Objective

These code examples show how to implement a real-time clock (RTC) using the 50/60-Hz frequency of the mains power line as the time base. PSoC 3, PSoC 4, and PSoC 5LP devices are supported. The example for PSoC 4 BLE also uses a 32-kHz watch crystal oscillator (WCO) that can be used as the secondary time-base in case of a mains power failure.

Overview

An RTC provides time and date information – second, minute, hour, day of the week, day of the month, month, and year. The time and date information are usually updated every second based on a one-second interrupt generated from a 32.768-kHz crystal. However, there can be long-term drifts in the time due to factors such as the temperature and aging of the crystal.

An alternative technique is to use the frequency of the mains power line as a time base. Systems that are wall-powered and need a system clock can make use of this technique. This technique is applicable only in countries where mains power frequency adjustment is done.

Refer to the associated application note AN96667, PSoC Real Time Clock Based on Power Line Frequency for the theory behind this technique.

Two code examples are provided:
- RTC with PSoC 5LP using the Power Line
- RTC with PSoC 4 BLE using the Power Line with Crystal Back-Up

Requirements

Tool: PSoC Creator 3.1 SP1 or higher
Programming Language: C (ARM® GCC 4.8.4 and ARM MDK compilers)
Associated Parts: All PSoC 5LP and PSoC 4 BLE parts
Related Hardware: CY8CKIT-050, CY8CKIT-042-BLE
**Design**

*Figure 1* shows the code example design for PSoC 5LP.

*Figure 1. RTC Code Example for PSoC 5LP Device on CY8CKIT-050*

The code example features the following:

- A one-second event using the interrupt generated from the 50/60-Hz power line
- A character LCD that displays the RTC date and time

**Note:** This design does not have a crystal or oscillator-based backup to maintain the time in the case of a mains power failure. If the design has a battery backup to power the PSoC device if the mains power fails, then you should implement a crystal-based backup using the existing RTC Component in PSoC Creator.

This design can also be ported to other devices such as PSoC 3, PSoC 4000, PSoC 4100, and PSoC 4200. To implement a crystal backup for the PSoC 4100 and PSoC 4200 series devices, see the code example **CE95915**.
Figure 2 shows the code example design for PSoC 4 BLE.

Figure 2. RTC Code Example for PSoC 4 BLE Devices on CY8CKIT-042-BLE

This code example features the following:

- A one-second event using the interrupt generated from the 50/60-Hz power line
- A watchdog timer (WDT), running on a 32.768-kHz watch crystal oscillator (WCO) that generates a one-second interrupt. This is used as the secondary time base if the main power supply fails.
- Automatic switching between primary and secondary time bases
- UART-based communication with a PC. Because a software-based transmit UART is used, some CPU processing bandwidth is used

**Code Design**

**PSoC 5LP Code Example:**

Figure 3 shows the flow chart of the PSoC 5LP code example.
Figure 3. Flow Chart for PSoC 5LP Code Example

Start

Start Components in Top Design

Initialize the RTC firmware registers (sec, min, hour etc.)

Is Power line Interrupt Triggered?

Yes

Increment Power line count

Is Power line count = 50/60

No

Yes

Update RTC Firmware registers (sec, min, hour etc.)

Display Date and Time on LCD
**PSoC 4 BLE Code Example**

Figure 4. Flow Chart for PSoC 4 BLE Code Example

- **Start**
  - Start Components in Top Design
  - Initialize the RTC firmware registers
  - Set State_Second Variable = INVALID
  - Is Power line Interrupt Triggered?
    - Yes
      - Increment Power line count
      - Is Power line Failure flag set?
        - Yes
          - Reset the Crystal Counter and Power Line Count
        - No
          - Is Power line count = 50/60?
            - Yes
              - Update RTC firmware registers
            - No
              - Set Power Line Count=0
  - No
    - Present_Second Variable = RTC_currentTimeData.Sec
    - Is Present_Second Variable = State_Second Variable?
      - Yes
        - Update RTC firmware registers
      - No
        - Power Line Failure Flag=1
          - Power Line Count=0
          - Set State_Second Variable = INVALID
          - Is Power Line Fail Flag set or Power Line Count < Threshold?
            - Yes
              - Update RTC firmware registers
            - No
              - Power Line Failure Flag=0
                - Set State_Second Variable = INVALID
                - Set Power Line Count=0
    - A

- **A**
  - Is 1 Sec XTAL based interrupt triggered?
    - Yes
      - Present_Second Variable = RTC_currentTimeData.Sec
    - No
      - Set Stale_Second Variable = RTC_currentTimeData.Sec.
      - Sec
      - Is Present_Second Variable = Stale_Second Variable?
        - Yes
          - Update RTC firmware registers
        - No
          - Power Line Failure Flag=1
            - Power Line Count=0
            - Set Stale_Second Variable = INVALID
            - Set Power Line Count=0
  - Is Power Line Fail Flag set or Power Line Count < Threshold?
    - Yes
      - Update RTC firmware registers
    - No
      - Power Line Failure Flag=0
        - Set State_Second Variable = INVALID
        - Set Power Line Count=0
  - A

- **B**
  - No
    - Start
      - Start Components in Top Design
      - Initialize the RTC firmware registers
      - Set State_Second Variable = INVALID
      - Is Power line Interrupt Triggered?
        - Yes
          - Increment Power line count
          - Is Power line Failure flag set?
            - Yes
              - Reset the Crystal Counter and Power Line Count
            - No
              - Is Power line count = 50/60?
                - Yes
                  - Update RTC firmware registers
                - No
                  - Set Power Line Count=0
        - No
          - Present_Second Variable = RTC_currentTimeData.Sec
          - Is Present_Second Variable = State_Second Variable?
            - Yes
              - Update RTC firmware registers
            - No
              - Power Line Failure Flag=1
                - Power Line Count=0
                - Set State_Second Variable = INVALID
                - Is Power Line Fail Flag set or Power Line Count < Threshold?
                  - Yes
                    - Update RTC firmware registers
                  - No
                    - Power Line Failure Flag=0
                      - Set State_Second Variable = INVALID
                      - Set Power Line Count=0
            - A

- **A**
Note: This project can be used in designs that have a battery back up to power the PSoC device in the case of a mains power failure. During a mains power failure, the PSoC 4 BLE device is put to the Deep-Sleep Mode to minimize current consumption. The current consumed by this design in the Deep-Sleep mode is approximately 100 µA.

Design Considerations
Off-kit connections are needed to implement the power-line interface as shown in Figure 5.

The CY8CKIT-050 can be powered using a 12-V AC power adapter. To test the designs, all development kits can be powered using the USB power. Check the “Hardware Setup” section in the user guide for the respective kits to see how the PSoC 4 BLE Development Kit can be powered using a 5-V power adapter.

The PSoC supply voltage in the development kits should be set to 5 V because the power-line interface components include a 4.7-V Zener diode. Also, the wall powering should come directly from the mains power line. The code examples have not been tested with power lines from inverters or UPS systems. This technique is suitable for long-term time accuracy, but not for accurate short time-intervals, for which the direct 32.768-kHz WCO frequency is better suited.

Hardware Setup

- You need the following hardware for the power-line interface, as 5 shows:
  - One 12-0-12 step-down transformer (100-240 V, 500 mA)
  - One P-N junction diode
  - Two 10 kΩ resistors
  - One 0.1 µF capacitor
  - One 4.7-V Zener Diode

Figure 5. Power-Line Interface Design

Figure 6 shows the hardware setup required to test the project with the CY8CKIT-050 kit.
Figure 6. Hardware Setup Diagram for CY8CKIT-050

Figure 7 shows the hardware setup required to test the project with the CY8CKIT-042-BLE kit.

Figure 7. Hardware Setup Diagram for CY8CKIT-042-BLE
Make the following connections:

- Connect a wire from the Power Line signal shown in Figure 5 to Pin P0[0] of the CY8KIT-050 kit. This acts as the Power Line signal to the PSoC GPIO pin.

- Connect a wire from the Power Line signal as shown in Figure 5 to Pin P1[7] of the CY8CKIT-042-BLE (J4, Pin 4 of CY8CKIT-042-BLE). This acts as the Power Line signal to the PSoC GPIO pin. The pin used for transmitting the data over UART (P1[5]) is hardwired to the receiver pin of the PSoC 5LP device in the kit. This enables displaying the time and date on a UART console over the USB-UART Interface.

**Note:** The CY8CKIT-042-BLE kit can be powered using an external 5-V power adaptor if USB power is not used. To do so, connect the output of the power adaptor to the “VIN” Pin (J1 Header, Pin 1) of the Kit. You can also connect a 5 V Battery to the “BT1” Slot provided at the backside of the Kit. This can be used as the secondary power source if main power fails.

**Software Setup**

No special software setup is required for this project. All supported compilers can be used with any optimization required.

At the PSoC Creator project’s default CPU clock speed (12 MHz for PSoC 4 BLE and 24 MHz for PSoC 5LP), the CPU has enough cycles to support the example. The RTC update ISR uses about 0.03% of the CPU’s bandwidth, and the software transmit UART operating at 115,200 baud uses approximately 0.2% of the CPU bandwidth.

**Components**

Table 1 lists the PSoC Creator Components used in the PSoC 5LP example as well as the hardware resources used by each Component.

<table>
<thead>
<tr>
<th>Component</th>
<th>Hardware Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Character LCD</td>
<td>1 – uses 7 I/O pins</td>
</tr>
<tr>
<td>isr</td>
<td>1 interrupt</td>
</tr>
<tr>
<td>Pin</td>
<td>1 I/O pin for the receiving the power line signal</td>
</tr>
</tbody>
</table>

Table 2 lists the PSoC Creator Components used in the PSoC 4 BLE example as well as the hardware resources used by each Component.

<table>
<thead>
<tr>
<th>Component</th>
<th>Hardware Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>SW_Tx_UART</td>
<td>None – Software-based UART does not use any hardware resources</td>
</tr>
<tr>
<td>isr</td>
<td>2 interrupts</td>
</tr>
<tr>
<td>Pins</td>
<td>1 I/O pin for the receiving the power line signal</td>
</tr>
<tr>
<td>Global Signal</td>
<td>WDT Int Global Signal</td>
</tr>
</tbody>
</table>

**Parameter Settings**

Table 3 lists the parameter settings for each PSoC Creator Component used in the PSoC 5LP code example. Only the parameters that vary from the default values are listed.

<table>
<thead>
<tr>
<th>Component</th>
<th>Non-Default Parameter Settings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pin</td>
<td>Interrupt = Rising Edge</td>
</tr>
<tr>
<td></td>
<td>Threshold = LVTTL</td>
</tr>
</tbody>
</table>
Table 4 lists the parameter settings for each PSoC Creator Component used in the PSoC 4 BLE code example. Only the parameters that vary from the default values are listed.

Table 4. List of PSoC Creator Component Parameter Settings for PSoC 4 BLE Example

<table>
<thead>
<tr>
<th>Component</th>
<th>Non-Default Parameter Settings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pin</td>
<td>Interrupt = Rising Edge</td>
</tr>
<tr>
<td></td>
<td>Threshold = LVTTL</td>
</tr>
<tr>
<td>Global Signal</td>
<td>Global signal name = WDT Int</td>
</tr>
</tbody>
</table>

**Design-Wide Resources**

Figure 8 shows the pin assignments for the PSoC 5LP code example.

Figure 8. Pin Assignments for PSoC 5LP Example

Figure 9 shows the Clock Tree. Enable XTAL 32kHz in the design-wide resource.

Figure 9. PSoC 5LP Clock Tree

Figure 10 shows the pin assignments for the PSoC 4 BLE code example. Enable the 32.768-kHz WCO in the design-wide resource. Figure 11 shows the Clock Tree.

Figure 10. Pin Assignments for PSoC 4 BLE Example

Figure 11. PSoC 4 BLE Clock Tree
Operation

**PSoC 5LP Code Example**

1. Set the suitable Power Line frequency for the define `POWERLINE_FREQ_HZ` in main.c file of the Code Example. The value is 50u by default. Change this to 60u if power line frequency is 60 Hz.

2. Make the necessary hardware connections. See Figure 5.

3. Build the project in PSoC Creator.

4. Program the PSoC 5LP project into the CY8CKIT-050.

5. Observe the date and time getting displayed on the Character LCD. Figure 12 shows the output on the Character LCD. The LCD is powered from the 3.3 V On-Board Regulator. Hence it can be safely used even if PSoC is powered at 5V.
PSoC® Real-Time Clock Based on Power Line Frequency

Figure 12. Date and Time Shown in the LCD for PSoC 5LP Code Example

PSoC 4 BLE Code Example
1. Set the suitable Power Line frequency for the define POWERLINE_FREQ_HZ in main.c file of the Code Example. The value is 50u by default. Change this to 60u if power line frequency is 60 Hz.

2. Make the necessary hardware connections. See Figure 5.

3. Build the project in PSoC Creator.

4. Program the project into the CY8C4247LQI-BL483 device, which is the default device in the CY8CKIT-042 BLE Pioneer Kit.

5. Configure any UART console (such as Hyperterminal or Coolterm) for a baud rate of 115,200.

6. Select the COM port that is enumerated as “KitProg USB-UART” in the Device Manager of the PC.

7. Connect the console and reset the device by pressing SW1 (Reset Switch). Verify that the time is updated once per second, as Figure 13 shows. Figure 13 also shows the crystal updating the RTC when the mains power line fails and switching back to the mains power line when it is back and stable).

Figure 13. Time shown in the console for PSoC 4 BLE Code Example

Note: The CY8CKIT-042 BLE kit has an option to insert a coin-cell battery. If the main power supply fails, then the PSoC 4 BLE device can run on this coin cell. While testing the code example, we assume that the kit is always powered with the USB so that we can observe the date and time on the serial console. The power failure can be simulated by removing the connection between the Power Line Signal and the GPIO pin.
Related Documents

Table 5 lists relevant application notes, code examples, knowledge base articles, device datasheets, and Component datasheets.

Table 5. Related Documents

<table>
<thead>
<tr>
<th>Application Notes</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AN54181 Getting Started with PSoC 3</td>
<td>AN54181 introduces you to PSoC® 3, an 8051-based programmable system-on-chip.</td>
</tr>
<tr>
<td>AN77759 Getting Started with PSoC 5LP</td>
<td>AN77759 introduces you to PSoC® 5LP, an ARM® Cortex®-M3-based programmable system-on-chip.</td>
</tr>
<tr>
<td>AN54460 PSoC 3 and PSoC 5LP Interrupts</td>
<td>AN54460 explains the interrupt architecture in PSoC® 3 and PSoC 5LP, and its configuration in PSoC Creator™ IDE with the help of code examples.</td>
</tr>
<tr>
<td>AN60631 PSoC 3 and PSoC 5LP Clocking Resources</td>
<td>AN60631 describes PSoC 3 and PSoC 5LP's oscillators and clock sources, phase-locked loop (PLL), and clock distribution network.</td>
</tr>
<tr>
<td>AN54439 PSoC 3 and PSoC 5LP External Crystal Oscillators</td>
<td>AN54439 describes how to configure hardware and firmware for PSoC 3 or PSoC 5LP using the integrated oscillator subsystems and external crystal or ceramic resonators.</td>
</tr>
<tr>
<td>AN79953 Getting Started with PSoC 4</td>
<td>Introduces user to PSoC® 4, an ARM® Cortex™-M0 based programmable system-on-chip.</td>
</tr>
<tr>
<td>AN90799 PSoC 4 Interrupts</td>
<td>Explains the interrupt architecture in PSoC 4 and its configuration in PSoC Creator IDE</td>
</tr>
<tr>
<td>AN91267 Getting started with PSoC 4 BLE</td>
<td>AN91267 introduces you to PSoC® 4 BLE, an ARM® Cortex™-M0 based Programmable System-on-Chip (PSoC) that integrates a Bluetooth Low Energy (BLE) radio system.</td>
</tr>
</tbody>
</table>

Code Examples

- RtcDesign: Example Project for RTC Implementation in PSoC 3 and PSoC 5LP using the available RTC Component
- CE95915: Example Project for Implementing an RTC with PSoC® 4100 / PSoC 4200 Devices with an external crystal

Knowledge Base Articles

- Implementing a 32-kHz ECO Interface with PSoC® 4100 / PSoC 4200 – KBA95848: How can we implement a 32.768 kHz ECO interface with PSoC 4100 and PSoC 4200 series devices?

PSoC Creator Component Datasheets

- Character LCD: Implements the industry standard Hitachi HD44780 LCD display driver chip protocol
- Interrupt: Defines hardware-triggered interrupts
- Software Transmit UART: Provides an 8-bit RS-232 data-format compliant serial transmitter through software bit-banging
- Pins: Controls interface with physical I/O port pins
- Global Signal Reference: Allows access to device level global signals

Device Documentation

- PSoC 3 Datasheets: PSoC 3 Technical Reference Manuals
- PSoC 5LP Datasheets: PSoC 5LP Technical Reference Manuals
- PSoC 4 Datasheets: PSoC 4 Technical Reference Manuals

Development Kit (DVK) Documentation

- PSoC 3 Kits
- PSoC 5LP Kits
- PSoC 4 Kits
Document History

Document Title: CE96926 – PSoC® Real-Time Clock Based on Power Line Frequency
Document Number: 001-96926

<table>
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<tr>
<th>Revision</th>
<th>ECN</th>
<th>Orig. of Change</th>
<th>Submission Date</th>
<th>Description of Change</th>
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<td>4709131</td>
<td>BMAH</td>
<td>04/01/2015</td>
<td>New code example</td>
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<tr>
<td>*A</td>
<td>5735367</td>
<td>AESATMP9</td>
<td>05/18/2017</td>
<td>Updated logo and copyright.</td>
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