Selecting an External Crystal

TI Precision Labs – Microcontrollers

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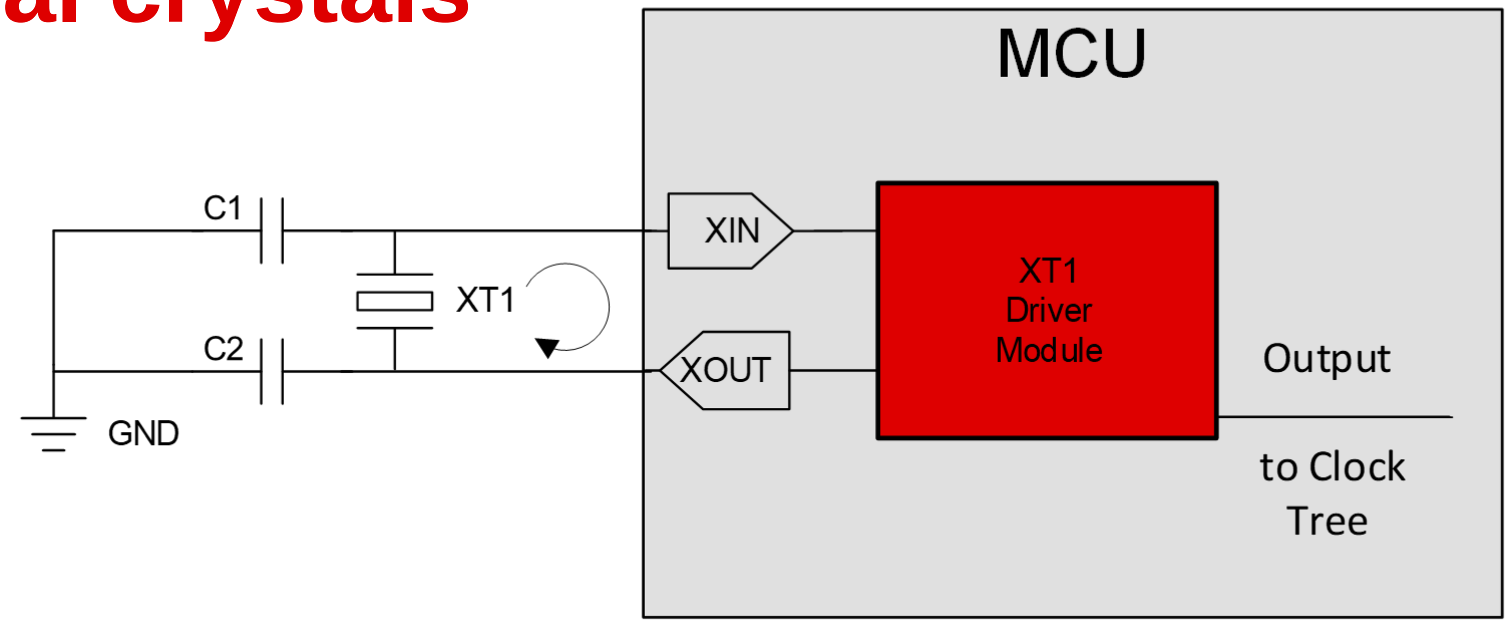
External crystals



- More accurate with less drift over operating conditions
- Lower power consumption than internal sources
- Long startup time
- Frequency is set by source
- Added system cost
- Needs special board layout considerations to operate properly

External crystal accuracy

Internal Oscillator Specification

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
I_{REFO}	REFO oscillator current consumption	T_A = 25°C	1.8 V to 3.6 V		3		µA
f_{REFO}	REFO frequency calibrated	Measured at ACLK	1.8 V to 3.6 V		32768		Hz
	REFO absolute tolerance calibrated	Full temperature range	1.8 V to 3.6 V			±3.5%	
		T_A = 25°C	3 V			±1.5%	

$$F_{RANGE} = 32768\ Hz\ \pm 491.52\ Hz$$

External Oscillator Specification

Parameters	Min	TYP	MAX	Units
Frequency Tolerance @ +25°C	-10		+10	ppm

Note: $1\ ppm = 0.0001\%$

$$F_{RANGE} = 32768Hz\ \pm 0.33Hz$$

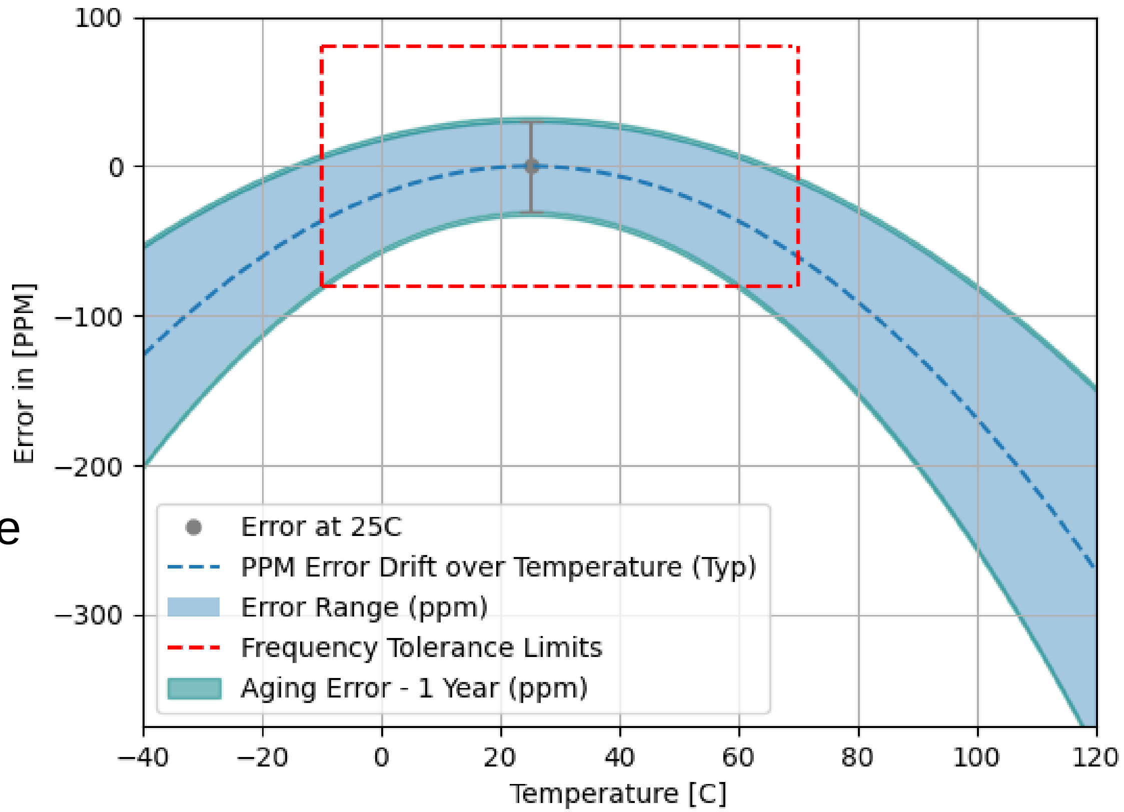
$$Error_{RTC} = \frac{24hr}{day} * \frac{60_m}{hour} * \frac{60s}{m} * \mathrm{Error_{CLK}}$$

$$Error_{RTC} = 86400\frac{s}{day} * \frac{1.5}{100} \cong \mathbf{21.5}\frac{\mathbf{minutes}}{\mathbf{day}}$$

$$Error_{RTC} = 86400\frac{s}{day} * \frac{10}{10^6} = \mathbf{0.864}\frac{\mathbf{seconds}}{\mathbf{day}}$$

Accuracy stability and drift

Parameters	Conditions	Min	TYP	MAX	Units
Frequency		3.57		70.000	MHz
Frequency Tolerance	25°C			±30	ppm
Temperature Coefficient		-0.04	-0.03	-0.02	ppm/T^2



Temperature [C]

Frequency Tolerance is sometimes given a temperature range

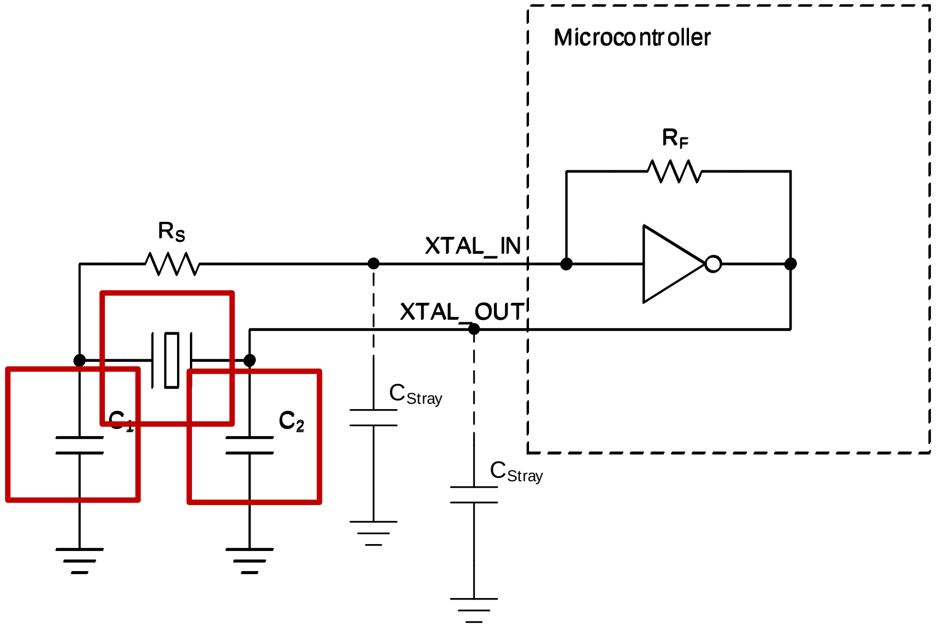
Parameters	Conditions	Min	TYP	MAX	Units
Frequency Tolerance	25°C			±30	ppm
	-10 ~ + 70 °C			±80	

Crystals also drift over time, the rate at which they drift is often given as “**Aging**”

Parameter	MAX	Units
Aging	±3	ppm/year

Load capacitance

Parameters	MIN	TYP	MAX	Units
Load Capacitance (C_L)		12		pF



In the Ideal Case: $C_L = \frac{C_1 * C_2}{C_1 + C_2}$

Really: $C_L = \frac{C_1' * C_2'}{C_1' + C_2'}$ **Where:** $C_x' = C_x + C_{Stray}$

In most cases, we choose $C_1 = C_2$: **So:** $C_L = \frac{C_1 + C_{Stray}}{2}$

For this example:

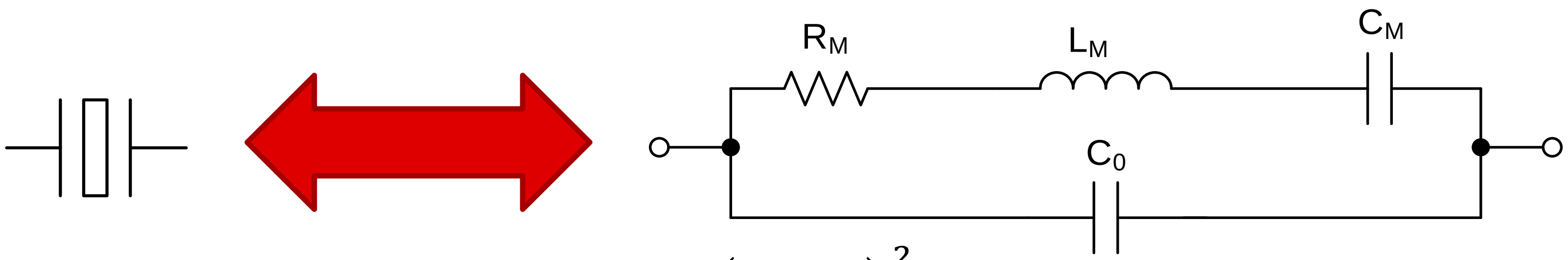
$\mathbf{C_1 = C_2 = 22_{pF}}$ if $C_{stray} = 2pF$

We can check if this is right:

$$C_L = \frac{C_1 + C_{Stray}}{2} = \frac{22pF + 2pF}{2}$$

$$\boldsymbol{C_L = 12pF}$$

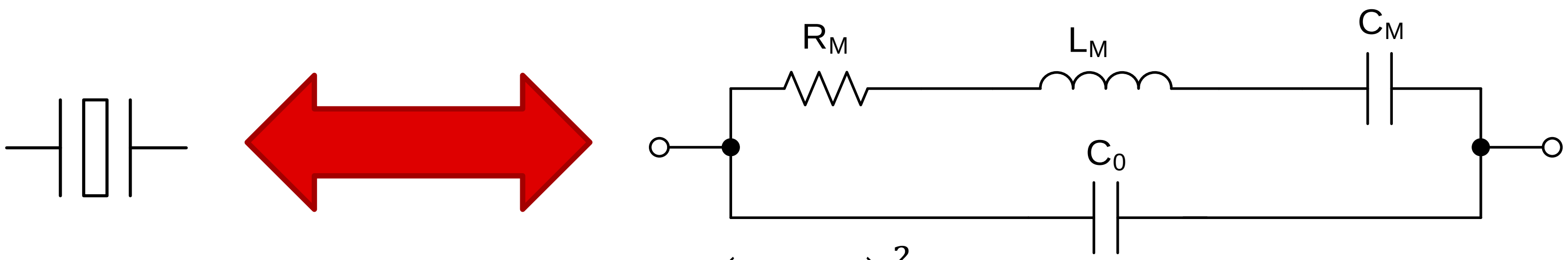
Equivalent series resistance



$$ESR = R_M * \left(1 + \frac{C_0}{C_L}\right)^2$$

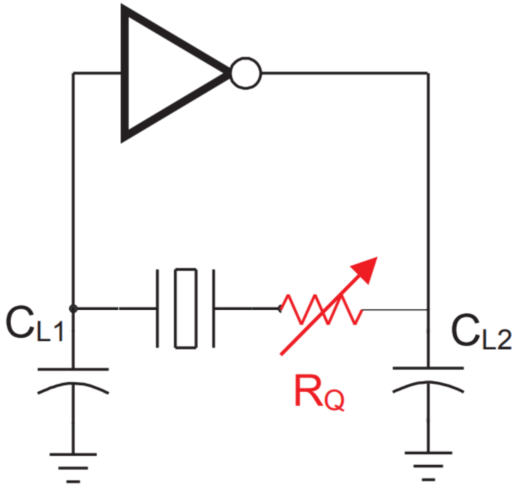
Design Parameter	Higher ESR Crystal	Lower ESR Crystal
Safety Factor	− Worse	+ Better
Startup Time	− Worse	+ Better
Power Dissipation	− Worse	+ Better
Peak Drive Level	− Worse	+ Better
Cost	+ Better	− Worse
PCB Footprint	+ Better	− Worse

Equivalent series resistance



$$ESR = R_M * \left(1 + \frac{C_0}{C_L}\right)^2$$

How do you know how high of an ESR Value is too high?



Oscillation Allowance (OA) OR Negative Resistance = Test Crystal ESR + R_Q

$$\text{Safety Factor (SF)} = \frac{\text{OA}}{\text{ESR}}$$

Safety Factor	Qualification
SF < 2	Unsafe
2 ≤ SF < 3	Suitable
3 ≤ SF < 5	Safe
SF ≥ 5	Very Safe

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