IEEE Consumer Electronics Society Meetup:

Cypress Semiconductor Solutions for IoT and Wearables

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Today, we will discuss:

- **Programmable System-on-Chip** (PSoC)
- **Bluetooth Low Energy** (BLE, also known as Bluetooth Smart)
- **Energy Harvesting** – capturing tiny amounts of power over time and doing interesting things with it

Arrow Electronics

- Founded in 1935 in NYC, selling AM radios
- Today: A global provider of products, services and solutions to industrial and commercial users of electronic components and enterprise computing solutions
- Supply channel partner for over 100,000 original equipment manufacturers, contract manufacturers and commercial customers
- 2015 sales of $23.28 billion
- 460 locations serving over 85 countries

Cypress Semiconductor

Gear Live Smart Watch by Samsung

Cypress + Spansion = New $1.6B company

No. 1 in SRAMs, No. 1 in NOR Flash

No. 3 in MCUs and memories for the automotive market

First to market USB Type-C controllers with Power Delivery

PSoC® BLE solution to drive traction in IoT, wearables

Traveo® MCUs: First to market ARM®-based 3-D Graphics controller for automotive cluster (dashboard) displays

Technology leadership in **Power Management ICs** (PMICs)

Infotainment Touchscreen by Tesla

PlayStation 4 by Sony

PowerShot XS7 by Canon

Cypress-Spansion Merger Expands Leadership in Embedded Systems

No. 1 in SRAM, No. 1 in nvSRAM, No. 1 in F-RAM™
30+ years memory and 15 years of PSoC experience

No. 1 in Flash Memory for Embedded Markets
No. 2 in Japan MCU, well-positioned in Analog

SYNERGISTIC MARKETS: AUTOMOTIVE, INDUSTRIAL, CONSUMER, COMMUNICATIONS

PSoC | Touch | USB | nvRAM | F-RAM | SRAM

NAND | NOR | Software | SoC | MCU | Analog

Global Embedded Systems Leader

Memory for Embedded Systems: SRAM and Flash + **MCU, Analog, SoC, USB, Touch** = **Market Leadership in Embedded Systems**


CYPRESS
Embedded in Tomorrow™
Cypress to Acquire Broadcom's Wireless IoT Business
A Quantum Leap for Its IoT and Wireless Efforts
April 28, 2016

Leading Embedded Systems Portfolio

Acquisition accelerates embedded system connectivity with "2018 wireless technology"

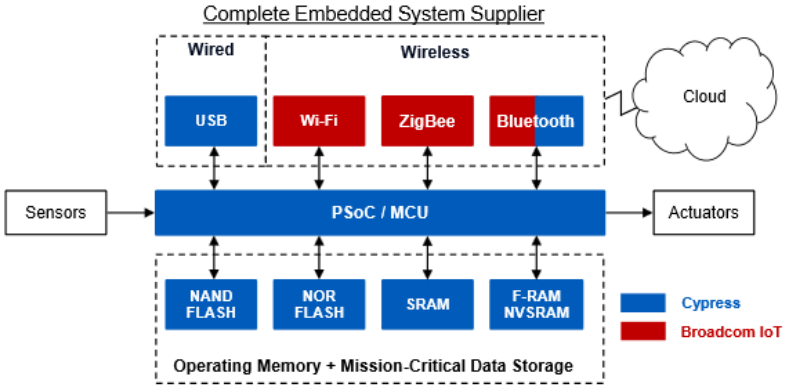
Three main wireless standards, Wi-Fi, Bluetooth, ZigBee on state-of-the-art, low-power 40-nm and 28-nm CMOS processes

Broad product portfolio for embedded processing

Low-power ARM-based PSoC with programmable analog and digital enables rapid embedded system design

Highest-performance ARM Cortex®-M4 MCU devices with advanced connectivity (Ethernet, CAN-FD, USB Type-C)

Broadest memory selection from any supplier



Acquisition adds state-of-the-art wireless connectivity for next-generation Automotive, Industrial and Internet of Things embedded systems

Diverse Customer Base Requires Scalable IoT Platform and Ecosystem

Wireless Internet Connectivity for Embedded Devices (WICED) platform

Software Development Kit enables the addition of wireless and cloud connectivity to any embedded device
Supports all wireless IoT connectivity standards (Wi-Fi, Bluetooth, ZigBee)
11K+ WICED Software Development Kit registered users

Partner Ecosystem delivers end-to-end solutions based on the WICED platform

Partners provide software, mobile applications, cloud connectivity, wireless modules and system development

Module Makers	Value Added Resellers (VARs)	Technology Partners	ODMs
Murata SPIL, USI …	Lantronix, LM Technology …	Particle, Ayla Networks …	Jabil, Chicony …

Cypress has an established global channel and support model for 30K+ customers

46 distributors worldwide with over 700 branches
42K+ PSoC Creator Software Development Kit registered users
10K+ Customer engineers trained per year

Leverage Cypress global channel and support model to accelerate WICED platform adoption to profitably serve the broad, diverse IoT customer base

Programmable System-on-Chip with Bluetooth Low Energy

Wearables

Cypress offers a complete portfolio of the industry's smallest, lowest-power solutions for wearable electronics with intuitive user interfaces and fast time-to-market

CapSense controllers: The industry's smallest, lowest-power devices with superior SNR and waterproofing
PSoC 4 and PRoC2 Bluetooth Low Energy (BLE) Solutions: Easy-to-use, ultra-low-power wireless connectivity
Low-Power (MoBL®) Asynchronous SRAMs: Memories that buffer data to reduce radio usage and extend battery life
F-RAMs: High-reliability memories that store the most vital data—"black box" data—with the lowest possible energy

Fitbit Surge
Fitness Watch

Casio Exilim EX-FR10
Wearable Camera

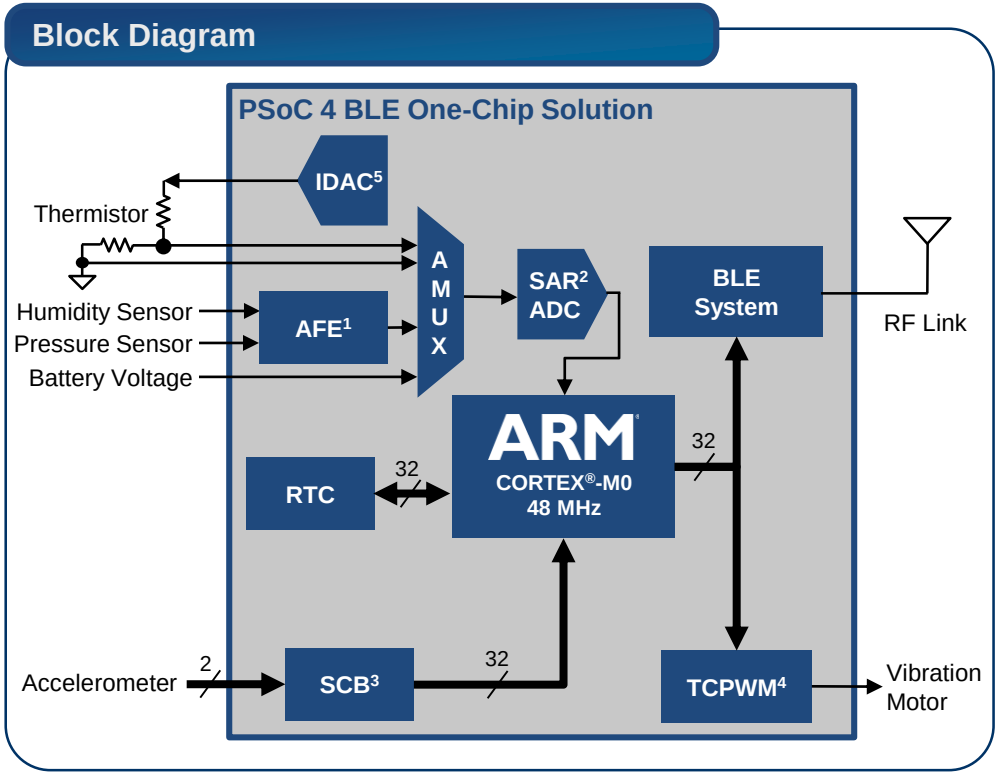
Microsoft Band
Fitness Band

BM Innovations'
Under Armour Fitness
Watch

Samsung Gear S
Smart Watch

Design Example: Fitness Monitor

Wearable Fitness Monitor
by Jawbone



PSoC: Programmable System-on-Chip

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**, and **CapSense**

PSoC Value

- Reduced components = Reduced BOM cost
- Smaller BOM = Better quality, smaller footprint
- Simpler, smaller system = Fast time-to-market

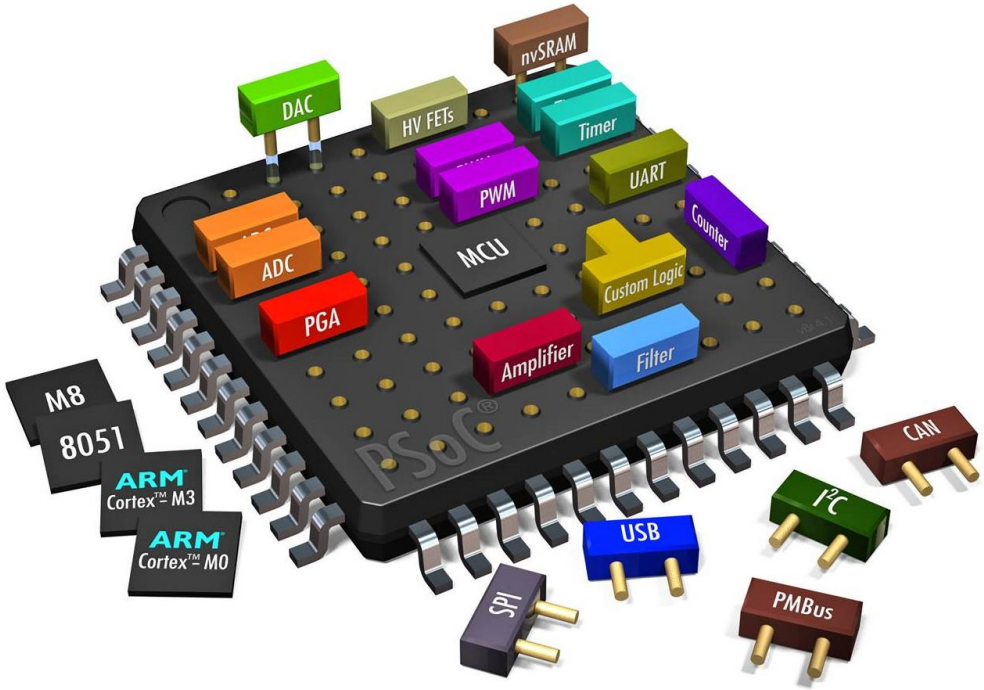
Product Highlights

- A decade of explosive growth: >2 billion units shipped
- Thousands of active PSoC customers

Feature	PSoC 1	PSoC 3	PSoC 4	PSoC 5LP
Processing Core	8-bit M8C (4 MIPS)	8-bit 8051 (33 MIPS)	32-bit ARM Cortex-M0 (43 DMIPS[1])	32-bit ARM Cortex-M3 (100 DMIPS[1])
Code Storage (Flash)	Up to 32KB	Up to 64KB	Up to 256KB	Up to 256KB
Connectivity	FS USB 2.0, I^2C, SPI, UART	FS USB 2.0, I^2C, SPI, UART, CAN, LIN, I^2S	I^2C, SPI, UART, I^2S	FS USB 2.0, I^2C, SPI, UART, CAN, LIN, I^2S
I/Os (w/CapSense)	Up to 64	Up to 72	Up to 55	Up to 72
AFE[1] Resolution	8-14 bit	12-20 bit	12-bit	12-20 bit

[1] Dhrystone MIPS (Million Instructions Per Second)

The One-Chip PSoC Embedded Design Platform



This PSoC “Lego” image illustrates how designers use free, embedded PSoC Components to create one-chip solutions

PSoC Terms

Programmable Analog Block

- A hardware block that is configured using PSoC Components 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 to implement custom digital peripherals and glue logic
- Includes Universal Digital Blocks, Serial Communication Blocks (SCBs) and TCPWMs

PSoC Terms

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 using PSoC Components, 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

Timer, Counter, PWM (TCPWM) Block

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

PSoC Terms

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 Terms

PSoC Creator™

- PSoC 3, PSoC 4, PSoC 5LP and PRoC BLE Integrated Design Environment:
  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

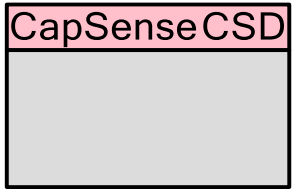
Components

- 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

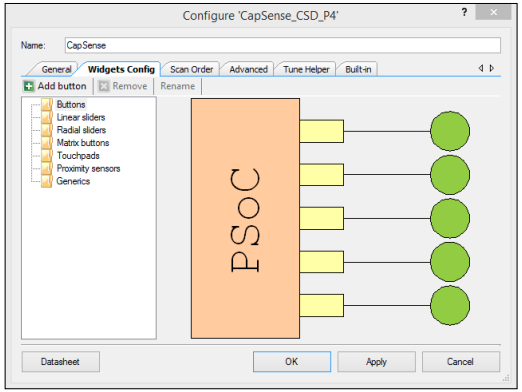
Component Configuration Tools

- Simple graphical user interfaces in PSoC Creator embedded in each Component
- Used to customize Component parameters as shown to the right

Component Icon

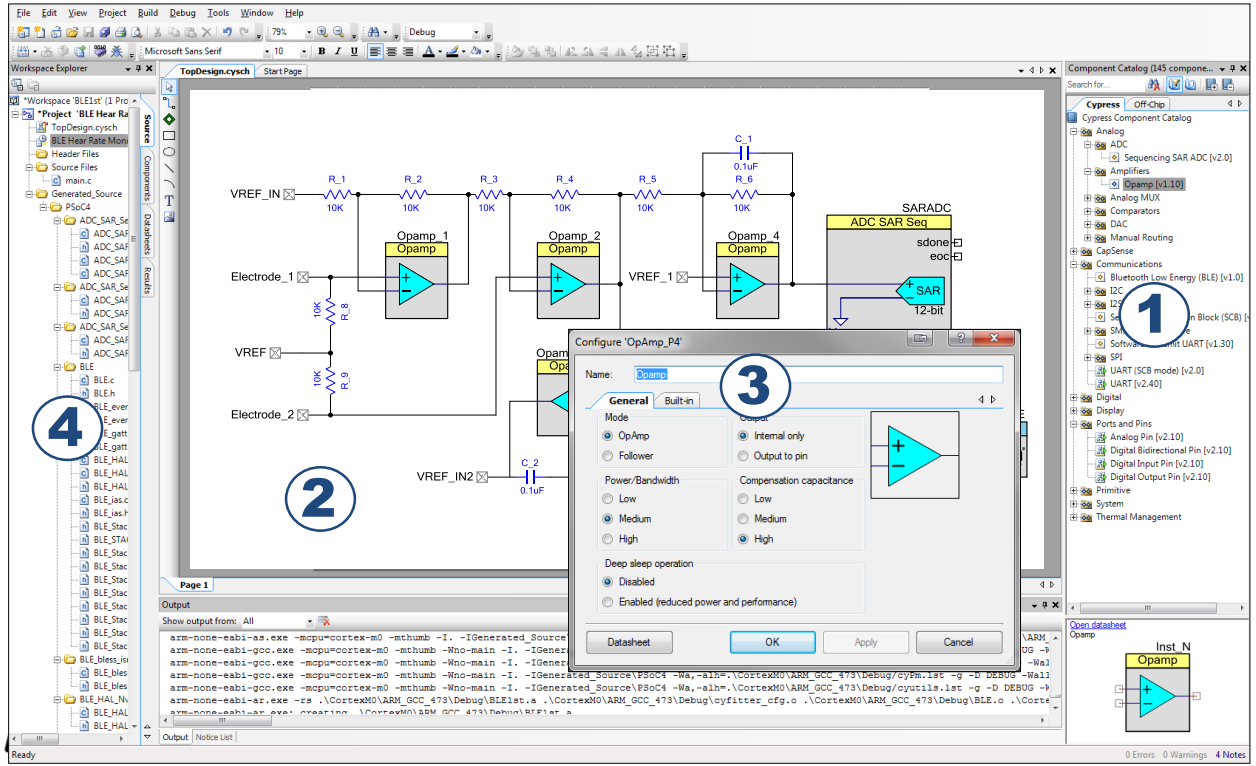


Component Configuration Tool



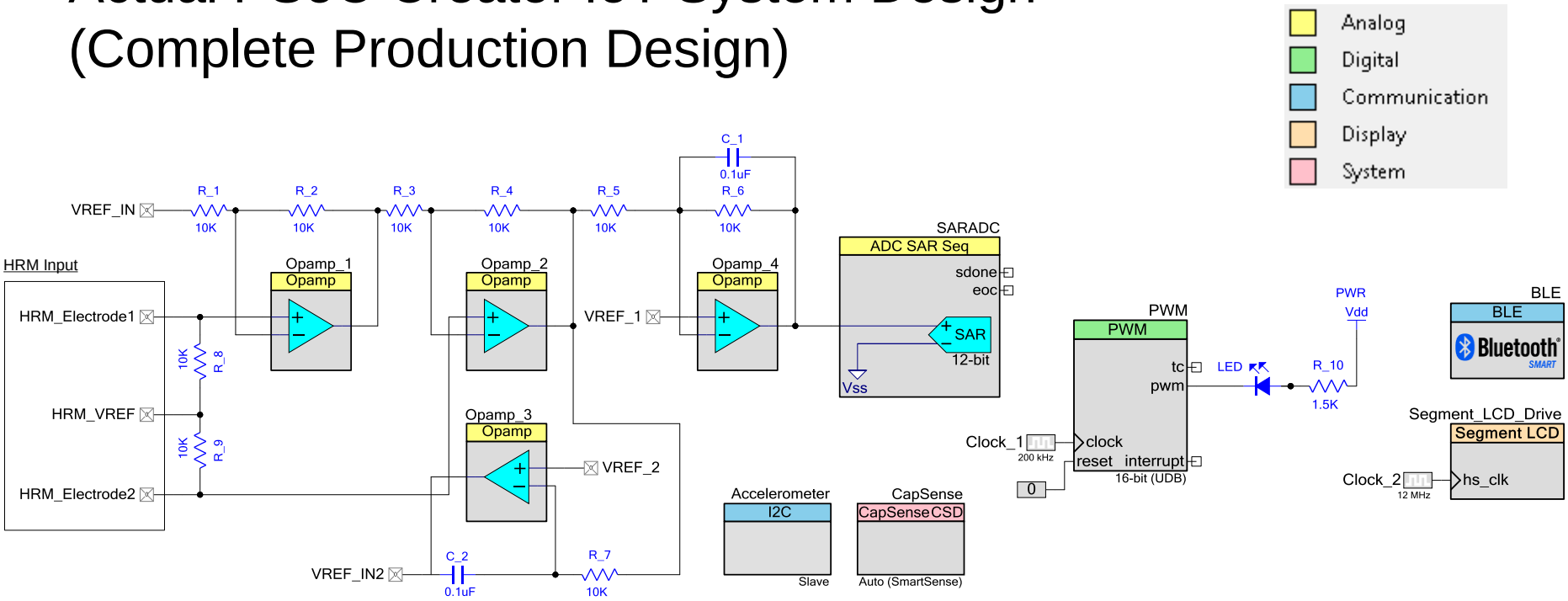
PSoC Creator Enables Complete System Design

BLE Heart Rate Monitor Example Project With a Custom AFE Shown in the PSoC Creator IDE



1. Explore the library of 100+ Components
2. Drag and drop Component icons to complete your hardware system design in the main design workspace (e.g., use the BLE Component for Bluetooth Smart designs)
3. Configure Components using the Component Configuration Tools
4. Co-design your application firmware and hardware in the PSoC Creator IDE

Actual PSoC Creator IoT System Design (Complete Production Design)



BLE Is the Industry's Choice for Short-Range, Low-Power Wireless

BLE's low-power consumption and new features enable it to address a wide range of applications

- BLE transmits information at a low data rate
- BLE connections are quick and transient, enabling connection, data transmission and disconnection in less than 3 ms
- Bluetooth 4.2 improves security and increases the maximum data rate to 800 Kbps

The market for BLE products is expanding rapidly

- The 149 million Bluetooth Smart devices shipped in 2014 will grow at a CAGR of 43% to 1.4 billion by 2019
- The 2.7 billion Bluetooth Smart Ready devices shipped in 2014 will grow at a CAGR of 10% to 4.4 billion by 2019

Wearables

151 Mu by 2019[1]

Home Automation

298 Mu by 2019[1]

Beacons

41 Mu by 2019[1]

Security

63 Mu by 2019[1]

[1] Source: IHS Wireless

Bluetooth Low Energy Terms

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 security, throughput and power consumption
- Bluetooth 4.2 (2014) increases packet length, and improves privacy and security

PSoC 4 BLE

- A 32-bit, 48-MHz ARM® Cortex™-M0 PSoC device with programmable subsystems: analog, digital, CapSense and a BLE radio
- Includes a royalty-free Stack compatible with Bluetooth 4.2

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 Stack compatible with Bluetooth 4.2

Bluetooth Low Energy Terms

BLE Component

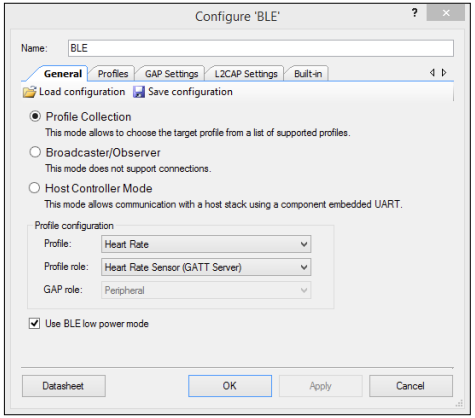
- A PSoC Creator Component that creates Bluetooth Smart products in minutes
- Includes a Component Configuration Tool that makes the complex BLE Protocol Stack and Profiles simple to implement with a GUI

Over-The-Air (OTA) Firmware Upgrade

- The process of replacing an existing firmware with a newer version over a wireless interface like BLE

Component Icon

Component Configuration Tool



Cypress's BLE Supports ALL features of the Bluetooth 4.2 Standard

Bluetooth 4.2 Feature	Benefit	Example	
LE[1] Data Length Extension Increases payload from 27 bytes to 251 bytes…	Enabling ~2.5x higher throughput (up to 800 Kbps)…		For **Faster** OTA Upgrades 110 KB stack and application in 25 s 20 KB application in 5 s
LE[1] Privacy 1.2 Moves address resolution from firmware to hardware…	Enabling frequent address change with low power consumption…		For **Privacy** of User Data Control visibility of wearables Safeguard sensitive user data
LE[1] Secure Connections Uses FIPS-compliant ECDH as the key-generation algorithm for encryption…	Enabling enhanced security with interoperability…		For **Secure** Payment Solutions Transfer passwords and financial information without worrying about being hacked

Cypress's BLE Enables Low-Power Wireless Systems

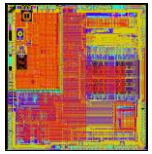
Power Mode	Current Consumption	Code Execution	Digital Peripherals Available	Analog Peripherals Available	Clock Sources Available	Wake-Up Sources	Wake-Up Time
Active	2.2 mA @ 6 MHz	Yes	All	All	All	-	-
Sleep	1.3 mA	No	All	All	All	Any interrupt source	0
Deep-Sleep	1.3 µA	No	WDT[1], LCD[2], I²C/SPI, Link-Layer[3]	Comparator, Opamps, POR[4], BOD[5]	WCO[6], 32-kHz ILO[7]	Comparator, GPIO[8], WDT, SCB[9]	25 µs
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

Cypress's BLE has best-in-class low-power modes

- Consumes the lowest current in Stop mode with GPIO retention
- Retains SRAM data in Hibernate mode
- Retains complete system status in Deep-Sleep mode
- Provides APIs to switch easily between low-power modes
- Consumes 17.1-µA avg. current for a 1-sec connection interval

Complete, End-to-end BLE Solution Set

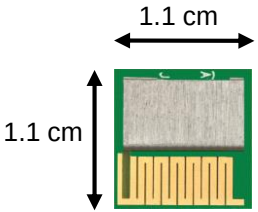
Silicon



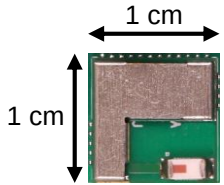
QFN

CSP

Modules



EZ-BLE PSoC Module



EZ-BLE PRoC Module

Software and Kits

PSoC Creator IDE

BLE Pioneer Kit

Reference Designs

Remote Control

Touch Mouse

Energy Harvesting

Terms You Will Hear Today

WSN

- Wireless Sensor Node

Energy Harvesting

- The process of capturing and converting tiny amounts of energy (e.g., from light, vibration or heat) into electricity

Energy Harvesting Power Management IC (PMIC)

- An IC that converts intermittent harvested power to stable power with low startup power (1.2 µW) and quiescent current[1] (250 nA)

Energy Harvesting Device

- A device that harvests energy, e.g., solar cells, which harvest light; piezoelectric and electromagnetic induction devices, which harvest vibration; and thermoelectric generators, which harvest heat

Energy Storage Device

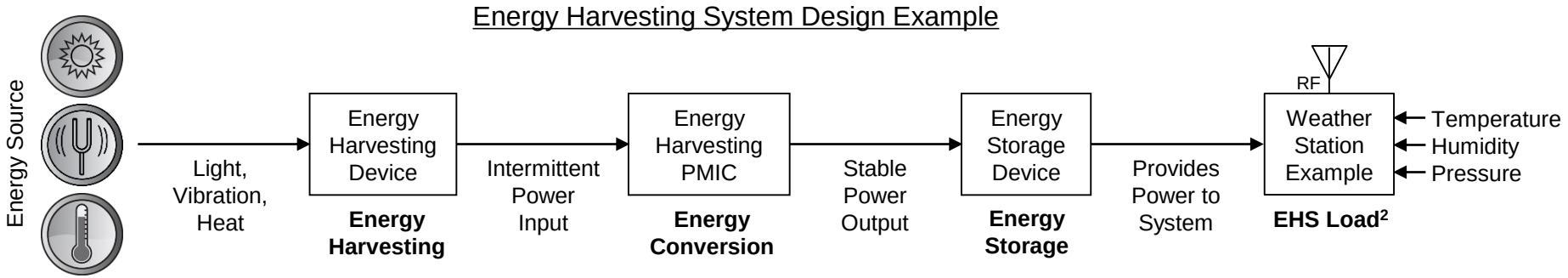
- A device that stores energy
- Low-leakage, low-impedance capacitors are commonly used for harvested energy storage—e.g., ceramic (100 µF), tantalum (470 µF), aluminum electrolytic (1,000 µF) or electric double-layer (500,000 µF) capacitors (e.g., supercapacitor)

[1] Current consumed at no load condition

Terms You Will Hear Today

Energy Harvesting System (EHS)

- A system used to deliver power to a wireless sensor, or other low-power system, which includes an Energy Harvesting Device, a PMIC for energy conversion, and an Energy Storage Device



[1] Current consumed at no load condition

The WSN Device Market Is Set for Explosive Growth in the IoT

It will grow from 500M units in 2015 to more than 5B units in 2020[1]

- Each WSN is a device in the Internet of Things (IoT) that communicates with servers on the Internet
- Each WSN monitors and reports on conditions in buildings, equipment and the environment

Energy Harvesting and low-power wireless communication enable WSN IoT Device market growth

- Next-generation WSNs will be powered by light, vibration or heat
- Next-generation WSNs will communicate over low-power BLE networks

The most compelling new WSNs are self-powered and can be deployed anywhere

- The WSN must last more than 10 years and require minimal deployment and maintenance costs

[1] Source: *802.15.4 & ZigBee: Enabling the Internet of Things* by On World Inc., 2014

Applications

WSNs for Building Automation

WSNs monitor conditions in buildings to reduce energy consumption

WSNs for Residential Control

WSNs monitor conditions in homes such as temperature and humidity

WSNs for Factory Automation

WSNs monitor factory pollution control to meet air quality standards

[1] Source: *802.15.4 & ZigBee: Enabling the Internet of Things* by On World Inc., 2014

Energy Harvesting PMIC: S6AE101A

Applications

Series solar cell Energy Harvesting[2]

Wireless Sensor Node[3]

Features

Ultra-low power: Enables 1 cm^2 minimum solar cell size for startup operation[4]

Input voltage range:

- Series solar cell: 2.0-5.5 V
- Primary battery: 2.0-5.5 V

Output voltage range: 1.1-5.2 V

Quiescent current[5]: 250 nA

Startup power: 1.2 µW

Power gating[6] switch circuit

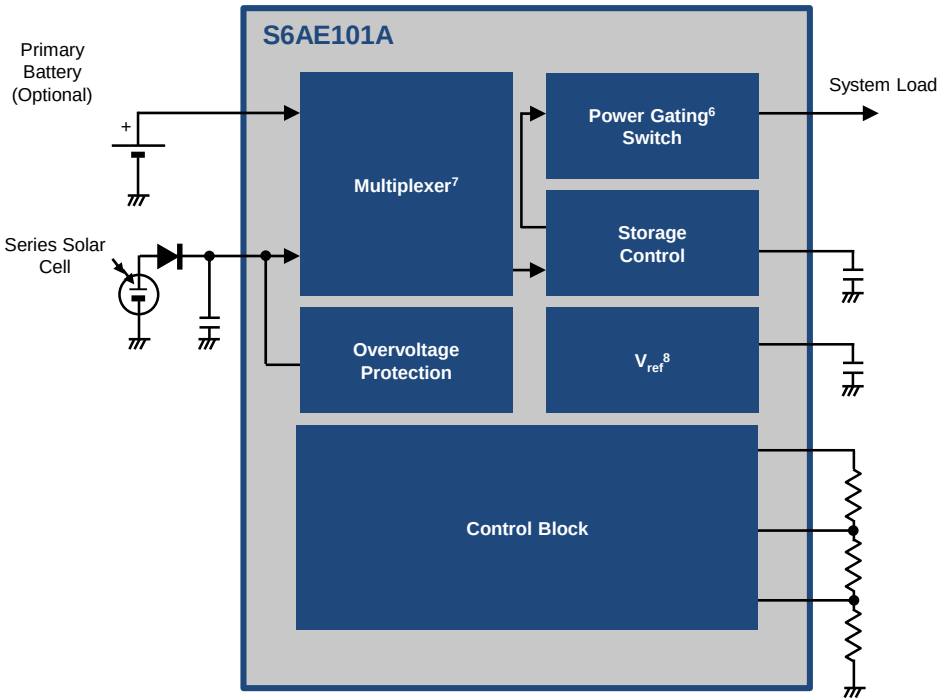
Storage control circuit

Multiplexer[7] circuit (battery vs. solar cell)

Overvoltage protection

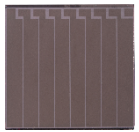
Packages: 10-pin SON (3.0 x 3.0 mm)

Block Diagram

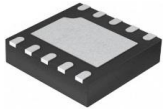


Low-Power, Tiny WSN Design

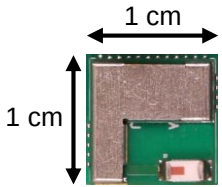
Combine a small solar cell, PMIC, and BLE radio...



Series solar cell, 1 cm^2, 2 µW @ 100 lux (lx)[1]

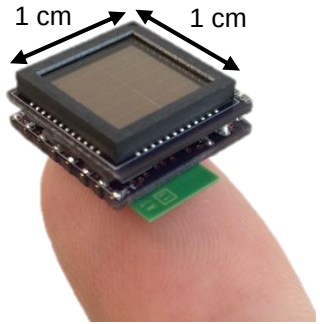


S6AE101A Single-chip Energy Harvesting PMIC



EZ-BLE PRoC Module

To create the lowest-power **WSNs powered by** a tiny solar module.



Demonstration of a tiny 1-cm^2 solar-powered WSN using the Cypress S6AE101A Energy Harvesting PMIC Solution

Five Years Out

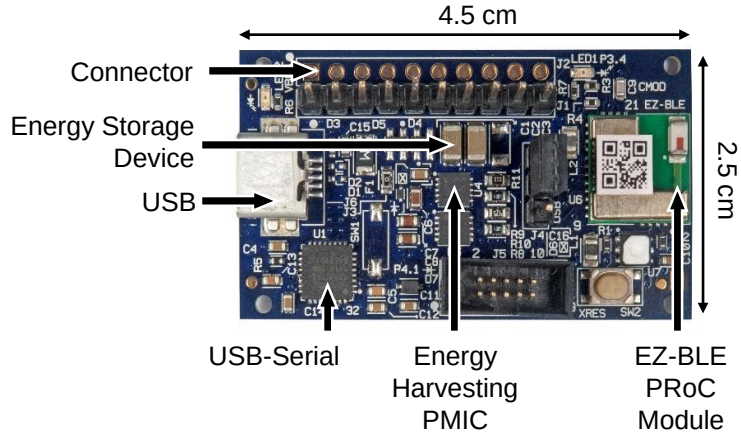
Solar-Powered IoT Device Kit

The $49 kit contains a motherboard, solar module and a BLE-USB Bridge[1]

The Energy Harvesting motherboard includes:

- S6AE101A Energy Harvesting PMIC
- EZ-BLE PRoC Module
- I²C sensor for temperature and humidity
- CY7C65213 USB-Serial device to program the BLE module firmware
- Ceramic capacitor (200 µF) for the Energy Storage Device
- Connector to interface to additional devices

Energy Harvesting Motherboard



The solar module includes:

- Series solar cell that produces 55 µW at 200 lux (lx)[2] (Panasonic AM-1801)

The BLE-USB Bridge[1] with PRoC BLE includes:

- An onboard LED, push button and connector for program and debug

The kit may be powered by several DC energy sources, including:

Series solar cell (2.0 V-5.5 V)

- USB bus power (5-V) and coin cell (3-V)

Five Years Out

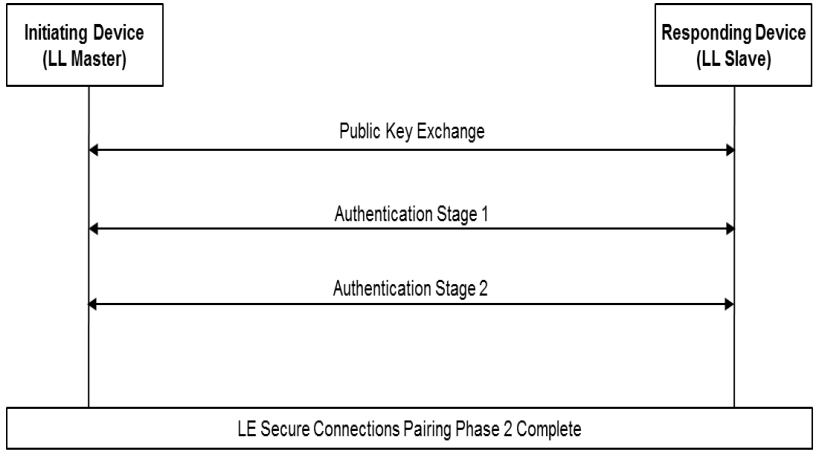
[1] Source: *802.15.4 & ZigBee: Enabling the Internet of Things* by On World Inc., 2014

Questions? Comments? Good (clean) jokes?

Appendices

- 4.2 LE Authentication and Privacy
- BLE Mesh Introduction
- BLE 5.0 Sneak Peek

BLE 4.2: LE Secure Connections: Authentication



Authentication phase is the key difference between Bluetooth 4.1 and Bluetooth 4.2(LE Secure connections)

Bluetooth 4.1: The Temporary Key (used to derive the key that encrypts the BLE link) is the only random data not exchanged over the BLE link. As all other keys are exchanged over air, eaves dropper can decipher temporary key and hack the link.

Bluetooth 4.2: In LE Secure connections, initiating device and responding device exchange their public keys and start computing Diffie-Hellman key. This key is never exchanged over air.

Bluetooth 4.1 and 4.2 Privacy

Feature	4.1	4.2
Address Generation timeout	Recommended time 15mins	Host programmable 1sec-11.5 hours
RPA Resolution	in the Host	in the Controller
RPA Generation	in the Host	in the Controller
Directed Advertisement	Cannot be used for connections with RPA	Can be used for connections with RPA
Whitelist filtering	Cannot be used for connections with RPA	Can be used for connections with RPA
Resolving List	Maintained in the host	Maintained in the Controller. Host adds/deletes devices in the list.

RPA =Resolvable Private Address

Introduction to BLE Mesh

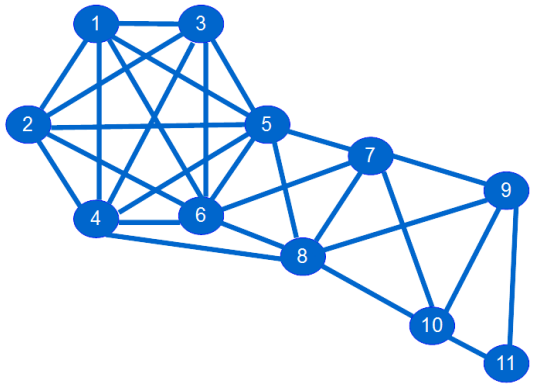
BLE Mesh Network (earlier termed as Smart Mesh) is a mesh networking protocol over BLE defined by the Bluetooth SIG, to transfer data from one device to another either directly or by relaying through intermediate devices

Two versions of BLE Mesh

- BLE Mesh V1 is under development and expected to be release by end of 2016 . It is based on flooding[1] mechanism. Due to the simplicity, its development and adoption to market will be fast
- BLE Mesh V2 is expected to be released by end of 2017. It will be based on routing[2] mechanism. This protocol is expected to be backward compatible with BLE Mesh V1. Though complex in implementation, it will optimize network utilization and power consumption

BLE Mesh V1 Features:

- Primarily transfers data using advertisement (all of the 3 advertisement channels)
- Extends range of BLE communication by relaying data through intermediate nodes
- Securely communicates message between nodes and minimizes security threats
- Provides GATT connectivity for legacy devices that cannot communicate mesh packets over advertisement
- Specification is under development (at 0.7) with most of the features finalized



[1] Flooding is a simple process where every incoming packet is sent out (relay)

[2] Routing is a process where a device decides on certain conditions before it relays the packet.

Bluetooth 5.0 Sneak Peek

LE Advertising Extension

- Increases length of the BLE advertisement packet. Allows usage of all 40 channels for advertisement

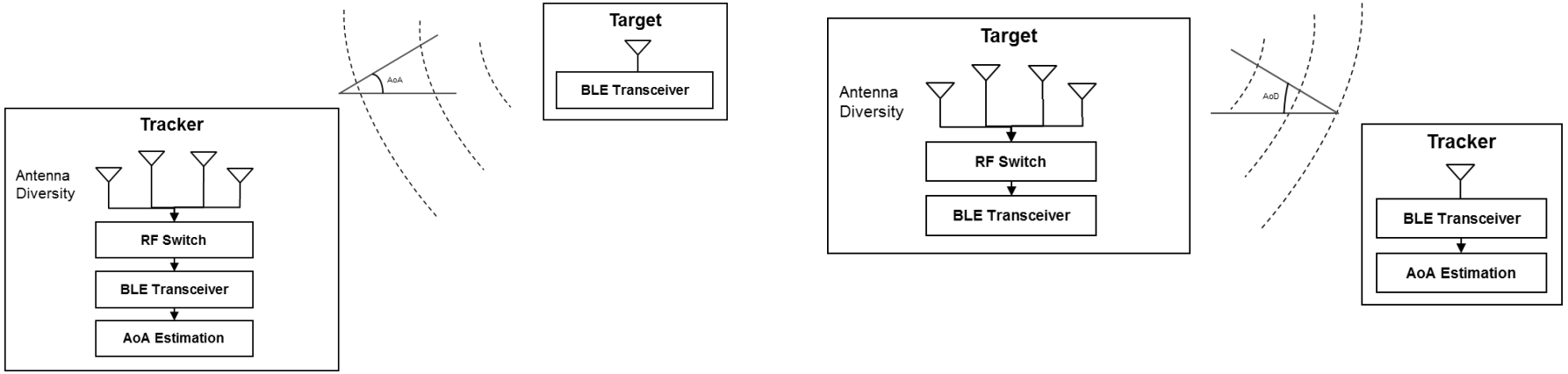
LE 2 Mbps PHY

- Increases the data rate supported by BLE

Long Range

- Forward Error Correction (FEC) to increase receive sensitivity and therefore range
- Data is encoded with 2-bit or 8-bit codes in FEC to increase the amount of bit errors that can be tolerated

Bluetooth 5.0 - Connection Oriented AoA (Angle of Arrival) and Connectionless AoD (Angle of Departure) for Direction Finding



- Tracker is the device that does the calculation of AoA or AoD
- Target is the device being tracked
- Antenna diversity and analysis of I &Q[1] baseband signals are used to determine the direction of the target

[1] Quadrature signals or signals that differ in phase by 90 degrees

The End. Sleepy-Sleepy Nighttime!