Selectable bandwidth IF filter reduces measurement noise	
Nominal 3dB Bandwidths	200Hz, 60Hz, 10Hz	
Fractional frequency multiplication		
Selectable	High multiplier 10^5	
	Low multiplier 10^3	
Measurement resolution	A7-MX	
Relative frequency difference mode		
RMS resolution (filter 200Hz)	Using internal phase/freq. meter (TIC) and Windows software	
Measured resolution	Digits/second	
High multiplier	$1x10^{-13}$/gate time	
Low multiplier	$1x10^{-12}$/gate time	
Analogue Meter Resolution manually selected from 6 ranges		
Full scale ranges (decade steps)	$\pm 1x10^{-7}$ to $\pm 1x10^{-12}$	
Time constant (linked to range)	20ms to 10s	
Time constant multiplier	x1, x3, x10	
Displayed Noise	$<2x10^{-13}$ peak	
Zero drift	$<2x10^{-13}$/hour	
Phase difference mode		
(High resolution, Filter 200Hz)		
RMS resolution (single measurement)	50fs (See note 1)	
Analogue Meter		
Full scale ranges (decade steps)	±10us to ±100ps	
Displayed noise	<1ps peak	
Zero drift	<1ps/hour	
	Note 1: Measured as the standard deviation of 1024 phase difference measurements/1.024s	
Short-term stability (noise floor)	**Tau**	**Allan variance**
	1ms	$<5x10^{-11}$
	10ms	$<5x10^{-12}$
	100ms	$<5x10^{-13}$
	1s	$<5x10^{-14}$
	10s	$<1x10^{-14}$
	100s	$<2x10^{-15}$
	1,000s	$<5x10^{-16}$
	10,000s	$<1x10^{-16}$
Sampling interval – gate time	1ms to 2000s	
	1, 2, 5 Steps	
Drift		
Hour	<1ps typical at constant ambient temp	
Day	<5ps typical at constant ambient temp	
Temperature	<2ps/°C	

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Measurement Error		
Input referred self generated spurii		
10^3 multiplication	<-90dBc	
10^5 multiplication	<-100dBc	
Corresponding peak phase modulation		
10^3 multiplication	<1ps	
10^5 multiplication	<0.3ps	
Allan Variance Error (due to each spur)		
10^3 multiplication	10^{-12} divided by averaging interval (tau)	Note: phase modulation spurii will be present at multiples of the input frequency difference.
10^5 multiplication	$3x10^{-13}$ divided by averaging interval (tau)	

Phase Spectral Density Specification (Close-In Phase Noise)

Applications	Phase noise measurement at very small frequency offsets Identification of spurious components in the data which can distort an Allan variance plot
Specifications	
Maximum offset frequency	500Hz (at 1ks/s)
Close-in Phase Noise floor	typically: -100dBc/Hz @ 10mHz offset (0.01Hz offset) -115dBc/Hz @ 100mHz offset (0.1Hz offset) -130dBc/Hz @ 1Hz offset -150dBc/Hz @ 100Hz offset -160dBc/Hz @ 500Hz offset

Broadband Mode

Note: 5 or 10MHz reference must be present at reference (front panel) input of A7-MX

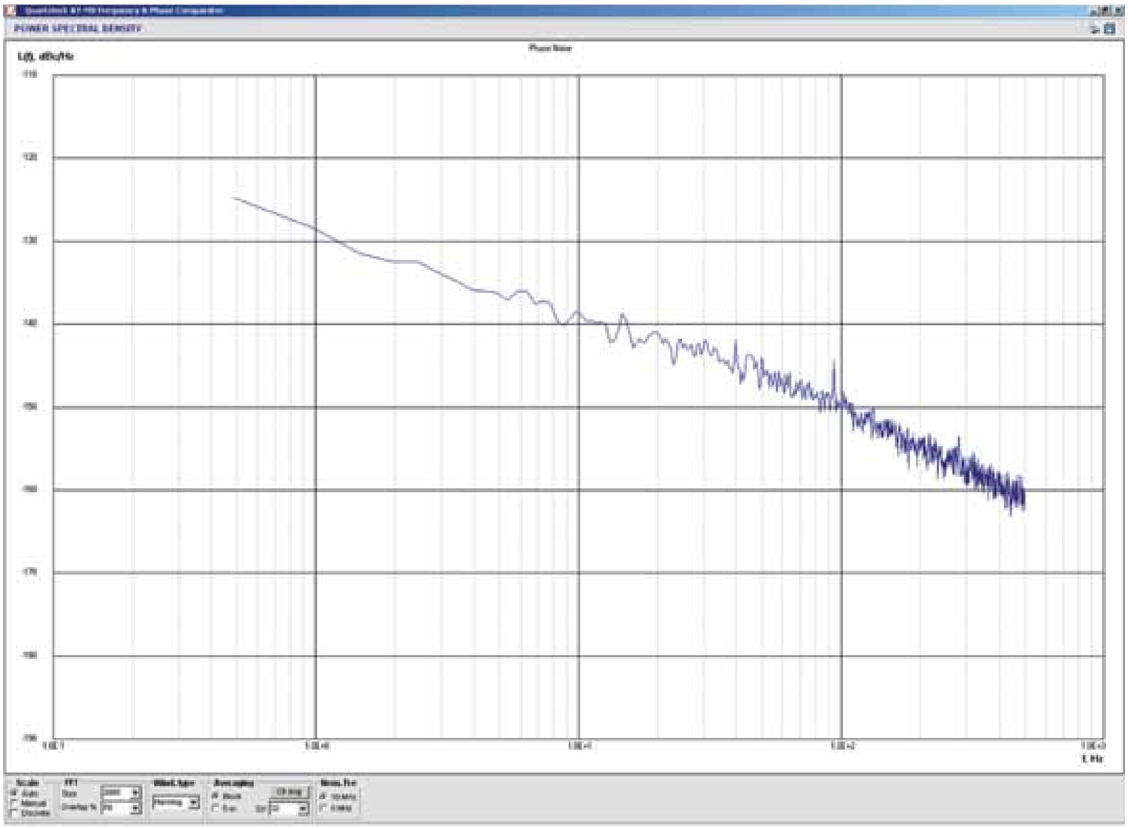
Input 50kHz to 65MHz	Type	BNC, rear panel	
	Impedance	1Mohm	
	Input levels		
50kHz to 1MHz	224mV rms (0dBm) to 2V rms (+19dBm)		
1MHz to 50MHz	70.7mV rms (-10dBm) to 2V rms (+19dBm)		
50MHz to 65MHz	224mV rms (0dBm) to 2V rms (+19dBm)		
Connector	BNC rear panel		
Resolution (nominal) Broad- and Narrowband	11 digits /second of gate time (averaging on)		
Noise Floor (allan variance) (measured at 10MHz, 10dBm input)		**Allan variance**	**tau**
Averaging off	All gate times	$< 2x10^{-9}$	100ms
		$< 2x10^{-10}$	1s
		$< 2x10^{-11}$	10s
Averaging on	Averaging factor	(Averaging factor =	gate time/1ms)
	10	$< 2x10^{-11}$	1s
	100	$< 6x10^{-12}$	1s
	1000	$< 2x10^{-12}$	1s

General Specification

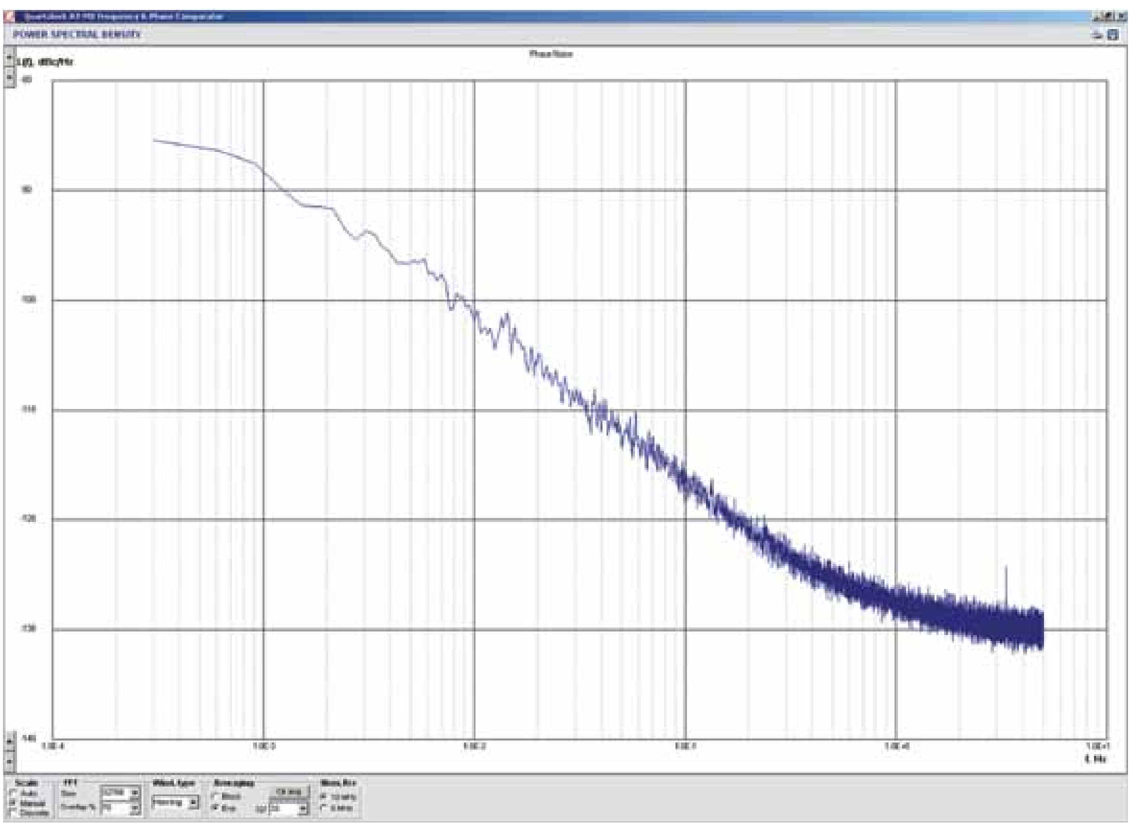
Virtual Front Panel	Absolute or relative (normalised) frequency display User entered normalisation frequency Allan Variance graph Frequency data graph Data storage of phase or frequency data
Temperature Range	Operating: 10C to 35C (± 5C within this range during measurement) Storage: -10C to 60C
Mechanical	2U 19" rack unit WxHxD(max) 450(483)x88(96)x345(370) <9kg
Power Supply	120/ 240V AC line 50W max 24V DC battery backup with automatic switching. Current consumption 1Amp max. With option 1 add 1Amp
Supplemental Performance Data (SPD)	Please contact Quartzlock for SPD and applications note.

→

Typical Narrowband Performance (PSD)



A7-MX Phase Noise Floor (10MHz) – Narrowband high resolution mode. 500MHz to 500Hz offset



A7-MX Phase Noise Floor (10MHz) – Narrowband high resolution mode. 300uHz to 500Hz offset

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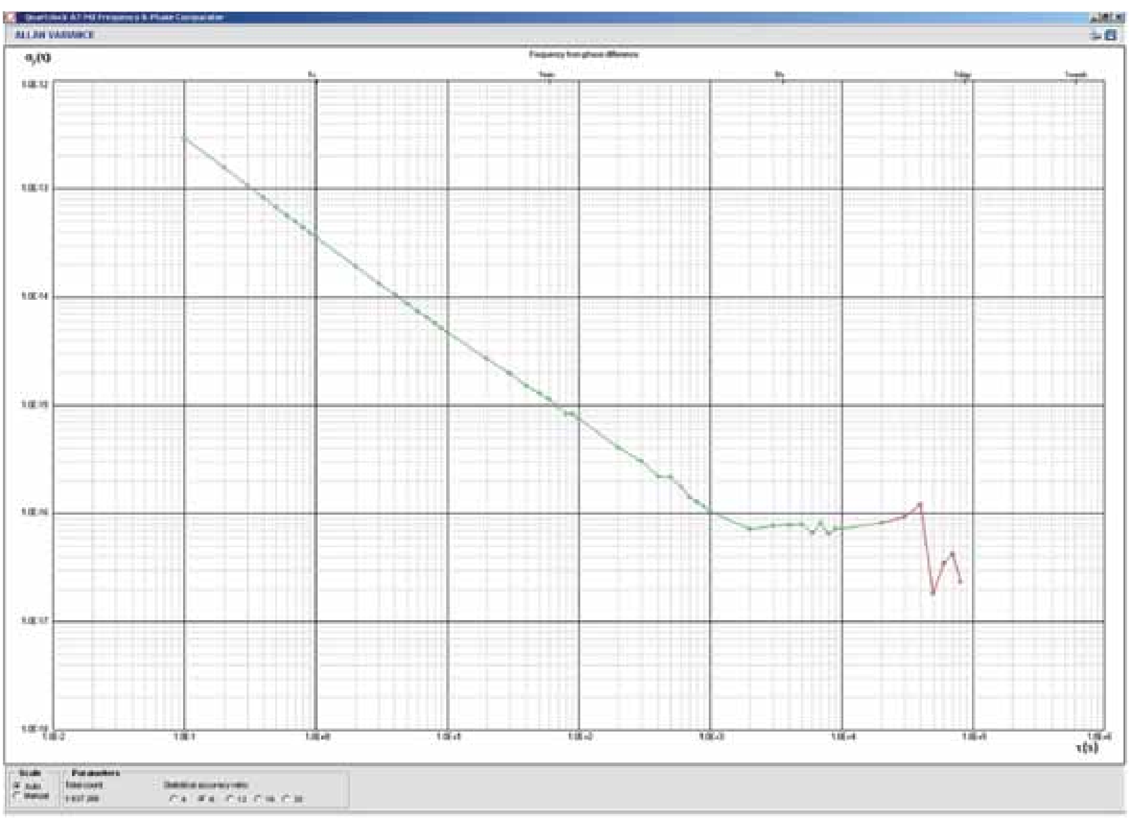
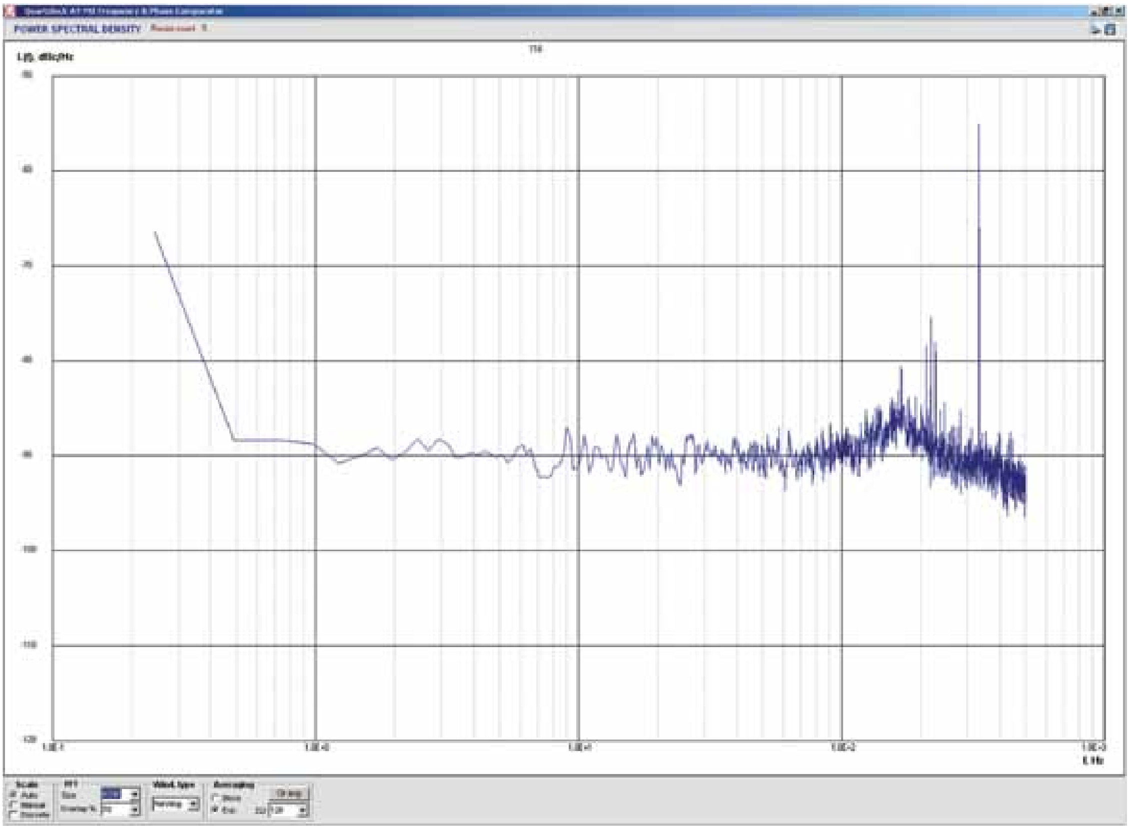
Typical Narrowband Performance Graphs (AVAR)

A7-MX Allan Variance (10MHz) – Narrowband high resolution mode. 10^{-3}s t0 10s (red plot is predicted)



A7-MX Allan Variance (10MHz) – Narrowband high resolution mode. 10^{-1}s t0 $8x10^{-4}$s (red plot is predicted)

Typical Broadband Performance Graphs (PSD & AVAR)



Broadband Phase Noise Floor 300MHz to 500Hz offset

Broadband Allan Variance Noise Floor. 100ms to 1000Hz offset (red plot is predicted)

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Operational Description

There are two inputs on the front panel. One of these is for the phase/ frequency reference which will often be an atomic frequency standard. The reference frequency can be 5 or 10MHz with automatic switching. The other input is for the measurement signal, also 5 or 10MHz, also with automatic switching.

There are pushbutton controls for phase/frequency mode, multiplier ratio , filter selection, sampling rate (tau) and phase reset. There are also a number of controls which adjust the analog meter function. There are indicator lights to confirm that the reference and measurement inputs are at the required level, and that the internal phase locked multipliers are locked. The analog meter shows fractional frequency difference with full scale ranges from +/-1x10-7 to +/-1x10-12, and phase differences with full scale ranges from +/10us to +/-100ps.

When the instrument is connected to a PC, the control positions are read by the PC and displayed on the virtual control panel

On the rear panel is the broadband frequency input which can be between 50kHz and 65MHz. Also on the rear panel are outputs to an external timer/counter, and a switch which adjusts the analogue meter time constant.

The instrument has two main modes, narrowband, high resolution, and broadband. The selection between these modes is made on the PC virtual control panel.

In narrowband, high resolution mode, the measured signal must be at 5 or 10MHz. In this mode the instrument uses multiply and mix techniques to increase the fractional frequency difference (or phase difference) between the measured input and the reference. This improves the resolution of the digital phase comparator, and results in a theoretical phase resolution of 0.125fs. The actual resolution is noise limited to about 50fs. The corresponding fractional frequency resolution is 1x10-13 in one second of measurement time.

In broadband mode the multiply and mix is not used. The digital phase comparator makes direct phase measurements with a resolution of 12.5ps. This is comparable to the fastest frequency counters and gives a fractional frequency resolution of 3x10-11 in one second of measurement time, or 2x10-12 with averaging switched on.

When connected to a PC, the software provides 4 scalable windows. One of these is the virtual panel and digital display. The other 3 are data plot, Allan variance plot, and phase spectral density (phase noise) plot.

The virtual panel provides control of measurement rate (tau), and mode (narrowband, high resolution, or broadband). Repeater indicators are provided to show the settings of controls on the physical instrument. It is possible to store blocks of measurements up to 32768 measurements into a computer file. Once a measurement is started, the instrument will store the complete measurement block internally, provide power is maintained. This makes certain that data is never lost, even if the computer crashes and has to be restarted. In order to make sure that a long measurement run is not interrupted by a power failure, the instrument may be powed from a battery supply of 24V. This will automatically be used if line power should fail.

The digital display shows phase or fractional frequency offset depending upon mode. The units and number of significant digits is adjustable.

Averaging mode may be selected from this window. If averaging is off, the digital phase comparator makes single measurements at the selected sampling rate. If averaging is on, the comparator operates at the maximum sampling rate of 1ks/s. A block average reduces the data rate to the slected sampling rate.

Dither mode may be selected from this window. Dither is a technique which reduces unavoidable internally generated spurii to below the noise floor, at the expense of an increase in noise floor. For further details see operating manual.

The data window shows real time accumulation of the data as a graph. The last 8 to 32768 data points may be shown on the graph. A statistics display shows max, min mean, and standard deviation for the data shown on the graph. The scaling of the y axis may be auto, manual, or max/min.

The Allan variance window shows calculated Allan variance for all data accumulated since the start of a run. If averaging is off, single phase measurements are made at the requested sampling rate and the statistic is true Allan variance. If averaging mode is on, the statistic becomes modified Allan varaince. The graph title correctly indicates this.

The Phase Spectral Density (PSD) window shows phase noise as a graph of L(f) in units of dBc against offset frequency on a log scale. Various window functions and averaging modes are provided. The routines are identical to those used in the Industry standard software "Stable32".

The user can select the basic length of the FFT, and also the degree of overlap. As data is accumulated, new FFTs are performed on a mix of old and new data depending on the overlap parameter.

Each FFT result can either replace the last graph, be added to a block average, or be used in a continous or exponential average.

All FFTs are correctly normalised for bin bandwidth, window ENBW, window coherent gain, and nominal frequency.

Frequency data always has a fixed offset removed before being used for the FFT calculation. Phase data has a fixed slope ramp removed by linear regression. This avoids a large component in the lower frequency bins which will distort the result, even when windowing is used.

A mode is provided for the measurement of discrete components (spurii). In this mode the scale is changed from L(f), dBc/Hz to Power,dBc. Corrections for bin bandwidth and window ENBW are removed. A flat top window is provided for measurement of discretes, with scallop loss of only 0.01dB.

Technical Description

The principle behind the A7-MX is to increase the resolution of a digital phase meter. This is achieved by multiplying the frequency to be measured to a higher frequency, and then mixing it down to a lower frequency using a local oscillator derived from the frequency reference. The principle is illustrated in Figure 1, and has been made the basis of a number of instruments in the past. The relationship is shown for signals down the mix/multiply chain for an input signal with a difference of delta f from the reference, and also for a signal with no frequency difference, but with a phase difference of delta t. (An important clarification is that "phase" difference beteween two signals can either be measured either in time units or angle units. A measurement in time units does not specify or imply the frequency of the signals. A measurement in angle units (radians) needs a prior knowledge of the frequency. Throughout this description, phase will be measured in time units) It should be noted that a frequency multiplication multiplies a frequency difference but leaves a phase difference unchanged. Conversely, a mixing process leaves a frequency difference unchanged, but multiplies a phase difference. When the frequency differences are converted to fractional frequency differences by dividing by the nominal frequency, it will be seen that the multiplication factors for frequency and phase are the same.

The big disadvantage in the simple approach shown in Figure 1 is that phase drift with temperature will be excessive. As rate of phase drift is equal to the fractional frequency difference, the measurement of the frequency of an unknown device will be in error. For example, a drift rate of 10ps per second in the first multiplier in the Figure 1 diagram will be multiplied to 1ns per second at the output. This is equivalent to a 1 x 10^{-12} frequency error due to drift. Phase drift may occur in mixers and multipliers, but more especially in multipliers. If harmonic multipliers are used, drift will occur in the analogue filters that are used to separate the wanted harmonic from the subharmonics and unwanted mixer products. If phase lock multipliers are used, phase drift will occur in the digital dividers.

To overcome the drift problem, the multiplier/mixer chain is made differential, ie the reference signal is processed in an identical way to the unknown. When the two channels are subtracted, any drift in the multipliers will cancel. The method of doing this can be seen from the functional block diagram of the A7-MX, figure 2. The first stage of the processing for both the reference and measurement channels is a multiplication by 10 (20 for 5MHz inputs). The multipliers are phase locked loops with a VCXO of 100MHz locked to the input by dividing by 10 (20 for 5MHz inputs). The phase detectors used are double balanced diode mixer type phase detectors. These exhibit the lowest phase drift with temperature. The dividers used are ECL types with very small propagation delays. The outputs of the dividers are reclocked using a D type flipflop clocked by the 100MHz VCXO signal. In this way the divider delay is made equal to the propagation delay of one D type, approx 500ps. As a further refinement, the reclocking D types for the reference and measurement channels are closely thermally coupled. As the divider propagation delays are equal to the reclocking flipflop delays, the tracking between the reference and measurement channels is exceptionally good.

The VCXO signals at 100MHz also drive double balanced FET mixers for the first down conversion to 1MHz. The 99MHz LO is common to both the reference and measurement channels, and is obtained from a 2 way passive inductive type power splitter. The output from the mixers is filtered by diplexer type filters to remove the image at 199MHz and the signal and LO feed through at 100MHz and 99MHz respectively. The wanted IFs at 1MHz are passed without further processing to the second multipliers. The avoidance of IF amplifiers at this point avoids drift which could be substantial as the propagation delay of the IF amplifier could be several 100 nanoseconds. IF amplifiers are used for the first IF take off points to the IF processing board. The first IFs are used when a multiplication of 103 is selected.

The second multipliers are nearly identical to the first multipliers with the difference that the phase lock loop dividers divide by 100. This multiplies the first IF of 1MHz to the second VCXO frequency of 100MHz. The second downconvert is identical to the first, with the second IFs being passed to the IF processing board.

The first and second multipliers/mixers for the reference and measurement channels are built symmetrically on one PCB (Printed Circuit Board). In order to ensure the best possible temperature tracking beween the channels, the PCB is in good thermal contact with a thick metal baseplate. This minimises rapid temperature changes between the channels.

The two pairs of IF signals (sine wave) are passed to the IF processing PCB. The two pairs are the outputs from the first and second downconvertors. They correspond to final multiplication factors of 103 and 105. Also on the IF processing board is the 99MHz LO generation and phase lock. A 10MHz unmultiplied signal is passed to the IF processing board from the reference channel on the Multiplier board.

The 1MHz IFs could be divided down and measured directly by the frequency counter, which would make a time difference measurement between the measurement and reference IF signals. In this way the difference between the channels would be measured and any drift would cancel. Although this would work for a phase measurement, there would be no way of making a conventional frequency measurement. The IFs cannot be directly subtracted in a mixer as they are both nominally 1MHz, and the nominal difference frequency would be zero. In order to avoid this problem, the multiplied reference IF is frequency shifted to 900kHz using an LO of 100kHz derived from the unmultiplied reference. The 900kHz is then mixed with the 1MHz measurement channel IF to give a final IF of 100kHz. This final IF contains the multiplied frequency difference, but drift in the multipliers and phase noise in the common 99MHz LO will have been canceled out.

The detailed process is as follows:

The 10MHz reference from the multiplier board (this is derived from the reference input without multiplication) is divided by 25 to 400kHz. The 400kHz is then divided by 4 to give two quadrature signals at 100kHz. These signals are filtered using low pass filters to give 100kHz quadrature sine waves. The 1MHz multiplied reference IF (after limiting) is delayed by 250ns to give quadrature square waves. These operate dual switching mixers with the 100kHz quadrature sine waves as the linear inputs. The outputs are combined to form an image reject mixer, with the wanted sideband at 900kHz and the unwanted sideband at 1.1MHz. The 900kHz sideband is filtered in an LC bandpass filter to further remove the unwanted sideband and the 1MHz feed through. This output is used as the linear input to a further switching mixer which downconverts the 1MHz multiplied measurement IF (after limiting) to the final IF of 100kHz. The final IF is filtered in an LC bandpass filter to remove the unwanted sideband at 1.9MHz and any other mixer products. The measurement and reference channels have now been combined into a single IF of 100kHz with the drift and LO instabilities removed. This IF is now further processed to provide the counter outputs as will be described in the next paragraphs.

The measurement bandwidth of the system has been defined up to this point by the loop bandwidths of the phase lock multipliers and the bandwidth of the 100kHz LC filter. The 3dB bandwidth is about 8kHz. This means that fourier frequencies further displaced from the carrier of greater than 5kHz will be attenuated. The phase measurement process essentially samples the phase of the unknown signal relative to the reference at a rate determined by the selected tau (selectable from 1ms to 2000sec). As with any sampling process, aliasing of higher frequency noise into the baseband will occur. Thus further band limiting of the 100kHz IF is desirable before measurement takes place. The A7-MX has a crystal filter following the LC filter with selectable bandwidths of nominally 10Hz, 60Hz, and 200Hz. For most Allan variance plots at least the 200Hz filter should be used. The use of a filter will reduce the noise floor of the instrument which is desirable when measuring very stable active sources and most passive devices.

After the crystal filter the 100kHz IF is limited to a square wave by a zero crossing detector. This output is made available to the counter A channel when frequency mode is selected. Both the 100kHz IF containing the multiplied frequency difference information and the 100kHz unmultiplied reference are divided in identical divider chains down to 1kHz to 1mHz in selectable decade steps. The output of the dividers trigger digital (clocked) monostables to generate 10us pulses which are routed to the counter A and B channels when phase mode is selected.

When the internal digital phase comparator is in use, the phase of both the 100kHz reference and the 100kHz multiplied IFs are measured relative to the unmultiplied 10MHz reference. The digital phase comparator then calculates the resulting phase difference or fractional frequency offset depending upon the selected mode. The digital phase meter also applies averaging if selected. It has internal storage sufficient for 32768 measurements. The RS232 interface to the computer uses full handshaking to prevent data loss. The internal phase comparator has a resolution of 12.5ps, obtained by using an analogue pulse expander circuit.

The meter circuit also uses the 100kHz IF and 100kHz reference. The basis of the circuit is a differential frequency to voltage convertor. However in order to increase the resolution of this circuit, a further stage of multiplication and mixing is employed. The 100kHz reference is divided down to 500Hz. This frequency is then multiplied to 4.9995MHz using a phase lock loop with a divider of 9999. The 100kHz measurement IF is multiplied to 5MHz also using a phase lock loop. Finally the 5MHz signal and the 4.9995MHz signal are mixed together to give an IF of 500Hz. An additional fractional frequency multiplication of 104 results. On the least sensitive meter range this 500Hz IF varies in frequency from 0Hz to 1kHz. The 500Hz measurement IF and the 500Hz reference both trigger digital monostables which produce very accurate fixed width pulses . These pulses are used to gate an accurate positive and negative current into a chopper stabilised summing amplifier. The output of the summing amplifier is a voltage which drives the moving coil centre zero meter. The meter circuit has four decade ranges which in conjunction with the two multiplication factors of the main comparator results in 6 meter ranges with full scale deflections of 10^{-7} to 10^{-12}.

The meter time constants are linked to the meter range, however may be increased if desired using a switch mounted on the rear panel.

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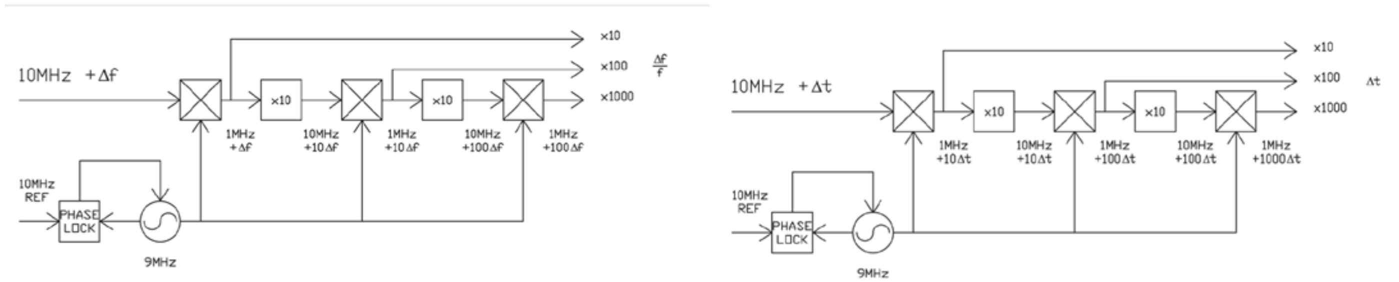
A7-MX Block Diagram

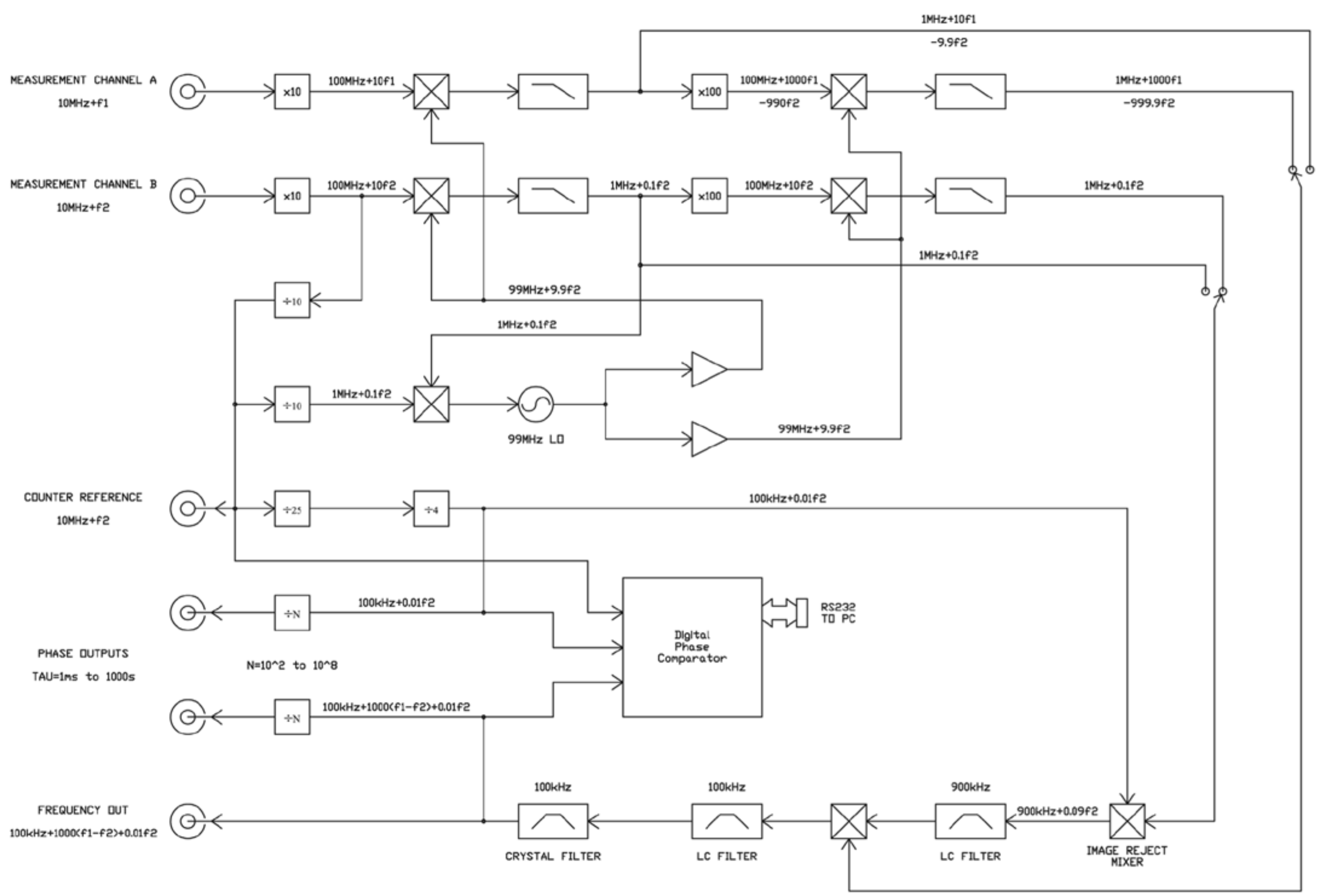
Figure 1



Typical Mix/Multiply Chain Showing Frequency Relationships

Typical Mix/Multiply Chain Showing Phase Relationships

Figure 2



GPS Timing & Frequency Reference

- Accurate to 25ns RMS UTC
- No Drift
- High Stability
- Internationally Traceable Standard

Approx actual size

The Quartzlock E8-X represents a breakthrough in exceptionally low cost, tracable, calibration-free "GPS" frequency & time standards. These very low cost references maintain the high frequency & time accuracy required for demanding applications. This product is available as a PCB level component.

Features

- 1 x 10^{-12} accuracy
- 12 Channel GPS Receiver with TRAIM
- 10MHz Output
- 1PPS Output

Benefits

- No calibration required
- 12 Channel GPS Receiver provides high accuracy UTC Time & Frequency Reference
- Very cost effective
- 1 year warranty
- Compact form factor

Applications

- Production Test Frequency Reference
- Time & Frequency standard for calibration & RF Laboratories
- Frequency Standard for counters, signal generators, Spectrum & Network Analysers
- Time & Frequency Reference for satellite communications ground stations CDMA, LTE, DTV & DAB

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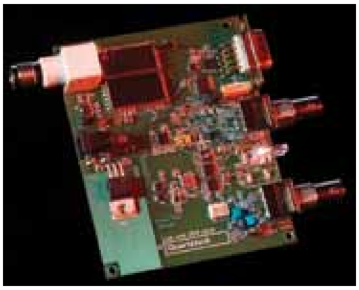
Specification

Outputs	a) Sinewave	10MHz, 12dBm +/- 2dBm into 50 Ohms
	Harmonics	<-50dBc
	Spurii	<-75dBc
	b) TTL 3.3VCMOS	1pulse per second 4ns standard deviation
Frequency Accuracy	$1x10^{-12}$ Long Term	
Short Term Stability	**tau**	**Allan Variance (typ)**
	1s	$<2x10^{-10}$
	10s	$<4x10^{-10}$
	100s	$<5x10^{-11}$
	1000s	$<2x10^{-11}$
	10000s	$<5x10^{-12}$
Phase Noise (typ)	1Hz	-60 dBc
	10Hz	-90 dBc
	100Hz	-115 dBc
	1kHz	-130 dBc
	10kHz	-140 dBc
Lock Indicator	On - Not Locked Off - Locked, Low Phase Error Short flash every second - Locked, High Phase Error	
GPS Indicator	Green - Indicates number of satellites used in time solution Amber - Indicates number of satellites tracked but not used in time solution	

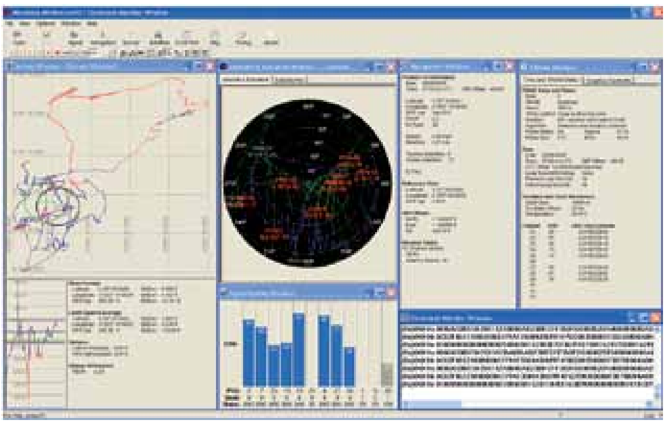
Warm Time	<15 minutes to specified accuracy	
Power Supply Antenna	15V dc (ac psu provided) Active GPS antenna supplied (5m lead). **High gain antenna option** with 20m lead.	
Current Consumption	250mA typical	
Size	E8-X	105 x 30 x 125mm desktop module
	Option 43	100 x 120mm
USB Option	Ask Quartzlock	
Option 43 (E8-X or Y)	PCB version	
Option 46	Antenna & PSU (5m antenna lead) (for the E8-X OEM)	
Option 47	High gain antenna & PSU (20m antenna lead)	

E8X-OEM (Option 43)



Survey, Satellite Azimuth & Elevation, Navigation, Timing & Signal Quality Monitoring

These software packages will find educational survey and GNSS applications. Demonstration of the location, timing and navigation functions are provided.



Quartzlock GPS instruments have been designed to work with various external software packages such as WinOncore.

These programmes enable the main parameters of the GPS signals to be easily verified, particularly input signal level and satellites in view.

WinOncore12 has been designed for use as an evaluation and testing tool in conjunction with Motorola's GT, UT and M12 Oncore GPS receivers. This utility will aid the user in initializing and operating the Oncore receiver, displaying, plotting and printing data from the receiver, and recording and replaying data files.

Other Oncore receivers such as the VP, Basic or XT Oncore may also be used with WinOncore12; however, not all of the input and output (I/O) messages are defined. If you are using a receiver which supports I/O messages not defined in WinOncore12, you may customize support for each desired message in the Command Manager.

WinOncore12 supports both NMEA and Motorola Binary protocol, and thus may be used to record live data or playback previously recorded data from a NMEA (*.GPS) file or Motorola Binary (*.bin) file.

WinOncore12 will run under Windows 95/98/2000 and NT.

Quartzlock accept no responsibility for accuracy or performance of these external programs.

Quartzlock E8-Y / E8-Y OEM

GPS Time & Frequency Reference

- ☐ -110dBc/Hz @ 1Hz offset Phase Noise
- ☐ Internationally Traceable Standard
- ☐ Accurate to 25ns RMS UTC
- ☐ No Drift

The E8-Y GPS provides low noise, traceable, calibration free Time & Frequency Reference. These time and frequency standards maintain high time & frequency accuracy required for demanding applications. The E8-Y may be considered as a primary reference clock.

Features

- 10MHz Output
- 1PPS Output
- 1 x 10^{-12} accuracy
- RS232 Connection (USB option)
- 12 Channel GPS Receiver with TRAIM
- Excellent Holdover performance

Benefits

- No Calibration required
- GPS Traceable Reference
- 12 Channel GPS receiver provides high accuracy UTC time & frequency reference
- 1 year warranty
- NTP option in place of GPS View

Applications

- Time & Frequency Reference for Satellite communication ground stations, CDMA, LTE, DTV & DAB
- Production test frequency standard
- Time & Frequency standard for calibration & RF laboratories
- Frequency reference for counters, signal generators, spectrum & network analysers
- Wired & wireless network synchronization

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Specification

Outputs	**a) Sinewave** Harmonics Spurii	10MHz, 12dBm +/- 2dBm into 50 Ohms <-50dBc <-75dBc
	b) TTL 3.3VCMOS	1pulse per second Jitter 7ns standard deviation
Frequency Accuracy	1 x10^{-12} Long Term	
Hold over	100us per day	
Short Term Stability	**tau** 1s 10s 100s 1000s	**Allan Variance (typ)** 2x10^{-12} <4x10^{-13} <5x10^{-12} <2x10^{-12}
Phase Noise (typ)	1Hz 10Hz 100Hz 1kHz 10kHz	-110 dBc -136 dBc -145 dBc -155 dBc -157 dBc
Lock Indicator	**On** - Not Locked **Off** - Locked, Low Phase Error **Short flash every second** - Locked, High Phase Error	
GPS Indicator	**Green** - Indicates number of satellites used in time solution **Amber** - Indicates number of satellites tracked but not used in time solution	

Warm Time	<30 minutes to specified accuracy	
Power Supply Antenna	15V dc (ac psu provided) Active GPS antenna supplied (5m lead). **High gain antenna option** with 20m lead.	
Current Consumption	250m A typical	
Size	E8-Y E8-Y PCB OEM E8-Y MIL	105 x 30 x 125mm desktop module 100 x 120mm CNC machined microwave housing

GPS Master Clock Very Low Noise
Frequency & Timing Primary Reference Source

- Phase Noise is -110dBc/Hz@1Hz offset as standard
- Stability (AVAR) is $8x10^{-13/s}$ typically
- Accuracy 25us, 100us/day holdover

The Quartzlock E8000 represents a breakthrough in very low noise, traceable, calibration-free GPS frequency & time standards. These very cost effective references maintain the high frequency and time accuracy required for demanding applications. Low distortion 10MHz Sine & 1PPS outputs. Ultra low noise options are available.

Considerably enhanced surveillance, wired and wireless communications are possible with E8000's much lower noise levels

Features

- $1x10^{-12}$ accuracy
- No Drift
- Highest Stability available
- 1 Year Warranty
- Lowest Cost Available
- Very long production life & support

Benefits

- No calibration required
- Traceable Reference, nationally & internationally
- External & Internal BBU options
- Many options available including NTP Clock Reference Output
- ULN options: -115dBc/Hz @ 1Hz offset & -170dBc/Hz @ 100kHz
  5MHz option has -123dBc/Hz @ 1Hz offset Phase Noise
  $5x10^{-13}$/s AVAR short term stability

Applications

- Frequency Reference for: Satellite Communication Ground Stations, VHF, UHF & PMR TX, CDMA, Tetra, DTV & DAB, Wired & Wireless network synch
- Network Time Protocol use in Financial, Utilities, Security & Communications Timing
- OEM
- Frequency Standard for: Calibration Labs, Radio Workshops, RF Labs & Production Test
- Calibration of: Counters, Frequency Meters, Spectrum & Network/VNA Analysers, Synthesizers & Communication Analysers

Specification

E8000 VERY LOW NOISE **10MHz**		
Outputs	a) Sinewave	10MHz, 12dBm +/- 2dBm into 50 Ohms
	Harmonics Spurii	< -30dBc <-80dBc
	b) TTL 3.3VCMOS	1pulse per second (4ns std dev)
Frequency Accuracy	$1x10^{-12}$ Long Term	
Hold over	100 us/24hrs	
Short Term Stability	tau	Allan Variance
	1s 10s 100s 1000s 10,000s	$<2x10^{-12}$ $<4x10^{-13}$ $<5x10^{-12}$ $<2x10^{-12}$ $<8x10^{-13}$
Phase Noise (typ)	1Hz 10Hz 100Hz 1kHz 10kHz	-110 dBc/Hz -136 dBc/Hz -145 dBc/Hz -155 dBc/Hz -157 dBc/Hz
Lock Indicator	**On** - Not Locked **Off** - Locked, Low Phase Error **Short flash every second** - Locked, High Phase Error	
GPS Indicator	Green - Indicates number of satellites used in time solution Amber - Indicates number of satellites tracked but not used in time solution	
Warm Time	<30 minutes to specified accuracy	
Power Supply	100 ... 240V ac (External 12Vdc Battery Back Up seamless switching option) (Internal 12Vdc Lithium Ion battery with charger > 1 hour holdover option)	
Current Consumption	250mA typical	
Size	19” x 1¾” 1U Rack Mount 483 x 44 x 230mm excl connectors 560 x 340 x 100mm packed	
GPS Antenna	5m cable and connector supplied	
Option	High gain antenna with 20m cable	

E8000 ULTRA LOW NOISE **5MHz** OPTION		
Outputs	a) Sinewave	10MHz, 12dBm +/- 2dBm into 50 Ohms
	Harmonics Spurii	< -30dBc <-80dBc
	b) TTL 3.3VCMOS	1pulse per second (4ns std dev)
Frequency Accuracy	$1x10^{-12}$ Long Term	
Hold over	100 us/24hrs	
Short Term Stability	tau	Allan Variance
	1s 10s 100s 1000s 10,000s	$<5x10^{-13}$ $<4x10^{-13}$ $<5x10^{-13}$ $<2x10^{-12}$ $<8x10^{-13}$
Phase Noise (typ)	1Hz 10Hz 100Hz 1kHz 10kHz	-123 dBc/Hz -140 dBc/Hz -150 dBc/Hz -155 dBc/Hz -158 dBc/Hz
Lock Indicator	**On** - Not Locked **Off** - Locked, Low Phase Error **Short flash every second** - Locked, High Phase Error	
GPS Indicator	Green - Indicates number of satellites used in time solution Amber - Indicates number of satellites tracked but not used in time solution	
Warm Time	<30 minutes to specified accuracy	
Power Supply	100 ... 240V ac (External 12Vdc Battery Back Up seamless switching option) (Internal 12Vdc Lithium Ion battery with charger > 1 hour holdover option)	
Current Consumption	250mA typical	
Size	19” x 1¾” 1U Rack Mount 483 x 44 x 230mm excl connectors 560 x 340 x 100mm packed	
GPS Antenna	Supplied with 5m cable and connector	
Option	High gain antenna with 20m cable	

Interface

GPS	9.6kbaud, Motorola binary format RS232 PC compatible (8bits no parity, no handshake) or NTP Clock Reference Output option
DPLL Tracking	5mHz to 500mHz typical in 8 binary Bandwidths increments default 20mHz
Option 9	See Quartzlock E5-X Specification on page 12 Outputs: 6 x10MHz low distortion, sinewave, isolated, +13dBm 1V rms 50 Ohms

→

GPS Disciplined Rubidium Time & Frequency Reference

- No drift
- Internationally traceable standard
- 110dBc/Hz @ 1Hz phase noise option
- Accurate to 25 Nanoseconds RMS UTC

The E8010 provides a stable and accurate calibration free GPS time and frequency reference with multiple output signal formats in an easy to install 1U rack mountable chassis.
These references maintain high time and frequency accuracy required for demanding applications.

Features

- 10MHz Output
- 1PPS outputs
- Network Time Server (NTP) Option
- Excellent hold over performance 1us/day
- 12 Channel GPS Receiver with TRAIM
- $2x10^{-12}$/s AVAR option

Benefits

- No calibration required
- GPS traceable reference
- Caesium replacement
- 12 channel GPS receiver provides high accuracy UTC time and frequency reference

Applications

- Time and frequency reference for satellite communication ground stations, CDMA, LTE, DTV & DAB
- Production test frequency standard
- Time and frequency standard for calibration and rf laboratories
- Frequency standard for counters, signal generators, spectrum and network analysers
- Wired and Wireless network synchronization
- Stratum 1 primary reference clock

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Specification

Outputs	**a) Sinewave**	10MHz, 12dBm +/- 2dBm into 50 Ohms
	Harmonics	<-50dBc
	Spurii	<-75dBc
	b) TTL	
	3.3VCMOS	1pulse per second
	Accuracy	4ns standard deviation
Frequency Accuracy	$x10^{-13}$ Long Term	
Hold over	1us per day	
Short Term Stability	**tau**	**Allan Variance (typ)**
	1s	$3x10^{-12}$
	10s	$2x10^{-12}$
	100s	$8x10^{-13}$
	1000s	$5x10^{-13}$
	10000s	$5x10^{-13}$
	1 hour	$x10^{-13}$
Phase Noise (typ) (see low noise options)	1Hz	-70 dBc
	10Hz	-100 dBc
	100Hz	-120 dBc
	1kHz	-140 dBc
	10kHz	-145 dBc
Hold-over	Exceeds telecom stratum 1 requirements	
Lock Indicator	**On** - Not Locked **Off** - Locked, Low Phase Error **Short flash every second** - Locked, High Phase Error	
GPS Indicator	**Green** - Indicates number of satellites used in time solution **Amber** - Indicates number of satellites tracked but not used in time solution	
Warm Time	<15 minutes to specified accuracy	
Power Supply	85 ... 240V ac (BBU option)	
Current Consumption	250m A typical	

Size	19" x 1.75" 1U rack mount
Antenna	Supplied with cable & connectors
Interface	Shared between DPLL and GPS receiver
DPLL	9.6kbaud, RS232, PC compatible (8bits no parity, no handshake)
GPS	9.6kbaud, Motorola binary format (8bits no parity, no handshake)
DPLL Tracking	5mHz to 500mHz typical in 8 binary bandwidths increments default 20mHz
Option 9	See Quartzlock E5-X **Outputs** 6 x10MHz low distortion, sinewave, isolated, +13dBm 1V rms 50 Ohms
Option 48	Ultra Low Noise (contact Quartzlock)
Option 0	24V dc BBU (Battery Back-Up switch)
Option 1	4 Outputs – see model E5 spec. For use with ULN option only.
Option 43	OEM Open Frame version

Quartzlock GPS instruments have been designed to work with various external software packages such as WinOncore. We accept no responsibility for accuracy or performance of these external programs.

These programmes enable the main parameters of the GPS signals to be easily verified, particularly input signal level and satellites in view.

WinOncore12 has been designed for use as an evaluation and testing tool in conjunction with Motorola's GT, UT and M12 Oncore GPS receivers. This utility will aid the user in initializing and operating the Oncore receiver, displaying, plotting and printing data from the receiver, and recording and replaying data files.

Other Oncore receivers such as the VP, Basic or XT Oncore may also be used with WinOncore12; however, not all of the input and output (I/O) messages are defined. If you are using a receiver which supports I/O messages not defined in WinOncore12, you may customize support for each desired message in the Command Manager.

WinOncore12 supports both NMEA and Motorola Binary protocol, and thus may be used to record live data or playback previously recorded data from a NMEA (*.GPS) file or Motorola Binary (*.bin) file.

WinOncore12 will run under Windows 95/98/2000 and NT.
See screenshot image on E8000, page 40

Rubidium Oscillator –
Sub Miniature Atomic Clock (SMAC)

- Compact rubidium oscillator for a wide range of applications
- OCXO form factor and pin out
- Low power operation
- Ageing 5x10^{-10}/year

Actual size

The E10-MRX rubidium oscillator is a sub miniature atomic clock exhibits normal rubidium oscillator performance in a 65cc OCXO style package.
This rubidium oscillator has 100x less drift than OCXO's.
With short term stability of 8x10^{-12}/s @ 100s this rubidium oscillator provides significant improvements in performance over.

Features

- 10MHz output
- 2" x 2" x 1" form factor
- -95dBc/Hz @10Hz
- 5x10^{-11} accuracy
- 8x10^{-12}/s @100s

Benefits

- Atomic accuracy
- Low power consumption
- 100x less drift than OCXOs

Applications

- Stand-alone (free-run) stable frequency source (for UMTS and LTE)
- Extended holdover for CDMA, WiMAX and LTE base stations
- Stability for various other communication and transmission applications

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Specification

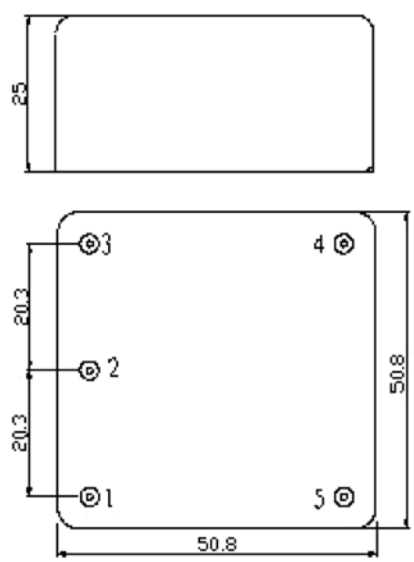
Outputs	10MHz Sine, 7~13dBm (HCOMS option)
Harmonics	<-40dBc
Accuracy	±5x10^{-11} at shipment @ 25C
Short Term Stability (AVAR)	1s 8x10^{-11} 10s 3x10^{-11} 100s 8x10^{-12}
Drift	Day 5x10^{-12} Month 5x10^{-11}
Phase to Noise (SSB)	1Hz -67dBc/Hz 10Hz -95dBc/Hz 100Hz -127dBc/Hz 1kHz -140dBc/Hz
Input Power	6W at 12V @ 25°C, Max 1.2A
Input Voltage Range	+12V~+18Vdc
Warm Time	5 minutes to lock @ 25C
Retrace	≤±2x10^{-11}
Magnetic field sensitivity, dc (±2 GAUSS)	<±4x10^{-11}/GAUSS
Frequency Control	>5x10^{-9} (External trim range: 0V~5V)
External Trim Range	≥5x10^{-9} (0V~5V)
Size	50.8~50.8~25 (mm3) (65cc)
Weight	<150gm
Warranty	24/36 months
Magnetic Field Sensitivity Atmospheric Pressure Approx MTBF, Stationary	 <2x10^{-11}/Gauss -60m ~ 4000m <1x10^{-13}/mbar 100,000 hours
Mechanical	51 x 51 x 25mm (2 x 2 x 1”)

Connector Interface	5 Pins match standard OCXO configurations Pin 1: Input frequency control Pin 2: Lock monitor Pin 3: Output signal Pin 4: Ground (signal & supply) Pin 5: Input supply (+)

Environmental Specification

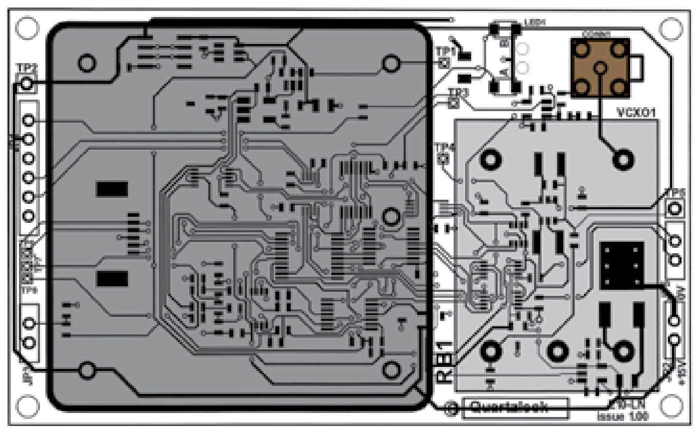
Operating Temp Range	-20°C~+50°C Typical: -30~+65°C
Base Plate Temp	-30°C~+85°C
Case Temperature	<45°C (after 1 hour, ambient temp 25°C. No ventilation
Temperature Coefficient (ambient)	5x10^{-10} (0~50°C)
Storage Temp	-55°C~+85°C
MTBF	100,000 hours
Environmental health	RoHS
Shock / Vibration	GR-CORE-63, 4.5.2/4, locked to 1.0g
EMI	Compliant to FCC Part 15 Class B

Outline Dimensions



Very Low Noise Miniature Rubidium Oscillator Module

- Very low phase noise -110dBc/Hz @ 1Hz
- Low power operation
- Ageing 5x10^{-10}/year



Actual size

The E10-LN Very Low Noise Rubidium Oscillator Module is a sub miniature atomic clock with Quartzlock's A6-CPS 'active noise filter' technology. This rubidium oscillator has 100x less drift than OCXO's. With short term stability of 2x10^{-12}/s @ 100s this rubidium oscillator provides significant improvements in performance over other rubidium components.
Ultra Low Noise 100MHz versions for radar and millimetre wave applications

Features

- 10MHz output
- 91 x 55 x 30mm form factor
- -110dBc/Hz @1Hz phase noise
- 5x10^{-11} accuracy
- 5x10^{-12}/s @100s

Benefits

- Very low noise and higher stability in customers' product
- Atomic accuracy
- Low power consumption
- 100x less drift than OCXOs

Applications

- Where sizes are restricted this 'breakthrough' very low noise rubidium oscillator will enable new applications
- LTE
- Extended holdover for CDMA, WiMAX and LTE base stations
- Higher stability and lower phase noise communication and surveillance applications

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Specification

Outputs See options	10MHz, +7dBm into 50Ω, 0.5VRMS	
Adjustment		
Mechanical Range	$2x10^{-9}$ min	
Electrical Range	$2x10^{-9}$ min	
Control Voltage	0 ~ 5V	
Factory Setting	$\pm 5x10^{-11}$	
Frequency Stability AVAR	1s	$2x10^{-12}$
	10s	$5x10^{-12}$
	100s	$4x10^{-13}$
	1 hour	$6x10^{-12}$
Ageing	1 day	$5x10^{-12}$
	1 month	$5x10^{-11}$
	1 year	$4x10^{-10}$
Phase Noise dBc/Hz in 1Hz BW		**dBc/Hz**
	1Hz	-110
	10Hz	-140
	100Hz	-145
	1kHz	-155
	10kHz	-157
Harmonics	<30dBc	
Spurious	<80dBc	
Warm Time to 1 x 10^{-9}	5 minutes	
Retrace after 24h off & 1h on, same temp	$<3x10^{-13}$	
Power Supply Power at steady state at 25C	6W at 15V @ 25°C, Max 1.2A	
Frequency Offset over output voltage range	$<2x10^{-11}$	
Temperature		
Operating	-20C ~ +50C	
Storage	-40C ~ +70C	
Freq offset over operating temp range	$<3x10^{-10}$	
Magnetic Field		
Sensitivity	$<2x10^{-11}$/Gauss	
Atmospheric Pressure	-60m ~ 4000m $<1x10^{-13}$/mbar	
Approx MTBF, Stationary	100,000 hours	
Mechanical	91 x 55 x 30mm PCB component	

Options to 100MHz

- 100MHz
-182dBc/Hz Noise Floor

CNC Machined Defence Housing

Low Profile Rubidium Oscillator

- High Performance Reference
- Three year warranty
- 24V dc 13W
- Excellent stability & drift out to 1hr & 1day

The A10-LPRO is a compact cost effective OEM Low Profile Rubidium Oscillator Frequency Standard that maintains the high time & frequency accuracy demanded in applications such as telecoms, aviation, nautical and precision test & measurement. Ideal for mission critical applications. A current production replacement for earlier products. These references maintain high time and frequency accuracy required for demanding applications.

Features

- 10MHz Output
- Stability 3 x 10^{-12}/100s
- Ageing: 5 x 10^{-10}/year
- 100dBc/Hz @ 10Hz phase noise

Benefits

- Simple integration into systems
- Fits 1U case
- Low Failure risk

Applications

- Telecom Network Synchronisation
- Frequency Calibration
- Broadcast
- Cellular Wireless Base Stations
- Design in frequency reference

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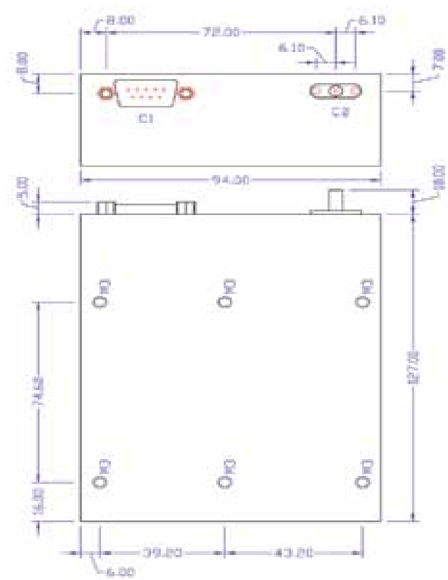
Standard Specification

Output	10MHz, +7dBm into 507 OHMS, 5V RMS	
Adjustment		
Mechanical range	$2x10^{-9}$ min	
Electrical range	$2x10^{-9}$ min	
Control range	0–5V	
Factory setting	$\pm 5x10^{-11}$	
Frequency Stability	1s	$3x10^{-11}$
	10s	$1x10^{-11}$
	100s	$3x10^{-12}$
	1 day	$1x10^{-11}$
Aging	1 day	$3x10^{-12}$
	1 month	$4x10^{-11}$
	1 year	$5x10^{-10}$
Phase noise	10Hz	100dBc
	100Hz	120dBc
	1000Hz	140dBc
	10000Hz	145dBc
Harmonics	<40dBc	
Spurious	<80dBc	
Warm time to $1x10^{-9}$	5 minutes	
Retrace after 24h off and 1h on, same temp	$<3x10^{-11}$	
Power Supply		
Power at steady state at 25°C	13W @ 24V (22–30Vdc) @ 25°C, Max 2A	
Freq offset over output voltage range	$<2x10^{-11}$	
Temperature		
Operating	-20°C – +50°C	
Storage	-40°C – +70°C	
Freq offset over operating temperature range	$<3x10^{-10}$	
Magnetic Field		
Sensitivity	$<2x10^{-11}$/Gauss	
Atmospheric Pressure	-60m – 4000m $<1x10^{-13}$/mbar	
Approx MTBF, Stationary	100,000Hrs	
Mechanical	38 (40 RS232 version) x 94 x 127mm, 650g max 1.5" (1.57" RS232 version) x 3.7 x 5", 23oz max	

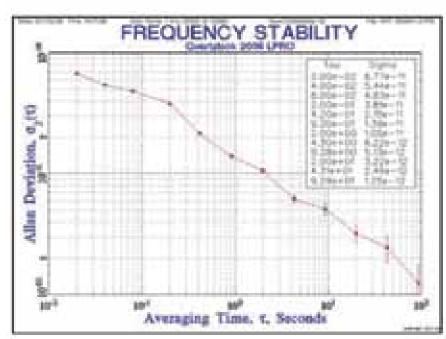
Pin Connections

C1: 'D' 9 Pin Male
C2: SMA RF Output
1. Lock Monitor (BIT)
2. DC Return
3. Case
4. N/C
5. Ext 'C' Field Voltage (0–5V)
6. N/C
7. DC Power (+24V)
8. VCXO CV Monitor
9. Lamp (Light) Monitor

Dimensions



STS



Ultra Low Noise Rubidium Oscillator

- 10MHz standard version has -110dBc/Hz @ 1Hz phase noise
- Uses Quartzlock Digital PLL DDS Clean-up Loop technology
- 5MHz option has -123dBc/Hz @ 1Hz offset
- 100MHz option has -180dBc/Hz noise floor

Features

- Ageing $5x10^{-10}$/year
- Three Year Warranty
- Short Term Stability $3x10^{-12}$/100s
- $5x10^{-11}$ accuracy

Benefits

The use of ULN-Rb Oscillators enables:
- Weak Signal Detection
- Low Error Rates
- Higher Radar Sensitivity
- Higher Definition in MRI Imaging Systems

Applications

- Security
- Low Noise Instrumentation Reference
- Radar
- Navigation
- RF & Microwave Test Solution Reference
- Secure Communications

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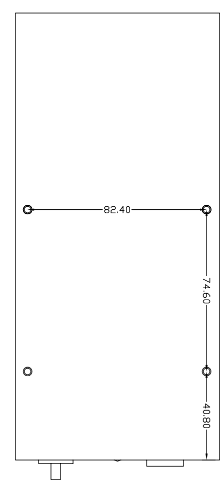
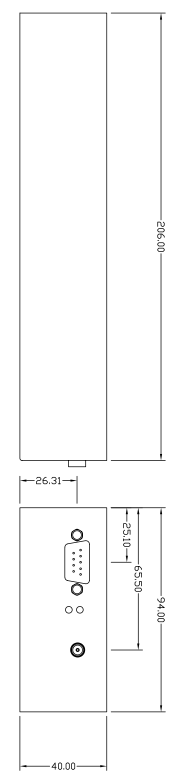
Specifications

Output (100MHz ULN option)	10MHz, +7dBm into 50Ω, 0.5VRMS 1MHz to 40MHz output. Option 5MHz output (not using DDS).
Adjustment	Mechanical Range: $2x10^{-9}$ min Electrical Range: $2x10^{-9}$ min Control Voltage: 0 ~ 5V Factory Setting: $\pm 5x10^{-11}$
Frequency Stability (10MHz)	**10MHz** / **5MHz** 1s: $<5x10^{-12}$ / $<5x10^{-13}$ 10s: $<5x10^{-12}$ 100s: $<3x10^{-12}$ 1 hour: $<6x10^{-12}$ / $<6x10^{-12}$
Aging	1 day: $1x10^{-12}$ 1 month: $4x10^{-11}$ 1 year: $5x10^{-10}$
Phase Noise dBc/Hz	**10MHz dBc/Hz** / **5MHz Opt dBc/Hz** 1Hz: <-110 / <-123 10Hz: <-140 / <-140 typ 100Hz: <-145 / <-145 typ 1kHz: <-150 / <-150 typ 10kHz: <-155 / <-156 typ
Harmonics	<30dBc
Spurious	<80dBc
Warm time to 1x10-9	5 minutes
Retrace	$<3x10^{-11}$ after 24h off & 1h on, same temp
Power Supply	Power at steady state at 25°C: 13W @ 24V (22~30Vdc) @ 25°C, Max 2A Freq offset over output voltage range: $<2x10^{-11}$
Temperature	Operating: -20°C ~ +50°C Storage: -40°C ~ +70°C Freq offset over operating temperature range: $<3x10^{-10}$

Magnetic Field	Sensitivity: $<2x10^{-11}$/Gauss Atmospheric Pressure: -60m ~ 4000m $<1x10^{-13}$/mbar Approx MTBF, Stationary: Approx MTBF, Stationary
Mechanical	40 x 94x 206mm, 1000g approx 1.6"x 3.7"x8.1", 35oz approx
Lock Indicator	**On** - Not Locked **Off** - Locked, Low Phase Error **Short flash every second** - Locked, High Phase Error
Interface	9.6kbaud, RS232, PC compatible
Interface Codes	See separate document
Option 42	1MHz to 40MHz output. 5MHz output (not using DDS).

Outline Drawing





Pin Connections

C1: 'D' 9 Pin Male   C2: SMA RF Output

1. Lock
2. GND
3. GND
4. Rx
5. EXT control
6. TX
7. +24V
8. VCXO monitor
9. Lamp monitor

Miniature Rubidium Oscillator

- □ 1PPS Discipline I/0 Sync
- □ 12V dc 8W
- □ High Performance Reference, exhibits excellent drift per hour and per day

The E10-MRO is a compact cost effective Miniature Rubidium Oscillator Frequency Standard that maintains the high time and frequency accuracy demanded in applications such as telecoms, aviation, nautical and precision test and measurement.

Features

- RS232 Interface
- Low Phase Noise to -165dBc/Hz (option)
- Ageing: 5 x 10^{-10}/year
- Stability 5 x 10^{-12}/100s
- 10MHz Output

Benefits

- Simple integration into systems
- Fits 1U case
- Low Failure risk
- 2 year Warranty

Applications

- Telecom Network Synchronisation
- Frequency Calibration
- Broadcast
- Cellular Wireless Base Stations

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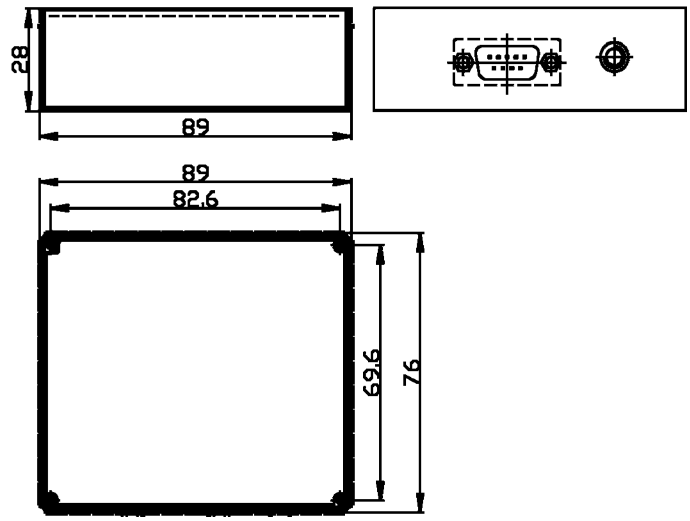
Specification

Output	10MHz
Optional Outputs	Consult factory
Accuracy	±$5x10^{-11}$ at shipment @25°C
Aging	$5x10^{-12}$/day $5x10^{-11}$/month
Retrace	≤±$3x10^{-11}$
Short Term Stability	1s $5x10^{-11}$ 10s $1.6x10^{-11}$ 100s $5x10^{-12}$
Phase Noise	**dBc/Hz** 10Hz -85dBc 100Hz -125dBc 1kHz -140dBc
Input Power	8W at 12V@25°C, Max 2.5A
Input Voltage Range	12 ±0.5Vdc
Warm-up	5 minutes to lock @ 25°C
Frequency Control	Internal trim range (trimpot) ≥$2x10^{-9}$ External trim range ≥$2x10^{-9}$ (0V~5V)
Temperature	Operating -20°C to +50°C Temperature Coefficient (ambient) $2x10^{-10}$ (-20°C to 50°C) Storage -55°C to +85°C
MTBF	100,000 hours
Connector	DB-9 Connector, SMA
Size	89 × 76 × 28 (mm³) (190cc)
Weight	0.25kg max
Warranty	2 years
Low Noise Option E10-MRO LN	This high performance version exhibits lower phase noise and higher short term stability. A 1PPS locking module is included (see A6-1PPS). Customers may specify lower phase noise than above.

Dimensions

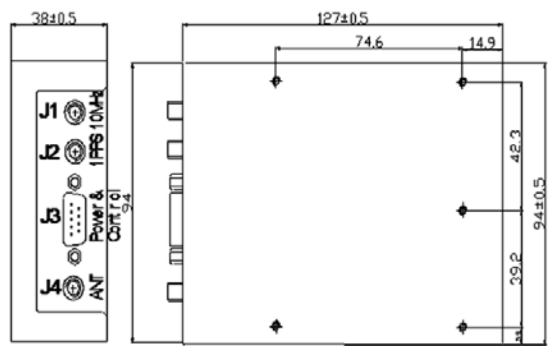


Connector Interface

J1: SMA, RF OUTPUT
J2: DB-9
1: lock monitor(bit)
2&4: dc return/ground
3: locking signal
5: ext C-field (0~5V)
6, 8 & 9: NC (Used for RS232 option)
7: +12V

GPS Disciplined Rubidium Oscillator

- Low Phase Noise
- High Short Term Stability
- RS232C Digital Monitor & Control



The E10-GPS Disciplined Rubidium Oscillator is the most cost effective way to maintain the high time & frequency accuracy required for demanding applications for the OEM manufacturer. This Rubidium Oscillator provides the precision synchronization required by base stations, optical network nodes, and high-speed digital networks.

Features

- 12V dc operation
- Low Distortion
- 7 minutes to lock
- 10MHz Output
- 1PPS Output

Benefits

- Cost effective GPS Disciplined Rubidium
- 2 year warranty
- GPS Traceable Standard
- Calibration free
- Quick & simple to install

Applications

- Internal Frequency Reference
- Telecom Network Synchronisation
- Cellular Wireless Base Stations

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Specification

Accuracy	Disciplined to GPS or to EXT. 1PPS	Frequency Time	≤$1x10^{-12}$ (after disciplined for one day, 24 hours average, 25°C) ±100ns (relative to GPS or Ext. input, 25°C)
	Holdover (no GPS)	Frequency Time	≤$5x10^{-12}$/day ≤1μs/24 hours
Short Term Stability	≤$3x10^{-11}$@1s ≤$1x10^{-11}$@10s ≤$3x10^{-12}$@100s		
Phase Noise	< -100dBc@10Hz < -130dBc@100Hz < -140dBc@1kHz		
Harmonics	<-40dBc		
Spurious	<-80dBc		
Temperature Coefficient	±$3x10^{-10}$ over -20°C ~+50C		
Time to Lock (@25°C)	<7 min		
Earth Magnetic Field Sensitivity	≤$2x10^{-11}$		
Retrace	≤$2x10^{-11}$		
Output	1×10MHz Sine wave (7~13)dBm/50Ω SMA 1×1PPS TTL/50Ω SMA PC channel (RS232) for Time & Locality & Other Data and Frequency Control		
Input	GPS Antenna/50Ω SMA Ext. 1PPS/50Ω BNC		
Mode of Operations	A. Disciplined to GPS B. Disciplined to external 1PPS C. Auto Select: first priority to external 1PPS and second to internal GPS receiver.		
Remote Setting Via Serial Port Software for PC	Export UTC time. Export the location of the local place, including longitude, latitude and length. Export the model of the Atomic Oscillator. Export the version number of the software. Adjust the accuracy of 10MHz.		
Power Supply Input Voltage Power Dissipation	12VDC 22W@ Warm-up, 9W@ Steady (25°C)		
Dimensions	≤$127^{\pm0.5}$x$94^{\pm0.5}$x$38^{\pm0.5}$		
Weight	<0.6kg		
Operating Temperature	-40°C ~ +60°C		
Storage Temperature	-40°C ~ +70°C		
Humidity	≤90%		
MTBF	≥100000h		

Mechanical & Electrical

J1 (SMA):10MHz output
J2 (SMA): 1PPS output
J3 (9 PIN D-SUB):
- Pin1 +12V
- Pin2 GND
- Pin3 Lock Signal
- Pin4 1PPS_Ext
- Pin5 GND
- Pin6 TxD
- Pin7 Lock TAG
- Pin8 1PPS OUT_GPS
- Pin9 RxD

J4 (SMA): GPS Antenna

Quartzlock

A10-M (A10-MX)

Rubidium Frequency Reference

- Low Phase Noise
- Ageing <5x10^{-10}/year
- High Precision Atomic Clock

A7-MX using A10-MX as reference

A7-MX

A10-MX

The Quartzlock A10-M rubidium frequency reference is a 10 MHz, high-stability Rubidium frequency standard with flexible output options and very low cost of ownership primarily for production test of quartz oscillators and RF instrumentation frequency referencing.
The A10-MX incorporates the latest high stability and low drift designs. It may also have both 5MHz and 10MHz outputs presented on the front panel to align with A7-MX Signal Stability Analyzer reference input.

Features

- Multiple Output options
- 3 year Warranty
- Custom Frequency outputs
- Low Noise Floor
- Front panel outputs (A10-MX)
- Exceptionally low drift/ageing and high stability per hour/day

Benefits

- Stability to 8 x 10^{-14}/s @ 5MHz
- 10MHz Standard Output
- 1-40MHz optional
- 100MHz option (-180dBc/Hz NF)
- 5MHz option (-123dBc/Hz@1Hz)
- The A10-M can accommodate many options including customized requirements.

Applications

- Frequency Calibration
- Telecom Network Synchronisation
- Broadcast-Radio & TV & Satellite Communications
- HDTV
- Production Test Reference for instrumentation
- Microwave Test Bench or Test Solution

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Specification

Output	10MHz, +7dBm into 50Ω, 0.5VRMS -see options				
Adjustment					
Mechanical Range	2x10^{-9} min				
Electrical Range	2x10^{-9} min				
Control Voltage	0 ~ 5V				
Factory Setting	±5x10^{-11}				
Frequency Stability typical	A10-M	A10-MX			
	STD	LN	ULN[1] 5MHz	ULN[2] 10MHz	ULN[3] 5MHz
1s	3x10^{-12}	2x10^{-12}	5x10^{-13}	1–30s from	1s 8x10^{-14}
10s	2x10^{-12}	5x10^{-12}	2x10^{-13}	1x10^{-13} to	3 to 30s
100s	8x10^{-13}	4x10^{-13}	4x10^{-13}	2.5x10^{-13}	1.3x10^{-13}
Aging					
1 day	3x10^{-12}	1x10^{-12}	5x10^{-12}	5x10^{-12}	5x10^{-12}
1 month	4x10^{-11}	4x10^{-11}	4x10^{-11}	4x10^{-11}	4x10^{-11}
1 year	5x10^{-10}	4x10^{-10}	4x10^{-10}	4x10^{-10}	4x10^{-10}
Phase Noise dBc/Hz in 1Hz BW	STD	LN	ULN[1] 5MHz	ULN[2] 10MHz	ULN[3] 5MHz
1Hz	-90	-110	-123	-122	-123
10Hz	-120	-139	-148	-137	-140
100Hz	-135	-152	-158	-143	-145
1kHz	-145	-154	-165	-145	-150
10kHz	-150	-154	-168	-145	-155
Harmonics	<30dBc	<30dBc	<40dBc	<40dBc	<40dBc
Spurious	<80dBc	<80dBc	<80dBc	<70dBc	<70dBc
Warm time to 1x10^{-9}	5 minutes				
Retrace after 24h off & 1h on, same temp	<3x10^{-11}				
Power Supply Power at steady state at 25°C	90 .... 245V ac Battery Back Up option 13W @ 24V (22~30Vdc) @ 25°C, Max 2A				
Freq offset over output voltage range	<2x10^{-11}				
Temperature					
Operating	-20°C ~ +50°C				
Storage	-40°C ~ +70°C				
Freq offset over operating temperature range	<3x10^{-10}				
Magnetic Field					
Sensitivity	<2x10^{-11}/Gauss				
Atmospheric Pressure	-60m ~ 4000m <1x10^{-13}/mbar				
Approx MTBF, Stationary	Approx MTBF, Stationary				
Mechanical	88mm (3.5”) 2U x 19” rack mounted				
Option	**Calibrator outputs** can be provided additionally as options. Sinewave +13dBm 50 Ohm 1Vrms Output frequencies:1MHz, 5MHz, 10MHz, 100MHz, 1GHz				

Options

- Multiple Outputs
- 1 .... 40MHz Output Frequency
- Ultra Low Noise 50 .... 100MHz Outputs (-180dBc Noise Floor)
- 24V dc Battery Back-up Input

A10-MX Uses Quartzlock DPPL-DDS Clean Up Loop Technology

Please contact Quartzlock about your application. We can help you choose the most cost effective low noise solution.

The Quartzlock A10-M or A10-MX find applications in standards laboratories, as low noise frequency references and as calibrators.

Rubidium Time & Frequency Reference

- Low phase noise
- Ageing <4x10^{-10}/year
- High Precision Atomic Clock

The A1000 exhibits extraordinarily low ageing/drift and very high stability per hour and per day. These characteristics along with our three year warranty make the A1000 suitable for mission critical applications. The A1000 can be highly customised with multiple outputs and frequencies.

Features

- Multiple Output options
- 3 year warranty
- Custom Frequency outputs
- -120dBc/Hz @ 10Hz phase noise

Benefits

- Stability to 5 x 10^{-13}/s
- 10MHz Standard Output
- 1–40MHz optional
- 100MHz option (-180dBc/Hz NF)
- 5MHz option (-123dBc/Hz @ 1Hz)

Applications

- Frequency Calibration
- Telecom Network Synchronisation
- Broadcast – Radio & TV & Satellite Communications
- HDTV
- Production Test Reference for instrumentation
- Microwave & Radar Test Bench or Test Solution

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Specification

Outputs See options	10MHz, +7dBm into 50Ω, 0.5VRMS	
Adjustment Mechanical Range Electrical Range Control Voltage Factory Setting	2x10^{-9} min 2x10^{-9} min 0 ~ 5V ±5x10^{-11} 1x10^{-11}	
Frequency Stability	1s 10s 100s 1day	3x10^{-11} 1x10^{-11} 3x10^{-12} 8x10^{-12}
Ageing	1 day 1 month 1 year	3x10^{-12} 4x10^{-11} 5x10^{-10}
Phase Noise	dBc/Hz in 1Hz BW 1Hz 10Hz 100Hz 1kHz 10kHz	**Standard** -70 -100 -120 -140 -145
Harmonics	<40dBc	
Spurious	<80dBc	
Warm Time to 1 x 10^{-9}	5 minutes	
Retrace after 24h off & 1h on, same temp	<3x10^{-13}	
Power Supply Power at steady state at 25C	90 .... 245V ac Battery Back Up option 13W @ 24V (22–30Vdc) @ 25C, Max 2A	
Frequency Offset over output voltage range	<2x10^{-11}	
Temperature Operating Storage Freq offset over operating temperature range	-20C ~ +50C -40C ~ +70C <3x10^{-10}	

Magnetic Field Sensitivity Atmospheric Pressure Approx MTBF, Stationary	 <2x10^{-11}/Gauss -60m ~ 4000m <1x10^{-13}/mbar Approx MTBF, Stationary
Mechanical	88mm (3.5”) 2U x 19” rack mounted
Options	**0** Seamless Battery Back-up Switch **1** High Performance Distribution Card 1 Input 4 Outputs **2** E1 Output **3** T1 Output **4** 13MHz Output **5** TTL Output **7** 10.24MHz Output **8** 10.23MHz Output **9** Add 6 Output Distribution Card (not available with option 48 – ULN) **18** Add Additional 1–5 Years Warranty (18.1 = 1 Year … 18.5 = 5 Years) **40** Reduced Harmonic (<-50dBc) and Spurii **48** ULN Ultra Low Noise Outputs 5MHz -123dBc/Hz @ 1Hz offset 10MHz -115dBc/Hz @ 1Hz 100MHz -135dBC/Hz @ 100Hz -162dBc/Hz @ 1kHz -180dBc/Hz @ 100kHz

Rubidium Frequency Reference

☐	Stability	(AVAR) $8x10^{-13}$/s typically
☐	Low phase noise	110dBc/Hz offset as standard
☐	Stability	(AVAR) $8x10^{-13}$/s typically
☐	Drift	$5x10^{-10}$/year

Features

- Ultra High Performance Reference
- Multiple Output Options
- Custom Frequency Outputs
- Noise Floor – 167dBc/Hz
- Ageing - $4x10^{-10}$/year

Benefits

- Stability to $5x10^{-13}$/s
- 10 MHz Standard Output
- 1–40 MHz optional
- 100 MHz option (-180dBc/Hz NF)
- 5 MHz option (-123 dBc/Hz @ 1 Hz)
- E1000 uses Quartzlock Active Noise Filter Clean Technology

Applications

- Frequency Calibration
- Telecom Network Synchronisation
- Broadcast – Radio & TV HDTV
- Satellite communications
- Production Test Reference for instrumentation
- Microwave & Radar Test Bench or Test Solution

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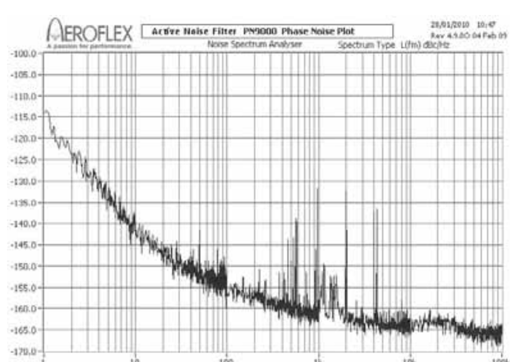
Specification

Outputs See options	10MHz, +7dBm into 50Ω, 0.5VRMS	
Adjustment Mechanical Range Electrical Range Control Voltage Factory Setting	 $2x10^{-9}$ min $2x10^{-9}$ min 0 ~ 5V $\pm 5x10^{-11}$ $1x10^{-11}$	
Frequency Stability 1s 10s 100s 1 hour 1day	Standard spec $2x10^{-12}$ $5x10^{-12}$ $4x10^{-13}$ $1x10^{-12}$	ULN option $5x10^{-13}$ $2x10^{-13}$ $4x10^{-13}$ $1x10^{-12}$
Ageing 1 day 1 month 1 year	$3x10^{-12}$ $4x10^{-11}$ $5x10^{-10}$	$3x10^{-12}$ $4x10^{-11}$ $5x10^{-10}$
Phase Noise dBc/Hz in 1Hz BW 1Hz 10Hz 100Hz 1kHz 10kHz 100kHz	 Standard -110 -140 -145 -155 -157	 ULN option -115 -146 -156 -163 -164 -167
Harmonics	<30dBc	<30dBc
Spurious	<80dBc	
Warm Time to 1 x 10^{-9}	5 minutes	
Retrace after 24h off & 1h on, same temp	$<3x10^{-13}$	
Power Supply Power at steady state at 25C	90 .... 245V ac Battery Back Up option 13W @ 24V (22–30Vdc) @ 25C, Max 2A	
Frequency Offset over output voltage range	$<2x10^{-11}$	
Temperature Operating Storage Freq offset over operating temperature range	 -20C ~ +50C -40C ~ +70C $<3x10^{-10}$	

Magnetic Field Sensitivity Atmospheric Pressure Approx MTBF, Stationary	 $<2x10^{-11}$/Gauss -60m ~ 4000m $<1x10^{-13}$/mbar Approx MTBF, Stationary
Mechanical	88mm (3.5") 2U x 19" rack mounted
Options	**0** Seamless Battery Back-up Switch **1** High Performance Distribution Card 1 Input 4 Outputs **2** E1 Output **3** T1 Output **4** 13MHz Output **5** TTL Output **7** 10.24MHz Output **8** 10.23MHz Output **9** Add 6 Output Distribution Card (with option 48 a ULN card is fitted) **18** Add additional 1–5 Years Warranty (18.1 = 1 Year … 18.5 = 5 Years) **40** Reduced Harmonic (<-50dBc) and Spurii **48** ULN Ultra Low Noise Outputs 5MHz -123dBc/Hz @ 1Hz offset 10MHz -115dBc/Hz @ 1Hz 100MHz -135dBc/Hz @ 100Hz -162dBc/Hz @ 1kHz -180dBc/Hz @ 100kHz



E1000 with 10MHz ULN Option. Typical Phase Noise

Compact Portable Rubidium Frequency Reference

- Greater than 2 hours battery operation
- Operates from car 12vdc output
- Less than 3 minute warm up
- Compact form factor 103x55x122mm <500g for a wide range of applications

Actual size

This portable Rubidium frequency standard will operate from an External 12Vdc Supply or its Internal Batteries.
For remote site operation i.e. cellular BTS the E10-P may run from the cigarette lighter socket to arrive fully charged and warm.
The E10-P Portable Rubidium frequency reference benefits from Quartzlock's SMAC Rubidium Oscillator technology and state-of-the-art internal high capacity batteries.

Features

- 10MHz Output
- Ageing <$5x10^{-10}$/year
- -95dBc/Hz @10Hz
- $5x10^{-11}$ accuracy
- $8x10^{-12}$/s @ 100s

Benefits

- Atomic accuracy
- No antenna
- Quick and simple use and installation
- Low drift
- Hand held

Applications

- Remote site frequency reference for cellular BTS & satellite communication ground stations
- Field service & production test frequency reference
- Frequency standard for counters, signal generators, spectrum and network analysers

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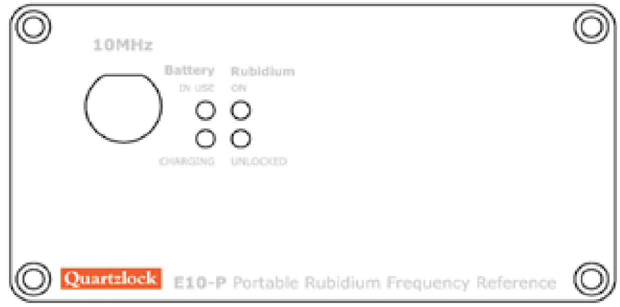
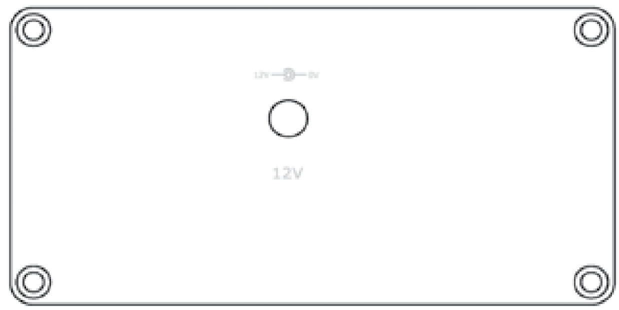
Specifications

Output	10MHz Sine, 10dBm, ±3dBm	
Harmonics	<-40dBc	
Accuracy	±5x10^{-11} at shipment @25°C	
Short Term Stability (AVAR)	1s	8x10^{-11}
	10s	3x10^{-11}
	100s	8x10^{-12}
Drift	1 day	5x10^{-12}
	1 month	5x10^{-11}
Phase to Noise (SSB)	10Hz	-95dBc
	100Hz	-125dBc
	1kHz	-135dBc
Input Power	6W at 12V @ 25°C, Max 1.2A	
Input Voltage Range	90...245V ac or +12V dc	
Run Time Battery	2 hours	
Charge Time Battery	4 hours	
Warm Up	5 minutes to lock @ 25°C	
Retrace	≤±2x10^{-11}	
Magnetic field sensitivity, dc (±2 GAUSS)	<±4x10^{-11}/Gauss	
External Trim Range	≥5x10^{-9} (0V~5V) option	
Size	103 x 55 x 122 mm	
Weight	500gm approx	
Warranty	24 months	





Environmental Specifications

Operating Temp Range	-20°C~+50°C Typical: -30~+65°C
Temperature Coefficient (ambient)	2x10^{-10} (0~50°C)
Storage Temperature	-55°C~+85°C
MTBF	100,000 hours
Environmental health	RoHS
EMI	Compliant to FCC Part 15 Class B

Compact Desktop Rubidium Frequency Reference

- Compact light weight portable for a wide range of applications
- Fast warm time
- Low power operation
- 12V dc operation (ac plug top adaptor supplied)

Actual size

Compact simple to install atomic frequency reference for use as a general purpose 10MHz rubidium frequency standard.
This frequency standard benefits from having Quartzlock's SMAC (Sub Miniature Atomic Clock) technology built in.

Features

- 10MHz Output
- Ageing $<5x10^{-10}$/year
- -95dBc/Hz @10Hz
- $5x10^{-11}$ accuracy
- $8x10^{-12}$/s @ 100s

Benefits

- Atomic accuracy
- No antenna
- Quick and simple use and install
- Transfer standard

Applications

- Production test frequency standard
- Time and frequency standard for calibration and RF laboratories
- Frequency standard for counters, signal generators, spectrum and network analysers
- Wired and Wireless network synchronization

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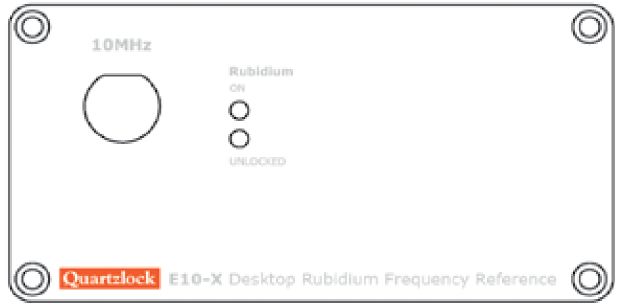
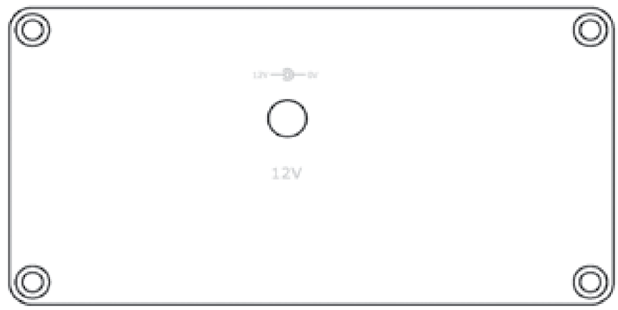
Specifications

Output	10MHz Sine, 10dBm, ±3dBm
Harmonics	<-40dBc
Accuracy	±5x10^{-11} at shipment @25°C
Short Term Stability (AVAR)	1s 8x10^{-11} 10s 3x10^{-11} 100s 8x10^{-12}
Drift	1 day 5x10^{-12} 1 month 5x10^{-11}
Phase to Noise (SSB)	10Hz -95dBc 100Hz -125dBc 1kHz -135dBc
Input Power	6W at 12V @ 25°C, Max 1.2A
Input Voltage Range	90...245V ac or +12V dc
Warm Up	5 minutes to lock @ 25°C
Retrace	≤±2x10^{-11}
Magnetic field sensitivity, dc (±2 GAUSS)	<±4x10-11/GAUSS
Size	103 x 55 x 122 mm
Weight	500gm approx
Warranty	24 months





Environmental Specifications

Operating Temp Range	-20°C~+50°C Typical: -30~+65°C
Temperature Coefficient (ambient)	2x10^{-10} (0~50°C)
Storage Temperature	-55°C~+85°C
MTBF	100,000 hours
Environmental health	RoHS
EMI	Compliant to FCC Part 15 Class B

Rubidium Frequency Reference Low Noise Multiple Outputs

- Eight outputs
- -110dBc/Hz @ 1Hz phase noise
- Compact light weight portable for a wide range of applications
- Low drift $5x10^{-12}$/day

Approx actual size

Compact simple to install low noise multi-output atomic frequency reference for use as a general purpose 10MHz rubidium frequency standard.
This very low noise rubidium frequency reference will enable up to eight separate instruments to be referenced.
This frequency standard benefits from having Quartzlock's SMAC (Sub Miniature Atomic Clock), and very low noise distribution amplifier technology built in.

Features

- 10MHz multiple outputs
- Ageing <$5x10^{-10}$/year
- $5x10^{-11}$ accuracy
- $8x10^{-12}$/s @ 100s

Benefits

- Atomic accuracy
- Quick and simple to use and install
- Higher sensitivity
- Enables narrower bandwidth filtering
- Improved instrument frequency accuracy & phase noise

Applications

- Frequency referencing of interception and monitoring receivers
- ***Time and frequency standard for calibration and external referencing of all quartz-based instrumentation in RF and microwave laboratories to significantly reduce noise levels and improve accuracy***
- Frequency reference for counters, signal generators, spectrum, DSO, VNA, SA and network analysers
- Secure communications, C4, defence and R&D

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Specification

Outputs – 4 or 8	4 (E10-Y4) or 8 (E10-Y8) 10MHz, 13dBm ±1db into 50Ω, 0.5VRMS
Output Connectors	SMA
Adjustment Mechanical Range Electrical Range Control Voltage Factory Setting	 $2x10^{-9}$ min $2x10^{-9}$ min 0 ~ 5V $\pm 5x10^{-11}$ $1x10^{-11}$
Frequency Stability	0.2s $4x10^{-12}$ 1s $2x10^{-12}$ 10s $5x10^{-12}$ 100s $4x10^{-13}$ 1 hour 1 day $1x10^{-12}$
Ageing	1 day $1x10^{-12}$ 1 month $4x10^{-11}$ 1 year $4x10^{-10}$
Phase Noise	dBc/Hz in 1Hz BW — Standard 1Hz -110 10Hz -140 100Hz -145 1kHz -155 10kHz -157
Harmonics	<30dBc -46dB -36dB
Spurious	<80dBc
Warm Time to $1 x 10^{-9}$	5 minutes
Retrace after 24h off & 1h on, same temp	$<3x10^{-13}$
Power Supply Power at steady state at 25C	90 .... 245V ac Battery Back Up option 15Vdc @ 500mA 7.5W (1.5A warm-up 22.5W) @ 25C, Max 2A
Frequency Offset over output voltage range	$<2x10^{-11}$
Temperature Operating Storage Freq offset over operating temperature range	 -22C ~ +30C max -40C ~ +70C $<3x10^{-10}$

Magnetic Field Sensitivity Atmospheric Pressure Approx MTBF, Stationary	 $<2x10^{-11}$/Gauss -60m ~ 4000m $<1x10^{-13}$/mbar Approx MTBF, Stationary
Size	103 x 55 x 122 mm
Weight	500gm approx
Warranty	24 months

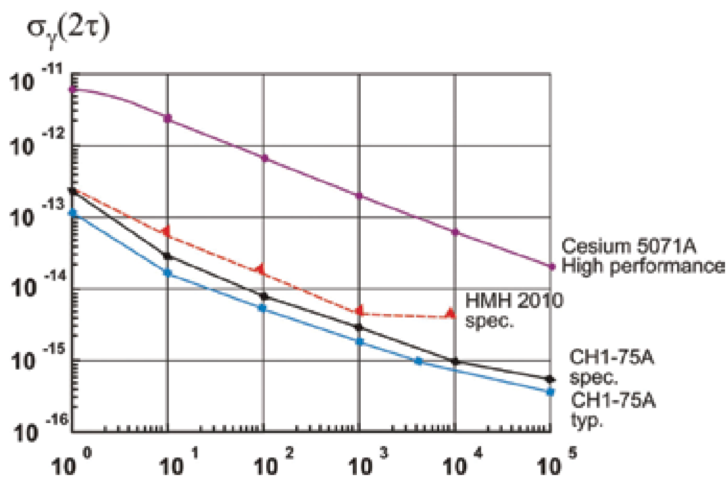
Options

The E10-Y series is a new product range introduced in 2012. A few options will be available to meet customer requirements – please discuss with Quartzlock.

Cable set: 8 x SMA to BNC cables 1.5m long can be supplied.

Active Hydrogen Maser

- $<5x10^{-13}$ frequency accuracy
- -100dBc/Hz @ 1Hz
- Autonomous automatic cavity tuning (without a second H-Maser)
- $1.5x10^{-13}$ @ 1s short term stability



The CH1-75A Active Hydrogen Maser is designed to operate as a high stability, precision spectrally pure 5 and 100MHz signal source and provides time scale signals of 1s period. The AHM has similar lifetime cost to Cs.

Features

- $<1x10^{-15}$/day ageing
- $1.5x10^{-12}$/year accuracy
- 5MHz output
- 1PPS
- $<1x10-^{14}$/°C temperature coefficient

Benefits

- Low cost of ownership
- Primary frequency reference
- 15 Year lifetime

Applications

- National time and frequency services
- Ground control
- Surveillance
- Radio navigation systems
- Radio interferometers with a very long baseline

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Specification

Frequency Outputs	5MHz,10 MHz and 100 MHz (sine), 1±0.2 V rms into 50 Ohm
Timing Output	1Hz (1PPS)
Amplitude	>2.5V into 50 Ohm
Width	10–20ms
Rise time	<15ns
Jitter	<0.1ns
Frequency stability (Allan Deviation)	1s $\leq 2\times10^{-13}$ 10s $\leq 3\times10^{-14}$ 100s $\leq 7\times10^{-15}$ 1 hour $\leq 2\times10^{-15}$ 1 day $\leq 7\times10^{-16}$

(Although this is a rugged instrument which operates within +10°C to +35 °C ambient, the quoted specifications for 100 s, 1 hour and 1 day apply while the instrument is confined to a ±1°C ambient temperature change).

Temperature sensitivity	1.5×10^{-15}/C
Magnetic field sensitivity	$<1\times10^{-14}$/Gauss
Drift (aging)	2×10^{-15} /day at delivery 5×10^{-16} /day after 1 year operation
Frequency trim range	1×10^{-10}
Setting resolution	1×10^{-15}
Phase noise Offset from carrier	SSB phase noise, dBc/Hz 10Hz –130 100Hz –140 1kHz –150 10kHz –150
Harmonic distortion	< 30dB (for 5 MHz output)
Non-harmonic distortion	< –100dB in the range from 10Hz to 10kHz
Power	100, 120, 220 V±10 %, 240 V+5–10 %, 47–63 Hz or 22–30 V dc At power line failure the Instrument automatically switches to an external 22–30V dc power supply
Power consumption	150 VA ac, 100 W dc
Operating temperature	+10°C to +35°C
Storage temperature	–50°C to +50°C
Humidity	up to 80% at 25°C
Size	(H ×W ×D) 70.8 × 48.0 × 59.5 cm
Weight	90 kg
Service Life	15 years before service

See Quartzlock Hydrogen Maser compatible instrumentation

A5-8 Distribution Amplifier – see page 8
A6 Frequency Converter – see page 20
A7-MX Signal Stability Analyzer – see page 28

CH1-75A Active Hydrogen Maser

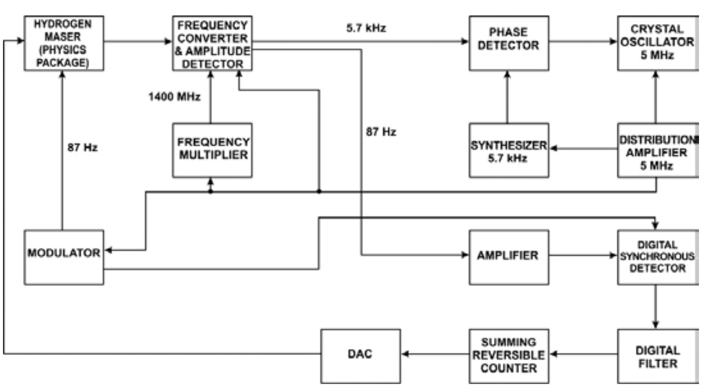
1 second ≤ $1{,}5 \times 10^{-13}$
1 day ≤ 7×10^{-16}
Temperature sensitivity ≤ $1{,}5 \times 10^{-15}$/C

KVARZ has been developing and manufacturing H-Masers over 40 years and has a great experience in this field.This model is the third H-Masers generation.
During this period of time, more than 500 units have been built.
It five times exceeds the number of hydrogen masers produced by all other maser manufactures in the world.
The performance specifications of the CH1-75A Active Hydrogen Maser exceed those available from any other unit manufactured world-wide.

The CH1-75A mechanical architecture is focussed on modular construction in a tough transportable package. A lightweight tubular aluminium space frame is used in transport and for mobile applications.

Frequency Stability (Allan Deviation)

Frequency Stability (Hadamar Deviation)



CH1-75A Hydrogen Maser Block Diagram

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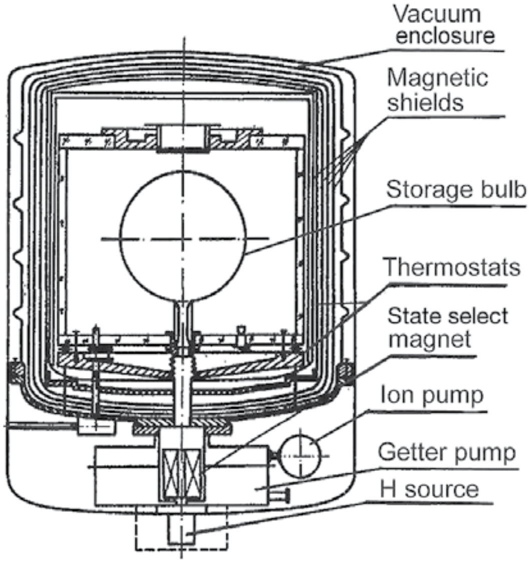


CH1-75A Active Hydrogen Maser Physics Package Schematic
Very efficient beam optics including quadrapole magnet and unique multipath collimator.
It allows to reduce hydrogen usage to 0.01 mole per annum thus simplifying its vacuum pumping.

Autonomous Cavity Auto Tuning – Long-term Stability
The most recent development to improved performance of the Active Hydrogen Maser is an advanced Cavity Auto Tuning System, which insures the Maser remains centered on the hydrogen line over the long term.
The advantages of the cavity auto tuning in the CH1-75A are as follows:

- a modulation frequency of 87Hz is approximately three times higher than that in other auto-tuning systems. As a result, very low spurious components at frequency modulation of 87Hz are achieved. It is especially important where the Maser is used for VLBI.
- very low temperature sensitivity of the Maser of ~ $1.5x10^{-15}$/ C.

Hydrogen pumping is performed by a very efficient getter pump, having extended lifetime (over 15 years). The advantages of such a pump are:

- no power supply during operation is required
- high reliability
- small size and weight (5 kg)

Very efficient magnetic shielding. Magnetic sensitivity of the Maser is less than $1x10^{-14}$/Oersted. This is achieved thanks to a five-layer magnetic shield made of permalloy with initial magnetic permeability of more than 100,000.

High temperature frequency stability of the Maser
The hydrogen maser frequency is linearly dependent on the cavity frequency:

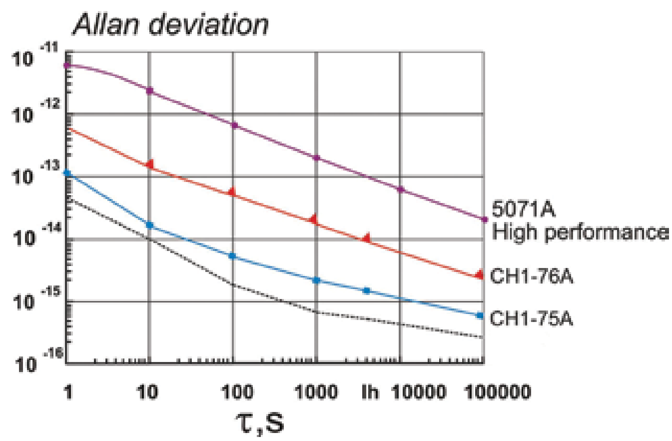
$$\Delta f_{maser} = \frac{Q_{cavity}}{Q_{line}} \Delta f_{cavity}$$

In order to reduce temperature influence on the cavity frequency, it is manufactured of a unique glass material, which exhibits virtually zero temperature coefficient (~$1–2x10^{-7}$ /°C).

Temperature stabilization of such a cavity with an accuracy of 0.001˚ C allows a decrease in the Maser temperature sensitivity to $5x10^{-15}$/C even without auto-tuning.

Passive Hydrogen Maser

- $<8x10^{-13}$/s @ 1s short term stability
- -100dBc/Hz @ 1Hz
- Small size and weight
- 15 year life time



The CH1-76A Passive Hydrogen Maser is designed to operate as a high-stability frequency source with precise, spectrally pure 5 MHz output. The CH1-76A is the first in the world Time and Frequency Hydrogen Maser of a passive type. This maser is the ideal, much higher performance alternative to caesium atomic clocks at less than half the lifetime cost of Cs.

Features

- $<1x10^{-15}$/day aging. $5x10^{-15}$/day stability AVAR.
- $1.5x10^{-12}$/year accuracy
- 5MHz output
- 1PPS (100ps Jitter)
- $<1x10^{-14}$/C temperature coefficient
- $3x10^{-14}$/1000s AVAR

Benefits

- Low cost of ownership
- Second most stable time & frequency standard available
- No expensive wear out-throw away Cs tube.

Applications

- National time and frequency services
- Ground control for GNSS
- Surveillance
- Radio navigation systems
- T&F laboratory reference

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Specification

Frequency Outputs	5MHz (sine), 1±0.2V rms into 50 Ohm
Timing Output	1Hz (pulse)
Amplitude	≥2.5V into 50 Ohm
Width	10–20µs
Rise time	<30ns
Jitter	<0.1n
Frequency stability AVAR	σ(τ)

Averaging time	Specifications	Typical Values
1s	$\leq 1.5\times10^{-12}$	$\leq 4.8\times10^{-13}$
10s	$\leq 5\times10^{-13}$	$\leq 1.5\times10^{-13}$
10^2s	$\leq 2\times10^{-13}$	$\leq 4.5\times10^{-14}$
10^3s	$\leq 5\times10^{-14}$	$\leq 1.5\times10^{-14}$
1h	$\leq 3\times10^{-14}$	$\leq 8.5\times10^{-15}$
1 day	$\leq 1\times10^{-14}$	$\leq 4\times10^{-15}$

Drift (Ageing)	$<3\times10^{-15}$/day
Accuracy	$\pm1.5\times10^{-12}$/year
Temperature sensitivity	$\leq 2\times10^{-14}$/C
Magnetic field sensitivity	$\pm2\times10^{-14}$/Gauss
Frequency trim range	1×10^{-10}
Setting resolution	1×10^{-14} Steps
Phase noise	

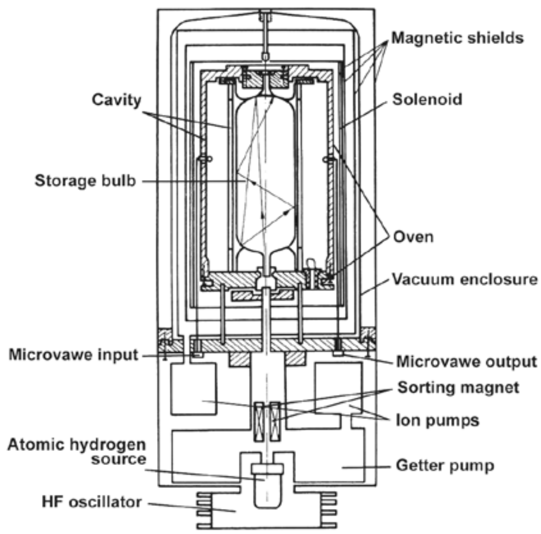
Offset from carrier	SSB phase noise, dBc/Hz
1Hz	–110
10Hz	–125
100Hz	–150
10kHz	–150

Harmonic distortion	< 30dB
Non-harmonic distortion	< 100dB
Power	220±22V, 50±1Hz, 220±11V, 115±6V, 400Hz At power line failure the instrument automatically switches to an external 22–30V DC power supply
Power consumption	140VA, 90W
Operating temperature	5–40°C
Storage temperature	–50 – +50°C
Humidity	up to 80% at 25°C
Size	(HxWxD) 28 x 48 x 55.5cm
Weight	51 kg
Service Life	12 years before service

See Quartzlock Hydrogen Maser compatible instrumentation

A5-8 Distribution Amplifier – see page 8
A6 Frequency Converter – see page 20
A7-MX Signal Stability Analyzer – see page 28

←



Schematic Picture of a Passive Hydrogen Maser Physics Package

CH1-76A Passive Hydrogen Maser

The size and weight of the active hydrogen maser in some cases hinder its application, especially in the field conditions.
The problem of reducing the active hydrogen maser size is connected with reduction of microwave cavity size, which results in reduction of its Q-factor.
Reduction of cavity Q-factor leads to the failure of the maser generation conditions, and it goes into amplifying mode, so called "passive" mode. Due to this factor, an idea of creation of a passive hydrogen maser was realised.
In 1988 KVARZ created the first industrial Passive Hydrogen Maser in the world (the CH1-76); at the present time KVARZ produces its improved version, the CH1-76A.

Passive Hydrogen Maser Features
A hydrogen atom generation system and a vacuum system of a passive maser are the same as those of an active maser. Their service life is 15 years.
KVARZ realised the so called "magnetron" cavity construction which is very rigid and insures a passive hydrogen maser suitability for field and space applications.
In this instrument, one 12.5 kHz modulation frequency and a free-running local oscillator are used.

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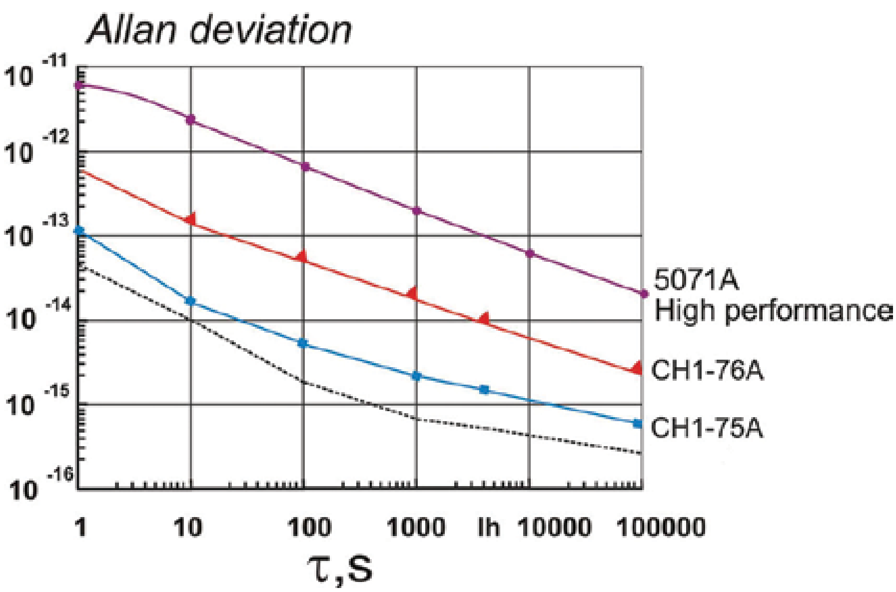
Atomic Clock Comparisons



As for a frequency stability, a passive maser holds a middle position between an active hydrogen maser and a cesium frequency standard.
Its stability for measurement time from 1 sec to 100.000 sec is a factor of 10 better than the best cesium standard – 5071A Primary Frequency Standard (High Performance Cesium Beam Tube).

Air Interface Simulator

Radio Path Modelling System

This is one example of a customer defined special product designed by Quartzlock.

This AIS simulated the air interface between a number of mobile and BTS with interfering mobile and BTS facilities.

To discuss your special product requirement please call Quartzlock.

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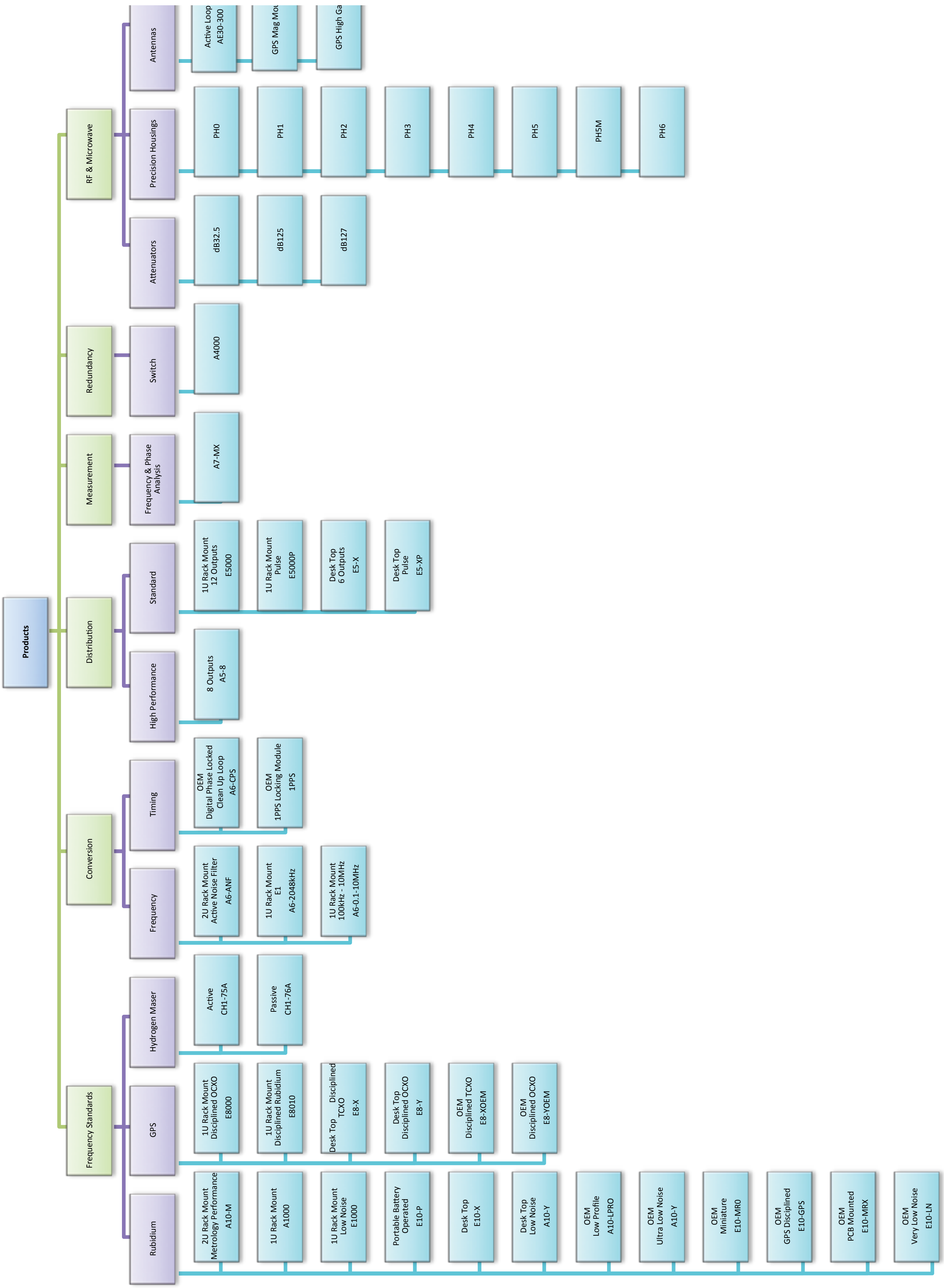
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Antennas
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AE30-300
Precision Housings
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PH1
PH2
PH3
PH4
PH5
PH5M
PH6
Attenuators
dB32.5
dB125
dB127
Switch
A4000
Frequency & Phase Analysis
A7-MX
Standard
1U Rack Mount 12 Outputs E5000
1U Rack Mount Pulse E5000P
Desk Top 6 Outputs E5-X
Desk Top Pulse E5-XP
High Performance
8 Outputs A5-8
Timing
OEM Digital Phase Locked Clean Up Loop A6-CPS
OEM 1PPS Locking Module 1PPS
Frequency
2U Rack Mount Active Noise Filter A6-ANF
1U Rack Mount E1 A6-2048kHz
1U Rack Mount 100kHz - 10MHz A6-0.1-10MHz
Hydrogen Maser
Active CH1-75A
Passive CH1-76A
GPS
1U Rack Mount Disciplined OCXO E8000
1U Rack Mount Disciplined Rubidium E8010
Desk Top Disciplined TCXO E8-X
Desk Top Disciplined OCXO E8-Y
OEM Disciplined TCXO E8-XOEM
OEM Disciplined OCXO E8-YOEM
Rubidium
2U Rack Mount Metrology Performance A10-M
1U Rack Mount A1000
1U Rack Mount Low Noise E1000
Portable Battery Operated E10-P
Desk Top E10-X
Desk Top Low Noise A10-Y
OEM Low Profile A10-LPRO
OEM Ultra Low Noise A10-Y
OEM Miniature E10-MRO
OEM GPS Disciplined E10-GPS
OEM PCB Mounted E10-MRX
OEM Very Low Noise E10-LN

Quartzlock

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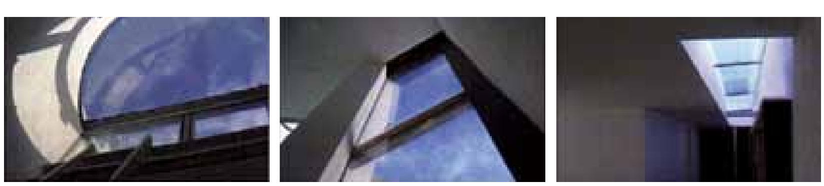

Quartzlock's new observatory building for our Maser Laboratory