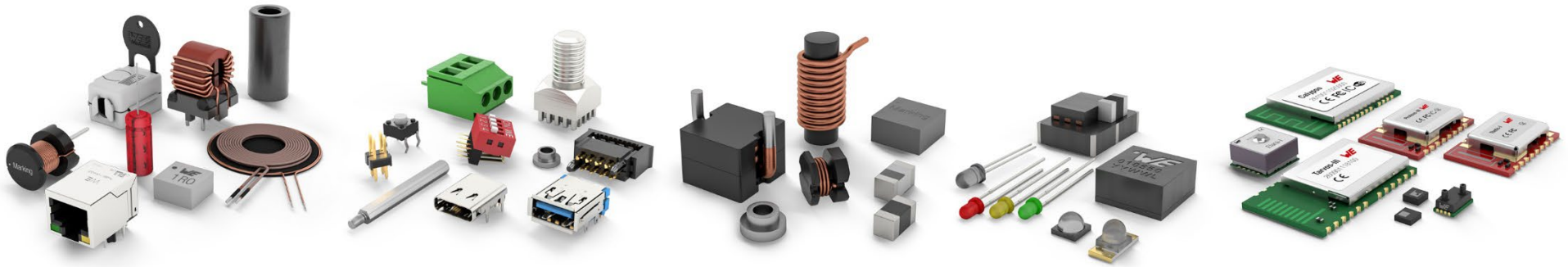
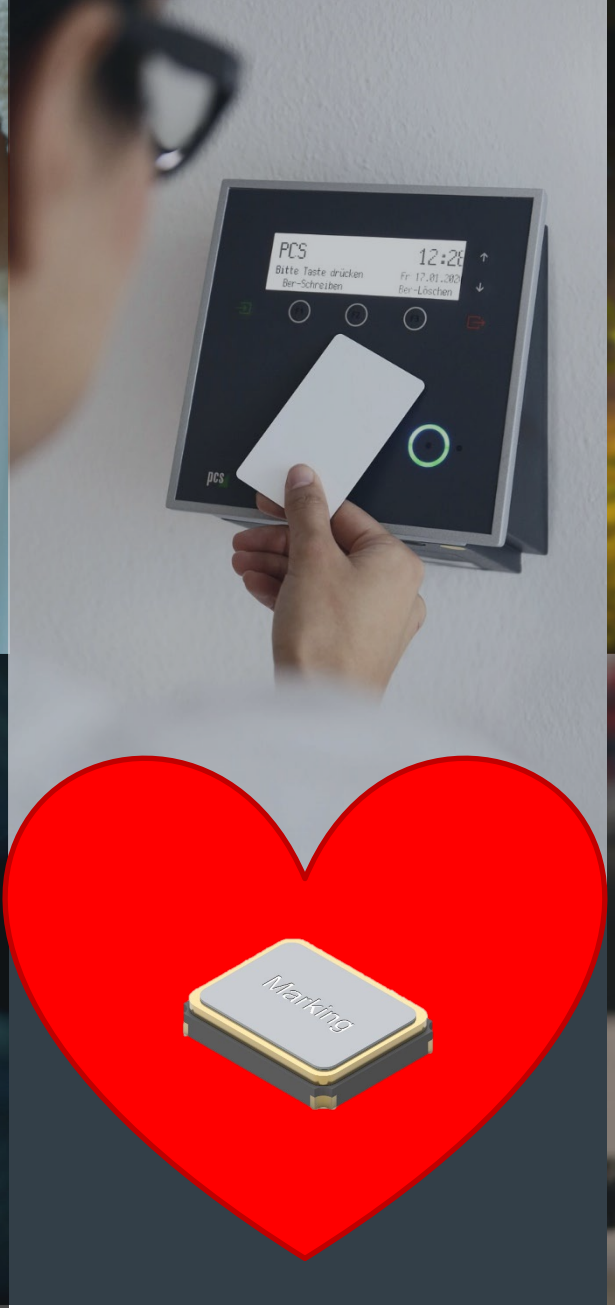


STAY AHEAD OF TIME: NAVIGATING MARKET SHIFTS AND MINIATURISATION IN QUARTZ AND OSCILLATORS

Sarah Moschüz – Product Manager


Montréal
4:42
19°


PCS
12:28
Bitte Taste drücken
Ber-Schreiben
Ber-Löschen
Marking


HOME CONTROL
21° C
CONTROL
MODE


CREDIT CARD
1234 5678 9876 5432
YOUR NAME
Clear
Stop

AGENDA

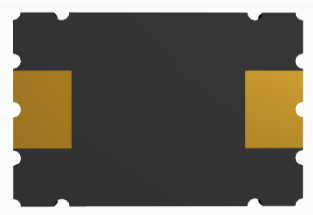
- Reasons for a Re-Design
- Current market trends
- Key parameters for Re-Design with a crystal
- Key parameters for Re-Design with an oscillator
- Summary

REASONS FOR A RE-DESIGN

Status Quo

Many PCB designs have been done years or even more than a decade ago

Old package style like DIL or plastic moulded housing



None-standard sizes (e. g. 6.0 x 3.5 mm) or Pad Layout (e. g. 2-Pad 3.2 x 2.5 mm)

Big package sizes (e. g. 11.05 x 4.7 mm or 13.4 x 4.9 mm)

REASONS FOR A RE-DESIGN

Status Quo

Reasons for a Re-Design

The crystal or oscillator used no longer meet the market standard

Increasing prices and lead times

EOL

The size of the crystal or oscillator should be reduced

TRENDS ON THE MARKET

Smaller sized crystals and oscillators

End-of- Life of “old” designs, e. g. plastic housing

Higher requirements for temperature ranges and accuracy

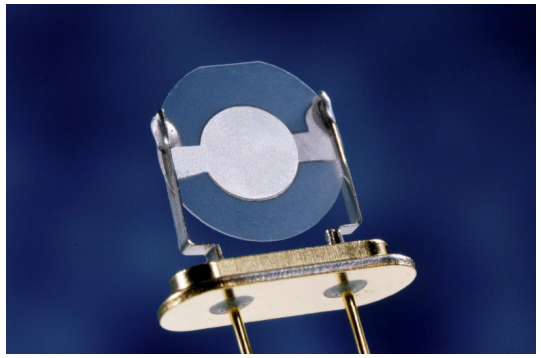
Variable supply voltage for oscillators

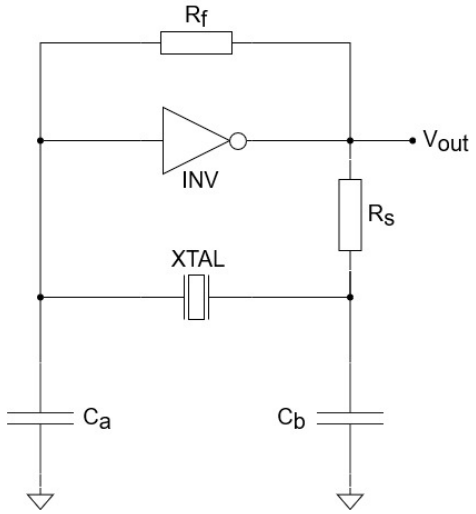
TYPES OF FREQUENCY PRODUCTS

eiSos Portfolio

Quartz Crystal (XTAL)

- crystalline form of silicon dioxide (SiO_2)
- An external oscillation circuit is needed to generate a frequency





QUARTZ CRYSTALS

What parameters are important to consider while doing a re-design?

- Frequency
- Tolerance and Stability
- Load Capacitance
- Trim sensitivity
- ESR

QUARTZ CRYSTALS

What parameters are important to consider while doing a re-design?

- **Frequency**
- Tolerance and Stability
- Load Capacitance
- Trim sensitivity
- ESR

- For MHz crystals, the resonance frequency is mainly determined by the thickness of the quartz blank
- Rule: The thicker the crystal blank, the lower the frequency

⇒ In smaller sized crystals, lower frequencies cannot be achieved

HC49/4HSMX (13.4 x 4.9 mm)
Lowest frequency available: 3.2768 MHz

CFPX-180 (3.2 x 2.5 mm)
Lowest frequency available: 8 MHz

IQXC-26 (1.6 x 1.2 mm)
Lowest frequency available: 24 MHz

What parameters are important to consider while doing a re-design?

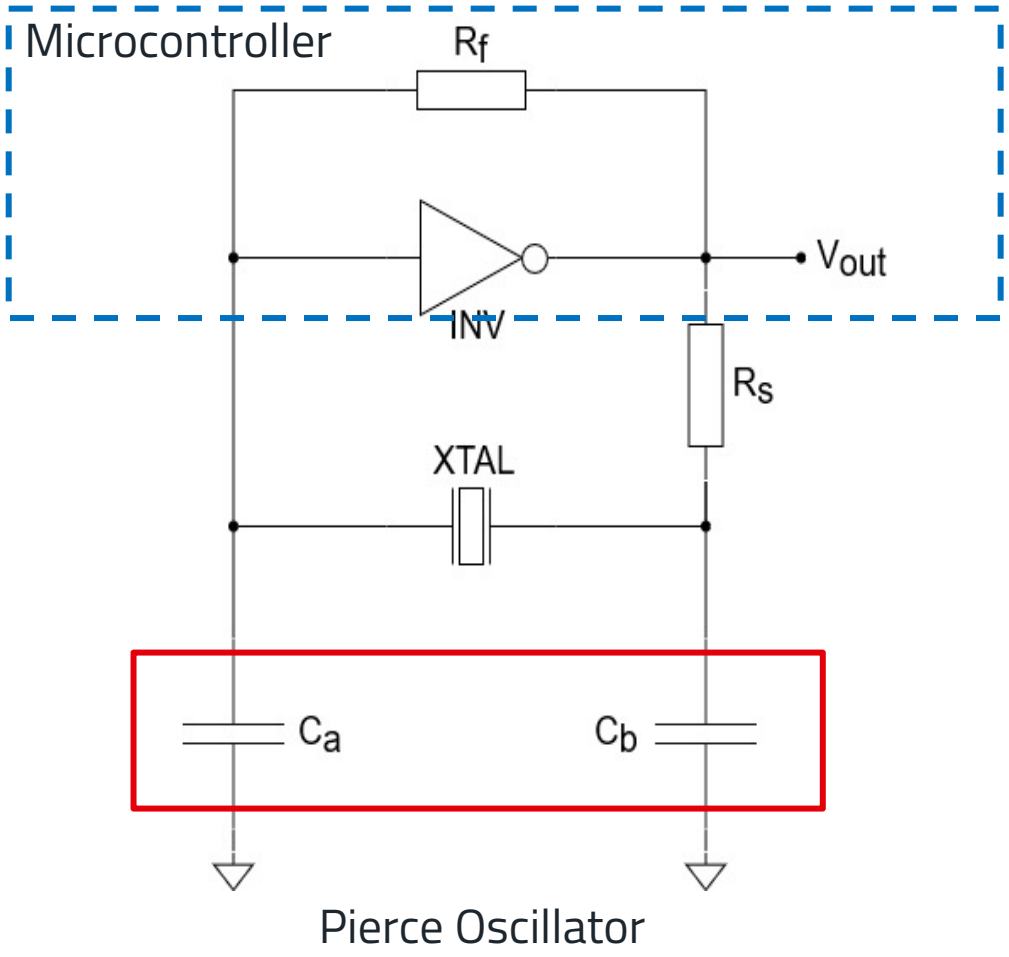
- Frequency
- **Tolerance and Stability**
- Load Capacitance
- Trim sensitivity
- ESR

- Tolerance: maximum frequency deviation at 25 °C in ppm
- Stability: maximum frequency deviation over the operating temperature range in ppm
- Both parameters are not directly influenced by the size of the crystal, but need to considered if the accuracy should be improved

QUARTZ CRYSTALS

What parameters are important to consider while doing a re-design?

- Frequency
- Tolerance and Stability
- **Load Capacitance**
- Trim sensitivity
- ESR



Pierce Oscillator

- To activate a crystal to oscillate, it requires an additional oscillation circuit
- Load capacitance in the circuit = specified load capacitance in the datasheet

Electrical Parameters	
Load Capacitance (CL)	10.00pF

- Formula to calculate the load capacitance in the circuit:

$$C_L = \frac{C_a * C_b}{C_a + C_b} + C_{stray}$$

QUARTZ CRYSTALS

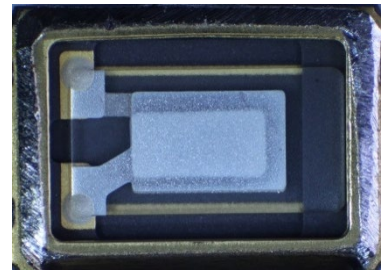
What parameters are important to consider while doing a re-design?

- Frequency
- Tolerance and Stability
- Load Capacitance
- **Trim sensitivity**
- ESR

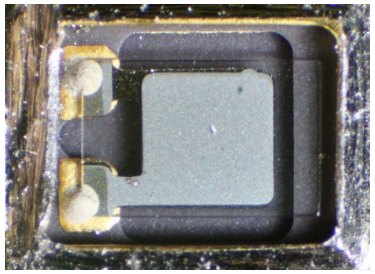
- Trim sensitivity: frequency deviation in ppm if the load capacitance in the circuit changes

$$T_s = \frac{C_1 * 10^6}{2(C_0 + C_L)^2} \quad \text{[ppm/pF]}$$

- The trim sensitivity of a crystal depends on:
  - Size of the blank
  - Size and shape of the electrodes
  - The load capacitance in the circuit
  - Frequency



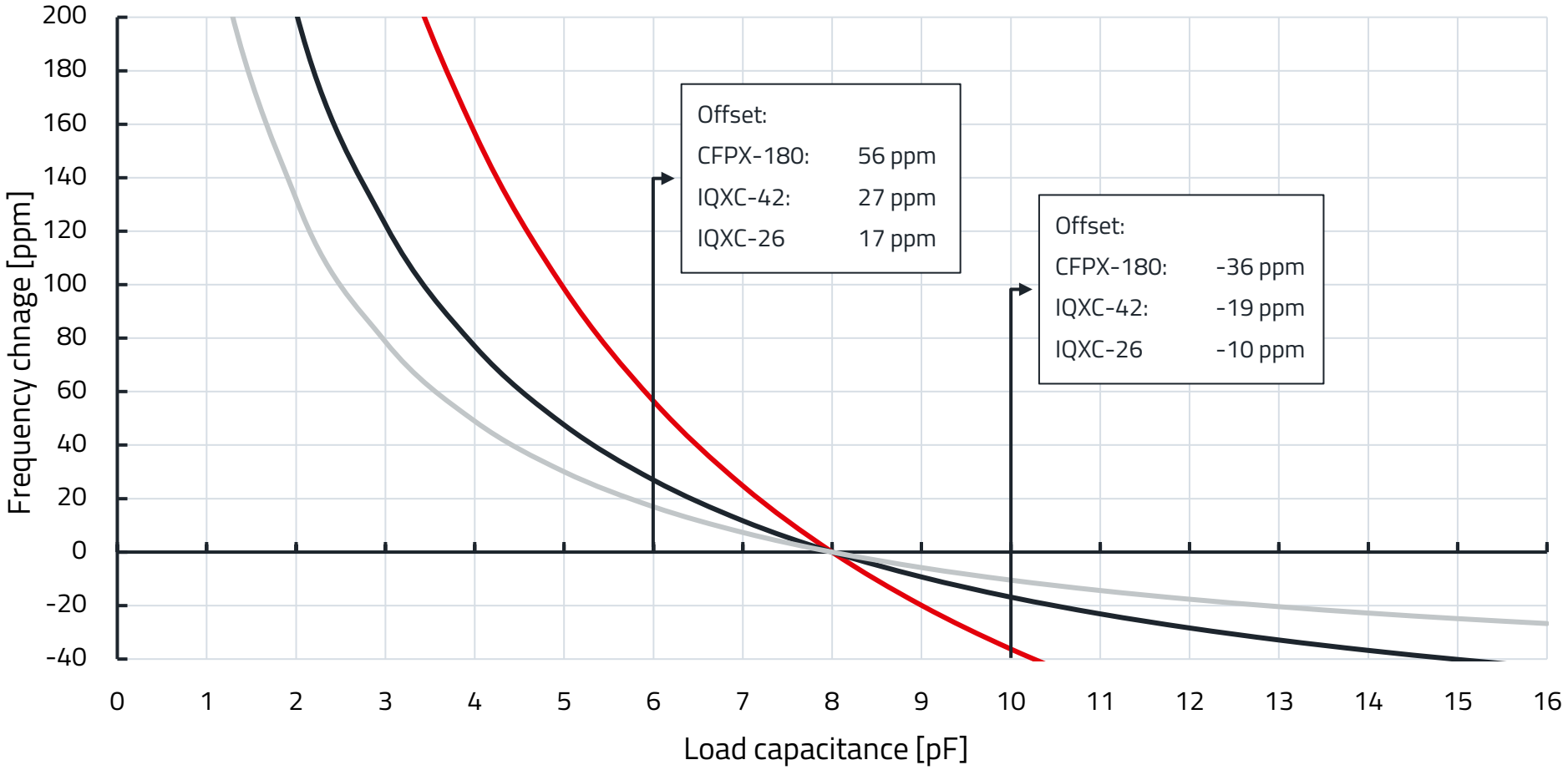
7.0 mm x 5.0 mm

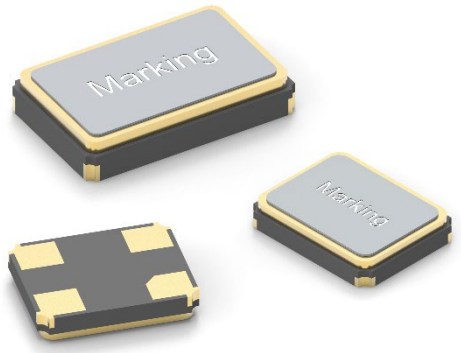


3.2 mm x 2.5 mm

FREQUENCY DEVIATION

CFPX-180 vs. IQXC-42 vs. IQXC-26

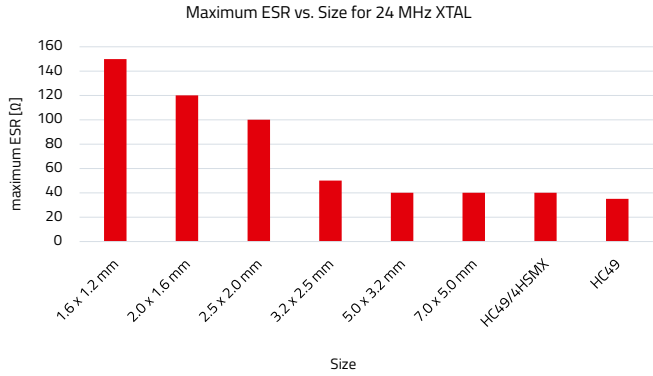




QUARTZ CRYSTALS

What parameters are important to consider while doing a re-design?

- Frequency
- Tolerance and Stability
- Load Capacitance
- Trim sensitivity
- **ESR**
  - Is defined as the maximum resistance of the quartz in Ω at the series resonance frequency
  - An important parameter to be considered when designing the oscillation circuit
  - The smaller crystal the higher the ESR
    - The thickness of the blank stays the same, but the blank and the electrode gets smaller



QUARTZ CRYSTALS

What parameters are important to consider while doing a re-design?

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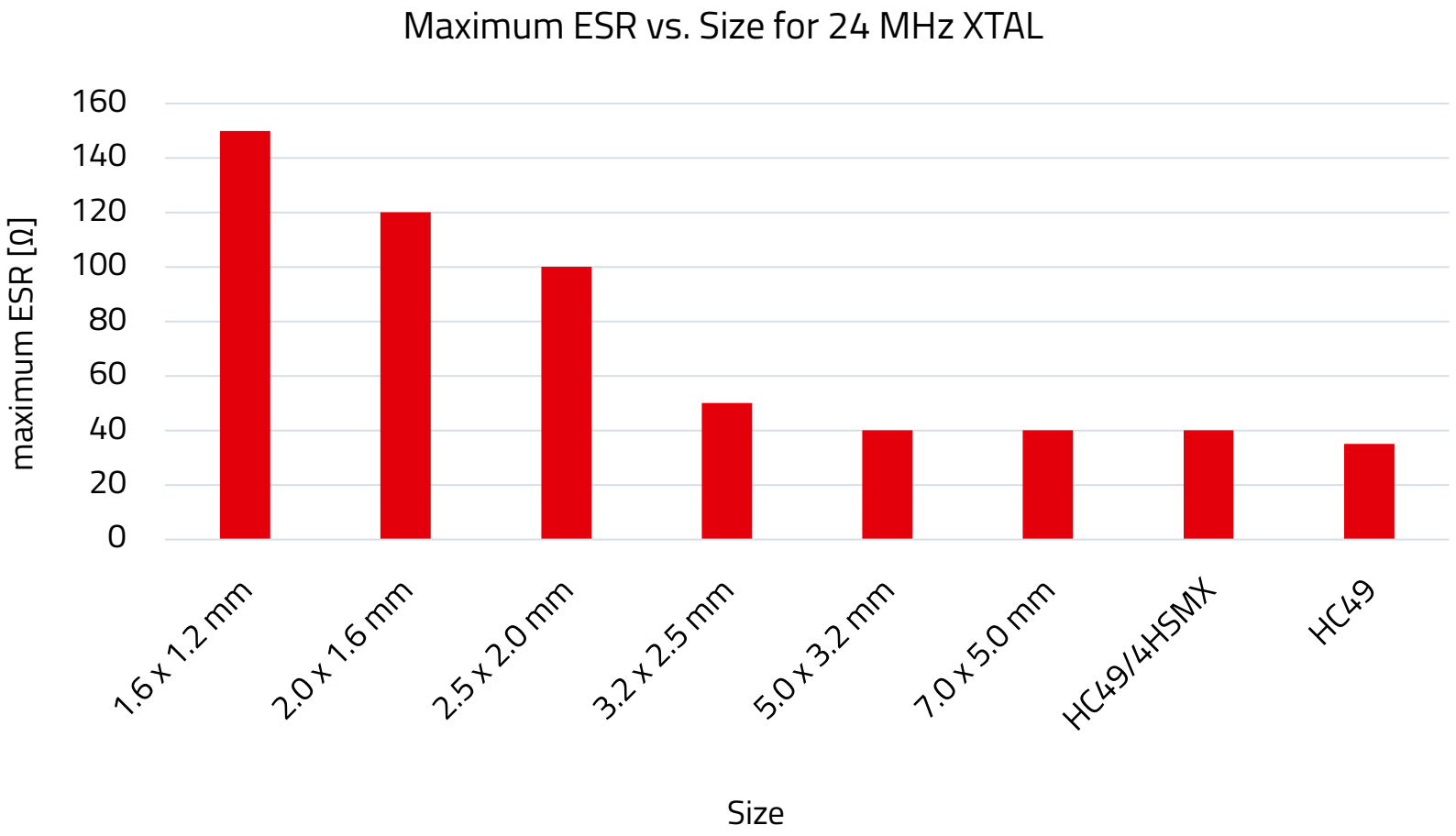
- Load Capacitance
- Trim sensitivity
- **ESR**



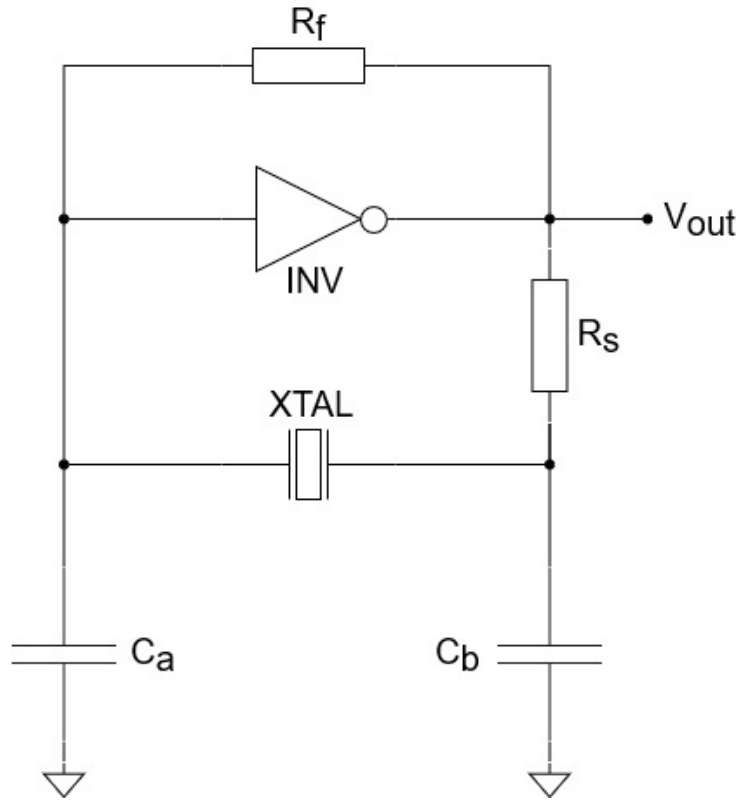
WHY ARE THESE VALUES IMPORTANT?

NEGATIVE RESISTANCE / GAIN

- The gain must be large enough to ensure that the quartz oscillates safely, even over temperature
- The gain is often also called ‘negative resistance’
- Negative Resistance in the circuit under ideal conditional and without considering C_0:

$$-R = -g_m * X_{C_a} * X_{C_b} = \frac{g_m}{\omega^2 C_a C_b}$$

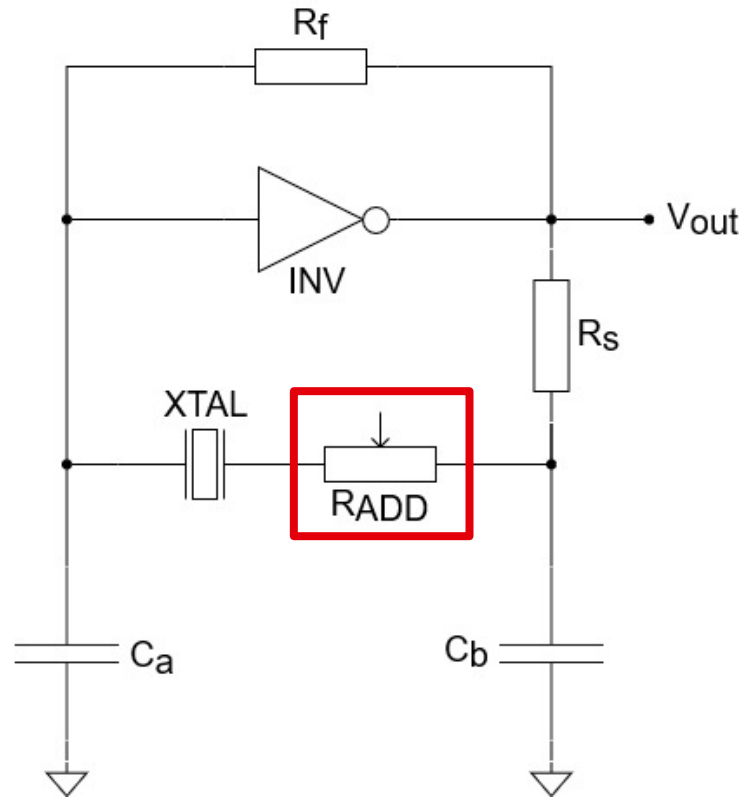
- There are 2 ways to improve the gain in the circuit:
  - g_m(= transconductance of the microcontroller) need to be increased
  - The capacitors C_a and C_b need to be decreased



MEASUREMENT OF THE NEGATIVE RESISTANCE

- The negative resistance can be analysed by connecting a series test resistor R_{ADD} to the quartz crystal
- This resistor is used to find the maximum value $R_{ADD\,max}$ that keeps the circuit oscillating

$$Negative\ resistance\ of\ the\ oscillator = R_{ADDmax} + ESR$$



SAFETY FACTOR SF

- The safety factor is the ratio of the negative resistance of the oscillator and the ESR of the crystal
- This is often also called gain margin or negative resistance ratio
- This is an indicator on how stable the oscillation will be

$$SF = \frac{Negative\ resistance}{ESR} = \frac{R_{ADDmax} + ESR}{ESR}$$

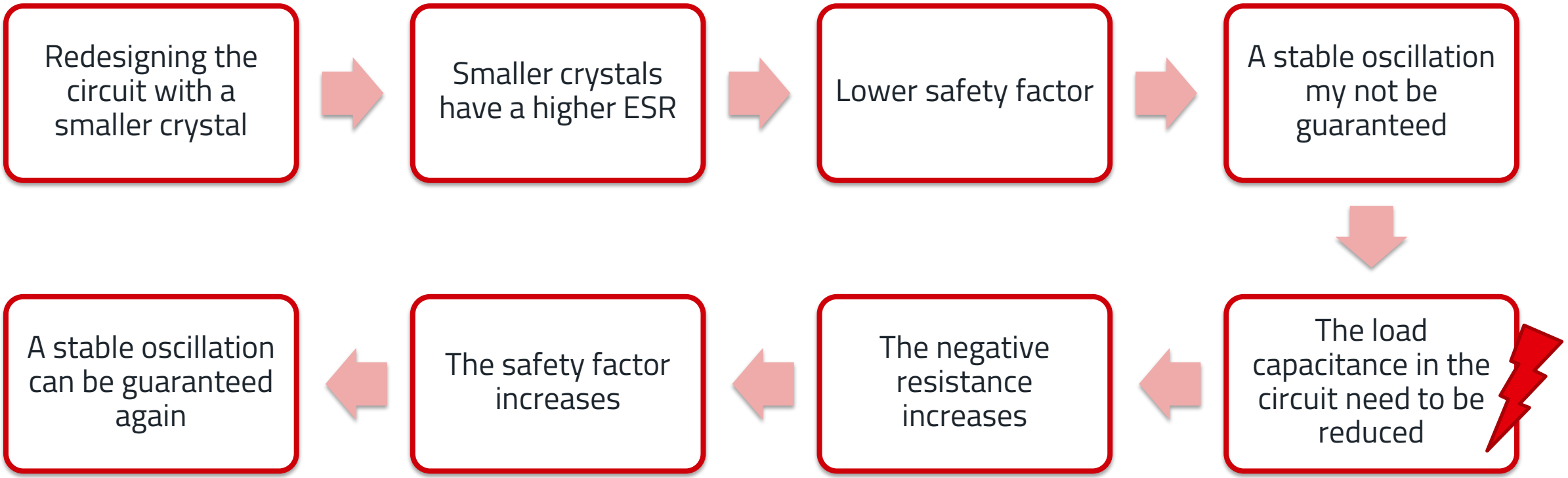
- SF > 3: the crystal will oscillate
- SF ≥ 5 : A stable oscillation can be guaranteed even with variation across the batch or with temperature variations

DRIVE LEVEL

- The drive level is the power necessary to initiate and maintain the oscillation in the quartz crystal
  - If the drive level is too high, the crystal can get damaged
  - If the drive level is too low, the crystal may not start to oscillate
- The maximum drive level specified in datasheets
  - describes the maximum power the crystal can receive without being damaged
  - is not an indicator of the level of drive that can be found in the circuit

→ drive level in the circuit is influenced by the oscillation circuit / IC, the ESR of the crystal and additional resistors

DESIGN IN OF SMALLER CRYSTALS



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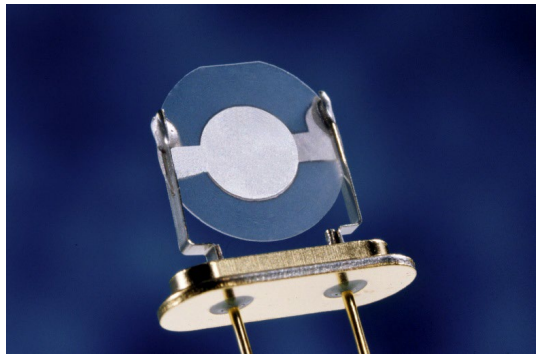
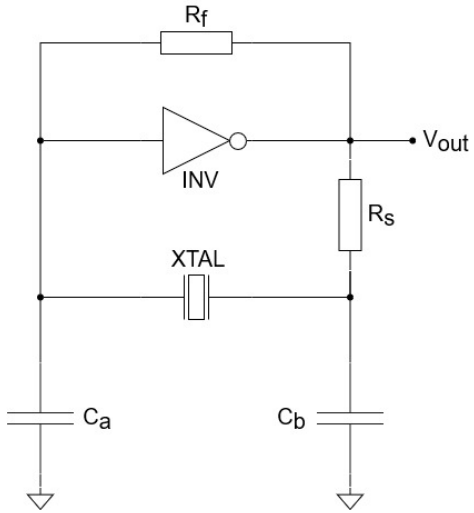
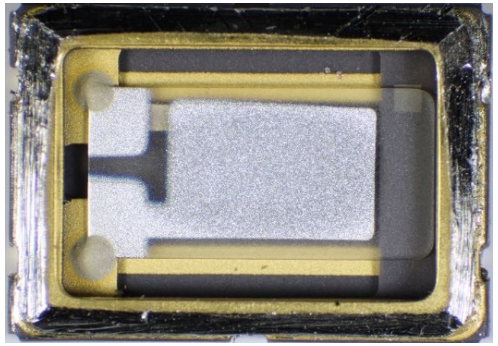
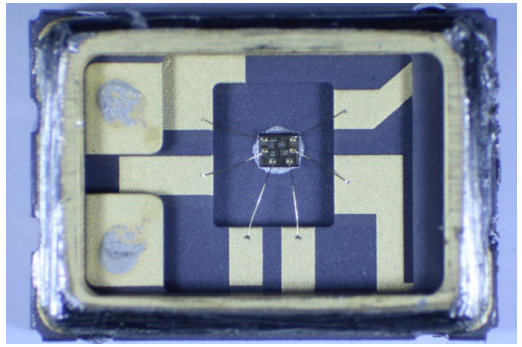




Oscillator (SPXO)

- Quartz crystal together with an IC in one package
- IC contains the additional oscillation circuit
- Customer only needs to apply a supply voltage and receives an output signal at the resonant frequency





OSCILLATORS

What is important to consider while doing a re-design?

Replacing a crystal with an oscillator

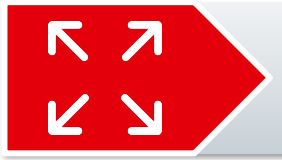
- No additional oscillation circuit is needed
- More flexibility when it comes to available frequencies
- Filters need to be considered to guarantee the signal quality

Reducing the size of the oscillator

- Will not influence the available frequencies
- Will not significantly influence the current draw

RECOMMENDATIONS FOR NEW DESIGNS

Summary



If possible, use XTAL and SPXO in size 3.2 x 2.5 mm or smaller

Avoid 5 V SPXOs

Avoid none-standard sizes like 6.0 x 3.5 mm, 3.2 x 2.5 mm with 2 Pads

Avoid Plastic molded parts

- When re-designing your circuit with a smaller crystal, consider:
  - Frequency
  - ESR and Gain Margin
  - Drive Level