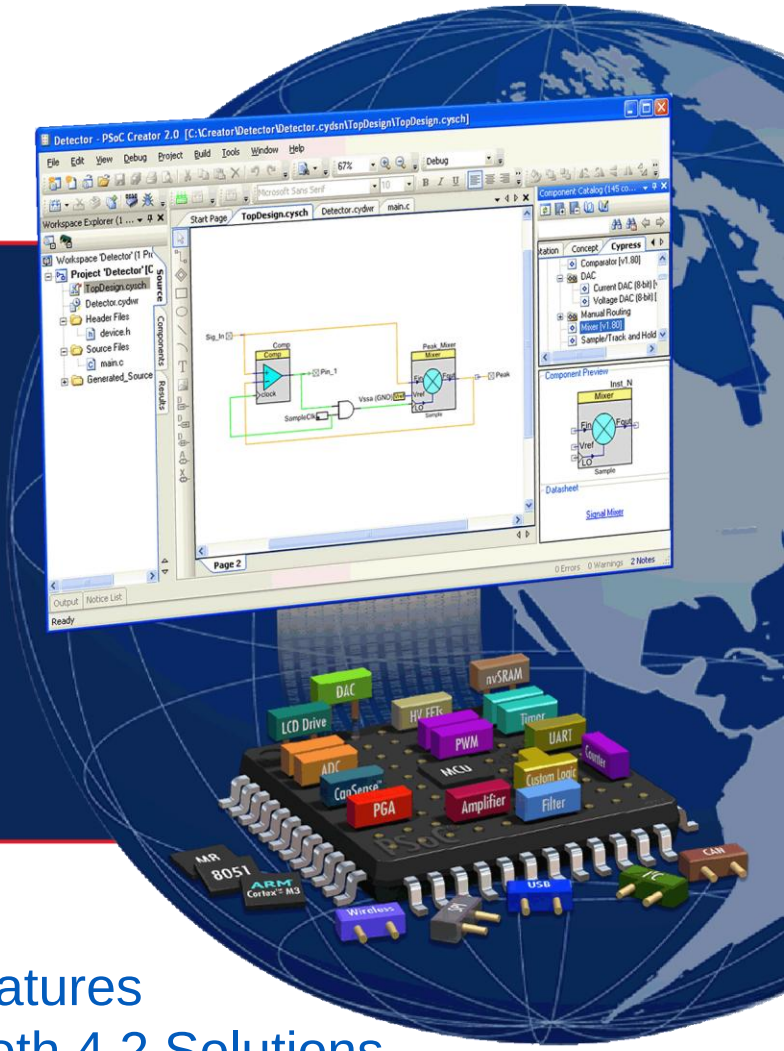
Customer Training Workshop:

Advanced BLE System Design

BLE = Bluetooth® Low Energy



Rapidly Design Systems with Complex BLE Features
Using the Industry's First Full-Featured, Bluetooth 4.2 Solutions

Workshop Objectives and Prerequisites

By the end of this workshop, you will

Learn how to use PSoC® Creator™[1] to rapidly design BLE systems using:

- Over-the-air firmware upgrades[2]
- New Bluetooth 4.2 features[3]: Data Length Extension, Enhanced Security and Privacy 1.2
- Multi-Role[4] BLE devices

Workshop prerequisites

Attend the "Introduction to BLE System Design" workshop or watch the "PSoC 4 BLE Video Tutorial Series" online

Workshop resources

Visit Cypress's BLE Solutions webpage for product datasheets, development kits, App Notes, software downloads, example projects and demo videos

[1] PSoC 3, PSoC 4, PSoC 5LP and PRoC BLE Integrated Design Environment (IDE)

[2] The process of replacing an existing firmware with a newer version over a wireless interface like BLE. Over-the-air firmware upgrade is described in the Lab #1: Over-The-Air Firmware Upgrade section

[3] Bluetooth 4.2 features are described in the Lab #2: Bluetooth 4.2 Features section

[4] Refers to multiple Generic Access Profile (GAP) roles described in the Lab #3: Multi-Role BLE Devices section

Workshop Agenda

Time	Page	Topic
0:00 (15 min)	4	Set Up and Install Software
0:15 (15 min)	5	PSoC and BLE Terms
0:30 (20 min)	8	Cypress BLE Portfolio
0:50 (30 min)	13	Demo: Upgrading to Bluetooth 4.2
1:20 (60 min)	20	Lab #1: Over-The-Air Firmware Upgrade[1]
2:20 (30 min)	25	Session Break
2:50 (60 min)	26	Lab #2: Bluetooth 4.2 Features[2]
3:50 (60 min)	33	Lab #3: Multi-Role[3] BLE Devices
4:50 (10 min)	37	Wrap-up
5:00		End of Workshop

[1] The process of replacing an existing firmware with a newer version over a wireless interface like BLE. Over-the-air firmware upgrade is described in the Lab #1: Over-The-Air Firmware Upgrade section
[2] Bluetooth 4.2 features are described in the Lab #2: Bluetooth 4.2 Features section
[3] Refers to multiple Generic Access Profile (GAP) roles described in the Lab #3: Multi-Role BLE Devices section

Set Up and Install Software

Required software and initial steps

Copy the contents of the provided USB drive onto your laptop and install the software featured in the table below

Follow the on-screen instructions to complete the installation in approximately 15 minutes

Software	Version	File Name
PSoC Creator[1] Installer	3.3 CP3 (or newer)	*"PSoCCreatorSetup_3.3_cp3_b9648.exe"*
CySmart[2] Installer	1.2 (or newer)	*"CySmartSetup_1.2.exe"*
BLE Pioneer Kit Installer	Revision ** (or newer)	*"CY8CKIT-042_BLE-A_SetupOnlyPackage_RevSS.exe"*
TeraTerm[3]	4.89	*"teraterm-4.89.exe"*
BLE Lab Exercise Files	2.0	*"AdvancedBLEWorkshop_2.0.zip"*

Required hardware:

BLE Pioneer Kit (CY8CKIT-042-BLE-A), shown at right

Android or iOS smartphone (not provided)

Raise your hand if you need help!

[1] PSoC 3, PSoC 4, PSoC 5LP and PRoC BLE Integrated Design Environment (IDE)
[2] A GUI-based software tool that installs on your PC to test and debug BLE functionality
[3] An open-source, free, terminal emulator software

PSoC Terms

PSoC

PSoC is the world's only programmable embedded **system-on-chip** integrating an MCU core, **Programmable Analog Blocks**, **Programmable Digital Blocks**, **Programmable Interconnect and Routing**[1] and **CapSense®**

Programmable Analog Block

A hardware block that is configured using **PSoC Components**[2] to create Analog Front Ends (AFEs), signal conditioning circuits with opamps and filters

Includes **Continuous Time Blocks**, analog-to-digital converters (ADCs) and digital-to-analog converters (DACs)

Continuous Time Block (CTB)

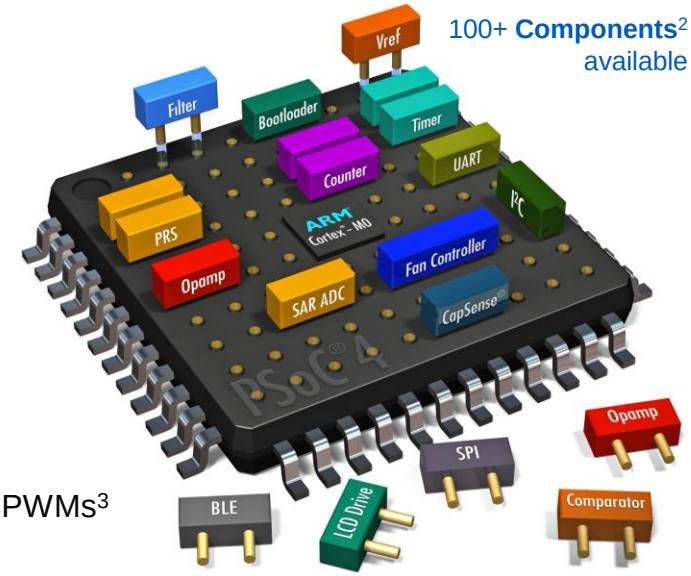
A **Programmable Analog Block** that is used to implement continuous time analog circuits such as opamps and programmable gain amplifiers (PGAs)

Programmable Digital Block

A hardware block that is configured using **PSoC Components**[2] to implement custom digital peripherals and glue logic

Includes **Universal Digital Blocks**, Serial Communication Blocks (SCBs) and TCPWMs[3]

Illustration of a PSoC Device Being Flexibly Configured by Plugging in PSoC Components[2]



Universal Digital Block (UDB)

A PSoC **Programmable Digital Block** that contains two programmable logic devices (PLDs), one programmable datapath with an arithmetic logic unit (ALU), one status register and one control register

Configured in **PSoC Creator**[4] using **PSoC Components**[2], or with the graphical UDB editor or using Verilog code

Serial Communication Block (SCB)

A PSoC **Programmable Digital Block** that is configurable as a UART, SPI or I²C interface

[1] Connects the Programmable Analog Blocks, Programmable Digital Blocks and I/Os
[2] Free embedded ICs represented by an icon in PSoC Creator software
[3] Timer/Counter/Pulse-Width Modulator
[4] PSoC 3, PSoC 4, PSoC 5LP and PRoC BLE Integrated Design Environment (IDE)

PSoC Terms

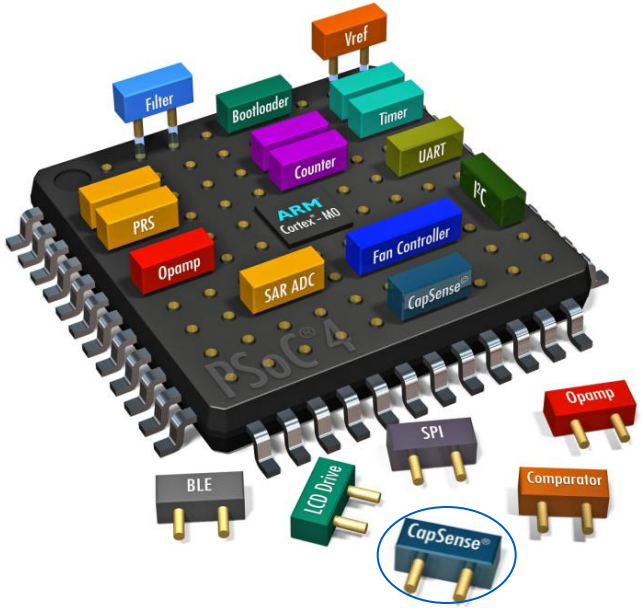
Timer/Counter/PWM (TCPWM) Block

A PSoC **Programmable Digital Block** that is configurable as a 16-bit Timer, Counter, PWM[1] or quadrature decoder

CapSense®

Cypress's third-generation touch-sensing user interface solution that "just works" in noisy environments and in the presence of water

The industry's No. 1 solution in sales by 4x over No. 2



Programmable Interconnect and Routing

Connects the Programmable Analog Blocks, Programmable Digital Blocks and I/Os

Enables flexible connections of internal analog and digital signals to internal buses and external I/Os

PSoC Creator™

PSoC 3, PSoC 4, PSoC 5LP and PRoC BLE Integrated Design Environment (IDE)

Software that installs on your PC that allows:
- Concurrent hardware and firmware design of PSoC systems, or
- PSoC hardware design followed by export to popular IDEs

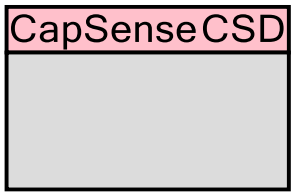
Components

Free embedded ICs represented by an icon in **PSoC Creator** software

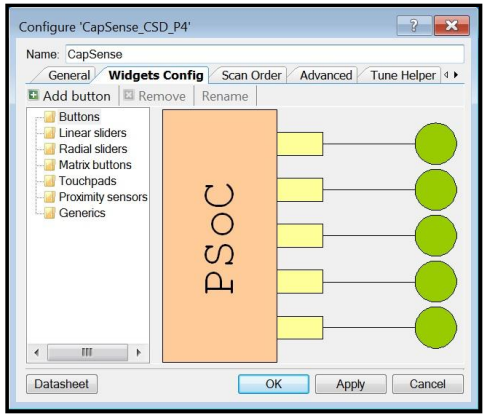
Used to **integrate multiple ICs** and system interfaces into one **PSoC**

Dragged and dropped as icons to design systems in PSoC Creator

Component Icon



Component Configuration Tool



Component Configuration Tools

Simple graphical user interfaces in PSoC Creator embedded in each Component

Used to customize Component parameters as shown to the right

[1] Pulse-Width modulator

BLE Terms

BLE (Bluetooth Low Energy)

A standard for short-range, low-power wireless applications that communicates state or control information

Operates in the 2.4-GHz ISM Band with GFSK modulation and supports a 1-Mbps over-the air data rate

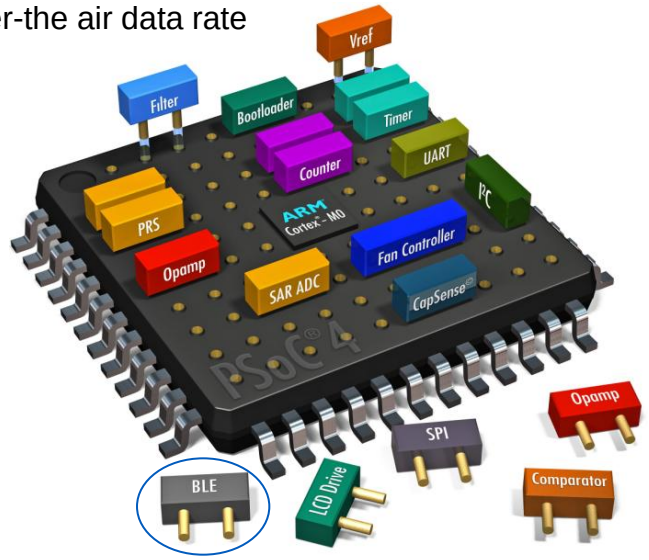
Not backward-compatible with Bluetooth Classic

Bluetooth 4.0/4.1/4.2

Bluetooth 4.0 (2010) is an upgraded Bluetooth Classic specification that adds BLE

Bluetooth 4.1 (2013) improves throughput and power consumption

Bluetooth 4.2 (2014) increases packet length, and improves privacy and security



BLE Protocol Stack

Firmware that implements the Bluetooth 4.0/4.1/4.2 specification to provide BLE communication

PSoC 4 BLE

A 32-bit, 48-MHz ARM® Cortex®-M0 PSoC device with Programmable Analog and Digital Blocks, CapSense and BLE

Includes a royalty-free, Bluetooth 4.2-compliant BLE Protocol Stack

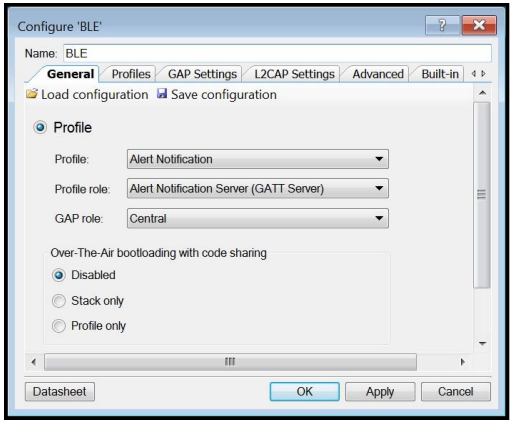
PRoC™ BLE (Programmable Radio-on-Chip)

A 32-bit, 48-MHz ARM Cortex®-M0 connectivity MCU with peripherals: CapSense, ADC, SCBs and BLE

Includes a royalty-free, Bluetooth 4.2-compliant BLE Protocol Stack

Component Icon

Component Configuration Tool



BLE Component

A Component that creates **Bluetooth Smart**[1] products in minutes

Includes a Component Configuration Tool that makes the complex BLE Protocol Stack and Profiles[2] simple to implement with a GUI

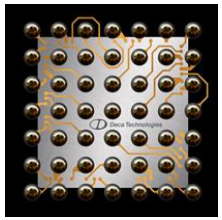
[1] A brand of Bluetooth products that supports only BLE

[2] A Bluetooth specification that describes a set of operations used by devices to communicate with one another

Advanced BLE System Design

CYPRESS BLE PORTFOLIO

Cypress's BLE Product Roadmap Meets Evolving Market Needs



November 2014
Most Integrated BLE Product

August 2015
Ultra-Thin CSP[1] For Credit Cards

December 2015
Bluetooth 4.2 Features For Security, Privacy and Throughput

July 2016
Smaller Packages, Low-Cost and Multi-Protocol Devices

Features	PSoC 4 BLE	BCM20737[4]	BCM20719[3,4]
CPU	ARM CM0	ARM CM3	ARM CM4
Flash (KB/MB), RAM (KB)	256KB, 32KB	NA, 60KB	1MB, 512KB
Supply Voltage (V)	1.9-5.5V	1.62-3.63V	1.62-3.6V
UDBs, Opamps, Comparators, ADC, DAC	4, 4, 2, 12-bit, No	0, 0, 0, 16-bit, No	0, 0, 0, 16-bit, No
CapSense®	Yes	No	No
MCU Active Current Slope (µA/MHz)	260	96	30
Rx Sensitivity[2] (dBm)	-91	-93	-96.5
Avg. Current for 1-s interval (µA)	17.8	~30	~9
Integrated 32-kHz Crystal-Less Oscillator	No	Yes	Yes
Multi-Master Multi-Slave	No	Yes (1M, 3S)	Yes (3M, 16S)
Availability	Now	Now	Sampling in Q4'16

Cypress's BLE portfolio is evolving to reduce power consumption and enhance best-in-class integration

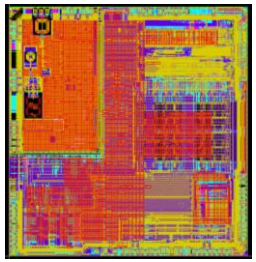
[1] Chip Scale Package
[2] Pre-Balun in all cases
[3] Integrates TRIAC Control, IR RX/TX, Crypto block.
[4] Uses WICED IDE

Cypress: Complete BLE Solution

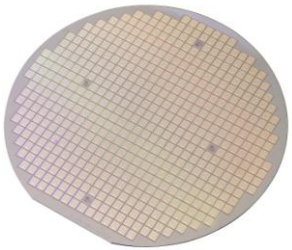
Cypress is your BLE solution provider with expertise in silicon, stack, module hardware and software

Solution Discipline	Cypress	BLE Module Suppliers			BLE Silicon Suppliers[1]
		Panasonic	TDK	Murata	
BLE Silicon Design	✓				✓
BLE Wafer Fabrication	✓				✓
BLE Silicon Package Assembly/Test	✓				✓
BLE Stack Development	✓				✓
Software (IDE)	✓				✓
BLE Module Hardware Design	✓	✓	✓	✓	
BLE Module Manufacturing	✓	✓	✓	✓	

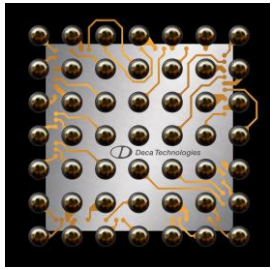
BLE Silicon Design



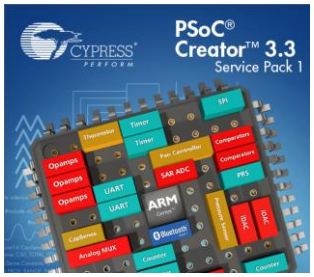
BLE Wafer Fabrication



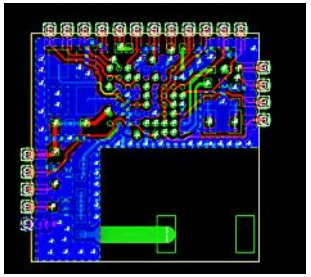
BLE CSP Package[2]



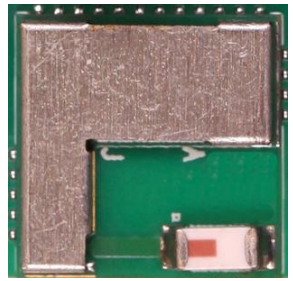
PSoC Creator Software



Module Hardware Design



EZ-BLE™ PRoC Module



Cypress is the end-to-end expert for all of your BLE needs

[1] Nordic, TI, CSR, Dialog
[2] Chip-scale package (CSP) manufactured by Cypress subsidiary Deca Technologies

Bluetooth Low Energy (BLE) Portfolio

WICED™	PSoC® Creator™	
BLE + MCU	**PRoC™ BLE (MCU + Touch[1])**	**PSoC 4 BLE (MCU + Touch + Mixed-Signal)**
NEW **BCM20719** Q416 CM4[2], SPI, UART, I²C[3], IR TX/RX[4], ADC, 6 PWM, KB Scanner[5], Mouse QD[6], Crypto[7], 4 TRIAC Control, 40 GPIO, 1MB Flash, 512KB RAM, BT[8] 4.2, 2 Mbps support, WICED SDK[9]		
	Q316 **CYBL1117x** CM0, DMA, 2 SCB, I²S 4 TCPWM, 4 PWM, ADC, 36 GPIO, 256KB Flash, 32KB RAM, BT 4.2, PSoC Creator	Q316 **CYBL1147x/57x** CM0, DMA, 2 SCB, I²S 2-Finger[1], 4 TCPWM, 4 PWM, ADC, 36 GPIO, 256KB Flash, 32KB RAM, BT 4.2, PSoC Creator
NEW **BCM20738** CM3, SPI, UART, I²C, IR TX/RX, ADC, 4 PWM, KB Scanner, Mouse QD, 40 GPIO, 60 KB RAM, BT 4.1, ADK	NEW **BCM20737** CM3, SPI, UART, I²C, IR TX/RX, ADC, 4 PWM, LE Audio, NFC[15], Crypto, 14 GPIO, 60KB RAM, BT 4.1, WICED SDK	**CYBL1057x** CM0, 2 SCB, I²S 2-Finger, 4 TCPWM, 4 PWM, ADC, 36 GPIO, 256KB Flash, 32KB RAM, BT 4.1, PSoC Creator
NEW **BCM20732** CM3, SPI, UART, I²C, IR TX/RX, ADC, 4 PWM, 14 GPIO, 60KB RAM, BT 4.0, WICED SDK	NEW **BCM20736** CM3, SPI, UART, I²C, IR TX/RX, ADC, A4WP[16], 4 PWM, 40 GPIO, 60KB RAM, BT 4.1, WICED SDK	**CYBL1016x** CM0, 2 SCB, I²S, 4 TCPWM, 4 PWM, ADC, 36 GPIO, 128KB Flash, 16KB RAM, BT 4.2, PSoC Creator

PSoC® Creator™	
Q316 **CY8C41x8-BL5xx** CM0, DMA, 2 SCB, 4 Opamp, 2 CMP, ADC, 4 TCPWM, 36 GPIO, 256KB Flash, 32KB RAM, BT 4.2, PSoC Creator	Q316 **CY8C42x8-BL5xx** CM0, DMA, 2 SCB, 4 Opamp, 2 CMP, 4 UDB, ADC, 4 TCPWM, 36 GPIO, 256KB Flash, 32KB RAM, BT 4.2, PSoC Creator
CY8C41x8-BL4xx CM0, 2 SCB, ADC, 4 Opamp, 2 CMP, 4 TCPWM, 36 GPIO, 256KB Flash, 32KB RAM, BT 4.1, PSoC Creator	**CY8C42x8-BL4xx** CM0, 2 SCB, ADC, 4 Opamp, 2 CMP, 4 UDB, 4 TCPWM, 36 GPIO, 256KB Flash, 32KB RAM, BT 4.1, PSoC Creator
CY8C41x7-BL4xx CM0, 2 SCB, ADC, 4 Opamp, 2 CMP, 4 TCPWM, 36 GPIO, 128KB Flash, 16KB RAM, BT 4.1, PSoC Creator	**CY8C42x7-BL4xx** CM0, 2 SCB, ADC, 4 Opamp, 2 CMP, 4 UDB, 4 TCPWM, 36 GPIO, 128KB Flash, 16KB RAM, BT 4.1, PSoC Creator

Integration and Flexibility

[1] Touch-sensing technology with up to 2-finger gestures
[2] ARM® Cortex®-M0/M0+/M3/M4
[3] Broadcom serial communications block
[4] Infrared transmit and receive
[5] Keyboard scanner
[6] Mouse quadrature decoder
[7] Cryptographic accelerator block for security
[8] Bluetooth Specification
[9] Software development kit
[10] Direct memory access
[11] Serial communication block (SPI/I²C/UART)
[12] Comparator
[13] Universal digital block
[14] Timer/Counter/PWM
[15] Out-of-Band pairing with NFC
[16] Alliance for Wireless Power BLE Profile

	Concept	Development	Sampling	Production
Status				
Availability			QQYY	QQYY

EZ-BLE™ Module Portfolio

	Programmable Radio-on-Chip (EZ-BLE™ PRoC™)			Programmable System-on-Chip (EZ-BLE PSoC®)	
	128KB Flash	256KB Flash		128KB Flash	256KB Flash
Standard Range[1]	**CYBLE-022001-00** **EZ-BLEPRoC Module BLE[5] 4.1** CM0[3], 2 SCB[4] 16 GPIOs 10 x 10 x 1.80 mm SMT[8]	**CYBLE-222005-00** **EZ-BLE PRoC Module BLE 4.1** CM0, 2 SCB 16 GPIOs 10 x 10 x 1.80 mm SMT	**CYBLE-222014-01** Q316 **EZ-BLE PRoC Module BLE 4.2** CM0, 2 SCB 16 GPIOs 10 x 10 x 1.80 mm SMT	**CYBLE-014008-00** **EZ-BLE PSoC Module BLE 4.1** 4 Opamps, 1 CMP[6], 4 UDBs[7] CM0, 2 SCB,25 GPIOs 11 x 11 x 1.80 mm SMT	**CYBLE-214009-00** Q316 **EZ-BLE PSoC Module BLE 4.1** 4 Opamps,1 CMP, 4 UDBs CM0, 2 SCB,25 GPIOs 11 x 11 x 1.80 mm SMT
	CYBLE-012011-00 **EZ-BLE PRoC Module BLE 4.1** CM0, 2 SCB 23 GPIOs 14 x 19 x 2.00 mm SMT	**CYBLE-212019-00** Q316 **EZ-BLE PRoC Module BLE 4.1** CM0, 2 SCB 23 GPIOs 14 x 19 x 2.00 mm SMT	**CYBLE-212020-01** Q316 **EZ-BLE PRoC Module BLE 4.2** CM0, 2 SCB 23 GPIOs 14 x 19 x 2.00 mm SMT		**CYBLE-214015-01** Q316 **EZ-BLE PSoC Module BLE 4.2** 4 Opamps,1 CMP, 4 UDBs CM0, 2 SCB,25 GPIOs 11 x 11 x 1.80 mm SMT
	CYBLE-012012-10 **EZ-BLE PRoC Module BLE 4.1** CM0, 2 SCB 23 GPIOs, NS[10], NC[11] 14 x 19 x 2.00 mm SMT	**CYBLE-212023-10** Q316 **EZ-BLE PRoC Module BLE 4.1** CM0, 2 SCB 23 GPIOs, NS[10], NC[11] 14 x 19 x 2.00 mm SMT			
Long Range[2]		**CYBLE-212006-01** Q316 **EZ-BLE PRoC Module BT 4.2** PCB Antenna CM0, 2 SCB, PA[9], 19 GPIOs 15 x 23 x 2.0 mm SMT	**CYBLE-202007-01** Q316 **EZ-BLE PRoC Module BT 4.2** External Antenna via u.FL CM0, 2 SCB, PA[9], 19 GPIOs 15 x 23 x 2.0 mm SMT		**CYBLE-224110-00** Q316 **EZ-BLEPSoC XT/XR[12] Module** BLE 4.1, 4 Opamps,1 CMP,PA[9] 4 UDBs,CM0,2 SCB, 25 GPIOs 9.5 x 15.4 x 1.80 mm SMT
			NEW **CYBLE-202013-11** Q316 **EZ-BLE PRoC Module BT 4.2** External Antenna via RF Pin CM0, 2 SCB, PA[9], 19 GPIOs 15 x 23 x 2.0 mm SMT		**CYBLE-224116-01** Q316 **EZ-BLEPSoC XT/XR[12] BLE 4.2** 4 Opamps,1 CMP,4 UDBs,PA[9] CM0,2 SCB, 25 GPIOs 9.5 x 15.4 x 1.80 mm SMT

Integration

[1] Range up to 30 meter Line-of-Sight
[2] Range up to 400 meter Line-of-Sight
[3] ARM® Cortex® -M0
[4] Serial communication block
[5] BLE Specification Version
[6] Comparator
[7] Universal Digital Block
[8] Surface mount technology
[9] Power Amplifier
[10] NS = No Shield
[11] NC = No Certifications
[12] XT/XR = Extended Temperature/Extended Range

	Concept	Development	Sampling	Production
Status				
Availability			QQYY	QQYY

Advanced BLE System Design

DEMO: UPGRADING TO BLUETOOTH 4.2

Upgrade Your BLE Pioneer Kit With Three New Bluetooth 4.2 Add-Ons

The existing BLE Pioneer Kit (CY8CKIT-042-BLE) contains:

BLE Pioneer Kit baseboard

Plug-In Boards[1]

BLE-USB bridge using PRoC BLE

Example projects

CySmart[2] software

BLE Pioneer Kit (CY8CKIT-042-BLE)

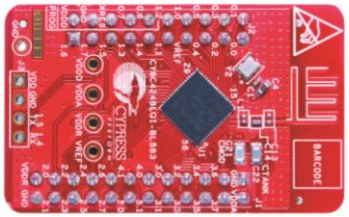
It can be upgraded with two new BLE plug-in boards…

Plug into the existing BLE Pioneer Kit Baseboard

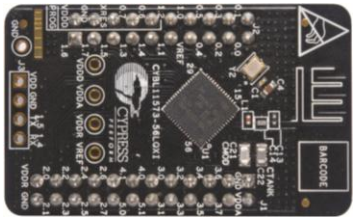
Use new Bluetooth 4.2 PSoC 4 and PRoC devices

Feature 256KB flash, 32KB SRAM and an 8-channel DMA[3] controller, plus compatibility with existing devices

PSoC 4 BLE Plug-In Board[1] (CY8CKIT-143A)



PRoC BLE Plug-In Board[1] (CY5676A)



And one new BLE-USB bridge:

Enables testing and debugging of new Bluetooth 4.2 features[4]

Retains all existing functionality

BLE-USB Bridge Using PRoC BLE (CY5677)

Upgrade your Bluetooth designs with Cypress's BLE Pioneer Kit and three new Bluetooth 4.2 add-ons

[1] Production-ready, fully certified EZ-BLE modules with PSoC 4 or PRoC BLE devices are also available. Refer to the EZ-BLE Module Portfolio slide for more details

[2] A GUI-based software tool that installs on your PC to test and debug BLE functionality

[3] Direct memory access: A method to transfer data between hardware subsystems and main system memory without involving the main processor, typically implemented in a coprocessor

[4] Bluetooth 4.2 features are described in the Lab #2: Bluetooth 4.2 Features section

Upgrade Your PSoC Creator Project To Use Bluetooth 4.2

Objectives:

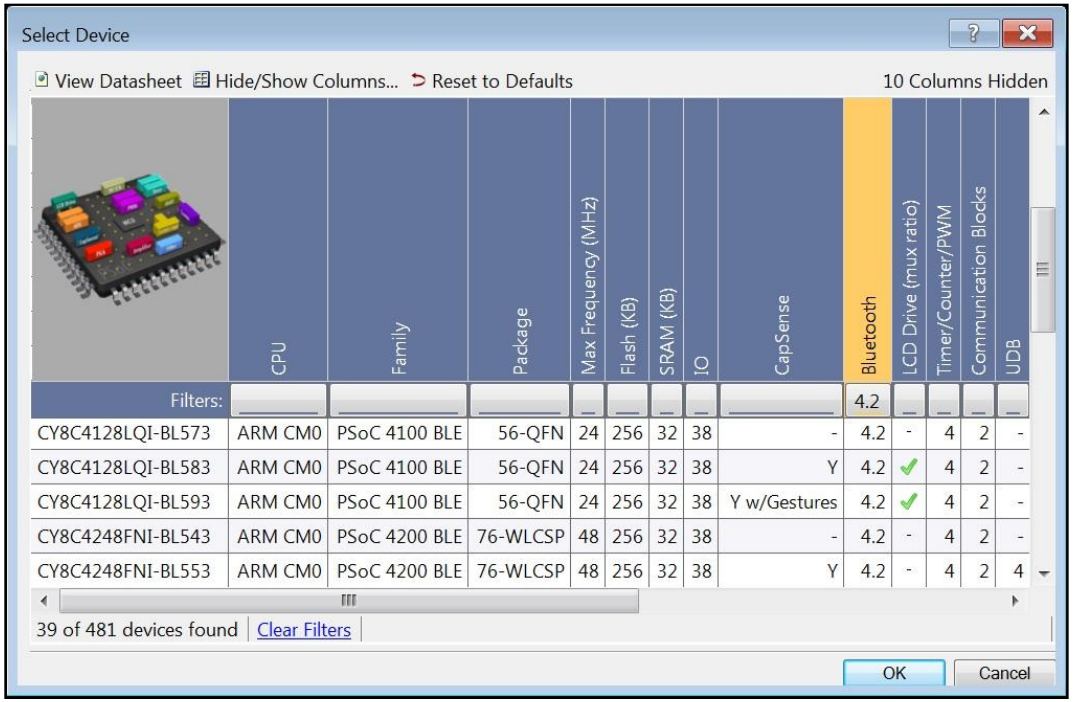
Learn how to use PSoC Creator to upgrade an existing project to use a Bluetooth 4.2 device:

- Use the New Project GUI[1] to open a code example[2] for a Bluetooth 4.1 device
- Use the Device Selector GUI[3] to upgrade to a Bluetooth 4.2 device
- Use the Component Update GUI[4] to upgrade the Components
- Build and program your project onto your BLE Pioneer Kit

Software tool:

PSoC Creator

Device Selector GUI[3] in PSoC Creator



[1] The New Project GUI in PSOC Creator is used to create a new project or open an example project for any Cypress device
[2] An example project available as part of PSoC Creator
[3] The Device Selector GUI in PSoC Creator is used to change the target device for a project
[4] The Component Update GUI in PSoC Creator is used to upgrade the Components in your PSoC Creator project

Advanced BLE System Design

LAB #1: OVER-THE-AIR FIRMWARE UPGRADE

Over-The-Air Firmware Upgrade[1] Using Bootloader[2] Functionality

Over-the-air firmware upgrade[1] allows firmware updates after the product has shipped

Eliminates the need for product recall to fix firmware issues and enables firmware enhancements for products in the field

Over-the-air firmware upgrade[1] requires a bootloader[2]

Bootloaders are classified as external memory[3], fixed stack[4] and upgradeable stack[5], based on features supported

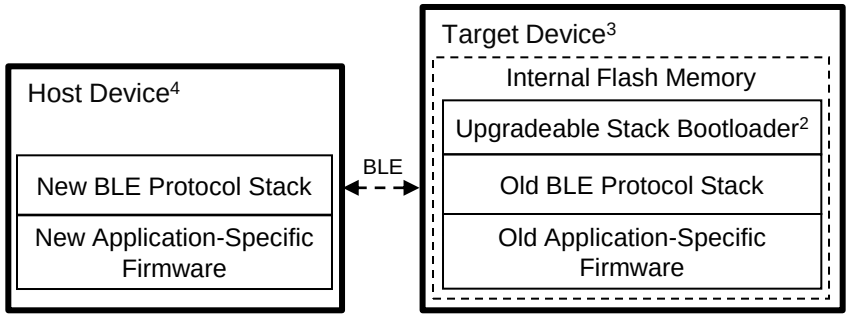
Bootloader[2] Features	External Memory Bootloader[3]	Fixed Stack Bootloader[4]	Upgradeable Stack Bootloader[5]
Does not require external memory	X	✓	✓
Can upgrade BLE Protocol Stack	✓	X	✓
Can upgrade application-specific firmware	✓	✓	✓

Cypress's BLE devices support all types of bootloaders[2] including the upgradeable stack bootloader[5]

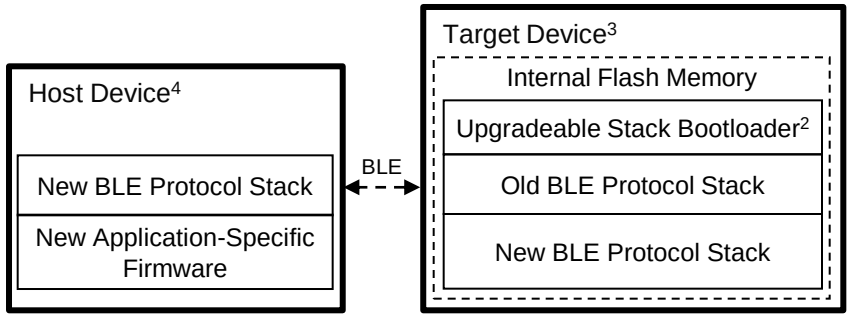
[1] The process of replacing existing firmware with a newer version over a wireless interface like BLE
[2] The part of the firmware that is responsible for upgrading the internal memory of the device
[3] External memory bootloader is supported on Cypress BLE devices with 128 KB or 256 KB of flash.
For external memory use the Cypress FRAM (FM24V10) on the BLE Pioneer Kit for prototyping and the Cypress NOR-Flash (S25FL and S25FS families) to reduce cost for mass production
[4] Fixed stack bootloader is supported on all Cypress BLE devices with 128 KB or 256 KB of flash
[5] Upgradeable stack bootloader is supported on all Cypress BLE devices with 256 KB of flash

Over-The-Air Firmware Upgrade[1] Using Upgradeable Stack Bootloader[2]

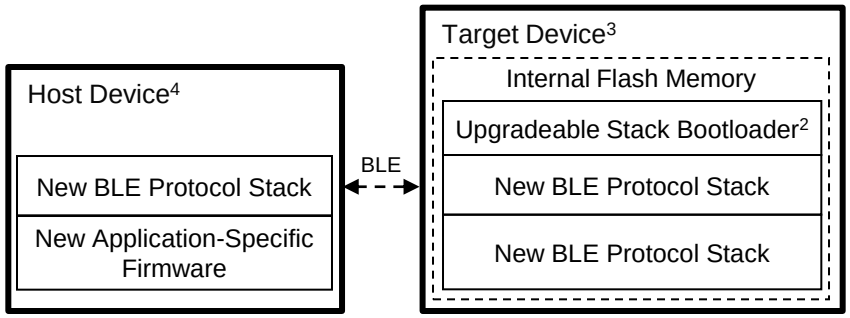
1. The bootloader[2] on the target device[3] establishes a BLE connection with the host device[4] using the old BLE Protocol Stack



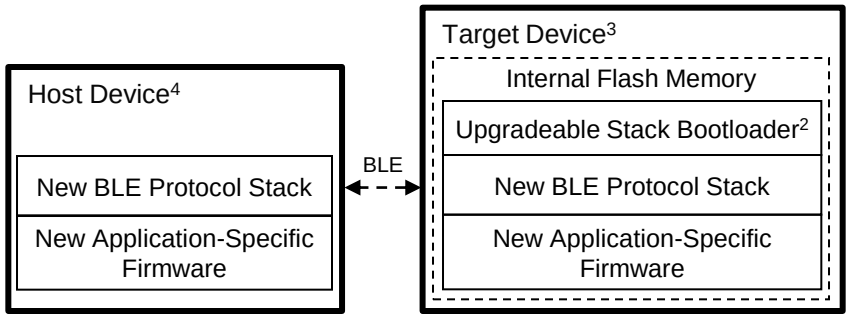
2. The bootloader[2] uses the old BLE Protocol Stack to receive the new BLE Protocol Stack and overwrites the old application-specific firmware



3. The bootloader[2] overwrites the old BLE Protocol Stack with a copy of the new BLE Protocol Stack



4. The bootloader[2] uses the new BLE Protocol Stack to receive the new application-specific firmware and overwrites the copy of the new BLE Protocol Stack made in Step 2. Over-the-air firmware upgrade[1] is now complete



[1] The process of replacing existing firmware with a newer version over a wireless interface like BLE
[2] The part of the firmware that is responsible for upgrading the internal memory of the device
[3] The device that needs to be upgraded using over-the-air firmware upgrade
[4] The host device is responsible for sending new firmware to the target device that needs to be upgraded

Prototyping Over-The-Air Firmware Upgrade[1]

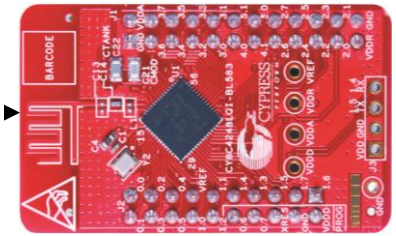
The CySmart[2] software with BLE-USB bridge emulates a host[3] device

The BLE Component simplifies the addition of the over-the-air firmware upgrade[1] feature to the target device[4] firmware

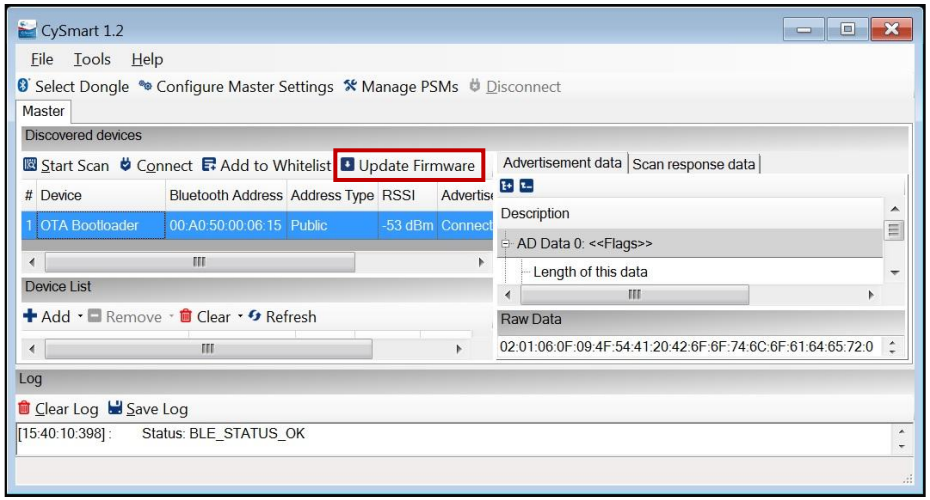
Host Device[3]: BLE-USB Bridge (CY5677)

BLE

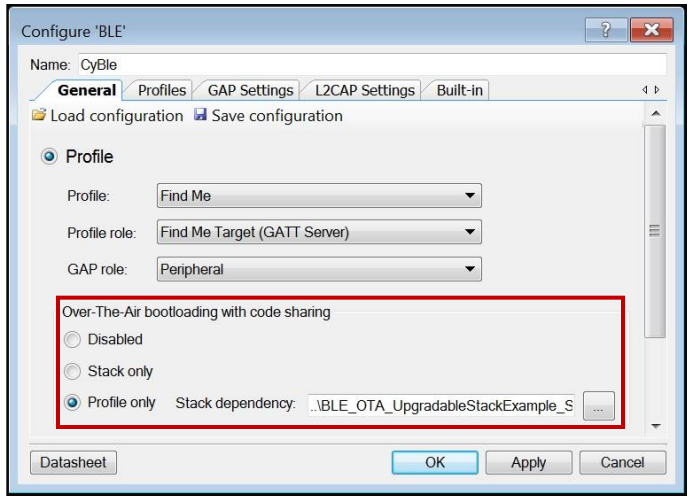
Target Device[4]: PSoC 4 BLE Plug-In Board (CY8CKIT-143A)



CySmart[2] (for host[3])



BLE Component Configuration Tool (for target[4])



[1] The process of replacing existing firmware with a newer version over a wireless interface like BLE
[2] A GUI-based software tool that installs on your PC to test and debug BLE functionality
[3] The host device is responsible for sending new firmware to the target device that needs to be upgraded
[4] The device that needs to be upgraded using over-the-air firmware upgrade

Lab #1: Over-The-Air Firmware Upgrade[1]

Objectives:

Understand the architecture of an upgradeable stack bootloader[2]

Learn how to add over-the-air firmware upgrade[1] feature to your project in PSoC Creator

Learn how to use the CySmart[3] software and the BLE-USB bridge as a host[4] to upgrade firmware

Software tools:

PSoC Creator

CySmart[3]

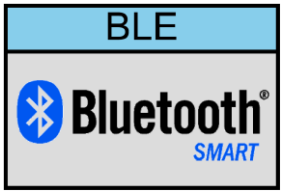
Components:

BLE Component

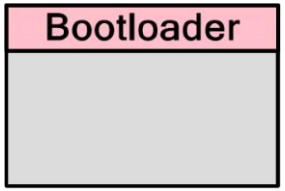
Bootloader[2] Component

Bootloadable[5] Component

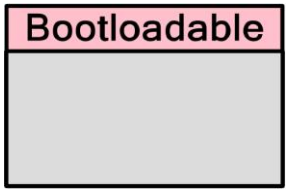
BLE Component Icon



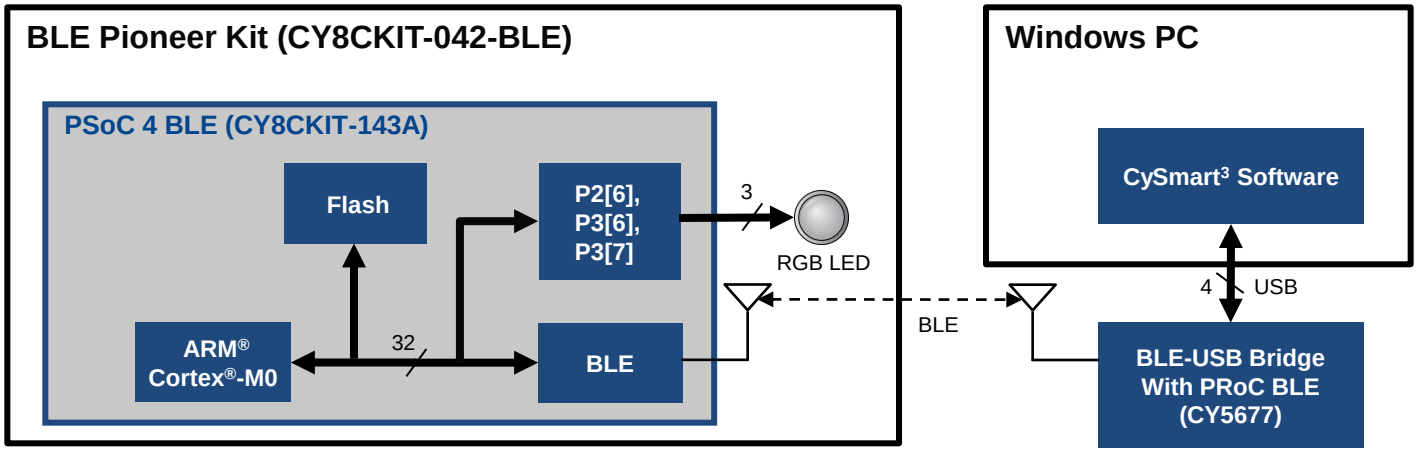
Bootloader[2] Component Icon



Bootloadable[5] Component Icon



Lab 1: Block Diagram



[1] The process of replacing existing firmware with a newer version over a wireless interface like BLE

[2] The part of the firmware that is responsible for upgrading the internal memory of the target

[3] A GUI-based software tool that installs on your PC to test and debug BLE functionality

[4] The host device is responsible for sending new firmware to the target device that needs to be upgraded

[5] The part of the firmware in the target device that needs to be upgraded

Advanced BLE System Design

SESSION BREAK

Advanced BLE System Design

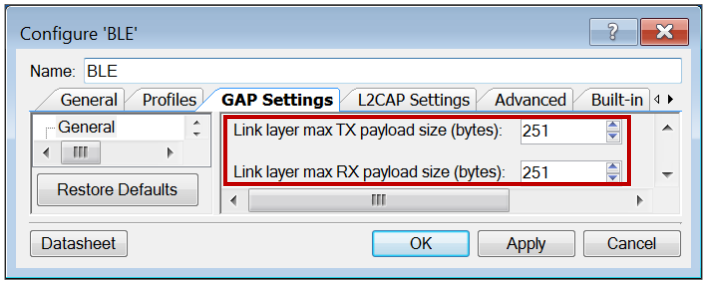
LAB #2: BLUETOOTH 4.2 FEATURES

Cypress's BLE Solutions Support New Bluetooth 4.2 Features

Bluetooth 4.2 Features

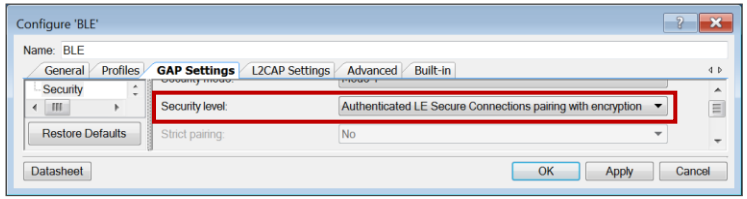
Data Length Extension

Increases payload from 27 bytes to 251 bytes



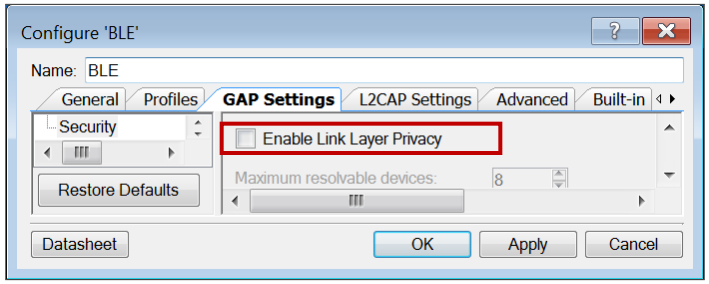
Enhanced Security

Uses FIPS[1]-compliant ECDH[2] for key-exchange



Privacy 1.2

Reduces power consumed during address resolution[3]



Benefits

For Faster Data Transfer

2.6x higher throughput (up to 800 Kbps) than Bluetooth 4.1 (up to 300 Kbps)

Implement bi-directional voice transfer
Leverage asymmetric bandwidth[4] to improve power consumption

For More Secure Payment Solutions

Enhanced encryption ensures industry standard security with interoperability

Transfer passwords and financial information without worrying about being hacked

For Smarter BLE Devices

Privacy prevents tracking of BLE devices and safeguards sensitive user data

Prevent unauthorized tracking of wearables
Safeguard personal health information

[1] Federal Information Processing Standards
[2] Elliptic Curve Diffie-Hellman algorithm provides a mechanism to exchange keys over an unsecured channel.
[3] The process that derives the original address from encrypted random addresses
[4] Asymmetric bandwidth refers to different maximum throughput in TX and RX directions

Bluetooth 4.2: Data Length Extension

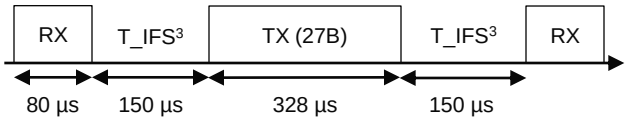
Data length extension enables 2.6x higher throughput (≤ 800 Kbps) than Bluetooth 4.1 (≤ 300 Kbps)

Data length extension enables over-the-air packets to carry up to 251B of payload[1] compared to 27B with Bluetooth 4.1

Larger payload[1] sizes result in lower transmission time and lower power consumption

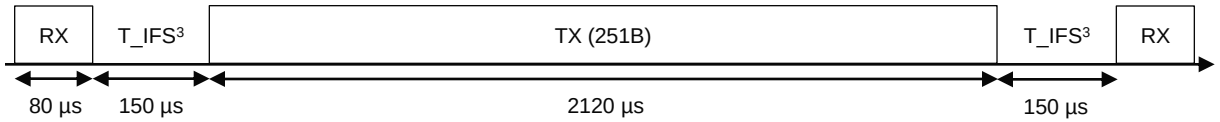
Payload[1] size can be negotiated and can be asymmetrical[2] to ensure optimal throughput for the application

BLE Data Transfer With Bluetooth 4.1



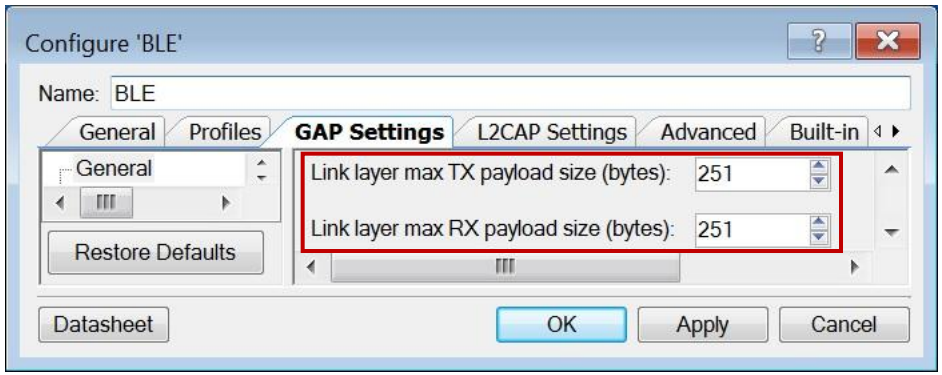
Payload[1] Size = 27B = 216b
Total Time[4] = 708 µs
Throughput[5] = ~298 Kbps

BLE Data Transfer With Bluetooth 4.2



Payload[1] Size = 251B = 2008b
Total Time[4] = 2500 µs
Throughput[5] = ~784 Kbps

BLE Component Configuration Tool in PSoC Creator Makes Bluetooth 4.2's Data Length Extension Feature Easy to Use



[1] The data contained in a packet excluding all overhead and meta-data added for transmission purposes
[2] TX and RX payloads can be set to different values. This enables throughput to be optimized based on application-specific requirements
[3] Inter-Frame Spacing Time: The time interval between RX and TX packets. This is defined as 150 µs by the Bluetooth Core Specification
[4] Time taken for 1 RX, 1 TX and 2 T_IFS
[5] Throughput = Payload Size/Total Time

Bluetooth 4.2: Privacy 1.2

Privacy prevents tracking of BLE devices and safeguards sensitive user data

BLE devices with privacy use a resolvable private address (RPA)[1] that can be changed frequently to prevent tracking

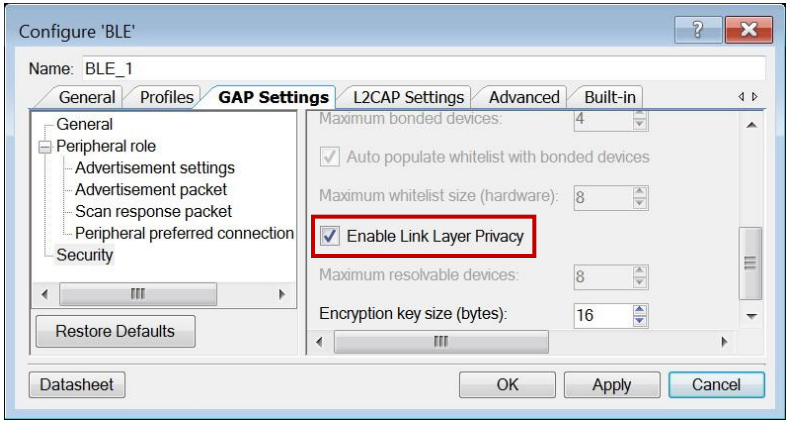
Only peer devices that posses the identity resolving key (IRK)[2] of the BLE device can connect to the BLE device

The Privacy 1.2 feature in Bluetooth 4.2 enables power-efficient BLE devices

Address resolution[3] is implemented in hardware, eliminating the need for CPU intervention during connection establishment

The RPA[1] can be changed at intervals of 1 second compared to 15 minutes in Bluetooth 4.1

BLE Component Configuration Tool in PSoC Creator Makes Bluetooth 4.2's Privacy 1.2 Feature Easy-To-Use



[1] A 48-bit address generated by a BLE device using its identity resolving key (IRK)
[2] A 128-bit number used to generate and resolve the resolvable private address (RPA) of a BLE device
[3] The process that derives the original address from resolvable private address (RPA) for BLE communication

BLE Security Concepts

Security mechanisms in BLE ensure confidentiality and integrity of data

Pairing: The process of authentication and key-exchange between two BLE devices

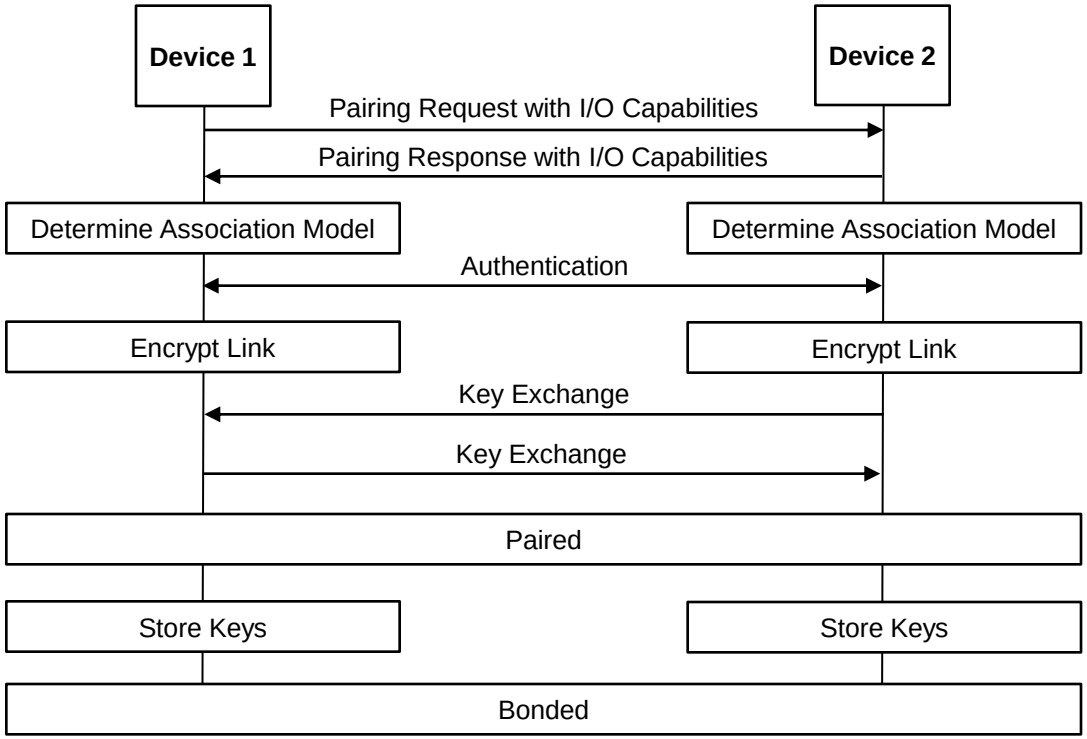
Association model[1]: A model that defines the method of pairing based on the input and output capabilities of the two BLE devices

Authentication: The process of verifying the identity of a device

Key-Exchange: The process of exchanging keys that will be used to encrypt future data exchanges between the two BLE devices

Bonding: The process of storing the keys exchanged during the pairing process in internal flash memory. Bonding allows the BLE devices to reconnect without the pairing process

BLE Pairing And Bonding Procedure



The pairing process involves authentication and key-exchange between BLE devices. After pairing the BLE devices must store the keys to be bonded.

[1] The types of association models and how to choose an association model based on device I/O capabilities are described in the Bluetooth Core Specification

Bluetooth 4.2: Enhanced Security

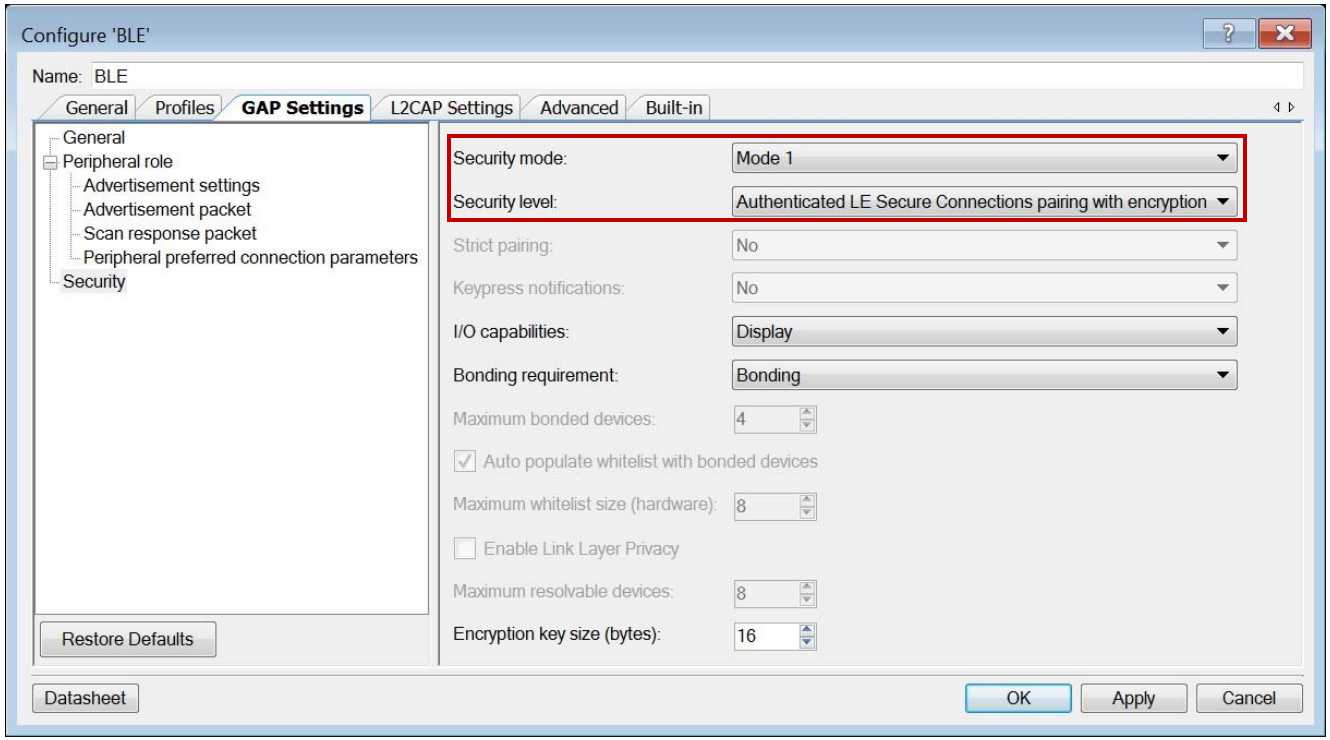
Bluetooth 4.2 enhances the protection against passive eavesdropping[1] and MITM[2] attacks

A new secure connections feature, that uses the ECDH[3] algorithm for key-exchange, to protect against passive eavesdropping[1]

A new Numeric Comparison[4] association model to protect against MITM[2] attacks[5]

Bluetooth 4.1's legacy security mechanisms are supported for backward compatibility

BLE Component Configuration Tool in PSoC Creator Makes Bluetooth 4.2's Enhanced Security Features Easy to Use



[1] The process of monitoring the private communication between two BLE devices

[2] Man-in-the-middle: An attack wherein the attacker monitors and alters the communication between two BLE devices. Both BLE devices believe they are directly communicating with each other

[3] Elliptic Curve Diffie-Hellman algorithm provides a mechanism to exchange keys over an unsecured channel. Refer to the Elliptic Curve Diffie-Hellman (ECDH) slide for details

[4] An association model that requires both BLE devices to have display and "Yes/No" input capability

[5] Passkey entry and out-of-band pairing association models also provide protection against man-in-the-middle attacks. Refer to the Bluetooth Core Specification for a complete description of these

Lab #2: Bluetooth 4.2 Features

Objectives:

Learn how to implement Bluetooth 4.2 features on Cypress's BLE devices

Understand how Bluetooth 4.2's Data Length Extension feature provides higher throughput than Bluetooth 4.1

Understand how Bluetooth 4.2's Privacy 1.2 feature prevents the tracking of BLE devices

Understand how Bluetooth 4.2's Numeric Comparison[1] association model works

Software tools:

PSoC Creator

CySmart[2]

TeraTerm[3]

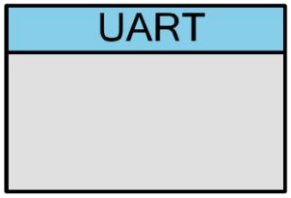
Components:

BLE Component

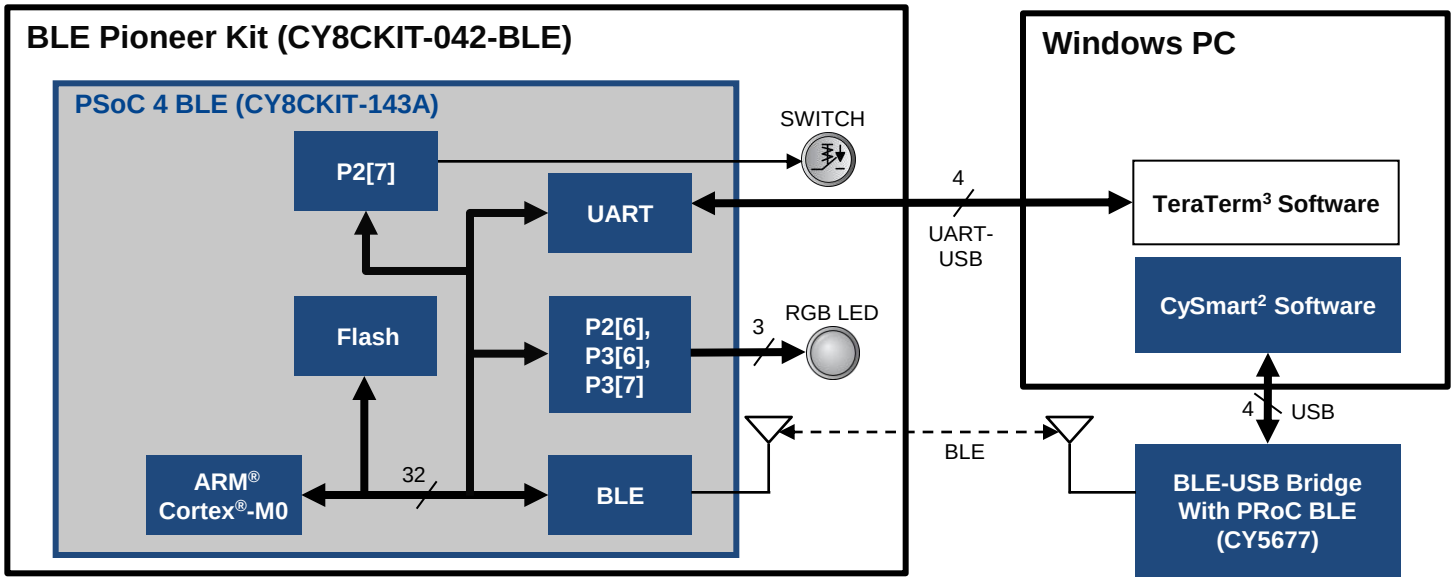
UART Component

BLE Component Icon

UART Component Icon



Lab 2: Block Diagram



[1] An association model that requires both BLE devices to have display and "Yes/No" input capability

[2] A GUI-based software tool that installs on your PC to test and debug BLE functionality

[3] An open-source, free, terminal emulator software

Advanced BLE System Design

LAB #3: MULTI-ROLE BLE DEVICES

Generic Access Profile (GAP) Roles

Generic Access Profile (GAP)

Defines how BLE devices discover each other, establish a connection and interact based on their roles

A BLE device can operate in the following GAP roles:

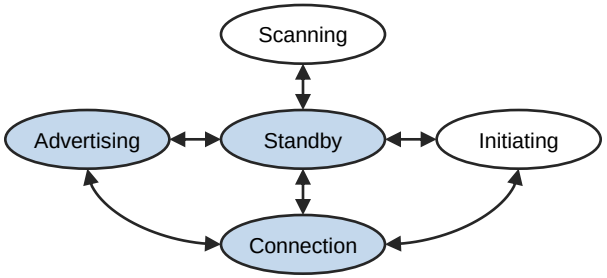
Peripheral: Role in which a device, like a fitness monitor, connects to a **Central** device, like a mobile phone

Central: Role in which a device, like a mobile phone, connects to a **Peripheral** device, like a fitness monitor

Broadcaster: Role in which a device only advertises or transmits data

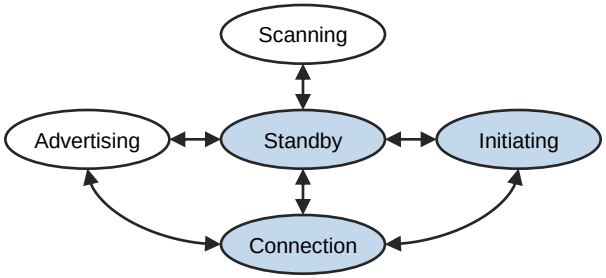
Observer: Role in which a device only listens or scans for devices

Peripheral



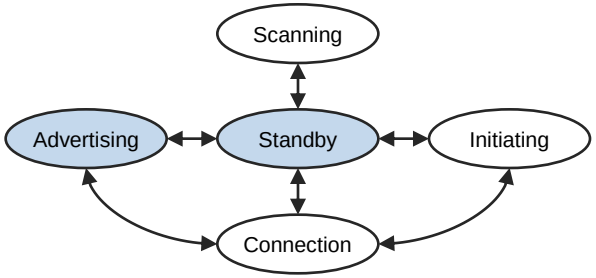
Advertises its capabilities and establishes connections

Central



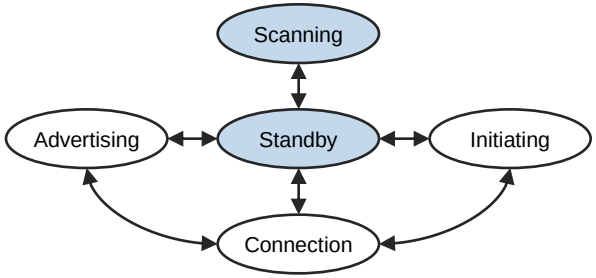
Scans for advertising devices and initiates connections

Broadcaster



Advertises its capabilities only, does not establish connections

Observer



Scans for advertising devices only, does not establish connections

Multi-Role BLE Devices

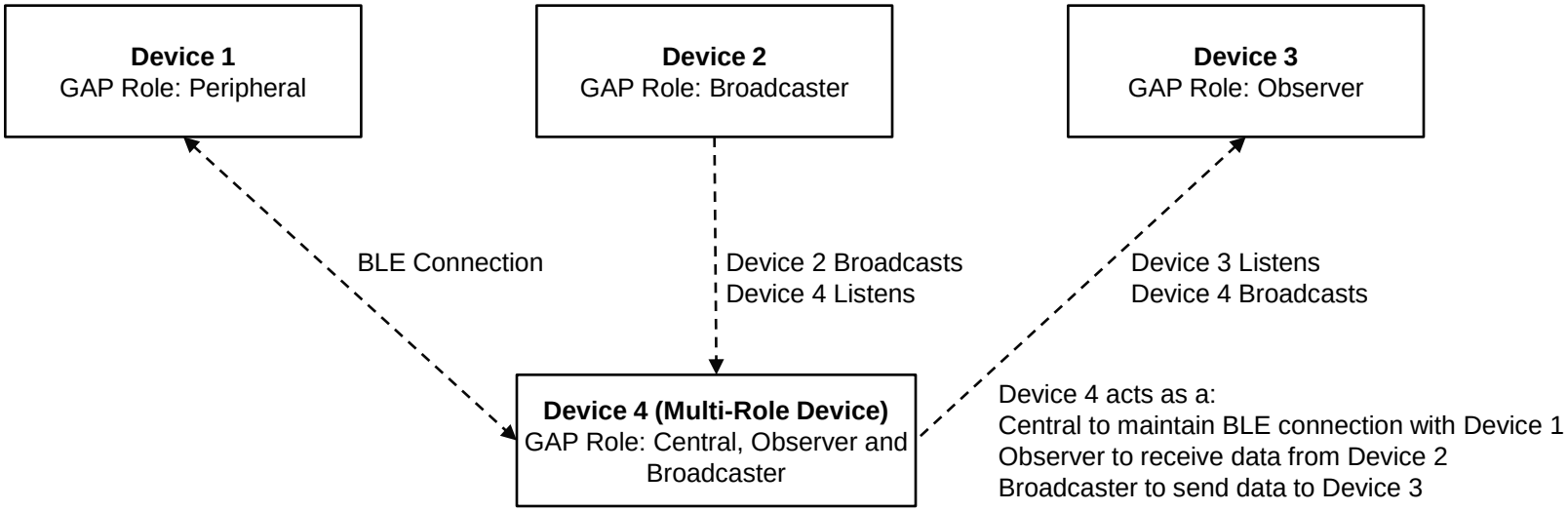
Multi-role BLE devices can support multiple GAP roles without reprogramming

A BLE device can maintain a connection in the central role and simultaneously support broadcaster and observer roles

A BLE device can maintain a connection in the peripheral role and simultaneously support broadcaster and observer roles

A BLE device can switch between central and peripheral roles

Example: Multi-Role BLE Device



Lab #3: Multi-Role BLE Devices

Objectives:

Learn how to assign a central or peripheral role to a BLE device

Learn how to assign a broadcaster and observer roles while maintaining BLE connection as a central or peripheral

Learn how to configure the settings for all assigned GAP roles

Software tools:

PSoC Creator

TeraTerm[1]

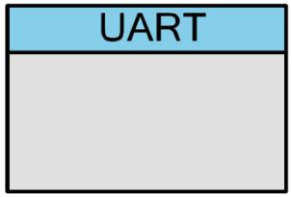
Components:

BLE Component

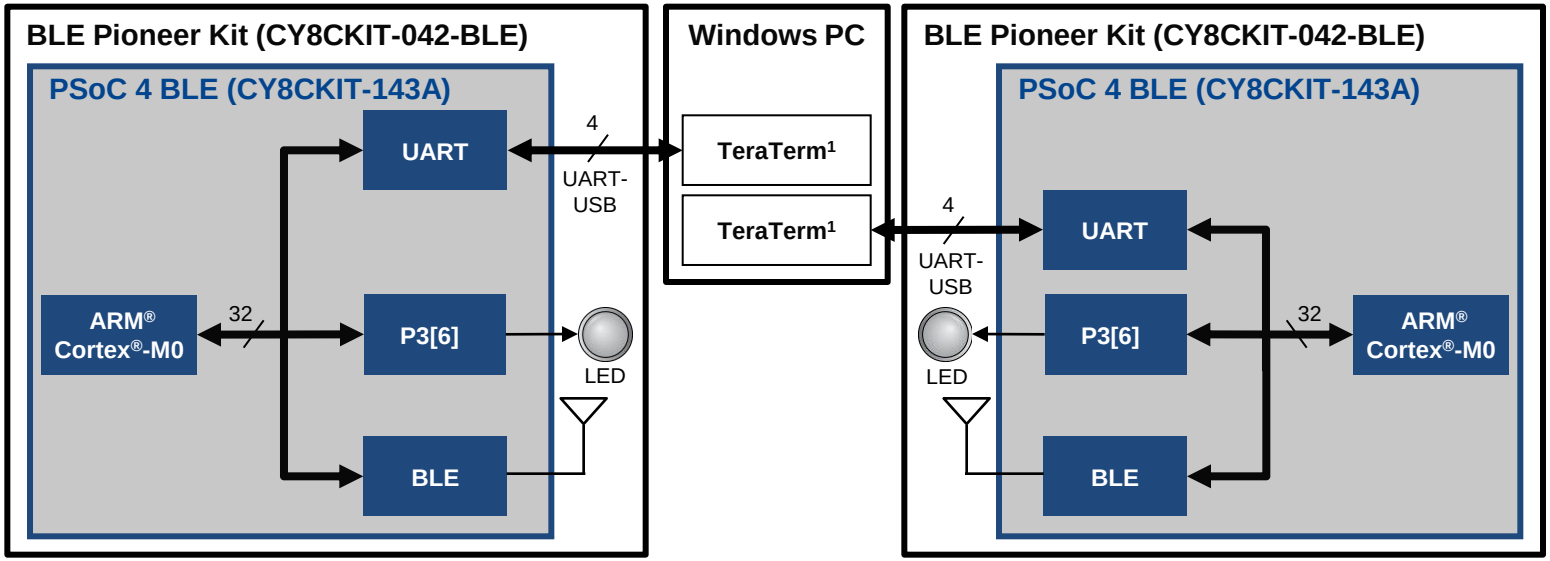
UART Component

BLE Component Icon

UART Component Icon



Lab 3: Block Diagram



[1] An open-source, free, terminal emulator software

Advanced BLE System Design

WRAP-UP

References and Links

Product, Software and Kit Webpages:

BLE Solutions: www.cypress.com/BLE

PSoC 4 BLE: www.cypress.com/PSoC4BLE

PRoC BLE: www.cypress.com/PRoCBLE

EZ-BLE Module: www.cypress.com/EZ-BLEModule

PSoC Creator: www.cypress.com/PSoCCreator

CySmart for Windows® PC: www.cypress.com/CySmart

CySmart for Mobile: www.cypress.com/CySmartMobile

BLE Pioneer Kit: www.cypress.com/CY8CKIT-042-BLE

BLE Pioneer Kit (Bluetooth 4.2 complaint): www.cypress.com/CY8CKIT-042-BLE-A

PSoC 4 BLE Bluetooth 4.2 Development Module: www.cypress.com/CY8CKIT-143A

PRoC BLE Bluetooth 4.2 Development Module: www.cypress.com/CY5676A

Bluetooth 4.2 BLE-USB Bridge: www.cypress.com/CY5677

Other Resources:

BLE Frequently Asked Questions: www.cypress.com/BLEFAQ

Datasheets:

PSoC 4 BLE: www.cypress.com/PSoC4BLEDatasheet

PRoC BLE: www.cypress.com/PRoCBLEDatasheet

BLE Component: www.cypress.com/go/comp_BLE

Application Notes:

Getting Started with PSoC 4 BLE (AN91267): www.cypress.com/go/AN91267

Getting Started with PRoC BLE (AN94020): www.cypress.com/go/AN94020

Getting Started With EZ-BLE Module (AN96841): www.cypress.com/go/AN96841

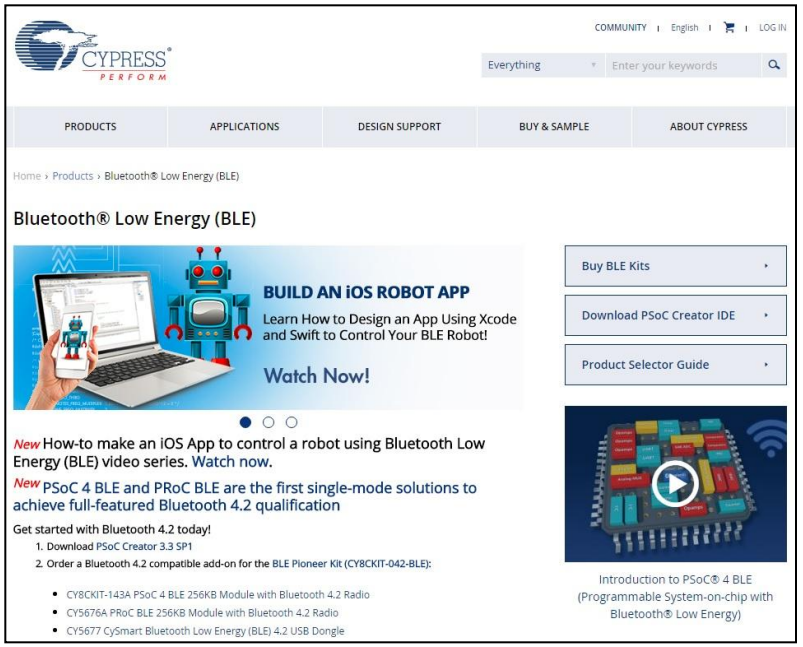
Over-The-Air Firmware Upgrade Guide (AN97060): www.cypress.com/go/AN97060

General Online Resources

Cypress Resources

Cypress BLE Solutions: www.cypress.com/BLE
PSoC: www.cypress.com/PSoC
Nonvolatile RAM: www.cypress.com/products/Nonvolatile-RAM
Serial NOR Flash: www.cypress.com/products/Serial-NOR-Flash-Memory
Cypress Roadmap: www.cypress.com/Roadmap
Kits: www.cypress.com/kits
Support: www.cypress.com/support
Training: www.cypress.com/training
Cypress Online Store: www.cypress.com/store
Developer Community & Forums: www.cypress.com/forums
App Notes: www.cypress.com/AppNotes

Cypress BLE Solutions



Cypress's BLE solutions webpage is your *one-stop-shop* for product datasheets, kits, App Notes, software, example projects and more

Bluetooth Resources

Bluetooth SIG website: www.bluetooth.org
Bluetooth Core Specifications (including Profiles and Services): www.bluetooth.org/en-us/specification/adopted-specifications
Bluetooth Low Energy - The Developer's Handbook by Robin Heydon (ISBN-10:013288836X)

Other Resources

Number Theory by George E. Andrews (ISBN-10:0486682528)

Workshop Objectives Recap

You should now

Know how to use PSoC Creator to rapidly design advanced BLE systems with:

- Over-the-air firmware upgrades[1]
- New Bluetooth 4.2 features[2]: Data Length Extension, Enhanced Security and Privacy 1.2
- Multi-Role[3] BLE devices

Please help us improve this workshop by completing our feedback form

[1] The process of replacing an existing firmware with a newer version over a wireless interface like BLE. Over-the-air firmware upgrade is described in the Lab #1: Over-The-Air Firmware Upgrade section

[2] Bluetooth 4.2 features are described in the Lab #2: Bluetooth 4.2 Features section

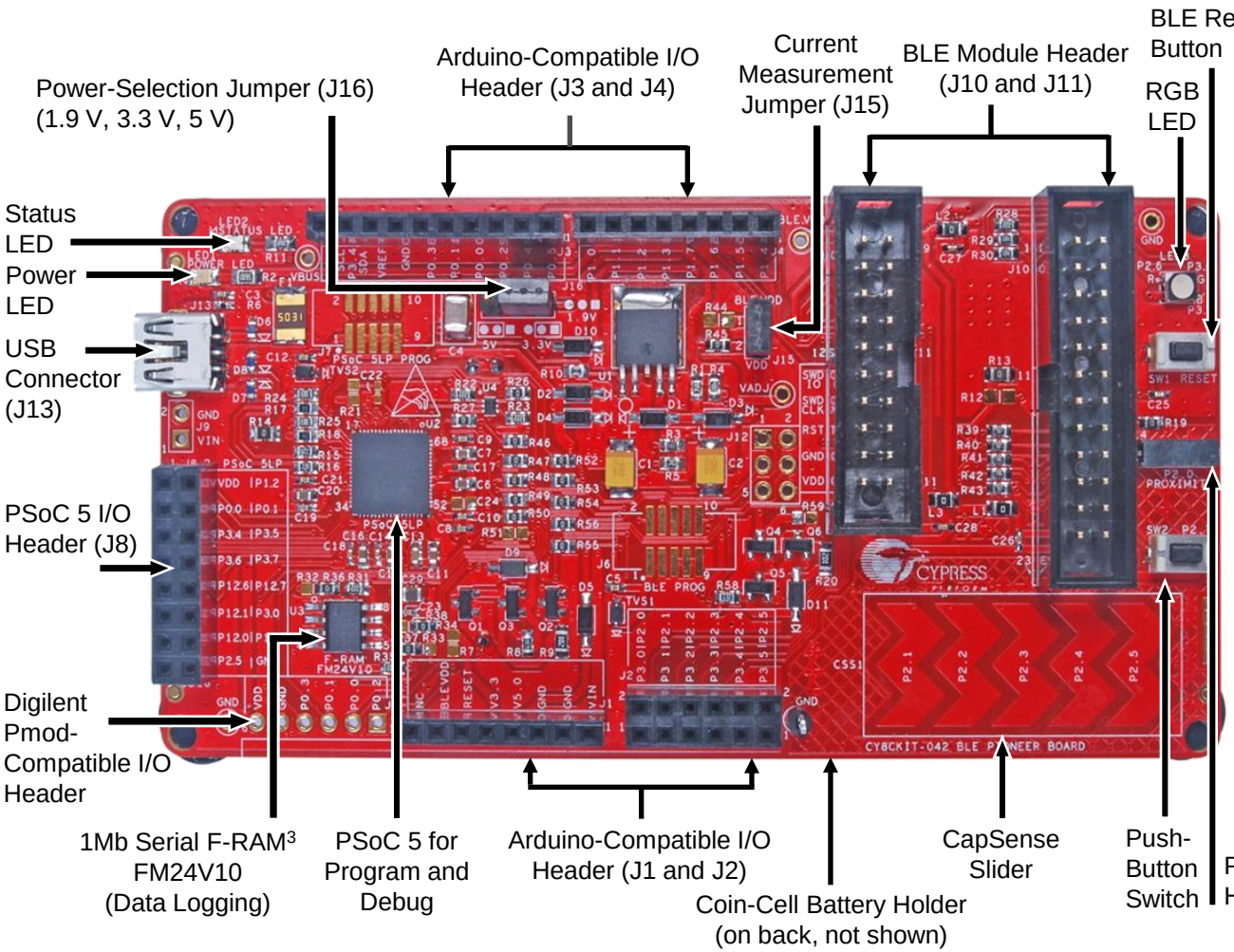
[3] Refers to multiple Generic Access Profile (GAP) roles described in the Lab #3: Multi-Role BLE Devices section

Advanced BLE System Design

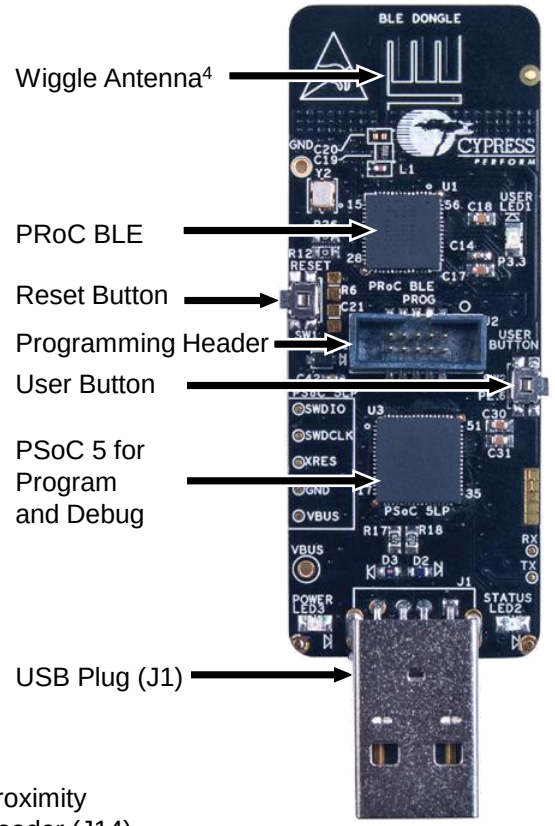
APPENDIX

BLE Pioneer Kit Baseboard and BLE-USB Bridge

BLE Pioneer Kit Baseboard to Develop a "GAP[1] Peripheral[2]"



BLE-USB Bridge With PRoC BLE (CY5670) to Simulate a "GAP[1] Central[2]"

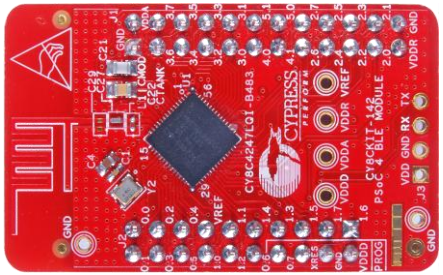


[1] The Generic Access Profile defines how BLE devices discover each other, establish a connection and interact based on their roles
[2] Devices like fitness monitors are assigned the GAP Peripheral role and connect to devices like mobile phones that are assigned the GAP Central role
[3] Ferroelectric RAM with an I²C serial interface
[4] A low-cost antenna made from a trace on the surface of a PCB

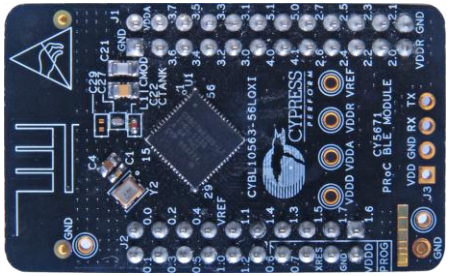
PSoC 4 BLE and PRoC BLE Features

Feature	PSoC 4 BLE with Bluetooth 4.2	PRoC BLE with Bluetooth 4.2
Applications	IoT[1] sensor nodes, wearables, small home appliances, home automation and portable medical devices	Mice, keyboards, trackpads, game controllers, remote controls, toys and simple BLE connectivity
CPU Core	ARM Cortex®-M0	ARM Cortex®-M0
CPU Speed	48 MHz	48 MHz
Flash/SRAM Sizes	128/16-256/32KB	128/16-256/32KB
ADC	1-Msps 12-bit SAR[2]	1-Msps 12-bit SAR[2]
Opamps/Comparators/IDACs	4/2/2	-
UDBs	4	-
Timers/Counters/PWMs	4/4/8	4/4/8
CapSense (I/Os)	Yes (36)	Yes (36)
Serial Interfaces	4 SPI/2 I²C/4 UART/I²S	2 SPI/2 I²C/2 UART/I²S
Packages	56-QFN/68-CSP/76-CSP	56-QFN/68-CSP/76-CSP

PSoC 4 BLE Plug-In Board (CY8CKIT-143A)



PRoC BLE Plug-In Board (CY5676A)



[1] Internet of Things: An expansion of the Internet to include everyday physical objects such as thermostats

[2] Successive approximation register

Elliptic Curve Diffie-Hellman (ECDH)

ECDH in Bluetooth 4.2 provides protection against passive eavesdropping[1]

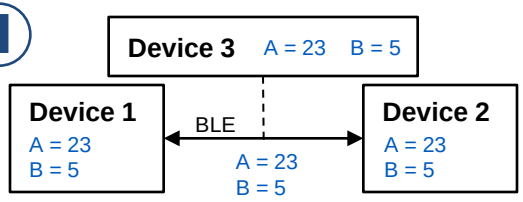
In Bluetooth 4.1, it is possible to listen to the key-exchange between two BLE devices and then monitor future communication

In Bluetooth 4.2, ECDH is used to establish a shared secret between two BLE devices

The shared secret is not exchanged over-the-air and is used by the BLE devices to derive the keys that encrypt communication

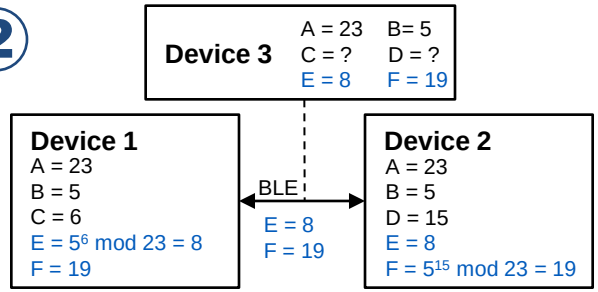
Using ECDH To Establish A Shared Secret Between Two BLE Devices

1



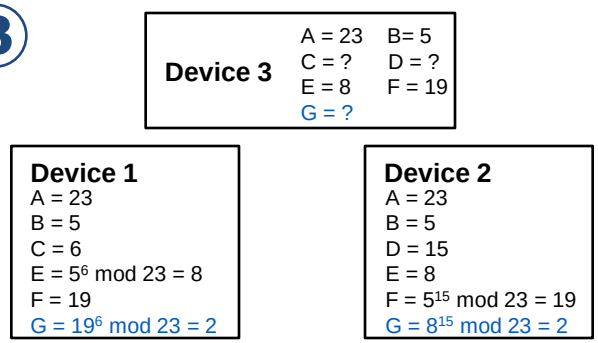
Device 1 and device 2 want to securely communicate using BLE
Device 3 is passively eavesdropping[1]
Devices 1 and 2 agree to use two integers:
"A" a prime integer, for example A = 23
"B" a primitive root modulo[2] of "A", for example B = 5
Device 3 monitors the BLE data packets to find "A" and "B"

2



Device 1 chooses a secret integer "C", for example C = 6
Device 1 sends device 2 "E" calculated as $E = B^C \bmod A = 5^6 \bmod 23 = 8$
Device 2 chooses a secret integer "D", for example D = 15
Device 2 sends device 1 "F" calculated as $F = B^D \bmod A = 5^{15} \bmod 23 = 19$
Device 3 monitors the BLE data packets to find "E" and "F"

3



Device 1 calculates the shared secret "G" as follows: $G = F^C \bmod A = 19^6 \bmod 23 = 2$
Device 2 calculates the shared secret "G" as $G = E^D \bmod A = 8^{15} \bmod 23 = 2$
Device 3 cannot calculate the shared secret "G" because it does not have the values of "C" and "D"

Note that this is just an example, the actual numbers used will be larger than shown here

[1] The process of monitoring the private communication between two BLE devices

[2] To understand "primitive root modulo" refer to *Number Theory* by George E. Andrews

Cypress Bluetooth Qualification Details

QDID	Declaration ID	Name	Product Type	Spec
63199	D025070	Profiles supported by the BLE Component in PSoC Creator	Profile Subsystem	4.1
61908	D024756	Host or BLE Protocol Stack	Component	4.1
76858	D028204	Host or BLE Protocol Stack	Component	4.2
62243	D024755	Link Layer	Component	4.1
76764	D028203	Link Layer	Component	4.2
62245	D024754	RF-PHY for 56-QFN package	Component	4.1
63368	D025068	RF-PHY for 68-ball and 76-ball CSP package	Component	4.1
62887	D024757	PSoC 4 BLE and PRoC BLE (56-QFN package)	End Product	4.1
63683	D025069	PSoC 4 BLE and PRoC BLE (68-ball and 76-ball CSP package)	End Product	4.1
77810	D028205	PSoC 4 BLE and PRoC BLE (56-QFN package)	End Product	4.2
77961	D028206	PSoC 4 BLE and PRoC BLE (76-ball CSP package)	End Product	4.2
67366	D026297	EZ-BLE PRoC Module (CYBLE-022001-00)	End Product	4.1
79920	D029884	EZ-BLE PRoC Module (CYBLE-222005-00)	End Product	4.1
79919	D029885	EZ-BLE PRoC Module (CYBLE-012011-00)	End Product	4.1
79697	D029647	EZ-BLE PSoC Module (CYBLE-014008-00)	End Product	4.1
79480	D029646	EZ-BLE PSoC Module (CYBLE-214009-00)	End Product	4.1
67366	D026297	EZ-BLE PRoC Module (CYBLE-022001-00)	End Product	4.1