

Function and Operation of the GEYER Y-Design App

Objective:

- Simple circuit design based on the required technical parameters
- Review and optimization of an existing design of a crystal oscillator circuit

1. Function:

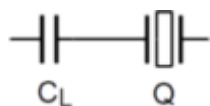
- Simulates the transmission behavior of the Pi network formed by R_v , C_b , Q , C_a , according to gain (amplification), phase at f_L (center) and environment (span).
- Aim: Gain (amplification) at f_L as high as possible.
Phase at f_L as close to -180° as possible.
- Optimization: Search, either manually or using the optimization button, the values for R_v , C_b , C_a , for which the target (see above) is maximized.
- To Note: R_v , C_b , C_a are the effective values.
 - R_v can be fully or partially realized in the controller, e.g. current limitation, slew-rate limitation, $R_{ds(on)}$ of the gates, AGC etc.
 - C_b and C_a are composed of the stray capacitance of the PCB, input capacitance of the controller pins and the capacitance of the mounted capacitors.
- Design support: the Geyer App complements and facilitates your design by allowing you to verify and optimize your circuit.

2. Simulation capabilities:

In the Circuit menu you can choose between "Quartz Crystal" and "Pierce Oscillator".

I. Quartz Crystal - Oscillating crystal with switching capacitance

The display shows the impedance or admittance of an oscillating crystal in series with a (circuit) capacitance and thus acts as an impedance or admittance analyzer. During manufacturing, the crystals are matched with a specified nominal serial capacitance. In the user circuit, this corresponds to the circuit capacitance that the crystal 'sees'.



The crystal load is calculated for $1 V_{rms}$ ($2.8 V_{pp}$) at the oscillating crystal. For other voltages the load value has to be adjusted accordingly.

The main display shows the gain and phase of the impedance or admittance. You can choose an additional display of admittance or impedance with respective real and imaginary part. "Play" with the crystal parameters to learn more about the behavior of the crystals!

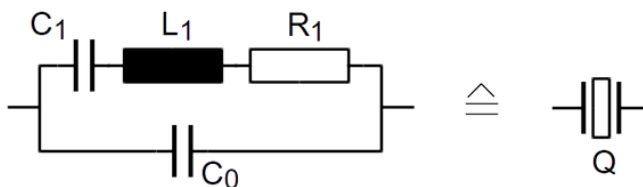
Resonance type

- It is possible to specify a nominal load capacitance. If you choose the same value as for C_L (menu 'Circuit'), you will obtain the load resonant frequency f_{Lnom}

For series resonance oscillating crystals, activate the 'Series resonance' option. The nominal frequency is then obtained with the slider for C_L set to maximum (C_L short-circuit).

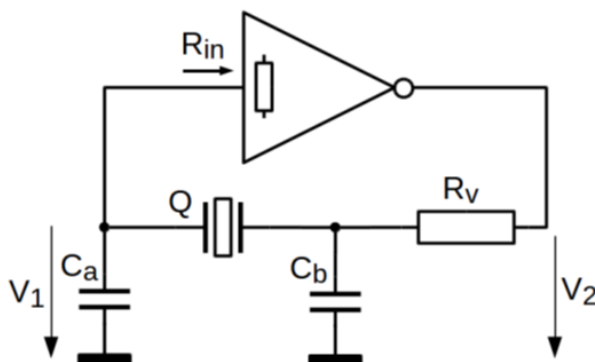
Spurious resonances

- With this option you can simulate an additional spurious resonance of the crystal. When the temperature changes, these 'secondary resonances' can move across the main resonance because of their much larger temperature coefficient. There are three secondary resonance resistors to choose from. The secondary resonance C_1 is always $C_1 / 10$ in the respective simulations.



II. Pierce-Oscillator

The display shows the ratio V_1 / V_2 of a feedback network typical for a Pierce oscillator. Circuit components related to the operating voltage or the operating point are not included in the diagram.



The Pierce circuit requires a quartz crystal with load capacitance if there are no additional inductors in series with the crystal.

The output resistance of the inverter together with the resistor R_v and the PI element $C_a / \text{crystal} / C_b$ form a narrow bandpass with frequency-dependent phase shift. According to the oscillation condition, the total phase must be 360° . The inverter provides slightly more than 180° because of additional semiconductor related propagation delays. Therefore, the external phase shift can be slightly smaller than 180° .

3. Proceeding:

Step 1: Enter the data of the selected quartz crystal and confirm the value by CR (return).

Step 2: Manually change C_a , C_b and R_v such that for small frequency deviation from the nominal value, the gain and phase are maximized.

Instead of the manual change, one can use the optimization button.

Step 3: You can also select the desired crystal size and save or read in your results. You can send us the results by e-mail. We will then deliver the corresponding samples for verification upon request.

Step 4 (mandatory): Verification of the dimensioning on a prototype of the circuit, whether the controller can cope with the proposed circuit, i.e. whether the frequency is correct, the stray capacitances have been correctly recorded, and whether there is sufficient transient margin.

4. Additional Points:

- To check or dimension the values of the capacitors C_a and C_b , one can choose either the classical or the alternative approach for a given C_L :

Classical Approach

(equal capacitors):

$$C_a = C_b = 2x C_L - C_s$$

Alternative Approach

(different value capacitors):

$$C_a \approx 1,1 \sim 1,2x C_L - C_s$$

$$C_b \geq 4x C_L - C_s$$

The alternative approach often brings advantages: Larger oscillation reserve, faster oscillation, lower crystal load.

- There are controllers which require C_a and C_b equally dimensioned. There are controllers whose AGC (automatic gain control) intervenes on the input side of the oscillator amplifier, meaning that even with an appropriately dimensioned PI-network no voltage increase can be obtained.

5. Further design rules: can be found in our [Short Tutorial on Quartz Crystals and Oscillators](#) on our homepage under

<https://www.geyer-electronic.de/en/design-test-center/design-support/#white-papers>