# Approved Crystals for NanoBeacon SoC IN100

Control number:
Revision: V1.2

# Contents

# 1. Summary

This document describes some strategies for developers to properly select and configure 26MHz crystals when developing InPlay NanoBeacon SoC IN100-based systems, explains which crystal parameters affect the system, and provides a list of several verified recommended reference crystal manufacturers and their part numbers.

Three parameters are critical to the stable operation of the IN100 based system. Figure 1 shows the IN100 default settings for the 26MHz crystal.

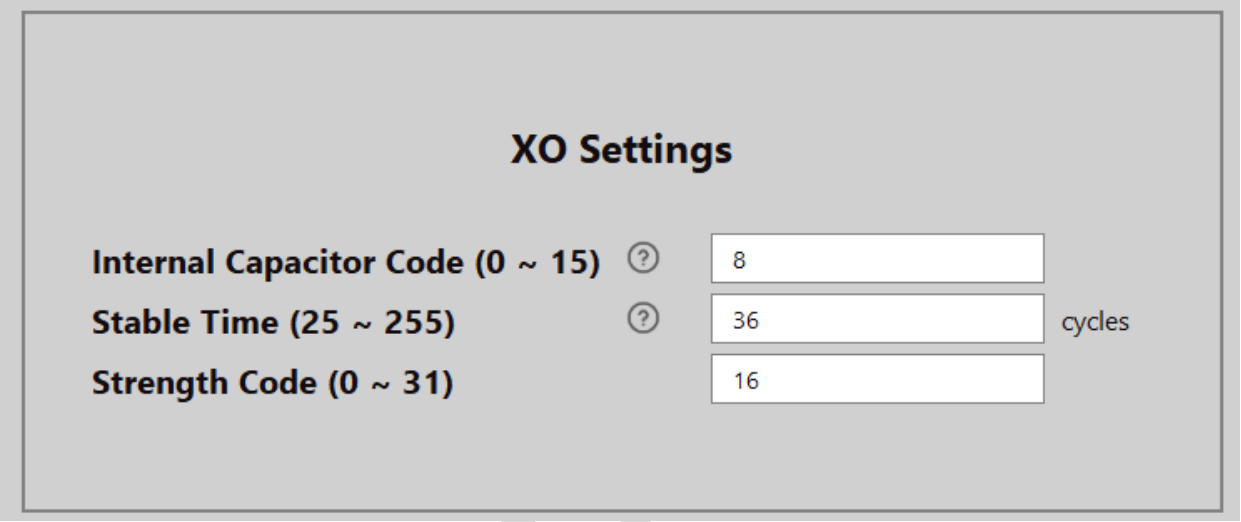


Figure 1: NanoBeacon Config Tool for Crystal Setting

**Internal Capacitor Code**: It is used for frequency bias calibration. Adjusting this value is the process of adjusting the frequency of the crystal oscillator to match to an exact reference frequency. The accuracy of the crystal oscillator depends on the accuracy of the crystal resonator itself and the temperature stability of the oscillator circuit. Note: Adjusting the capacitance value of the on-chip crystal oscillator will affect the start-up time and drive strength.

**Stable Time**: Crystal stabilization time is the time required for a crystal oscillator to reach its stable operating frequency after power is applied. A long stabilization time will result in longer system start-up time and will consume more power, while a short stabilization time will reduce the reliability of the system and cause the chip to fail to start. The stabilization time of a crystal oscillator is affected by various factors, such as the drive strength (the amount of current applied to the crystal), the type and size of the crystal, and the oscillator circuit design. Optimizing the crystal start-up time requires a careful balance between drive strength, crystal specifications, and oscillator circuit design.

**Strength Code**: The drive strength is the amount of current applied to the crystal to drive it to oscillate at its resonant frequency. A higher drive strength reduces the crystal's stabilization time, but it also increases power consumption and may damage the crystal. The optimal drive strength of a crystal oscillator depends on various factors, such as the type and size of the crystal, and the operating conditions.

This document applies to the following products:

Table 1 : IN100 Product list

| Applicable products | Product status |
|---|---|
| IN100-D1-R-RC1I | Mass production |
| IN100-D1-R-YC1I | Mass production |
| IN100-Q1-R-RC1I | Mass production |
| IN100-Q1-R-YC1I | Mass production |
| IN100-Q1-R-YC1F | Mass production |
| IN100-W10-R-SC1I | Mass production |

# 2. Approved 26MHz Crystal

For all approved crystals, no external load caps are required. Frequency calibration only requires trimming the internal cap code of IN100. **Do not install C4 and C5** when using approved crystals.

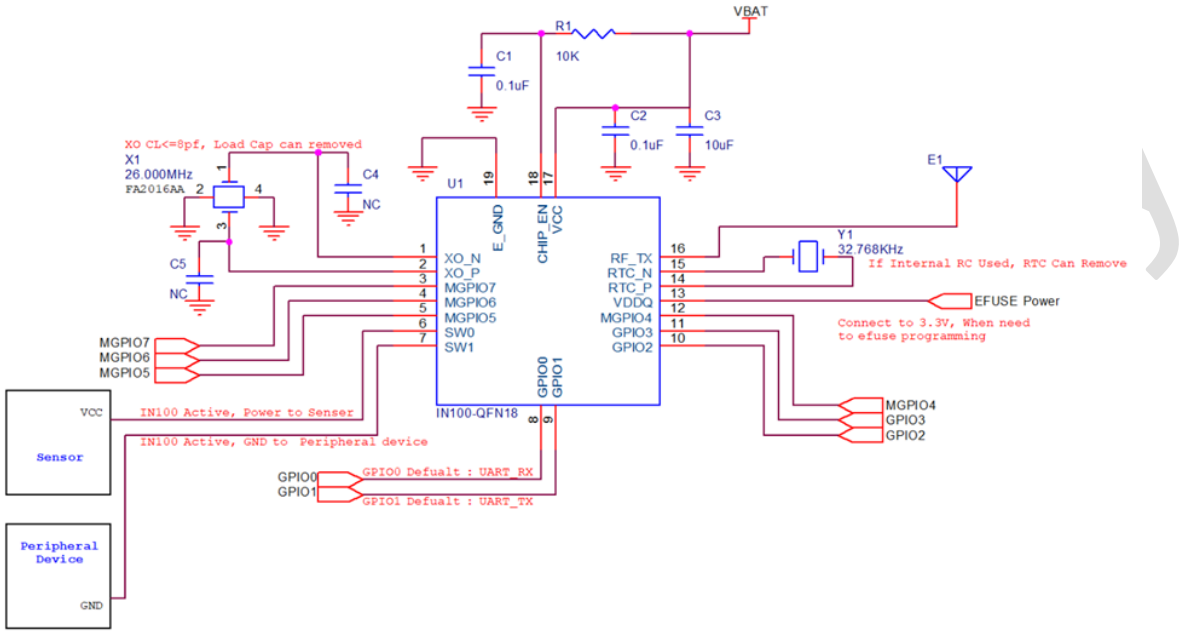


Figure 2: IN100 QFN18 reference design

The following is the list of approved crystals:

Table 2: Approved 26MHz crystals.

| No | Part number | Vender | Package Size | CL | C0 | ESR | Temp Range |
|---|---|---|---|---|---|---|---|
| 1 | CN4026M00006BE840000 | JWT | 2.0 x 1.6 x 0.5 mm | 6pF | ≤2pF | ≤40ohm | -40°C ~ +125°C |
| 2 | CN4026M000067A840000 | JWT | 2.0 x 1.6 x 0.5 mm | 6pF | ≤2pF | ≤40ohm | -40°C ~ +85°C |
| 3 | XRCGE26M000FXA2AR0 | Murata | 2.0 x 1.6 x 0.65 mm | 8pF | ≤3pF | ≤60ohm | -40°C ~ +125°C |
| 4 | XRCGB26M000F1SBLR0 | Murata | 2.0 x 1.6 x 0.7 mm | 7pF | ≤3pF | ≤40ohm | -40°C ~ +105°C |
| 5 | ABM12L-0000-T3 | Abracon | 1.6 x 1.2 x 0.33 mm | 8pF | ≤2pF | ≤80ohm | -40°C ~ +85°C |
| 6 | ABM11W-0018-T3 | Abracon | 2.0 x 1.6 x 0.5 mm | 8pF | ≤2pF | ≤80ohm | -40°C ~ +85°C |
| 7 | LFXTAL081614Reel | IDQ/Wurth | 1.6 x 1.2 x 0.35 mm | 8pF | ≤7pF | ≤70ohm | -40°C ~ +85°C |
| 8 | LFXTAL082126RL3K | IDQ/Wurth | 1.6 x 2.0 x 0.5 mm | 8pF | ≤7pF | ≤25ohm | -40°C ~ +85°C |

For more test result, please refer appendix A and B.

Note:

1* All test setups are at room temperature using IN100. 3.3V supply voltage is used.

2* Default settings are used for XO setting of stabilization time and drive intensity code.

3* Frequency is calibrated by the IN100's internal cap code

The following is the list of approved crystals XO setting for IN100. User needs to adjust according to the actual hardware situation.

Performance below was measured at the following condition with IN100 DK board: Ta = 25°C, VCC = 3.0V, unless otherwise noted.

Table 3: Approved 26MHz Crystal Setting on IN100DK

| No | Part number | Vender | IN100 Capacitor Code | Stable Time | Strength Code |
|---|---|---|---|---|---|
| 1 | CN4026M00006BE840000 | JWT | 5 | 36 | 16 |
| 2 | CN4026M000067A840000 | JWT | 5 | 36 | 16 |
| 3 | XRCGE26M000FXA2AR0 | Murata | 10 | 36 | 25 |
| 4 | XRCGB26M000F1SBLR0 | Murata | 7 | 36 | 16 |
| 5 | ABM12L-0000-T3 | Abracon | 11 | 45 | 16 |
| 6 | ABM11W-0018-T3 | Abracon | 11 | 45 | 16 |
| 7 | LFXTAL081614Reel | IQD/Wurth | 11 | 36 | 20 |
| 8 | LFXTAL082126RL3K | IQD/Wurth | 10 | 36 | 18 |

# 3. Vendor Contact information

- **JWT**

  **Company:** HEFEI JINGWEITE ELECTRONICS CO.,LTD.
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  **Telephone:** +86 0551-63350130,63350092
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  **Mobile:** +86-156 5656 9669
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  **Telephone:** +1 (512)371-6159
  **Fax:** (512) 351-8858
- **IQD/Wurth**
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  **Address:** Station Rd, Crewkerne TA18 8AR, United Kingdom
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# 4. Revision History

| Revision | Description | Update date | Owner |
|---|---|---|---|
| V1.0 | Preliminary Version | 9/1/2023 | Liang X. |
| V1.1 | Preliminary Version | 9/18/2023 | Aidan M. |
| V1.2 | Updated to include latest approved xtals | 10/20/2023 | Aidan M. |
| V1.3 | Updated for latest approved xtals | 4/20/2024 | Aidan M. |
| | | | |
| | | | |

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# 6. Appendix A

JWT CN4026M00006T2998001 test results as follows:

**频率测试（Measure the FREQ. of crystal on PCB board）：**

**初始测试（Original）**

1、在PCB上测试输出频率（Measure the output frequency on PCB board）Fout1：

输出频率(Fout1) = 25.999908 MHz， -3.54 ppm

2、晶振性能测试（室温） Crystal characteristic test（at room tei 26℃

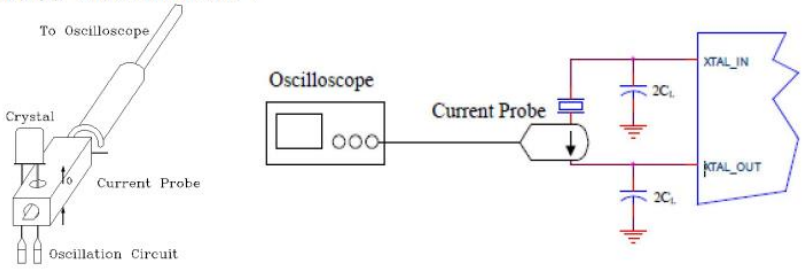
Specification(CL1) = 6 pF

| FL1 (MHz) | FL1 (ppm) | Rs (ohm) | C0 (pF) | C1 (fF) | Ts (ppm/pF) |
|---|---|---|---|---|---|
| 26.000034 | 1.29 | 18.53 | 0.65 | 1.67 | 18.9 |

3、△F = | Fout1 - FL1 | = -4.83 ppm

**驱动功率测试（Measure the drive level of crystal on PCB board）：**

1、测试线路（Measured Circuit）：




2、测试方法（Measured Method）：

使用电流探头进行Vrms测量(Tek CT-1, 50Ω)

Use AC current probe to conduct Vrms measuring (Tek CT-1, 50 ohms terminated)

Irms = Vrms/5(mA)

3、计算方法（Calculation Method）：

Irms = 0.63 mA

RL = Rs (1+ C0/ CL)$^2$

= 18.53 *(1+ ( 0.65 / 6 ))$^2$ = 22.76 ohms

Drive Level = Irms2 * RL

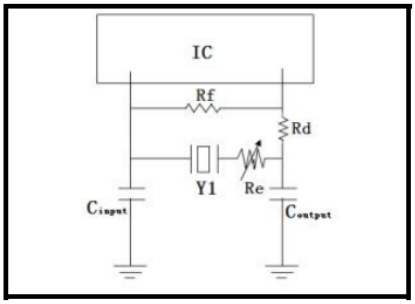
= 0.63 $^2$* 22.76 = 9.09 μW Data sheet Max Leve 200 μW

Drive Level ≤ Data sheet Max Level Good

Drive Level ≥ Data sheet Max Level Not matching

**振荡电路负阻测试（Measure the negative resistance (- R) value of chip set）：**

1、测试线路（Measured Circuit）：




2、计算方法（Calculation Method）：

| -R | = Re + RL = 270 + 22.76 = 292.76 ohms

n = | -R | / R = 292.76 / 40 = 7.32

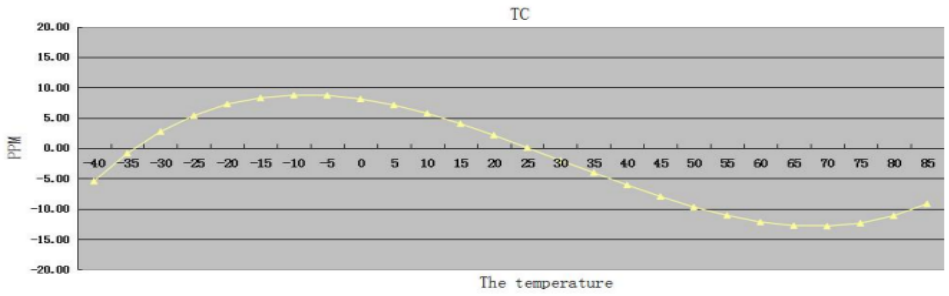
| n: |
|---|
| Poor –R value: n < 3 |
| Normal –R value: 3 < n < 5 |
| Good –R value: n > 5 |

| |
|---|
| **RL：** 负载电阻（Load Resistance） |
| **R：** 等效电阻（ESR） |
| **Re：** 可调电阻（Variable Resistor） |

## Measured oscillation characteristics

| Parameter | Measured Typical Results |
|---|---|
| **Work the amplitude** | 558 [mv] |
| **Maximum operating amplitude** | 520 [mv] |
| **Minimum operating amplitude** | 620 [mv] |
| **Drive level** | 6.32 [uW] |
| **The actual load capacitance** | 6.0 [pF] |
| **Temperature frequency drift** | See chart below |
| **Crystal start time** | 0.408 [ms] |

## Measured frequency drift by temperature



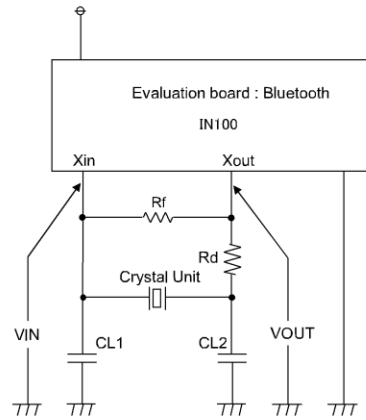
# 7. Appendix B

Murata XRCGB26M000F1SBLR0 test results as follows:

| Item | | | | Condition |
|---|---|---|---|---|
| IC name | | IC名 | | IN100 |
| Parts Number of Crystal Unit | | 村田型号 | | XRCGB26M000F1SBLR0 |
| Circuit Parameter | External load capacitance | 负载电容 | CL1 | Open |
| | | 负载电容 | CL2 | Open |
| | Feedback resistance | 反馈电阻 | Rf | No mount |
| | Damping resistance | 阻尼电阻 | Rd | 0ohm |
| Supply Voltage Range | | 电源电压范围 | | 1.6 to 3.6V |
| Temp. Range | | 温度范围 | | -40 to 105deg.C |

Test Circuit

Set : 3.3 V




Murata standard Measurement equipment

| | |
|---|---|
| Oscilloscope | DSO6052(K) |
| Current probe | CT-6(T) |
| Passive probe | P5100A(T) (40Mohm/2.5pF) |
| DC supply | E3631A(K) |
| Spectrum analyzer | N9010A(K) |

(K) Keysight
(T) Tektronix

| Circuit Characteristics<br>特性 | Value<br>测定值 | | | Remarks<br>备注 |
|---|---|---|---|---|
| **Center Frequency and Difference**<br>**起振回路上起振频率与偏差量 (*1)**<br>(Typical sample at Set=3.3V,+25deg.C) | 25.999905 | | [MHz] | Oscillating frequency and its shift against nominal frequency<br>在起振回路上的频率以及相对于公称频率之间的偏差量 |
| | -4 | | [ppm] | |
| **Load Capacitance on your PCB**<br>**负载容量值**<br>(Typical sample at Set=3.3V,+25deg.C) | 7.3 | | [pF] | This value shows load capacitance the evaluated circuit has<br>在起振回路上等价于连接在谐振器两端的容量 |
| **Negative Resistance and Oscillation margin**<br>**负性电阻/起振余裕度**<br>(at Set=3.3V,+25deg.C) | \|-R\| | 317 | [Ω] | The details is explained in page 2<br>详细内容参见下页说明 |
| | Ratio | 5.3 | [Times] | |
| **Drive Level**<br>**激励功率**<br>(Typical sample at Set=3.3V,+25deg.C) | 11 | | [uW] | Drive power of crystal under circuit condition<br>起振回路在工作状态下谐振器消耗的功率 |
| **Oscillating Voltage**<br>**起振电压**<br>(Typical sample at Set=3.3V,+25deg.C) | VINp-p | 0.5 | [V] | Swing level at input side<br>输入端起振振幅 (VIN_H - VIN_L) |
| | VOUTp-p | 0.5 | [V] | Swing level at output side<br>输出端起振振幅 (VOUT_H - VOUT_L) |
| **Oscillation Start up Time**<br>**启动时间 (*2)**<br>(Typical sample at Set=3.3V,+25deg.C) | 0.54 | | [ms] | Time to reach 90% of the oscillation level under steady state<br>达到稳定状态振幅的90%所需要时间 |

*1 Frequency difference means the oscillating frequency difference between your PCB and Murata's frequency sorting circuit.
频率偏差指在贵公司基板上的测定频率与本公司标准回路上测定频率间的偏差。
*2 The measurement results is affected by the rise-up characteristics of supplied voltage on your PCB.
测定结果受实装基板上电源启动方式的影响。

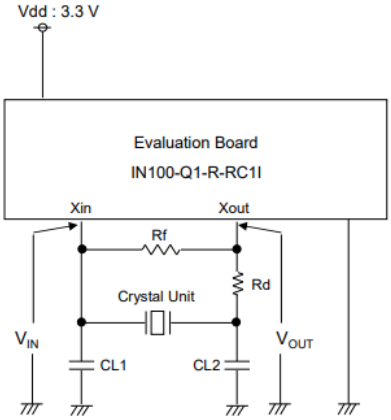
Murata XRCGE26M000FXA2AR0 test results as follows:

| | | |
|---|---|---|
| IC name | IC名 | IN100-Q1-R-RC1I |
| Parts Number | 品番 | XRCGE26M000FXA2AR0 |
| IC's setting value | Internal Capacitance Code | 10 |
| | Stable Time | 36 |
| | Strenght Code | 25 |
| CL1[pF] | 負荷容量 | Open |
| CL2 [pF] | 負荷容量 | Open |
| Rf [ohm] | 帰還抵抗 | No mount |
| Rd [ohm] | 制限抵抗 | Short |
| Supply Voltage Range[V] | 電源電圧範囲 | 3.3 V |
| Temp. Range [deg.C] | 温度範囲 | -40 to +125deg.C |

Murata standard Measurement equipment

| | |
|---|---|
| Oscilloscope | DSO6052(K) |
| Current probe | CT-6(T) |
| Passive probe | P5100A(T) (40Mohm/2.5pF) |
| DC supply | E3631A(K) |
| Spectrum analyzer | N9010A(K) |

(K) Keysight
(T) Tektronix




Xin : 2
Xout: 1

| Characteristics 特性 | | Value 測定値 | | | Criterion 基準 | Notes 備考 |
|---|---|---|---|---|---|---|
| **Oscillating Voltage 発振電圧** (Vdd=3.3V,+25deg.C) (Vcel=1.2V) Vcel is driving voltage of oscillation circuit Vcelは発振回路の電圧を表します | Typical sample 標準品 | VIH | 0.8 | [V] | ≤ 1.5V | Input high voltage 発振入力電圧High側レベル |
| | | VIL | 0.2 | [V] | ≥ -0.3V | Input low voltage 発振入力電圧Low側レベル |
| | | VOH | 0.8 | [V] | ≤ 1.5V | Output high voltage 発振出力電圧High側レベル |
| | | VOL | 0.1 | [V] | ≥ -0.3V | Output low voltage 発振出力電圧Low側レベル |
| | R1 limit sample R1規格限界品(*1) | VIp-p | 0.5 | [V] | | Swing level at input side 発振入力振幅 (VIH - VIL) |
| | | VOp-p | 0.6 | [V] | ≥ 0.55V | Swing level at output side 発振出力振幅 (VOH - VOL) |
| **Oscillation Start up Time 発振立ち上がり時間 (*2)** (Typical sample at Vdd=3.3V,+25deg.C) | | | 0.72 | [ms] | | Time to reach 90% of the oscillation level under steady state 定常状態の発振振幅の90%に達するまでの時間 |
| **Center Frequency Difference (Reference) 発振回路における発振周波数ずれ量 (*3)** (Typical sample at Vdd=3.3V,+25deg.C) (参考値) | | | -2 | [ppm] | | Oscillating frequency shift against nominal frequency 振動子の公称周波数と発振回路における発振周波数のずれ量 |
| **Negative Resistance Analysis 発振余裕度** (at Vdd=3.3V,+25deg.C) | | Rs_max [Ω] | \|-R\| [Ω] | Ratio [Times] | | The details is explained in page 2 詳細につきましては、次頁をご参照下さい。 |
| | | 270 | 318 | 5.3 | | |
| **Load Capacitance on your PCB 負荷容量値** (Typical sample at Vdd=3.3V,+25deg.C) | | | 8.2 | [pF] | | This value shows load capacitance the evaluated circuit has. 発振回路において振動子の両端に仮想的に接続される容量 |
| **Drive Level ドライブレベル** (Typical sample at Vdd=3.3V,+25deg.C) | | | 20 | [uW] | | Drive power of crystal under circuit condition 発振回路が動作している状態において振動子で消費される電力 |

*1 R1: Equivalent series resistance. "R1 limit sample" means R1 resistance of applied sample is equal as its R1 spec.
R1は振動子の等価直列抵抗を意味します。R1規格限界品とは、適用する振動子の等価直列抵抗値が、その規格値まで低下した状態のサンプルとなります。
*2 The measurement results is affected by the rise-up characteristics of supplied voltage on your PCB.
測定結果は実装基板の電源立ち上がり特性の影響を受けます。
*3 Frequency difference means the oscillating frequency difference between your PCB and Murata's frequency sorting circuit.
Please refer to appendix 1.
貴社基板と当社検査回路では、同一振動子を使用した場合でも発振周波数の差が生じます。これを発振周波数相関と呼びます。添付資料1をご参照下さい。

# 8. Appendix C

Abracon ABM12L-0000-T3 test results as follows:

**Series-Parallel resonance & motional parameters @ (+25°C ± 3°C)**

| Crystal Parameters | | | |
|---|---|---|---|
| Nominal Frequency | Fnom | 26,000,000 | Hz |
| Parallel Resonance | FL | 25,999,937 | Hz |
| Motional resistance | Rm | 24.64 | Ω |
| Motional inductance | Lm | 34.17 | mH |
| Motional capacitance | Cm | 1.10 | fF |
| Static capacitance | C0 | 0.91 | pF |

**In-Circuit Frequency**

| Basic Oscillator Parameters | | | |
|---|---|---|---|
| Nominal Frequency | Fnom | 26,000,000 | Hz |
| Crystal Parallel Resonance | FL | 25,999,937 | Hz |
| Operating Frequency | F | 25,999,926 | Hz |
| Internal Capacitor Code | (0~15) | 11 | |

**Negative Resistance and Safety Factor**

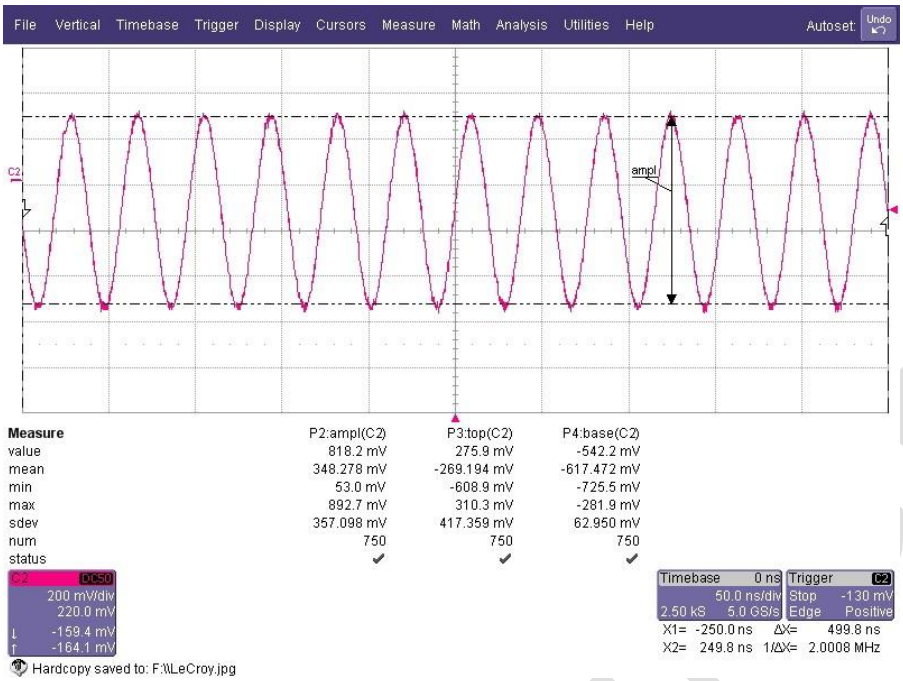
| Basic Oscillator Parameters | | | |
|---|---|---|---|
| Crystal Motional resistance | Rm | 24.7 | Ω |
| Maximum Crystal Resistance | Max ESR | 80 | Ω |
| Added Series Resistance | Rs | 400 | Ω |
| Negative Resistance | \|-R\| | >424 | Ω |
| Safety Factor (Ratio) | SF | >5 | |

Oscillator loop continues to operate beyond an added series resistance of 400 ohms.

**Drive Level**

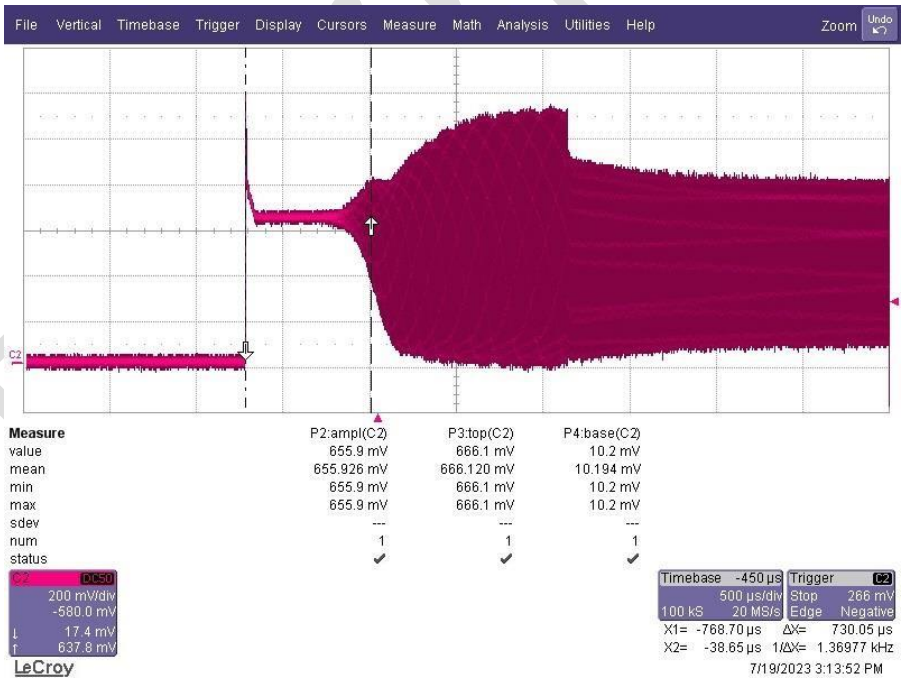
| Basic Oscillator Parameters | | | |
|---|---|---|---|
| Crystal Effective Series Resistance | ESR | 26.3 | Ω |
| Through-Crystal Current | I | 0.7 | mA |
| Drive Level | DL | 11.5 | µW |

### Oscillation Waveform




Passed Waveform Testing: Amplitude > 550 mV

### Oscillation Start-up Waveform




Passed Startup Testing: Amplitude > 400mV in 730µs (Stable Time = 45)

# 9. Appendix D

IQD LFXTAL081614Reel test results as follows:

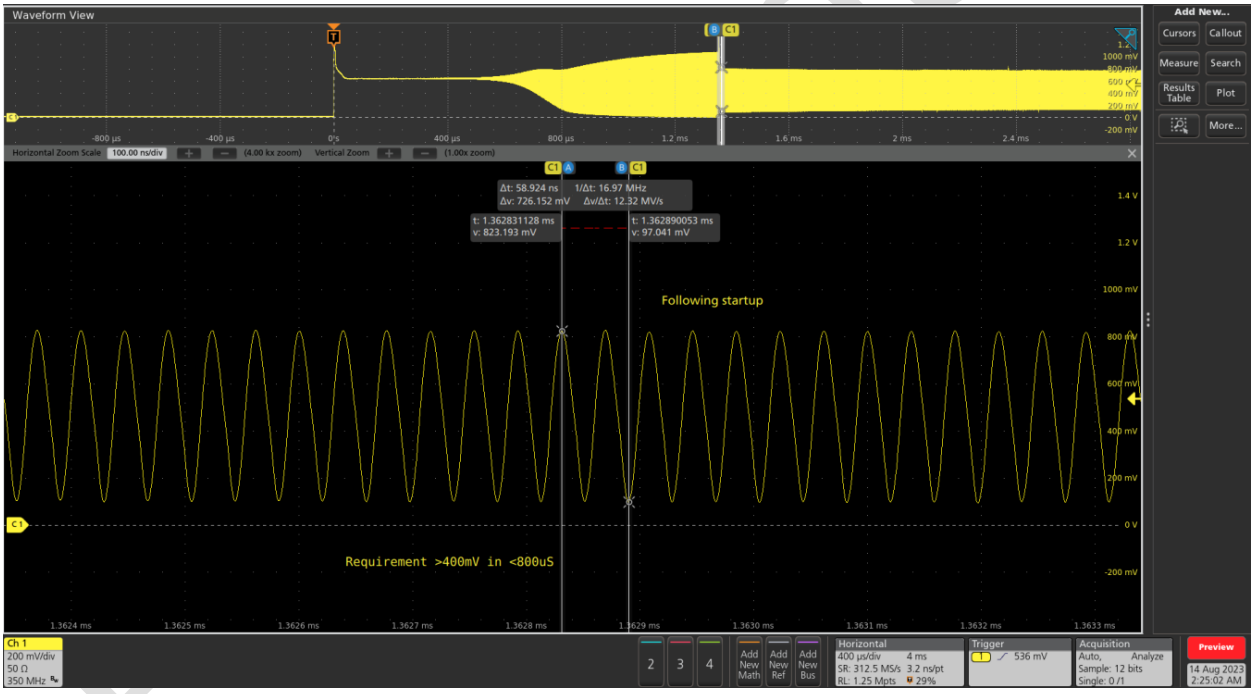
### PPM Results

| Part Tested | PCB Identifier | IC Fitted | Xtal Manufacturer | Fundamental frequency Hz | Measured Frequency Hz On PCB | Δ Hz | Calculated ppm deviation in circuit ppm |
|---|---|---|---|---|---|---|---|
| LFXTAL081614 | PCB #1-81614 | IN100 | IQD | 26000000.00 | 25999720.7636220 | -279.2363780 | -10.74 |
| LFXTAL081614 | PCB #2-81614 | IN100 | IQD | 26000000.00 | 25999745.9191951 | -254.0808049 | -9.77 |

$$ppm = \frac{measured\ Hz - fundamental}{fundamental\ Hz} * 1000000$$

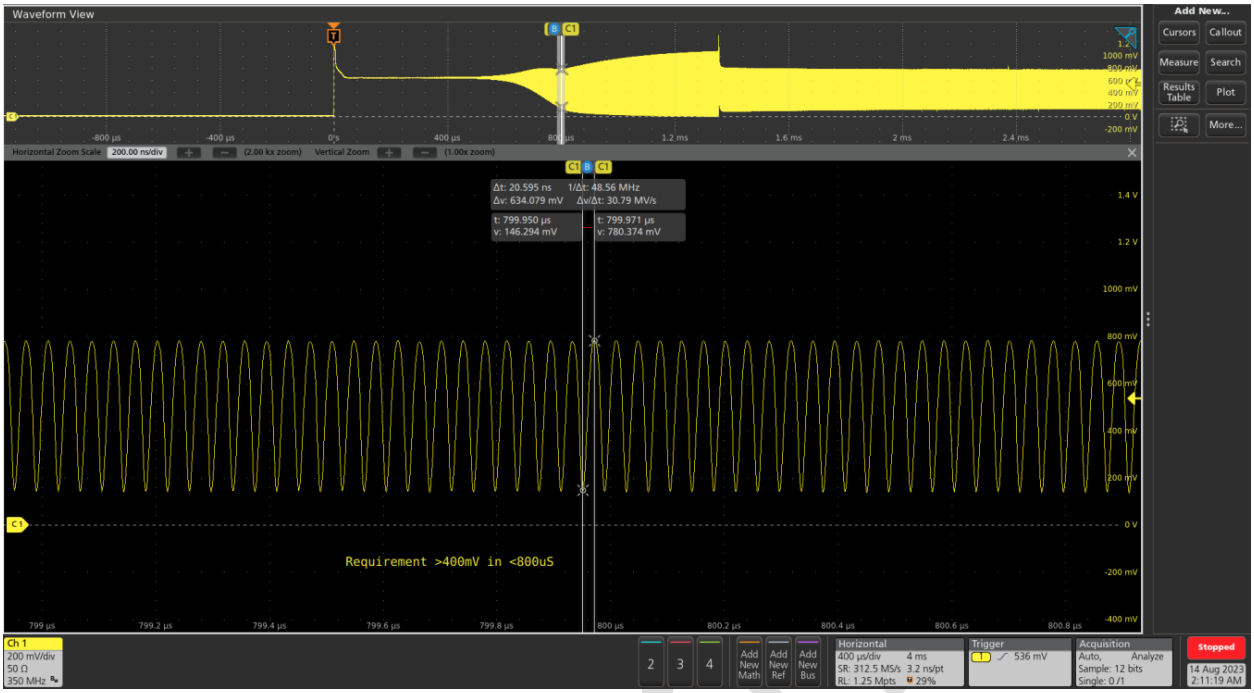
Passed BLE PPM requirements

### Oscillation Waveform




Passed oscillation waveform test: Greater than 550 mV amplitude

### Oscillation Startup Waveform




Passed startup requirements: 400 mV or greater amplitude in 800 us or less.

**Negative Resistance Ratio and ESR:**

| Resistance at failure to oscillate Ohms | Calculated Neg Ratio Based upon measured ESR | Neg R Ratio based upon Max ESR in datasheet | Max ESR from datasheet |
|---|---|---|---|
| 301.20 | 4.30 | 1.51 | 200 |

*Figure 8 - Negative resistance ratio with ESR measured at 70Ω*

$$Negative\ resistance\ ratio = \frac{Resistance\ at\ point\ of\ poor\ startup\ or\ failure\ to\ start}{ESR\ from\ datasheet}$$

It can be seen that the negative resistance ratio in this part is below 5 when we consider the maximum advertised ESR of 200Ω, however IQD historical measured data shows this part does not exceed 70Ω which gives a ratio of 4.3 times.

Passed negative resistance ratio: negative resistance ratio between 4 and 5. *Note that measured ESR by IQD was 70 Ohms, while datasheet number is an over estimate according to IQD engineer.