



## Oscillator selection for ST62

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### Introduction

The purpose of this note is to give indications on how to choose a resonator or a quartz crystal in order to achieve reliable oscillation with the ST62 Microcontroller. This document provides first the major resonator parameters useful for a design. It then proposes measurement methods to ensure a safe oscillation.

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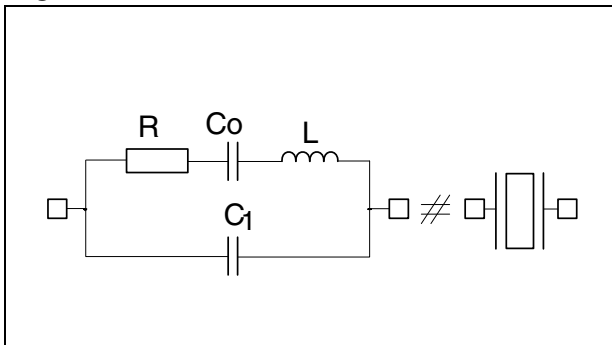
# 1 Oscillation frequency

The resonator can be modelised by a serial/parallel oscillator circuit as described in [Figure 1](#).

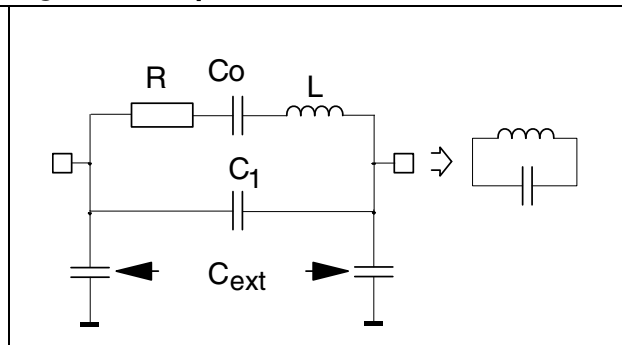
The additional capacitances  $C_{\text{ext}}$  are usually connected to the oscillator pins in order to define a stable oscillating frequency. The value of these capacitances is usually given by the manufacturer of the resonator.

The oscillation frequency is the resonant frequency of the equivalent circuit given in [Figure 2](#). The resonator is inductive in the oscillation frequency range.

**Figure 1. Resonator model**



**Figure 2. Equivalent circuit**



## 2 Oscillation conditions

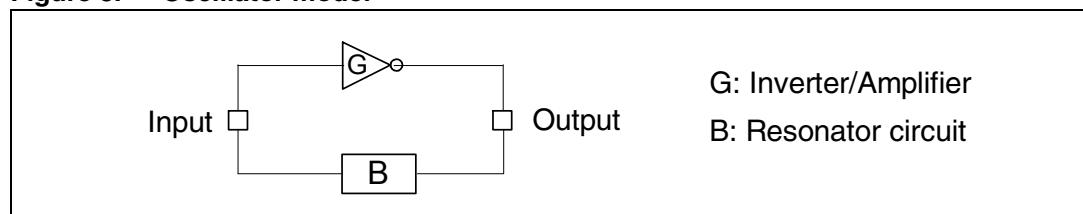
The proposed method is based on the Barkhausen criteria. This leads to a safe result providing that the oscillator fulfills these criteria. Three points have to be analysed: oscillator start-up, frequency stability and the start-up time.

### 2.1 Barkhausen criteria

An oscillator can be modeled as defined in [Figure 3](#). B is the resonator gain and G the amplifier/inverter gain. The value of  $B \times G$  defines the oscillator behaviour:

- $B \times G \gg 1$ : square waveform, start-up OK
- $B \times G > 1$ : waveform with harmonic distortion, start-up OK
- $B \times G = 1$ : sine waveform, start-up critical
- $B \times G < 1$ : no oscillation

**Figure 3. Oscillator model**



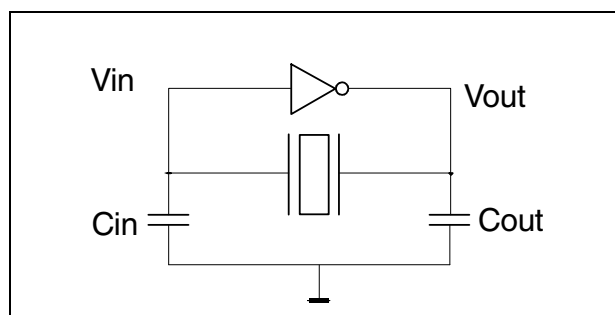
### 2.2 Start-up

The oscillator can start if the gain  $B \times G$  is above 1. The amplifier gain must compensate for the resonator circuit attenuation and provide a sufficient gain margin ( $>3$  dB).

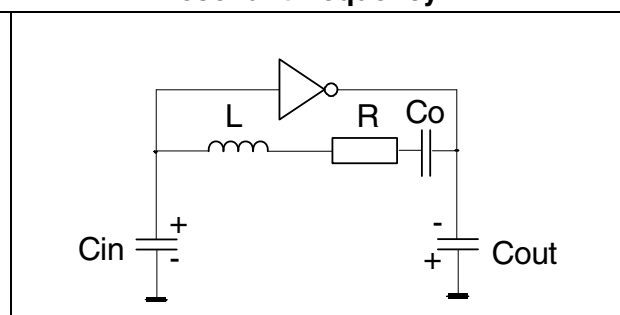
In addition, the resonator circuit B must introduce a  $180^\circ$  phase delay if the G amplifier is an inverter and no rotation if it is a non inverting amplifier.

With classical circuits such as a Pierce type oscillator ([Figure 4](#)), the  $180^\circ$  phase rotation is due to capacitances ( $C_{out}$  and  $C_{in}$ ).

**Figure 4. Pierce type oscillator**



**Figure 5. Equivalent schematic at the resonant frequency**



At the resonance frequency (serial mode), the circuit can be modeled as described in [Figure 5](#). The resonator voltage is balanced between the two capacitances. So the phase of the voltages  $V_{in}$  and  $V_{out}$  is delayed by  $180^\circ$ . Depending on the capacitance values,  $V_{in}$  is either higher ( $C_{out} > C_{in}$ ), smaller ( $C_{out} < C_{in}$ ) or equal to  $V_{out}$ .

The trade offs in the choice of  $C_{in}$  and  $C_{out}$  are:

- $C_{out} = C_{in} : V_{in} = V_{out}$   
This is the typical case and is to be used as often as possible.
- $C_{out} > C_{in} : V_{in} > V_{out}$   
The loop gain is increased but there is a risk that the oscillation occurs at a harmonic of the resonator frequency.
- $C_{out} < C_{in} : V_{in} < V_{out}$   
The output voltage is increased. The risk of oscillation at a harmonic of the resonator frequency is low.  $V_{in}$  must be high enough to satisfy the condition  $B \times G > 1$ .

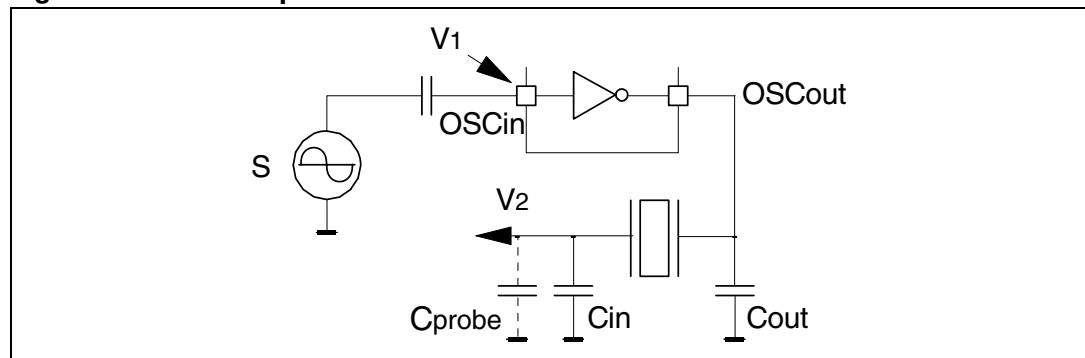
## 2.3 Measurement of the loop gain (open loop)

The measurement is based on the schematic shown in [Figure 6](#). The method is the following:

1. Open the loop as described in [Figure 6](#).
2. Place an oscillator probe on points 1 and 2. Note that the real C value for the calculation is  $C_{probe} + C_{in}$ .
3. Inject a voltage S with a signal generator. This signal must be adjusted in frequency to maximize the voltage  $V_2$ .
4. Adjust S to a value small enough to avoid saturation of the amplifier (around 200 mV on  $V_1$ ).
5. Calculate the ratio  $V_1/V_2$ . This value has to be between +3 and +10 dB (1.5 to 3).

If the ratio is above +3 dB, the oscillator start is safe. If it is below,  $C_{in}$  should be decreased.

**Figure 6. Gain loop measurement schematic**



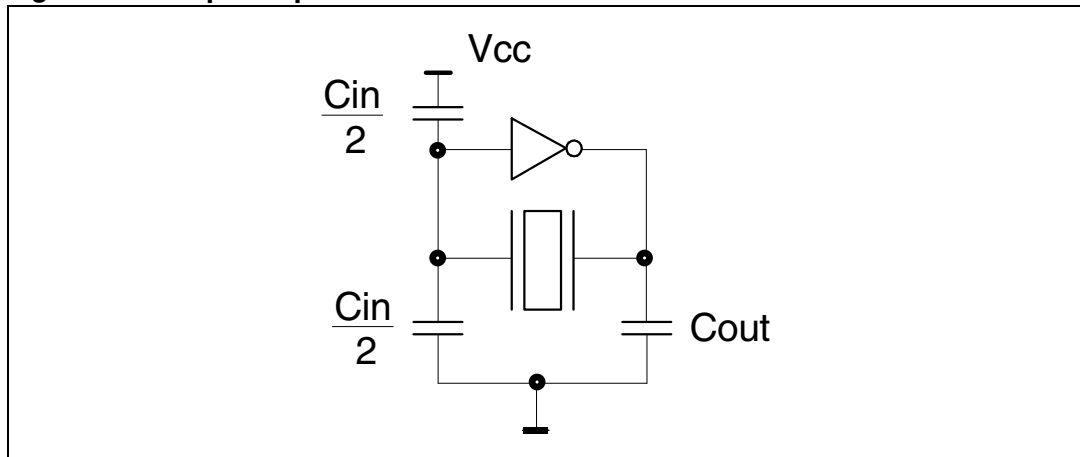
## 2.4 Frequency stability

The stability is first defined by the resonator characteristics. Nevertheless, if the open loop gain exceeds +10 dB, the oscillation could occur on a harmonic of the resonator frequency. In such cases, the value of  $C_{in}$  should be increased to reduce the loop gain or a filter rejecting this harmonic must be added.

## 2.5 Start-up time

The start-up time depends on the amplifier polarisation time and on the circuit transients. The polarisation of the amplifier can be accelerated by dividing the  $C_{in}$  capacitance in two as described in [Figure 7](#).

**Figure 7. Amplifier polarisation acceleration**



The start-up time is also longer when  $C_{in}$  and  $C_{out}$  are increased. As a result, for very low start-up time (i.e. low frequency quartz crystal), these capacitances values should be as small as possible. Generally, the higher the crystal Q factor and lower the crystal frequency, the longer the start-up time.

### 3 Conclusion

This note describes a method to choose oscillator network capacitances adapted to standard resonators and quartz crystals (i.e.  $r_s < 60$  ohms and gain  $> 500$ ). Since several network values can be chosen, the capacitances values should be minimized in order not to affect the resonance frequency and reduce the start-up time.

## Appendix A Test of a CSA Murata crystal resonator with an ST6210xx

### A.1 Choice of the network capacitances

Resonator equivalent values:

$$L = 385 \mu\text{H}$$

$$C_0 = 4.4 \text{ pF}$$

$$C_1 = 36.3 \text{ pF}$$

$$r_s = 8.7 \text{ ohm}$$

$$Q = 1134$$

The oscillation mode is the fundamental mode.

The recommended load capacitances for 4 MHz oscillation frequency are 2x30 pF.

The corresponding oscillation frequency as calculated from the formula given in [Appendix B](#) is 4.03 MHz.

### A.2 Pseudo closed loop measurement

In the worst case ( $T_{\text{ambient}}$  max,  $V_{\text{supply}}$  min) the gain  $V_{\text{out}}/V_{\text{in}}$  is 4.8. So the safety margin is +13.6 dB.

### A.3 Start-up time

The start-up time is measured in closed loop. In the worst conditions ( $T_{\text{ambient}}$  max,  $V_{\text{supply}}$  min), it is less than 1 ms.

### A.4 Conclusion

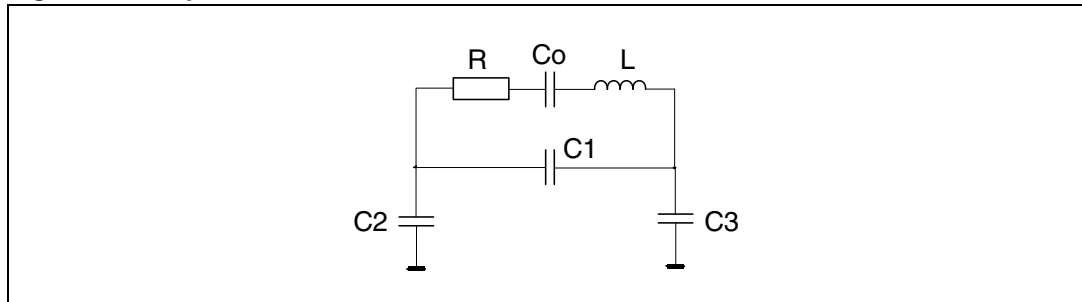
The selected ceramic resonator matches with the ST6210 oscillator.



## Appendix B Calculation of the resonant frequency of ceramic resonator

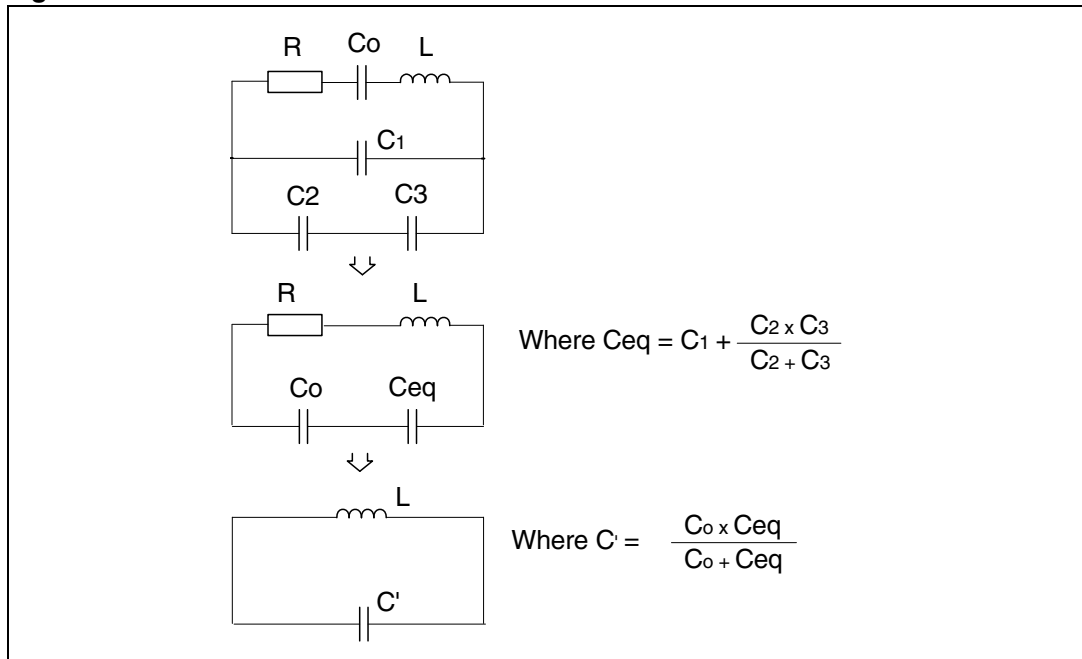
### B.1 Equivalent circuit at the resonance frequency

Figure 8. Equivalent circuit



### B.2 Transformation for simple calculation

Figure 9. Transformed circuit



### B.3 Resonant frequency

$$f = \frac{1}{2\pi\sqrt{L \times C'}}$$

## B.4 Note

When using a ceramic resonator, the oscillation frequency is usually between the parallel and the series resonances. So both  $C_1$  and  $C_0$  have to be included in the calculation.

The resonance frequency of a crystal resonator is very near to the series frequency. So only  $C_0$  has to be used for the frequency calculation.

## 4 Revision history

**Table 1. Document revision history**

Date	Revision	Changes
February-1994	1	Initial release.
03-Oct-2008	2	Format changed. Title of <a href="#">Appendix A</a> modified (ST6210xx instead of ST6210). Logo and disclaimer updated.

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