AoT-News

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Speed-Dating à la AoT
with Thomas Schwinghammer

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NEWS & EVENTS

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Under the Microscope

Support for Universities

Universities are often not in a position to manufacture their research-specific electronic systems in an industrial manner. In other words, there may be difficulties reproducing a given system, if the person responsible has left the institution as the documentation may be incomplete, or simply not available. It is also possible that several people were involved in the development or want to use it for their projects.

Especially when the focus of an institution is not electronic design, the system design is often limited to a quick setup without a clear, understandable and reproducible design. Such development projects often have quality problems, requiring a significantly longer duration than necessary. Art of Technology (AoT) offers a special redesign service, which strives for an industrial quality.

- Hardware redesign using industry standard components
- Layout of manufacturable Prints
- Optimised assembly process
- Creation or improvement of documentation

The result is a design that can be easily made in quantities of a few hundred by the Institute itself to be used for internal use, or for distribution to other universities or research institutions. It is also possible to maintain a system (repairs, upgrades) following the departure of the inventor, which in turn optimises the use of the time invested. Our documents are especially created to ensure a smooth (re-)entry into such projects.

This allows the basic platform to be used for new projects, avoiding the need to "re-invent the wheel", making it possible for academic institutions to live up to their claims of leading edge research. The advantages over permanent internal staff (infrastructure) are increased flexibility and ultimately lower costs.

In contrast to other alternatives, AoT comes from the same background, knows from own experience the job situation in universities and have proven to be more flexible and faster. As an ISO-certified company (ETH spin-off, 1999) we have successfully completed, in addition to commercial projects, several challenging projects with and for universities.

Institute	Project	Focus	Link
ETZ Zürich IfE	QBIC	Design & Development	www.ethz.ch/qbic
ETH Zürich, TIK	BTNode	Production optimisation, Production & Marketing	www.btnode.ethz.ch
ETH Zürich, TIK	PermaSense I/II & GPS	Design, Development & Production	www.permasense.ch
University of Zürich, Institute of Anatomy	EEG-Logger (for mmice)	Design, Development & Production	eeg-data-logger
University of Zürich, Institute of Anatomy	GPS Logger (for pigeons)	Design, Development & Production	gps-data-logger-pigeons

The emphasis was on development, technical consulting and production, as well as cost control and management. For further information contact: paul.sphikas@aotag.ch

Tech Corner

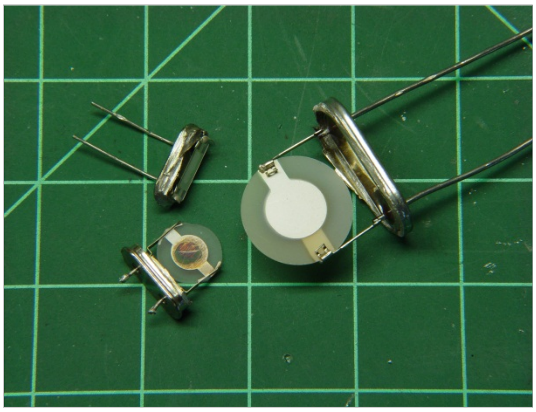
Precision Quartz Oscillators

Attila Dogan

Introduction and Applications

Hardly anyone leaves home today without some form of watch, be it a wrist watch or a smart phone that doubles as a multi-function clock. A world without clocks and their role as a precision timepiece is inconceivable. The driving force behind all of these timers is a quartz oscillator, which "shows" how long one second is. Crystal oscillators are not only an important component in clocks, but can be found in virtually all electronic devices, indicating with its oscillations, the time.

Crystals and crystal oscillators are by far the most important frequency-determining component in electronic systems, where fixed or precisely adjustable frequencies are required. They provide the clock in microcontroller circuits, determine transmit and receive frequencies in our mobile phones and help to prevent interference between different calling parties. They keep their spectrum so well that deviations are not measured in parts per thousand, but rather in parts per million (ppm). Despite their high accuracy, they are robust and easy to use, with the result that they are often not given much attention; if a crystal oscillator with the required frequency is found in a supplier's catalogue, it is often used without further scrutiny. However, not all oscillators are identical and for many applications, even in the consumer sector, the quartz oscillator itself is not accurate enough...at least the usual "run-of-the-mill" crystal oscillator.



Crystals are designed as oscillating plates
Courtesy of Ed Nisley

The most important application for crystal oscillators is the clocking of microcontrollers. The requirements in this case are usually not very high and quite often the integrated RC oscillators are sufficient; where ceramic resonators or crystals are used as the frequency-determining elements, which together with the integrated amplifier (in the micro-controller) create an oscillator.

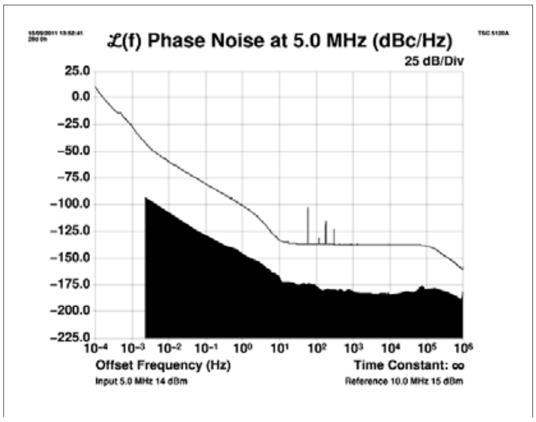
The highest demands on quartz oscillators in microcontrollers come from the integrated communication interface. While the integrated RC oscillators are still quite adequate for simple asynchronous interfaces (10,000 - 40,000 ppm = 1 - 4%), modern, fast ports are much more demanding, e.g.

- USB 2.0 requires a signal frequency with an absolute accuracy of + / - 500 ppm
- USB 3.0, due to the higher transfer rate requires, an absolute accuracy of + / - 300 ppm
- while 100 ppm to 30 ppm can be reached with simple crystal oscillators, faster transfer rates and increasingly sophisticated methods of communication demand their price.

In RF communications, low frequency quartz oscillators (operating at several 100 MHz or in the low GHz range) are often used as a reference for an internal VCO and multiplied up via a phase-locked loop (PLL). With this method, even the smallest of deviations or disturbances in the reference frequency results in a large effect on the final signal frequency, e.g. a wireless transceiver operating at 2.4 GHz typically uses a 40 MHz crystal oscillator as the reference for the VCO; as the oscillator frequency is multiplied 60 times to get to the signal frequency, small deviations and disorders can lead to losses in reception and communication errors. As such, the specifications on the crystal oscillators used for wireless applications are accordingly much higher, lying in the range of 20 ppm for frequency accuracy and low phase noise.

The requirements for frequency accuracy and stability of today's modern communication systems are constantly increasing, primarily due to attempts to reduce the power consumption - on both sides. Reducing both transmission power and the receiver sensitivity results in a significant reduction in the signal to noise ratio. The useful signal is increasingly obscured by noise and the decoding of the desired signal becomes progressively more difficult. This problem can be lessened if the exact frequency of the desired signal is known… as if you already know where the needle in the haystack is.

The best example of this is GPS receiver: the GPS signal received at ground-level is so weak that it is already 10 - 20 dB below the ambient noise, even if there is a clear view of sky…in urban areas and indoors, it can be sometimes 30dB below. This means that the environmental noise is a thousand times stronger than the desired GPS signal. Under such conditions very stable, low-noise oscillators are required to detect the GPS signals effectively… like looking for a needle with a magnifying glass.



Phase noise of FTS2050A Quartz

- The spikes at around 100Hz are radiation from nearby power lines and radio stations
- The black area below the curve is the measurement limit of the instrument

Courtesy of John Ackermann, N8UR

Differences beween Oscillators: XO, VCXO, TCXO, OCXO and MCXO

The basic crystal oscillator, the XO (Crystal Oscillator) forms the backbone of all other variants. It consists of an amplifier with a quartz frequency-determining component in the feedback path. In its simplest form, the amplifier is an inverter gate; a circuit with many simple oscillators which is common in microcontrollers. As an inverter is a highly non-linear amplifier whose gain is neither clearly defined nor constant, the phase noise and stability of this type of oscillator are not very high. For this reason, discrete linear transistor amplifiers are used in high-quality oscillators in accordance with the Pierce, Colpitts or Butler principle. In general XO oscillators have a stability of 100 ppm to 20 ppm.

Since the crystal rarely works well enough at the required frequency and the frequency of oscillation depends on the components in the oscillator circuit, a varactor diode is often inserted to fine tune the oscillation frequency during use, via a control voltage. This type of oscillator is called a VCXO (Voltage Controlled Crystal Oscillator). Apart from the input control, the circuit is identical to the XO and has similar performance levels.

The biggest disadvantage of the XO and VCXO is its temperature response. To improve its stability, the temperature profile can be corrected electronically. The resulting oscillator is then called a TCXO (Temperature

Compensated Crystal Oscillator) and has a stability ranging from 5 ppm to 1 ppm across the specified temperature range. In addition, many TCXO’s can be fine-tuned to correct frequency offsets, either by programming a correction value, or by applying of an external control voltage, similar to the VCXO. However, it should be noted that the temperature compensation has to be made relative to the fundamental frequency of the TCXO. If the frequency of the TCXO is adjusted, the temperature curve changes slightly and the temperature compensation is no longer appropriate; resulting in reduced stability.

The deviation of a TCXO is still determined to a large extent by temperature fluctuations. In order to achieve even greater stability, the well-known quartz furnace, or OCXO (Oven Controlled Crystal Oscillator) is used. Here, the quartz is maintained at a constant temperature, via built-in heating, to achieve the minimum variation in frequency. However, a major drawback of the OCXO is their relatively high power consumption, due to the continuous heating (the crystal is usually kept at 70 °C to 90 °C) and that the furnace temperature characterizes the upper limit of the ambient temperature. With an OCXO, a stability < 1 ppb (parts per billion) can be achieved.

The relatively unknown, microcomputer-compensated quartz MCXO (Microcomputer Compensated Crystal Oscillator) lies, in terms of stability, between the TCXO and OCXO. Similar to the TCXO, the temperature of the quartz is measured. However, the frequency is not corrected directly, but rather via an additional oscillator, whose frequency is determined by a master or main oscillator. This allows temperature stability close to the OCXO, but does not consume as much electricity. The stability of an MCXO is better than 100 ppb.

Stability and Power Consumption

Unfortunately, high stability and low phase noise is reflected in the power consumption: XO’s and VCXO’s have the lowest power consumption. TCXOs require energy for their temperature compensation, while the MCXO and it’s the microcontroller requires even more. OCXO’s due to their internal heating need up to several watts; in particular the heating can, depending on the type OCXO, require up to 10W.

Type	Power Consumption (typical)	Accuracy/Stability (over 1 year)	
XO/VCXO	1 mW - 50 mW	10^{-5} - 10^{-4}	(10 - 100 ppm)
TCXO	3 mW - 100 mW	10^{-6} bis 10^{-5}	(1 - 10 ppm)
MCXO	50 mW - 500 mW	10^{-8} bis 10^{-7}	(10 - 100 ppb)
OCXO	1 W - 5 W	10^{-9} bis 10^{-8}	(1 - 10 ppb)

The different types of Quartz oscillators have very different properties, in particular with regard to stability, phase noise and power consumption and selection of the right oscillator for an application is not always straightforward.

Although crystal oscillators are generally considered very basic, they should not be forgotten in the system design, as they are often the critical lynchpin of the actual system function.

References

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Speed-Dating à la AoT

with Thomas Schwinghammer

Age	33
Profession	HW/SW Engineer
With AoT	since
Stare Sign	Scorpion

What motivates you?
Life itself! Overcoming new challenges, sensible approach to Life and making the most of it.

How do you spend your free time?
I've been playing chess for 2 years. I like immersing myself in concentration, the broad range of possible configurations and the power of the various pieces.

I also play Guitar, write songs and am often underway outside in the nature: Walking, Climbing, Hiking, Cycling Tours, Skiing or just doing nothing in a beautiful place

Which hobby would you never do voluntarily?
Bungee-Jumping, I don't need such a thrill. Otherwise I'm open minded and would probably try pretty much anything except for motor sports, I prefer to my own "engine".

What things do you want to do in Life?
Start a family, provide a service to mankind.

Describe yourself in a few words?
Quiet, intelligent, friendly, sincere, helpful

What upsets you?
Nothing, other than disrespect for nature!

What is your best quality?
Difficult, I have some good qualities. If I have to choose one, then patience!

What are you strengths a work?
Patience, persistence and the ability to persevere with something!

What would you never spend money on?
A sports car.

What would you spend a lot of money on?
For natural and high quality products: food, drink, clothing and of course beautiful guitars and good music. I'm a connoisseur☺

You're invited to a Costume Party; how would you disguise yourself?
A Black Mamba

If you were an animal, which animal would you be?
A Butterfly!

What should your Epitaph say?
I'm too young to have thought about it. Normally, the epitaph is written by others. Maybe something like "he lived what he believed".