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User manual for the I²C-bus RTC PCF8523 demo board OM13511

Rev. 1 — 2 February 2015 User manual

Document information

Info	Content
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Abstract	User manual for the RTC I²C-bus demo board OM13511 which contains the RTC PCF8523

Revision history

Rev	Date	Description
v.1	20150202	First revision

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1. Introduction

The PCF8523 is a real-time clock based on an ultra-low power oscillator and using an I^{2}C-bus for interfacing. The OM13511 is the ideal evaluation/demo board to use during the design phase of any project, just power and I^{2}C-bus must be connected. If an SPI-bus would be the preferred interface, the PCF2123 with demo board OM13512 could be used for evaluation.

2. Key features

2.1 Demo board OM13511

The RTC PCF8523TS with I^{2}C-bus is mounted together with a quartz crystal, a coin cell lithium battery and the decoupling capacitors to buffer the supply voltage. All signals are accessible on a row of pins, overcoming the need to build a test printed-circuit board before the circuit can be evaluated or the functionality being tested together with the final application.

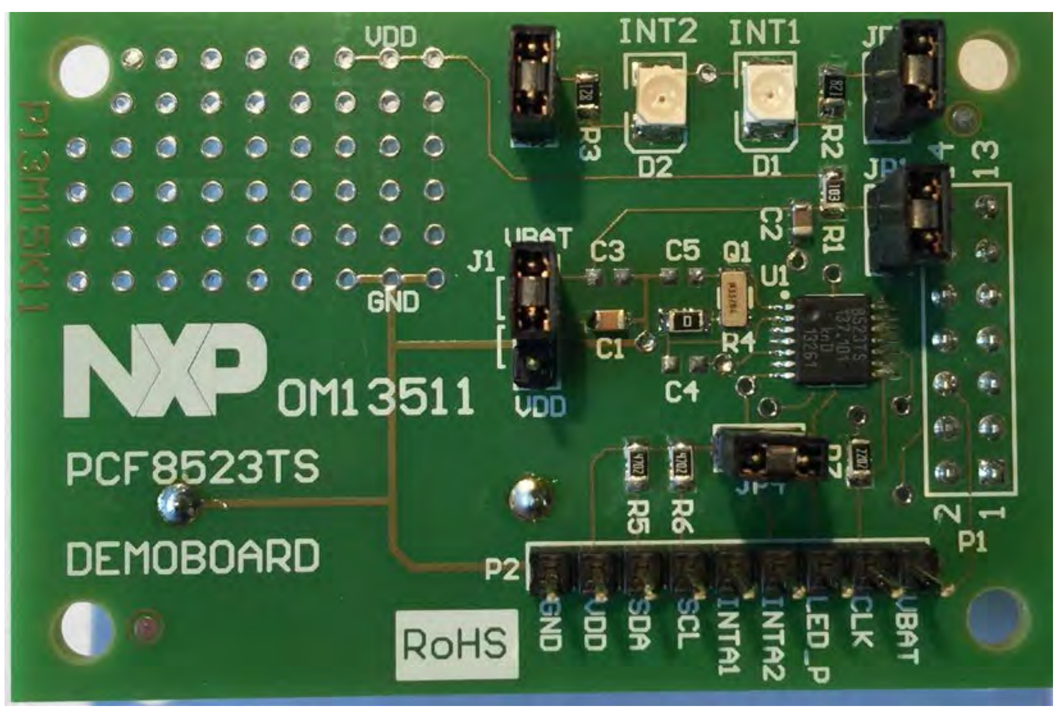


Fig 1. OM13511 demo board

2.2 Real-time clock PCF8523

The PCF8523

- Has an ultra-low power consumption
- Provides time and calendar from seconds to years

- Accuracy is based on a 32.768 kHz quartz crystal
- Clock operating voltage: 1.0 V to 5.5 V
- Low backup current: typical 150 nA at V_{DD} = 3.0 V and T_{amb} = 25 °C
- 2-line bidirectional 1 MHz Fast-mode Plus (Fm+) I^2C interface, slave address: read D1h, write D0h
- Battery backup input pin and switch-over circuit
- Freely programmable timer and alarm with interrupt capability
- Integrated oscillator load capacitors, programmable for quartz crystals with C_L = 7 pF or C_L = 12.5 pF
- Programmable offset register for frequency adjustment
- Internal Power-On Reset (POR)

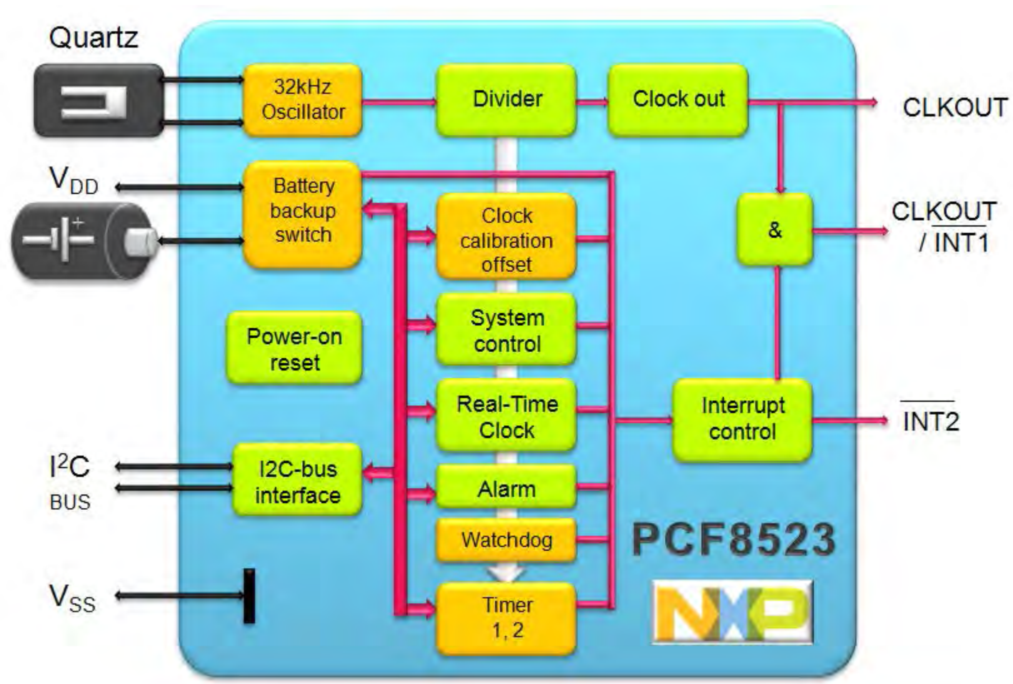


Fig 2. Block diagram PCF8523

3. Hardware setup

3.1 General requirement for the PCF8523

The RTC circuit just requires one external part: the tuning fork quartz crystal as resonator. The oscillation capacitors are integrated and therefore there is no need for external load capacitors. The quartz crystal must be placed close to the RTC circuit, avoiding long lines, which may pick up noise. Any tracks with high frequency signals (fast edges) close to the RTC, quartz crystal, or quartz interconnect should be avoided.

The I²C-bus interface works up to 1 MHz. Supply voltage: 1.8 V to 5.5 V. The RTC, excluding the I²C-bus interface, however is operating down to as low as 1.0 V. It is recommended to have a decoupling capacitor of 100 nF on the V_{DD}-V_{SS} rails close by. Due to the low power consumption of below 1 μW, no precautions for heat dissipations are required, even in a sealed housing environment. Frequencies of 1 Hz to 32.768 kHz on CLKOUT pin can be used to measure the frequency for calibration and/or for general purpose, e.g. as reference for frequency generation with a PLL.

3.2 Battery back-up

To guarantee the autonomy of the clock, continuous supply of power is needed. The battery backup assures it. Any type of battery can be used. The battery voltage might be larger (Lithium) or smaller (Alkaline or silver oxide) than the regular supply voltage V_{DD}. To reduce the power consumption of the RTC the V_{DD} voltage is sampled for taking the decision when to switch over to the battery. To assure the supply voltage does not drop below the minimal threshold, the falling slew rate of V_{DD} must be max 0.5 V/ms. R1, C2 are selected therefore accordingly (10 kΩ, 1 μF).

3.3 Optimizing power consumption

There are a number of factors influencing the power consumption:

- Supply voltage: the lower the supply voltage the lower the power consumption
- Oscillator: the quartz crystal is specified with the series resistance R_S and a load capacitance C_L. The PCF8523 can be set to accept quartz crystals with a C_L of 12.5 pF or 7 pF. With lower capacitance, the power consumption is lower. 6 pF quartz crystals can also be used but then the frequency must be adjusted slightly via the offset register. The serial resistance of the quartz dissipates energy. The lower R_S, the less energy is used. General rule: the larger the mechanical size of the quartz package, the lower is the impedance. Check the components' parameters of the preferred quartz crystal supplier.

4. Circuit diagram

4.1 Detailed circuit diagram

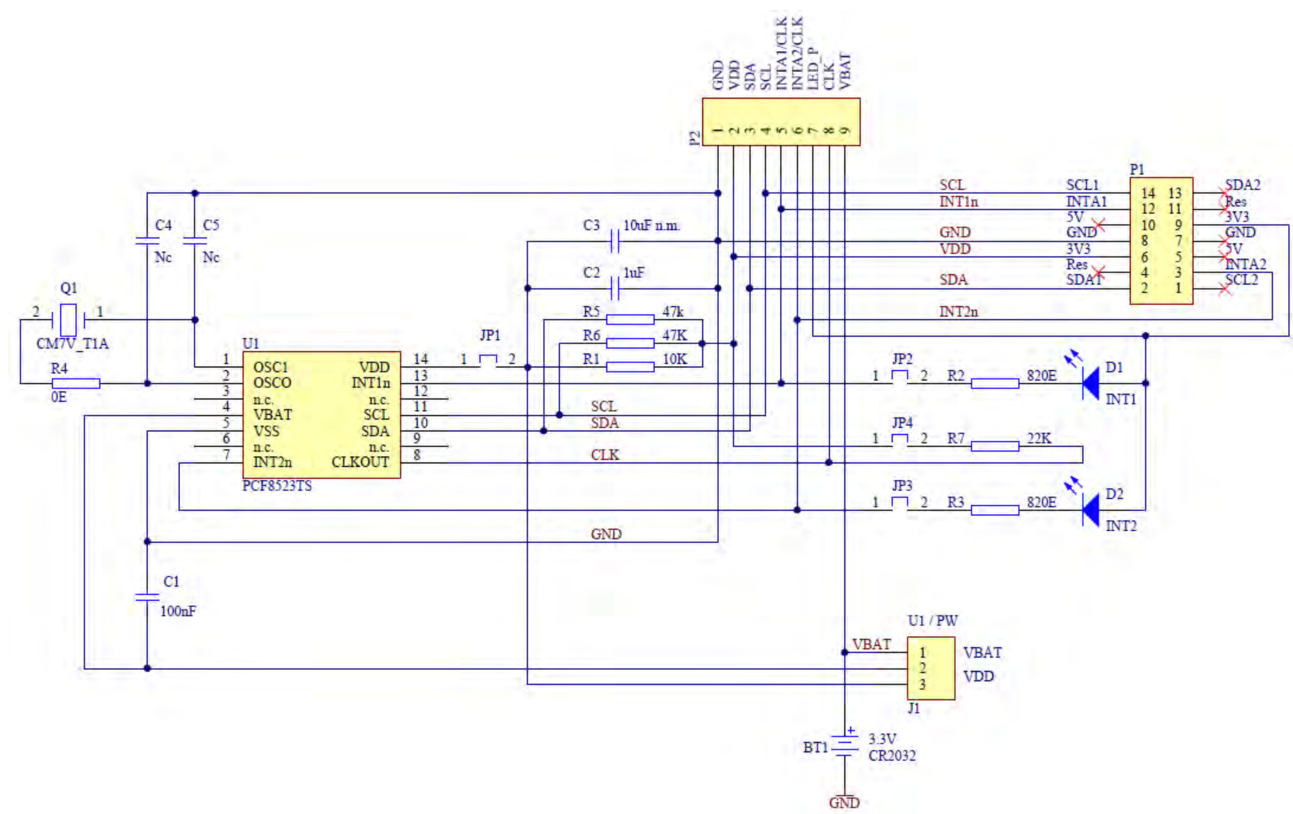


Fig 3. Circuit diagram of the demo board

Connectors and features:

- The single in line connector P2 (100 mil pitch) is giving access to all pins for integrating the RTC into the application.
- Connector P1 could be used for interfacing with the Fm+ development board OM13320.
- Jumper JP1 allows measuring the current consumption; for this, the jumper has to be removed and replaced by a μA meter.
- Jumper U1/PW is used to activate the back-up battery. If the battery is not needed, V_{BAT} must be connected to V_{DD}. This is also the default position of the jumper for delivery to avoid battery drain.
- Jumper JP2 and JP3 allow visualizing the interrupts by the LEDs INT1 and INT2 on top of the board. They are powered through dedicated LED-PW pin 7 on P2. The current through the LEDs is 3000 times higher than the needs of the RTC.

- Jumper JP4 links in a 10 kΩ pull-up resistor for the open-drain output in case that there is none in the application.
- The RC delay circuit R1 and C2 (plus C3) are guaranteeing that the V_{DD} at the RTC is not falling too fast to hamper uninterrupted power supply to the RTC.
- The pull-up resistors, R5 and R6, for the I^2C-bus are of 47 kΩ.
- Position of the jumpers and connectors are found in the circuit diagram in Fig 3 and the layout drawing in Fig 4.

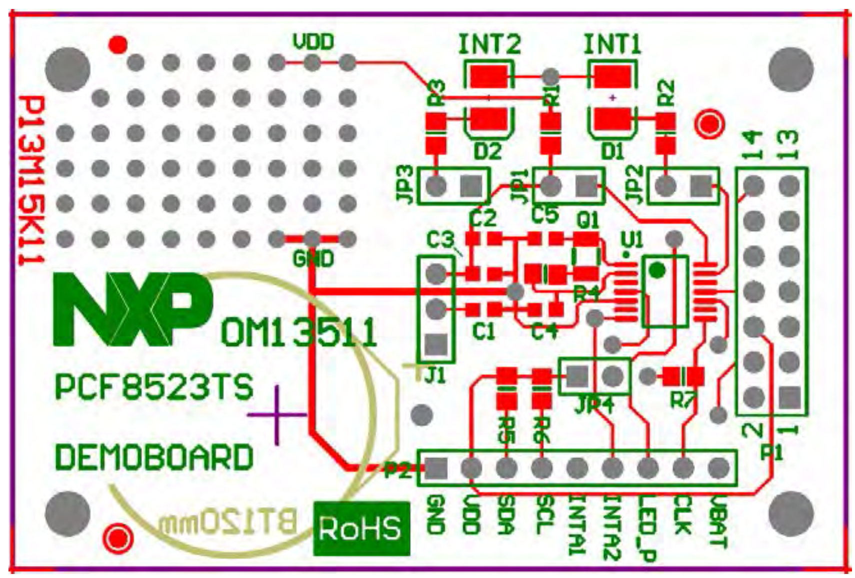


Fig 4. Demo board and top side layout

5. Optional features for test and evaluation

5.1 Oscillator

The characteristics of the oscillator with different quartz crystals can easily be verified.

- Landing pads for different size of quartz crystal
- Landing pads to add load capacitances C4 and C5
- Resistor R4 (0 Ω) can be replaced to simulate variance of quartz R_S tolerances. Total impedance of maximum 100 kΩ is recommended

5.2 Experimental area

On the board, there is space for adding a custom circuitry for general purpose. V_{SS} and V_{DD} are available for easy set-up.

6. Software

The actual time must be set after power-on. For this, straightforward I^2C-bus instructions are used.

6.1 Functionality

The RTC PCF8523 is controlled via standard I^2C-bus interface. Common I^2C protocol applies. The interface features the Fast Mode+ I^2C-bus, operating up to 1 MHz. There is theoretically no lower speed limit, however the access of the RTC should be completed within less than 1 second, otherwise time counter-increments could be lost. During access, the time registers of the RTC are frozen and after the read or write, sequence is completed, a second's increment is executed if necessary.

The clock tracks the actual time from seconds to year. It must initially be set to the correct time. The days per month and leap year are corrected automatically.

The RTC can be programmed to generate an interrupt every 30 seconds or every 60 seconds.

A general-purpose RAM byte to store temporary information is at address 03h.

6.2 Software instructions for setting the clock

6.2.1 Setting the time

Setting the clock to 3.45 PM, December 15, 2015:

- I^2C-bus START condition
- Slave address D0h, i.e. write bit set to 0
- Register address 00h: address pointer to register Control_1
- Register Control_1, 08h: set 12-hour mode and selects option for 7 pF quartz crystal
- Register Control_2, 00h: no timers or watch dog initiated
- Register Control_1, 88h: activate interrupt to monitor battery switch-over

Setting the actual time and date

- Register Seconds, 00h: 0 Seconds (clock integrity ok, MSB OS = 0)
- Register Minutes, 45h: 45 min
- Register Hours, 23h: PM, 3 hours
- Register Days, 15h: 15^{th} day of the month
- Register Weekdays, 02h: Tuesday (second day of the week)
- Register Months, 12h: December
- Register Years, 15h: (20)15
- I^2C-bus STOP condition

6.2.2 Reading the clock

Example reading the clock (some 2 minutes after writing)

- I^2C-bus START condition
- Slave address D0h, i.e. write bit set to 0
- Register address 03h: address pointer to forth byte (register Seconds)
- I^2C-bus repeated START condition
- Slave address D1h read mode, i.e. write bit set to 1

Reading the time/date registers:

- Register Seconds: e.g. 56 Seconds (clock integrity ok, i.e. OS = 0)
- Register Minutes: e.g. 46 Minutes
- Register Hours: e.g. 03 (PM, 03h)
- Register Days: e.g.15 (15th)
- Register Weekdays: e.g. 02 (Tuesday)
- Register Months: e.g. 12 (December)
- Register Years: e.g. 14 ((20)14)
- I^2C-bus STOP condition

6.3 Frequency tuning

The 32 kHz quartz crystals are typically sold with a tolerance of either ±10 ppm or ±20 ppm at room temperature.

Remark: 11.5 ppm corresponds to a deviation of 1 s/day.

The quartz crystals feature a characteristic load capacity of either 7 pF or 12.5 pF. Oscillators, utilizing 7 pF quartz crystals, feature slightly lower power consumption, where the quartz crystals of 12.5 pF have largest production quantities. The tracks between quartz and RTC represent some parasitic capacitances as well and must be kept short.

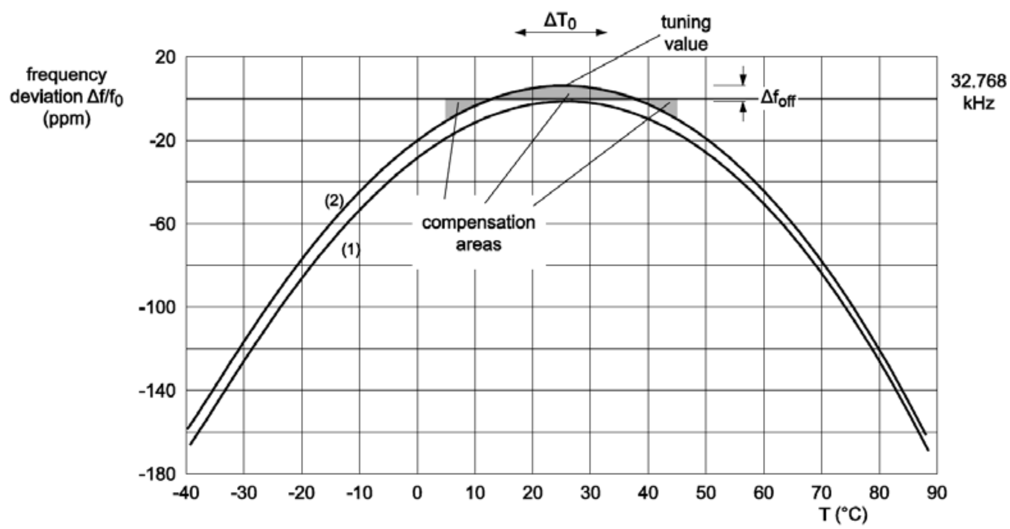
The PCF8523 has a tuning facility where above tolerances can be compensated.

Tuning procedure:

- Measure the 32xxx Hz (f) signal at the CLKOUT pin.
- The offset is calculated in ppm as Δf [ppm] = 106 × (f - 32768) / 32768
- Consult the offset table in the data sheet. Take the correction value and write it into the register 0Eh.
- The correction is done with inhibition or addition: the oscillator runs at constant speed, then every 2 hours (mode 0) 1 second is corrected by making it shorter or longer. This is not visible at the CLKOUT.

Corrections can also be applied every minute by using mode 1. This mode consumes slightly more power (< 1 % more).

The 32 kHz quartz crystal is of the type tuning fork and features a parabolic frequency response over temperature. When the application is dominantly used over a limited temperature range, it is often helpful to tune the frequency to be slightly higher at the turnover point. The error around 25 °C (clock goes too fast) is then compensated during the time when temperature is lower or higher. For example, for operation between 5 °C and 45 °C, tune the clock 8 ppm faster than the value for 25 °C would be. (See Fig 5.)



(1) Characteristic if tuned to 32.768 kHz at 25 ºC

(2) Characteristic if tuned with the positive offset Δf_{off}

Fig 5. Frequency averaged over application temperature range 5 °C to 45 °C

7. Reference

[1] **AN11247** – Improved timekeeping accuracy with PCF85063, PCF8523 and PCF2123 using an external temperature sensor, Application Note

[2] **PCF8523** - Real-Time Clock (RTC) and calendar, Data Sheet

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9. List of figures

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