MEMS-Based Resonators and Oscillators are Now Replacing Quartz

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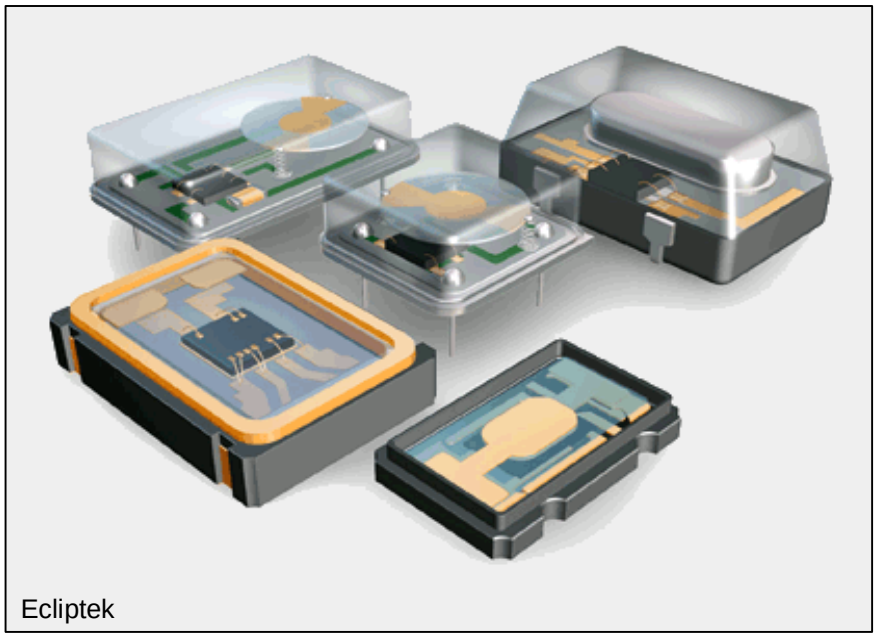
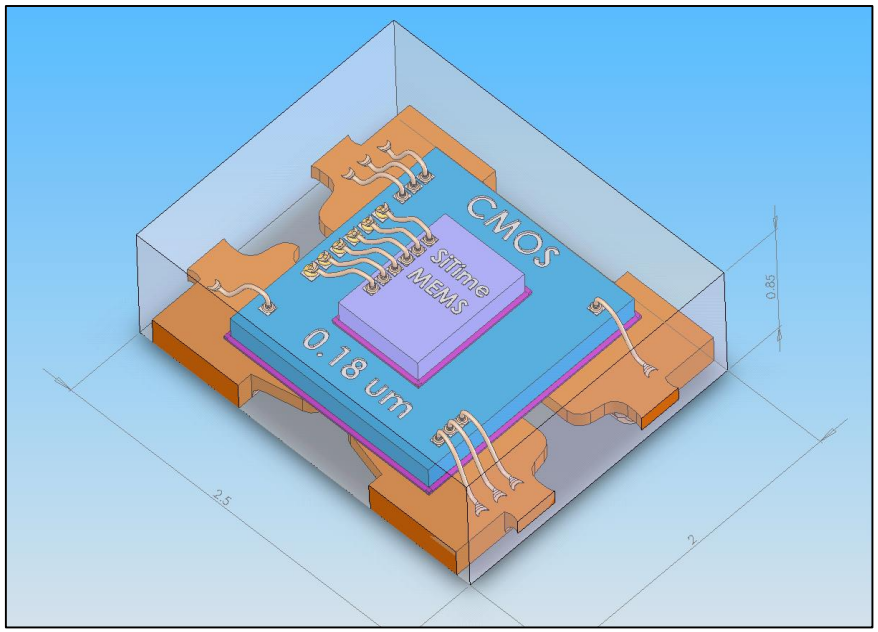
My purpose is to convince you that MEMS timing is here now. MEMS will replace quartz oscillators in most applications. The value add is strong enough to transform an industry.



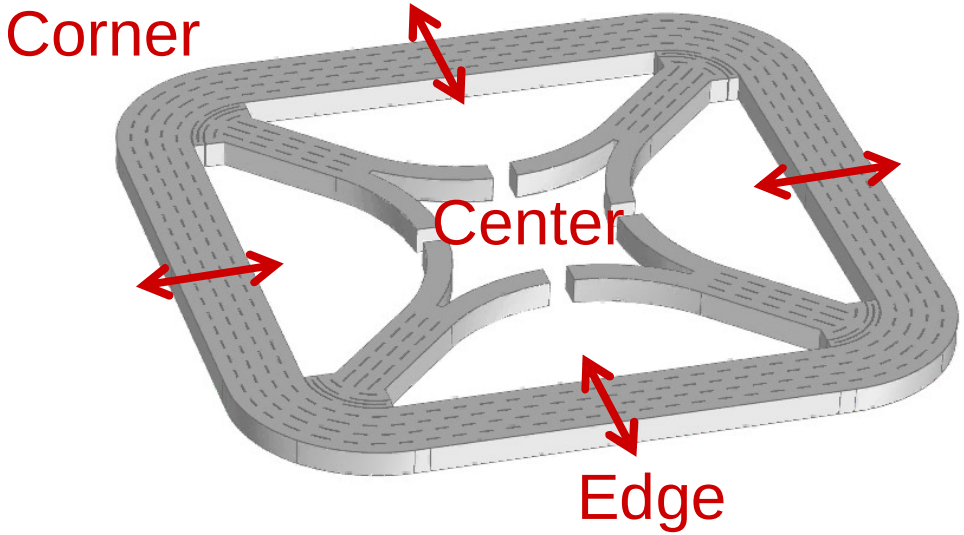


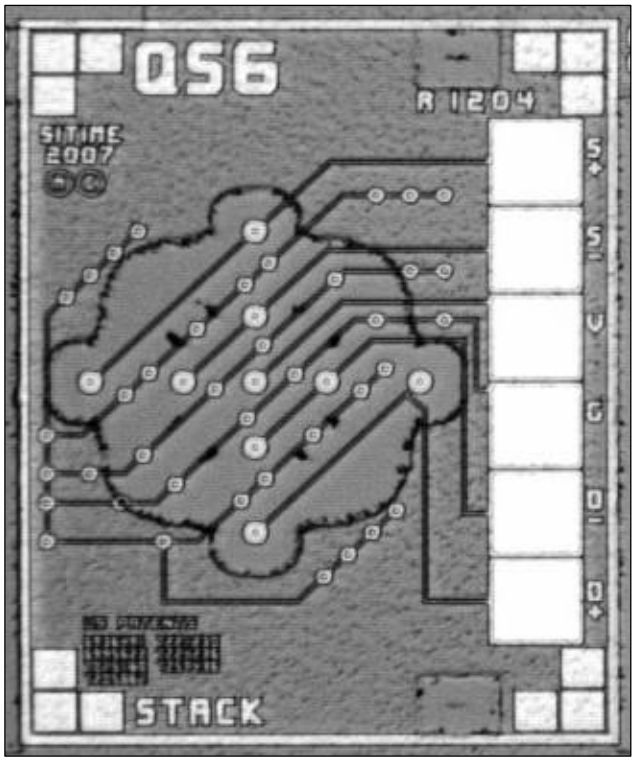
Quartz Oscillators:

- Ceramic/metal package
- Quartz plate and driver circuit
- Dedicated factories

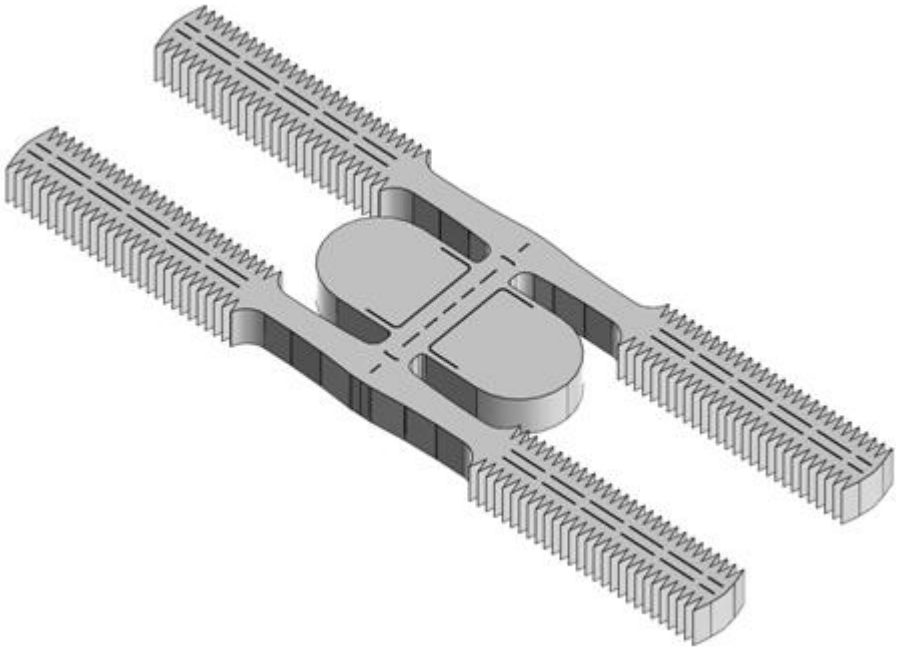
MEMS Oscillators:

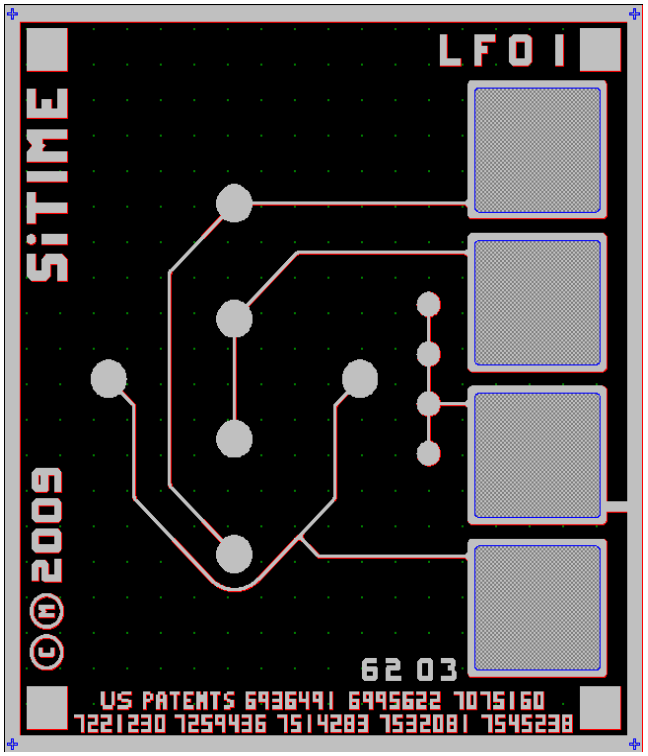
- Plastic QFN package
- Silicon MEMS die and CMOS die
- Standard IC fabs



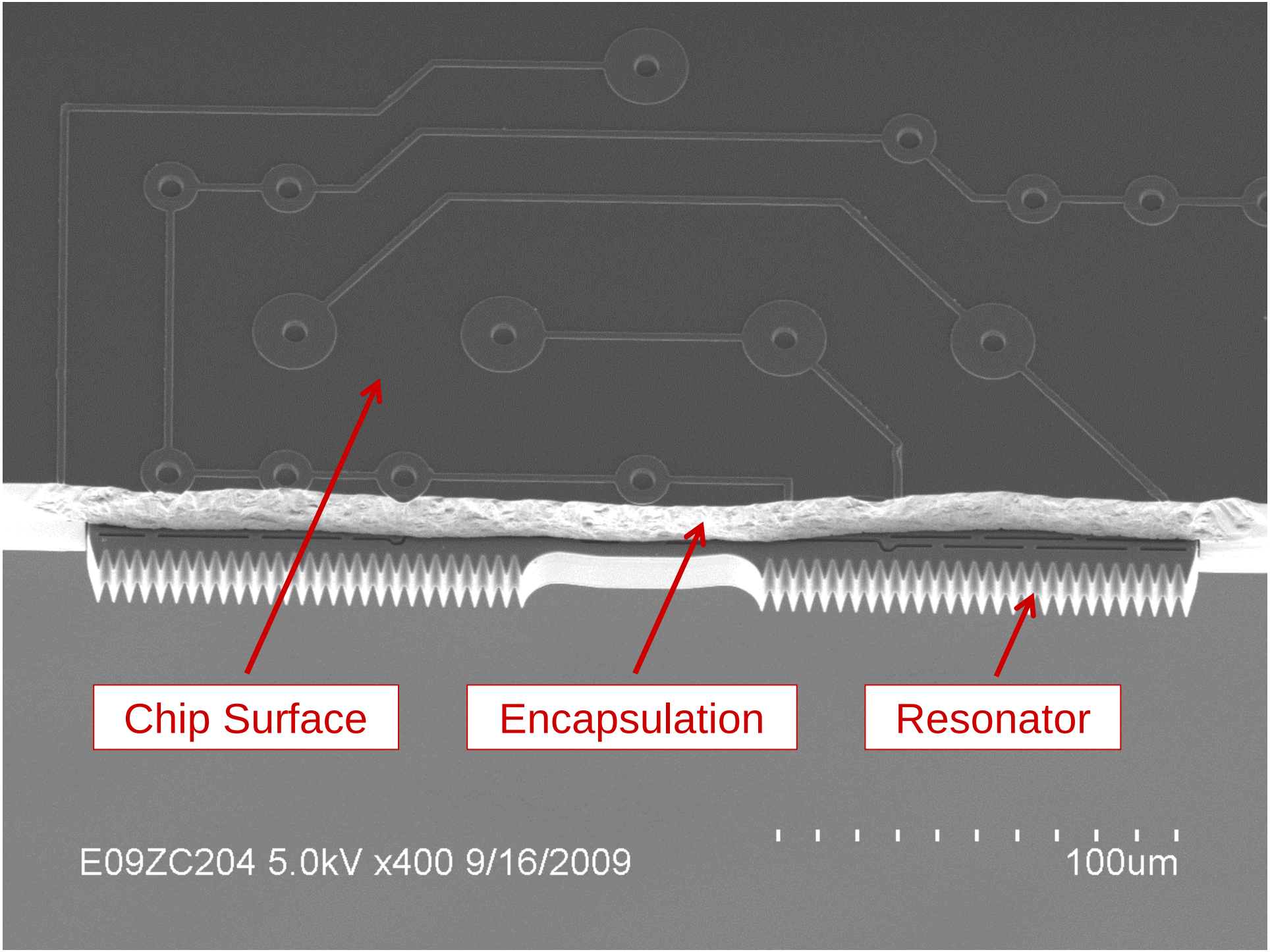


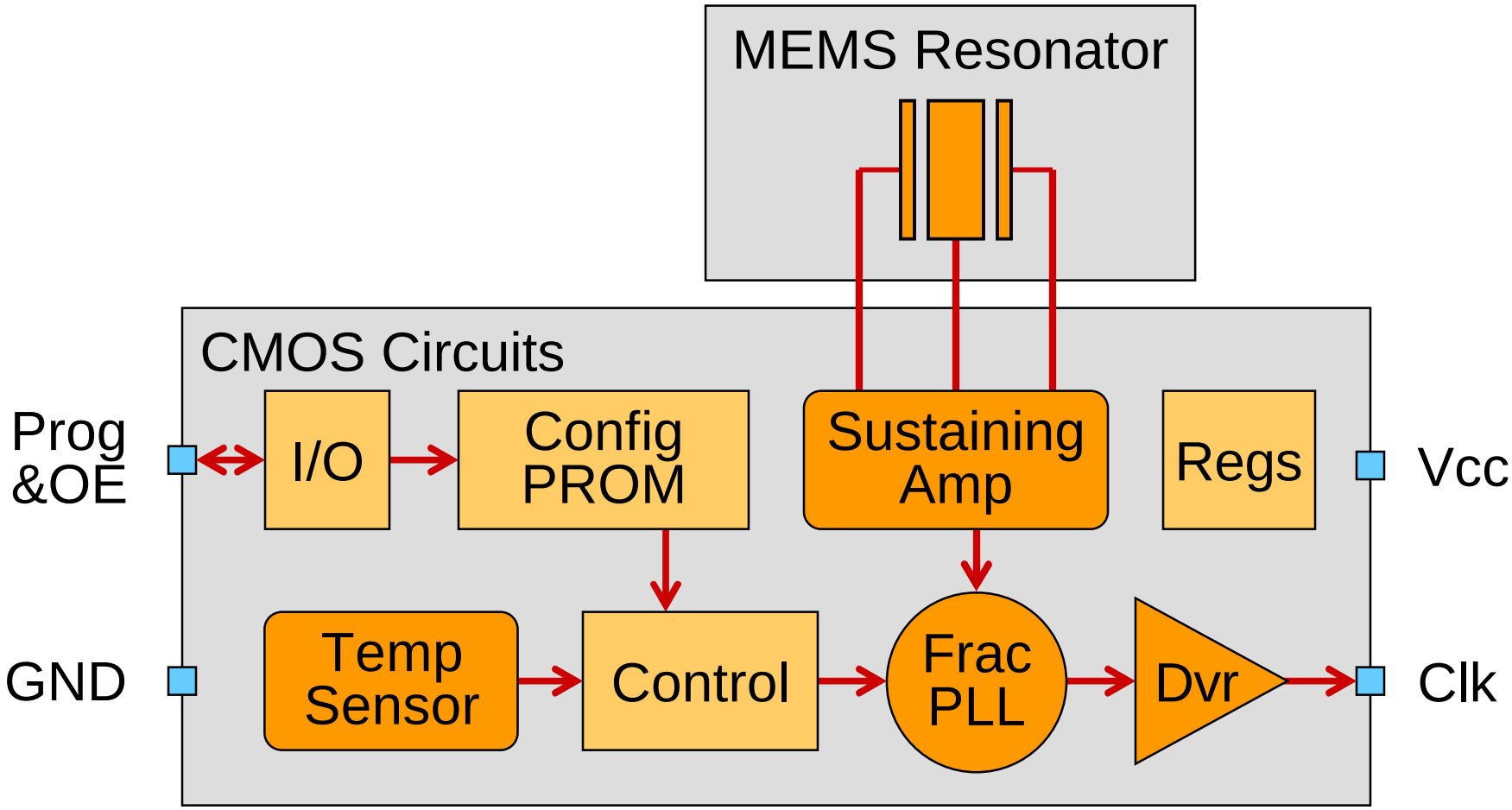
- Like a 2D bell – held in the center with its outer edges ringing. Motion is a few nanometers.
- Buried inside the chip, not on the surface.

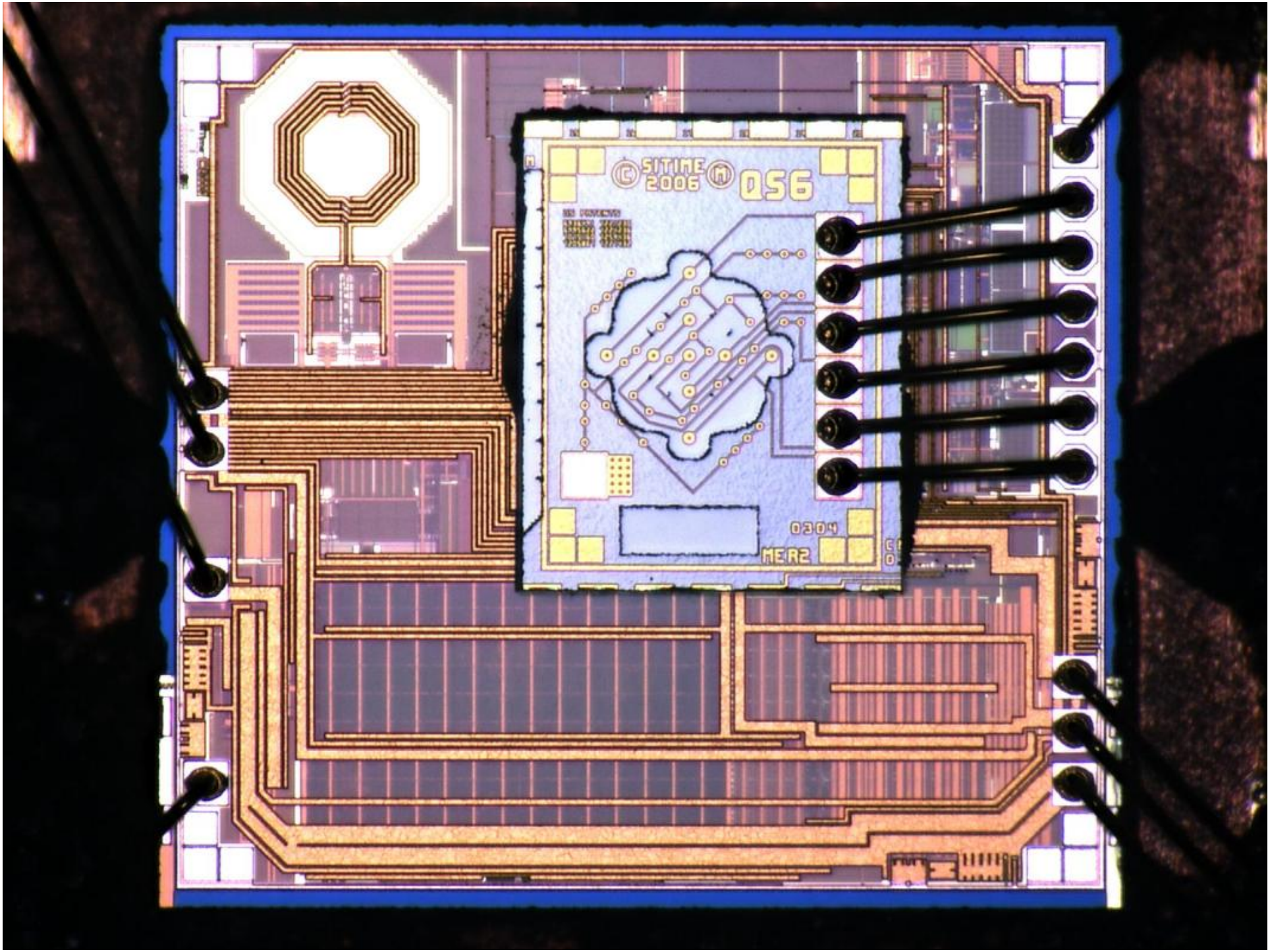




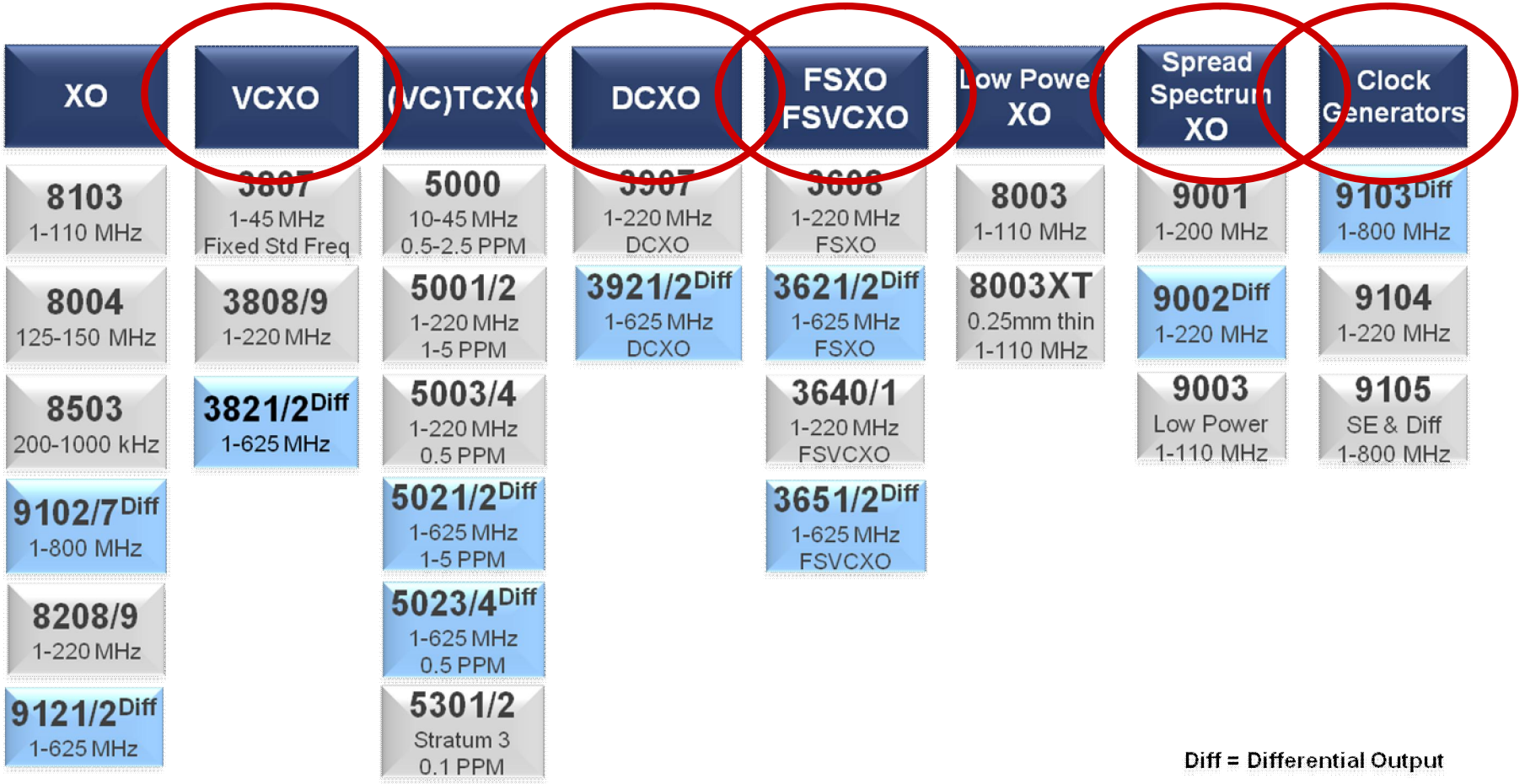
- kHz MEMS tuning forks for apps now served by 32kHz quartz tuning forks.
- Driven with sub-microamp supply currents.

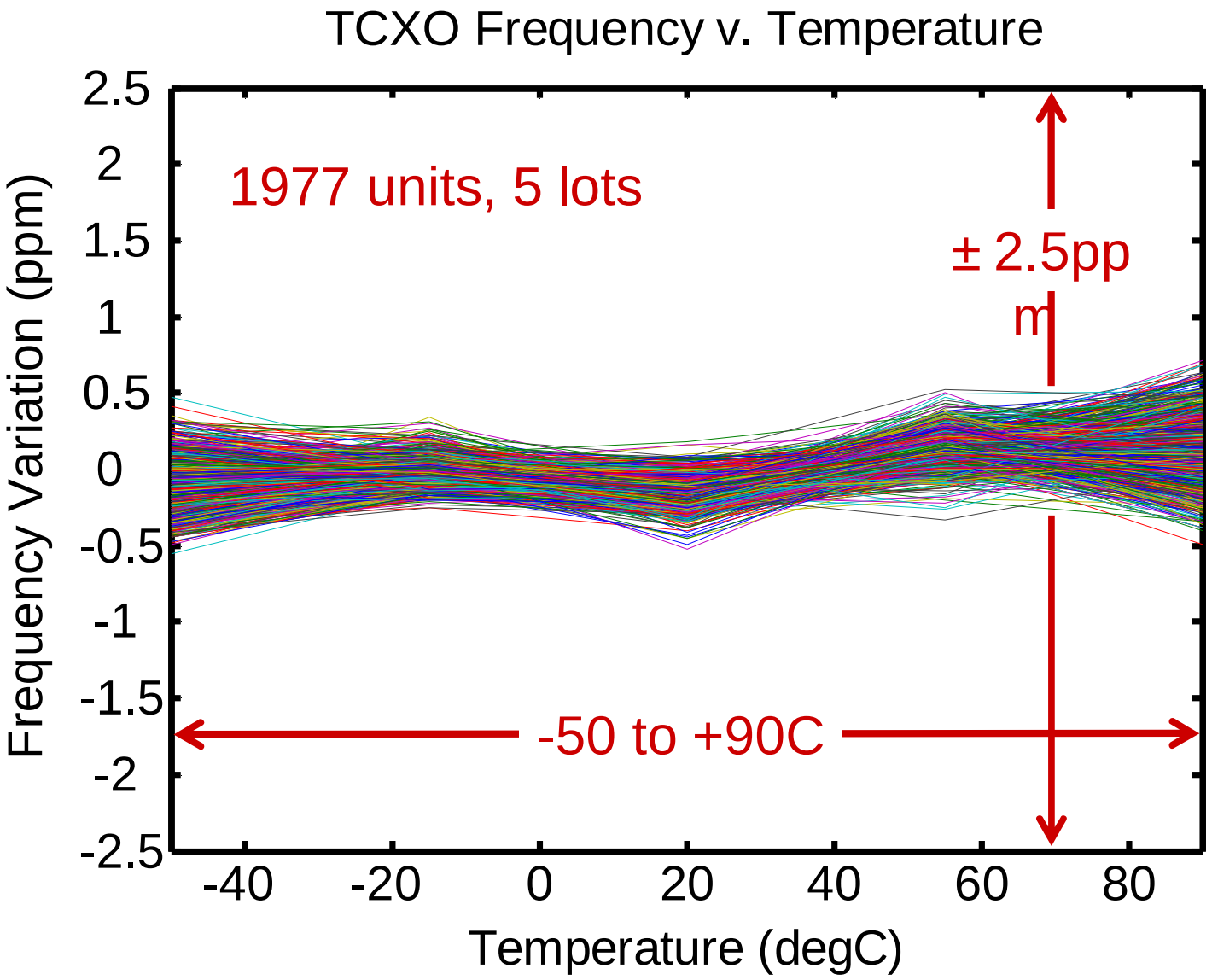

Chip Surface
Encapsulation
Resonator
E09ZC204 5.0kV x400 9/16/2009
100um

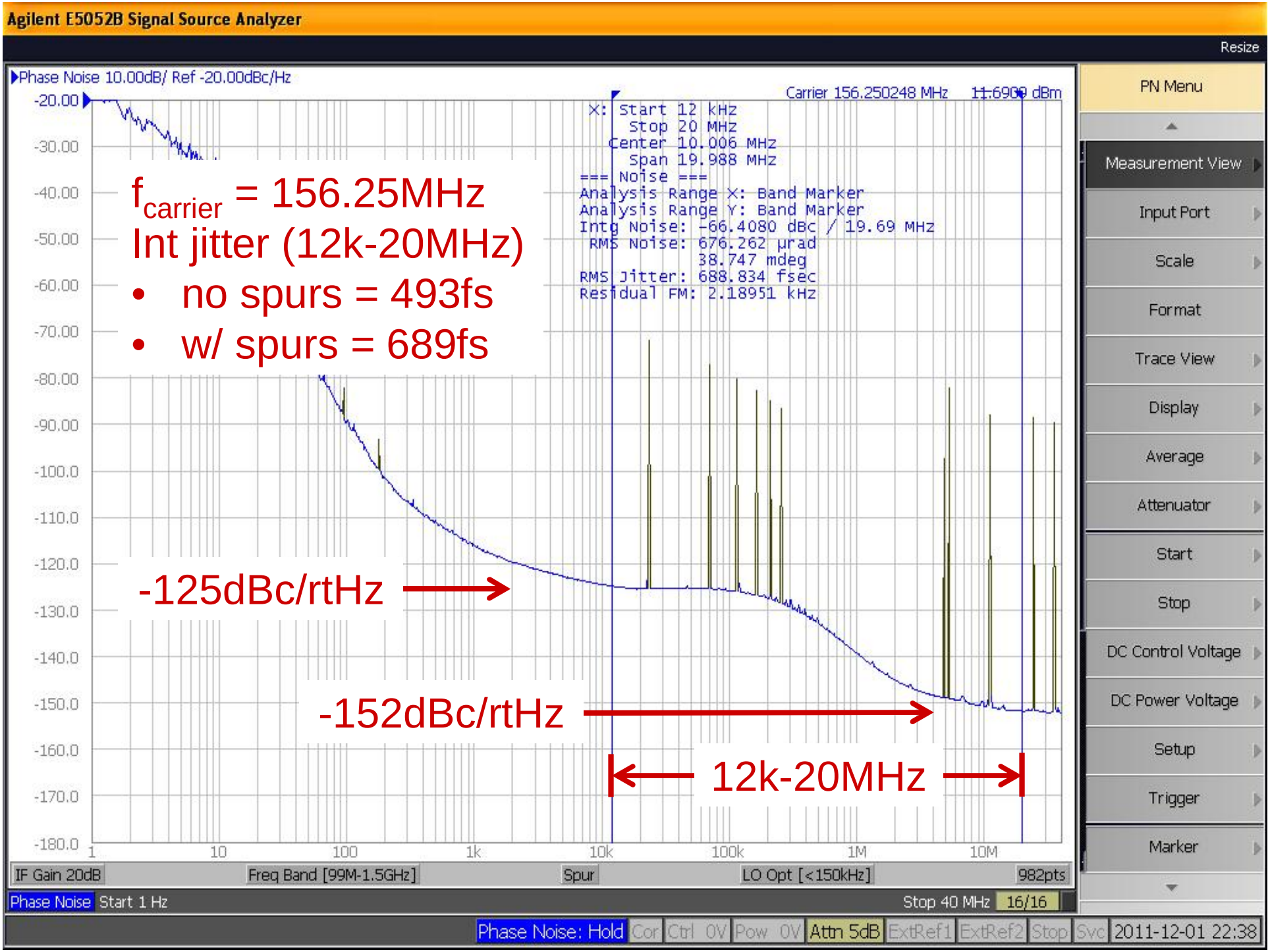

MEMS Resonator
CMOS Circuits
Prog
&OE
I/O
Config
PROM
Sustaining
Amp
Regs
Vcc
GND
Temp
Sensor
Control
Frac
PLL
Dvr
Clk

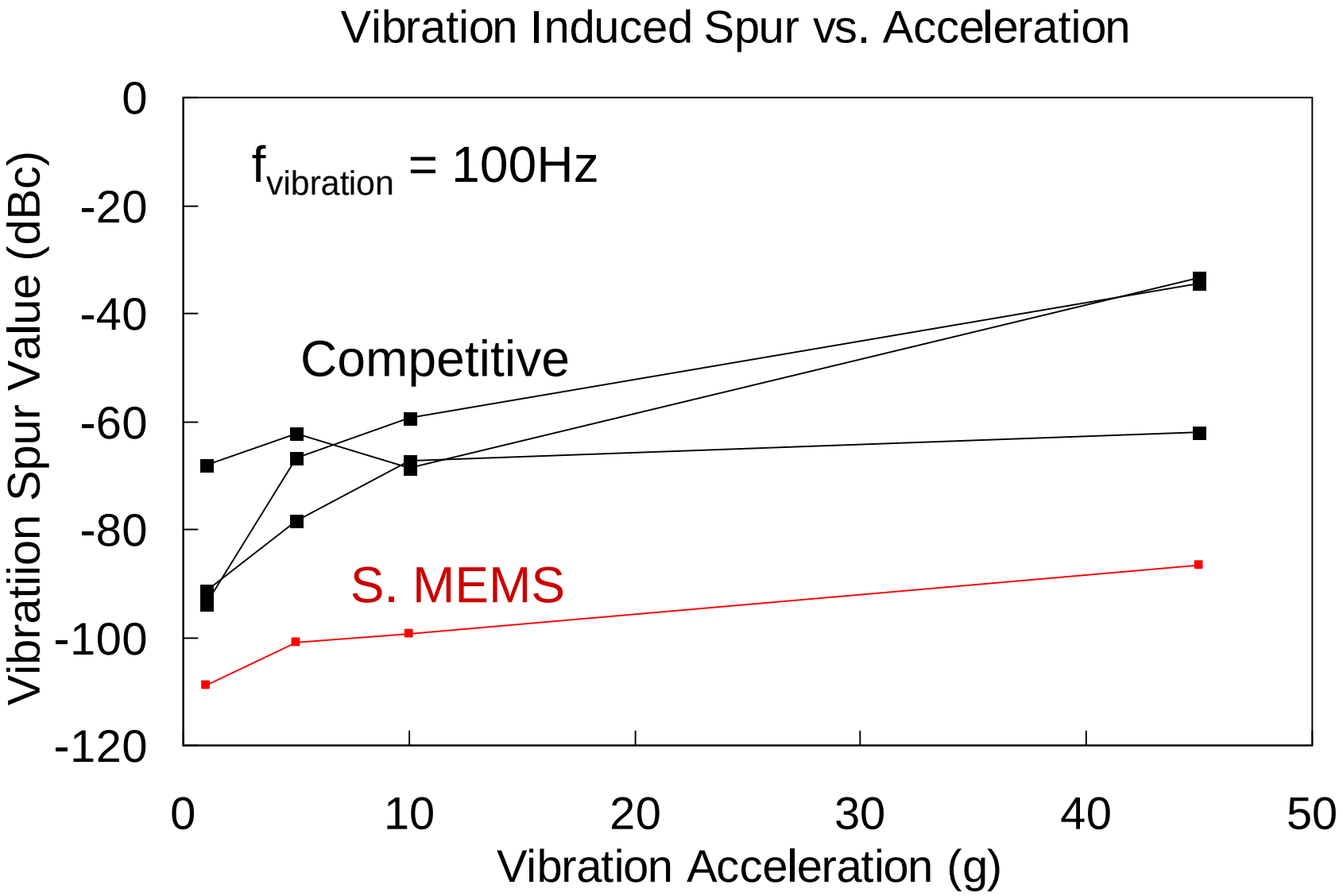

©SITIME 2006
056
0304
MER2

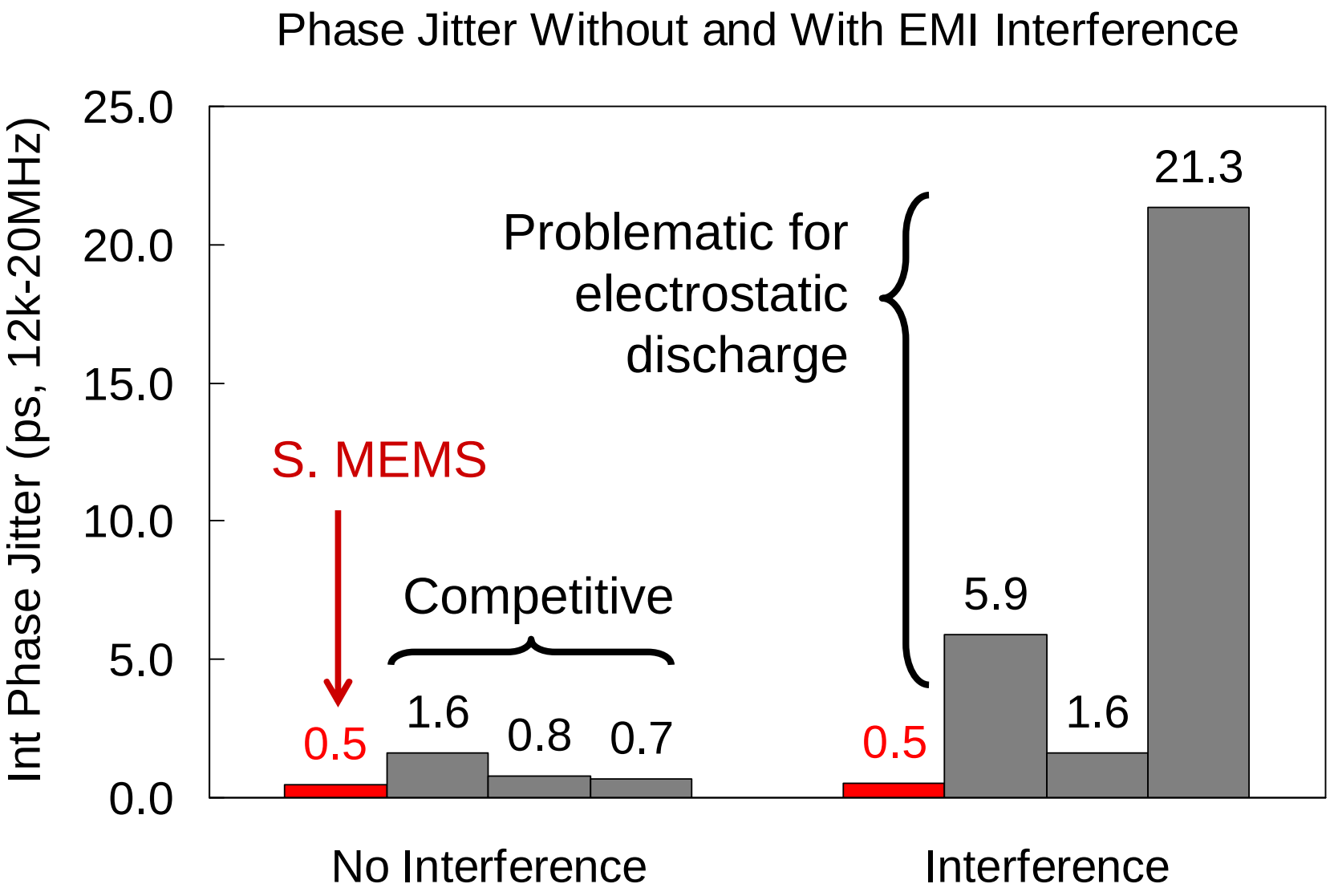
- Tremendous Flexibility
- New features
- Delivered performance
- Short lead times
- Exceptional quality and reliability
- Low cost, high value

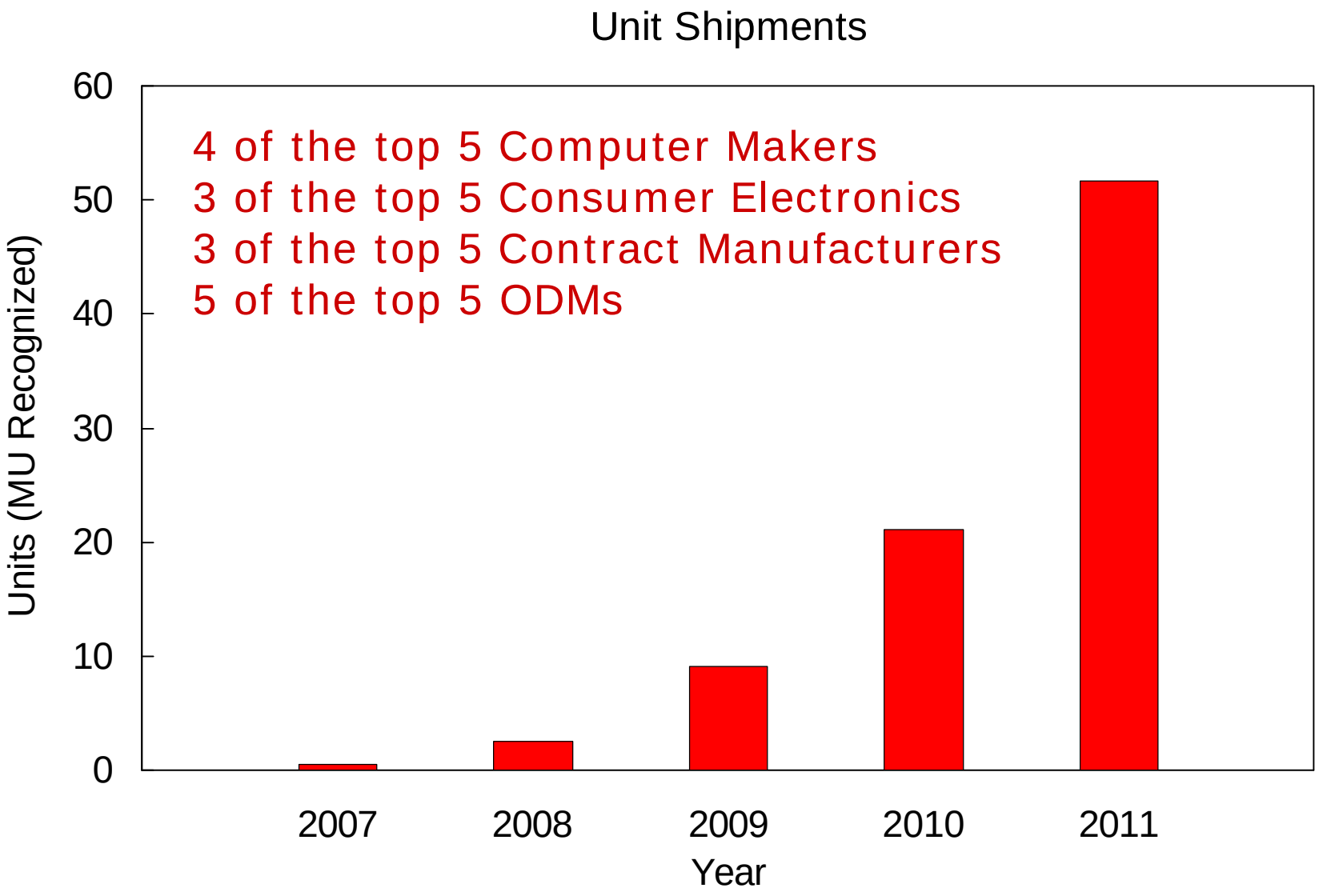

XO
8103
1-110 MHz
8004
125-150 MHz
8503
200-1000 kHz
9102/7 Diff
1-800 MHz
8208/9
1-220 MHz
9121/2 Diff
1-625 MHz
VCXO
3807
1-45 MHz
Fixed Std Freq
3808/9
1-220 MHz
3821/2 Diff
1-625 MHz
(VC)TCXO
5000
10-45 MHz
0.5-2.5 PPM
5001/2
1-220 MHz
1-5 PPM
5003/4
1-220 MHz
0.5 PPM
5021/2 Diff
1-625 MHz
1-5 PPM
5023/4 Diff
1-625 MHz
0.5 PPM
5301/2
Stratum 3
0.1 PPM
DCXO
3907
1-220 MHz
DCXO
3921/2 Diff
1-625 MHz
DCXO
FSXO
FSVCXO
3608
1-220 MHz
FSXO
3621/2 Diff
1-625 MHz
FSXO
3640/1
1-220 MHz
FSVCXO
3651/2 Diff
1-625 MHz
FSVCXO
Low Power
XO
8003
1-110 MHz
8003XT
0.25mm thin
1-110 MHz
Spread
Spectrum
XO
9001
1-200 MHz
9002 Diff
1-220 MHz
9003
Low Power
1-110 MHz
Clock
Generators
9103 Diff
1-800 MHz
9104
1-220 MHz
9105
SE & Diff
1-800 MHz
Diff = Differential Output


TCXO Frequency v. Temperature
1977 units, 5 lots
± 2.5pp
m
-50 to +90C
Frequency Variation (ppm)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-40
-20
0
20
40
60
80
Temperature (degC)


Agilent E5052B Signal Source Analyzer
Resize
Phase Noise 10.00dB/ Ref -20.00dBc/Hz
Carrier 156.250248 MHz 11.6900 dBm
X: Start 12 kHz
Stop 20 MHz
Center 10.006 MHz
Span 19.988 MHz
=== Noise ===
Analysis Range X: Band Marker
Analysis Range Y: Band Marker
Intg Noise: -66.4080 dBc / 19.69 MHz
RMS Noise: 676.262 µrad
38.747 mdeg
RMS Jitter: 688.834 fsec
Residual FM: 2.18951 kHz
-20.00
-30.00
-40.00
-50.00
-60.00
-70.00
-80.00
-90.00
-100.0
-110.0
-120.0
-130.0
-140.0
-150.0
-160.0
-170.0
-180.0
1
10
100
1k
10k
100k
1M
10M
$f_{carrier}$ = 156.25MHz
Int jitter (12k-20MHz)
• no spurs = 493fs
• w/ spurs = 689fs
-125dBc/rtHz
-152dBc/rtHz
12k-20MHz
IF Gain 20dB
Freq Band [99M-1.5GHz]
Spur
LO Opt [<150kHz]
982pts
Phase Noise
Start 1 Hz
Stop 40 MHz
16/16
PN Menu
Measurement View
Input Port
Scale
Format
Trace View
Display
Average
Attenuator
Start
Stop
DC Control Voltage
DC Power Voltage
Setup
Trigger
Marker
Phase Noise: Hold
Cor
Ctrl 0V
Pow 0V
Attn 5dB
ExtRef1
ExtRef2
Stop
Svc
2011-12-01 22:38


Vibration Induced Spur vs. Acceleration
$f_{vibration}$ = 100Hz
Competitive
S. MEMS
Vibratiion Spur Value (dBc)
0
-20
-40
-60
-80
-100
-120
0
10
20
30
40
50
Vibration Acceleration (g)


Phase Jitter Without and With EMI Interference
Int Phase Jitter (ps, 12k-20MHz)
25.0
20.0
15.0
10.0
5.0
0.0
S. MEMS
Competitive
Problematic for electrostatic discharge
0.5
1.6
0.8
0.7
0.5
5.9
1.6
21.3
No Interference
Interference


Unit Shipments
4 of the top 5 Computer Makers
3 of the top 5 Consumer Electronics
3 of the top 5 Contract Manufacturers
5 of the top 5 ODMs
Units (MU Recognized)
60
50
40
30
20
10
0
2007
2008
2009
2010
2011
Year

- Technology has fundamentally helped Humanity.
- Engineers make small contributions that are multiplied countless times.
- What you do matters to Billions of people!

Dorothea Lang,
‘Migrant Mother ”1936

Thank You

Abstract

The first commercial MEMS-based timing devices shipped in 2007. In just five years they are transforming the timing industry. The first parts offered XO stability and various advantages like programmability, but lacked the signal quality to support more than the basic applications. Recent parts are dramatically improved, offering TCXO stability, sub-picosecond integrated jitter, high frequency differential outputs, low phase noise for RF applications, low power for portable applications, and ultra low power for real time clock applications. Production rates are increasing exponentially with over 50 million units sold as of June 2011. How does this stuff work? Where will the technology go? Will MEMS replace quartz? What will MEMS timing do for the electronics industry? What will MEMS timing do for Humanity?