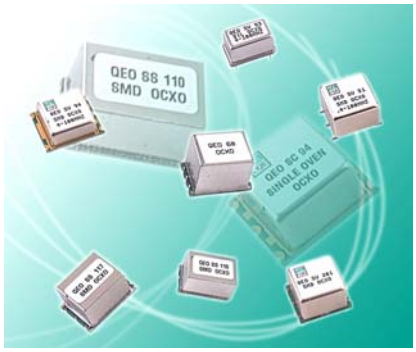
OCXO SIZE REDUCTION OVER TIME

Author : Thierry Delhomme
TEMEX
thierry.delhomme@temex.fr
www.temex-components.com



The latest developments of systems for use in the telecommunication world show that one of the main demands of designers is the size reduction of integral components.
The size reduction of components has always been a key parameter throughout the evolution of the electronics industry. In response, component manufacturers have proposed solutions in repeatedly smaller configurations. For example DIL, SO8, SOT223, SOT23, SC70... or 1206, 0805, 0603, 0402...

This tendency has remained a constant of a market that always seems to require a bigger integration. The arrival of SM technology was a decisive factor in this race for miniaturization. Essentially launched in the 80s, it was the mainspring for new technological developments. It is also necessary to note the progress realized since the late 1970s in the conception of integrated circuits and the possibility to now include several million transistors on a single chip.

Quartz oscillators and particularly OCXOs have also experienced a strong size reduction over the years. For example a frequency stability of 1ppb over a reasonable operating temperature range could initially only be achieved with a volume of approx 95 cm3 (5,8 $inch^3$). Equivalent performances are today achievable in $1/10^{th}$ of the volume.

See figure below.

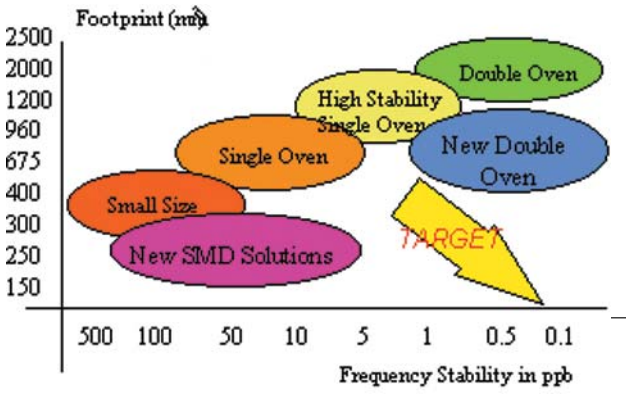


Fig 1 : OCXO stability vs package size : global trend

In this article, we intend to analyse the major reasons that allowed such an evolution in OCXO technology. An OCXO is an oscillator with a quartz crystal offering extremely good output frequency stability (from 0.5 ppm to 0.1 ppb) over it's specified operating temperature range. This stability is obtained by thermostatically regulating the environment of the quartz crystal.

An OCXO includes the following four main functions :

- The oscillator (strictly speaking)
- The thermal regulation
- The control and regulation of reference voltage
- The output buffer (sine, HCMOS, TTL...)

These functions entail the use of a maximum of one hundred active and passive components, some of these occasionally being partially included within an ASIC.

Fig 2 : 80s generation OCXO

Fig 3 : mid-90s generation OCXO

What are the major factors that allowed such an evolution?

1/ The quartz :

Over the last 5 years studies have been undertaken with quartz crystal technology to achieve improved performance especially with respect to Quality factor and ageing. It is possible today to achieve performance from a crystal housed in an HC46 or HC43 holder, comparable to that only previously achievable in an HC36 holder. (See table 1).

The following table demonstrates the reduction achieved in the size of the Double Oven OCXOs as a result of the quartz crystal improvements. Double Oven are OCXOs with two “thermostatic enclosures " independently regulated.

Case	HC36	HC46	HC43
Size (mm)	19.5x9.3x19	15x6.6x16	11.1x4.7x13.5
Size (inch)	0.77x0.37x0.75	0.59x0.26x0.63	0.44x0.18x0.53
Volume (mm^3/$inch^3$)	3445/0.21	1584/0.097	704/0.043
Ageing/year (ppb)	5 to 50		

Table 1: SC Cut/3rd O/10 MHz/ Cold Weld Metal Case.
Size vs Performances Evolution

Year	1980	1990	1997	1999	2001	2002
Size (mm)	85 x 75 x 55	75 x 75 x 60	50 x 50 x 38	50 x 50 x 38	50 x 40 x 25	36 x 27 x 20
Volume(mm^3)	350625	337500	95000	95000	50000	19440
Ratio		- 4%	-73%	-73%	-86%	-95%
Stability vs T°(ppb)			± 0.5	± 0.1	± 0.1	± 0.5
Ageing/year (ppb)			± 50	± 10	± 5	± 5
Power supply	24V / 12V	12V	12V / 5V	12V / 5V	12V / 5V	5V / 3.3V
TEMEX References				QEO DO 75	QEO DO 10	QEO DO 45

Table 2: Double Oven OCXO
SC Cut Size vs Performances Evolution

Fig 4 : TEMEX Double Oven Family

2) The reduction of the size of the OCXO's constituent components :

The use of passive SM components (resistors, capacitors and inductors) has made it possible to gain a significant reduction in the volume of the OCXO. This was amplified by the arrival of smaller and smaller components: size 0402 for the resistors and capacitors for example. One can estimate the board area saved by using 0603 SM components as opposed to leaded devices as between 30 and 50 %.

Also, the size reductions achieved with respect to active components was a major trump card. It is now possible to easily find operational amplifiers, voltage regulators, buffers or simple logical gates in typical Micro SM cases compared to 5 years ago when they only existed in SO8 cases.

3) The design:

The architecture of the OCXO has evolved strongly and allowed important savings in overall in volume. One can note 3 main factors:

a. The use of the ASIC. Whole functions (oscillators, thermal regulation) of the OCXO are sometimes replaced by ASIC. This allows both space saving and improved performance.

b. The simplification of ovens. Originally the quartz and the associated oscillators were completely integrated into a thermostatically controlled module. This module was then housed in a metal case and warmed by transistors and controlled via thermal regulation. Gradually ovens evolved leaving the place to more integrated and less voluminous solutions. One can quote for example a design constituted by two hybrid circuits with the quartz forming a sandwich. The hybrids include the functions of oscillator circuit and output buffer, voltage regulation and the warming elements. As time passed it has been possible to simplify the designs. In today's OCXO designs there is no need to thermostatically control an inner module. Detailed analysis of the thermal behaviour of the product has allowed new designs. The main advantage is a new reduction of the size and mainly of the height of the case. See Table 3

c. The development of SM solutions for OCXO. In the same way as the other component manufacturers, the suppliers of OCXOs have had to develop and to propose SM solutions. SM solutions offer the main advantage of automatic mounting: tape & reel, infrared reflow soldering (up to 260 °C / 10 sec). Some SM packages became standard, such as the 25.4 x 22 mm version. New developments are in progress that should allow even further miniaturization: 14 x 9 x 10 mm cases, representing a volume of 1260 mm^3. See table 4.

Year	1980	1990	1995	1997	2000	2001
Size (mm)	50 x 50 x 38	50 x 40 x 25	40 x 30 x 20	36 x 27 x 20	36 x 27 x 10	20 x 20 x 10
Volume(mm^3)	95000	50000	24000	19440	9720	4000
Ratio		- 47%	-75%	-80%	-90%	-96%
Stability vs. T°(ppb)		± 5	± 10	± 5 to ± 1	± 5	± 10
Ageing/year (ppb)		± 50	± 50	± 30	± 10	± 50
TEMEX Reference		QEO SC 10	QEO SC 31	QEO SC 45	QEO SC 45	QEO SC 94

Table 3 : Single Oven OCXO / SC Cut. Size vs. Performances Evolution

QEO SC 31
40 x 30 x 20 mm

QEO SC 45
36 x 27 x 20/10 mm

QEO SC 94
20 x 20 x 10 mm

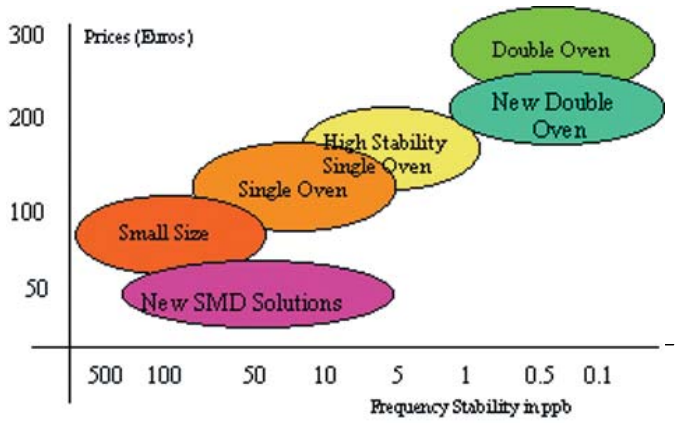
Fig 5 : SC Cut OCXO; Through hole packages

Year	1980	1995	1998	1999	2001	2002
Size (mm)		20 x 13 x 10	20 x 20 x 13	20 x 20 x 10	20 x 15 x 10	14 x 9 x 10
Volume(mm^3)		2600	5200	4000	3000	1260
Ratio				-23%	-90%	-96%
Package		Through Hole	Through Hole	SMD	SMD	SMD
Stability vs T°(ppb)		± 200	± 50	± 50	± 100	± 200
Ageing/year (ppb)		± 500	± 500	± 100	± 200	± 200
TEMEX Reference		QEO SV 93	QEO SV 51	QEO SV 94	QEO SS 117	QEO SS 60

Table 4: Small Single Oven OCXO / AT Cut. Size vs. Performances Evolution

Fig 6 : Single Oven OCXO. SMD and Small Sizes.

As conclusion we can notice that all these improvements in design and size have also allow a global price decreasing. Figure below presents prices trend according to OCXOs families.



Glossary:

OCXO: Oven Controlled Crystal Oscillator
ASIC: Application Specified Integrated Circuit
SM or SMD: Surface Mountable Devices