How to measure crystal start up time for nRF24LE1

nAN24-13

Application Note

September 2009

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Contents

1 Introduction

The modern wireless electronic manufacturing industry is constantly moving towards physically smaller applications and smaller printed circuit boards as a result of this. A significant amount of board area is used by the crystal that is needed to run the radio in wireless applications. This implies that in the process of making a smaller printed circuit board it is important to use a crystal which is physically smaller. When using crystal of a small size it is important to remember that small crystals also have a higher value of equivalent series inductance. The crystal start-up time is directly proportional with equivalent inductance. This application note focuses on how to measure the impact crystals with a smaller casing than 3.2x2.5 mm will have on the nRF24LE1.

2 Crystal oscillator

For the nRF24LE1 to be able to set up radio communication it needs to be connected to a 16MHz crystal which meets the requirements for the crystal with regard to frequency tolerance, equivalent series resistance, drive level, load and shunt capacitance. Please refer to the nRF24LE1 Product Specification for more details on these requirements.

The reference design for the nRF24LE1 uses a 16 MHz crystal in a 3.2x2.5 mm casing. If smaller crystal sizes are used they will lead to longer start up time due to the larger equivalent inductance introduced (ESI) by the smaller package. See Table 1. on page 5 to see how the increase in equivalent series inductance typically compares with crystal size.

It is recommended to ask manufacturers of crystal oscillators what the value of the series inductance is for their crystals. It will also be useful to verify the start up time in for example prototype stages of the design process.

Crystal size	ESI
3.2x2.4 mm	40mH
2.5x2.0 mm	60mH

Table 1. Example of ESI relative to crystal size

The code shown here can be used for such measurements.

```
------------------------------------------------------------------------------
#include <Nordic\reg24le1.h>
#include <stdint.h>

//IMPORTANT
// For 24-pin and 32-pin nRF24LE1 devices the WAKEUP_PIN is P0.6.
// For 48-pin nRF24LE1 devices the WAKEUP_PIN is P2.6.

#define WAKEUP_PIN P06

void main()
{
  OPMCON = 0x00;
  P0 = 0;
  P0DIR = 0xF0;

  WUOPC0 = 0x40;

  while(1)
 {
    P03 = 1;
    while( (CLKLFCTRL & 0x08) == 0 );
    P03 = 0;

    while( WAKEUP_PIN );
```

```
25:      P01 = 1;
26:      OPMCON = 0x02;
27:      PWRDWN = 0x01;
28:    }
29:  }
```

The code will normally have the nRF24LE1 in active mode running in a loop to check the status of the WAKEUP_PIN. If WAKEUP_PIN is pulled down it will set the nRF24LE1 in deep sleep for as long as WAKEUP_PIN is kept low. On the nRFgo development kit this means that you connect a button to WAKEUP_PIN and push the button to put the nRF24LE1 in deep sleep. When WAKEUP_PIN is pulled up (button released on nRFgo) it will toggle pin P0.3 after the crystal oscillator has settled. As a check that the firmware is working as intended it is possible to connect pin P0.1 to a LED. This pin will light the connected LED before the chip is put into deep sleep and kept on as long as you keep WAKEUP_PIN low.

To measure the start up time you need to compile the code and load the generated hex-file into the nRF24LE1 for example through nRFgo Studio. Once the firmware is installed you have to connect WAKEUP_PIN to one of the input probes on the oscilloscope and pin P0.3 to another input on the oscilloscope. The release of WAKEUP_PIN should be used as a trig point for the oscilloscope. Then it is possible to measure the time from WAKEUP_PIN was released to pin P0.3 is toggled. This time is the start up time for the crystal oscillator.

Figure 1. on page 7 shows a screenshot from an oscilloscope. The green line is the WAKEUP_PIN and is used to trig the oscilloscope when WAKEUP_PIN is released. The yellow line is pin P0.3. There is a short delay from the WAKEUP_PIN is released until pin P0.3 is set high. This is due to the time it takes the MCU to run the code down to line number 20 on the internal 16 MHz RC oscillator. In Figure 1. on page 7 pin P0.3 is toggled low after 922 µs which is the time it takes for the crystal to start up after WAKEUP_PIN has been released.

For these test measurements an Epsom Toyocom FA20-H 2.5x2.0mm 16MHz crystal has been used. This crystal has been mounted on an nRF2723 nRF24LE1 development kit module combined with an nRF6310 motherboard from the nRFgo Starter Kit. The parallel load capacitors (C1 and C2 in the reference design in the nRF24LE1 Product Specification) that have been used are 10pF +/-5% 0402 capacitors.

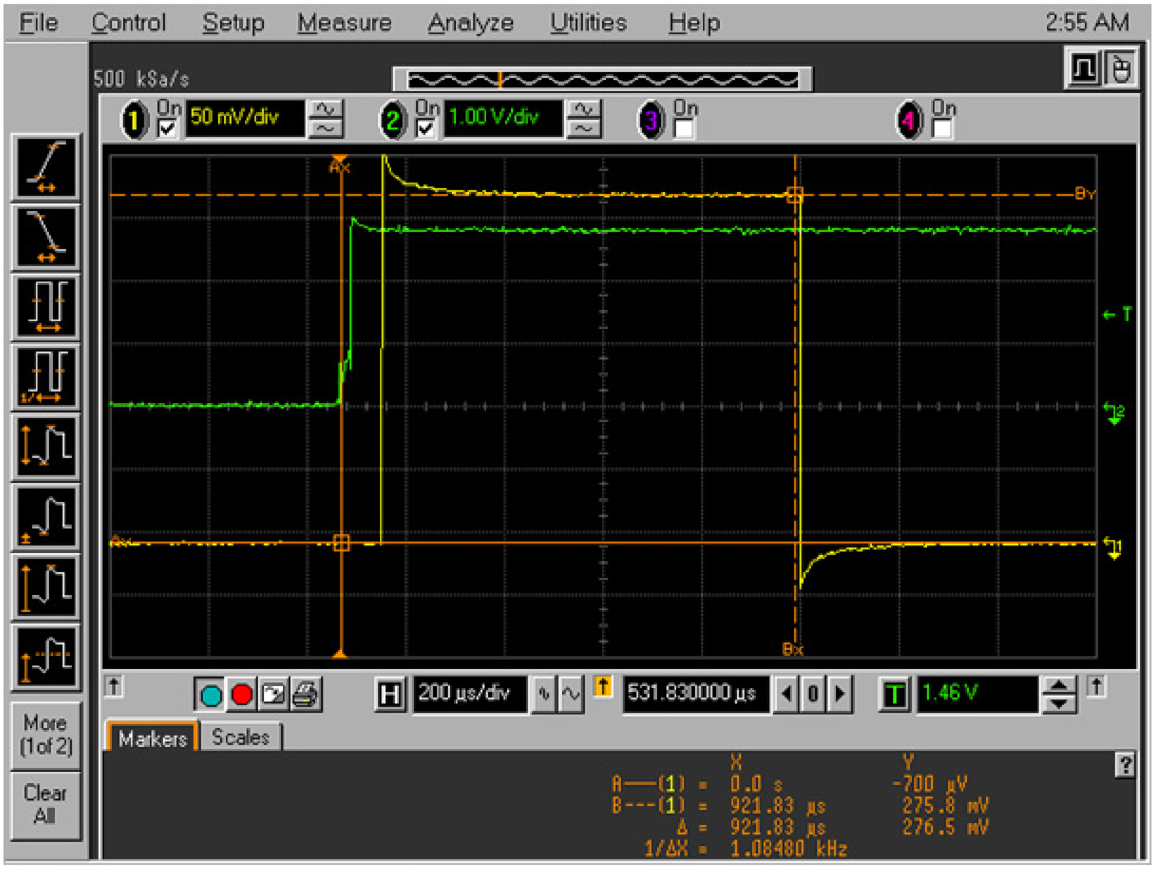

Figure 1. Screenshot from the oscilloscope