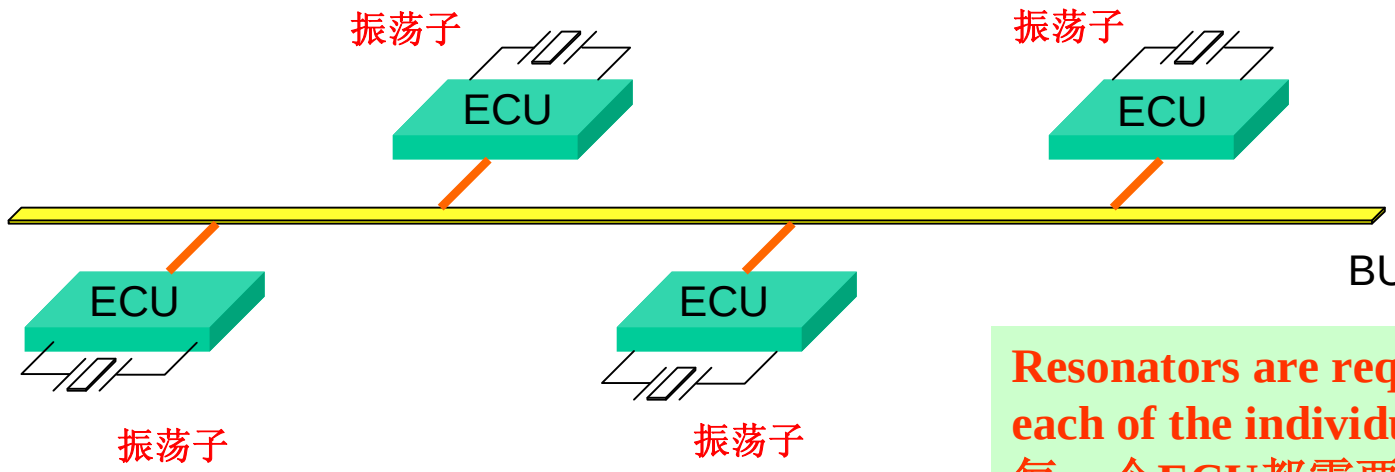
Technical trends of Ceramic Resonator in Car Electronics

汽车电子应用 陶瓷振荡子的技术趋势

Connection Image of ECUs　振荡子与ECU的连接示意图

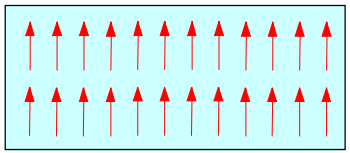


Resonators are required for each of the individual ECUs.
每一个ECU都需要振荡子

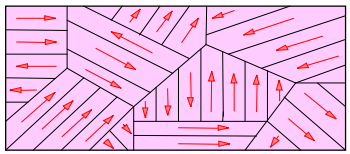
nBase Materials of Resonator 振荡子的基础材料

- Quartz Crystal 石英晶体
- **Ceramics　陶瓷**
- Other Single Crystal Materials (LiTaO3, LiNbO3, etc)
  其他单晶材料（钽酸锂，铌酸锂等）

Polarization and Piezoelectric Effect of Piezo Ceramics
压电陶瓷的极化及压电效应

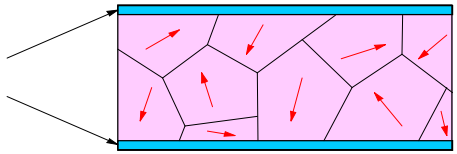


Monocrystal with single polar axis
具有单一极性轴的单晶体

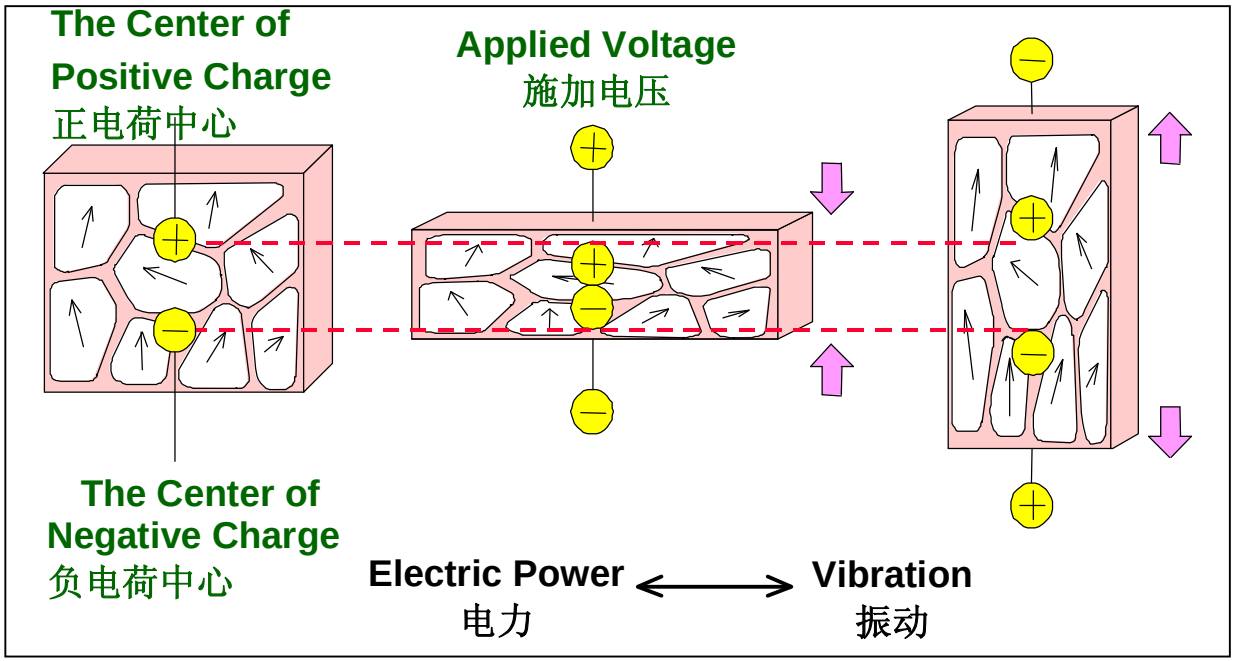


Polycrystal with random polar axis
具有任意排列极性轴的多晶体

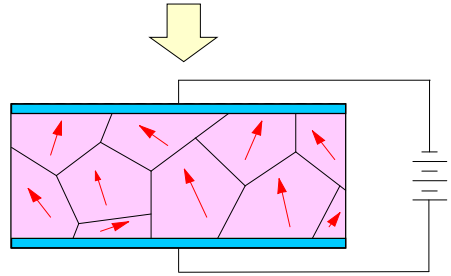
Electrode
电极



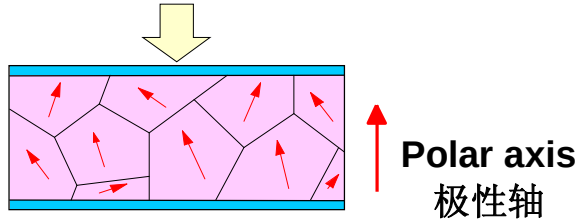
Random dipole after sintering
烧结后任意排列双极子



Piezoelectric Effect
压电效应

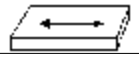
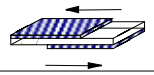
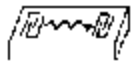


Polarization (3kV/mm)
极化



Surviving polarity
残留极性

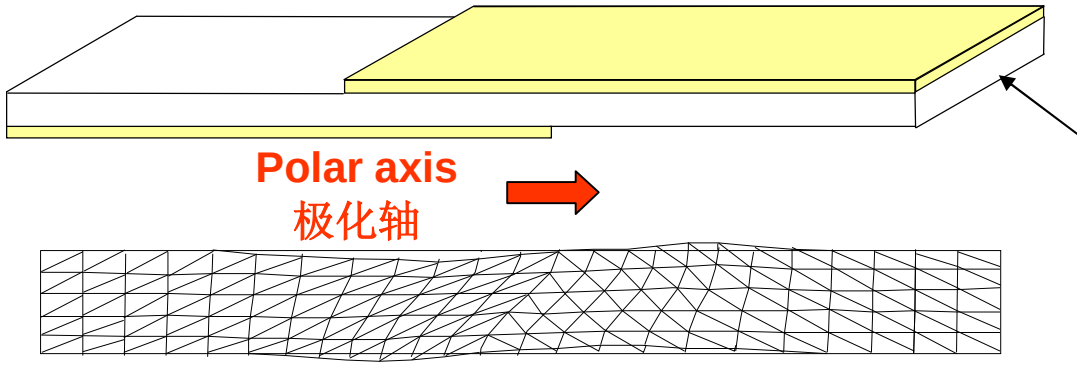
Vibration Modes and Resonant Frequency Band
振动模式与共振频率带

Frequency [Hz] 频率 / Vibrating mode 振动模式	1k 10k 100k 1M 10M 100M 1G	Applications 应用
Flexural mode 弯曲振动 		**Piezo Buzzer** 压电蜂鸣器
Length mode 长度方向振动 		**KHz Ceramic Filter** **KHz陶瓷滤波器**
Area expansion mode 面积扩展振动 		**KHz Ceramic Resonator/Filter** **KHz陶瓷振荡子/滤波器**
Radius Vibration 径向辐射振动 		
Thickness Shear mode 厚薄切变振动 		**MHz Ceramic Resonator/Filter** **MHz陶瓷振荡子/滤波器**
Thickness expander mode 厚度纵向扩展振动 		**MHz Ceramic Resonator/Filter** **MHz陶瓷振荡子/滤波器**
Surface Acoustic Wave 声表面波 		**SAW Filter** 声表面波滤波器 **SAW Resonator** 声表面波振荡子
BGS Wave BGS波 		**HF Trap** 高频陷波器 **HF Ceramic Resonator** 高频陶瓷振荡子 **HF Ceramic Filter** 高频陶瓷滤波器

Note: Signifies the direction of the vibration

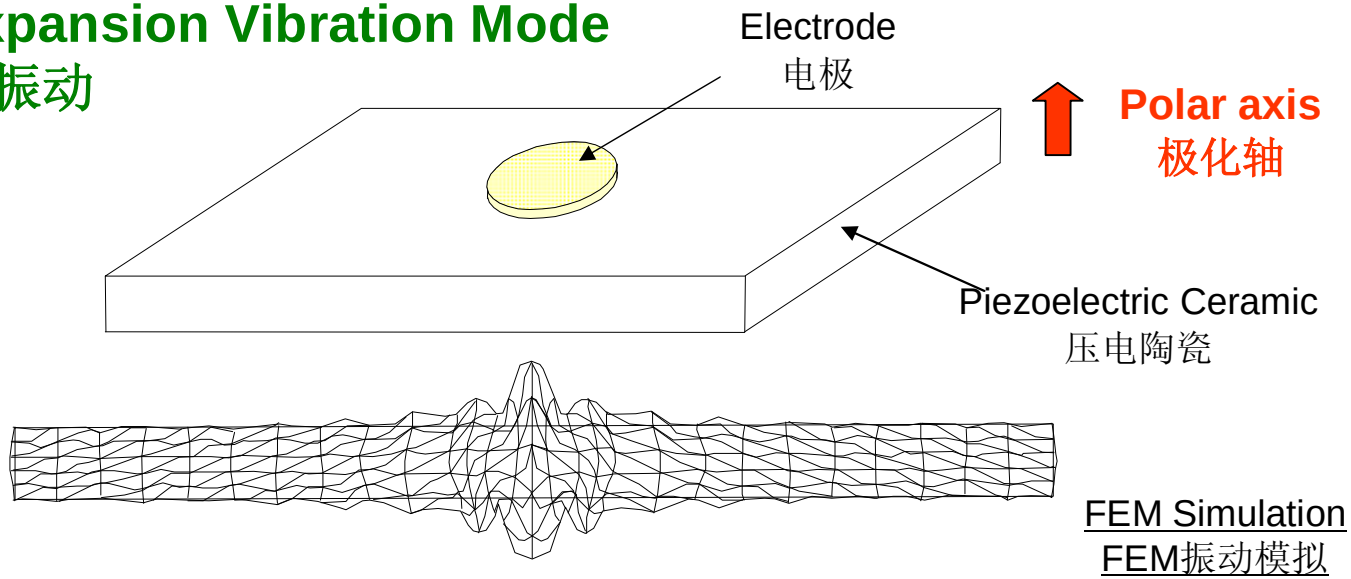
Typical Models of Vibration Mode 主要振动模式

nThickness Shear Vibration Mode
厚薄切变振动



FEM Simulation
FEM振动模拟

nThickness Expansion Vibration Mode
厚度纵向扩展振动

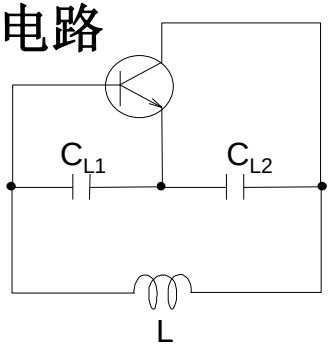


FEM Simulation
FEM振动模拟

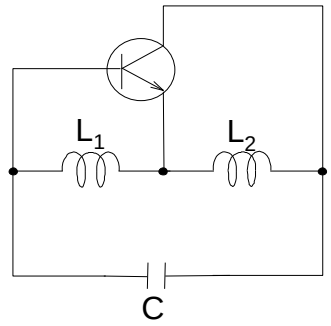
Oscillation Principle 震荡原理

nOscillation circuits can be classified into three types 振荡电路可以分为**3**类

1. positive feedback 正反馈电路
2. negative resistance elements 负阻抗电路
3. transmission time or phase delay
   传送时间或相位延迟电路



Colpitts Circuit
考毕兹电路



Hartley Circuit
哈特利电路

- LC oscillation circuits using ceramic resonators or crystal resonators are the first type, the positive feedback type.
  使用陶瓷振荡子或晶体振荡子的LC振荡电路属于第一类的正反馈电路
- Colpitts circuits and Hartley circuits are typical examples of positive feedback oscillation LC circuits.
  考毕兹电路和哈特利电路是典型的正反馈LC振荡电路
- When resonators are applied, Colpitts circuits are generally used.
  当使用振荡子时，通常会采用考毕兹电路。
- The oscillation frequencies can be represented by the following formulas.
  振荡频率可由下面的公式表示

（Colpitts Circuit考毕兹电路）

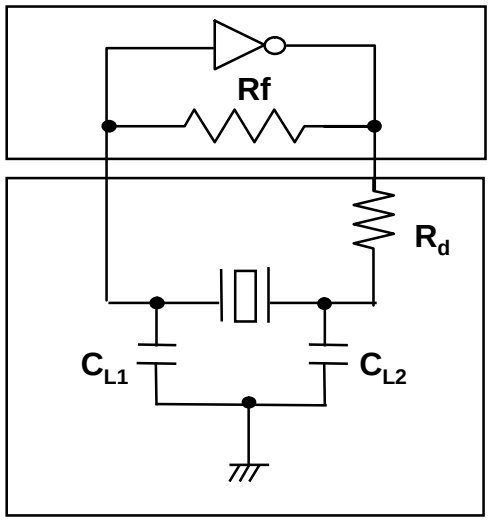
$$f_{osc} \cong \frac{1}{2p\sqrt{L \times \frac{C_{L1} \times C_{L2}}{C_{L1} + C_{L2}}}}$$

（Hartley Circuit哈特利电路）

$$f_{osc} \cong \frac{1}{2p\sqrt{C(L_1 + L_2)}}$$

Oscillation Principle 震荡原理

- When a ceramic resonator is used in an oscillation circuit, it is substituted for Element L of the Colpitts circuit.
  在振荡电路中使用的振荡子，就相当于考毕兹电路中的元件L
- Ceramic resonator becomes inductive between the resonance frequency and anti-resonance frequency.
  陶瓷振荡子在谐振频率与反谐振频率之间呈现电感性



$b\ (q_2)$

Positive Feedback Oscillation Circuit
正反馈振荡回路

Oscillation Condition
振荡条件

Loop Gain : $a \times b \geq 1$
环路增益

Phase Shift: $q_1 + q_2 = 360° \times n$
位相量

Where
a : ***Mu Factor*** *放大率*
b : ***Feedback Ratio*** *反馈率*

θ_1, q_2 : ***Phase shift***
位相量

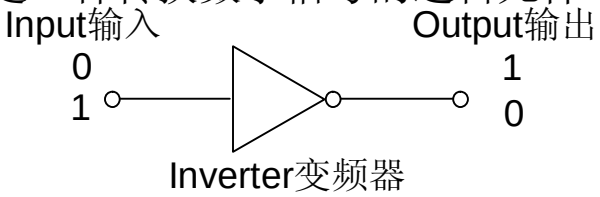
The Colpitts circuit uses an inversion amplifier for 180° phase inversion, and the feedback circuit uses a coil and capacitor for an additional 180° phase inversion.

考毕兹电路通过一个反相放大器实现180° 相位反转，然后反馈回路通过线圈和电容再实现180°的相位反转。

Inversion Amplifier by C-MOS Inverter
用C-MOS作为反相放大器

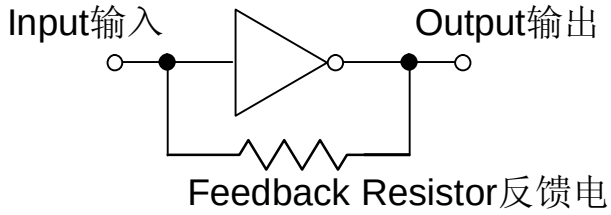
- Inverter is a logic element which invert a digital signal.

变频器是一种转换数字信号的逻辑元件

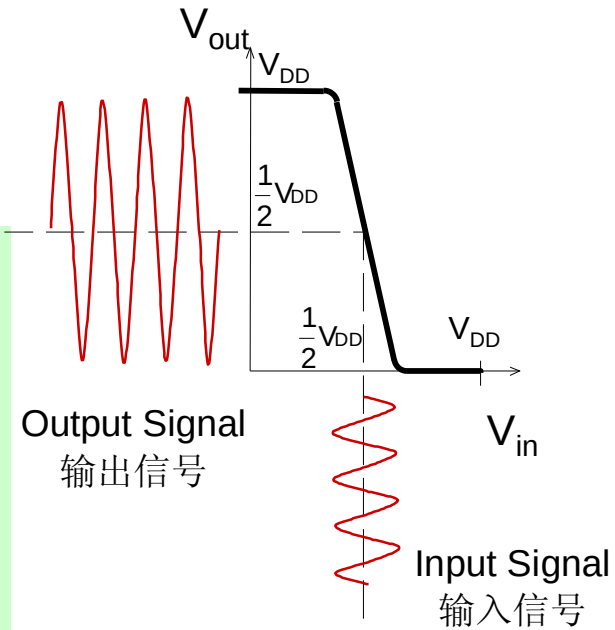


- Inverter serves as an analog amplifier when combined with a feedback resistor.

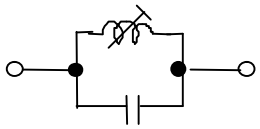
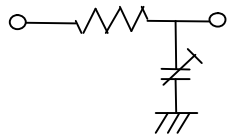
当变频器连接上一个反馈电阻后就成为一个模拟信号放大器



- When a feedback resistor is connected to both ends of the inverter, the current flows so that both ends of the inverter have equal potential. Finally, the output voltage is about one half of the power supply voltage.
  当把变频器的两端接上一个并联电阻，电流开始流动，最终输出电压会达到约为输入电压的1/2，即1/2V_{DD}。
- When a small AC voltage is applied to the input terminal, an amplified voltage is output, and the phase is inverted by 180°.
  当在输入端加上一个微小的交流电压时，能够输出一个放大的电压，并且相位反转180°.



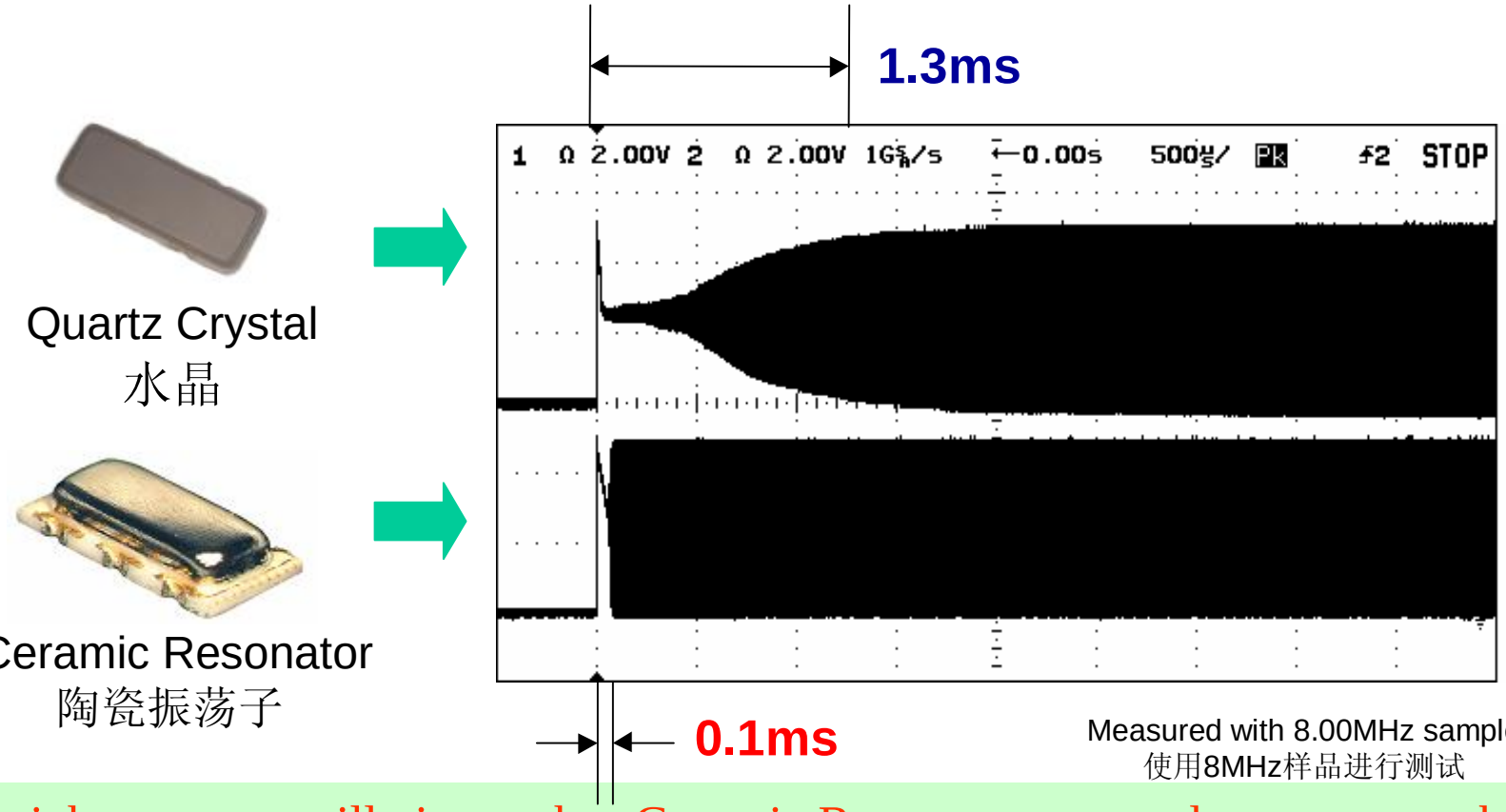
Various typical Oscillation Devices 各种典型的振荡器件

Type 种类	Symbol 符号	Cost 成本	Size 尺寸	Frequency Trimming 频率调整	Frequency Tolerance 频率公差	Oscillation Stability 振荡稳定性	Qm 机械值Q
LC		Inexpensive 便宜	Not small 大	Need 要	±2.0%	Not stable 不稳定	Small 小
CR		Inexpensive 便宜	Small 小	Need 要	±2.0%	Not stable 不稳定	Small 小
Quartz Crystal 水晶		Expensive 贵	Not small 大	No need 不要	± 10 to ± 50ppm	Stable 稳定	Large 大
Ceramic 陶瓷		Inexpensive 便宜	Small 小	No need 不要	± 0.1to ± 0.5%	Stable 稳定	Medium 中

Qm : Mechanical Q
机械值Q

Comparison of Ceramic Resonator and Quartz Crystal
陶瓷振荡子与水晶的比较

Comparison of oscillation start-up time 起振时间的比较

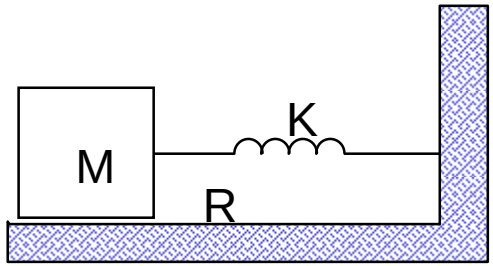


Measured with 8.00MHz sample
使用8MHz样品进行测试

Quick start up oscillation makes Ceramic Resonator more advantageous when it comes to powering a microcomputer back from sleep mode.
快速响应的特点使陶瓷振荡子在激活处于睡眠状态的微机时更具优势

Comparison of Ceramic Resonator and Quartz Crystal
陶瓷振荡子与水晶的比较

Equivalent Circuit Constant 等效电路常数



R : Friction摩擦力 (Corresponding to 相当于R1)

K : Spring constant弹簧常数 (Corresponding to 相当于$\frac{1}{C1}$)

M : Mass质量 (Corresponding to 相当于L1)

Mechanical equation
机械运动方程式

$$M\frac{dv}{dt} + Rv + k\int v\,dt = F$$

Electrical equation
电气运动方程式

$$L\frac{di}{dt} + Ri + \frac{1}{c1}\int i\,dt = V$$

	Ceramic Resonator 陶瓷振荡子	Quartz Crystal 水晶
Freq.	4.00MHz	4.00MHz
L1 (μH)	**385**	2.1X10^5
C1 (pF)	**4.4**	0.007
Co (pF)	**36.3**	2.39
R1 (Ω)	8.7	22.1
Qm	1134	240986
ΔF (kHz)	228	6

Ceramic Resonator can start up more quickly than quartz crystal

陶瓷振荡子能够比水晶快速起振

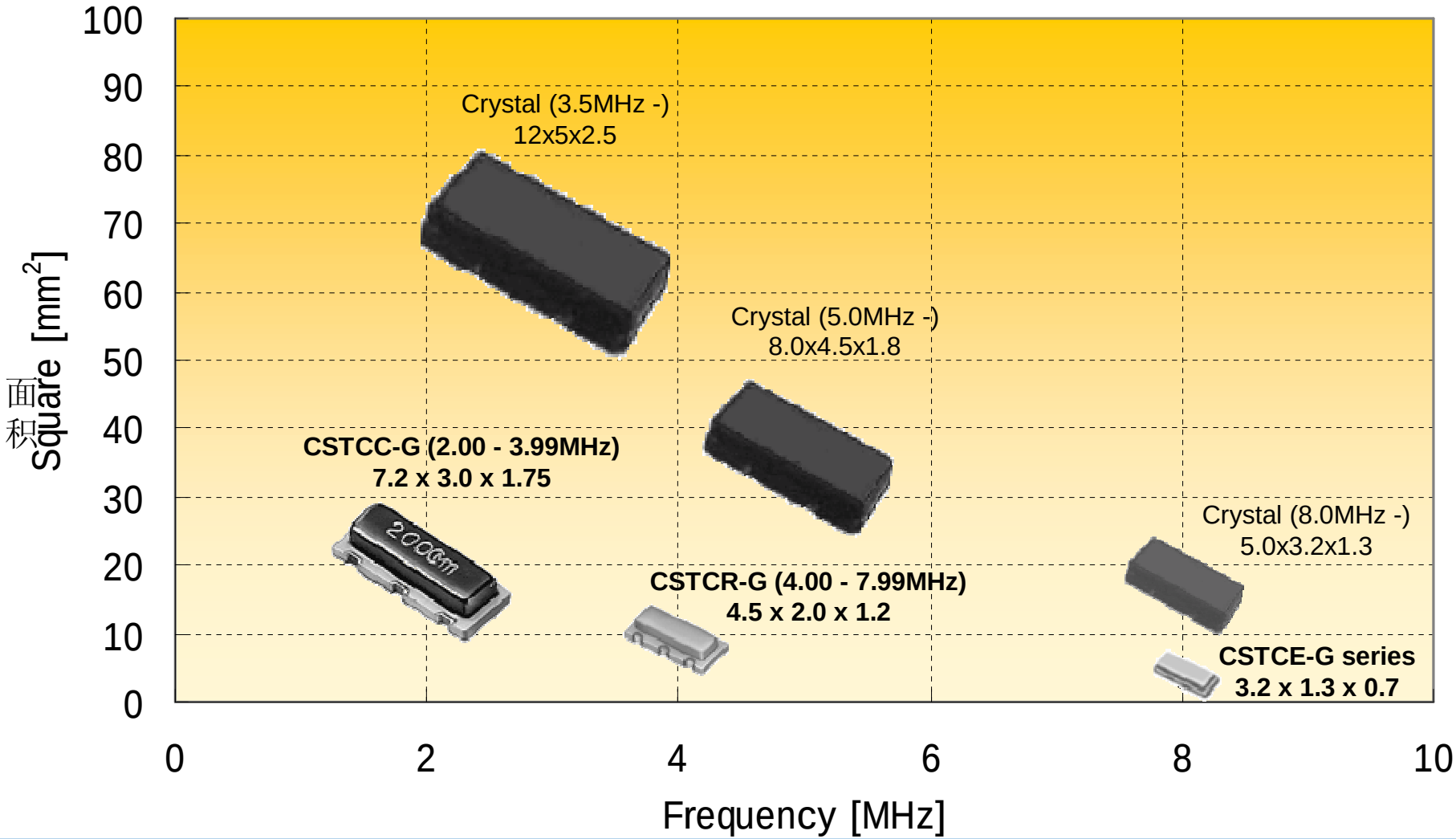
In mechanical motion (vibration by spring), vibration can start up quickly when small “M” and small “K”.
在机械运动中（弹簧振动），当“M” 和 “K”较小时能够快速起振。.

In the case of electrical motion, oscillation can start up quickly when small “L” and large “C1”
在电气运动中，当“L”较小 和 “C1”较大时能够快速起振。.

For these reasons, ceramic resonator can start up more quickly than quartz crystal.
正是基于上面的原因，陶瓷震荡子能够比水晶快速起振。

Comparison of Ceramic Resonator and Quartz Crystal
陶瓷振荡子与水晶的比较

Size Comparison 尺寸比较



Application of Ceramic Resonator to Automotive LANs
陶瓷振荡子在汽车LAN的应用

Electronic devices used in automotive ECUs are required to have the following characteristics;
用于**ECU**的电子部件必须具备以下的特点：

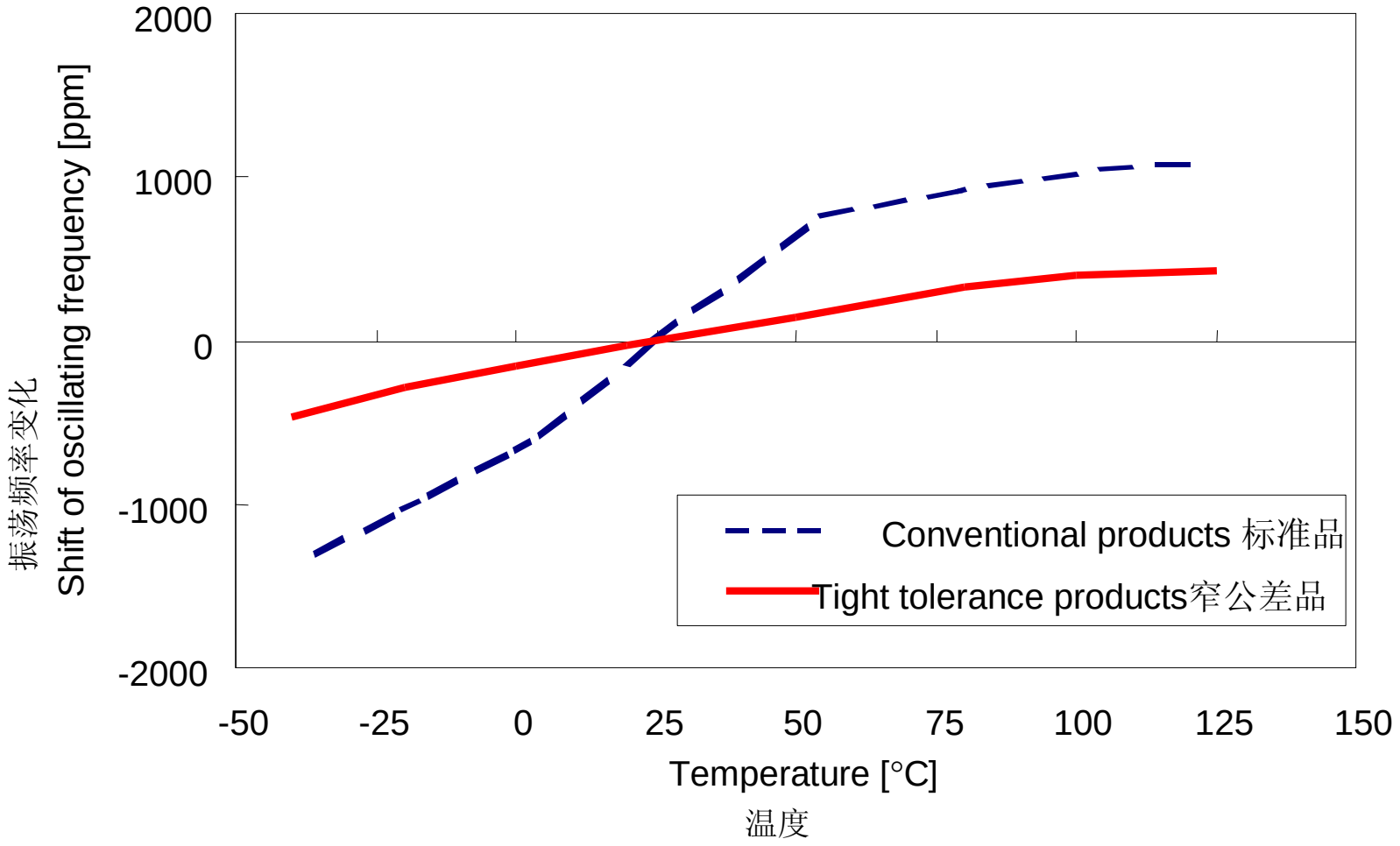
- **Operating temperature typically ranging between - 40°C and 125°C**
  工作温度范围**- 40°C and 125°C**
- **Excellent resistance to shock and vibration**
  良好的抗冲击和抗振性
- **Excellent solderability**
  良好的可焊性
- **Extremely low failure rate**
  极低的不良率

Ceramic Resonator (CERALOCK®) for Car Electronics
汽车电子用陶瓷振荡子（ CERALOCK®)

Frequency (MHz)	2	3	4	8	14	20	70
MHz Range							
Standard Tolerance Series 标准公差系列	2.00 2.99 / 3.00 3.99		4.00 7.99	8.00 13.99	14.00 20.00	20.01 70.00	
	 CSTCC-G-A		 CSTCR-G-B	 CSTCE-G-A	 CSTCE-V-C	 CSTCV-X-Q, CSACV-X-Q (3 terminals) (2 terminals)	
Size (W x L x T mm) Weight	*7.2x3.0x1.8 100mg*	*7.2x3.0x1.6 80mg*	*4.5x2.0x1.2 25mg*	*3.2x1.3x0.8 12mg*	*3.2x1.3x1.0 12mg*	*3.7x3.1x1.475mg*	
Tight Tolerance Series 窄公差系列			4.00 7.99	8.00 13.99	14.00 20.00		
			 CSTCR-G-C	 CSTCE-G-C	 CSTCE-V-C		

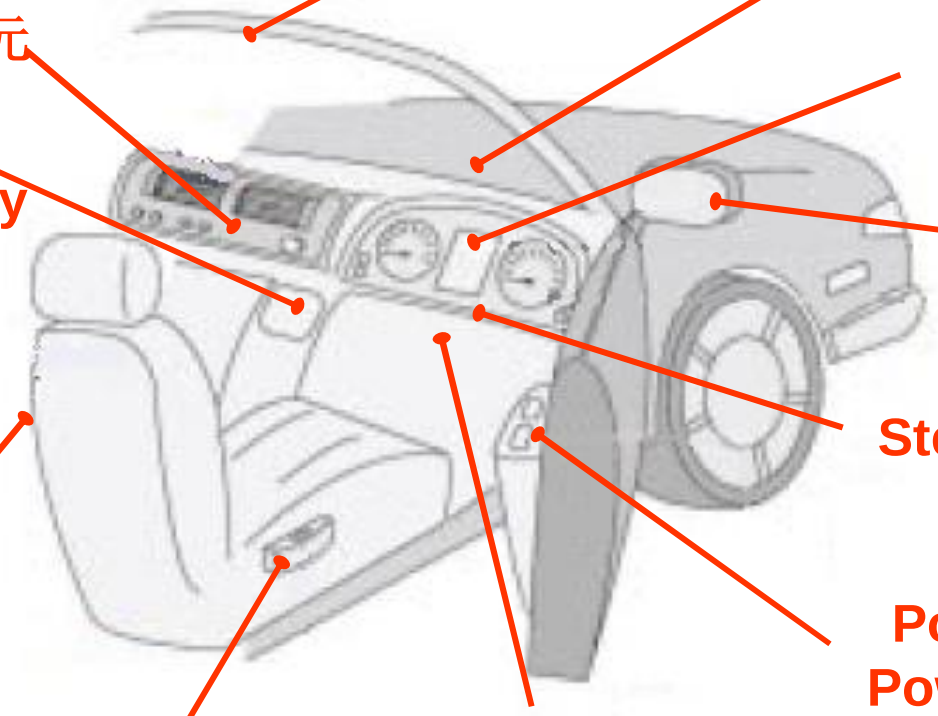
Available for Automotive LAN (CAN)
可适用于汽车LAN(CAN)

Improvement of Temperature Characteristics
温度特性的改善



Application of CERALOCK® in Car Electronics
CERALOCK® 在汽车电子上的应用

Body-Comfort



Remote Keyless Entry
遥控车门

Wiper Control,
Rain Sensor Unit
雨刮，雨水传感器单元

Climate Control Unit
空调控制单元

Instrument Cluster,
Drive Computer
驾驶仪表

Navigation Unit,
Information Display
Panel导航系统

Mirror Control Unit
后视镜单元

Power Slide
Door Unit
电力滑动门单元

Steering Column Switch
驾驶开关

Passenger
Pressure Unit
乘客紧急制动单元

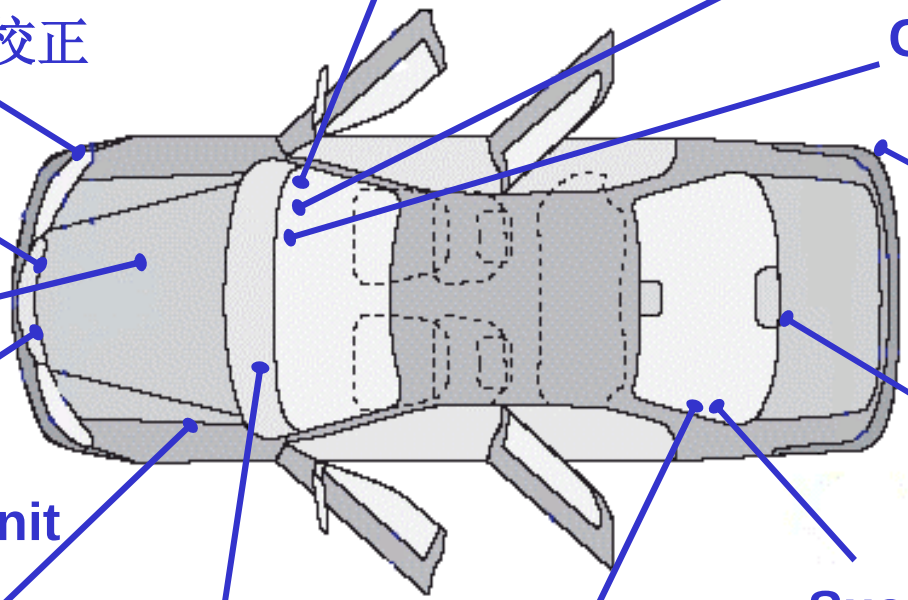
Power Window,
Power Door Rock
电动窗

Power Slide Seat,
Seat Memory
电力滑轨座位
座位记忆体

Immobilizer,
Anti-Theft Alarm Control
防盗警报系统

Application of CERALOCK® in Car Electronics

Power-Management



Electric Power Steering
电子助力转向

Airbag Unit
安全气囊单元

AFS, Auto-leveling Control
电动头灯，自动水平校正

Cruise Control System
巡航

Cooling System
冷却系统

Ultra Sonic
Sensor Unit
超声波传感器

Injection Unit
ECU Sub. Unit
喷油单元

Battery Control Unit
(for Hybrid Vehicle)
电力控制（混合动力车）

Pre-crash Sensor Unit
防撞传感器

Suspension Control
悬浮控制

Antilock Break System
防抱死系统

TPMS Unit
胎压检测单元

EPS, TRC Unit,
Parking Assist Break System
辅助泊车系统