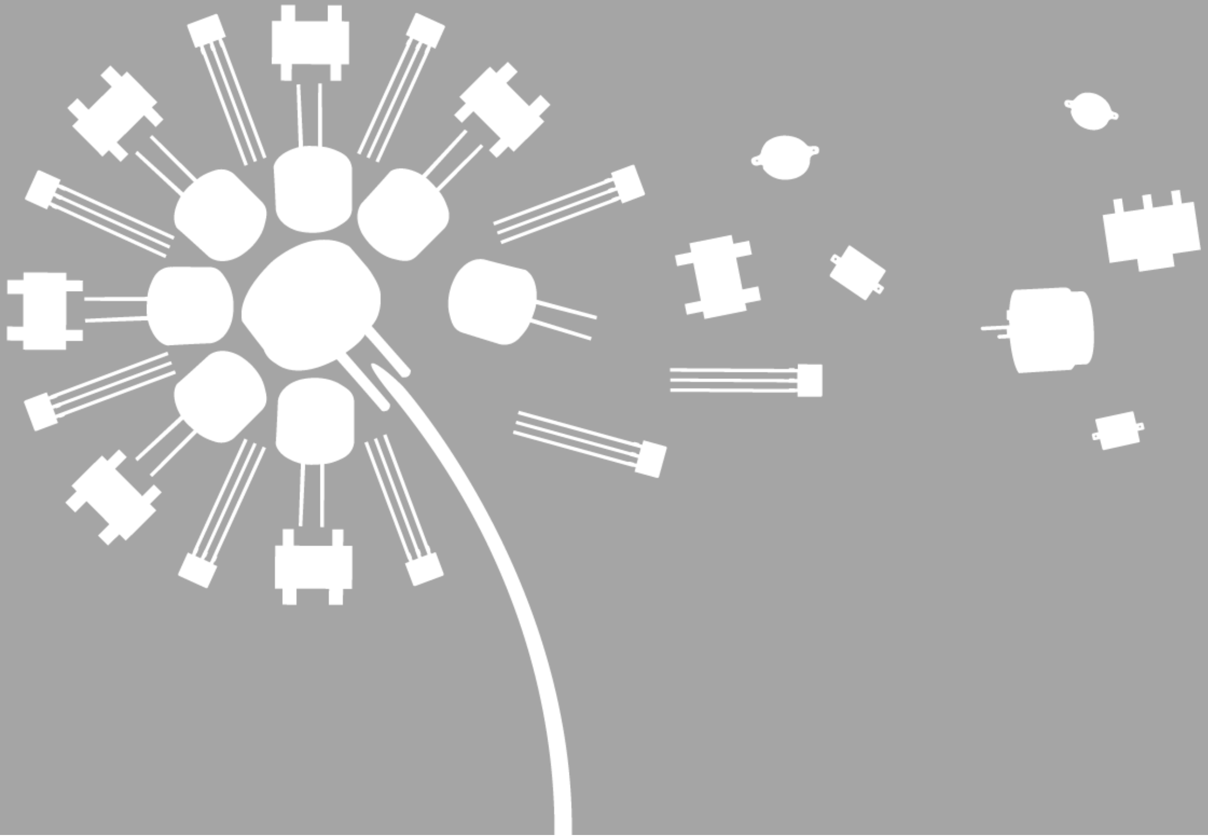


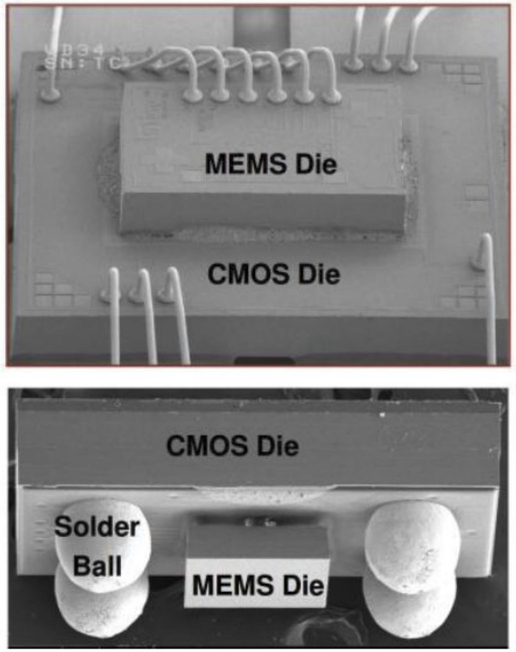
SiTime MEMS oscillators in handheld devices HandsOnTraining

Kiss Zoltán – *export manager, Endrich Bauelemente GmbH*

MEMS technology in timing

SiTime – fabless semiconductor manufacturer of MEMS timing solutions

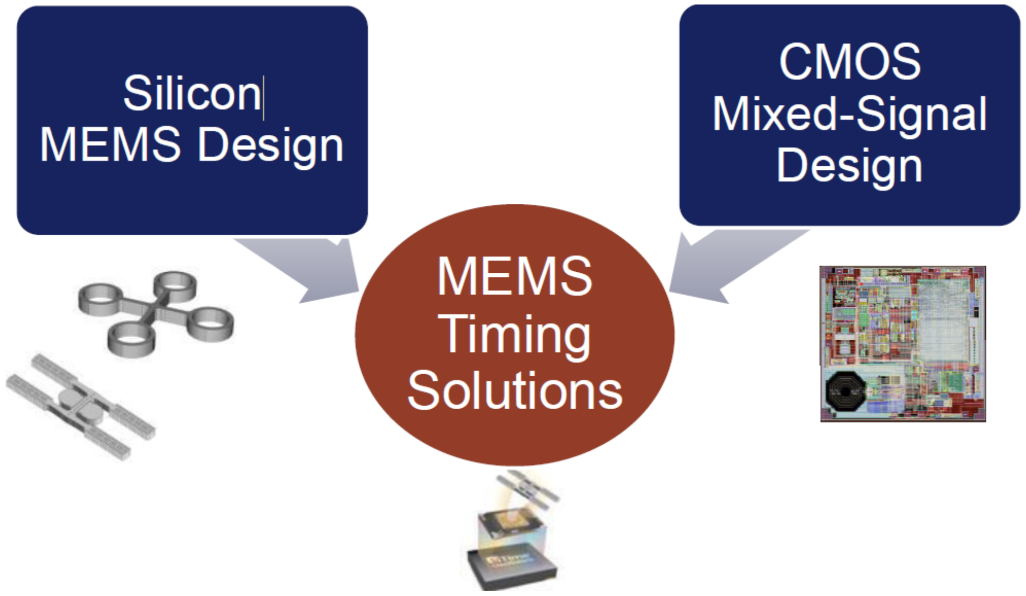
- MEMS oscillator technology instead of quartz crystal based solution
- MEMS chip + CMOS circuitry in one package



CSP
1.5 x 0.8 mm

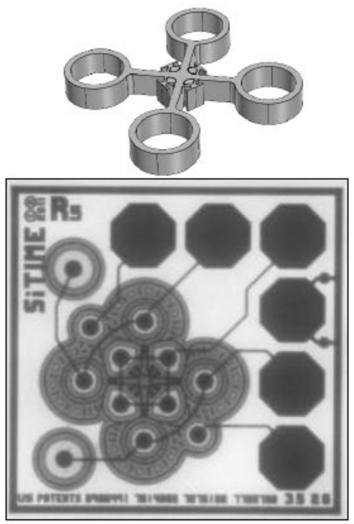
SiTime

- Fabless analog IC company, founded in 2005
- Mass production since 2007, 1Bu+ shipped to date
- The leader in MEMS-based silicon timing, with 90% market share
- SiTime’s mixed-signal and MEMS IP is 100% designed in-house



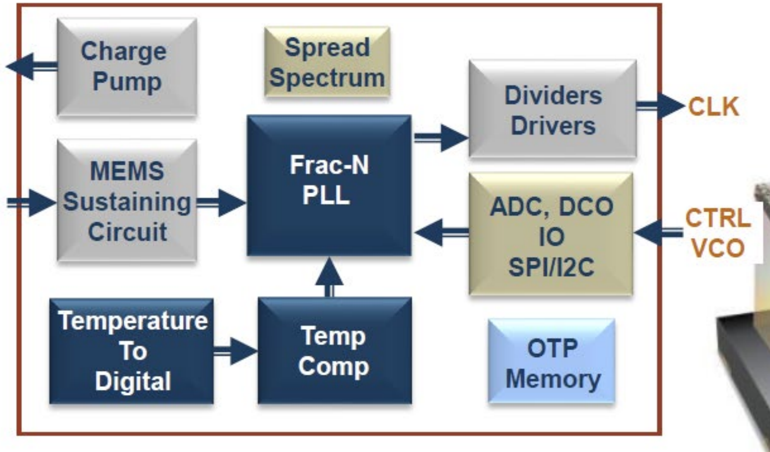
Structure

MEMS Die



- 0.4 mm x 0.4 mm
- 99% yields
- Vacuum sealed die
- Standard CMOS fab

Programmable CMOS IC



- Jitter - 250 fs
- Stability - 0.1 PPM TCXO
- Low Power - 1µA @ 32kHz
- 180nm CMOS – fab TSMC

MEMS Oscillator

- Plastic packages
- Robust - MSL1
- 99% Yields
- 0.15DPPM, 2Fit

Growth

2014	Today	Future
15 families, 200MUnits Oscillator	40 families, 1B Units Oscillator	All timing categories: Oscillator, Resonator, Clock Generators
75 patents Performance = quartz	100 patents Performance 30x higher	Performance 50x higher
1,000 customers 100 applications	5,000 customers 200 applications	5x more

Comparison

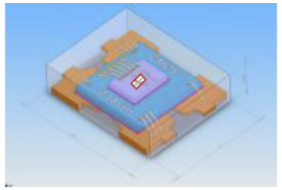
QUARTZ

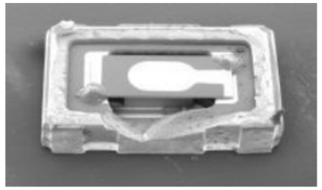
- Boutique hybrid customized supply chain
- Lower performance
- Long lead times
- Custom part for each frequency
- Sensitive to shock & vibration
- Loss Making

MEMS

- Scalable All Silicon volume technology
- Highest performance
- 4-8 weeks lead time
- Programmable to ANY frequency
- Robust shock resistant proven
- Complete 5G roadmap, Oscillators, Clocks, Jitter cleaners…
- Programmable rise/fall time to reduce EMI and improve jitter

MEMS wins on every metric





Metric	SiTime	Crystal
Supply Chain	Multiple sources	Single Source
Shock and Vibration	30x Better	3000x Larger Mass
Size	Always Smaller	Physically Limited
Lead Time	4-8 Weeks	26-52 Weeks
Quality	0.15 DPPM	50 - 200 DPPM
Reliability	800M Hours	28M Hours
Capacity	Infinite	Capital Intensive
Wide Temp Operation	-55 to +125 °C	-30°C to +85°C
Cost	Always Better	Expensive Process
Flexible Packaging	SOT, Plastic, CSP	Only Ceramic
Flexible Frequency	1Hz – 725MHz	Fixed Mainstream Only
Programmable	In lab (Many parameters)	Fixed Frequency

Technology – Silicon always wins

Best performance

- 30x better than quartz in dynamic, real world conditions
- 70% lower power
- 80% smaller
- 10mK resolution temperature sensor, best

Best Quality & Reliability

- No Aging
- Lifetime Warranty (MTBF 1140 MHrs while quartz<40)

Rapid innovation

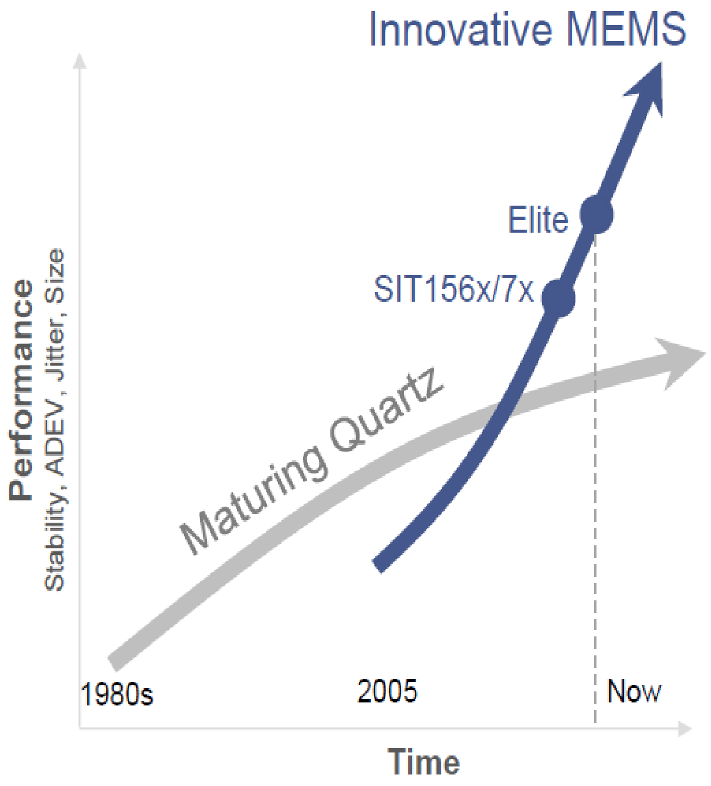
- 200x – 30,000x improvement in 10 years

Scalable manufacturing

- Standard semiconductor process

Best product availability

- Shortest leadtimes
- Integration
- Features, efficiency, programmability



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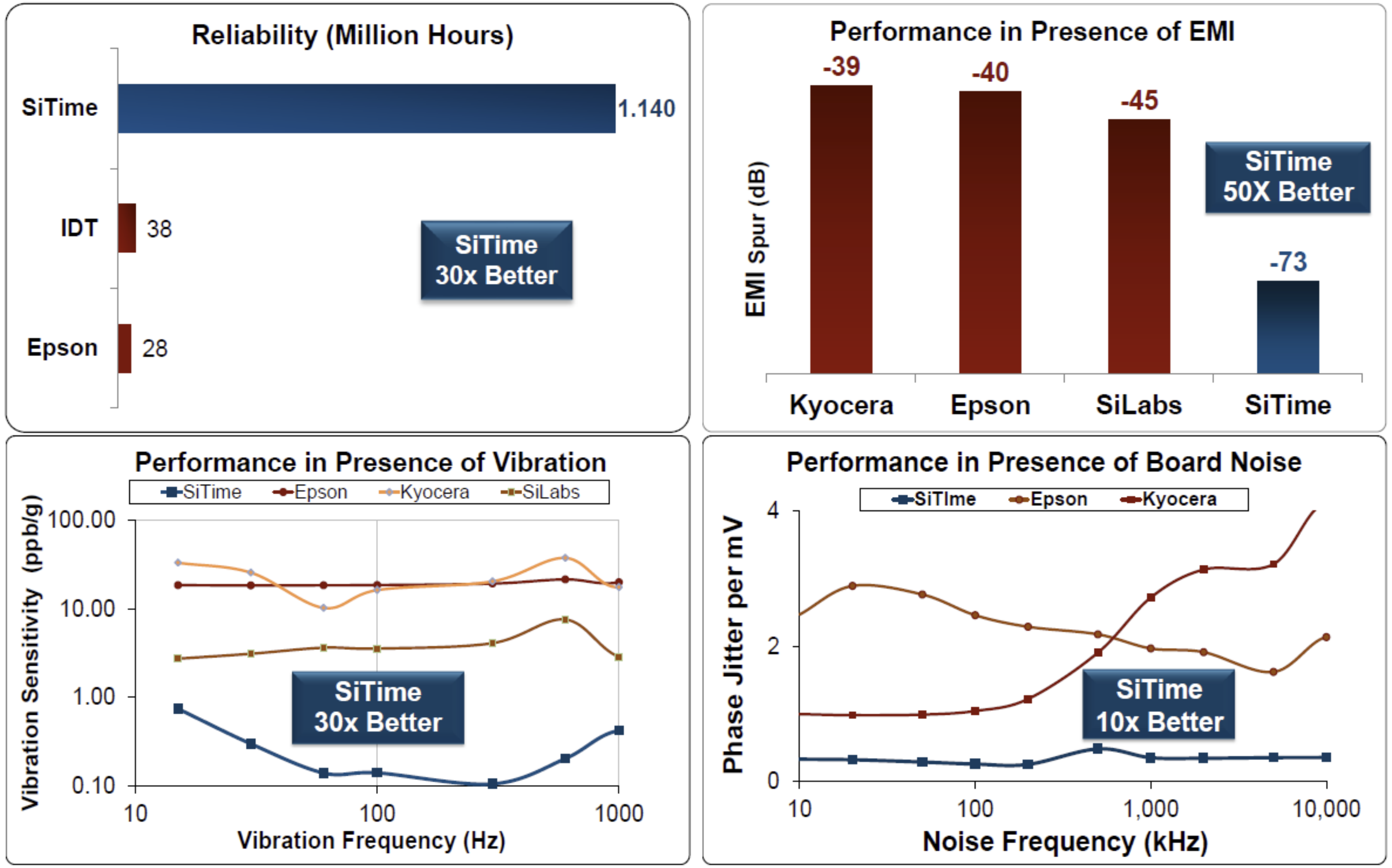
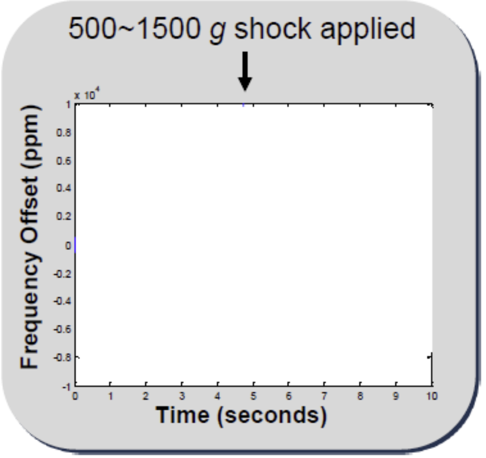
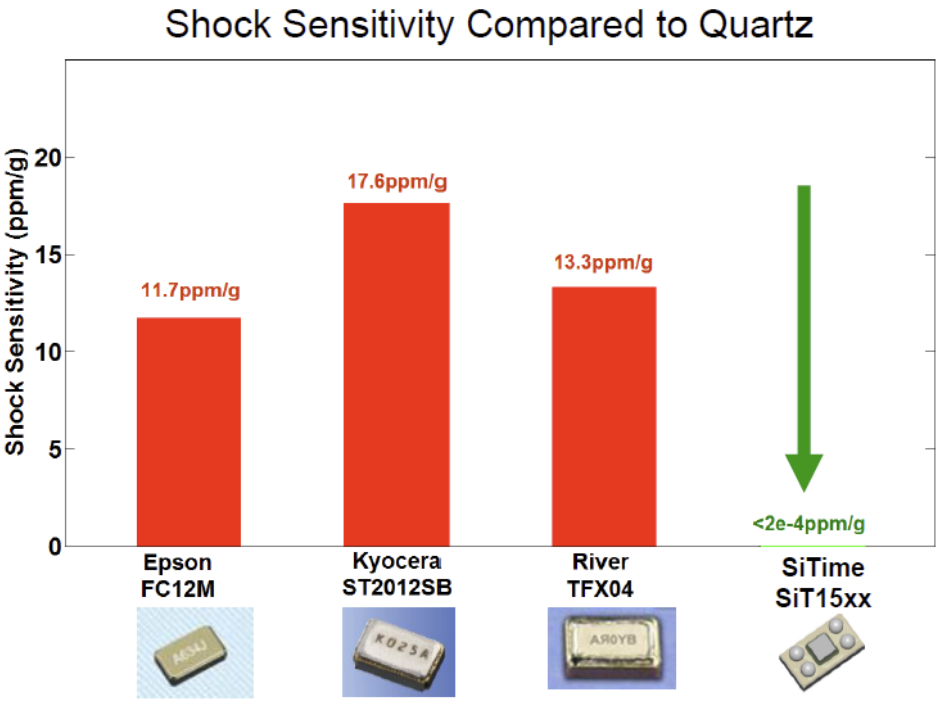
Reliability measures



Silicon MEMS Shock Sensitivity is 60k Times Better Than Quartz





MIL-STD-883F Method 2002, condition A: half sine wave shock pulse, 500-*g*, 1ms

SiTime device tested at 1500-g and quartz XTAL+RTC tested at 500-g

SiTime MEMS Oscillators are Inherently Robust Against Shock & Vibration

The resonator structure operates like a very stiff spring→ Very difficult to affect through external force.

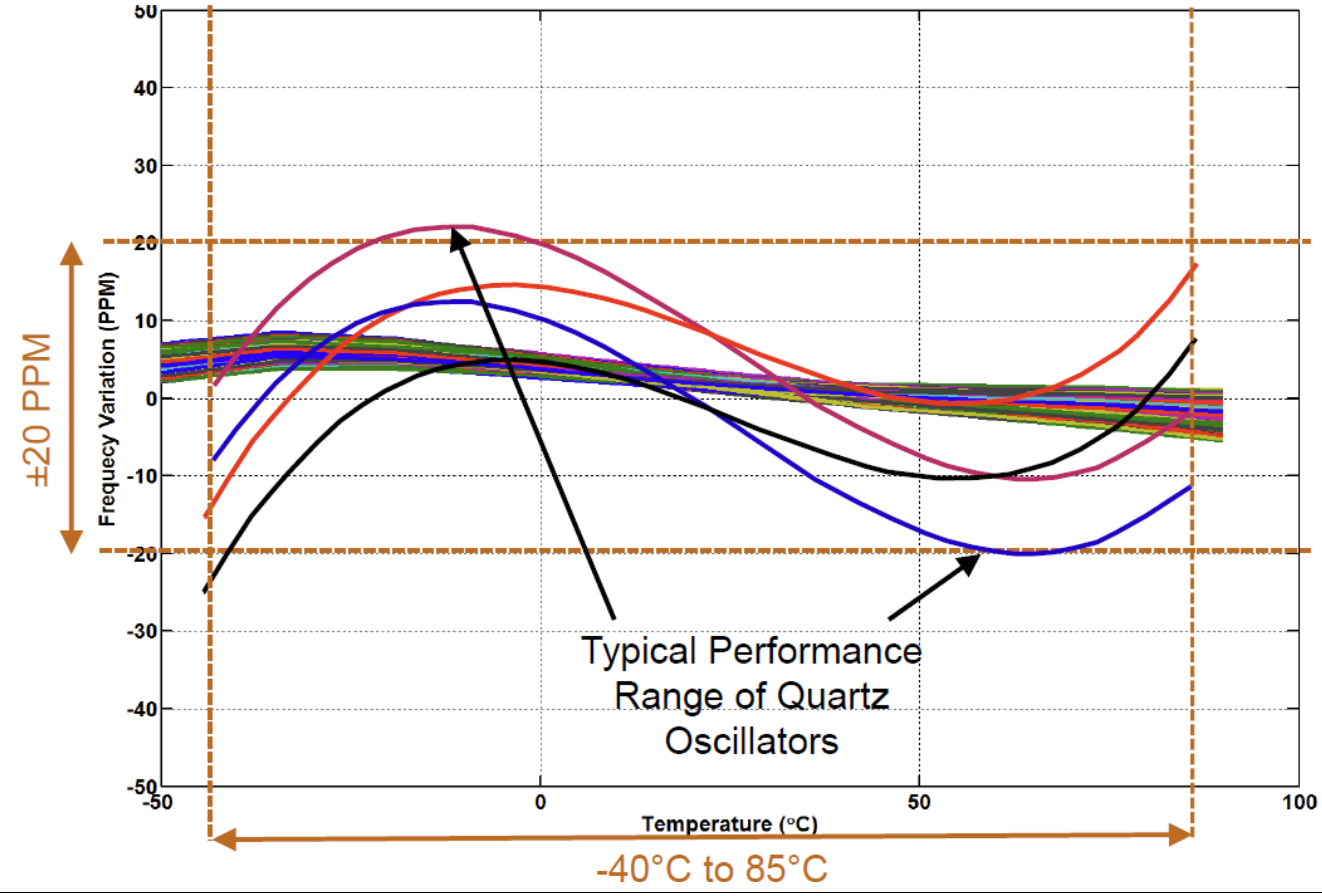
>1M *g* needed before resonator touches any surfaces. 55,000 times greater than a Cannon!

A Cannon Launches a Ballistic with a Force of 18k *g*

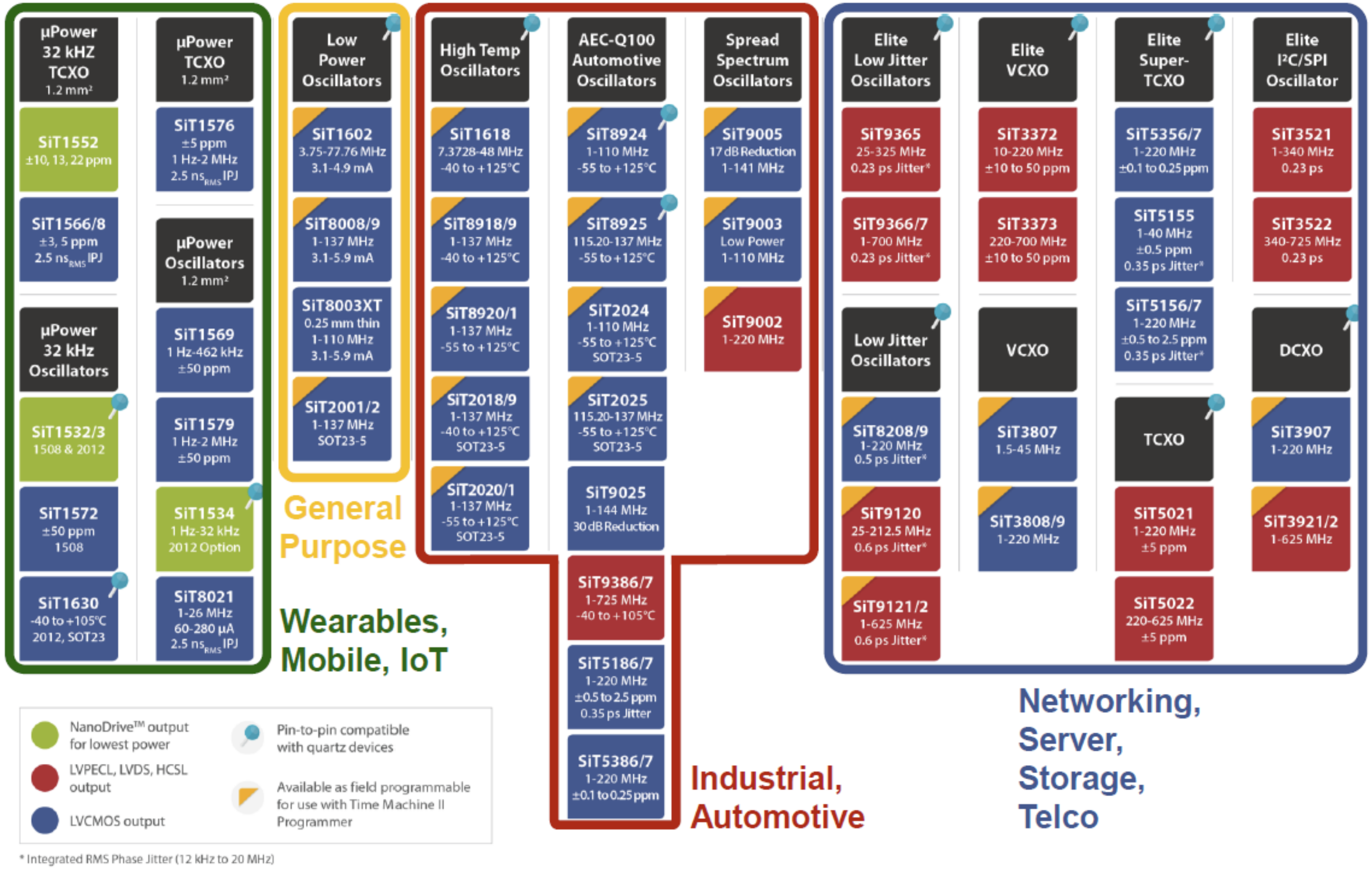
Frequency Stability Low Power MEMS Oscillator (1-150MHz)

Measuring unit multipliers

- 1% 0.01 10^{-2}
- 1‰ 0.001 10^{-3}
- 1ppm 0.000001 10^{-6}



Product portfolio



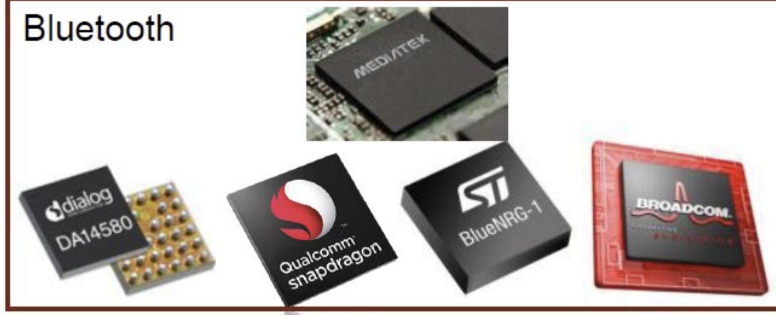
IoT & Wearables

SiTime kHz Offering

- Smallest Package 1508 CSP
- 85% Space Saving vs. Quartz
- 30% Lower Power consumption
- Time/Clock accuracy
- Drives multiple loads

MCUs

Bluetooth



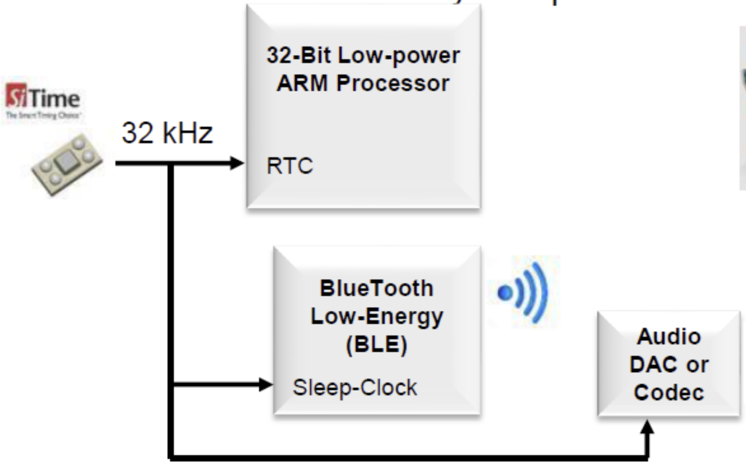
Application examples

Appl. Example: Single 32kHz XO/TCXO Drives the RTC, BLE, and Audio DAC

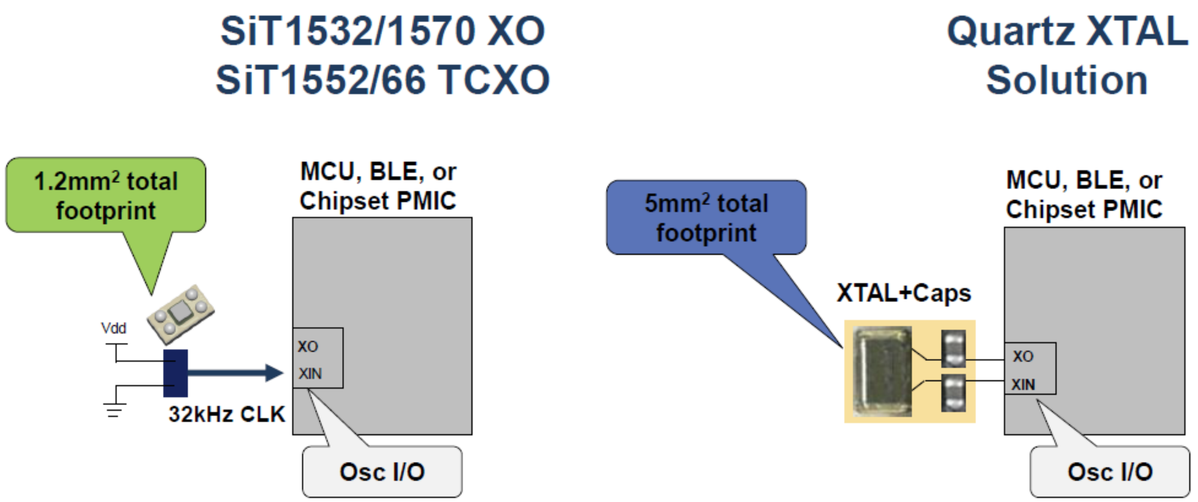
- Problem: Too many reference clocks, need to reduce BOM
- Solution: SiT1532/52 or SiT156x XO/TCXO drives multiple loads including audio
- Key Advantages:
  - 32kHz XO/TCXO drives multiple loads
  - Smaller footprint than 2 x 32kHz XTALs + 4 load caps and one MHz XTAL + load caps
  - Acceptable Integrated Phase Jitter (IPJ) performance, 2.5ns_{RMS}, to drive audio SoC
  - Optional TCXO saves 30% additional system power

SiT156x
(audio)

SiT1532/52
(no audio)



When the size matters….

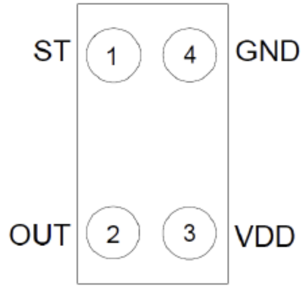


Features	SiT1532	Quartz XTAL
Package Footprint w/ Load Caps	$1.2mm^2$ (80% smaller)	$5.5mm^2$
Load Capacitors	No	Yes
Load Dependent Start-up	No	Yes
Bypass Caps	No	NA

Appl. Example : SiT802x µPower MHz Oscillator Highlight

Frequency Range	Frequency Stability	Supply Voltage	Package	Temp. Range	Active Current	Resume Time	Output
1 - 26 MHz	100 PPM	1.8 V ±10%	1.5 x 0.8mm CSP	-40 to +85 C	110 µA @ 3.072 MHz	5 ms	LVCMOS

- World's lowest power MHz oscillator
  - 110 µA active current (3.072MHz)
- Ultra-small package (1.5 mm x 0.8mm) at low frequency, not easily available from quartz
- Programmable drive strength for best EMI or driving multiple loads
- Low Jitter for portable audio: 2.5ns_{RMS} IPJ (20Hz – 40kHz)



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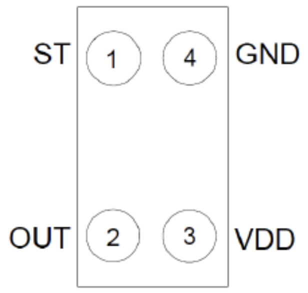
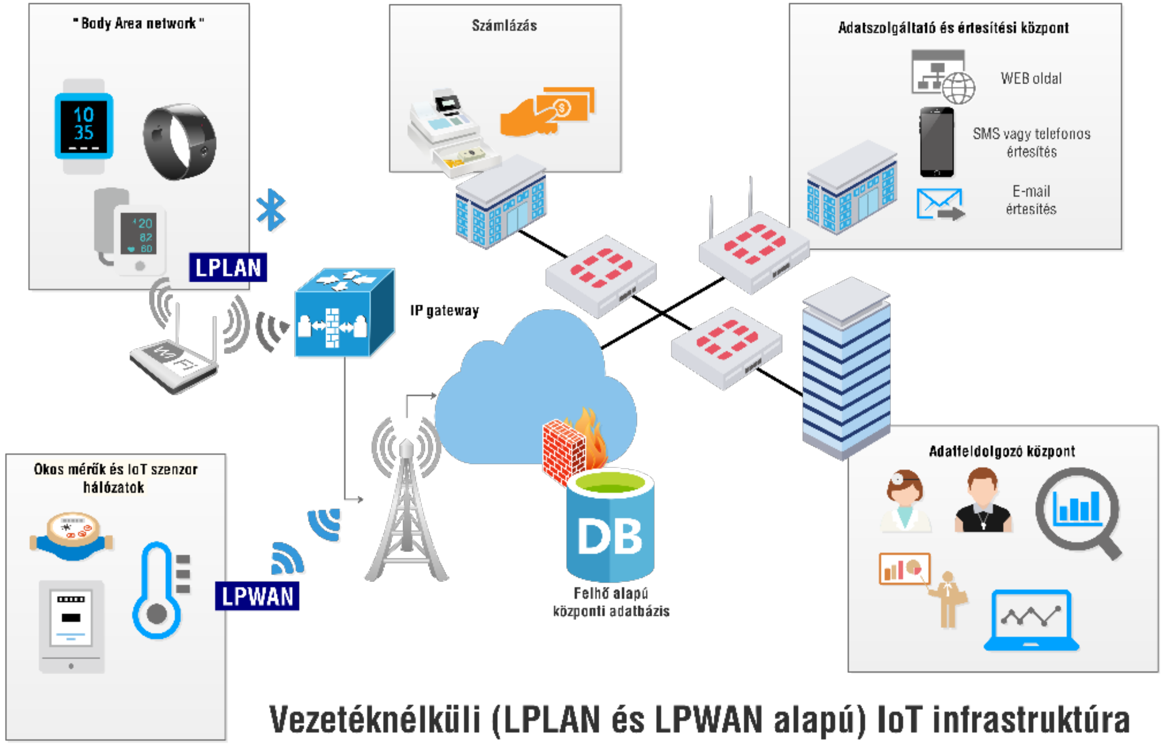
Production Now



SAVING BATTERY LIFE in handheld devices

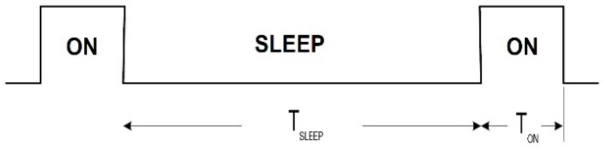
Typical RF sensor infrastructure



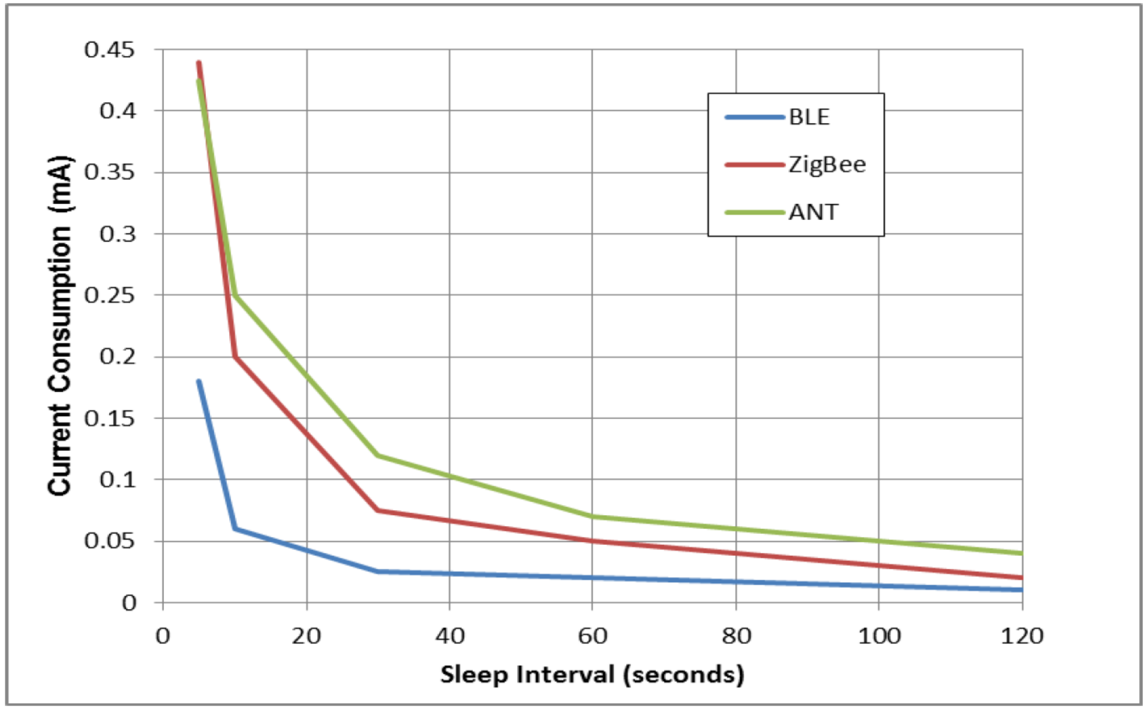
Vezetéknélküli (LPLAN és LPWAN alapú) IoT infrastruktúra

Wireless communication @ IoT

- RF communication with battery based power
- LPWAN or LPLAN (Body network) is use
    - LPLAN : BLE (Bluetooth® Low Energy) or Zigbee,
    - LPWAN LoRa, SigFox, or NB-IoT
- Main state is SLEEP, when hardly no power is consumed
- Power consumption is in ACTIVE COMMUNICATION mode
- Power consumption ~ Ton / Tsleep

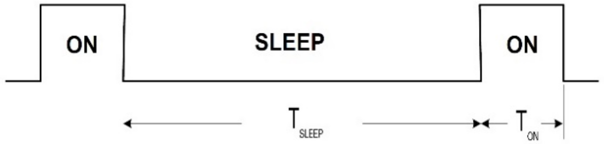


Compare power consumption of different LPLAN technologies



Best example for lowest power consumption @ same sleep time

- BLE (Bluetooth® Low Energy)
- Zigbee and others have higher power consumption in the function of sleep time
- General rule is that power consumption reduces with sleep time growth



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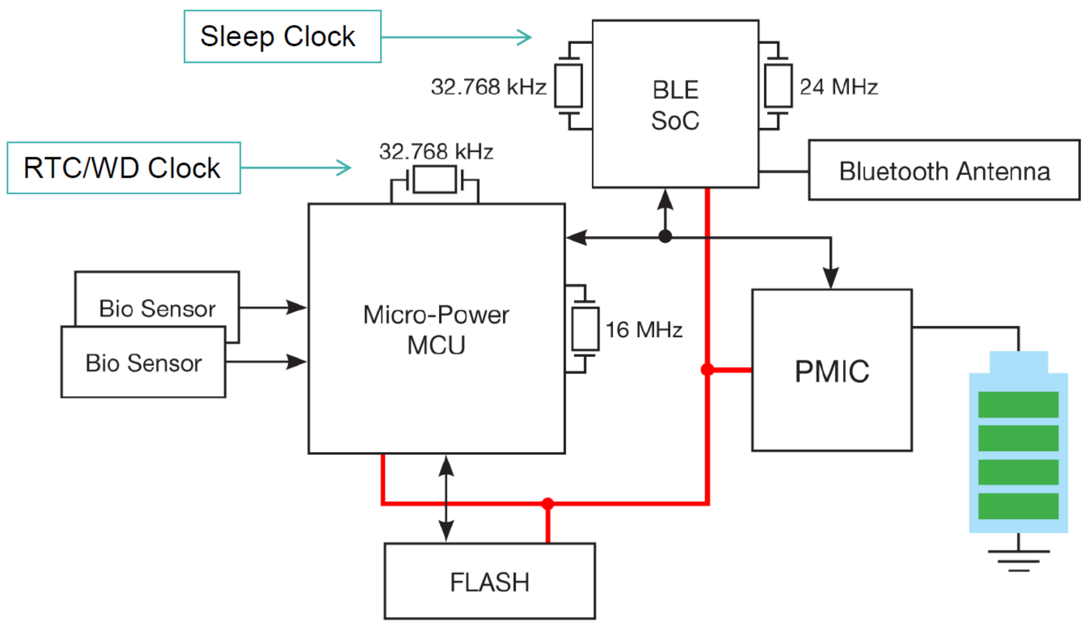
Typical BLE based communication block diagram



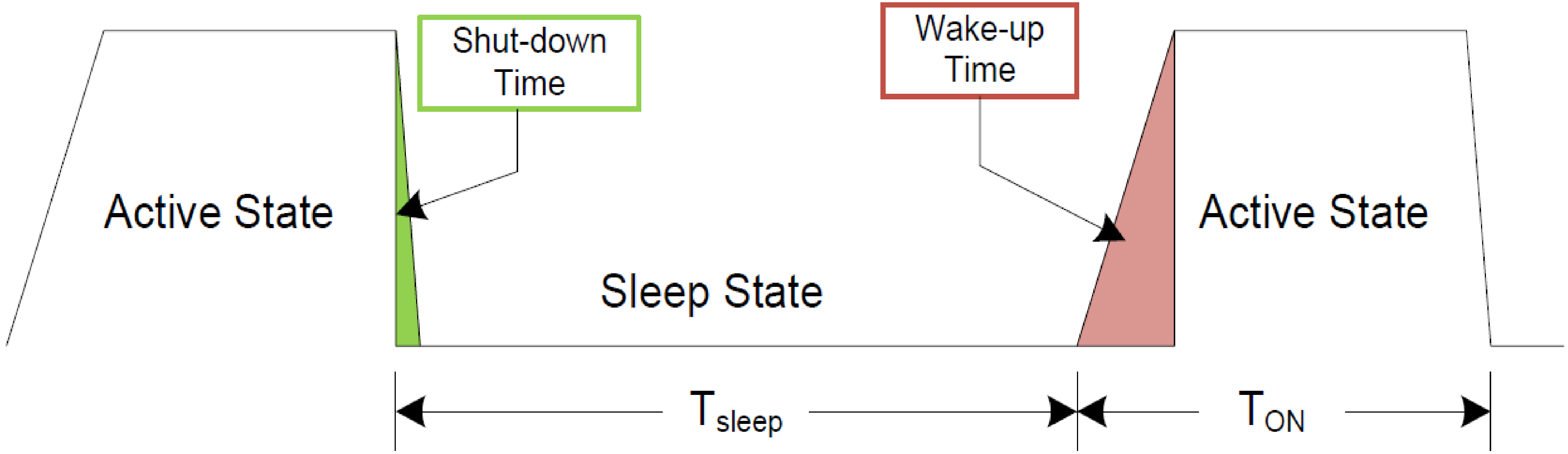
Main power consumers are :

- BLE (Bluetooth® Low Energy)
- Microcontroller

Wearables expectations / properties :

- Small size
- Collect and send data in short bursts
- Return to the lowest power state asap
- Stay in the lowest power state as long as feasible
- Run for days on a small capacity, small footprint battery
- Optimize current drain in a cyclic sleep scenario

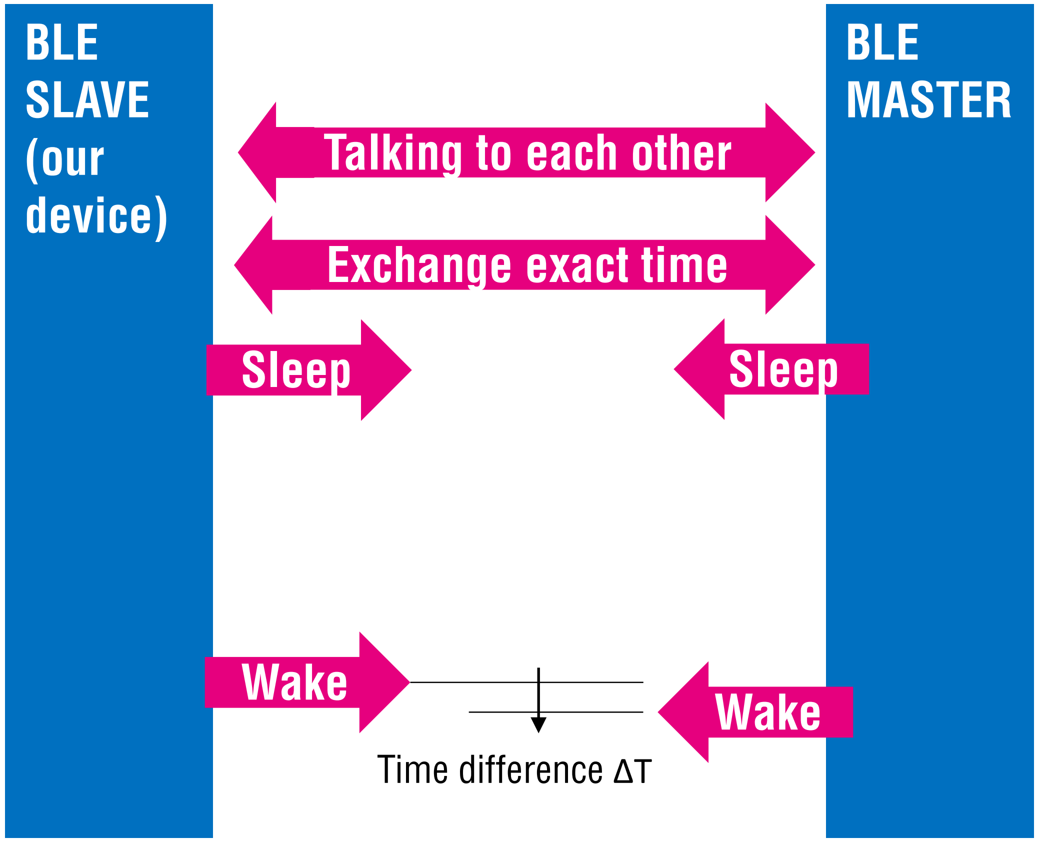
Battery life calculation



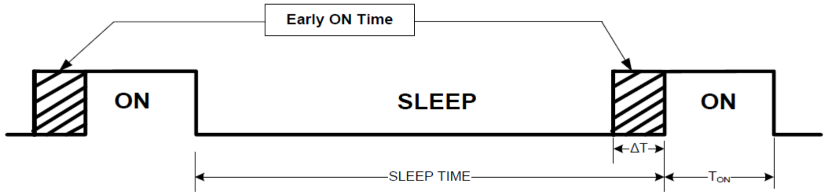
Battery life is dictated by the coulombs consumed per cycle

- Coulombs = $I_{active}.T_{ON} + I_{sleep}.T_{sleep}$
- Expressed in µC or mAH

BLE communication and power consumption



Average power is directly proportional to the ratio of "ON" time to "Sleep" time



Early ON time (ΔT) to accommodate inaccurate sleep clock causes power penalty

- ΔT = (SLEEP CLOCK ACCURACY) * (SLEEP TIME)

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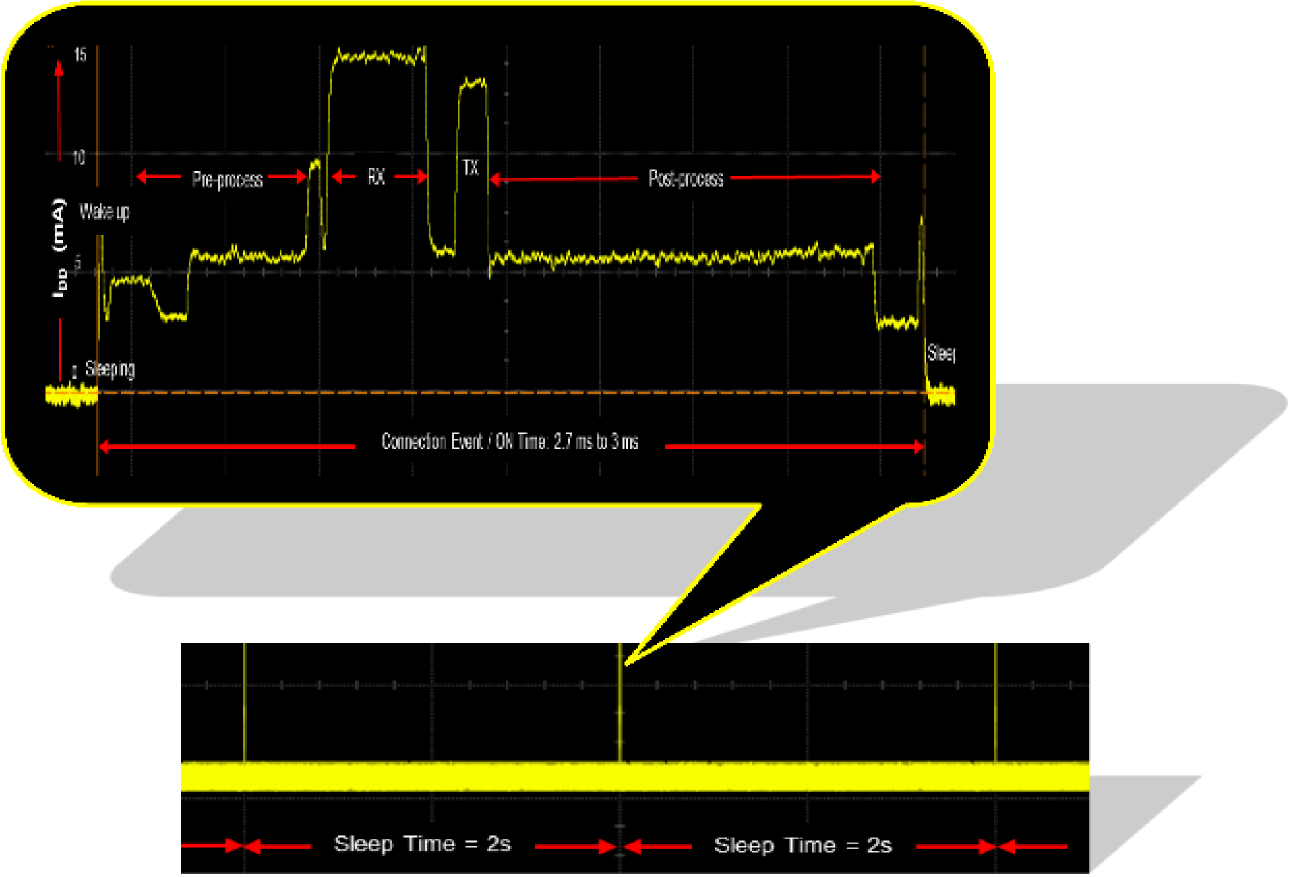
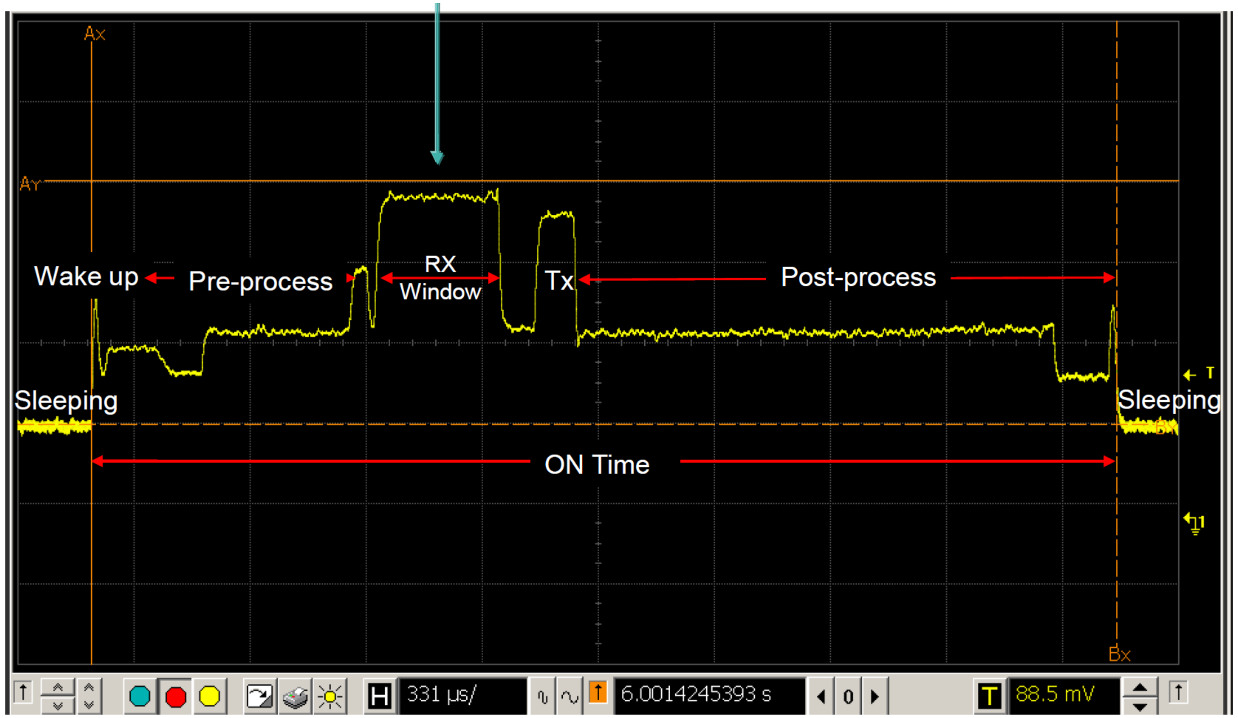
Sleep time vs Active time for better imagination



Rx window widening by inaccurate RTC

Rx window width is proportional to (masterSCA + slaveSCA)

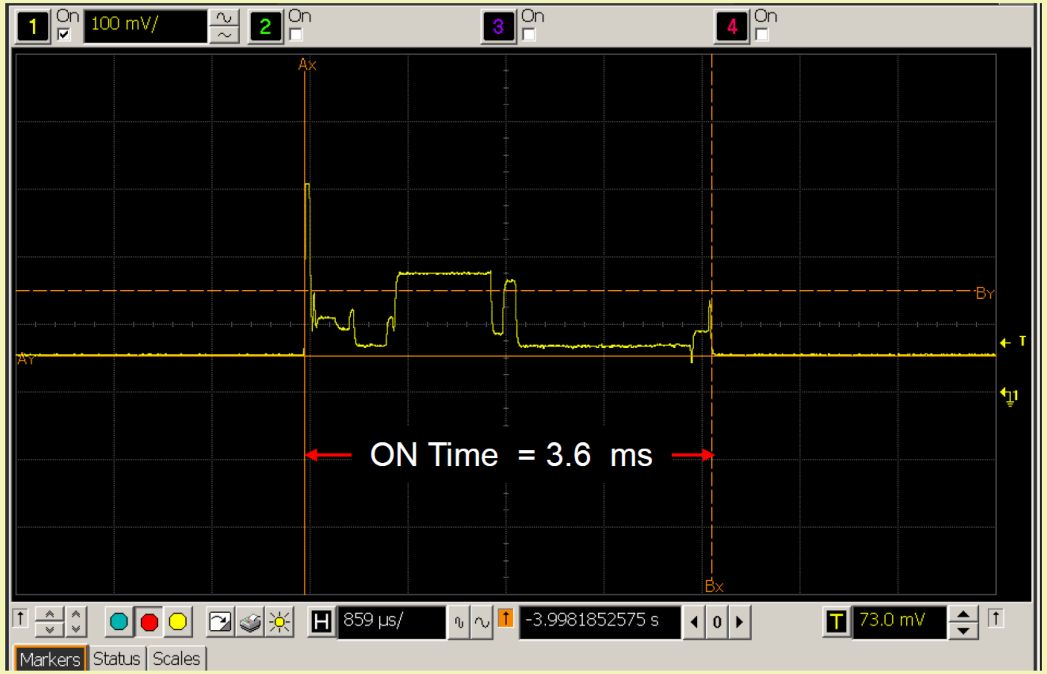


Time spent in high power consumption mode

- Rx window is open during the time early woken module is waiting for signal from the other module
- Transmit window (Tx) is not a problem, as it is standard width
- $\Delta T_{RX} = (SCA_{master} + SCA_{slave}) * 10^{-5} * \Delta T_{connection}$
- Master device : we do not have an influence, so go for SCA slave

Measured ON time based on different SLEEP times

- masterSCA + slave SCA= 80 ppm
- For Sleep Time = 4s; ON Time = 3.6 ms



Sleep Time (ms)	ON Time (ms)
100	2.9
2000	3.2
4000	3.6
8000	4.3
16000	5.2

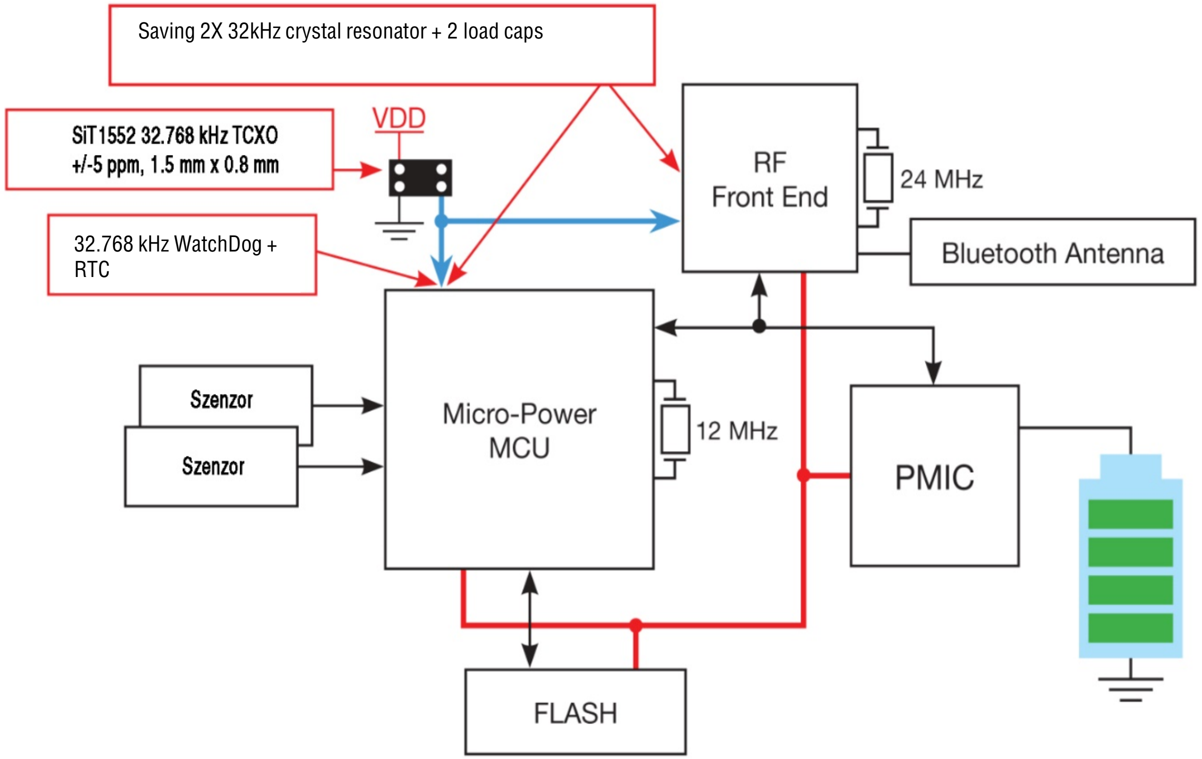
SCA affects Early ON time

	Sleep time= 2 sec	Sleep time= 20 sec	Sleep time= 50 sec
SleepClock Accuracy (SCA)	Early ON ΔT_{RX}		
5 ppm	0.01 ms	0.1 ms	0.25 ms
50 ppm	0,10 ms	1.0 ms	2.50 ms
70 ppm	0.14 ms	1.4 ms	3.50 ms
200 ppm	0.40 ms	4.0 ms	10.0 ms

- @20 sec sleep time and SCA = 5 ppm vs SCA= 200 ppm BLE's forced inactive receive state (ΔT_{RX}) shows 40X difference
- Its effect to the power consumption is:

$$P_2/P_1 = (T_{ON} + \Delta T_{RX1}) / (T_{ON} + \Delta T_{RX2}) = 2.26$$

Ideal BLE timing structure



Replacing the 32.768 kHz crystal resonator by a tiny(1.5x0.8mm) SiTime SiT1552 MEMS TCXO, with +/-5 ppm accuracy on the whole -40 .. + 85 ºC temperature range we will win :

- **Space**, as MEMS solution is able to drive multiple CMOS load
- **Space** as replaced two bulky crystals
- **Space** as no need of 2 load capacitors
- **Battery life** , as the better SCA offers more than double battery lifetime

Programming oscillators

Time Machine II – Program Oscillators to Your Exact Specification Instantly

Instant Oscillators – Create Quartz XO Replacement in Seconds

- Any frequency
- Any stability
- Any Voltage
- Any package

Features and Benefits

- Fast: One-click programming of SiTime oscillators
- Convenient: USB powered, compatible with all PC
- Portable: Small, thin and easy to carry
- User Friendly: Intuitive UI, built-in part # generator, history
- Auto Update: Hassle free upgrade to latest software
- Future Proof: Support future devices
- Durable: Connectors and sockets are rated for 5000 insertions

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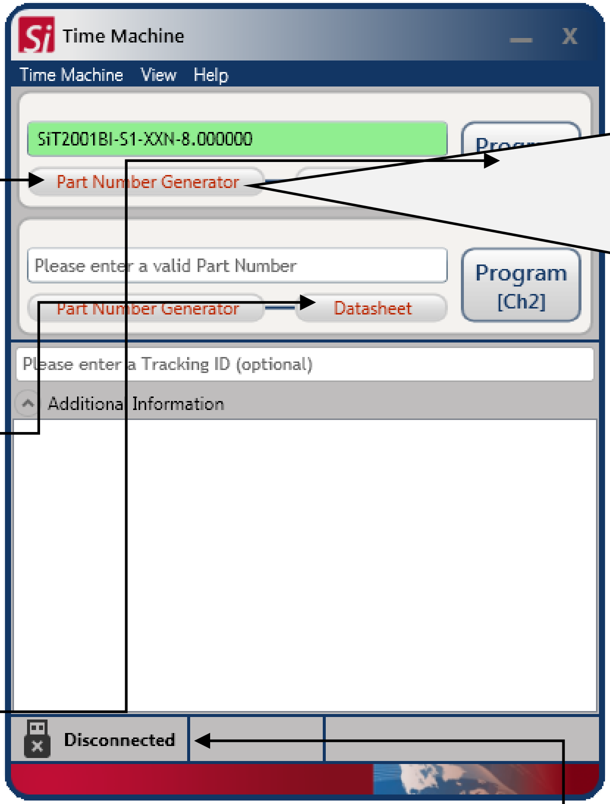
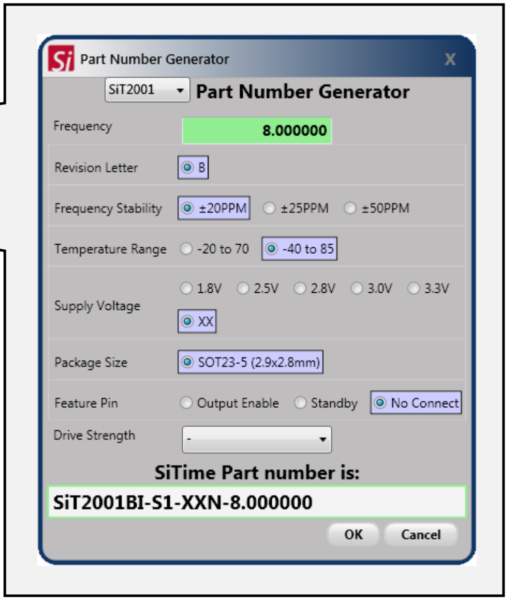
Time Machine II – Program Oscillators to Your Exact Specification Instantly

Part number configuration

Creating instant part number

The buit-in part number configuratiom makes it possible to generate a P/N that contains all technical information about the oscillator.





Datasheet on the fly

Getting the datasheet ready

Parallel to the P/N gerneration, the datasheet is being built automatically.

Programming

Physical programming the oscillator

The values set in the P/N generator are field programmed into the blank oscillator chip.

Status information

Connectivity and programming status

The status of the programming as well as the device connection status can be followed here

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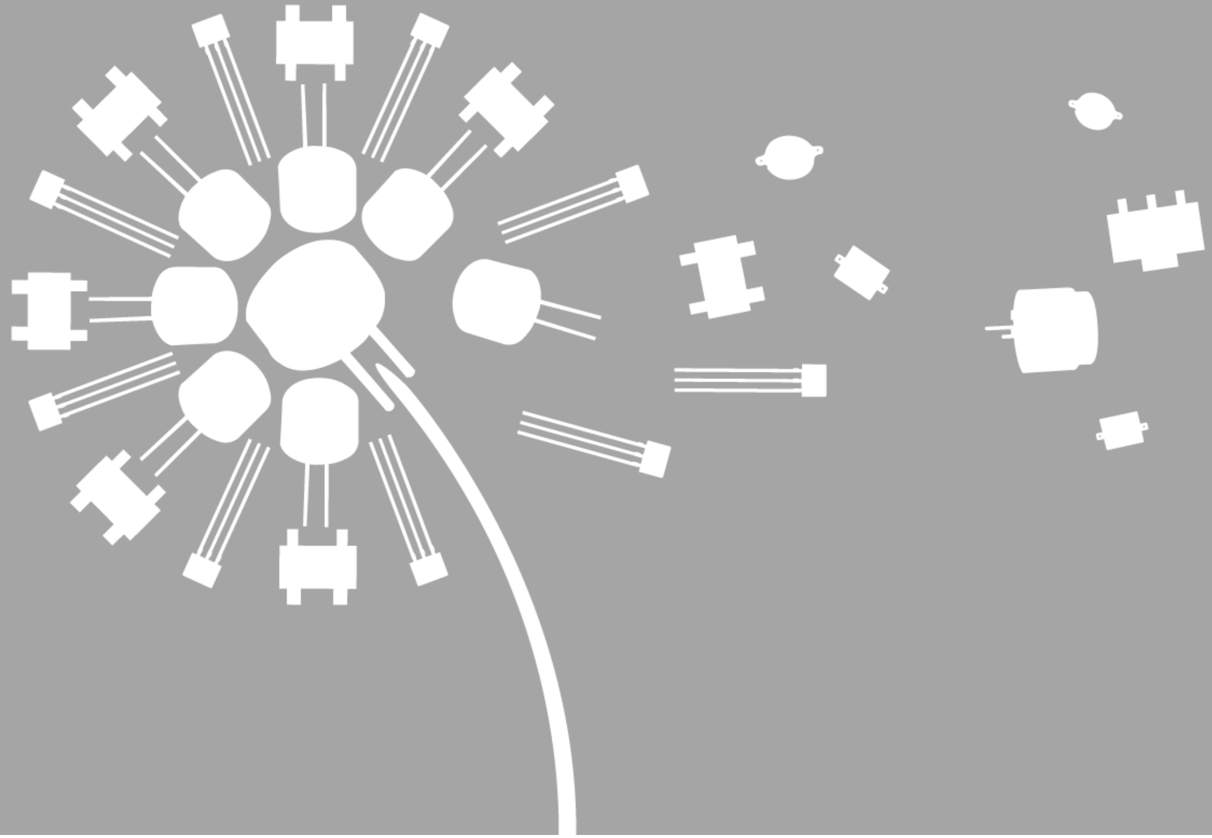

Thnx for attention