Please note that Cypress is an Infineon Technologies Company.

The document following this cover page is marked as "Cypress" document as this is the company that originally developed the product. Please note that Infineon will continue to offer the product to new and existing customers as part of the Infineon product portfolio.

Continuity of document content

The fact that Infineon offers the following product as part of the Infineon product portfolio does not lead to any changes to this document. Future revisions will occur when appropriate, and any changes will be set out on the document history page.

Continuity of ordering part numbers

Infineon continues to support existing part numbers. Please continue to use the ordering part numbers listed in the datasheet for ordering.

THIS SPEC IS OBSOLETE

Spec No: 001-64069

Spec Title: AN64069 - LED LIGHTING CONTROL USING POWERLINE COMMUNICATION AND BLUETOOTH

Sunset Owner: Aditya Yadav (ADIY)

Replaced by: None

AN64069 – LED Lighting Control Using Powerline Communication and Bluetooth

AN64069

Associated Project: Yes
Associated Part Family: CY8CPLCxx/CY8CLED16P01
Software Version: PSoC® Designer™ 5.1
Associated Application Notes: AN60934, AN60834

Application Note Abstract

AN64069 describes the control of smart home lighting systems using Cypress's Powerline Communication (PLC) solution interfaced to a PC via Bluetooth. Attached to this application note are a Graphical User Interface (GUI) and a firmware project that bridges the Bluetooth and PLC networks. The GUI allows visual control of the lighting parameters of multiple Cypress kits including CY3276, CY3277, CY3267, and CY3268.

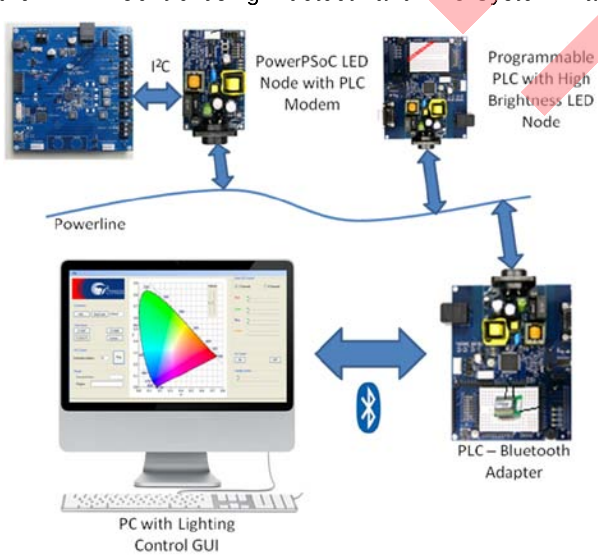
Introduction

Recent improvements in LED lighting and smart grid technology call for sophisticated methods of implementing home automation systems. We have developed a smart home application where PLC and Bluetooth are used to control different devices. PLC is the ideal networking technology for enabling the smart home as it does not require any additional infrastructure to communicate to all areas of the home. For smart home systems that require a sophisticated control center, a link needs to be established between that control center and the PLC system. The answer to the issue is Bluetooth, which is integrated in most PCs and portable devices. With a Bluetooth wireless transceiver connected to the PLC-enabled home network, a PC or portable device can be used as the sophisticated user interface into the smart home grid at no added cost.

The application described in the following sections implements an LED lighting control system. The user controls the color and brightness of the different PLC enabled LEDs through a PC GUI. The GUI connects to the Bluetooth – PLC adapter that uses Cypress's Programmable PLC platform to interface with a Parani ESD 200 Bluetooth module. The PLC enabled LEDs are either Cypress's Programmable PLC with Ez-Color (CY8CLED16P01) or PowerPSoC® Intelligent LED Drivers connected to PLC integrated solution through an I^2C interface.

This application note provides an overview of the PLC and Bluetooth technologies. It explains how to interface the Bluetooth module to the Cypress CY8CLED16P01 programmable PLC device, using the CY3276 or CY3277 PLC Development Kit or a PowerPSoC device interfaced to a CY8CPLC10 fixed-function PLC device. Lastly, it describes an example project for controlling LED modules with PLC from a Bluetooth-enabled PC.

Figure 1. LED Control using Bluetooth and PLC System Diagram



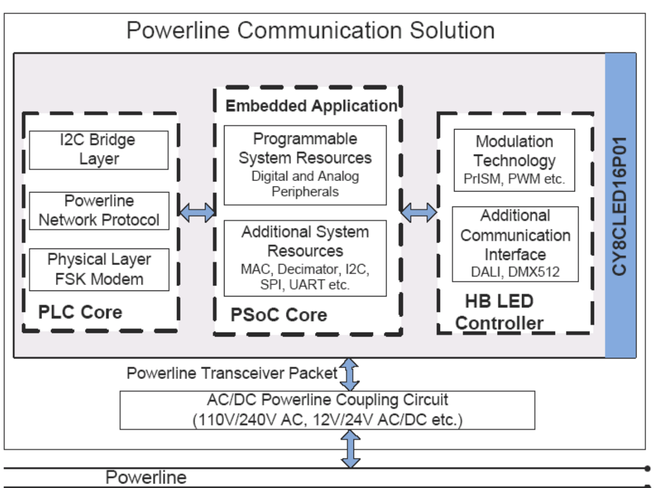
Powerline Communication

Powerlines are a widely available communication medium all over the world for PLC technology. The pervasiveness of Powerline also makes it difficult to predict the characteristics and operation of PLC products. Because of the variable quality of Powerlines around the world, implementing robust communication over Powerline has been an engineering challenge for years. The Cypress PLC solution enables secure and reliable communication over Powerline. Cypress PLC features that enable robust communication over Powerline include:

- Integrated Powerline PHY modem with optimized filters and amplifiers to work with high voltage and low voltage Powerlines.
- Powerline optimized Network Protocol that supports bidirectional communication with acknowledgement based signaling. In case of data packet loss due to noise on the Powerline, the transmitter has the capability to retransmit the data.
- 8-bit CRC for error detection and data packet retransmission.
- A Carrier Sense Multiple Access (CSMA) scheme built into the Network Protocol that minimizes collision between packet transmissions on the Powerline, supports multiple masters, and enables reliable communication on a bigger network.

A block diagram of the PLC solution is shown in Figure 2 with the programmable CY8CLED16P01 PLC transceiver with HB LED controller as the example. The PLC family of devices also contains the fixed-function CY8CPLC10 PLC transceiver that has an I^{2}C interface to the host, and a programmable CY8CPLC20 PLC transceiver. The programmable PLC devices can have the host application running inside or can have an external interface (I^{2}C, SPI, UART, and so on).

Figure 2. Cypress PLC Solution Block Diagram



To interface a PLC device to the Powerline, a coupling circuit is required. The following kits contain the required coupling circuitry for high voltage or low voltage powerline applications.

- CY3272 High Voltage PLC Evaluation Kit (EVK)
- CY3273 Low Voltage PLC Evaluation Kit (EVK)
- CY3274 High Voltage Programmable PLC Development Kit (DVK)
- CY3275 Low Voltage Programmable PLC Development Kit (DVK)
- CY3276 High Voltage Programmable PLC + HB LED Control Development Kit (DVK)
- CY3277 Low Voltage Programmable PLC + HB LED Control Development Kit (DVK)

The high voltage kits CY3272, CY3274, and CY3276, are designed with the filtering and power supply circuitry to operate on 110 V to 240 V AC Powerlines. They are compliant to the following CENELEC and FCC standards.

- Powerline Signaling (EN50065-1:2001, FCC Part 15)
- Powerline Immunity (EN50065-2-1:2003, EN61000-3-2/3)
- Safety (EN60950)

The low voltage kits CY3273, CY3275, and CY3277, are designed to operate on 12 V to 24 V AC/DC Powerlines. All three low voltage kits are designed with the filtering and power supply circuitry.

The CY3272 and CY3273 kits are used to evaluate the CY8CPLC10 PLC fixed function device, which has an I^{2}C port for interfacing to an external host microcontroller.

The CY3274 and CY3275 kits are used to develop an embedded powerline networking application on the CY8CPLC20 programmable PLC device. They contain user interface options such as I^{2}C, RS232, GPIO, analog voltage, LCD display, and LED to develop a full application.

The CY3276 and CY3277 kits are used to develop a powerline controller and embedded host application with High Brightness (HB) LED control on the CY8CLED16P01 Programmable PLC + HB LED Control device. They also contain many user interface options such as I^{2}C, RS232, GPIO, analog voltage, LCD display, and LED to develop a full application. They have the added feature of a HB RGB LED daughter card to evaluate lighting control with powerline communication by the CY8CLED16P01 device. More information on PLC can be found at www.cypress.com/go/plc.

Bluetooth Technology

Bluetooth technology is by far the most successful of any of the short-range wireless standards. Bluetooth was conceived with the mobile phone as the center of the universe. As noted on the Bluetooth Special Interest Group website, it has been around for just over ten years (twice as long as ZigBee) and outsells all of the other short-range standards put together, with over one billion chips shipped every year. The very first Bluetooth products can still communicate with new ones that you buy today – something that neither 802.11 nor ZigBee can claim.

Equally important, over the decade it has been shipping, it has evolved to address all of the key requirements of the smart home market.

- **Robustness**. Bluetooth technology is the only frequency hopping standard. That makes it very appropriate for the home environment, where the spectrum is unpredictable.
- **Coexistence.** Bluetooth technology is the only wireless standard that includes coexistence mechanisms to maintain performance in noisy environments. That means that it continues to work when new radios are introduced in a home.
- **Long Range.** The latest Bluetooth chips provide ranges as good as any other 2.4 GHz technology, at significantly lower operating power.
- **Proven security.** Bluetooth technology has mature security that has evolved to cope with a variety of security attacks, along with well tested implementations that have proven to be resistant to hacking.
- **Licensing.** The royalty-free license model of the Bluetooth SIG extends to all versions of the technology.

Currently, almost every portable device comes with a built-in Bluetooth transceiver, which is accessible to the developers in their applications. This enables the use of software developed for notebooks, smart phones or any other portable device into smart homes.

Bluetooth to PLC Adapter

Application Development

The hardware interface of the adapter is shown in Figure 3. It consists of a CY8CLED16P01 device, interfaced through UART to a Parani ESD 200 Bluetooth - Serial Module.

The CY8CPL20 operates at a typical voltage of 5 V and the Bluetooth module operates at 3.3 V. Because the kit does not have a 3.3 V power supply, a fixed output voltage regulator is used to generate 3.3 V. The power connections between 5 V, the regulator, and 3.3 V of the Bluetooth module are also shown in Figure 3. All of this can be implemented on the breadboard space provided on the CY3274.

There are also four LEDs to indicate communication on either network. Three of them indicate activity on the PLC network: receive, transmit, and band-in-use, and there is one LED for Bluetooth status. The latter output should be wired to one of the general-purpose LEDs on the kit. The PLC status LEDs already use pins P2[1], P2[3], and P2[5] for BIU, RX, and TX respectively.

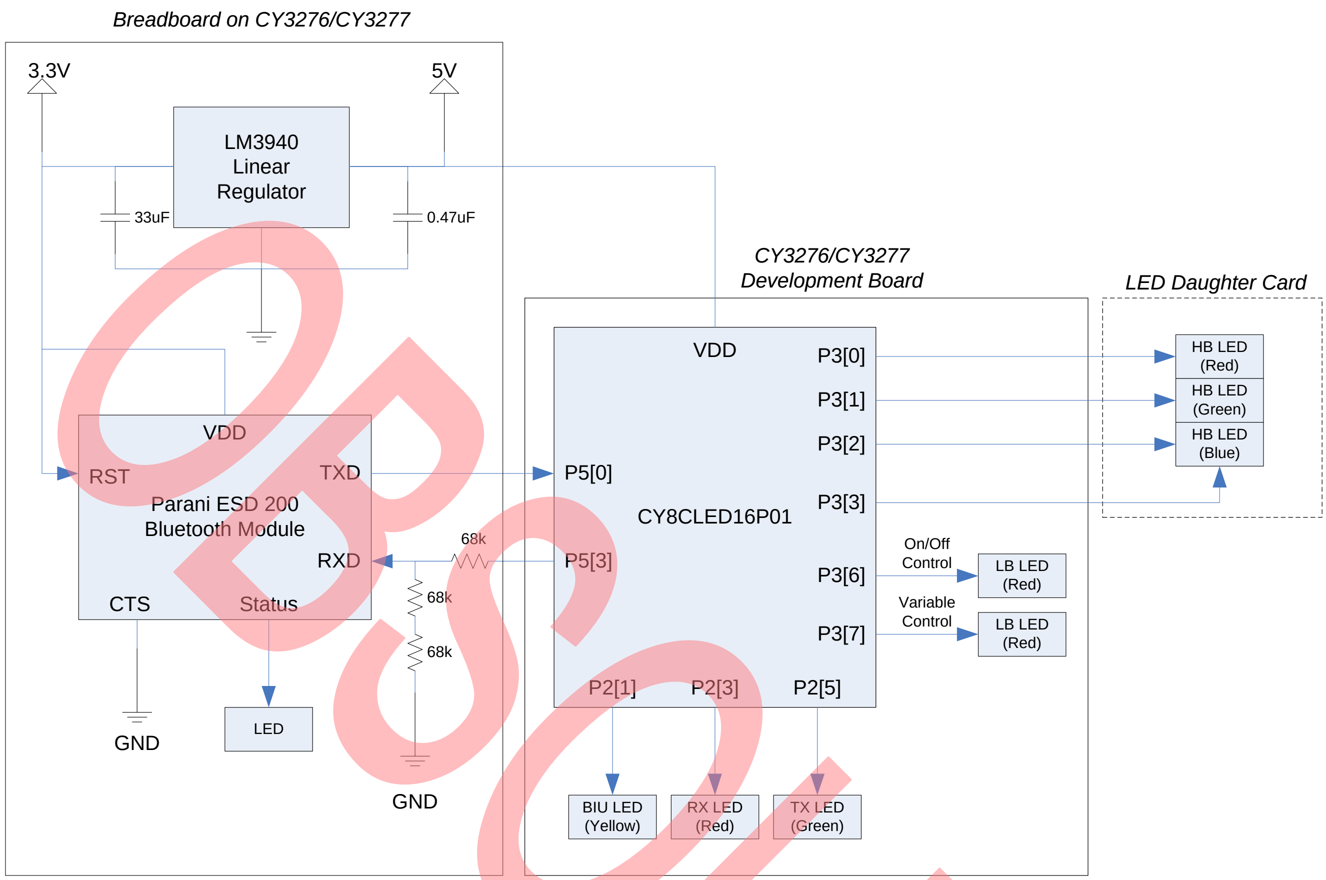
There is an LCD to display useful information to the user.

As the firmware is a bridge between the Bluetooth and PLC network, it does not initiate any communication on the Powerline unless it receives a command over Bluetooth.

The next sections describe how to transmit and receive a PLC packet using the memory array and how the Bluetooth packets are framed.

Pin	Name	Description
P2[1], P2[3], P2[5]	BIU, RX, TX LEDs	Already wired to the correct LEDs on the CY3275 or CY3277 boards.
P3[0], P3[1], P3[2]	Red, Green, Blue Dimming Output	Already wired to the High Brightness LEDs of the daughter card of the CY3275 or CY3277 boards.
P3[6]	DC Control LED	Connect to LED1. Switches either on or off when a digital control message is received.
P3[7]	Variable Control LED	Connect to LED2. Changes intensity depending on the value received in the variable control message.
P4[0] – P4[6]	LCD	Connect a LCD to the LCD1 header.

Figure 3. Bluetooth to PLC Adapter Pin Connections



Transmitting PLC Packets

To transmit a PLC packet, the following registers in the memory array need to be accessed. Only the bits that are important for this application are shown in Table 1. For details on these registers, refer to the PLT user module datasheet in PSoC® Designer™.

Table 1. PLC Memory Array Transmitter Registers

Offset	Register Name	Access	7	6	5	4	3	2	1	0
0x01	Local_LA_LSB	RW	8-bit Logical Address							
0x05	PLC_Mode	RW	TX_Enable	RX_Enable		Disable_BIU				
0x06	TX_Message_Length	RW	Send_Message			Payload_Length_MASK				
0x07	TX_Config	RW	TX_SA_Type	TX_DA_Type		TX_Service _Type	TX_Retry			
0x08	TX_DA	RW	Remote Node Destination Address (8 bytes)							
0x10	TX_CommandID	RW	TX Command ID							
0x11	TX_Data	RW	TX Data (31 bytes)							
0x69	INT_Status	R	Status_Value_ Change		Status_ UnableToTX	Status_TX_NO_ ACK				Status_TX_ Data_Sent

Interfacing the Bluetooth Module and the Packet Frame Structure

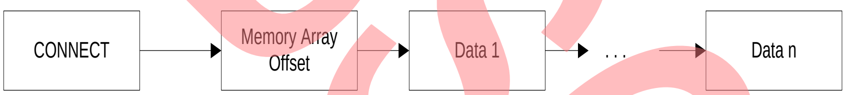
The Bluetooth module is controlled using AT commands. The firmware also sets the Bluetooth module into scanning mode, so that any other Bluetooth master can identify and connect to this Bluetooth slave device. For more information on the Parani ESD 200 Bluetooth module, please refer to the module's datasheet and the user manual available here.

The following AT commands are used in this application:

1. `AT\r\n` – It checks the connection status with the host controller.
2. `AT+BTCANCEL\r\n` – It terminates the current task that the Bluetooth module is executing.
3. `AT+BTSCAN\r\n` – It sets the Bluetooth module state to waiting. In this state, the other Bluetooth masters can ping and connect to the module.

When these commands are sent, the Bluetooth module sends a response back. The response could be a `\r\nOK\r\n` or a `\r\nERROR\r\n`. After sending the AT commands, the firmware waits until it receives the response from the module. The command terminator for the UART is set to `\n`.

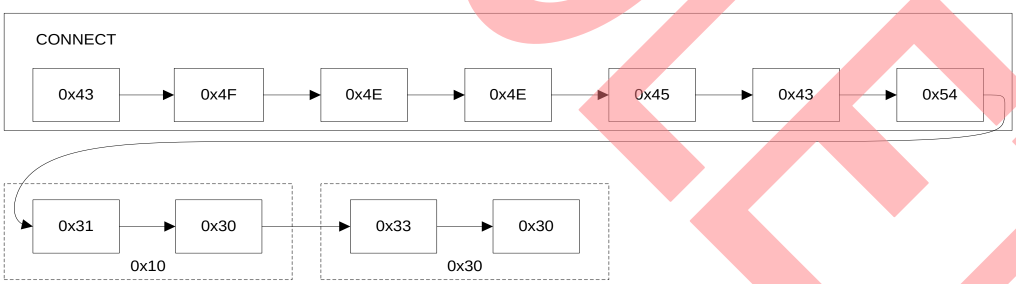
The Bluetooth to PLC Bridge receives commands over Bluetooth from a PC and transmits them over the Powerline. The method used to communicate data is similar to the one used for writing to a memory map. The key exception here is that the Bluetooth protocol has an identifier `CONNECT` before actual data. The bridge understands that the master is trying to communicate when it receives the identifier. When the firmware finds a packet received over Bluetooth, it checks for the identifier. If the identifier matches `CONNECT`, then the firmware decodes the remaining packet. Otherwise, the packet is discarded. The following diagram shows the packet structure for Bluetooth communication.



It should be noted that the Bluetooth module uses ASCII to transmit a packet. Therefore, for one byte of hexadecimal data, two bytes of characters are required to be transmitted.

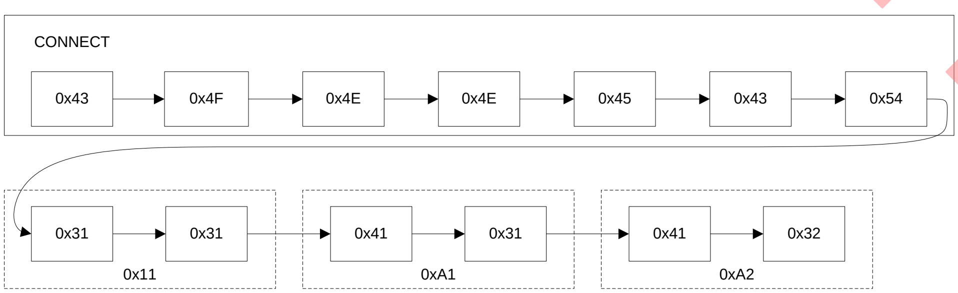
The following example shows how to set the TX Command ID to 0x30.

The PLT memory array offset for TX Command ID register is 0x10. The value to be set is 0x30. Therefore, adding these values in the packet frame shown in figure below gives:



The following example shows how to set the TX payload to 0xA1 0xA2.

The PLT memory array offset for Tx Data register starts from 0x11. The values to be set are 0xA1 and 0xA2. Therefore, adding these values in the packet frame shown in the figure below gives:

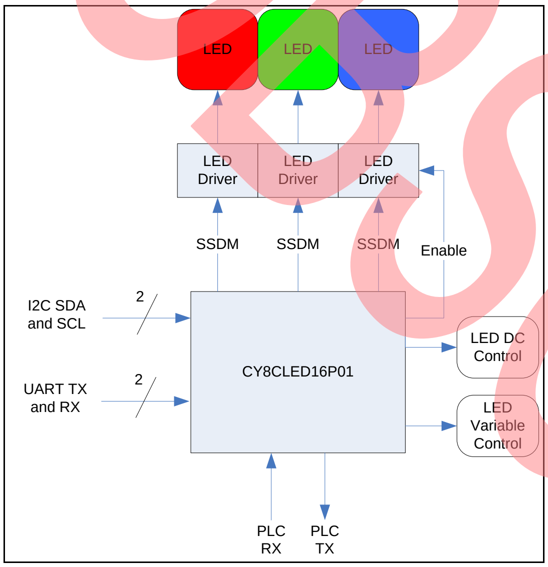


Since the same bridge can act as a Powerline node, if the destination address sent by the GUI matches the logical address of the bridge, then the bridge will process the received command.

Adapter Project

The project runs on the CY8CLED16P01 PLC plus HB LED controller device. A block diagram of the adapter system is shown in Figure 4. Note that this application can communicate with a PowerPSoC device and CY8CPLC10 fixed-function PLC device or a CY8CLED16P01 plus HB LED receiver. For more information on implementing either solution, refer to the application notes titled Remote High Brightness LED Control Using PowerPSoC® and Powerline Communication (PLC) - AN60934 and CapSense® Lighting Color Control with Powerline Communication (PLC) - AN60834 respectively. The firmware receiver project attached to either application note is compatible with the adapter project in this application note.

Figure 4. CY8CLED16P01 Adapter Block Diagram



The CY8CLED16P01 device has the following inputs and outputs.

- **I2C**: To provide an optional I2C interface. It can be used to communicate with a PC via a USB – I2C Bridge.
- **UART**: To provide the interface between the Parani Bluetooth module and the PLC device. It has a baud rate of 9600bps.
- **PLC:** The color information from the PC is received via Bluetooth. There are five possible messages that can be received. When the message received is addressed for the adapter, it processes the command. Otherwise, it sends out the command over PLC to the destination address. It should be noted that the current firmware does not support the ping feature that is available in the receiver project of AN60834.
  - **CIE Color Control (ID 0x31)**: This message contains the CIE color coordinates and brightness value. When this message is received, the CY8CLED16P01 performs the 3-channel color mixing algorithm. If the mixed color is valid (within the color gamut of the LEDs), the red, green, and blue channels are driven by their respective SSDM blocks. If the mixed color is invalid, the color mixing algorithm is performed on the previous valid co-ordinates with the most recent brightness value.
  - **Direct LED Control (ID 0x30)**: This message contains the dimming values of the red, green, and blue LEDs. The values are fed directly to the respective SSDM blocks for driving the LEDs.
  - **Digital Control (ID 0x32)**: When this message is received, the CY8CLED16P01 either switches on or off the DC Control LED.
  - **Variable Control (ID 0x33)**: When this message is received, the CY8CLED16P01 sets the value of the PWM that controls the Variable Control LED.

If the message received from the PC via Bluetooth is meant for a different node, it will transmit the packet out using the settings below. The PLC memory array settings for sending the CIE color coordinates is shown in the following table.

Table 2. Transmitter Memory Array Settings (CIE Co-ordinates)

Offset	Register Name	Access	7	6	5	4	3	2	1	0
0x01	Local_LA_LSB	RW	**0x01**							
0x05	PLC_Mode	RW	TX_Enable = '**1**'	RX_Enable = '**1**'						
0x06	TX_Message_ Length	RW	Send_Message = '**1**'			Payload_Length_MASK = '**00101**'				
0x07	TX_Config	RW	TX_SA_Type = '**0**' (Logical)	TX_DA_Type = '**00**' (Direct Logical)		TX_Service _Type = '**0**' (No ACK)	TX_Retry = '**0000**'			
0x08	TX_DA	RW	**0x00** (for broadcast) or **0x01 – 0xff** (depending on the value in the GUI)							
0x10	TX_CommandID	RW	**0x31**							
0x11	TX_Data[0]	RW	MSB of CIE x-coordinate							
0x12	TX_Data[1]	RW	LSB of CIE x-coordinate							
0x13	TX_Data[2]	RW	MSB of CIE y-coordinate							
0x14	TX_Data[3]	RW	LSB of CIE y-coordinate							
0x15	TX_Data[4]	RW	Brightness value							

The command ID and data payload for Direct RGB Control is shown in Table 3. Note that the other settings that are only shown in the previous table are the same.

Table 3. Transmitter Command ID and Data Payload Settings for Direct RGB Control

Offset	Register Name	Access	7	6	5	4	3	2	1	0
0x06	TX_Message_Length	RW	Send_Message = ‘**1**’			Payload_Length_MASK = ‘**00011**’ or ‘**00100**’				
0x10	TX_CommandID	RW	**0x30**							
0x11	TX_Data[0]	RW	Red Dimming Value							
0x12	TX_Data[1]	RW	Green Dimming Value							
0x13	TX_Data[2]	RW	Blue Dimming Value							
0x14	TX_Data[3]	RW	Amber Dimming Value (if 4 Channels are selected)							

Table 4 shows the command ID and data payload for a Digital Control message. Note that the other settings that are only shown in the previous table are the same.

Table 4. Transmitter Command ID Settings for the Digital Control Message

Offset	Register Name	Access	7	6	5	4	3	2	1	0
0x06	TX_Message_Length	RW	Send_Message = ‘**1**’			Payload_Length_MASK = ‘**00000**’				
0x10	TX_CommandID	RW	**0x32**							

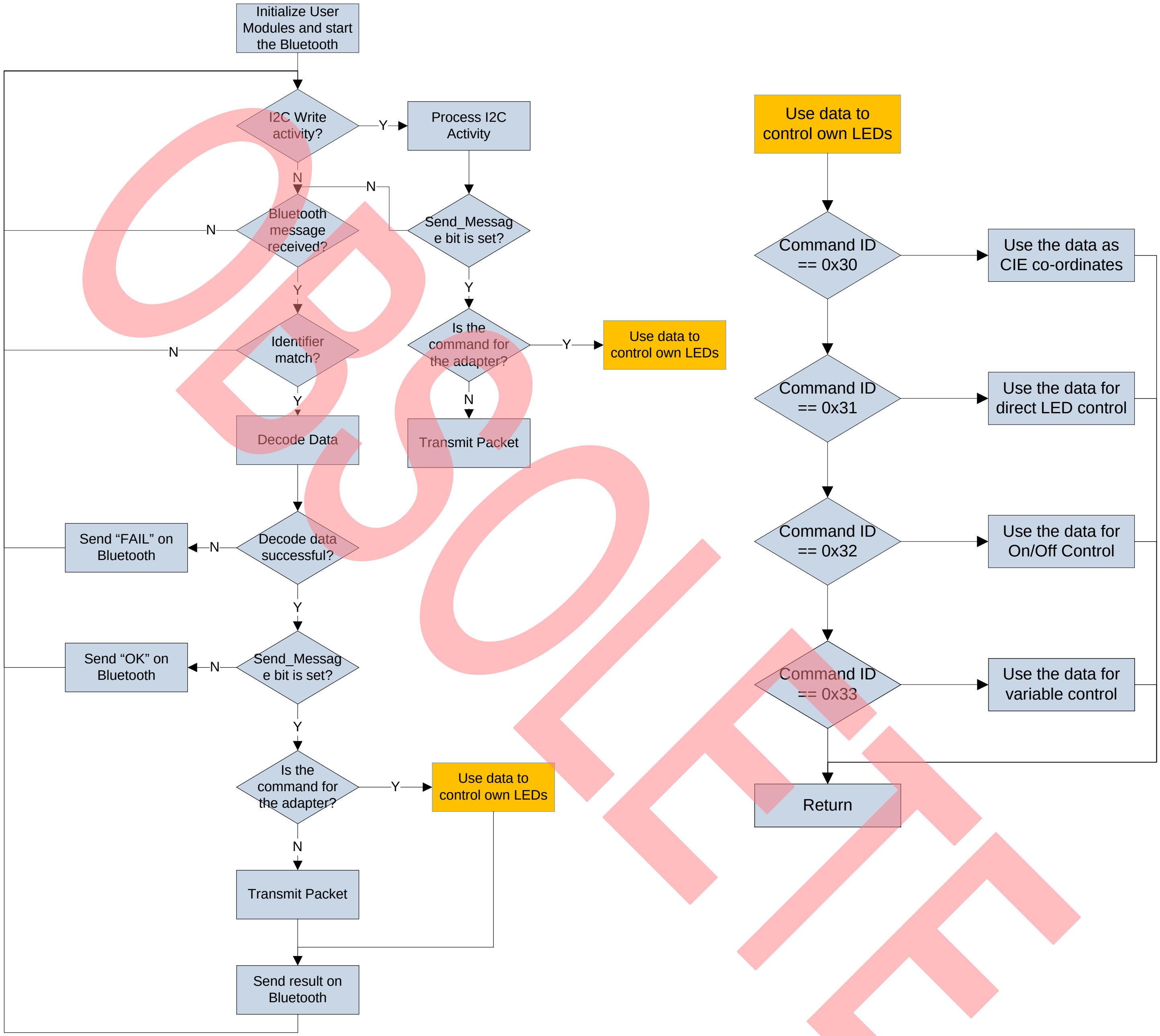
Table 5 shows the command ID and data payload for a Digital Control message. Note that the other settings that are only shown in the previous table are the same.

Table 5. Transmitter Command ID Settings for the Variable Control Message

Offset	Register Name	Access	7	6	5	4	3	2	1	0
0x06	TX_Message_Length	RW	Send_Message = ‘**1**’			Payload_Length_MASK = ‘**00000**’				
0x10	TX_CommandID	RW	**0x33**							

A flow chart of the adapter algorithm is shown in Figure 5.

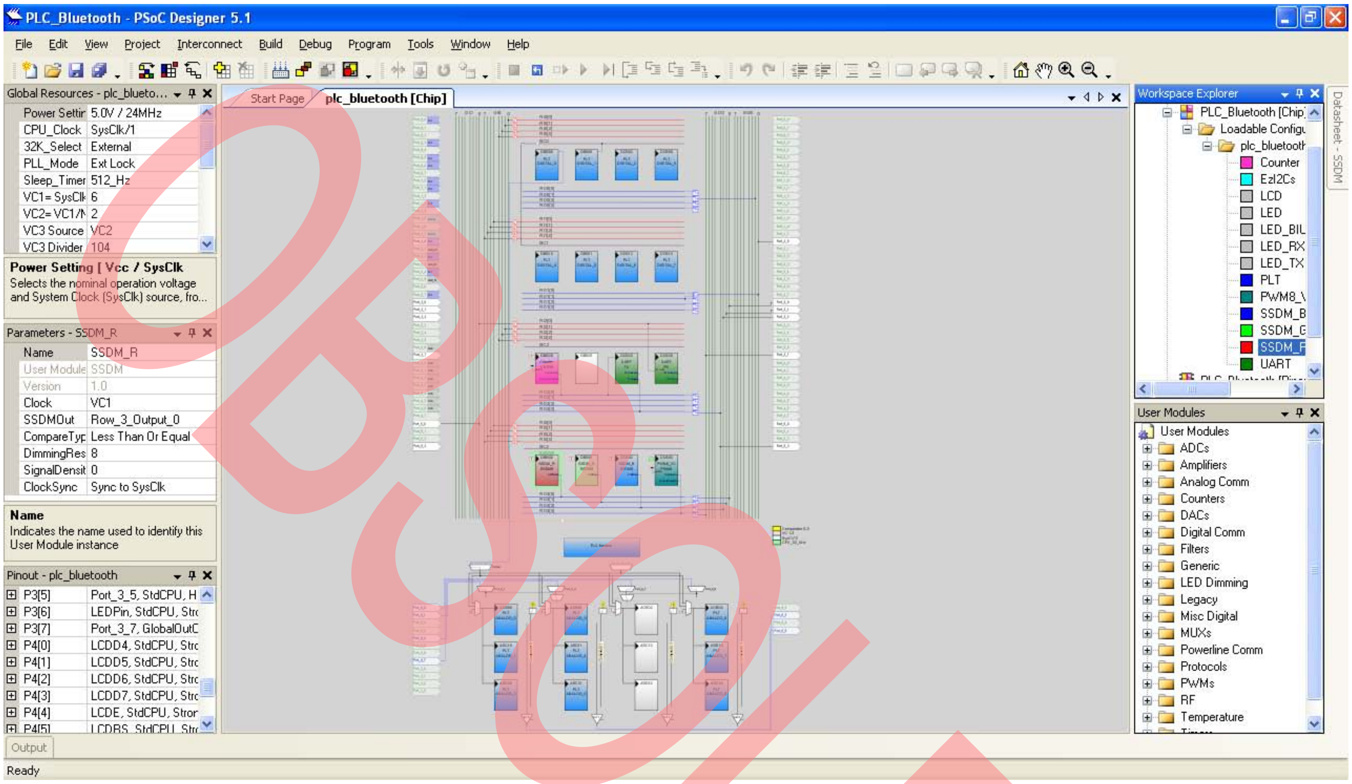
Figure 5. Adapter Flow Chart



PSoC Designer Project

The project was created with PSoC Designer 5.1. A figure of the chip level view of the project is shown in Figure 6. The configuration of the SSDM_R block is shown in the same figure. The configuration for the other SSDM blocks is the same, except for the *SSDMOut* property.

Figure 6. PLC Bluetooth PSoC Designer Project



The configuration of the UART that communicates with the Bluetooth module is shown as follows.

Properties - UART	
Name	UART
User Module	UART
Version	5.2
Clock	Row_2_Output_0
RX Input	Row_2_Input_0
TX Output	Row_2_Output_3
TX Interrupt Mode	TXComplete
ClockSync	Sync to SysClk*2
RxCmdBuffer	Enable
RxBufferSize	32
CommandTerminator	10
Param_Delimiter	13
IgnoreCharsBelow	0
Enable_BackSpace	Disable
RX Output	None
RX Clock Out	None
TX Clock Out	None
InvertRX Input	Normal

The configuration of the Counter that provides the clock reference for the UART is shown in the following figure. With VC1 = 4 MHz and a period of 51, this is equivalent to a baud rate of 9615bps.

Parameters - Counter	
Name	Counter
User Module	Counter8
Version	2.60
Clock	VC1
ClockSync	Sync to SysClk
Enable	High
CompareOut	Row_2_Output_0
TerminalCou	None
Period	51
CompareVal	26
CompareTyp	Less Than Or Equal
InterruptTyp	Terminal Count
InvertEnable	Normal

The firmware is written in C, with the exception of the PLT interrupt routines (in *PLTINT.asm*), which are modified to drive transmit, receive, and band-in-use LEDs.

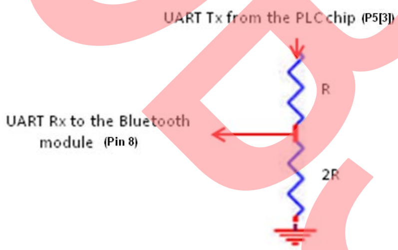
Implementation on Hardware

This section describes how to implement the adapter project in hardware.

Bluetooth to PLC Adapter Hardware

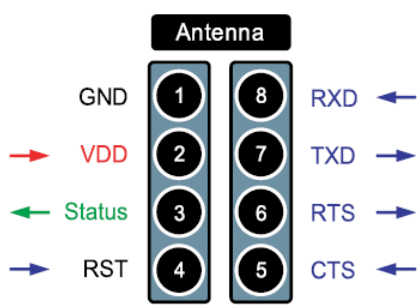
The adapter project was designed to run on the CY3276 High Voltage or CY3277 Low Voltage PLC + LED Control Development Kits. Follow these steps to set up the system (refer to Figure 7):

1. Connect jumper wires from P3[6] and P3[7] to the general purpose LEDs LED1 and LED2 on the board, respectively.
2. As the module operates at 3.3 V, it is recommended to use a potential divider on the UART TX pin of the PLC chip. A resistor ratio of 2:1 is used in this application as shown in the following figure.



The power supply is comprised of the LM3940 5 V to 3.3 V dropout regulator, a 0.47µF input capacitor and 33µF output capacitor (refer to Figure 3 for details). The current required by the Bluetooth module is over 100 mA.

Connect the Bluetooth Module as shown in Figure 3. Only seven pins of the Bluetooth module are used for the adapter.



Pin No	Pin	Function	Connected to
1	GND	Power pin	GND
2	VDD	Power pin	3.3V
3	Status	Bluetooth connection	LED3
4	RST	Reset	3.3V
5	CTS	Clear to Send	GND
6	RTS	Request to Send	NC
7	TXD	UART	P5[0]
8	RXD	UART	P5[3] through potential divider

3. Connect the LCD daughter card to the LCD connector.
4. Connect the LED daughter to the connector, ensuring that the connectors are aligned and the LEDs are facing down.
5. Plug the 12V DC adapter into J22. The LED drivers power up now.
6. Connect the board to the powerline. The blue power LED should turn ON.
7. Program the adapter firmware with the MiniProg in Reset mode.
8. Connect the LCD to the LCD1 connector.
9. Disconnect the programmer and reset the board.
10. The LCD on the board will display the welcome message “BT2PLC” on the first line as shown in Figure 8. If there is an error with the connections to the Bluetooth module, the LCD will display that on the second line.
11. If there was no error, the LCD will display various packet updates. The types of updates are:
    a. D = Shows the destination address.
    b. T = Shows the number of packets transmitted onto the powerline.
    c. C = Shows the command ID.
    d. Da = Shows the payload data.

    Note The display is only updated when a complete and correct color control command is received from the PC (via Bluetooth). Also, the adapter can be controlled by color commands and the logical address that the adapter has is set to 0x01. The user will need to modify the firmware to change this address.
12. Refer to the section “Binding the Bluetooth to PLC Adapter to the GUI” in the User Guide Provided with the GUI to connect the PC via Bluetooth or USB to the adapter. The adapter can be used to control the receiver nodes in either the Remote High Brightness LED Control Using PowerPSoC® or the Powerline Communication (PLC) - AN60934 or the CapSense® Lighting Color Control with Powerline Communication (PLC) - AN60834. The project can be evaluated using just the adapter, but to use the complete functionality of the adapter, it is advised to have one of these nodes also plugged into the powerline and set to a logical address other than 0x01.

Figure 7. CY3276 Hardware Configuration

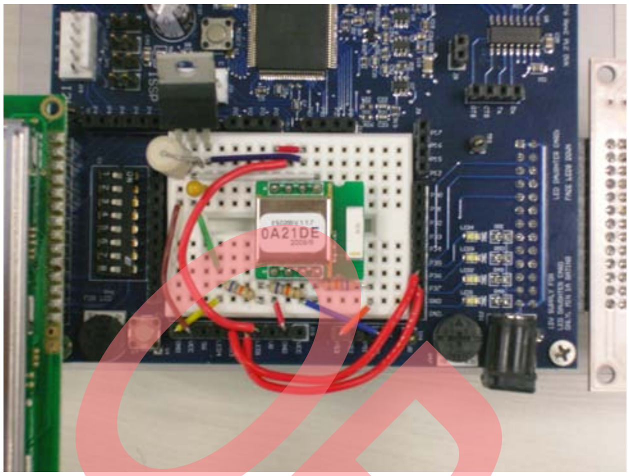
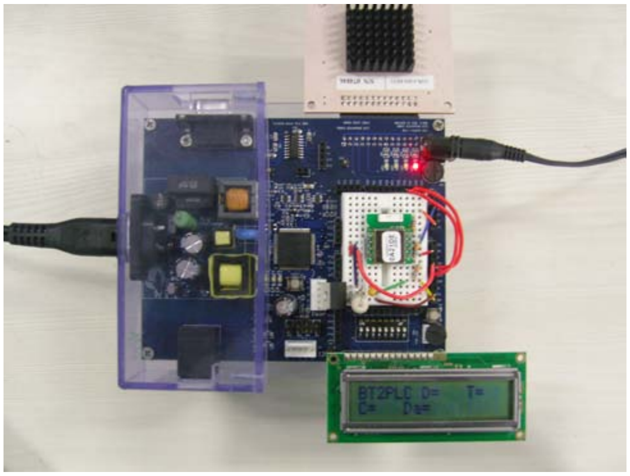


Figure 8 Using the Bluetooth to PLC Adapter



Document History

Document Title: AN64069 – LED Lighting Control Using Powerline Communication and Bluetooth

Document Number: 001-64069

Revision	ECN	Orig. of Change	Submission Date	Description of Change
**	3028540	RARP	09/15/2010	New application note
*A	3178409	FRE	02/23/2011	Corrected the decoupling capacitors and UART TX interface in Figure 3 Converted the firmware to use a Counter8 module instead of a Counter16 Replace Figure 3 with a new version. Fixed Typos Project updated to PSoC® Designer™ 5.1
*B	3333690	ADIY	08/01/2011	Obsolete document.

Cypress Semiconductor
198 Champion Court
San Jose, CA 95134-1709
Phone: 408-943-2600
Fax: 408-943-4730
http://www.cypress.com/