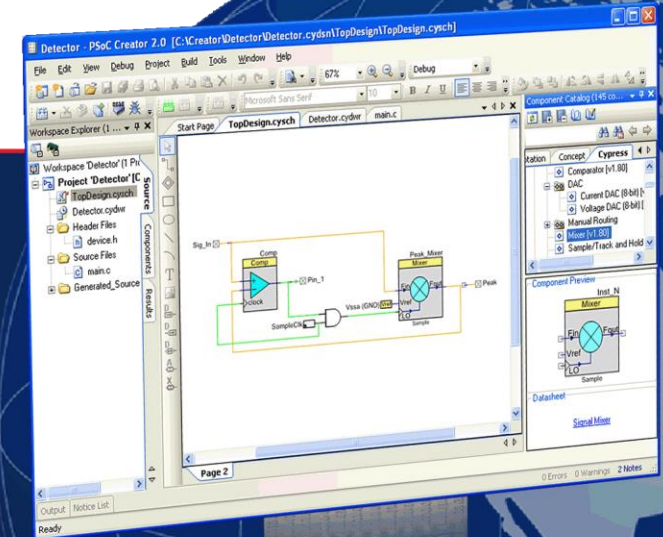




Customer Training Workshop: Introduction to BLE System Design

BLE = Bluetooth® Low Energy

Easily Design Wireless Systems with the Most
Integrated One-Chip BLE Solution



Workshop Objectives



By the end of this workshop, you will

Understand Cypress's BLE one-chip solutions including PSoC[®] 4 BLE and PRoC[®] BLE¹

Understand the BLE architecture

Learn how to use Cypress's BLE solutions and development environment to implement:

BLE connections with PSoC 4 BLE and PRoC BLE

One-chip, sensor-based system designs with BLE connectivity for the Internet of Things (IoT²)

One-chip, CapSense[®] touch-sensing user interface designs with BLE connectivity

¹ PSoC = Programmable System-on-Chip, PRoC = Programmable Radio-on-Chip

² An expansion of the Internet to include everyday physical objects such as thermostats

Workshop Agenda



Time	Page	Topic
0:00 (15 min)	4	Set Up and Install Software
0:15 (15 min)	5	Bluetooth and PSoC Terms
0:30 (15 min)	10	Demo #1: PSoC Creator™ ¹ and BLE Pioneer Kit ² Overview
0:45 (30 min)	16	Cypress BLE Solution Overview
1:15 (10 min)	25	Demo #2: BLE Component Overview
1:25 (45 min)	27	Lab #1: Your First PSoC 4 BLE Design
2:10 (30 min)	30	BLE Architecture Overview
2:40 (30 min)	36	Session Break
3:10 (45 min)	37	Lab #3: IoT Sensor-Based System Design
3:55 (45 min)	43	Lab #4: CapSense Design with BLE Connectivity
4:40 (10 min)	47	Cypress BLE Modules
4:50 (10 min)	52	Wrap-up
5:00		End of workshop

¹ PSoC 3, PSoC 4 and PSoC 5 Integrated Design Environment (IDE) software that installs on your PC

² The BLE Pioneer Kit baseboard is part of the \$49 BLE Pioneer Kit, which programs and debugs PSoC functionality

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 in the table below

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

Software	Version	File Name
PSoC Creator¹ Installer	3.2 (or newer)	"PSoCCreatorSetup_3.2.exe"
CySmart² Installer	1.0 SP1 (or newer)	"CySmartSetup_1.0_sp1.exe"
BLE Pioneer Kit Installer	Revision *C (or newer)	"CY8CKIT042BLEKITSetupOnlyPackage_RevSC.exe"
BLE Lab Exercise Files	2.0	"BLEWorkshop_2.0.zip"

Required hardware:

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

Raise your hand if you need help!



¹ PSoC 3, PSoC 4 and PSoC 5 Integrated Design Environment (IDE) software that installs on your PC

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

Bluetooth Classic

A legacy standard for personal area networks made popular by audio streaming to cell phone headsets
Operates in the 2.4-GHz ISM¹ Band with GFSK² modulation and supports up to a 3-Mbps data rate

Bluetooth Low Energy (BLE)

A standard for short-range, low-power wireless applications that communicates state or control information
Operates in the 2.4-GHz ISM¹ Band with GFSK² modulation and supports a 1-Mbps data rate
Not backward-compatible with Bluetooth Classic

Bluetooth 4.0

An upgraded Bluetooth Classic specification that adds BLE

Bluetooth 4.1 ([Bluetooth Spec](#))

An enhanced Bluetooth 4.0 specification, adopted in Dec. 2013
Includes improved security, lower power and higher throughput³

Bluetooth Smart

A brand for Bluetooth 4.0/4.1 products that support only BLE

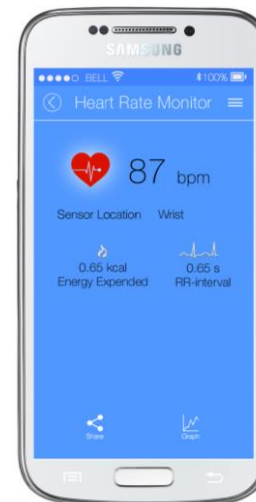
Bluetooth Smart Ready

A brand for Bluetooth 4.0/4.1 products that support both Bluetooth Classic and BLE

Bluetooth Special Interest Group (SIG)

The organization that oversees the development and licensing of Bluetooth standards

Bluetooth Smart Ready Product



Bluetooth Classic Product



Audio Streaming

Bluetooth Smart Product



Sensor Data

¹ An Industrial, Scientific, Medical (ISM) RF frequency band that is license-free worldwide

² Gaussian frequency shift keying

³ 272 Kbps (15% higher vs. 4.0) including protocol overhead

BLE Protocol Stack (BLE Stack)

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

BLE Profile (Profile)

A Bluetooth specification that describes a set of operations and behaviors that devices use to communicate with one another

Ensures interoperability when two or more devices use a common Profile

For example, keyboards use the HID Profile and Heart Rate Monitors (HRMs) use the HRM Profile

Analog Front End (AFE)

An analog signal-conditioning circuit that uses opamps, filters and comparators to interface to an analog-to-digital converter (ADC)

Internet of Things (IoT)

An expansion of the Internet to include everyday physical objects such as thermostats

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), among other capabilities

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 TCPWMs³

Universal Digital Block (UDB)

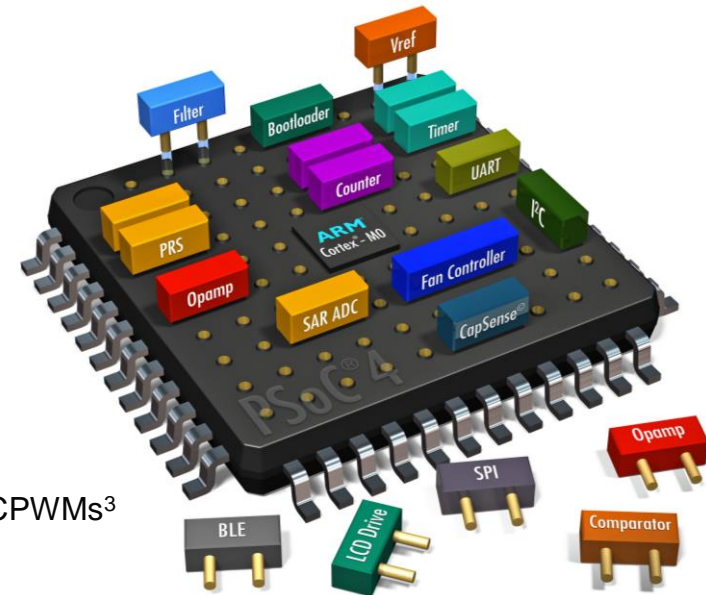
A PSoC **Programmable Digital Block** that contains: two programmable logic devices (PLDs), one programmable data path with an arithmetic logic unit (ALU), one status register and one control register

Configured in **PSoC Creator**⁴ using **PSoC Components**², or the graphical state machine editor or Verilog code

Serial Communication Block (SCB)

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

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



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 (PWM)

⁴ PSoC 3, PSoC 4 and PSoC 5 Integrated Design Environment (IDE) software that installs on your PC

PSoC Terms

Timer, Counter, PWM (TCPWM) Block

A PSoC **Programmable Digital Block** that is configurable as a 16-bit timer, counter, PWM 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 and PSoC 5 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

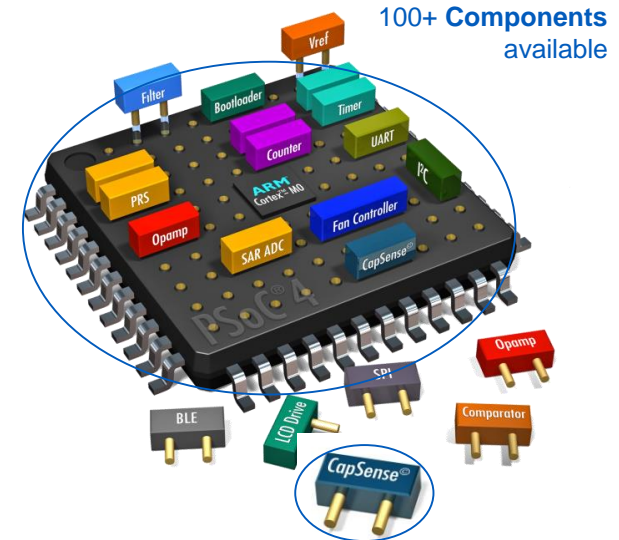
Used to **integrate multiple ICs** and system interfaces into one **PSoC**

Dragged and dropped as icons to design systems in PSoC Creator

Component Configuration Tools

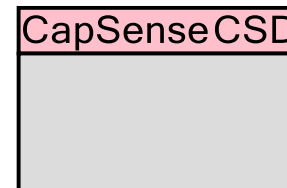
Simple graphical user interfaces in PSoC Creator embedded in each Component

Used to customize Component parameters

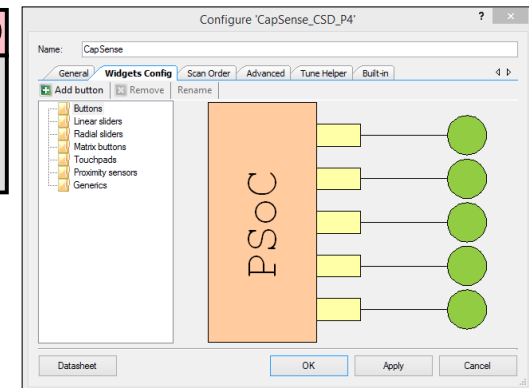


CapSense is used to create **touch buttons and sliders**

Component Icon



Component Configuration Tool



PSoC Terms

PSoC 4

A PSoC with an ARM® Cortex®-M0 MCU

PSoC 4 BLE

A PSoC 4 with up to 256KB flash, 36 I/Os,
10 **Programmable Analog Blocks**, 10 **Programmable Digital Blocks**
and an integrated BLE radio with a royalty-free BLE Protocol Stack

PRoC BLE (Programmable Radio-on-Chip)

An ARM Cortex-M0 MCU with up to 256KB flash, 36 I/Os,
2 **Programmable Analog Blocks**, 6 **Programmable Digital Blocks**,
an integrated BLE radio and a royalty-free BLE Protocol Stack

CySmart™

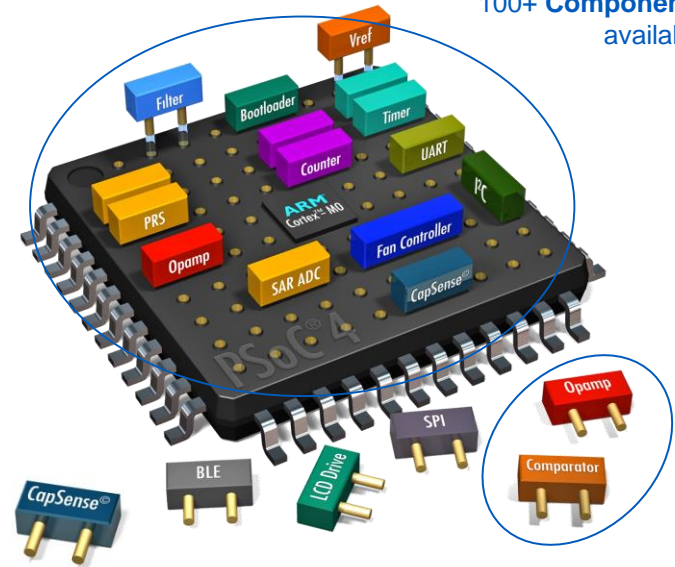
A GUI-based software tool that installs on your PC to test and debug BLE functionality

BLE Component

A Component that creates **Bluetooth Smart** products in minutes
Includes a Component Configuration Tool that makes the complex
BLE Protocol Stack and Profiles simple to implement with a GUI

As you will soon see, this is a big deal!

100+ **Components**
available

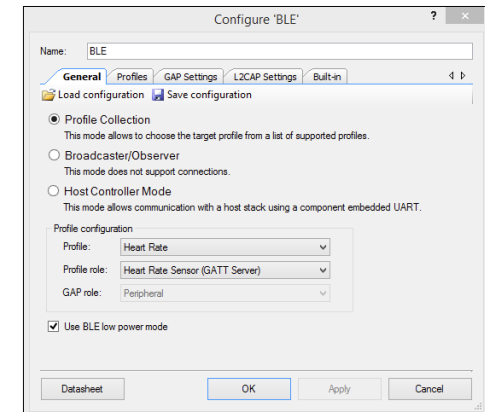


Programmable Analog Components are
used to create custom AFEs

Component Icon



Component Configuration Tool



Introduction to BLE System Design

DEMO #1: PSoC CREATOR AND BLE PIONEER KIT OVERVIEW

Demo #1: PSoC Creator Overview

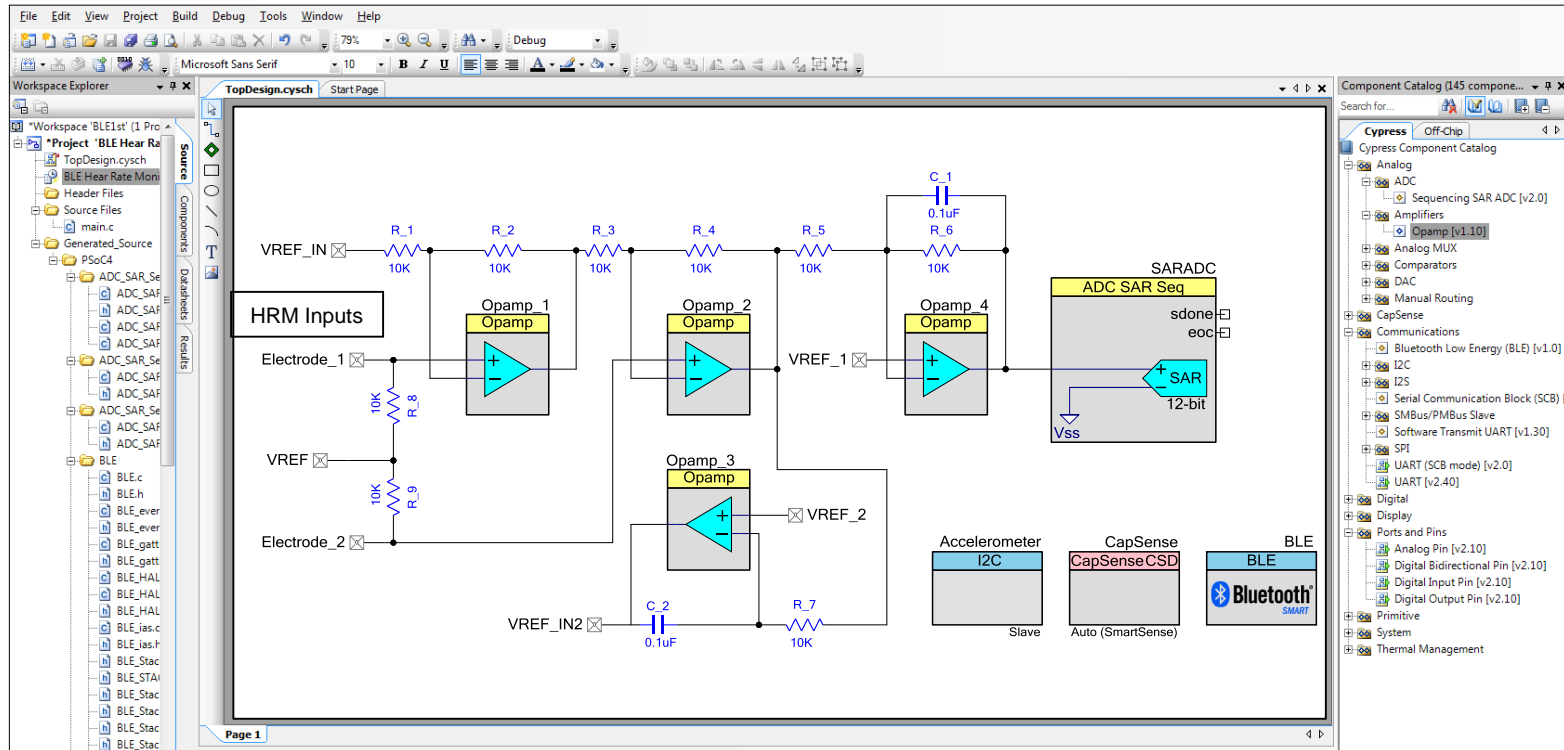
Objectives:

Learn about the PSoC Creator workflow:

- Create a new project
- Find 100s of example projects
- Place and configure a Component
- Open a datasheet
- Assign signals to pins
- Build and debug a design

A BLE Heart Rate Monitor Example Project in the PSoC Creator IDE

Software tool:
PSoC Creator IDE



BLE Pioneer Kit Overview



The \$49 BLE Pioneer Kit (CY8CKIT-042-BLE) contains:

BLE Pioneer Kit baseboard

- Is compatible with Arduino™ and Digilent® Pmod™ hardware ecosystems
- Features onboard CapSense slider, RGB LED, push buttons and Cypress F-RAM
- Includes PSoC 5 for program and debug
- Supports 1.9 V, 3.3 V, 5 V and coin cell battery operation

Modules¹

- Two FCC-certified² BLE modules that plug into the BLE Pioneer Kit Baseboard
- Feature an onboard antenna and provide access to all GPIOs
- Support BLE-UART bridge via an onboard four-pin header

BLE-USB bridge with PProC BLE

- Enables the use of a PC to develop and debug BLE peripherals
- Features an onboard LED, push button and PSoC 5 for program and debug

Example projects

- Demonstrate how to use PSoC Creator to implement common BLE Profiles, such as Heart Rate Monitor (HRM), Glucose Meter and Human Interface Device (HID)

Mobile apps³

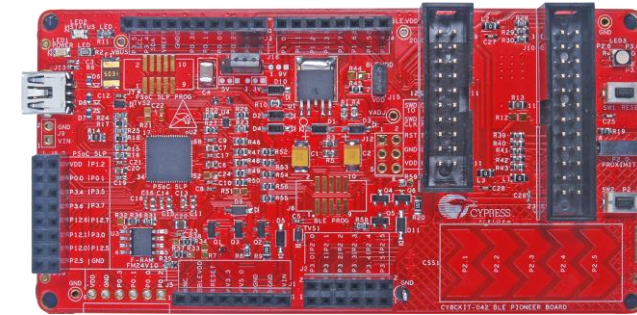
- Include CySmart mobile apps³ for both iOS and Android mobile operating systems to test and debug BLE systems

¹ Additional BLE modules are available, refer to the [wrap-up section](#) for more details

² Designation for products manufactured or sold in the U.S. that meet the electromagnetic interference standards of the Federal Communications Commission

³ Mobile apps are software programs that run on a mobile device

BLE Pioneer Kit Baseboard



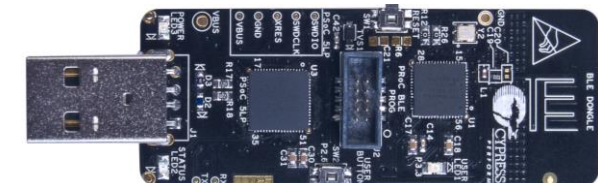
PSoC 4 BLE Module



PProC BLE Module



BLE-USB Bridge with PProC BLE

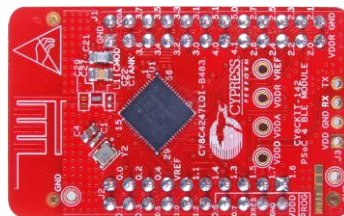


BLE Pioneer Kit Supports PSoC 4 BLE and PRoC BLE

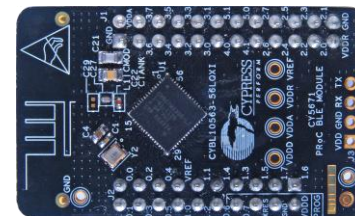


<u>Feature</u>	<u>PSoC 4 BLE</u>	<u>PRoC BLE</u>
Applications	IoT sensor nodes, wearables, small home appliances, home automation and portable medical devices	Mice, keyboards, trackpads, game controllers, remote controls, toys and BLE bridges
CPU Core	ARM Cortex-M0	ARM Cortex-M0
CPU Speed (MHz)	48	48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

PSoC 4 BLE Module



PRoC BLE Module

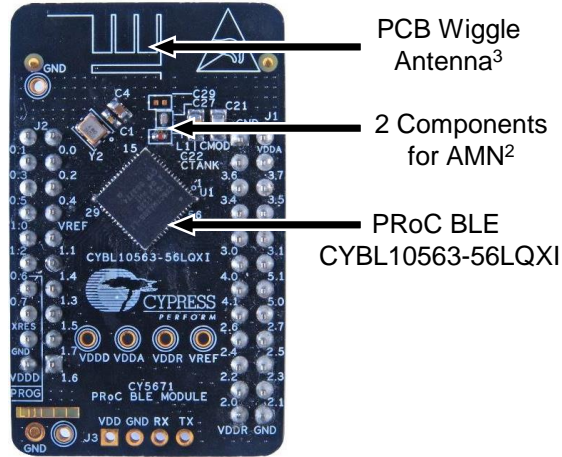


¹ Successive approximation register

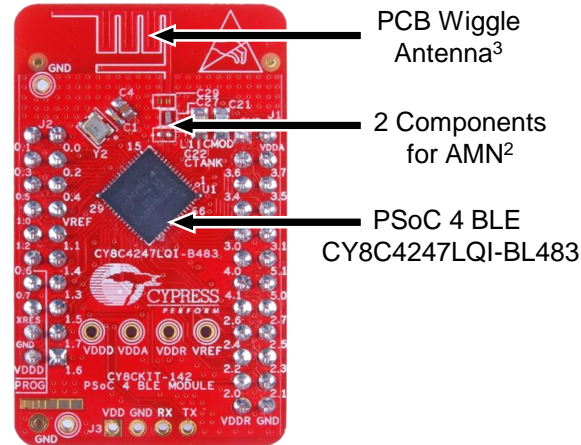
PSoC 4 BLE and PSoC BLE Modules



PSoC BLE Module



PSoC 4 BLE Module

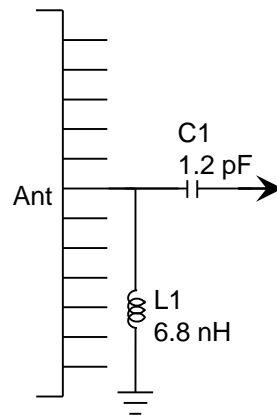


Cypress's BLE solutions integrate the Balun¹, simplifying AMN² design

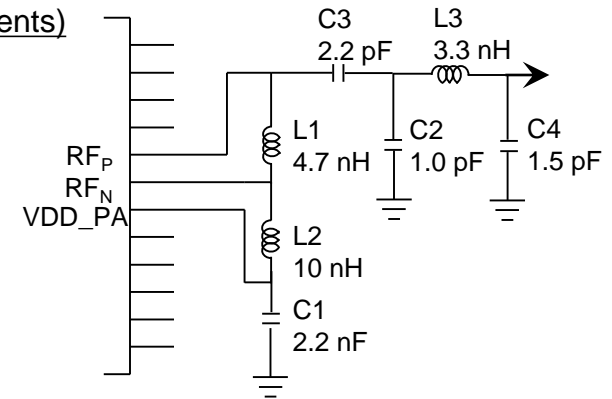
Traditional AMNs² are sensitive to PCB layout and parasitics and require tuning

Typical AMNs² have 7-9 external components vs. **only two** for the Cypress solution

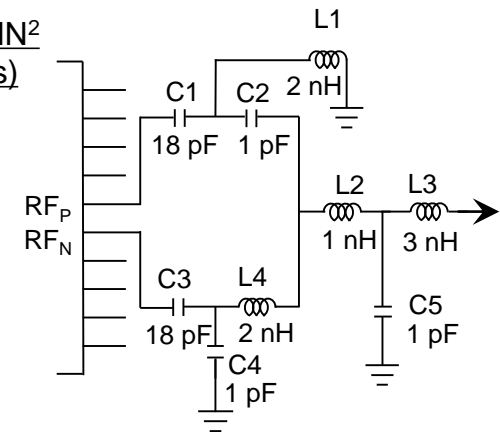
[Cypress's AMN²](#) (2 components)



[Vendor A's AMN²](#) (7 components)



[Vendor B's AMN²](#) (9 components)



¹ An electrical device that converts a differential RF signal to a single-ended signal or vice-versa

² Antenna matching network: An RLC circuit network that provides Balun functionality, antenna impedance matching and low-pass filtering

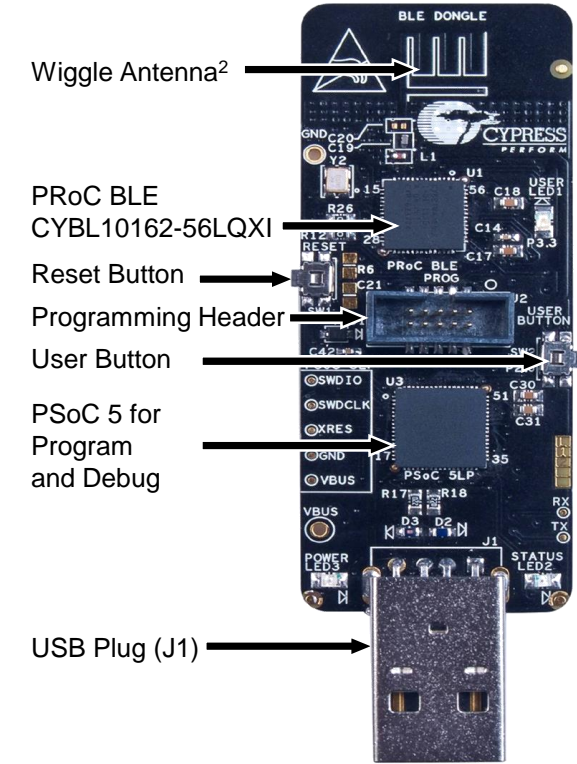
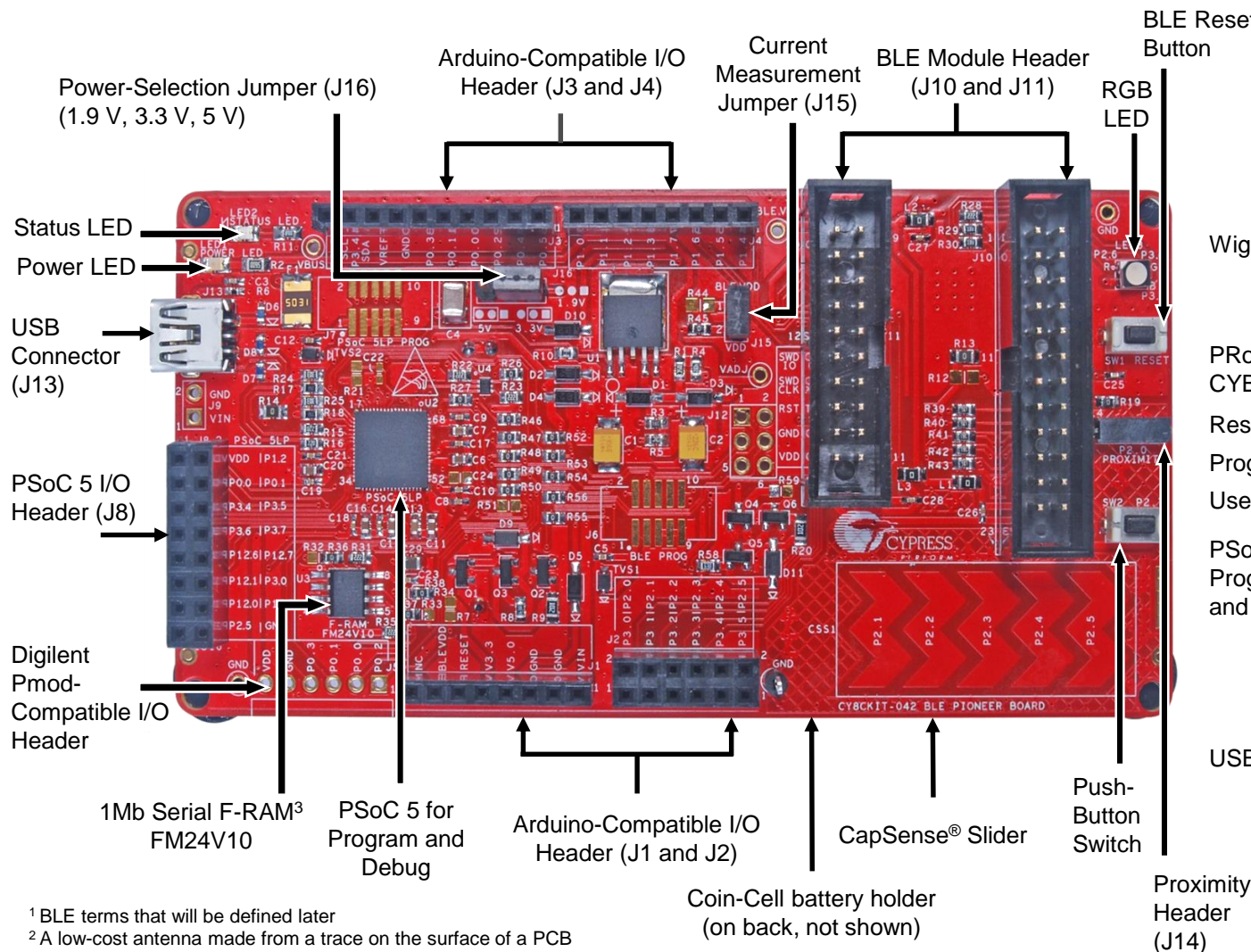
³ A low-cost antenna made from a trace on the surface of a PCB

BLE Pioneer Kit Baseboard and BLE-USB Bridge



BLE Pioneer Kit Baseboard to Develop a "GAP Peripheral"

BLE-USB Bridge With PProC BLE to Simulate a "GAP Central"



¹ BLE terms that will be defined later
² A low-cost antenna made from a trace on the surface of a PCB
³ Ferroelectric RAM with an I²C serial interface

Introduction to BLE System Design

CYPRESS BLE SOLUTION OVERVIEW

Cypress BLE Solution Overview



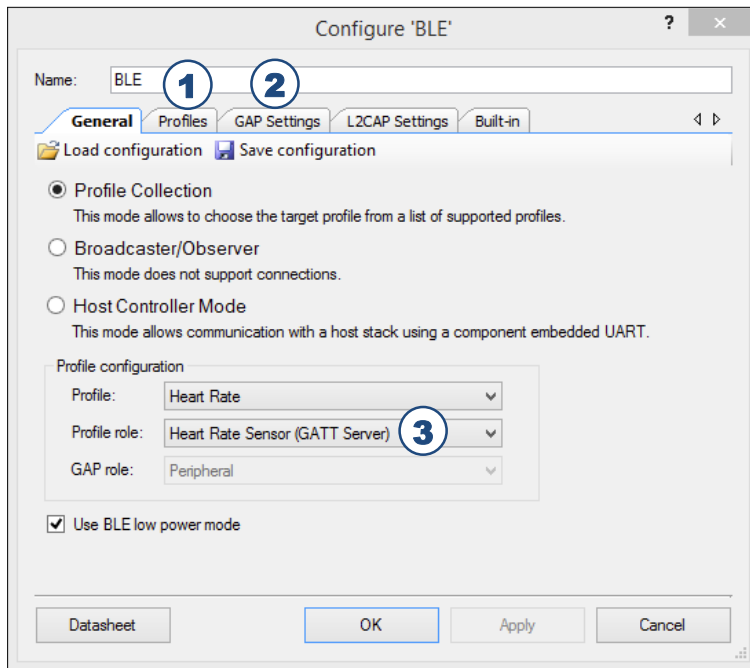
Cypress BLE integrates the entire BLE Architecture—Radio, BLE Stack and Application—on one chip

The royalty-free **BLE Stack** provided by Cypress is a complete implementation of the Bluetooth 4.1 Specification

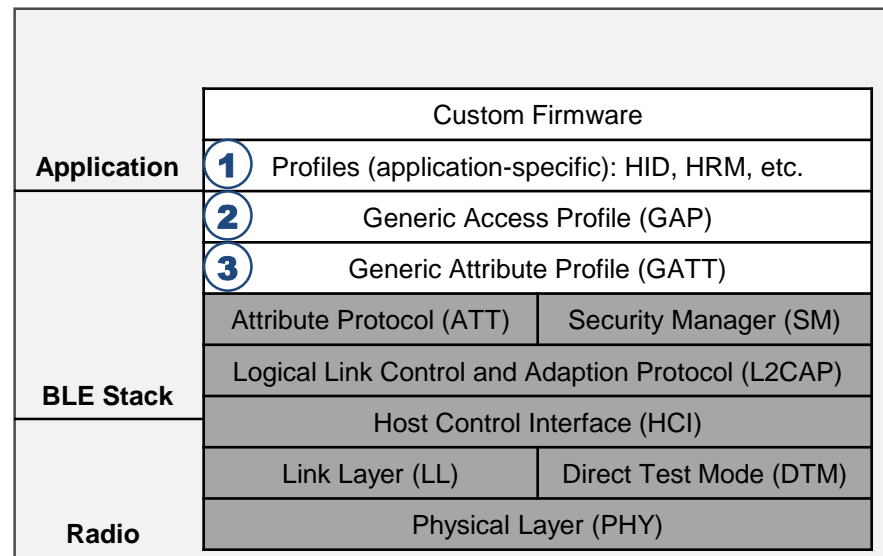
The **Application** is a combination of your firmware and the Cypress provided BLE Profile

The **Generic Access Profile (GAP)** and **Generic Attribute Profile (GATT)** define how BLE devices connect and exchange data¹

Simple: BLE Component Configuration Tool



Difficult: Typical BLE Architecture Diagram from the Bluetooth Spec²



All of the parameters of the BLE Stack and Radio are configured using the BLE Component Configuration tool. **Simply select the Profile, GAP and GATT parameters** in the tool. The **BLE Component automatically configures the remaining parameters** for the BLE Stack and radio.

The BLE Component simplifies the BLE Stack and Profile configuration process into three simple steps

¹ GAP and GATT are further defined on the following slides

² Source for terms and definitions: *Bluetooth Low Energy: The Developer's Handbook*

BLE Profile

A Bluetooth specification that guarantees application-level interoperability between devices that use the same **Profile**.

For example, keyboards use the HID Profile and heart rate monitors (HRMs) use the HRM Profile

Standard Profiles (or Adopted GATT Profiles)

Guarantee interoperability between two devices using the same **Profile**

Defined by the **SIG** in the Bluetooth Spec

Assigned a 128-bit **Universally Unique Identifier (UUID)**

Natively supported by client¹ operating systems

e.g., Google Android 4.x, Apple iOS 8.x, Microsoft Windows 8.1

Custom Profiles

Non-standard **Profiles** for custom applications not defined by the **SIG**

Often provided by solution vendors for proprietary technologies

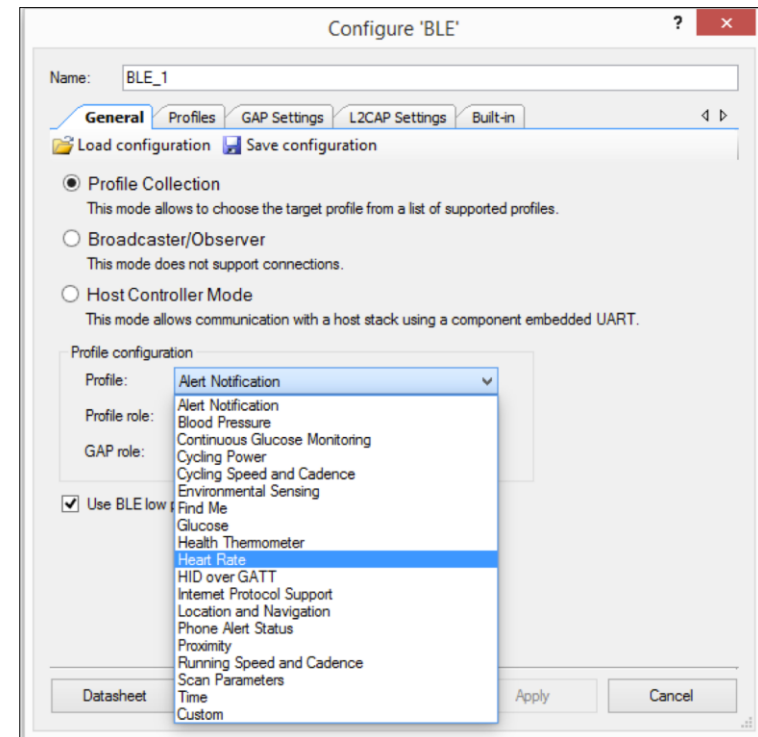
e.g., Cypress provides a custom **CapSense Profile**

Require a custom **UUID**

Require custom software on the Client¹

e.g., Cypress provides mobile apps for iOS/Android Clients¹ with support for the **Custom CapSense Profile**

Profiles in the BLE Component



The BLE Component supports all Standard Profiles and enables quick creation of Custom Profiles that meet the Bluetooth Spec

¹ A BLE device that requests and receives data, e.g., a mobile phone

The Anatomy of a Profile¹

A Profile is a collection of “Services”

- 1 For example, the Blood Pressure **Profile** contains four **Services**: “Generic Access,” “Generic Attribute,” “Blood Pressure” and “Device Information”

A Service is a collection of “Characteristics”

- 2 For example, the Blood Pressure **Service** contains three **Characteristics**: “Blood Pressure Measurement,” “Intermediate Cuff Pressure” and “Blood Pressure Feature”

A Characteristic is a collection of “Attributes”

- 3 For example, the Blood Pressure Measurement **Characteristic** contains one **Attribute** referred to as a set of “Fields” in the [Bluetooth Spec](#) as seen on the image on the right

An Attribute is the smallest unit of information

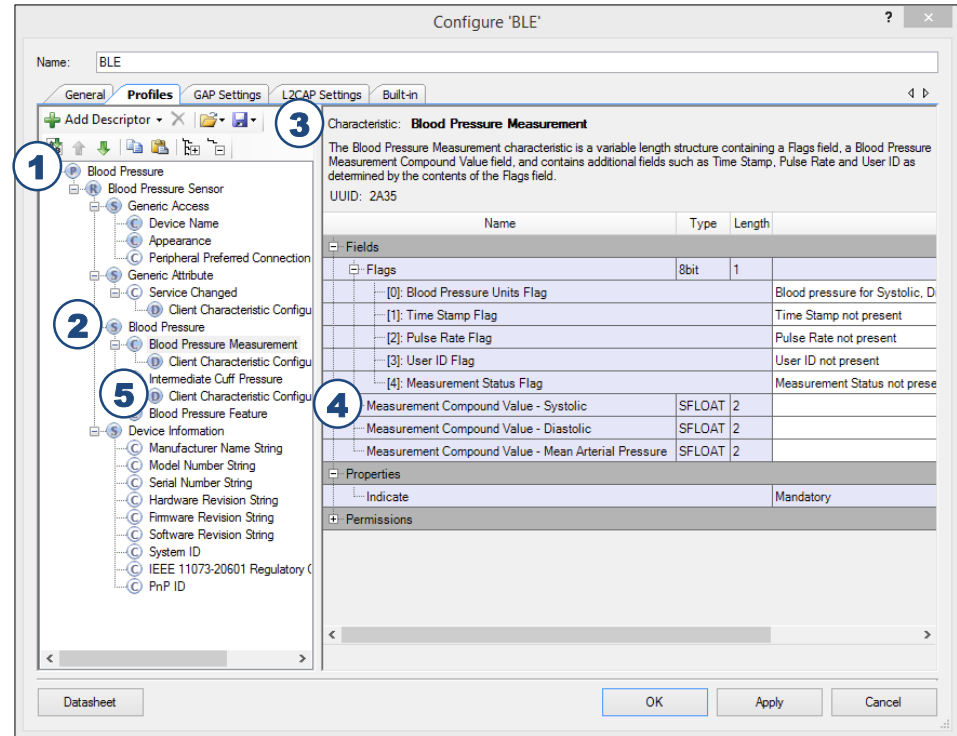
- 4 For example, the actual Blood Pressure value stored in one of several “Measurement Compound Value” Fields as seen in the image on the right

A Descriptor is a type of Attribute

- 5 Descriptors provide additional information about a given **Characteristic**

The BLE Component enables easy configuration of Profiles in the GUI-based Component Configuration Tool

Profile Tab in the BLE Component Configuration Tool



Easily configure the parameters for the Profiles, Services, Characteristics and Attributes

¹ For more details on the actual Blood Pressure Profile, Services, Characteristics and Attributes refer to the [Bluetooth Spec](#) or BLE Component Datasheet

GAP: Establishing a BLE Connection

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”:

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

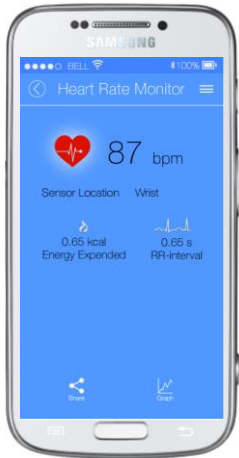
GAP Central: Role in which a device, like a mobile phone, connects to a **GAP Peripheral** device, like a fitness monitor

GAP Broadcaster: Role in which a device only advertises or transmits data¹

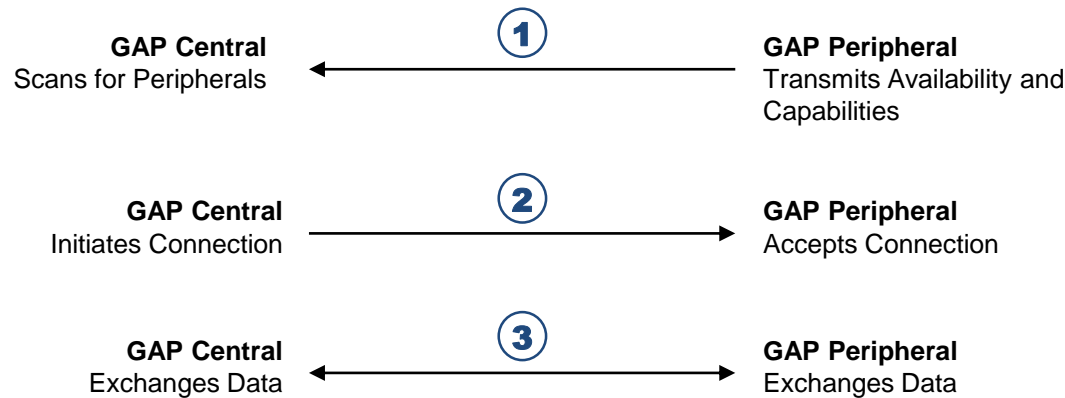
GAP Observer: Role in which a device only listens or scans for devices¹

Establishing a BLE Connection in Three Easy Steps

Bluetooth Smart-Ready Mobile Phone



Bluetooth Smart Fitness Monitor



¹ GAP Broadcaster and GAP Observer roles are included for completeness but not used in this introductory workshop. Refer to the [Appendix slide](#) for examples of GAP roles.

GATT: Defining How to Communicate

Generic Attribute Profile (GATT)

Defines the way that two BLE devices exchange data

A BLE device can operate in the following “GATT roles”:

GATT Server: A device that receives requests and sends data, typically a **GAP Peripheral**, like a fitness monitor

GATT Client: A device that requests and receives data, typically a **GAP Central**, like a mobile phone

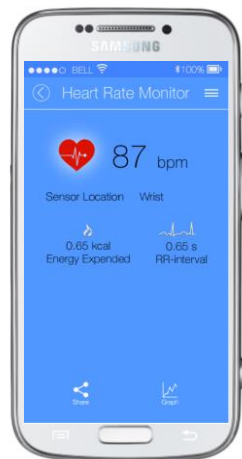
GATT Database (DB)

Stores and provides data and metadata¹ in the [Bluetooth Spec](#) format

Runs in a GAP Peripheral and responds to read and write requests from both GAP Central and the GAP Peripheral itself

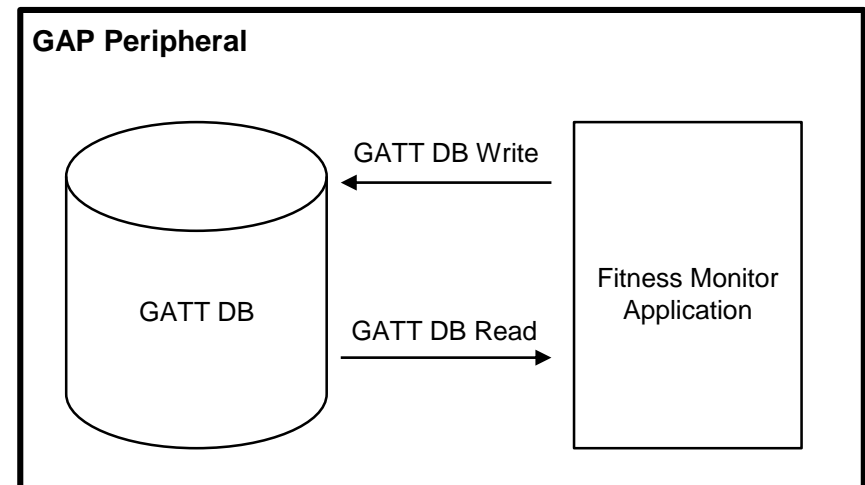
BLE Communicates via GATT DB Reads and Writes

GATT Client in a GAP Central
Like a Mobile App² on a Mobile Phone



Bluetooth Smart-Ready mobile phone

GATT Server in a GAP Peripheral
Like a Fitness Monitor Application



¹ Data that describes other data for the purposes of categorization

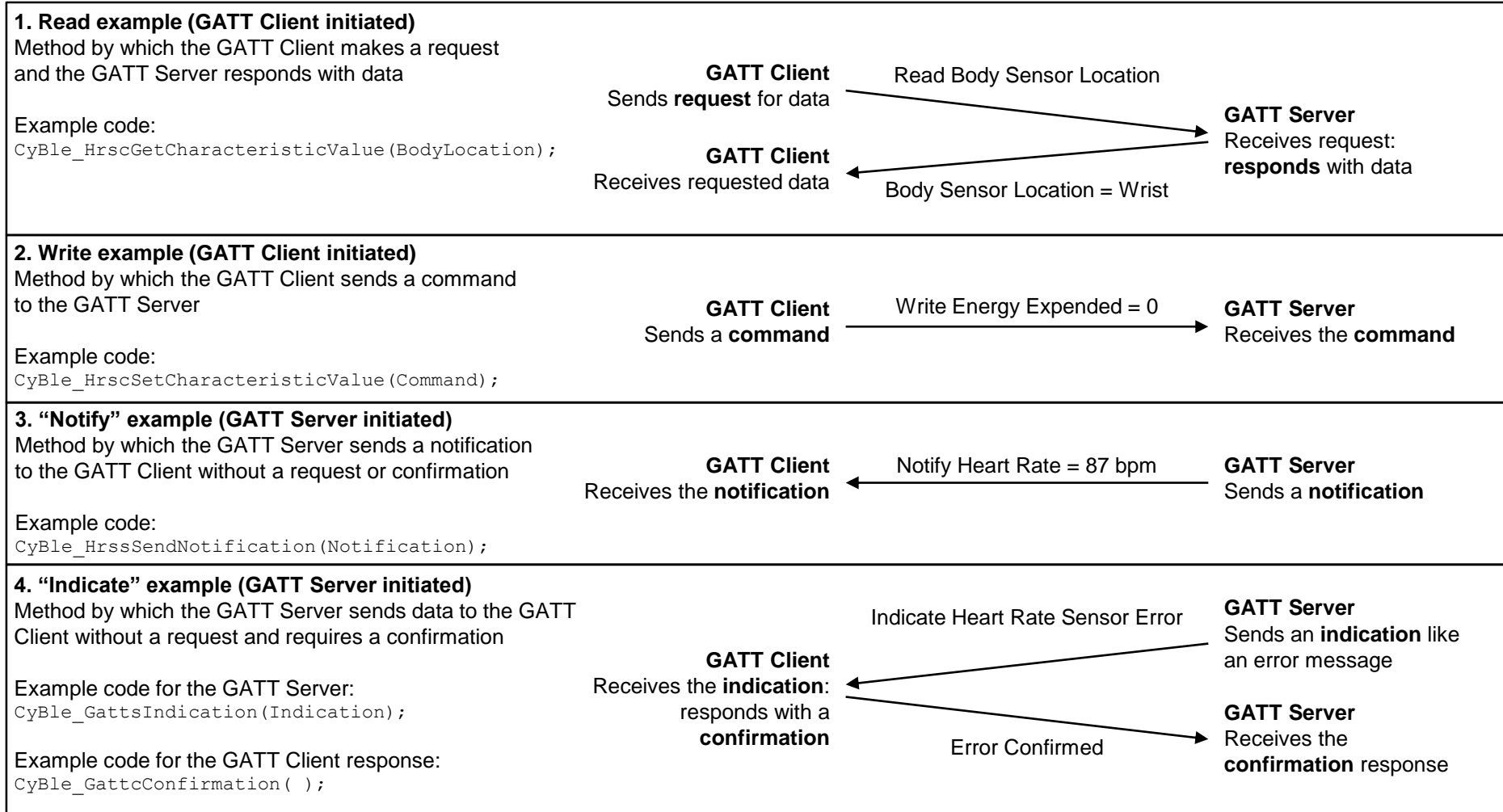
² Mobile apps are software programs that run on a mobile device

Attribute Protocol: Communication Example



Attribute Protocol (ATT) defines the rules for BLE communication

Enables **GATT Clients** to find and access **Attributes** on a **GATT Server** using six operations: Requests, Responses, Commands, Notifications, Indications and Confirmations



Security Manager: Establishing Secure Connections



The Security Manager (SM) defines the following security methods:

Pairing: A process to establish a secure connection using authentication and key distribution

Authentication: A process to verify the identity of a device

Key distribution: A process of exchanging security keys contained in 128-bit data packets for pairing two devices

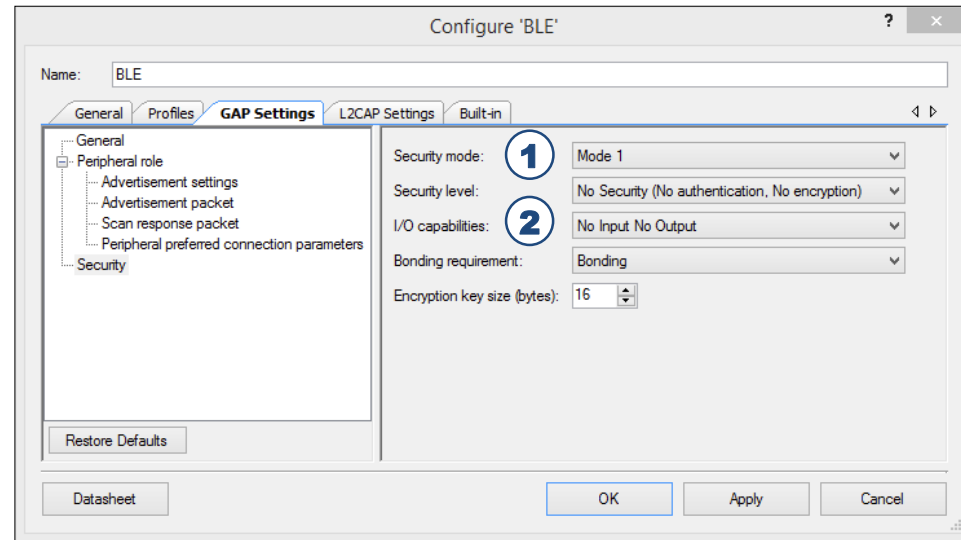
Bonding: A process of storing keys and authentication data in memory, so two devices can reconnect without the pairing process

Whitelist: An exclusive set of **GAP Central** devices that a **GAP Peripheral** can pair with, maintained in the **LL** hardware of the **GAP Peripheral** to enable low-power, secure and fast connections.

Cypress BLE SM: Supported I/O Capabilities and Security Levels¹

1	Security	Level 1	Level 2	Level 3
	Mode 1	No Security	Unauthenticated + Encrypted	Authenticated + Encrypted
	Mode 2	Unauthenticated + Data Signed ²	Authenticated + Data Signed ²	N/A

2	I/O Capabilities
	Display Only
	Display: Yes/No
	Keyboard Only
	No Input, No Output
	Display

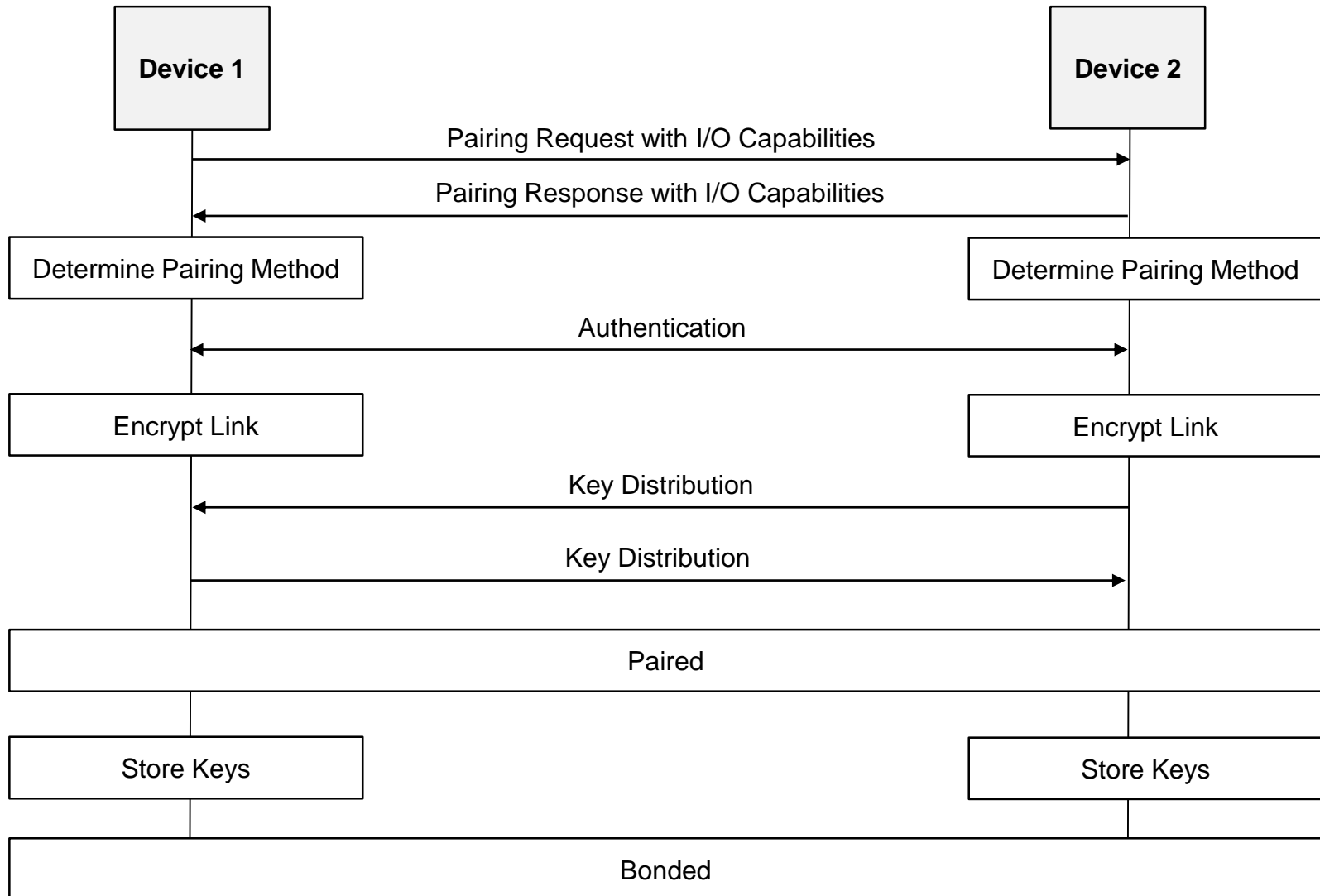


The BLE Component enables easy SM configuration in its GUI-based tool, without writing any firmware

¹ Refer to the [BLE Component Datasheet](#) for more information on these terms

² Data that is signed with a security key to ensure data integrity

Secure Connection Example



Introduction to BLE System Design

DEMO #2: BLE COMPONENT OVERVIEW

Demo #2: BLE Component Overview

Objectives:

- Review the BLE Component and Component Configuration Tool
- Learn where GAP, GATT and Profiles are configured
- Learn how to use the Component Datasheet and APIs¹

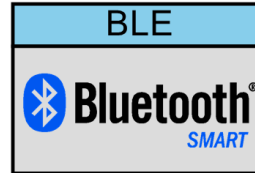
Software tool:

PSoC Creator IDE

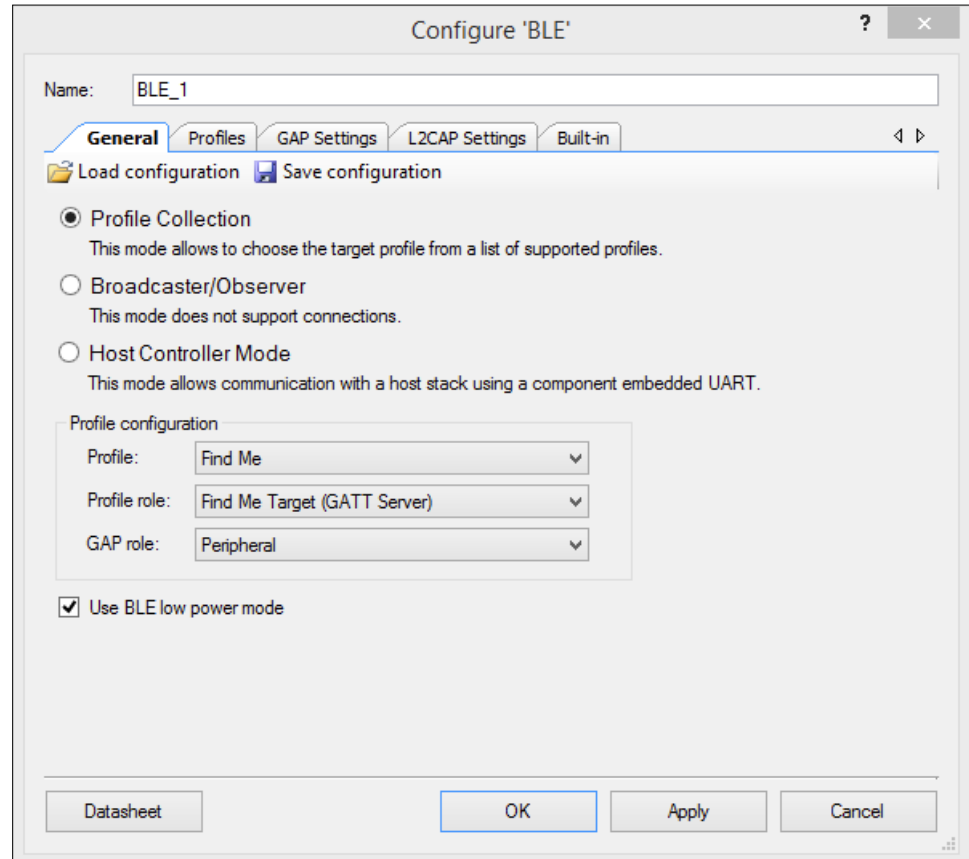
Component:

BLE Component

BLE Component Icon



BLE Component Configuration Tool



¹ Application programming interfaces are simplified sets of instructions used to interact with a Component

Introduction to BLE System Design

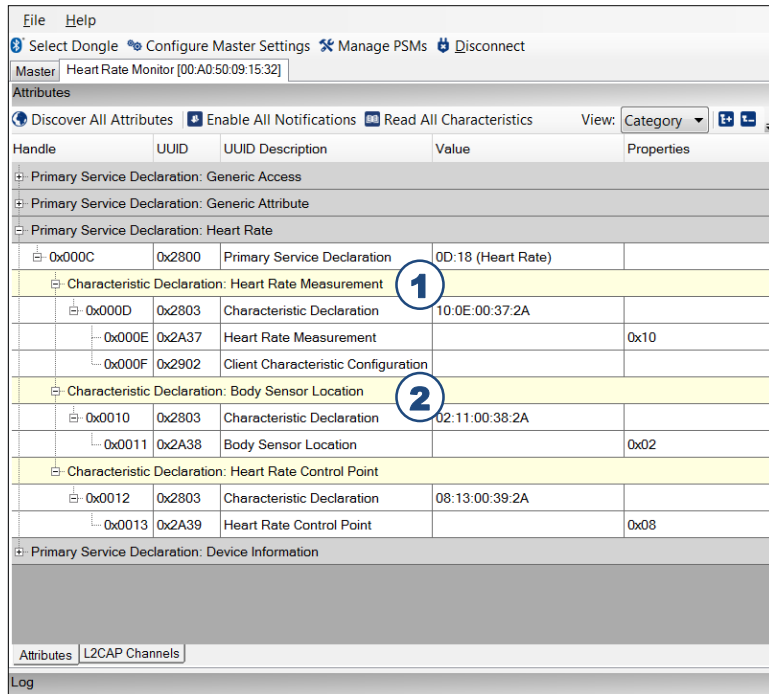
LAB #1: YOUR FIRST PSoC 4 BLE DESIGN

CySmart BLE Test and Debug Tool Overview

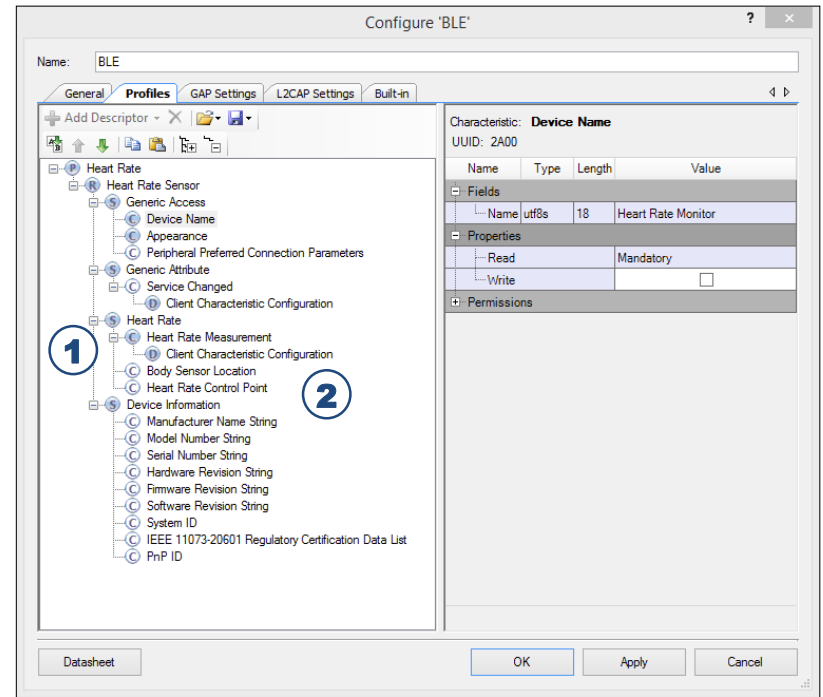


CySmart tool sends read and write requests to the GATT DB in BLE GAP Peripherals

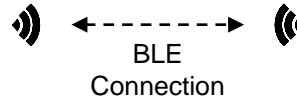
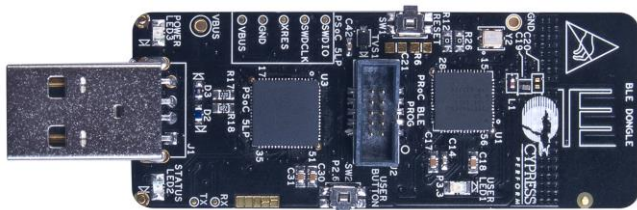
CySmart BLE Test and Debug Tool



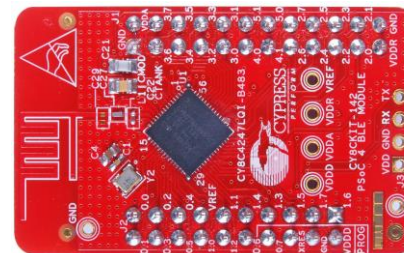
BLE Component Configuration Tool Profile Settings



BLE-USB Bridge with PSoC BLE Connected to a PC



PSoC 4 BLE Module Connected to the BLE Pioneer Baseboard



Lab #1: Your First PSoC 4 BLE Design

Objectives:

Learn how to use PSoC Creator to implement and debug PSoC designs

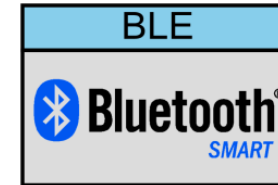
Implement a simple blinking LED design

Learn how to use the BLE Component

Implement a standard “Find Me” Profile with the Immediate Alert Service (IAS)¹

Learn how to use the CySmart tool to debug BLE designs

BLE Component Icon



Software tools:

PSoC Creator IDE

CySmart

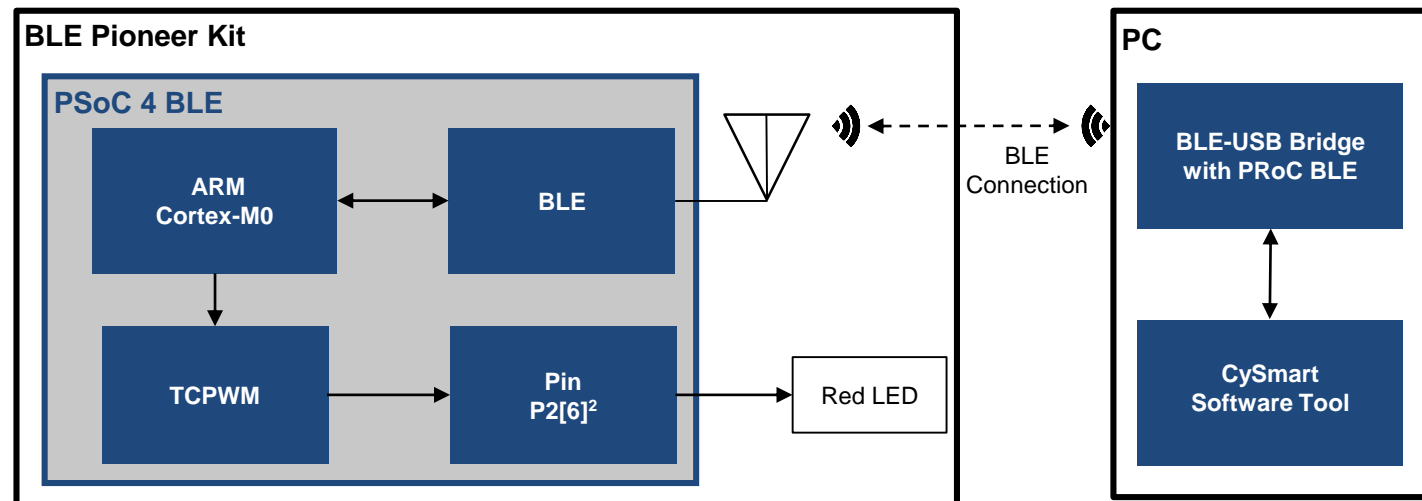
Components:

Pin Component

BLE Component

TCPWM Component

Lab 1: Block Diagram



¹ The “Find Me” Profile with IAS is a standard Profile in the Bluetooth Spec; refer to the [Bluetooth Spec](#) or Lab Manuals for more information

² Represents the logical pin placement at Port 3, Pin 7 in PSoC Creator

Introduction to BLE System Design

BLE ARCHITECTURE OVERVIEW

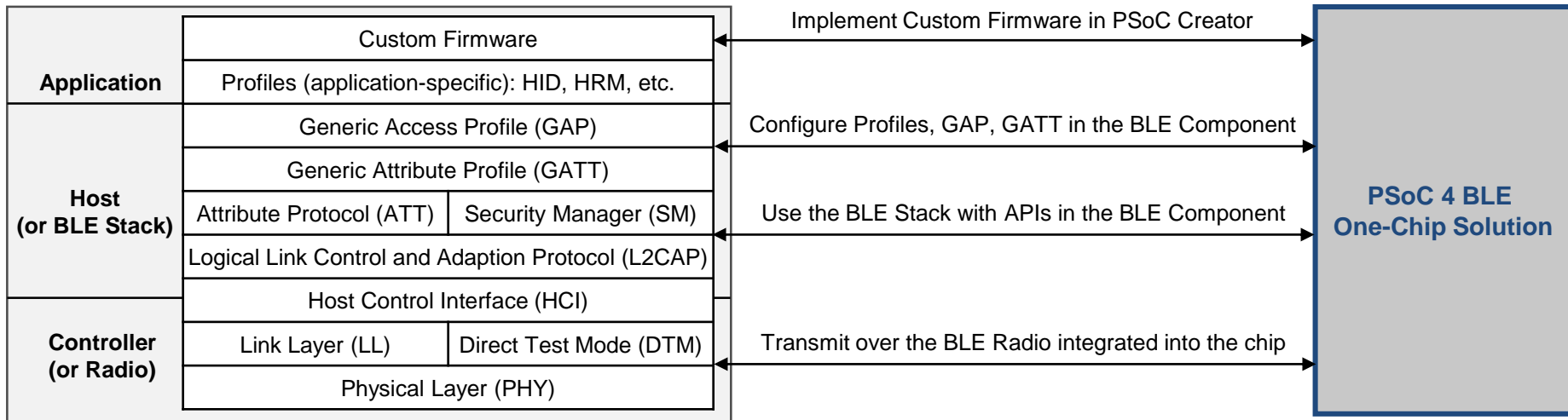
The BLE architecture consists of three parts: Application, Host and Controller

The **Application** implements specific functionality using the **Host** and **Controller**

The **Host** (or the **BLE Stack**) is a software stack with communication protocols that manage how two or more BLE devices communicate with each other

The **Controller** (or the **Radio**) is a physical device that transmits and receives encoded radio signals and decodes these signals

BLE Architecture Diagram from the [Bluetooth Spec](#)¹



PSoC 4 BLE integrates the entire BLE architecture into an easy-to-use, one-chip solution

¹ Refer to the [Appendix](#) for definitions of all BLE architecture terms. Source for terms and definitions: *Bluetooth Low Energy: The Developer's Handbook*

BLE Radio: Physical Layer (PHY)

The PHY transmits or receives bits of data using a 2.4-GHz Radio

Uses GFSK¹ modulation in the 2.4-GHz ISM² band

Operates at 1-Mbps data rate

Consists of 40 RF channels with 2-MHz of spacing between channels

37 channels for data, 3 channels for Advertising³

RF Output Power: -18 dBm to +3 dBm (0.01 mW to 2 mW)

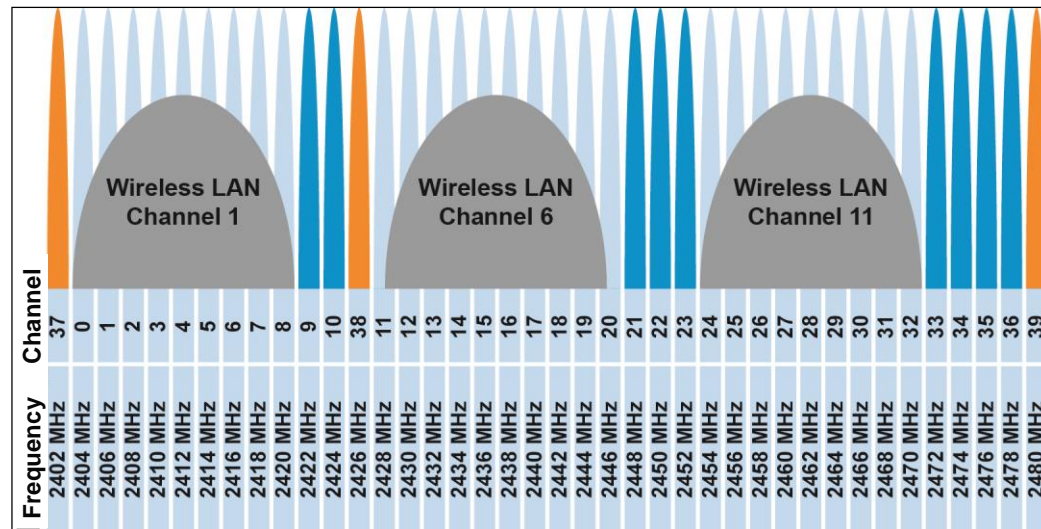
BLE Receiver Sensitivity: -89 dBm

BLE Architecture: PHY

Application	Custom Firmware	
	Profiles	
	GAP	
	GATT	
BLE Stack	ATT	SM
	L2CAP	
	HCI	
Radio	LL	DTM
	PHY	

Refer to [slide 31](#) for abbreviation descriptions

Example of BLE and WiFi Channels Coexisting in the 2.4-GHz ISM² Band



- Available BLE channels (0-39)
- BLE Channels used to exchange data
- BLE Channels used to establish a connection
- 802.11 Wireless Local Area Network (LAN) channels

Spacing of channels in the BLE PHY allows Advertising³ in the crowded 2.4-GHz ISM² band

¹ Gaussian frequency shift keying

² An Industrial, Scientific, Medical (ISM) RF frequency band that is license-free worldwide

³ A state in which BLE devices broadcast data to advertise that they are connectable and discoverable to nearby peer BLE devices

BLE Radio: Link Layer (LL)

Implements procedures to establish a reliable physical link, including:

Advertising: A state in which a BLE device broadcasts data to advertise that it is connectable and discoverable by nearby BLE devices

Scanning: A state in which a BLE device scans for nearby advertising BLE devices

Initiating and Creating Connections: The device that initiates the connection is called the **LL Master**; the device that accepts the connection is the **LL Slave**

Data Encryption: A hardware block that implements AES-128 encryption

Error Detection: A hardware block that implements a 24-bit cyclic redundancy check (CRC)

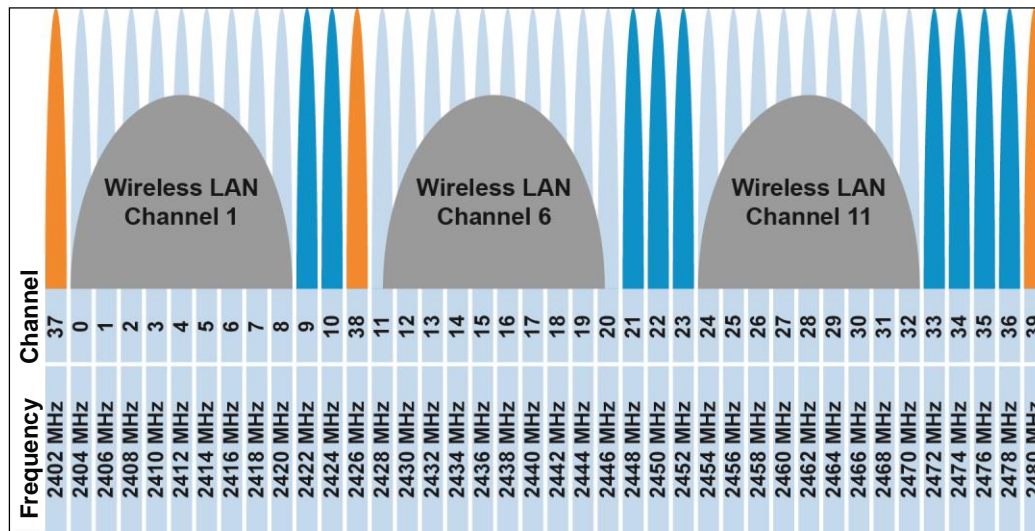
Adaptive frequency hopping (AFH): A process that enables BLE to adapt to the environment by avoiding channels that have poor signal strength or high error rates

BLE Architecture: LL

Application	Custom Firmware	
	Profiles	
	GAP	
	GATT	
BLE Stack	ATT	SM
	L2CAP	
	HCI	
Radio	LL	DTM
	PHY	

Refer to [slide 31](#) for abbreviation descriptions

Example of BLE Adapting to the Environment to Avoid Bad Channels



AFH identifies bad channels 0-8, 11-20 and 24-32 as those with interference and does not use those channels for BLE communication

- Available BLE channels (0-39)
- BLE Channels used to exchange data
- BLE Channels used to establish a connection
- 802.11 Wireless Local Area Network (LAN) channels

The LL on PSoC 4 BLE is implemented in an integrated on-chip Radio

BLE Radio: DTM and HCI

Direct Test Mode (DTM)

A mode to test the **PHY** by transmitting or receiving a sequence of test packets

Typically used for radio compliance testing and production-line calibration

PSoC 4 BLE enables **DTM** via the **Host Control Interface**

Host Control Interface (HCI)

An interface to exchange data between the **BLE Stack** and the **Radio**

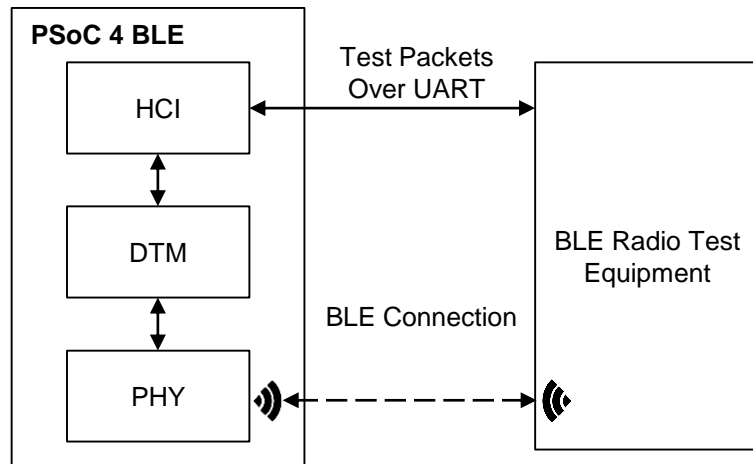
PSoC 4 BLE implements **HCI** over a UART interface to enter the **DTM**

BLE Architecture: HCI and DTM

Application	Custom Firmware	
	Profiles	
BLE Stack	GAP	
	GATT	
	ATT	SM
	L2CAP	
	HCI	
Radio	LL	DTM
	PHY	

Refer to [slide 31](#) for abbreviation descriptions

PSoC 4 BLE in DTM for RF Compliance Testing and Calibration



PSoC 4 BLE simplifies RF compliance testing and calibration by providing a DTM over a UART interface

Logical Link Control and Adaptation Protocol (L2CAP)

Segments large data packets into smaller packets

Reassembles segmented data into larger packets

Determines packet size by the **Maximum Transmission Unit**

Maximum Transmission Unit (MTU)

The largest possible size for data packets

Segmentation and reassembly improve transmission efficiency by allowing larger **MTUs**

PSoC 4 BLE supports a **MTU** size of 23 to 512 Bytes

The PSoC 4 BLE L2CAP layer is integrated in the BLE Stack

BLE Architecture: L2CAP

Application	Custom Firmware	
	Profiles	
BLE Stack	GAP	
	GATT	
	ATT	SM
	L2CAP	
	HCI	
Radio	LL	DTM
	PHY	

Refer to [slide 31](#) for abbreviation descriptions

Introduction to BLE System Design

SESSION BREAK

Introduction to BLE System Design

LAB #3: IoT SENSOR-BASED SYSTEM DESIGN

IoT Sensor-Based Systems

The Internet of Things (IoT) is now a commercial reality

The IoT is how everyday physical objects are connected to the Internet

Fitness monitors are examples of new IoT devices

To learn more about fitness monitors download our [Wearables Solutions Catalog](#)

Fitness monitors require:

A heart rate monitor (HRM)

Activity monitoring and a step counter

BLE connectivity to a mobile device

A touch-based user interface

Maximum battery life

Designing a fitness monitor requires:

AFEs with opamps and an ADC to amplify, buffer and capture heart rate signals

Accelerometer to capture changes in motion

MCU with a BLE radio to connect to a mobile device

Touch-sensing IC to detect touches and gestures

ICs with low-power modes to minimize system power consumption

IoT products commonly require sensor-based BLE systems

Up3 Fitness Monitor by Jawbone



The newest Jawbone Up3 Fitness Monitor features a heart rate monitor, a touch-sensing interface and connectivity to mobile devices

Microsoft Band Fitness Monitor

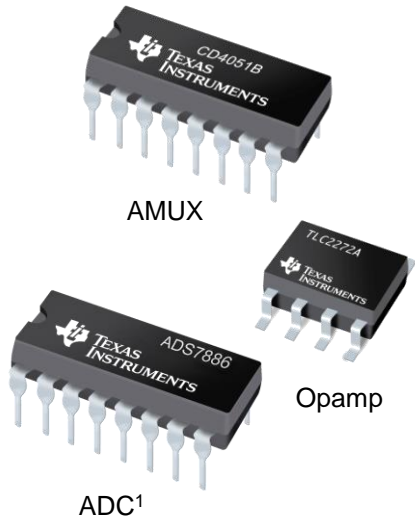


The new Microsoft Band includes a state-of-the-art heart rate monitor, a touch-sensing interface and connectivity to mobile devices

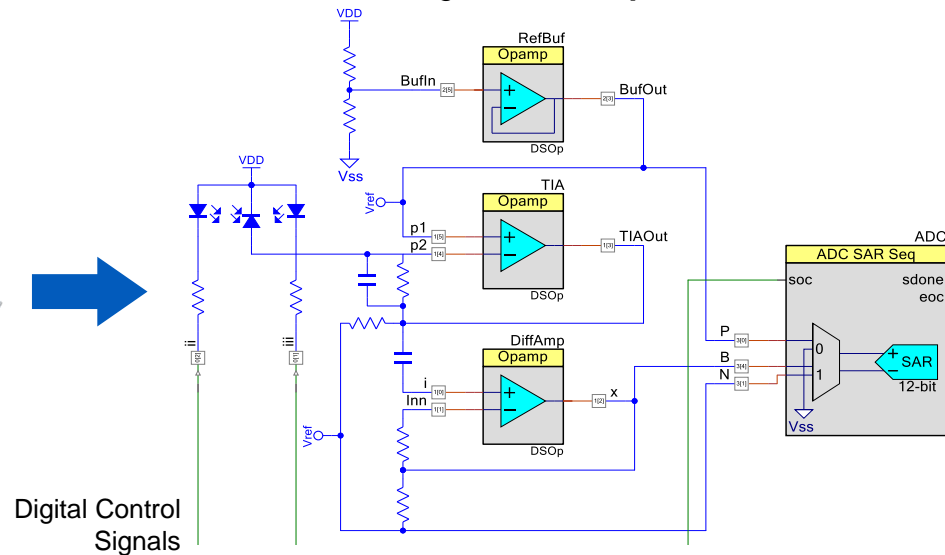
IoT Sensor-Based Systems Require Custom Analog Front Ends

Implementation of a Heart Rate Monitor AFE in PSoC 4 BLE

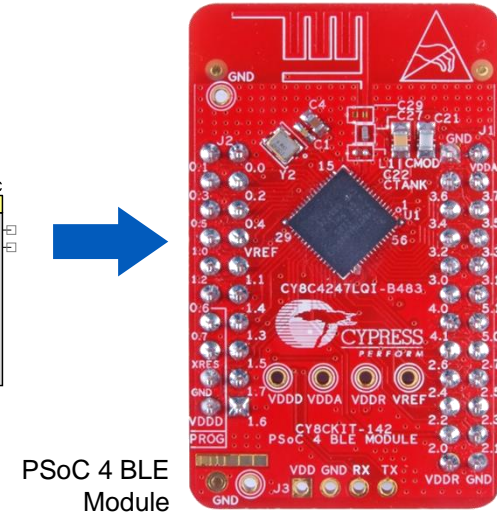
Integrate opamps, an ADC¹ and AMUX ...



With Programmable Analog Blocks in PSoC Creator using PSoC Components...



To implement a HRM AFE in PSoC 4 BLE



PSoC 4 BLE features Programmable Analog Blocks:

- One 12-bit 1-Msps SAR² ADC
- Four high-performance opamps (operational in Deep-Sleep mode)
- Two low-power comparators (operational in Deep-Sleep mode)
- Two current-output Digital Analog Converters (IDACs)
- Two analog multiplexers (AMUX) that can be flexibly configured to create custom AFE designs

Programmable Analog Blocks can be flexibly configured to create custom AFEs for sensors

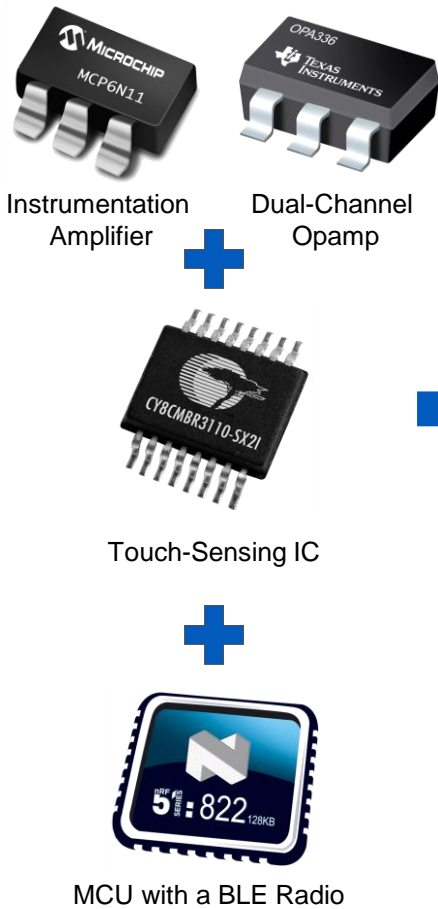
¹ MCUs with a BLE radio typically provide an ADC

² Successive approximation register

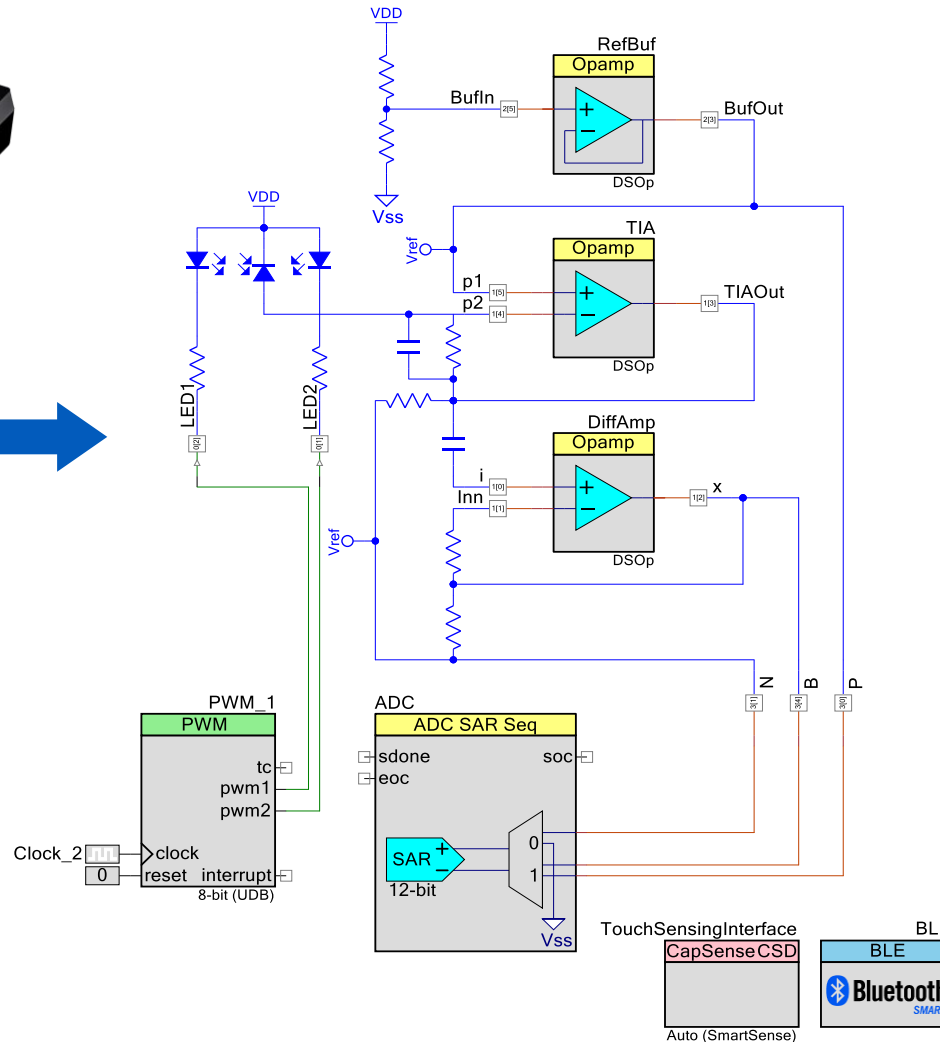
PSoC 4 BLE Integrates AFEs, CapSense and MCUs with a BLE Radio



Multiple AFE ICs, a touch-sensing IC and an MCU with a BLE radio...



Are integrated using **PSoC Components** in the **PSoC Creator IDE**...



To create a **PSoC 4 BLE one-chip solution** for the IoT.



PSoC 4 BLE Module

PSoC 4 BLE Provides Five Low-Power Modes to Minimize Power Consumption



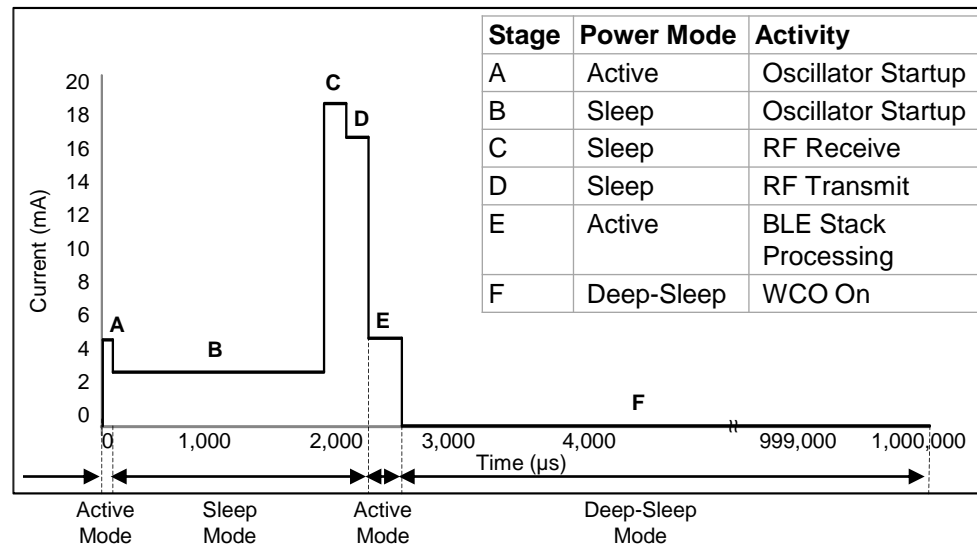
Power Mode	Current Consumption	Code Execution	Digital Peripherals Available	Analog Peripherals Available	Clock Sources Available	Wake-Up Sources	Wake-Up Time
Active	1.7 mA @ 3 MHz	Yes	All	All	All	-	-
Sleep	1.3 mA	No	All	All	All	Any interrupt source	0
Deep-Sleep	1.3 μA	No	WDT ¹ , LCD ² , I ² C/SPI, Link-Layer ³	Comparator, Opamps, POR ⁴ , BOD ⁵	WCO ⁶ , 32-kHz ILO ⁷	Comparator, GPIO ⁸ , Opamp, Link-Layer ³ , WDT ¹ , SCB ⁹	25 μ s
Hibernate	150 nA	No	No	Comparator, POR, BOD	No	Comparator, GPIO	2 ms
Stop	60 nA	No	No	No	No	Wake-Up pin, XRES ¹⁰	2 ms

Power mode summary:

Average current 18.9- μ A for a 1-sec connection interval
 Stop mode consumes only 60 nA while retaining I/O state
 Hibernate mode consumes only 150 nA while retaining SRAM APIs to switch easily between power modes

This lab uses four of the five low-power modes to create a low-power sensor-based system

PSoC 4 BLE Current Consumption



Average current consumption for connection interval of 1 sec = **18.9 μ A**

¹ Watchdog timer

² Liquid crystal display

³ Digital logic managing BLE Protocol

⁴ Power-on-reset

⁵ Brownout-detect

⁶ 32-kHz watch crystal oscillator

⁷ 32-kHz internal low-speed oscillator

⁸ General-purpose input/output

⁹ Serial communication block

¹⁰ External reset

Lab #3: IoT Sensor-Based System Design

Objectives:

- Measure simulated heart rate using the Programmable Analog Blocks
- Implement a Heart Rate Monitor Profile and send the data over BLE
- Optimize the design for low power consumption using Sleep, Deep-Sleep and Hibernate modes

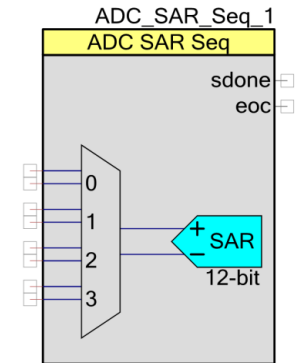
Software tools:

- PSoC Creator IDE
- CySmart

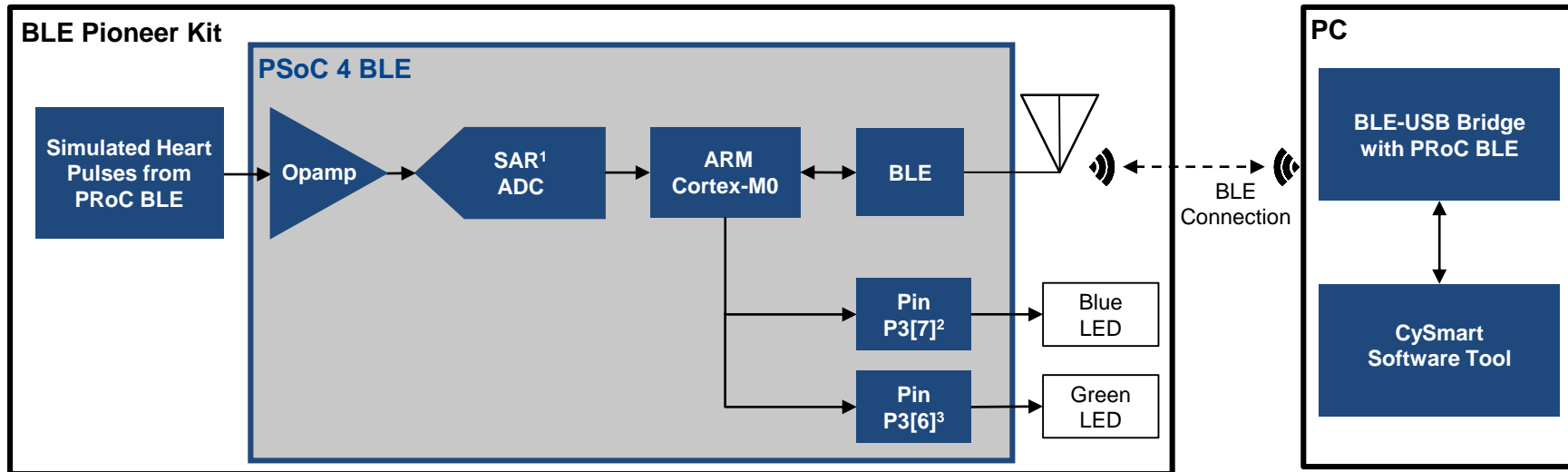
Components:

- SAR¹ ADC Component
- Opamp Component

SAR ADC Component



Lab 3: Block Diagram



¹ Successive approximation register

² Represents the logical pin placement at Port 3, Pin 7 in PSoC Creator

³ Represents the logical pin placement at Port 3, Pin 6 in PSoC Creator

Introduction to BLE System Design

LAB #4: CapSense DESIGN WITH BLE CONNECTIVITY

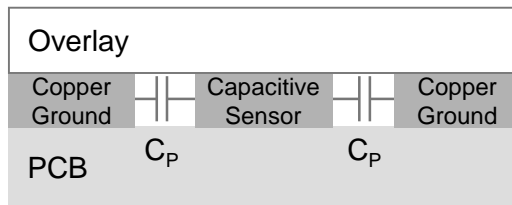
CapSense Touch Sensing

CapSense replaces mechanical buttons

A capacitive sensor is used to measure the change in capacitance between a pin and ground
CapSense algorithms and analog circuitry convert the measured capacitance to a raw count
A finger touch increases the capacitance of the system, which in turn increases the raw count
An increase in the raw count above a user-defined threshold registers a touch

Refer to the [Getting Started With CapSense](#) Guide for details on CapSense algorithms

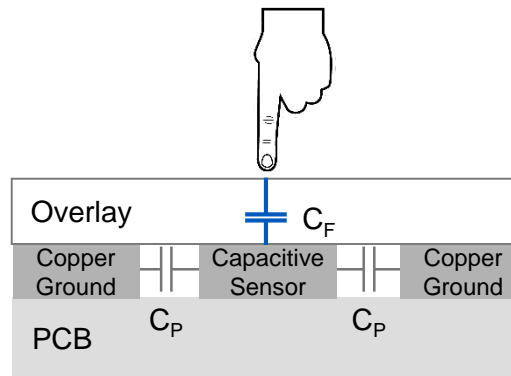
Capacitive Sensor
Without a Finger Touch



$$C_X = 2C_P$$

C_X = Total Capacitance on the capacitive sensor node
 C_P = Parasitic capacitance

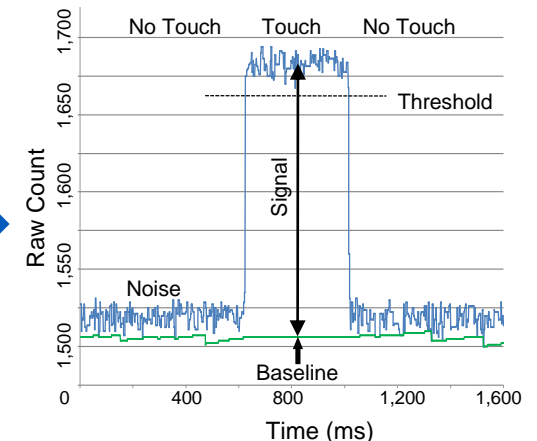
Capacitive Sensor
With a Finger Touch



$$C_X = 2C_P + C_F$$

C_F = Capacitance added by a finger touch
 C_F is dependent on the overlay material, overlay thickness and the dimensions of the finger (typical = 9mm) and sensor capacitances

Raw Count Variation on Finger Touch



CapSense algorithms use analog circuits to convert the capacitance to raw count, which is compared to the user-defined threshold to record a touch

SmartSense Auto-tuning sets, monitors and continuously maintains optimal capacitive sensor performance

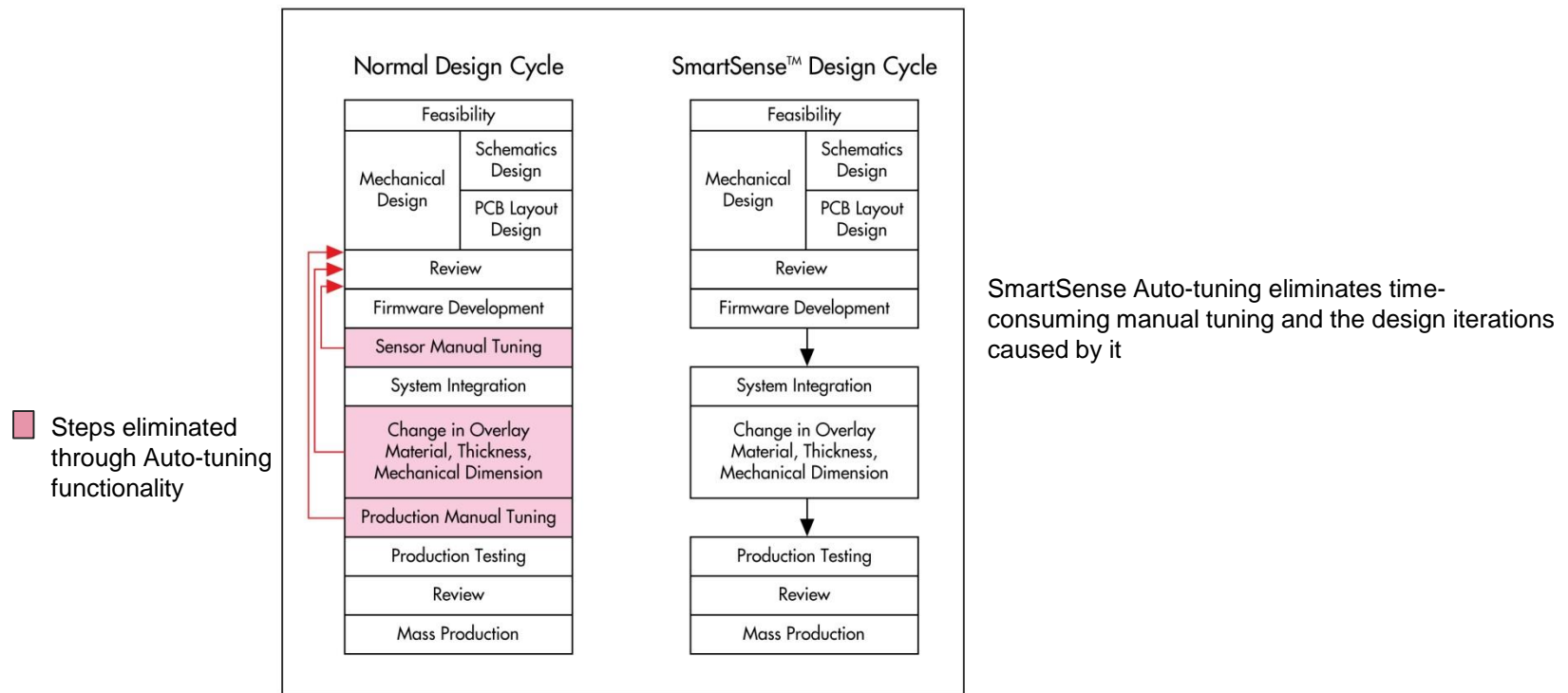
Reduces design effort by eliminating manual tuning (of baseline and threshold values) after the design phase

Adapts to manufacturing variations in PCB, overlay and paint that degrade touch-sensing performance

Adapts to changes in system environment due to RF noise sources

Allows a platform design approach that uses different overlays, button shapes and trace lengths with the same electronics

SmartSense Auto-tuning Cuts Design Cycle Time



Lab #4: CapSense Design with BLE Connectivity

Objectives:

- Adjust RGB LED color and intensity using the Precision Illumination Signal Modulation (PrISM) Component
- Implement a custom BLE Profile with a custom Service to send RGB LED color and intensity data over BLE
- Implement a custom Service to send CapSense slider data over BLE
- Use the CySmart application to validate the operation

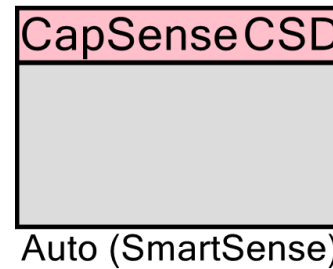
Software tools:

- PSoC Creator IDE
- CySmart

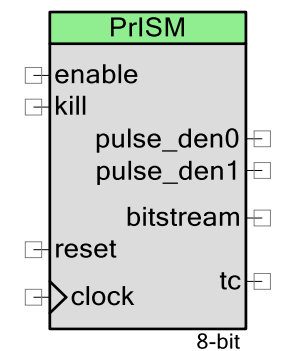
Components:

- PrISM Component
- CapSense CSD Component

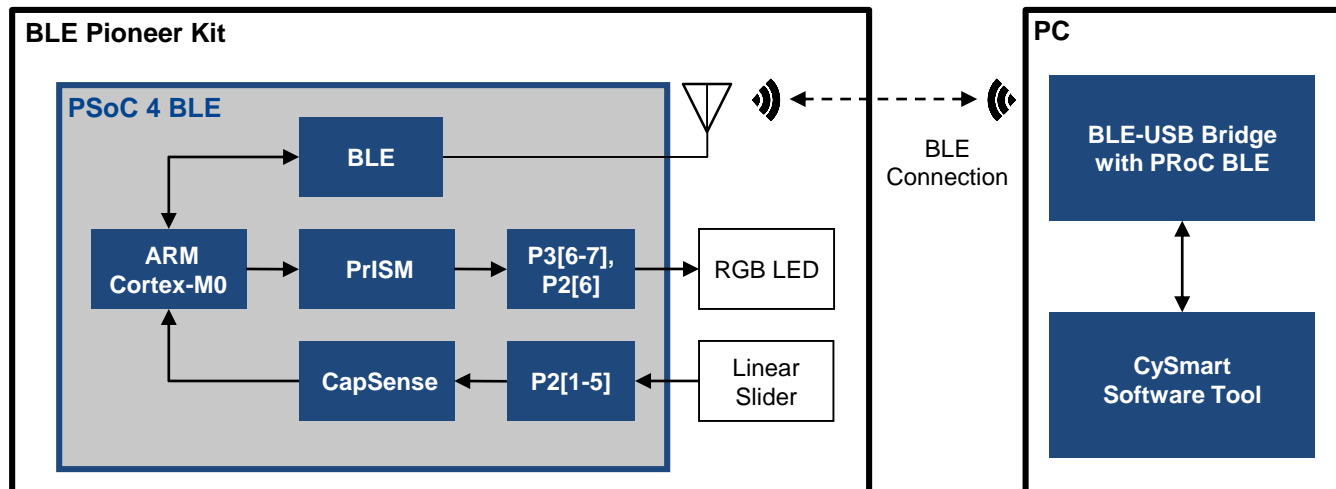
CapSense CSD Component



PrISM Component



Lab 4: Block Diagram



Introduction to BLE System Design

CYPRESS BLE MODULES

EZ-BLE PProC Module

Bluetooth Low Energy Module using PProC BLE

Applications

BLE¹ connectivity
Medical
Industrial
PC accessories
Toys
Smartphone accessories

Features

Qualification and Certification

Bluetooth SIG QDID²
FCC³, CE⁴, KC⁵, MIC⁶ and IC⁷

Small Footprint

10 mm x 10 mm x 1.8 mm, 21-pad SMT with 16 GPIO

Bluetooth Smart Connectivity with Bluetooth 4.1

2.4-GHz BLE radio and baseband
-91-dBm Rx sensitivity, +3-dBm Tx output power

Power Modes:

1.3- μ A Deep-Sleep, 150-nA Hibernate, 60-nA Stop

Highly Integrated Solution

2 crystals, chip antenna, passives, shield

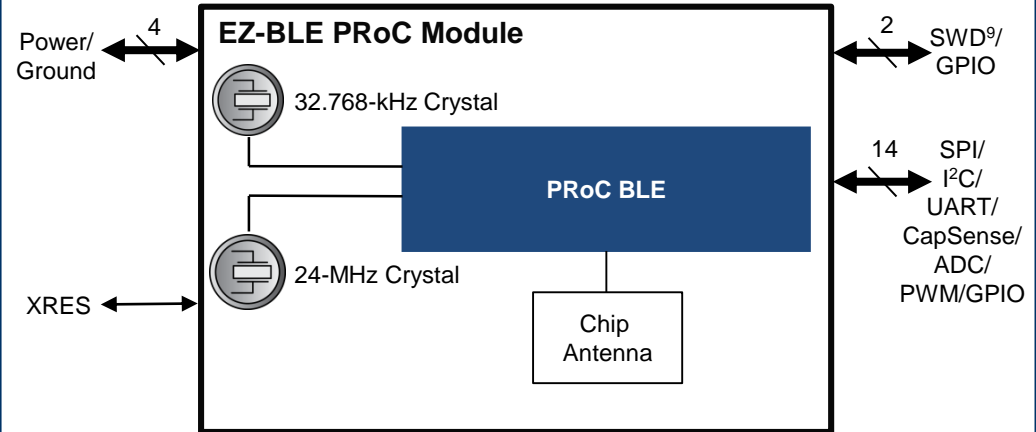
CYBLE-022001-EVAL Adapter Board Interface

Easy interface to CY8CKIT-042-BLE Pioneer Kit
Enables testing of CapSense, buttons, GPIOs, OTA⁸

Availability

Sampling: Now
Production: Now

Block Diagram



Collateral

[EZ-BLE PProC Module Webpage](#)

[PProC BLE Datasheet](#)

[Getting Started Application Note](#)

[PSoC Creator](#)

[PSoC Programmer](#)

[CySmart¹⁰ Windows Host Emulation Tool](#)

[CySmart iOS and Android Apps](#)

¹ Bluetooth Low Energy, also known as Bluetooth Smart

² Bluetooth Special Interest Group Qualification Design ID

³ Federal Communications Commission

⁴ Conformité Européenne (Europe)

⁵ Korea Certification

⁶ Ministry of Internal Affairs and Communications (Japan)

⁷ Industry Canada

⁸ Over-the-Air

⁹ Serial Wire Debug communication protocol

¹⁰ A GUI-based software tool that installs on your PC to test and debug BLE functionality; also available in iOS and Android mobile applications

EZ-BLE PRoC Module: Bluetooth Qualified, Global Regulatory Compliant



EZ-BLE PRoC Module is qualified by the Bluetooth SIG with a unique Qualified Design ID (QDID)¹



QDID	Declaration ID	Name	Product Type	Spec
67366	D026297	EZ-BLE PRoC Module	End Product	4.1
67366	N/A	EZ-BLE PRoC Module RF-PHY	Component (Tested)	4.1
63199	D025070	BLE Profiles on PSoC Creator 3.1	Component (Tested)	4.1

EZ-BLE PRoC Module complies with wireless regulations for the U.S., Canada, Japan, Korea and Europe

EZ-BLE PRoC Module Certified by Global Regulatory Agencies



U.S.: Federal Communications Commission (FCC)



Canada: Industry Canada (IC)



Japan: Ministry of Internal Affairs and Communications (MIC)



Korea: Korea Certification (KC)



Europe: Conformance Europeenne (CE)

Save over \$200K² and bring your BLE product to market faster without the hassle of regulatory and qualification processes

¹ Customers can refer to the EZ-BLE PRoC Module QDID and proceed with Bluetooth Declaration

² Cost includes development time, test equipment, and fees for Bluetooth SIG QDID, Declaration and Listing, and compliance for FCC, IC, MIC, KC and CE

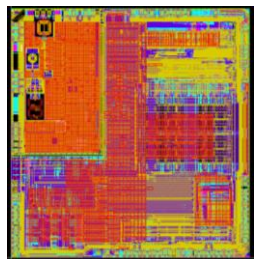
Cypress: A Complete BLE Solution



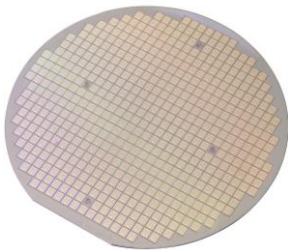
Cypress is the only BLE solution provider with expertise in silicon, stack, module hardware and software

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

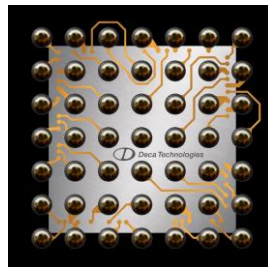
BLE Silicon Design



BLE Wafer Fabrication



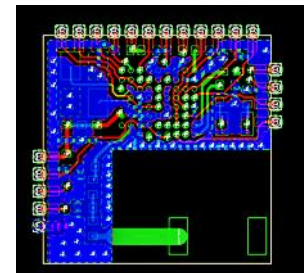
BLE CSP Package²



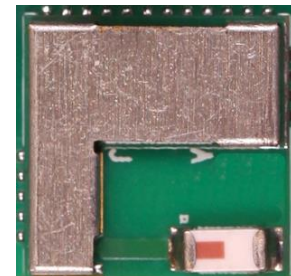
PSoC Creator Software



Module Hardware Design



EZ-BLE PSoC 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 Inc.

Small Footprint for Modern Industrial Designs

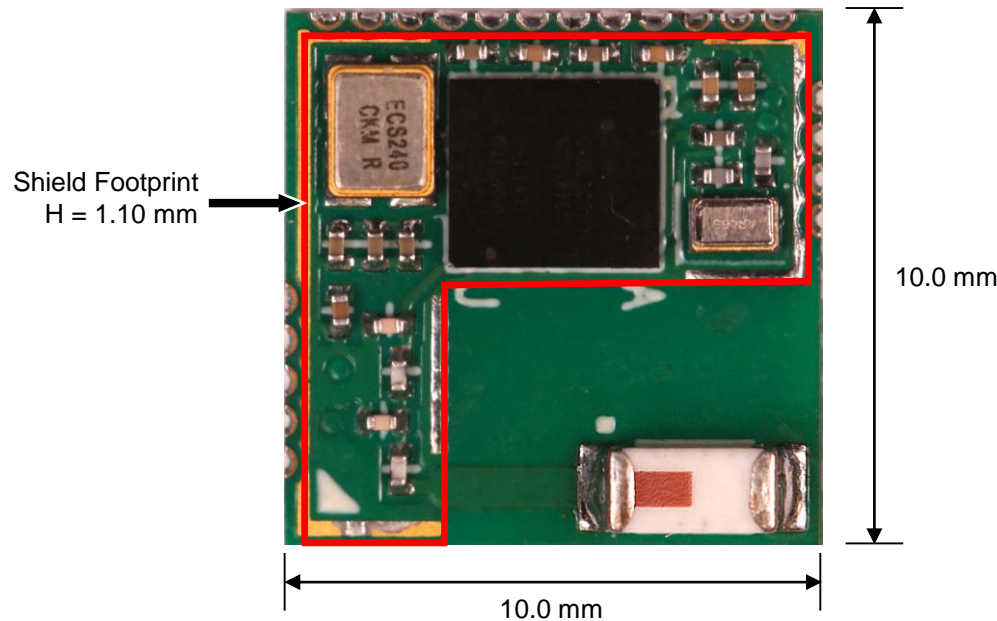
EZ-BLE PRoC Module supports a 10 x 10 x 1.80-mm footprint, including the shield

Available in a 21-pad SMT¹ module ideal for space-constrained applications

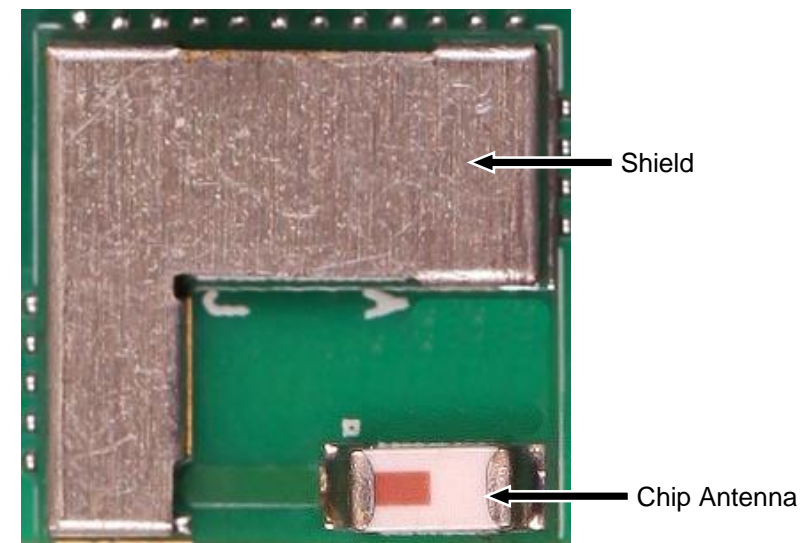
Supports 16 GPIOs that can be used for functions such as CapSense, I²S, I²C, SPI, UART, TCPWM² and LCD

Compatible with industry-standard reflow profiles for lead-free solders

Top View of EZ-BLE Module Without Shield



Top View of EZ-BLE Module With Shield



Side View of EZ-BLE Module Without Shield



EZ-BLE PRoC Module's footprint and feature set supports the needs of modern industrial designs

¹ A method for producing electronic circuitry in which the components are placed directly onto the surface of PCBs

² Timer, counter, pulse-width modulator (PWM); configurable as 16-bit timer, counter, PWM blocks

Introduction to BLE System Design

WRAP-UP

Product Webpages:

Cypress's BLE solutions webpage: www.cypress.com/BLE

PSoC 4 BLE product webpage: www.cypress.com/PSoC4BLE

PSoC 4 BLE product datasheet: www.cypress.com/PSoC4BLEDatasheet

PRoC BLE product webpage: www.cypress.com/PRoCBLE

PRoC BLE product datasheet: www.cypress.com/PRoCBLEDatasheet

EZ-BLE PRoC Module webpage: <http://www.cypress.com/EZ-BLEPRoCModule>

PSoC Creator IDE: www.cypress.com/PSoCCreator

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

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

CySmart for Mobile Apps: www.cypress.com/CySmartMobile

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

Remote Control RDK: www.cypress.com/CY5672

Touch Mouse RDK: www.cypress.com/CY5682

BLE Frequently Asked Questions: www.cypress.com/PSoC4BLEKBA

Cypress Wearables Solution Catalog: www.cypress.com/go/WearablesCatalog

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

Design Guides:

PSoC 4 BLE Antenna Design Guide: www.cypress.com/go/AN91445

CapSense Design Guide: www.cypress.com/go/AN85951

General Online Resources

Cypress Resources

PSoC: www.cypress.com/PSoC

Cypress Roadmap: www.cypress.com/Roadmap

Kits: www.cypress.com/kits

Support: www.cypress.com/support

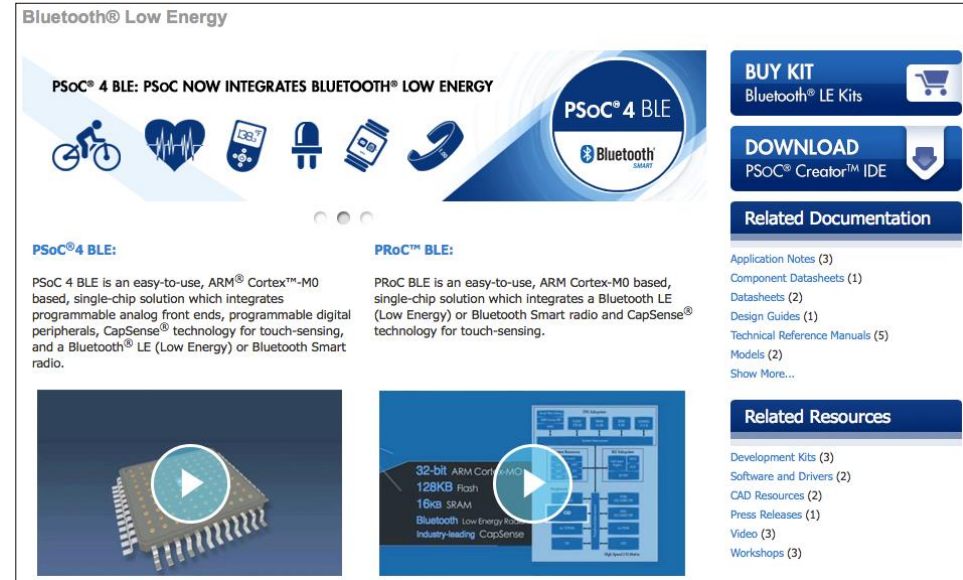
Training: www.cypress.com/training

Cypress Online Store: www.cypress.com/store

Developer Community & Forums: www.cypress.com/forums

App Notes: www.cypress.com/AppNotes

Cypress BLE Solutions: www.cypress.com/BLE



The screenshot shows the Cypress BLE Solutions webpage. At the top, it says "Bluetooth® Low Energy" and "PSoC® 4 BLE: PSoC NOW INTEGRATES BLUETOOTH® LOW ENERGY". Below this, there are icons for various applications: a bicycle, a heart with a pulse line, a medical device, a smartwatch, and a smartphone. To the right, there are buttons for "BUY KIT Bluetooth® LE Kits", "DOWNLOAD PSoC® Creator™ IDE", and "Related Documentation". Under "Related Documentation", there are links for "Application Notes (3)", "Component Datasheets (1)", "Datasheets (2)", "Design Guides (1)", "Technical Reference Manuals (5)", "Models (2)", and "Show More...". Below the main content, there are two video thumbnails. The left one shows a PSoC 4 BLE chip with a play button. The right one shows a PSoC 4 BLE chip with a play button and text: "32-bit ARM Cortex-M0", "128KB Flash", "16Kb SRAM", "Bluetooth Low Energy Radio", and "Industry-leading CapSense". To the right of the video thumbnails, there is a "Related Resources" section with links for "Development Kits (3)", "Software and Drivers (2)", "CAD Resources (2)", "Press Releases (1)", "Video (3)", and "Workshops (3)".

Cypress's BLE solutions webpage is your *one-stop-shop* for everything BLE, including product datasheets, development kits, App Notes, software downloads, example projects and demo videos

Bluetooth Resources

Bluetooth SIG website: www.bluetooth.org

[Bluetooth Spec](http://www.bluetooth.org/en-us/specification/adopted-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)

Workshop Objectives Recap



You should now:

Understand Cypress's BLE solutions including PSoC 4 BLE and PSoC BLE

Understand the BLE architecture

Know how to use Cypress's BLE solutions, the PSoC Creator IDE and the BLE Pioneer Kit, to implement:

BLE connections with PSoC 4 BLE and PSoC BLE¹

One-chip, sensor-based system designs with BLE connectivity for the Internet of Things (IoT)

One-chip, CapSense touch-sensing user interface designs with BLE connectivity

Please help us improve this workshop by completing our feedback form

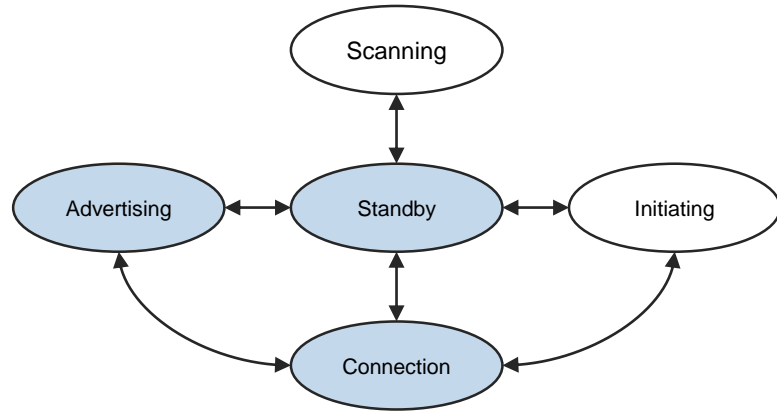
¹ PSoC BLE exercises are included in the Additional Exercises Section of each Lab Manual

Introduction to BLE System Design

APPENDIX

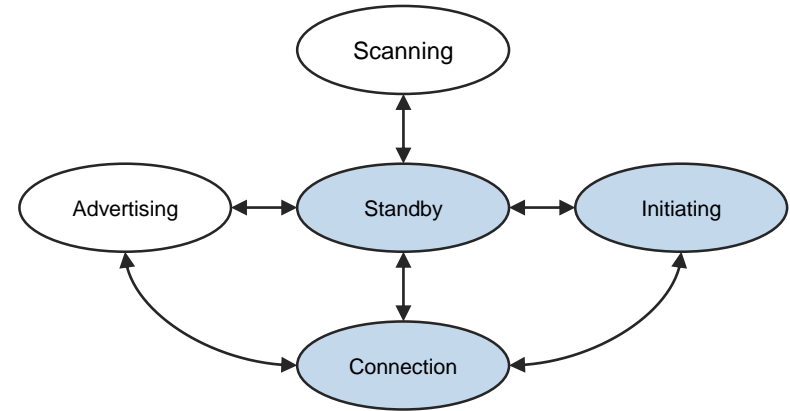
GAP: Example of GAP Roles

GAP Peripheral



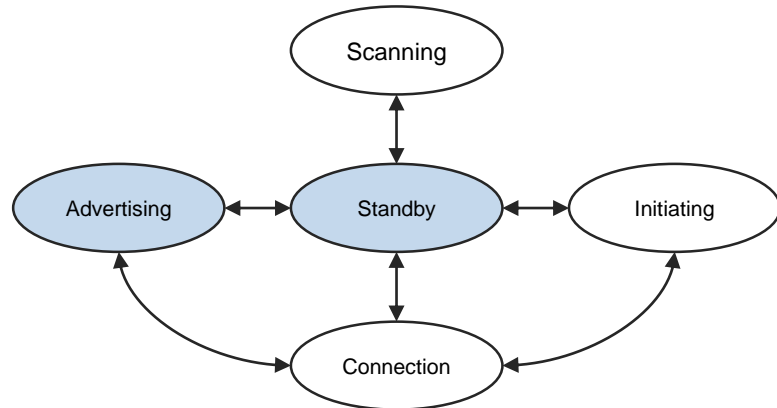
Advertises its capabilities and establishes connections

GAP Central



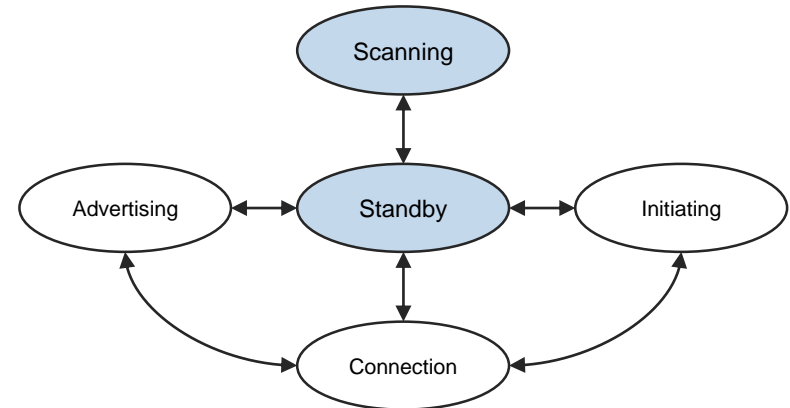
Scans for advertising devices and initiates connections

GAP Broadcaster



Advertises its capabilities only, does not establish connections

GAP Observer



Scans for advertising devices only, does not establish connections

Cypress BLE Certification



QDID	Declaration ID	Name	Product Type	Spec
63199	D025070	Profiles supported by BLE Component in PSoC Creator	Profile Subsystem	4.1
61908	D024756	Host	Component (Tested)	4.1
62243	D024755	Link Layer	Component (Tested)	4.1
62245	D024754	RF-PHY for 56-QFN package	Component (Tested)	4.1
63368	D025068	RF-PHY for 68-ball WLCSP package	Component (Tested)	4.1
62887	D024757	PSoC 4 BLE and PProC BLE (56-QFN package)	End Product	4.1
63683	D025069	PSoC 4 BLE and PProC BLE (68-ball WLCSP package)	End Product	4.1
67366	D026297	EZ-BLE PProC Module	End Product	4.1
67366	N/A	EZ-BLE PProC Module RF-PHY	Component (Tested)	4.1
63199	D025070	BLE Profiles on PSoC Creator 3.1	Component (Tested)	4.1