AN2387

# Core Independent Nightlight Using Configurable Custom Logic on ATtiny1617

## Features

- Low CPU Usage
- Core Independent Operation using a Configurable Custom Logic (CCL) Module
- Event System
- TCA0 – 16-Bit Timer/Counter Type A
- SPI0 – Serial Peripheral Interface
- AC0 – Analog Comparator
- DAC – Digital-to-Analog Converter
- EEPROM Data Memory
- Passive Infrared Detector
- Ambient Light Sensor
- 16 Intelligent Addressable RGB LEDs

## Introduction

This application note describes the use of Core Independent Peripherals (CIP), how to use the Configurable Custom Logic (CCL) to filter inputs from different sensors, and how to create specific communication protocols using a Microchip AVR® device, a Passive InfraRed sensor (PIR), Ambient Light Sensor, and 16 addressable RGB LEDs. Many peripherals are configured to work together, independent of the CPU.

The light should turn ON only when it is sufficiently dark and there is movement in front of the PIR sensor. The implementation uses the AVR Configurable Custom Logic module to determine when this occurs. Updating the addressable RGB LEDs take advantage of timer/counter PWM generation, SPI, and CCL to generate the specific single-line serial protocol.

## Table of Contents

# 1. Relevant Devices

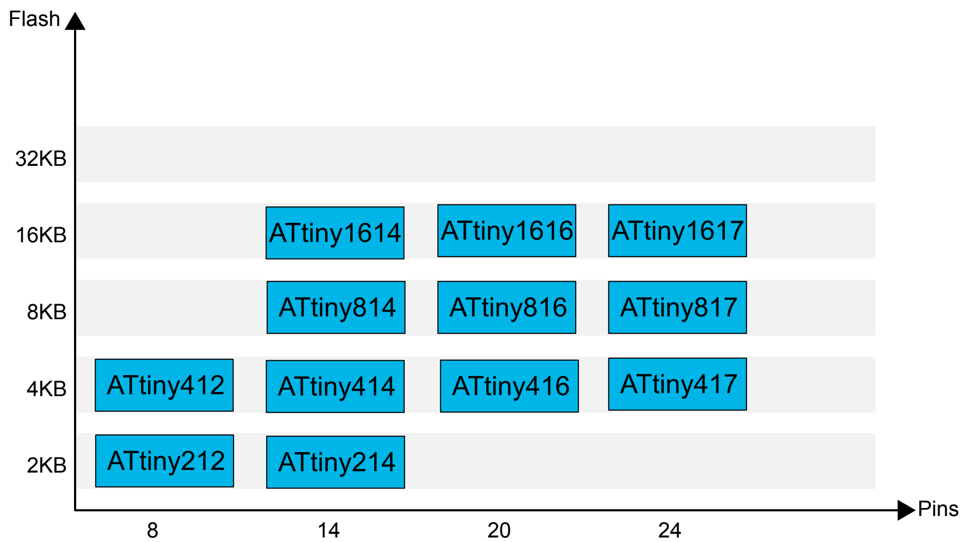
This chapter lists the relevant devices for this application note.

## 1.1 tinyAVR 1-Series

The figure below shows the tinyAVR® 1-series, laying out pin count variants and memory sizes:

- Vertical migration can be done upwards without code modification, since these devices are pin compatible and provide the same or even more features. Downward migration may require code modification due to fewer available instances of some peripherals.
- Horizontal migration to the left reduces the pin count and therefore also the available features.

**Figure 1-1. tinyAVR 1-Series Overview**




Devices with different Flash memory size typically also have different SRAM and EEPROM.

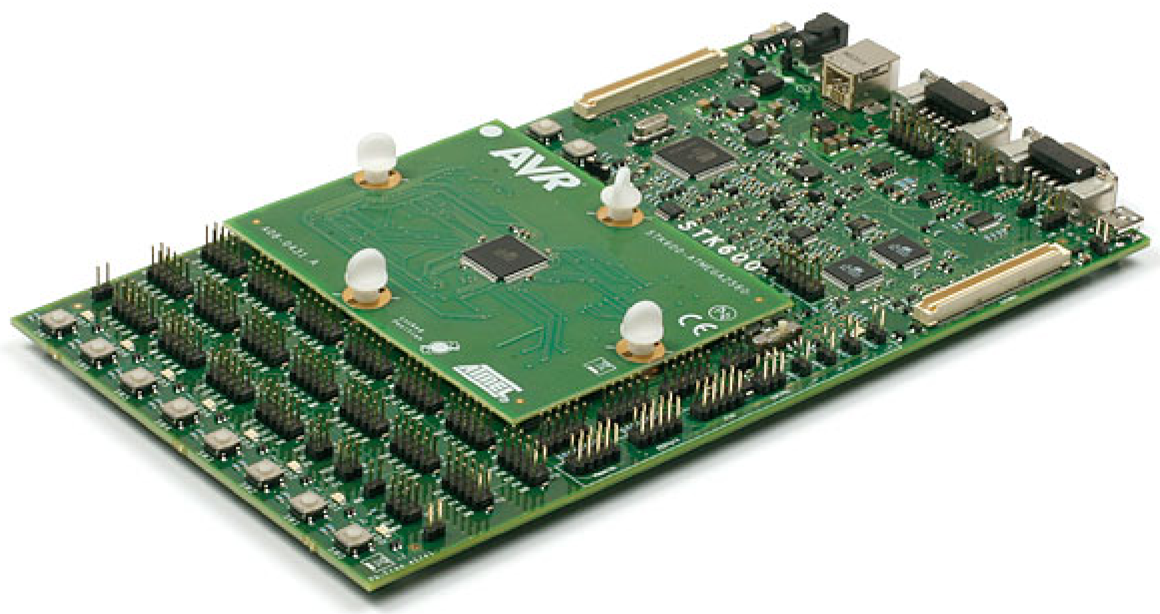
# 2. Components

Various hardware is needed for this application note. The hardware is listed and described below.

## 2.1 STK600

The STK®600 kit can be used for this application note together with the STK600-RC024T-103 routing card and the STK600-QFN24 top card.

**Figure 2-1. STK600**



## 2.2 Passive Infrared Detector

A PIR sensor detects changes in the amount of infrared radiation sensed. This varies depending on the temperature and surface characteristics of the object in front of the sensor.

When a person passes between the sensor and the background, the sensor detects the change from room temperature to body temperature, and then back again. The sensor converts the resulting change in the incoming infrared radiation into a change in the output voltage. Other objects with the same temperature as the background, but have different surface characteristics, will cause the sensor to detect a different emission pattern.

The PIR sensor used in this demo is the HC-SR505 mini, but any PIR sensor with a digital output above 3V can be used.

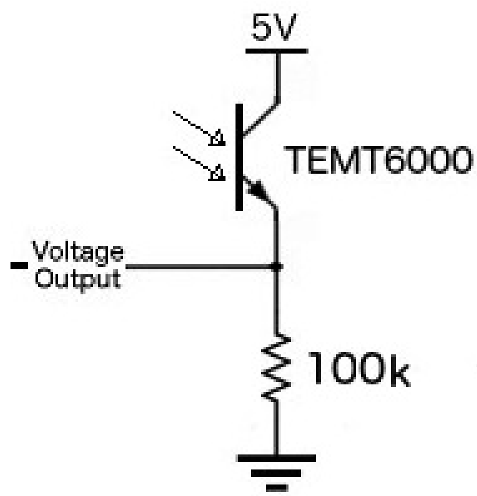
More information about how the PIR sensors work can be found at the following link: Passive Infrared Sensors.

**Figure 2-2. HC-SR505 Mini PIR Sensor**

## 2.3 Ambient Light Sensor

The ambient light sensor used is the TEMT6000 from Vishay. This sensor acts as an NPN transistor, so the more the sensor is exposed to light, the stronger the base bias, thus the higher the analog voltage on the signal pin.

**Figure 2-3. TEMT6000 Connections**




## 2.4 Intelligent Control LED

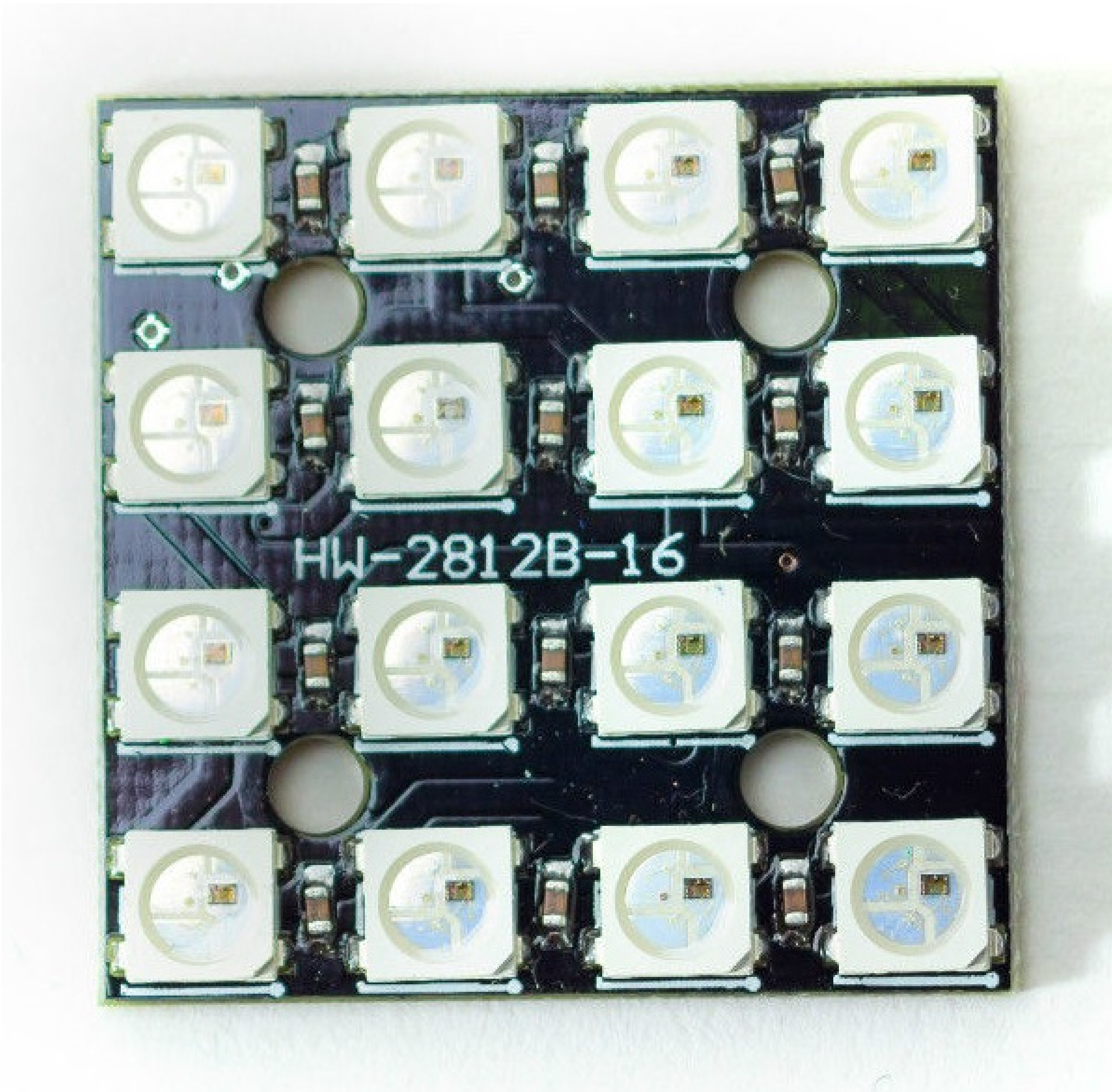
WS2812B is a smart RGB LED light where the control circuit is built into the package together with the RGB diodes. In addition to $V_{DD}$ and GND pins, the package has only one data input pin and one data output pin. By connecting the data output pin to the data input pin of the next device, it is possible to daisy chain the LEDs.

The data to the controller logic is transferred using a single-line serial protocol. This protocol is not directly supported by any general microcontroller, but it is possible to emulate it by either bit banging the pattern or using hardware like the CCL. The data needed for each LED consists of 24 bits, eight bits for each of the RGB diodes.

The number of LEDs used in the application is by default 16 and can be adjusted in the code by changing the Number_of_LEDS variable in the application code. These LEDs draw a lot of power, especially when white light is used with high intensity. Care must be taken to ensure that the power supply can handle the number of LEDs used.

A WS2812B-16 board was used for this demo.

**Figure 2-4. WS2812B-16 Board**




There is one data line and the protocol is timing sensitive. The details can be found in the WS2812B data sheet.

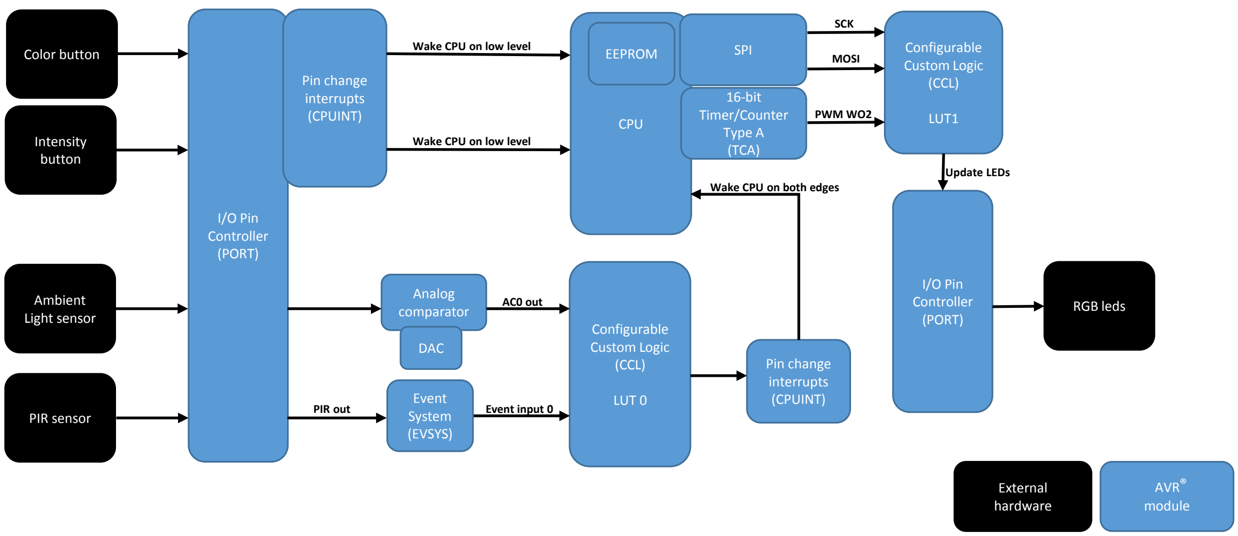
# 3. Implementation

## 3.1 System Overview

The Core Independent Nightlight demo uses the CCL module at its base.

The system overview can be seen in the figure below.

**Figure 3-1. System Overview**

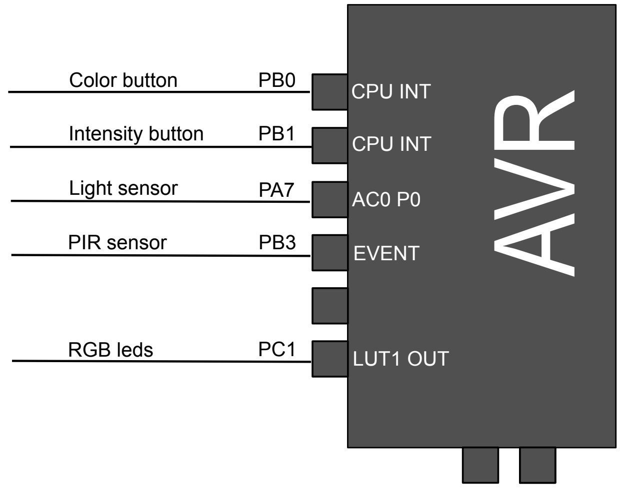



## 3.2 Connections

External hardware connected to the AVR is listed below.

- Color Button Connected to PB0
- Intensity Button Connected to PB1
- Ambient Light Sensor Connected to PA7
- PIR Sensor Connected to PB3
- RGB LED Connected to PC1

**Figure 3-2. External Pin Connection**

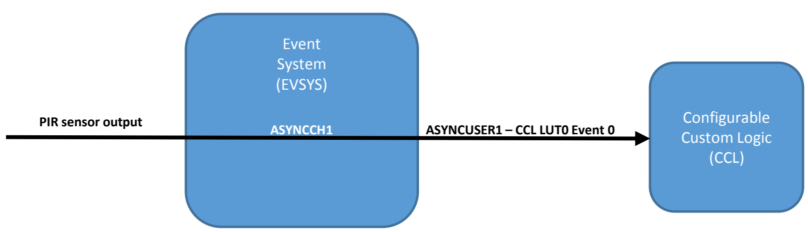



In addition, there are internal connections done in the code as described below:

- DAC output to negative input on Analog Comparator 0
- PB3 and LUT0 input 0 through event system
- Analog Comparator (AC) output to LUT0 input 1
- SPI0 SCK to LUT1 input 0
- SPI0 MOSI to LUT1 input 1
- TCA WO2 to LUT1 input 2

The PIR sensor needs to be connected to one of the input pins on LUT0. The *I/O Multiplexing and Considerations* chapter in the ATtiny1617 data sheet shows that the RESET and the LUT0-IN0 are on the same pin and that the SPI is sharing pins with the other LUT0 inputs. Moving the SPI to the alternate pin location can be done, but it will come into conflict with LUT1 out. To solve this problem, it is possible to use the Event system to route any other free I/O pin to the event input of LUT0.

**Figure 3-3. Event System Setup**



## 3.3 CCL Configuration

The CCL is a programmable logic peripheral which can be connected to the device pins, to events, or to other internal peripherals. The CCL can serve as “glue logic” between the device peripherals and external devices.

The CCL can be configured to form Combinatorial Logic Functions realizing a logic expression, which is a function of up to three inputs. This configuration is done in look-up tables. On ATtiny1617 there are two look-up tables available with three inputs where each can be configured separately.

On the ATtiny1617 nightlight, the Ambient Light Sensor and PIR sensor are attached to the LUT0 inputs. Addressable RGB LEDs are connected to the LUT1 output.

The idea is that the RGB LEDs should not turn ON before it is dark AND there is a movement in front of the PIR. This means that both sensors need to “trigger” before the CPU take action and turn ON the LEDs. To avoid the CPU polling the sensors to check if both sensors have triggered, the CCL does this while the CPU sleeps. When LUT0 wakes the CPU, LUT1 together with the SPI and TCA work to turn the LEDs ON or OFF.

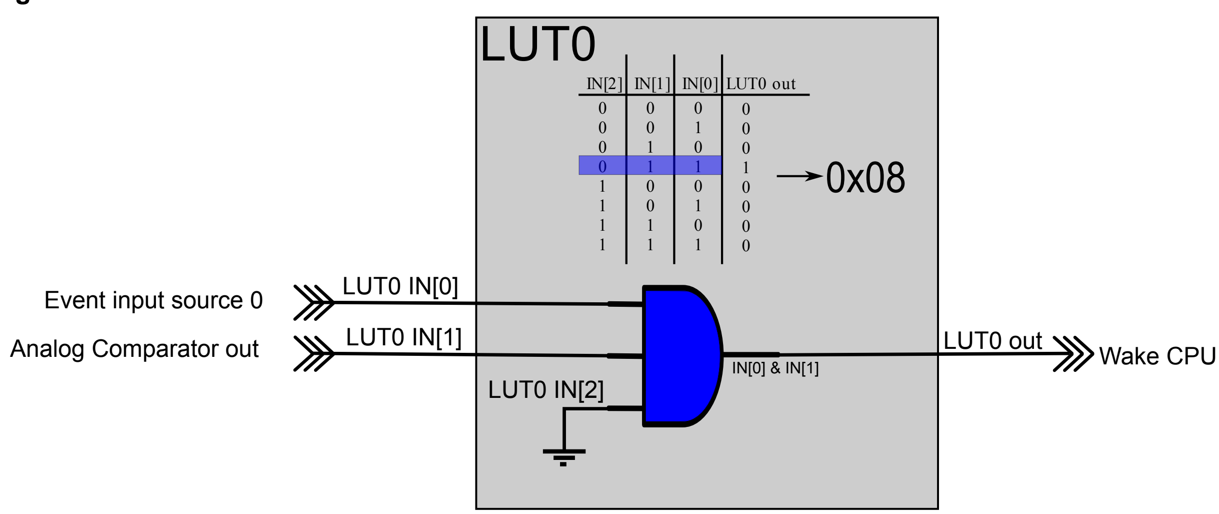
### 3.3.1 LUT0 Configuration

LUT0 should only wake the CPU when the Ambient Light Sensor is not exposed to light AND when there is movement in front of the PIR sensor. This means LUT0 needs to be configured as an AND gate to achieve the wanted behavior.

- IN[0] is connected to Event input 0
- [IN1] is connected to Analog Comparator 0
- [IN2] is masked (tied low internally)
- LUT0 out is on PORTB 4, which is configured with edge interrupt on both edges
- Value to put in TRUTH0 register to get this logic is 0x08

The CCL setup for LUT0 on how to create a 2-input AND gate can be found in the figure below.

**Figure 3-4. LUT0 Connections and Truth Table**




### 3.3.2 LUT1 Configuration

When the CPU is awakened by LUT0, the LEDs are either going to be turned ON or OFF. By using LUT1 together with the SPI and TCA, it is possible to generate the specific single-wire PWM signal used by the WS2812B LED without writing a specific driver to perform the update.

Using the CCL together with TCA and SPI, it will not be necessary to write a specific software driver to update the LEDs. After initial configuration of the TCA and SPI, the procedure for updating the LEDs is very easy:

1. Start TCA by writing '1' to the enable bit.
2. Write the data to the SPI data register.
3. Wait for SPI to be performed.
4. Stop TCA by writing '0' to the enable bit.

Since there is no synchronization between the TCA output and the SPI clock, it is necessary to start and stop the TCA each time data is sent to the LEDs. It is also necessary to clear the TCA CNT register before TCA is started. This is done to make sure that the TCA starts counting from zero each time the LEDs are updated.

The serial protocol used by the WS2812B has three states:

- State 1 is logical '0'
- State 2 is logical '1'
- State 3 is reset and latch

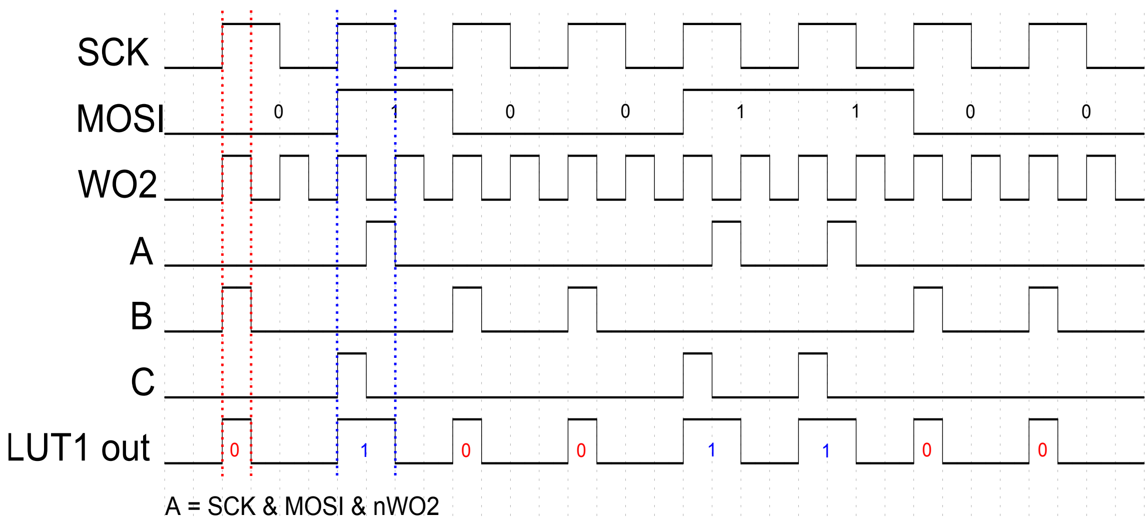
To be able to create State 1, which is equal to B in the timing diagram shown below, the logical expression (SCK, nMOSI, and WO2) needs to be realized.

Creating State 2, the logical expression (SCK and MOSI) is needed. This is not possible directly on LUT1 now since all three inputs are being used, and therefore must continue. This means that a combination of two logical expressions are needed to achieve this. In the timing diagram below, the logical expression C (SCK, MOSI, and WO2) will take care of the first half of State 2 and logical expression A (SCK, MOSI, and nWO2) will handle the remainder.

State 3 is the resetting and latching of the new data. If the data line is held low for 50 µs after the data has been sent, the control circuit inside each LED will reset and latch the new color.

When A, B, and C are combined through an OR gate, the correct signal one-wire protocol is generated.

**Figure 3-5. LUT1 Timing**



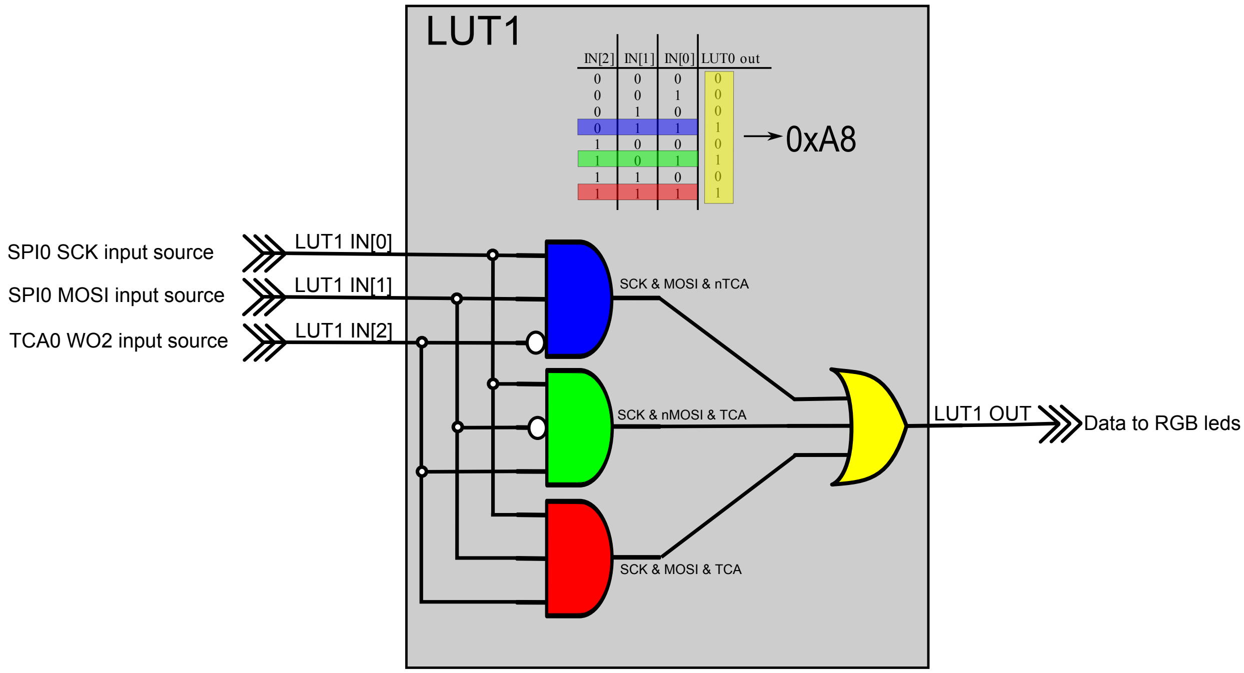

A = SCK & MOSI & nWO2
B = SCK & nMOSI & WO2
C = SCK & MOSI & WO2

LUT1 out = A || B || C

Connecting the TCA and SPI to LUT1 can be done internally when setting up the CCL.

- [IN0] is connected to SPI0 SCK
- [IN1] is connected to SPI0 MOSI
- [IN2] is connected to TCA0 WO2
- LUT1 out is connected to DIN on the first LED
- Value to enter in the TRUTH1 register to get this logic is 0xA8

**Figure 3-6. LUT1 Connections and Truth Table**



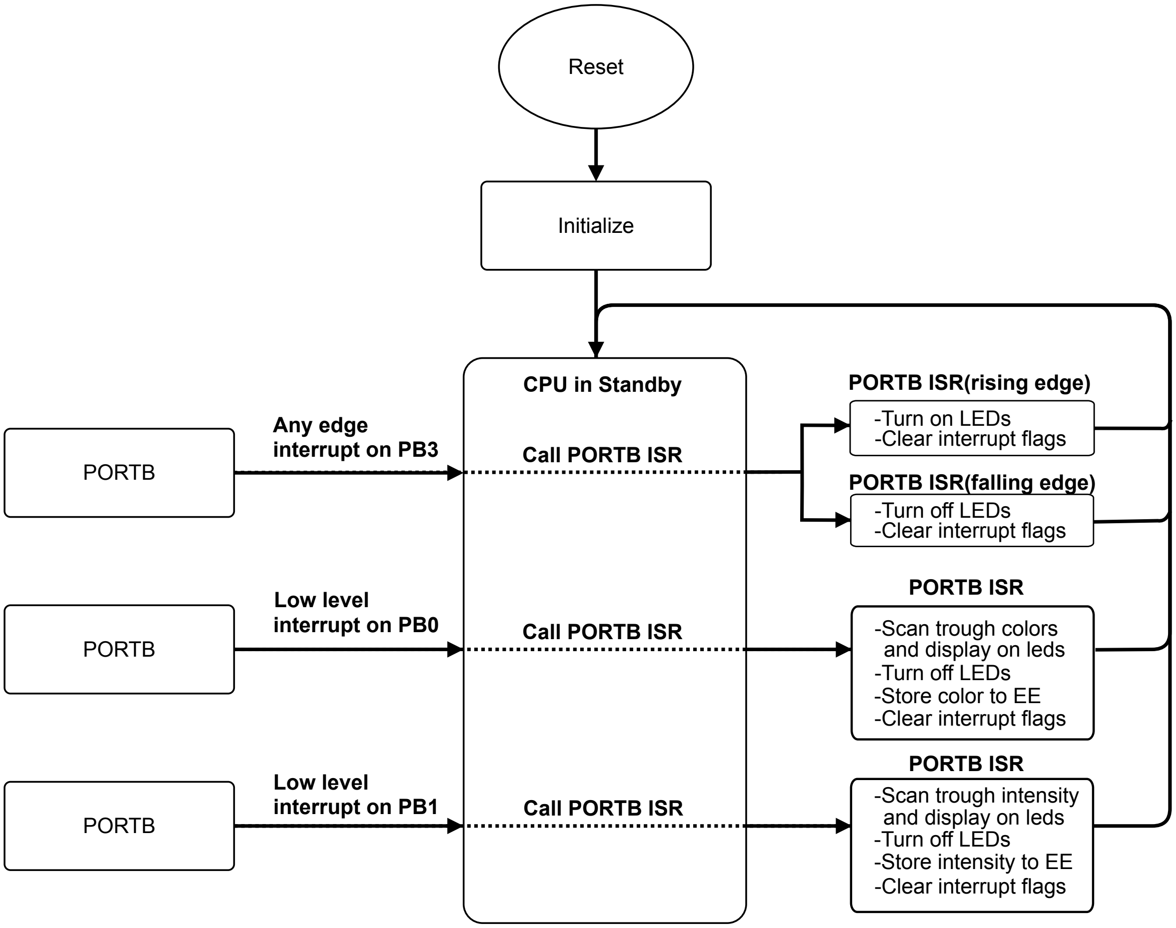

To get the correct timing it is important to set the correct CPU and peripheral speed by choosing the correct prescalers and clock sources.

- The CPU clock source is a 20 MHz internal oscillator with prescaler set to 2
- The SPI0 clock source is the system clock/16
- The TCA0 clock source is the system clock with the PER register set to 7 and the CMP2 register set to 4

## 3.4 Program Flow

The figure below shows an overview of the program flow.

**Figure 3-7. Program Flow**




The Initialize routine sets up:

- Configures CPU clock and prescaler
- Configures I/O pins
- Configures all the peripherals used
- Configures the Event system
- Configures the interrupts and Sleep mode
- Fetches the last used color and intensity data from EEPROM and puts them into variables
- Make sure the LEDs are turned OFF

The Color and Intensity buttons are connected to PB0 and PB1. When either of these buttons are pressed and held low, it will create a low-level interrupt to wake-up the CPU from standby sleep.

If the Color button is pressed, it will cause the CPU to wake-up and step through the different colors and display the color on the LEDs. When the button is released, the current color is stored to EEPROM, the Color variable is updated, the LEDs are turned OFF, and the CPU returns to standby sleep.

If the Intensity button is pressed, it will cause the CPU to wake-up and step through the different intensities and display the intensity of the color chosen on the LEDs. When the button is released, the current intensity is stored to EEPROM, Intensity variable is updated, the LEDs are turned OFF, and the CPU returns to standby sleep.

The system will remain in standby sleep as long as the logical expression setup in LUT0 is false and none of the buttons are pressed. Both the ambient light sensor and the PIR sensor need to provide a logical ‘1’ to LUT0 to wake the CPU. The PIR sensor will output a logical ‘1’ when there is movement in front of the sensor. The ambient light sensor is connected to the positive pin P0 on Analog Comparator 0 and the DAC provides the voltage to the negative input. The output voltage on the ambient light sensor will decrease when the light is reduced. By using the DAC on the negative input it is possible to adjust the level where the Analog Comparator 0 will trigger and output a logical ‘1’.

When both the AC0 and the PIR output a logical ‘1’ to the LUT0 inputs, the output of the AND gate configured in LUT0 will go from ‘0’ to ‘1’, thus creating a rising edge that will wake the CPU from standby sleep. The CPU will go into the correct interrupt routine and turn ON the LEDs and then go back to sleep. If the movement stops in front of the PIR or the ambient light sensor is exposed to more light, the Analog Comparator output will go from ‘1’ to ‘0’. The AND gate in LUT0 will go low, creating a falling edge on the pin connected to LUT0 output, the CPU will wake-up and turn OFF the LEDs, and then return to sleep.

# 4. Get Source Code from Atmel START

The example code is available through Atmel START, which is a web-based tool that enables configuration of application code through a Graphical User Interface (GUI). The code can be downloaded for both Atmel Studio 7.0 and IAR™ IDE via the **Examples**-link below, or the **BROWSE EXAMPLES** button on the Atmel START front page.

**Web page:** http://start.atmel.com/

**Documentation:** http://start.atmel.com/static/help/index.html

**Examples:** http://start.atmel.com/#examples

In the Examples-browser, search for: Core Independent Nightlight Using CCL on ATtiny1617 (press **User Guide** in Atmel START for detailed requirements for the example project).

Double-click the downloaded .atzip file and the project will be imported to Atmel Studio 7.0.

For information on how to import the project in IAR, press the **Documentation**-link above, select 'Atmel Start Output in External Tools' and 'IAR Embedded Workbench®'.

# 5. Revision History

| Doc Rev. | Date | Comments |
| --- | --- | --- |
| B | 08/2017 | Added chapter Relevant Devices. |
| A | 03/2017 | Initial document release. |

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ISBN: 978-1-5224-2008-8

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