Understanding Wireless Connectivity in the Industrial IoT

Texas Instruments

www.ti.com/wirelessconnectivity

Understanding Wireless Connectivity in the Industrial IoT

Contents **Page**

White Paper

Wireless connectivity design considerations for the industrial IoT

Texas Instruments

Olivier Monnier
marketing director,
wireless connectivity solutions

Eran Zigman
business line manager,
wireless connectivity solutions

Amit Hammer
business line manager,
wireless connectivity solutions

Texas Instruments

Introduction

Wireless communications, dominant in consumer electronics for some time now, is quickly making its way into the industrial Internet of Things (IoT). Developers of industrial systems, once freed from the restrictions of cables, are discovering new ways to increase efficiencies and productivity, cut costs and better control processes and equipment. In fact, the only limit on industrial wireless applications appears to be the imagination of developers.

Enabled by ultra-low power sensors and wireless communications devices, as well as highly integrated microcontrollers (MCUs), the IoT is quickly spreading throughout traditional industrial markets like factory and building automation, the energy infrastructure, smart lighting, as well as non-industrial markets such as automotive, retail, health care and others. In many cases, new wireless applications interoperate and enhance the established wired systems, providing value-added capabilities that ride the air waves instead of the wires. For instance, what had been a complex human/machine interface (HMI) can now run as a convenient app on a smartphone or tablet in the wireless industrial IoT. Moreover, tapping into powerful cloud-based analytics in real time adds another dimension to the sophistication of industrial applications.

Of course, system designers should consider a number of factors with regards to wireless connectivity. These include choosing the particular wireless technology that best fits the requirements and use cases of the application, the power consumption and the compatibility of the technology with other devices such as sensors, MCUs, gateways, servers and others, the ease of integrating wireless technology into industrial equipment, cloud connectivity and security.

Going wireless – it needs to be easy

Integrating wireless connectivity into industrial systems has become vastly easier in recent years as new end-to-end building blocks – low-power sensors, wireless connectivity devices, MCUs, gateways and servers – have been introduced. Industrial system developers now have access to a wide variety of wireless technology with diverse capabilities and varying degrees of integration. For example, some technology suppliers have simplified the inclusion of wireless connectivity into industrial systems by integrating wireless connectivity with the processing capabilities of an MCU. This significantly reduces the need for the industrial system developer to be an expert in radio frequency (RF) design techniques and gives developers a powerful MCU for running an application or subsystem. Some of these wireless MCUs include the entire wireless protocol stack as well as security measures. Other more integrated alternatives include as much as possible in one device, such as cloud connectivity, local wireless protocols, security protections and other capabilities in an attempt to make the inclusion of wireless connectivity a plug-in module exercise.

Figure 1: Examples of industrial applications where wireless connectivity may be implemented

In addition to the devices and capabilities needed, industrial system designers can now access the extensive support ecosystems that some wireless technology suppliers provide. The more complete ecosystems feature an array of developer kits, community support, reference designs, already integrated wireless protocol stacks, app developer tools, integrated development environments (IDE) for software programmers and many of the software and hardware modules that are typically implemented in industrial settings.

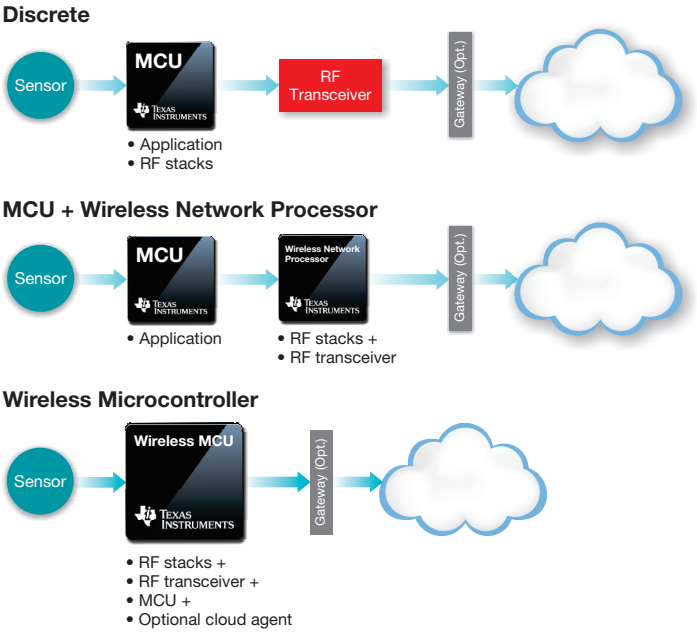


Figure 2: Integration variations for cloud connectivity

The more comprehensive suppliers of wireless technology are able to ensure end-to-end inter-operability among sensors, intermediary devices, industrial protocols like RS-485, RS-232 and the various real-time Ethernet networks, and the cloud. Such suppliers have simplified designing-in wireless connectivity and at the same time ensure interoperability with the cloud and a variety of IoT end nodes.

Industrial wireless: One size won't fit all

Fortunately, a variety of local area wireless connectivity standards with a wide range of capabilities and unique characteristics is available. This is especially beneficial to the developers of industrial systems because industrial applications cover a broad spectrum of use cases and each one has its own set of challenges. Developers are able to select the wireless connectivity technology that best meets the requirements of the application. For example, the developers of a smart metering system for a utility grid might decide that the longer signaling range of a Sub-1 GHz wireless protocol is best suited to this application. Another design team working on a home automation system could

Remote display / Wireless HMI

Before the emergence of the industrial wireless IoT, an HMI for a new monitoring application would have required extensive development and integration of the new subsystem and display hardware. Now, with low-power wireless technologies like Bluetooth® Smart, battery-operated sensors can transmit monitoring data to IoT user devices such as a smartphone or tablet PC. Technicians are familiar and comfortable with this sort of device so the learning curve is short.

opt for Wi-Fi® because of its compatibility with controlling appliances remotely. Lighting networks might be better suited to ZigBee® for its low power consumption, mesh topology and extensive support ecosystem. 6LoWPAN could be the choice of developers of a factory automation system who see real benefit in implementing a network of nodes with Internet Protocol (IP) addresses. For some systems, the very low power and limited range of near field communication (NFC) and *Bluetooth*® Smart or a proprietary 2.4-GHz protocol might suffice.

The point is that each wireless technology has its own set of strengths. An industrial IoT application is best served when the strengths of a particular wireless technology is matched with the requirements of the application. For example, Bluetooth has been deployed in a host of user devices, including smartphones and tablets. So an

	NFC RFID	*Bluetooth*® Bluetooth low energy	Proprietary 2.4 GHz	ZigBee®	Wi-Fi®	6LowPAN	Proprietary Sub-1 GHz
Network type	Identification	Personal connection	Customizable	Mesh	Existing infrastructure	IP Mesh	Customizable
Range	Proximity	Personal area networks		Local area networks			Neighborhood area networks
Key differences	Data • Up to 848 Kbps • No battery to coin cell	Data or voice • Up to 3 Mbps • Coin cell to AAA	Data • Up to 1 Mbps • Coin cell	Data • Up to 256 Kbps • Energy harvesting to AAA	Voice or video • Up to 100 Mbps • AA battery	Data • Up to 256 Kbps • Energy harvesting to AAA	Data • Up to 1 Mbps • Coin cell
Industrial applications	• Device configuration / Firmware upgrade	• Lighting • Wire replacement • Beaconing • Asset tracking • Factory automation	• Building and factory automation • Beaconing	• Smart energy • Building automation • Lighting networks • Industrial Internet	• Assets tracking • Remote control of machinery • Sensors • Building automation	• Smart energy • Building automation • Lighting networks • Low-power Industrial Internet-gateways	• Metering • Smart grid • Alarm and security • Environmental monitoring

Figure 3: Selection table of wireless connectivity technologies for industrial

industrial application supporting Bluetooth Smart would have immediate compatibility with many user devices. 6LoWPAN consumes very little power to the point where it could be supported by small coin cell batteries, energy harvesting or both. In addition, since 6LoWPAN nodes are assigned an IP address, they can be accessed directly from the cloud. If the wireless signal must travel a long distance and penetrate through objects like walls, a Sub-1 GHz protocol could be most appropriate.

Power consumption

The power consumption of an industrial wireless application must be examined at the macro level of the entire system and not just its individual elements.

To start with, an industrial IoT network would certainly call for low-power sensors to monitor factory processes, building equipment, residential systems, the electrical power grid or whatever the setting. Today's most advanced wireless sensors have brought new meaning to low power. When teamed with a low-power MCU with wireless connectivity, some sensor-based IoT end nodes can operate for up to 10 years on a coin cell battery while others will operate on energy harvested from the light, vibration, thermal or RF energy in their surroundings. Sophisticated power management as well as precision analog capabilities like analog-to-digital (ADC) converters and comparators are also critical to low-power IoT networks. Power management routines that are able to automatically place portions of the system into a power-saving sleep mode can extend the operational life of a battery considerably and reduce the need for regular maintenance to change batteries. This could be critical in applications where an IoT node is installed in a particularly inaccessible location, like a machine on the roof of a building, atop a tower or in a satellite. In these sorts of applications, the power management subsystem could lengthen the life of the batteries by keeping most of the system in a low-power sleep mode except for the sensor that is monitoring the inaccessible machine. When the condition being monitored by the sensor, such as vibration or temperature, exceeds a certain threshold, the rest of the system could be powered up so that it could communicate an alarm or take an action on its own.

Preventive maintenance was never so easy

Preventive maintenance – heading off a problem before it happens – is highly valued in many industrial environments. Wireless connectivity makes possible a new generation of preventive maintenance applications. In a power generation plant, for example, wireless sensors could communicate with a technician's smartphone when vibration in a machine exceeds a certain limit. Then, preventive maintenance could return the machine to its proper working order before a catastrophic problem occurs.

Sensors

Sensors deployed in a wireless industrial IoT will monitor a complex and widely diverse environment

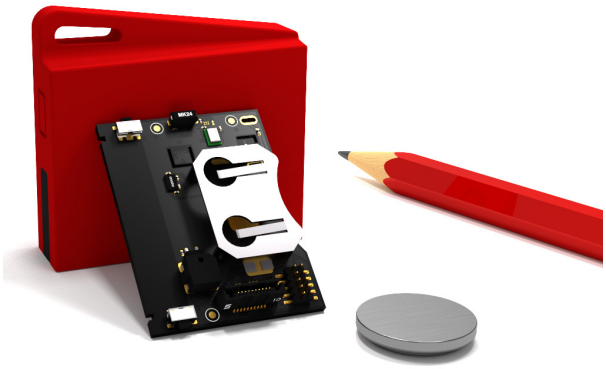


Figure 4: SimpleLink™ SensorTag quickly connects sensors to the cloud

where slight changes in conditions can be critical. High-resolution measurements and the monitoring of chemical composition, access control, vibrations, asset tracking information, motion, pressure, temperature, UV radiation, gas and fluid flow and many other variables could be required.

Some easy-to-implement devices integrate several of these capabilities, combining low-power wireless connectivity over Bluetooth Smart, ZigBee, 6LoWPAN, Sub-1 GHz, Wi-Fi or a proprietary protocol, with an MCU that's able to control a sensor and run an application. This also includes several interfaces to I/O peripherals. By bundling many of the basic capabilities into an integrated platform, such devices reduce the power consumption of the node even further than that of a discrete implementation.

Security

Security is an issue of concern in practically every aspect of the economy, including industrial wireless IoT networks. Security can be implemented in a number of ways, but the goal is always to prevent, detect and respond to malicious behavior when it occurs. On a physical level, IoT nodes should be as tamper resistant as possible. But with electronic systems, security must also be provided to protect IP investments as well as a loss of control over the system to rogue processes. In low-power, often remote wireless nodes, this security protection is usually best provided through hardware-based accelerators or co-processors executing security algorithms because this will consume less power and not diminish the throughput of the node. Conformance and certification to wireless standards, like Wi-Fi, Bluetooth Smart and others, also affect security since standards either incorporate built-in security measures or are compatible with security standards. Wi-Fi, for example, has a number of security standards associated with it, such as Wi-Fi Protected Access (WPA), SSL, TLS, X.509 and others. Cryptographic and authentication

Building security

Wireless connectivity can ensure the security of buildings in a convenient way. For example, locks, motion sensors, cameras, exterior and interior lighting, keypads and other security devices could connect through ZigBee or Sub-1 GHz to a Wi-Fi-based gateway with access to the Internet. With this sort of system, a business owner/operator who may not currently be at the property, could grant temporary access to a trusted employee through their smartphone and a cloud-based security application.

algorithms can also protect stored data. In addition, hardware security measures can be taken, such as secure boot loading mechanisms and logical memory locks.

Connectivity to the cloud and wired networks

At some point, most industrial wireless IoT networks usually interface with the cloud and/or traditional industrial wired networks.

Cloud connectivity has many advantages, but the first issue to address is where in the local IoT will this connectivity be implemented. Most likely, the IoT will connect to the cloud through one of its upper levels, such as a server or gateway. The gateway or server would aggregate cloud communications from other nodes and transmit over the cloud. Some industrial IoT implementations will access the cloud in order to connect with cloud-based strategic partners, like IBM, PTC or other third-party firms that offer application-specific analytics, specialized processing and other services that are sometimes required.

Probably the most critical issue relative to cloud connectivity will be how easy or difficult it will be to accomplish. Historically, developers of industrial systems have not needed experience in radio frequency (RF) engineering. In many cases, wireless cloud connectivity will be provided by Wi-Fi in a gateway or server, since Wi-Fi is already ubiquitous in many industrial settings and it features the requisite bandwidth and capacity for effective cloud connectivity. Some IoT end nodes might require dual wireless connectivity; Bluetooth Smart, ZigBee or 6LoWPAN for local interaction with sensors and operators, and Wi-Fi connectivity for linking into the wider industrial IoT and the cloud. Some industrial Wi-Fi solutions have been bundled with out-of-the-box connectivity capabilities, including single or dual wireless technologies, certified wireless protocols and security algorithms, sample code libraries and development tools and kits.

In addition to cloud connectivity, wireless industrial applications will likely interact with traditional wired equipment networks. For example, factory automation or building automation systems could very well feature both wired and local area wireless networks in the same environment. In such cases, the ability to interface wireless connectivity devices with wired connectivity protocols like RS-485, RS-232 and others will be quite beneficial. A technician might then monitor processes on the factory floor through a wireless connection to an HMI which is monitoring a wired equipment network running one of the industrial real-time Ethernet protocols like EtherCAT®, EtherNet/IP™, PROFINET® or POWERLINK.

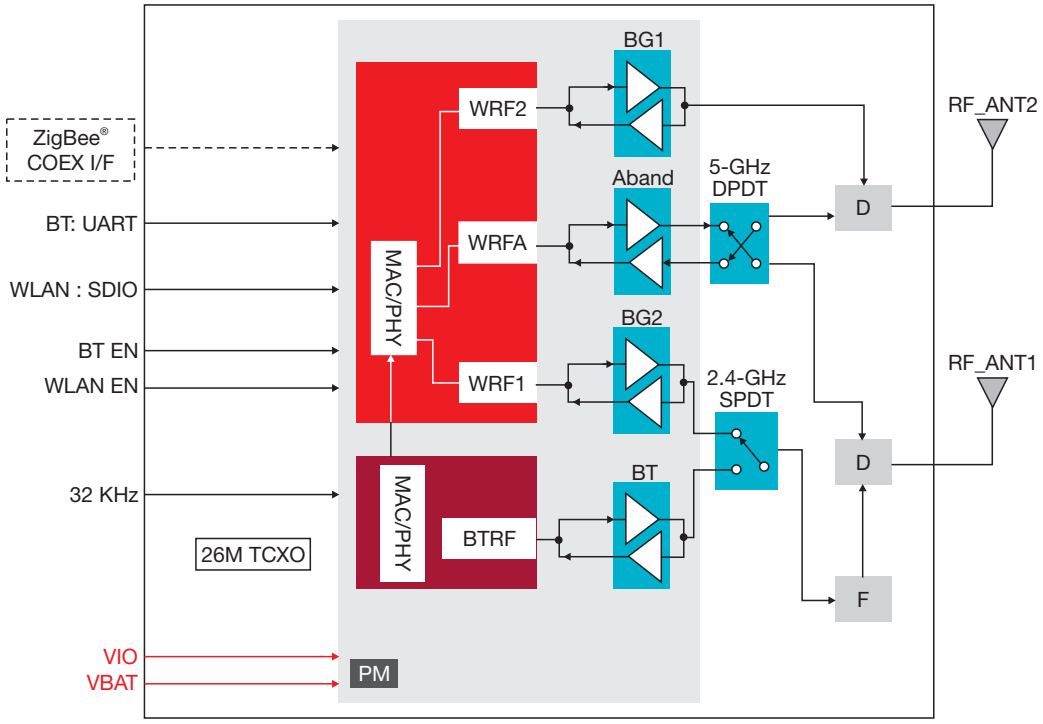
Conclusions

Texas Instruments has long had the industry's most extensive portfolio of enabling wireless technologies for industrial IoT networks. A pioneer in low-power innovation, TI's technologies include both integrated and discrete solutions, such as ultra-low power MCUs and sensors, analog devices like ADCs and comparators, as well as WiLink™ Wi-Fi and Bluetooth combo connectivity devices and SimpleLink™ wireless MCUs which have been integrated with local area wireless connectivity for all of the popular standards in addition to being easily customizable to proprietary protocols. Moreover, the SimpleLink wireless MCUs include the most popular peripheral interfaces as well as on-chip memory and

a sensor controller engine that quickly and easily interfaces to a wide range of TI's sensors.

All solutions are capable of operating over the 40–85°C industrial temperature range. Highly programmable, TI's wireless solutions are supported by an extensive ecosystem of tools, libraries of ready-to-use software modules, reference designs and other resources that allow industrial system developers to not only customize and differentiate their products, but also deliver their new system to the market quickly and efficiently.

For more information go to **www.ti.com/wirelessconnectivity**



Note: Dashed lines indicate optional configurations and are not applied by default.

Figure 5: WiLink 8 dual-band industrial module (WL1837MOD variant shown)

Wireless connectivity blog posts

Texas Instruments

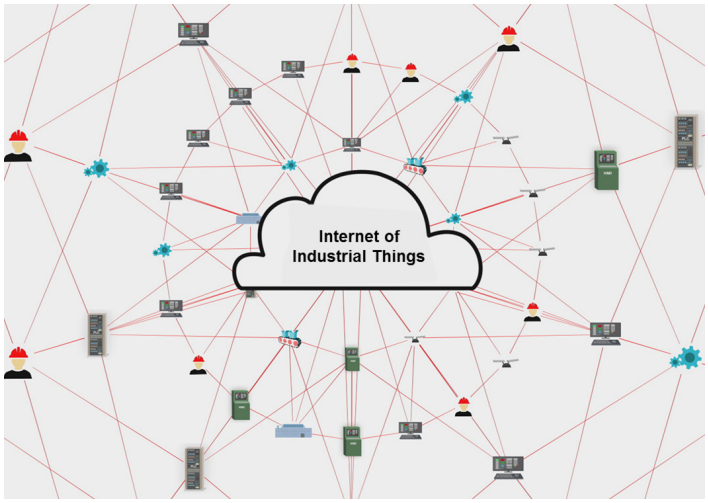
The Internet of industrial Things

Texas Instruments

The **Internet of Things** or IoT is not just for consumer applications. It has a strong potential in the industrial sector because of the services that will be provided as more sensors and equipment are connected to the cloud. It is important that **IoT** not be confused with machine-to-machine or M2M connectivity since they are not the same. M2M is traditionally based on proprietary technology that is a closed environment vs. IoT which offers an open environment and leverages standard Internet accessibility and services – just like the ones we humans use. This level of openness enables a gas sensor to tweet or text an operator when there is a problem, which is not straightforward with an M2M system.

With cloud connectivity there is a lot of potential for IoT-enabled applications within the industrial market.

- **Smart manufacturing:** Manufacturers are adding wireless connectivity to their products or production line to improve the manufacturing process. With integrated **wireless connectivity**, manufacturers are better able to get information from the factory floor to their cloud systems to quickly uncover and address any issues long before the product leaves the factory. Manufacturers also want to use connectivity to gather information about equipment in the field. This information helps them find bugs, monitor equipment and also allows for software and firmware updates over-the-air – something that was not possible before.
- **Building automation:** Much like factory automation, building automation can connect to sensors to turn lights on and off depending on occupancy and allow dynamic control of HVAC systems, which allows for energy optimization. Predicative maintenance is also a benefit to ensure that service is done in a timely fashion, which reduces costs.
- **Smart cities:** Connecting elements within a smart city to the IoT can provide enhancements to improve electricity and water usage with e-meters to improve conservation efforts. Connected smart street lights as well as cloud-connected surveillance and traffic-control monitors help provide a smooth-running city. Last, sensors throughout the city detect gas and water-pipe leak keep citizens safe and ensure operation.
- **Other markets:** There are additional opportunities to improve employee health and safety through the IoT outside of the workplace. Connected **wearables** and healthcare monitoring improves overall health and wellness. And IoT within automobiles provides **infotainment** but also lighter and more fuel efficient cars with wire replacement and predictive maintenance to save on costly repairs.



Many of the examples above play out in the consumer market as well. However, the industrial IoT is different than consumer applications. Industrial requires different interfaces and protocols that are robust against noise, environmental changes, controlled latency and are highly secure because of the conditions and applications they are used in.

Additionally, the industrial market moves much slower than the consumer market so its move to connected IoT enhancements will take some time. The benefits of predicative maintenance, monitoring and data analysis to improve output or working conditions, combined with the availability of the right hardware and software solutions, will provide a financial reason to migrate to IoT-connected systems in the future – its just a question of when.

- Learn more about TI's role in the IoT and its broad portfolio of **IoT-ready solutions**
- Watch this video and see how TI is innovating for **industrial automation**
- Read more **blogs on TI's IoT solutions**

Building the industrial Internet of Things

Texas Instruments

The Internet of Things or **IoT** is an enabling technology that is delivering new use cases and services across a wide variety of markets and applications. When people think of the IoT, they often think of home or personal applications, but in reality, IoT-connected products will play a role in smart manufacturing, smart cities, automotive, building automation and health care as well.

The **Industrial IoT** has strong potential because of the services that will be provided as more sensors and equipment are connected to the cloud. It is important that IoT not be confused with machine-to-machine (M2M) connectivity since they are not the same. M2M is traditionally based on proprietary technology that is a closed environment vs. IoT which offers an open environment and leverages standard Internet accessibility and services – just like the ones we humans use. This level of openness enables a gas sensor to tweet or text an operator when there is a problem or for an industrial end-equipment to leverage a generic public data base to see how it is performing compared to industry benchmarks, things which are not straightforward with proprietary M2M systems.

At a high-level, IoT is about improving efficiency (e.g., energy, manufacturing, maintenance, etc.), and delivering increased safety and security, better experiences, new business services and more to a variety of industries including:

- **Smart manufacturing:** Manufacturers are adding wireless connectivity to their products or production line to improve the manufacturing process. With integrated **connectivity**, manufacturers are better able to get information from the factory floor to their cloud systems to quickly uncover and address any issues long before the product leaves the factory. Manufacturers also want to use connectivity to gather information about equipment in the field. This information helps them find bugs, monitor equipment and also allows for software and firmware updates over-the-air – something that was not-possible before.
- **Building automation:** Much like factory automation, building automation can connect to sensors to turn lights on and off depending on occupancy and allow dynamic control of HVAC systems, which allows for energy optimization. Predicative maintenance is also a benefit to ensure that service is done in a timely fashion, which reduces costs.
- **Smart cities:** Connecting elements within a smart city to the IoT can provide enhancements to improve electricity and water usage with e-meters to improve conservation efforts. Connected, smart street lights as well as cloud-connected surveillance and traffic-control monitors help provide a smooth-running city. Last, sensors throughout the city detect gas and water-pipe leak keep citizens safe and ensure operation.
- **Automotive:** Connected cars provide **infotainment** services to stream entertainment and provide navigation and other connected services. Replacing wires with wireless connectivity is leading to lighter and more fuel-efficient automobiles

with sensor-driven predictive maintenance to save on costly repairs.

- **Retail stores:** A connected retail environment can better track inventory and dynamically change digital shelf labels. Combined with customer loyalty programs, IoT-connected beacons within a store can serve up coupons and offer sales based on customer preferences directly to their smartphones while they are shopping.
- **Healthcare:** There are additional opportunities to improve employee health and safety through the IoT outside of the workplace. Connected wearables and health care monitoring improve overall health and wellness.

Many of the examples above play out in the consumer market as well. However, the industrial IoT is different than consumer applications. Industrial requires different interfaces and communication protocols that are robust against noise, environmental changes, controlled latency and are highly secure because of the conditions and applications they are used in.

Additionally, the industrial market moves much slower than the consumer market so its move to connected IoT will take some time. The benefits of predicative maintenance, monitoring and big data analysis to improve output or working conditions, combined with the availability of the right hardware and software solutions, will provide a financial reason to migrate to IoT-connected systems in the future – it's just a question of how quickly it happens.

- Learn more about TI's role in the IoT and its broad portfolio of **IoT-ready solutions**
- Watch this video and see how TI is innovating for **industrial automation**
- Read more **blogs on TI's IoT solutions**

Taking power to a new low with the SimpleLink™ ULP wireless MCU platform

The new SimpleLink™ CC26xx/CC13xx ultra-low power platform for *Bluetooth*® Smart, 6LoWPAN, ZigBee®, Sub-1 GHz and ZigBee RF4CE™ is built and designed with low power in mind. We've looked at all aspects important to making sure the energy footprint of our solution is as small as possible enabling longer battery lifetimes, smaller batteries or even energy harvesting for battery-less applications.

Application

Contrary to popular belief, that radio transceiver itself is rarely the main contributor to the overall power consumption of a wireless microcontroller (MCU). As various technologies progress, there is more and more need for computing power, even as relatively small sensors and the wireless protocol stacks come with more overhead as the standards evolve.

In the SimpleLink CC26xx family, there are two very energy efficient MCUs available for the application.

ARM® Cortex®-M3

The ARM Cortex-M3 is the main system CPU inside the CC26xx device. One way of measuring the performance of MCUs is by using benchmark tools. One of the more popular benchmarks is **CoreMark** from the Embedded Microprocessor Benchmark Consortium (EEMBC). CoreMark is a simple, yet sophisticated, benchmark that is designed to test the efficiency of a processor core used in embedded devices. It is not system dependent, therefore it functions the same regardless of the platform (e.g., big/little endian, high-end or low-end processors, etc.). This benchmark also demonstrates the energy efficiency of the MCU core.

Table 1: Various CoreMark scores for the CC26xx, measured on CC2650-7ID @ 3.0V and 48 MHz

	CC26xx ARM Cortex-M3
CoreMark score	141.85
CoreMark / MHz	2.955
CoreMark / mA	48.49
µA / MHz	60.95

The scores in Table 1 allow for very low average power consumption during active use. Running the ARM Cortex-M3 at maximum speed (48 MHz), the CPU operation consumes less than 3 mA and outperforms any wireless MCU running at less efficient cores or at lower CPU clocks. The CC26xx CoreMark power efficiency (CoreMark / mA) is the best compared to any competitor with a comparable MCU, making it the most energy efficient microcontroller available today.

Sensor controller

The unique ultra-low power sensor controller is a 16-bit CPU coupled with peripherals like analog-to-digital converters (ADC), analog comparators, SPI/I^2C and capacitive touch. It is designed to run autonomously when the rest of the system is in standby. The Sensor Controller allows interface with external analog or digital sensors in a very low power manner.

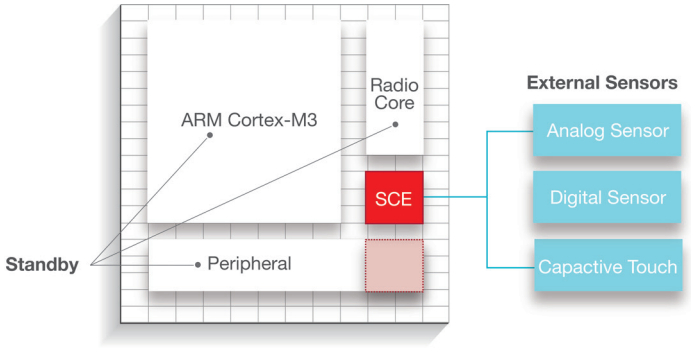


Figure 1: The ultra-low power sensor controller engine can run autonomously while the rest of the system is in standby.

Waking up the entire system to perform minor tasks is very often not energy efficient as it introduces a lot of overhead. In many use cases there are tasks that need to run at certain intervals that are at a higher duty-cycle than the actual RF or main activity.

One example could be a heart-rate monitor that needs to run the ADC 10 times per second to capture the heart rate accurately. Waking the entire system up to perform a wireless transmission 10 times per second will, in this case, be very energy inefficient. With the SimpleLink ultra-low power CC26xx platform, one can let the Sensor Controller perform

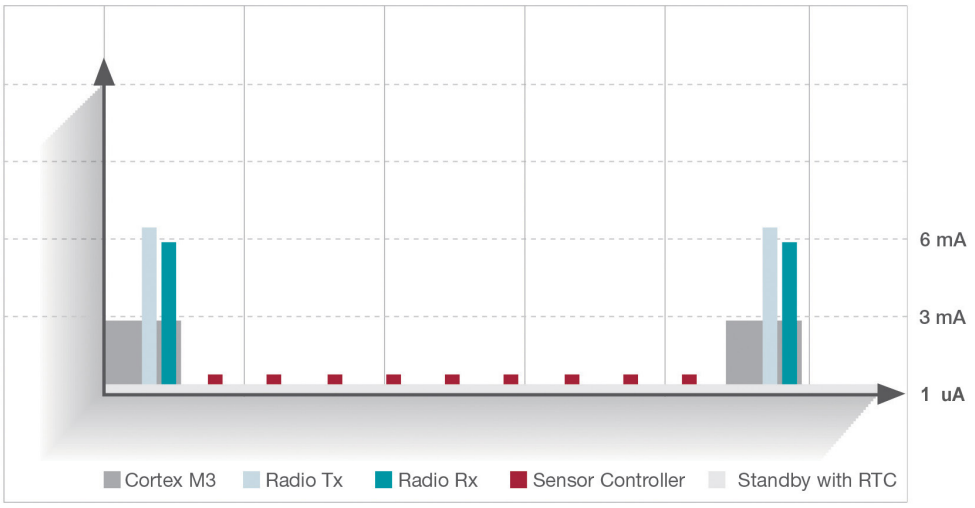


Figure 2: The sensor controller can significantly reduce average power consumption.

all the ADC measurements and wake up the ARM Cortex-M3 every 10th ADC sample for optional further processing and group RF transmission of this data.

In this example, the sensor controller can do 10 ADC reads per second at less than 3 µA average consumption. Performing the same task using the ARM Cortex-M3 will require 10× the power consumption.

Table 2: Energy efficiency of the sensor controller while running at the main clock.

	CC26xx ultra-low power sensor controller
uA / MHz	8.2

The sensor controller can run directly off a pre-scaled 24-MHz clock, making it capable of collecting data and performing simple processing of the data.

Radio

Traditionally the peak drain caused by high transmit and receive currents of wireless solutions puts constraints on the batteries that could be used or significantly reduced the battery lifetime. With the very low peak currents of the CC26xx at around 6 mA (0 dBm output), this no longer poses any limitations on the traditional CR2032 batteries and can even allow for smaller batteries to be used. From an average power consumption perspective, the radio is no longer the main contributor and is of less concern and there is no longer a need to back down on the output power to reduce the peak consumption.

Sleep and shutdown

In any battery-operated application, the RF (receive/transmit) duty cycle and its parameters decide the battery lifetime. Between transmissions, it is important to keep the standby currents as low as possible so that there is enough juice in the battery for the active use. The CC26xx uses an ultra-low leakage SRAM that can be fully retained (20 KB) and in addition have the real-time clock (RTC) running, and registers and CPU state retained while in standby consuming as little as 1 µA. In shutdown, the CC26xx can wake up on external I/O events while drawing as little as 150 nA.

The shelf lives for CR2032s are increasing and some vendors now state up to 10 years of battery life. The average system current drawn from a 220 mAh CR2032 has to be below 2.5 µA to reach 10 years lifetime[2]. If the base current of a system is above this, one cannot reach the maximum potential of the battery, no matter how low active duty cycle one implements.

How average current affects battery lifetime

Battery life time is mostly about the average power consumption. This will be very use-case dependent, but there is a benchmark now available from EEMBC called **ULPBench™** that standardizes on datasheet parameters and provides a methodology to reliably and equitably measure MCU energy efficiency. ULPBench uses a common set of workloads that are portable across 8-, 16- and 32-bit microcontrollers, enables the use of MCU low-power modes while focusing on real-world applications utilizing integrated hardware functions. In the end it analyzes the effects of active and low-power conditions[3].

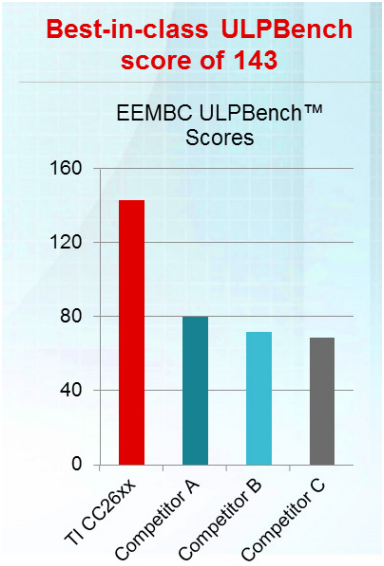


Figure 3: CC26xx ULPBench scores vs. competition.

Another common way of looking at average current is to look at a specific use-case for a given technology. For Bluetooth

Smart, one way is to point out the average while keeping a connection between two devices at a given interval.

Table 3: Average scores for the CC26xx, measured on CC2650-7ID @ 3.0 V

	CC26xx ARM Cortex-M3
ULPBench Score	143.6
1s Connection, *Bluetooth*® Smart (CC2640)	<10uA

All of what has been discussed comes into play when looking at the power profile of a wireless event. Figure 4 shows a connection event for Bluetooth Smart with wake-up, pre-processing of the software stack, radio events (both receive and transmit) and a post-processing / going back to sleep period.

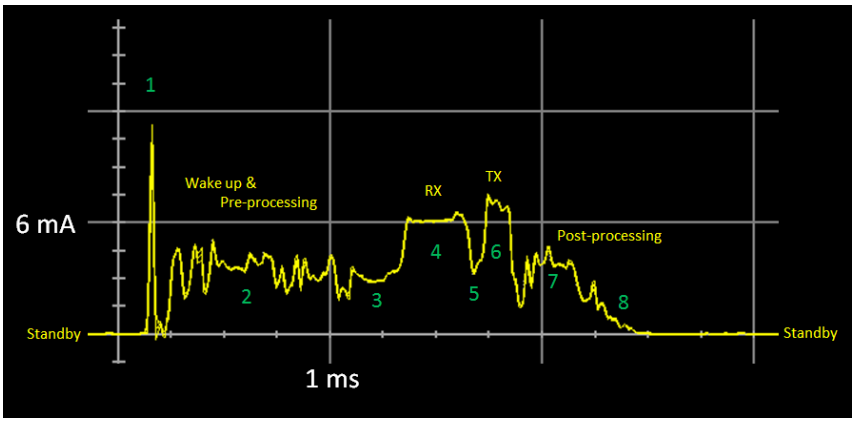


Figure 4: Power profile of a Bluetooth Smart connection event

Further details on how to calculate average currents and battery lifetime for a Bluetooth Smart application can be found in [4].

Reference

[1] **Cortex-M0+ Processor**

[2] Marketing Malarkey and Some Truths About Ultra-Low Power Design, Jack Ganssle 2014

[3] **EEMBC ULPBench**

[4] **Measuring *Bluetooth*® Smart Power Consumption**

Bluetooth® Smart in industrial

Have you ever heard of ***Bluetooth*® Smart**? It's the latest addition to the Bluetooth specification and it uses Bluetooth low-energy technology to enable the Internet of Things (IoT) for products that operate on small coin cells for years. How is that possible you may ask? Bluetooth low energy was designed to be low power, only waking up from time to time to transmit small amounts of data with rather high latency in a range that covers up to a couple of meters. Perfect for sensors! That's how it began in 2010.

It took a year or two until the first products showed up on the market in the form of heart-rate belts and smart watches. Then a smartphone came into the picture, Apple® iPhone® 4S. It was the first phone on the market to support Bluetooth low energy and the market took off. The fact that everyone carrying a smartphone, could connect to all kinds of products in a low-power manner was something new. Suddenly, everyone wanted their product to be connected to a smartphone.

As a natural progression came the talk about Internet of Things and cloud connectivity so your smartphone can connect to *any*-thing and so allowing *any*-thing to connect to the Internet (read cloud). With this dramatic change, firmware updates could be pushed to products out in the field, smartphones could control helicopter toys and wireless add-ons can replace wires in weird places.

We are at this point closing in on 2015 and all of a sudden, manufacturers are now using Bluetooth Smart (which is becoming the more common name for **Bluetooth low energy**) for longer-range communication, high-throughput transfers and tough ISM applications as well. This is not at all what Bluetooth low energy was designed for. However, Bluetooth low energy is now advancing into high-quality industrial applications; replacing whatever has been used for ages, or at least a very long time.

It's time for a revolution, time for Bluetooth Smart to show its worth in new places. Bluetooth Smart is emerging into unexplored new market segments from hardcore industrial applications and fancy home appliances to trendy beacon-systems [sic].

There are already deployed solutions for use cases including both wired and wireless technologies that can be replaced by Bluetooth Smart. As Bluetooth Smart is evolving and adapting to these new use cases, one might be afraid that there might be a "war" between standards coming. I like to think about it more of an evolution, where the survival of the fittest applies. The future will behold which technology is suitable for what.

However, we can already elaborate on some applications that might be impacted. Take lighting as an example, where ZigBee is dominating the market with smart bulbs connected in a network to a Wi-Fi® gateway. Bluetooth Smart can do star topologies as of now, with a central or smartphone controlling multiple light bulbs. However, ZigBee operates in a mesh network topology which means that information can be routed through nodes and range can be extended beyond the gateway limitation. Bluetooth Mesh is something that could address this in the future as well, if it's designed in an energy-efficient way (i.e., not using flooding, etc.) and the security

is robust including the complete solution for that matter. But what about the already-deployed ZigBee solutions, will those be redundant? Well, not necessarily. What if one node in the ZigBee network adds Bluetooth Smart? Or the gateway includes a Bluetooth Smart interface?

There are other use cases; i.e., Machine to Machine (M2M), cable replacements, asset tracking and automation control that can benefit from Bluetooth Smart in the industrial setting. There are already multiple connectivity technologies with a foothold in the industrial space including Ethernet, ZigBee, Wi-Fi, Sub-1 GHz, etc. and Bluetooth Smart can easily complement these technologies. What is needed is a focus on streamlining a set of technologies to define a wireless super-set similar to the useful Swiss army knife.

Why is Bluetooth Smart a good fit for industrial applications? Read the six-part blog series on ***ECN Magazine*** that covers the industrial applications mentioned above and allow me to enlighten you.

Reference

[1] **Why Bluetooth Smart is perfect for M2M**

[2] **Connecting machinery to the IoT**

[3] **How to use Bluetooth Smart in industrial lighting**

[4] **How you can replace wires with Bluetooth Smart**

[5] **Why Beacon is the next big thing in wireless**

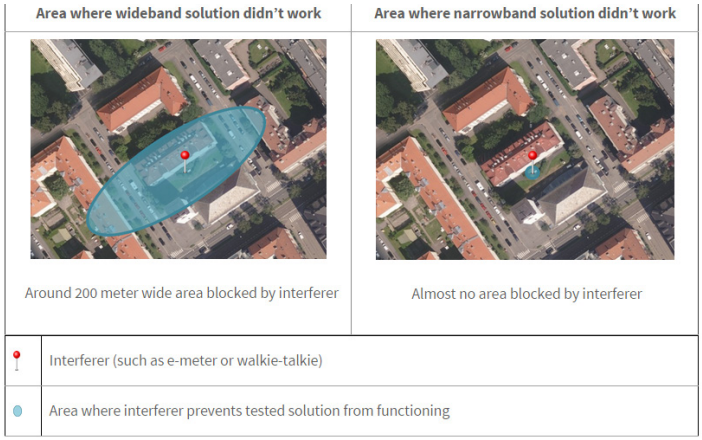
[6] **The key to using Bluetooth Smart in asset tracking**

The shocking impact of poor RF selectivity and blocking

At TI we have more than 15 years of experience with low-power RF solutions. Over time, working hands-on with customers, we have learned what it takes to design RF ICs that work well in industrial environments. The wireless communication needs to be robust and just plain work. To learn more about our **169-MHz, 315-MHz, 433-MHz, 470-MHz, 868-MHz, 915-MHz and 920-MHz solutions**, check out our Sub-1 GHz page.

Recently we wanted to test our newest long-range RF solution against a well-known competitor in the market. Both solutions have really great RF transmission range when tested in a quiet open space, such as in the countryside environment found **in this video from our 25-km range test video in South Africa**. However, many industrial RF solutions are not deployed in the countryside but rather in urban areas, which is why we shot our latest range test video in downtown Oslo, Norway.

In the video we set up 2 RF links (one with TI's **CC1120** long-range, narrowband, high-performance RF transceiver and one with a long-range wideband competitor) to compare



what happens to the RF link when we introduce an interferer, i.e., an e-meter, into the equation. We were really surprised by the results. The wideband solution basically ceased to function if the interferer was within ~200 meter range. This basically means that an e-meter in a neighboring building can block your wide-band RF link completely.

So why is the wideband solution prevented from receiving data while the narrowband solution is just fine?

There are two main benefits with a narrowband solution. First, there are more RF channels available which enable more systems to coexist peacefully. Secondly, wideband solutions have wider RF receive filters which pick up more RF noise and interference than a narrowband solution. Hence, narrowband is the best choice for robust RF solutions in urban and industrial areas. For an in-depth discussion on this topic, please check out our **Long-range RF communication: Why narrowband is the de facto standard** whitepaper.

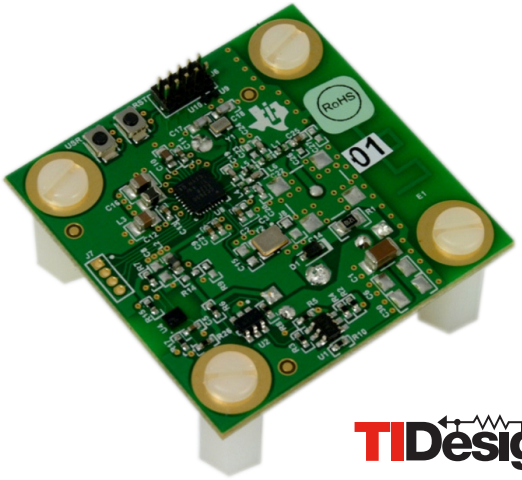
Return to ToC

Wireless connectivity
TI Design reference designs

Humidity & Temp Sensor Node for Star Networks Enabling 10+ Year Coin Cell Battery Life Ref Design

Description

This TI Design uses Texas Instruments nano-power system timer, SimpleLink™ ultra-low power wireless microcontroller (MCU) platform, and humidity-sensing technologies to demonstrate an ultra-low power method to duty-cycle sensor end nodes. These technologies lead to an extremely long battery life: over 10 years with a standard CR2032 lithium ion coin cell battery. The TI Design includes techniques for system design, detailed test results and information to get the design up and running quickly.



Features

- Use of nano-power system timer to duty-cycle the system results in 10+ year battery life from CR2032 coin cell
- Configurable system wakeup interval
- Extremely low off-state current (183 nA for 59.97 seconds)
- Ultra-low on-state current due to low active processor and radio transmit currents (4.04 mA for 30 ms)
- ±3% Relative humidity accuracy
- ±0.2°C Temperature accuracy

Part number	Name	Product family	Design kits and Evaluation modules
CC2650	SimpleLink™ multi-standard 2.4-GHz ultra-low power wireless MCU	Wireless MCUs	View Design Kits & Evaluation Modules
CC2640	SimpleLink ultra-low power wireless MCU for Bluetooth Smart	Wireless connectivity	View Design Kits & Evaluation Modules
CC2630	SimpleLink ultra-low power wireless MCU for 2.4-GHz IEEE 802.15.4-based RF protocols	Wireless connectivity	View Design Kits & Evaluation Modules
HDC1000	Low power, high accuracy digital humidity sensor with integrated temperature sensor	Sensor products	View Design Kits & Evaluation Modules
TPD1E10B06	Single-channel ESD in 0402 package with 10pF capacitance and 6V breakdown	ESD protection diodes	View Design Kits & Evaluation Modules
TPL5110	Ultra-low-power timer with MOS driver and MOSFET power ON	Clock and timing	View Design Kits & Evaluation Modules

To download the full TI Design Reference Design visit: **http://www.ti.com/tool/TIDA-00374**

Wireless Motor Monitor Reference Design

TEXAS INSTRUMENTS

Description

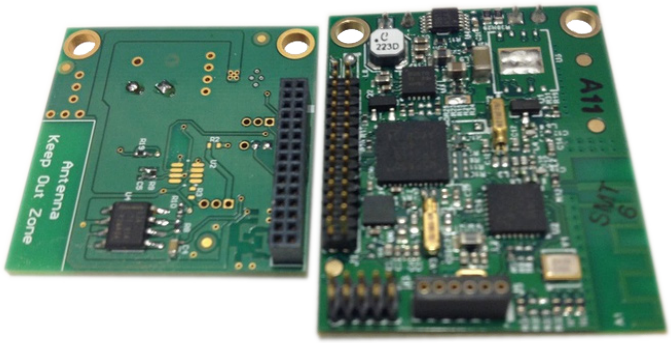
This TI Design is inspired by the need to monitor the health of motors and machines to accurately predict and schedule maintenance (or replacement) while minimizing cost and down time during industrial production. Millions of industrial motors are monitored today with handheld or wired Piezo accelerometer sensing devices. The annual cost of monitoring these motors is approximately $300 per motor.

Recent advancements in ultra-low-power processing technologies, radios and piezo sensor miniaturization have enabled the development and deployment of low-cost, small motor monitors with wireless capabilities. These wireless motor monitors are powered by coin cells that have a battery life of more than 10 years. These systems provide the same broadband sensitivity as existing handheld systems, collect vibrational data and perform spectral analyses on that data. This integrated intelligence lets you deploy and monitor these systems in difficult-to-reach locations. The money these capabilities save can pay for the systems within a few months. The wireless motor-monitoring TI Design uses two different, yet electrically equivalent, form factors for development and testing.

These form factors include:

- The modular form factor
- The compact form factor

In the modular form factor, TI LaunchPad™ Development Kits and EM connectors allow you to incorporate multiple radios and processors with energy-management and sensor subsystems. The compact form factor uses the MSP430FR5969 ultra-low-power microcontroller unit (MCU) with a CC2650 BLE radio, but can be connected to multiple sensor boards.



TIDesigns

The standard sensor board supports a PCB Piezotronic vibration sensor.

The 30-pin expansion connector on the small form factor board enables the base-board to be operated with the MCU, the CC2650 radio, or both. The system software assumes you are using both devices. This TI Design focuses on the compact form factor system.

Features

- 100-µA MSP MCU analyze/write
- 6-mA *Bluetooth*® Low Energy radio
- 40-nA system sleep
- 10-KHz/16-bit vibration sensor
- iPad®/Android™ visualization
- This circuit design is tested and includes firmware, GUI, demo, and Getting Started Guide

(continued)

TI devices

Order samples, get tools and find more information on the TI products in this reference design.

Part number	Name	Product family	Design kits and Evaluation modules
ADS8320	16-bit, high-speed, 2.7-V to 5-V micro power sampling analog-to-digital converter	Analog-to-digital converter	View Design Kits & Evaluation Modules
BQ25570	Ultra-low-power harvester power management IC with boost charger and nanopower buck converter	Battery management products	View Design Kits & Evaluation Modules
CC2650	SimpleLink™ multi-standard 2.4-GHz ultra-low power wireless MCU	Wireless MCUs	View Design Kits & Evaluation Modules
LMP7716	Dual-precision, 17-MHz, low-noise, CMOS input amplifier	Operational amplifier (Op Amp)	View Design Kits & Evaluation Modules
MSP430FR5969	16-MHz ultra-low-power microcontroller featuring 64 KB FRAM, 2 KB SRAM, 40 I/O	Ultra-low power MCU	View Design Kits & Evaluation Modules
TPL5100	Nano power programmable timer with power gating functionality	Clock and timing	View Design Kits & Evaluation Modules
TPS22969	1-Ohm SPDT analog switch 5-V/3.3-V single-channel 2:1 multiplexer/ demultiplexer	Signal switches	View Design Kits & Evaluation Modules
TPS7A7002	Very-low input, very-low dropout 3-A regulator with enable	Linear regulator (LDO)	View Design Kits & Evaluation Modules

To download the full TI Design Reference Design visit: **http://www.ti.com/tool/tidm-wlmotormonitor**

SimpleLink™ Multi-Standard CC2650 SensorTag Reference Design

Texas Instruments

Description

The new SimpleLink Multi-Standard SensorTag IoT kit invites you to realize your cloud-connected product idea. Including 10 low-power MEMS sensors in a tiny package, the kit is expandable with DevPacks to make it easy to add your own sensors or actuators.

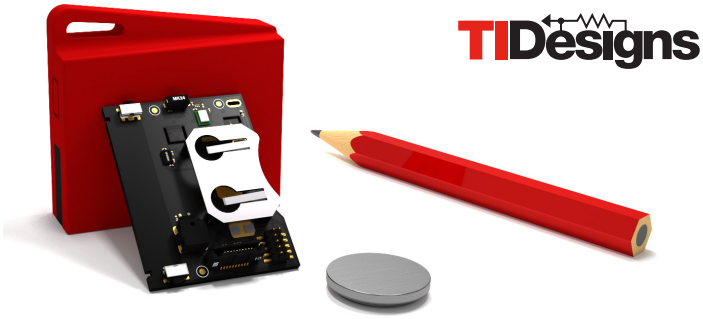
Connect to the cloud with *Bluetooth*® Smart and get your sensor data online in three minutes. The SensorTag is ready to use out of the box with an iOS™ and Android™ app, with no programming experience required to get started.

The new SensorTag is based on the CC2650 wireless MCU, offering 75% lower power consumption than previous Bluetooth Smart products. This allows the SensorTag to be battery powered and offer years of battery lifetime from a single coin-cell battery.

The Bluetooth Smart SensorTag includes iBeacon technology. This allows your phone to launch applications and customize content based on SensorTag data and physical location.

Additionally, the SensorTag can be enabled with ZigBee® and 6LoWPAN technology.

Visit **www.ti.com/sensortag** for more information.



TIDesigns

Features

- Support for 10 low-power sensors, including ambient light, digital microphone, magnetic sensor, humidity, pressure, accelerometer, gyroscope, magnetometer, object temperature and ambient temperature
- Ultra-low power, with years of battery life from a single coin-cell battery and enabling battery-less applications through the high-performance ARM® Cortex®-M3 **CC2650 wireless MCU**.
- Cloud connectivity lets you access and control your SensorTag from anywhere
- Multi-standard support enables ZigBee or 6LoWPAN through a simple firmware upgrade
- DevPacks allow you to expand the SensorTag to fit your designs

TI Designs

TI devices

Order samples, get tools and find more information on the TI products in this reference design.

Part number	Name	Product family	Design kits and Evaluation modules
CC2620	SimpleLink ultra-low power wireless MCU for RF4CE	Wireless connectivity	View Design Kits & Evaluation Modules
CC2630	SimpleLink ultra-low power wireless MCU for 2.4-GHz IEEE 802.15.4-based RF protocols	Wireless connectivity	View Design Kits & Evaluation Modules
CC2640	SimpleLink ultra-low power wireless MCU for Bluetooth Smart	Wireless connectivity	View Design Kits & Evaluation Modules
CC2650	SimpleLink multi-standard 2.4-GHz ultra-low power wireless MCU	Wireless MCUs	View Design Kits & Evaluation Modules
HDC1000	Low power, high-accuracy digital humidity sensor with integrated temperature sensor	Sensor products	View Design Kits & Evaluation Modules
OPT3001	Digital ambient light sensor (ALS) with high-precision human eye response	Optical sensing	View Design Kits & Evaluation Modules
TMP007	Infrared thermopile contactless temperature sensor with integrated math engine in WCSP package	Temperature sensors	View Design Kits & Evaluation Modules
TS5A3159A	1-Ohm SPDT analog switch 5-V/3.3-V single-channel 2:1 multiplexer/demultiplexer	Signal switches	

To download the full TI Design Reference Design visit: **http://www.ti.com/tool/TIDC-CC2650STK-SENSORTAG**

ETSI Cat. 1 Receiver-Capable wM-Bus 169-MHz RF Subsystem for Smart Gas and Water Meters

Texas Instruments

Description

This reference design is a very-low power, ETSI Cat. 1 receiver capable RF subsystem for **wM-Bus**-enabled smart gas and water meters at 169 MHz. It provides market-leading blocking, selectivity and RX sensitivity numbers for all wM-Bus N-modes as per EN13757-4:2013 and their respective variants, which were defined in Italy and France. This cost-optimized design, without SAW filter and without TCXO, uses the RF friendly DC/DC to reduce the average power consumption while keeping the highest RF performance.

TIDesigns

Features

- ETSI Cat. 1 receiver capable RF subsystem
- Market-leading blocking, selectivity and RX sensitivity subsystem for wM-Bus at 169 MHz
- Fully compliant with the wM-Bus requirements for Italy and France (with an external PA device) at 169 MHz
- Highly efficient, RF friendly DC/DC converter
- No costly SAW filter and TCXO required

TI devices

Order samples, get tools and find more information on the TI products in this reference design.

Part number	Name	Product family	Design kits and Evaluation modules
CC1120	High-performance RF transceiver for narrowband systems	Wireless connectivity	View Design Kits & Evaluation Modules
TPS62730	Step-down converter with bypass mode for ultra-low-power wireless applications	Converter (integrated switch)	View Design Kits & Evaluation Modules

To download the full TI Design Reference Design visit: **http://www.ti.com/tool/TIDC-WMBUS-169MHZ**

TI Designs

Texas Instruments

Implementing SimpleLink™ Wi-Fi® Connectivity in a Smart Electric Meter

Texas Instruments

Description

This design implements a three-phase energy meter with Wi-Fi connectivity. The e-meter SoC is used to perform all metrology functions and control the SimpleLink™ Wi-Fi transceiver. The smart meter data can then be displayed on any Wi-Fi connected device via a standard web browser.

TIDesigns

TI Designs

Features

- Three-phase e-meter implementation that calculates metrology parameters such as RMS current, RMS voltage, active and reactive power and energies, power factor and frequency
- Wi-Fi connectivity over IEEE 802.11 b/g/n networks from any smart phone, tablet or computer through a standard web browser
- 160-segment LCD display for Wi-Fi status and metrology parameter display
- Expandable to support other Internet applications
- PC-based GUI for calibration

TI devices

Order samples, get tools and find more information on the TI products in this reference design.

Part number	Name	Product family
CC3100	CC3100 SimpleLink™ Wi-Fi and Internet-of-Things solution for MCU applications	SimpleLink solutions
CC3100MOD	SimpleLink Wi-Fi CC3100 Internet-on-a-chip wireless network processor module	Wireless connectivity
MSP430F67791	MSP430F67791 mixed-signal microcontroller	Low power + performance

To download the full TI Design Reference Design visit: **http://www.ti.com/tool/TIDC-3PHMTR-WIFIXR**

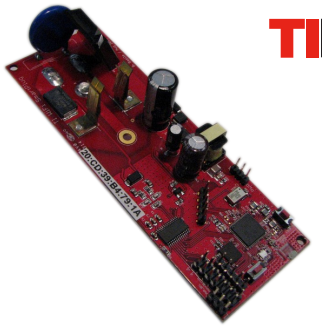
Texas Instruments

Smart Plug with Remote Disconnect and Wi-Fi® Connectivity

Texas Instruments

Description

This design implements single-outlet energy measurement with remote connect/disconnect capability and Wi-Fi® connectivity. Designers can quickly create networked load control devices for industrial building and home automation applications.



TIDesigns

Features

- SimpleLink™ Wi-Fi connectivity over IEEE-802.11 b/g/n networks from any smart phone, tablet or computer through a standard web browser
- Single-phase energy measurement that calculates RMS current, RMS voltage, active and reactive power and energies, power factor and frequency
- Solid-state relay provides remote connect/disconnect capability
- Compact physical design with minimal BOM components
- Low-power components plus efficient power supply provide low system power consumption
- The system design is tested and includes firmware for energy measurement, Wi-Fi connectivity and relay control along with Android™-based demo application and user's guide

TI Designs

TI devices

Order samples, get tools and find more information on the TI products in this reference design.

Part number	Name	Product family	Design kits and Evaluation modules
CC3200	CC3200 SimpleLink™ Wi-Fi® and Internet-of-Things solution, a single-chip wireless MCU	Wireless MCUs	View Design Kits & Evaluation Modules
CC3200MOD	SimpleLink Wi-Fi CC3200 Internet-on-a-chip wireless MCU module	Wireless connectivity	View Design Kits & Evaluation Modules
MSP430I2040	16-bit mixed-signal microcontroller	Ultra-low power	View Design Kits & Evaluation Modules
UCC28910	700-V flyback switcher with constant-voltage constant-current and primary-side control	AC/DC and isolated DC/DC power supply	View Design Kits & Evaluation Modules
UCC28911	700-V flyback switcher with constant-boltage constant-current and primary-side regulation	AC/DC and isolated DC/DC power supply	View Design Kits & Evaluation Modules

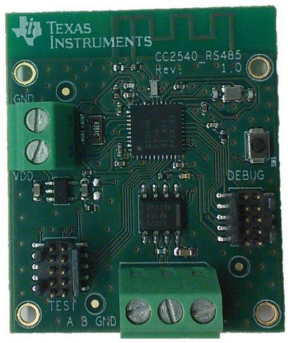
To download the full TI Design Reference Design visit: **http://www.ti.com/tool/TIDC-SMARTPLUG-WIFI**

Texas Instruments

Bluetooth® Low Energy (Bluetooth Smart) to RS-485 Gateway

Description

Modbus is an application protocol for serial data transmission that often uses RS-485 for serial data transfer. This reference design implements a gateway between Modbus and the ***Bluetooth*® Smart CC2540 wireless MCU**. It serves as a replacement for wires in an RS-485 network, and it allows another Bluetooth Smart-compatible device like a computer or smartphone to easily connect to an existing RS-485 network.



TIDesigns

Features

- Implements wireless connection to industrial electronic devices with the CC2540T Bluetooth Smart Gateway solution graded up to 125°C
- Simple and "ready-to-go" design shortens time to market
- Android™ app (ModbusController) provided to enable control and communication with Modbus peripheral software
- This design is tested and includes firmware, GUI, demo and user guide

TI Designs

TI devices

Order samples, get tools and find more information on the TI products in this reference design.

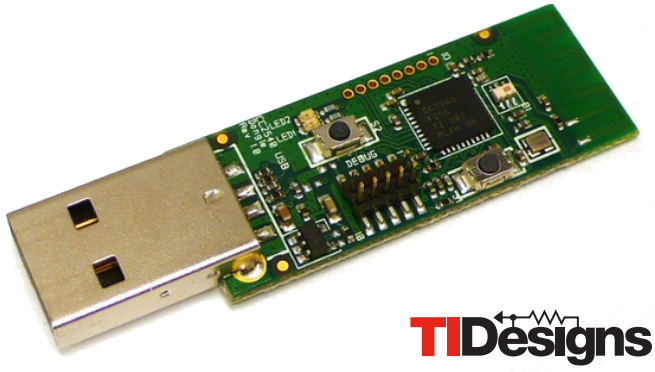
Part number	Name	Product family
CC2540T	SimpleLink high-temperature *Bluetooth*® Smart wireless MCU	Wireless connectivity
SN65HVD485E	Half-duplex RS-485 transceiver	Interface
TPS769	10-V, 100-mA, low Iq, low-dropout linear regulator	Linear regulator (LDO)

To download the full TI Design Reference Design visit:
http://www.ti.com/tool/TIDC-BLUETOOTH-SMART-TO-RS-485-GATEWAY

CC2540 Bluetooth® Low Energy USB Dongle Reference Design

Description

The CC2540 USB Dongle is a complete example of how to use the USB-enabled *Bluetooth*® Low Energy (BLE) Wireless MCU. The reference design can be used to enable Bluetooth Smart and Internet of Things applications on any system that contains a USB host.



Features

- Simple BLE-to-USB connection – Adds BLE to an existing product with USB
- Debug header, LEDs and buttons included – Enables faster development
- It can also be used as a packet sniffer for analyzing the BLE protocol and for software and system-level debugging (use the free tool SmartRF Packet Sniffer)

TI devices

Order samples, get tools and find more information on the TI products in this reference design.

Part number	Name	Product family
CC2540	SimpleLink *Bluetooth*® Smart wireless MCU with USB	Wireless connectivity
TPS769	10-V, 100-mA, low Iq, low-dropout linear regulator	Linear regulator (LDO)

To download the full TI Design Reference Design visit: **http://www.ti.com/tool/TIDC-CC2540-BLE-USB**

TI Designs

Gas Sensor Platform with *Bluetooth*® Low Energy

Texas Instruments

Description

This reference design is a low-power wireless gas sensor solution that supports a wide array of electrochemical gas sensors. With the versatility of a configurable interface for either *Bluetooth*® Low Energy, ZigBee® RF4CE, 6LoWPAN or ANT this flexible and certified sensor solution is ideal for various building safety, industrial process control, mining and health care applications.

TIDesigns

Features

- Monitors wide range of gases
  - Carbon monoxide, oxygen, ammonia, fluorine, chlorine dioxide … and more
  - Supports 2- and 3-lead electrochemical gas sensors
- Complies with FCC and IC regulatory standards
- Coin-cell battery operation
- Easily monitor gas concentrations via TI's gas sensor iOS mobile app

TI devices

Order samples, get tools and find more information on the TI products in this reference design.

Part number	Name	Product family
CC2541	SimpleLink™ *Bluetooth*® Smart and proprietary wireless MCU	Wireless connectivity
LM4120	Precision micropower low dropout voltage reference	Voltage reference
LMP91000	Configurable AFE potentiostat for low-power chemical-sensing applications	Sensor products
TPS61220	Low input voltage, 0.7-V boost converter with 5.5-µA quiescent current	Converter (integrated switch)

To download the full TI Design Reference Design visit: **http://www.ti.com/tool/TIDA-00056**

Smart Home and Energy Gateway Reference Design

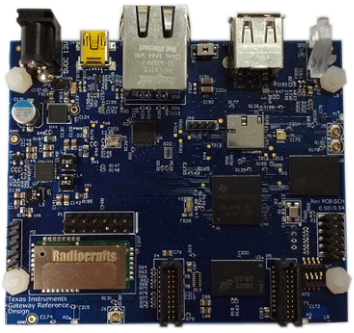
Texas Instruments

Description

The Smart Home and Energy Gateway Reference Design provides example implementation for measurement, management and communication of energy systems for smart homes and buildings. This example design is a bridge between different communication interfaces, such as Wi-Fi®, Ethernet, ZigBee® or *Bluetooth*®, that are commonly found in residential and commercial buildings. Since objects in the house and buildings are becoming more and more connected, the gateway design needs to be flexible to accommodate different RF standards, since no single RF standard is dominating the market. This example gateway addresses this problem by supporting existing legacy RF standards (Wi-Fi, Bluetooth) and newer RF standards (ZigBee, BLE).

Features

- Showcase co-existence of ZigBee, Wi-Fi, Bluetooth and NFC (Near Field Communication) allows for simultaneous operation of the different communication profiles



TIDesigns

- Showcase seamless profile integration for smart energy, lighting and building automation
- Showcase bridge between HAN (Home Area Network) and LAN (Local Area Network)/WAN (Wide Area Network)
- Enables development of real-world smart home and energy gateway applications, with the use of example schematics, bill of materials, design files and links to free software package downloads

(continued)

TI devices

Order samples, get tools and find more information on the TI products in this reference design.

Part number	Name	Product family	Design kits and Evaluation modules
AM3352	Sitara™ processor	ARM® Cortex®-A8 core	View Design Kits & Evaluation Modules
CC2530	Second-generation System-on-Chip solution for 2.4-GHz IEEE 802.15.4 / RF4CE / ZigBee	SimpleLink™ solutions	View Design Kits & Evaluation Modules
WL1835MOD	WiLink™ 8 single-band combo 2×2 MIMO Wi-Fi, Bluetooth and Bluetooth Low Energy module	Wireless Connectivity	View Design Kits & Evaluation Modules
DP83848J	PHYTER mini LS commercial temperature single-port 10/100 Mb/s Ethernet transceiver	Ethernet	View Design Kits & Evaluation Modules
SN74AVC4T774	4-bit dual-supply bus transceiver with configurable voltage translation and 3-state outputs	Voltage level translation	
SN74LVC04	Hex inverter	Buffer/Driver/Transceiver	
SN74LVC07A	Hex buffer/driver with open-drain outputs	Buffer/Driver/Transceiver	
TLV702	300-mA, low IQ, low-dropout regulator for portables	Linear regulator (LDO)	View Design Kits & Evaluation Modules
TLVH431	Low-voltage adjustable precision shunt regulator	Voltage reference	
TPD4S012	4-channel USB ESD solution with power clamp	ESD protection diodes	View Design Kits & Evaluation Modules
TPS2051B	Single, current-limited, power-distribution switch	USB power and charging port controllers	View Design Kits & Evaluation Modules
TPS51200	3-A sink/source DDR termination regulator w/ VTTREF buffered reference for DDR2, DDR3, DDR3L and DDR4	Power management	View Design Kits & Evaluation Modules
TPS650250	Power management IC (PMIC) for Li-ion powered systems	Power management	View Design Kits & Evaluation Modules

To download the full TI Design Reference Design visit: **http://www.ti.com/tool/TIEP-SMART-ENERGY-GATEWAY**

Texas Instruments

Return to ToC

Wireless connectivity product overviews

Texas Instruments

SimpleLink™ Ultra-Low Power Wireless Microcontroller Platform

The industry's **only multi-standard family** with code- and pin-compatibility across:

- *Bluetooth*® low energy (Bluetooth Smart)
- 6LoWPAN
- Sub-1 GHz
- ZigBee®
- RF4CE™ and
- Proprietary modes

Key benefits

- **The lowest power:**
  - Go battery-less with energy harvesting
  - Use a coin cell battery for multi-year, always-on operation
  - Integrated ultra-low power sensor controller
- **Industry's only multi-standard platform:**
  - Code- and pin-compatibility across Bluetooth Smart, 6LoWPAN, ZigBee, Sub-1 GHz and RF4CE
- **Easiest to design with:**
  - ARM® Cortex®-M3 based MCU
  - TI-RTOS
  - Simplest RF and antenna design
  - Built-in robust security
  - Ready-to-use protocol stacks
  - Tools and reference designs

Overview

The SimpleLink™ ultra-low power wireless microcontroller (MCU) platform is the broadest, lowest power and easiest to use wireless connectivity offering in the industry for Internet of Things (IoT) connected devices. With the capability to leverage multiple standards, customers have flexibility in design and TI makes it easy by providing tools and software, reference designs, community support and more.

What standard fits your design?

- **Bluetooth Smart:** Control ultra-low power wireless solutions with a smartphone or tablet
- **6LoWPAN:** Complete solution to the cloud in a wide-area mesh network using open IP standards
- **Sub-1 GHz:** Provides long range and reliable communication at ultra-low power
- **ZigBee:** Standardized stacks, protocols and application profiles for robust, low-power mesh networks
- **RF4CE:** Two-way communication standard designed for ultra-low power input devices such as remote controls

Available products

- **SimpleLink 2.4-GHz multi-standard CC2650 wireless MCU:** The CC2650 supports multiple 2.4 GHz standards allowing customers to leverage code compatibility across 2.4 GHz standards by downloading the corresponding protocol stack.
- **SimpleLink Bluetooth Smart CC2640 wireless MCU:** The CC2640 is the lowest power Flash-based Bluetooth 4.1 solution with multi-year operation on smaller coin cells.
- **SimpleLink 6LoWPAN/ZigBee CC2630 wireless MCU:** The CC2630 supports large networks connecting 1,000s of nodes in homes, buildings and cities. Take advantage of easy IP and cloud connectivity through 6LowPAN operation where each device has an IPv6 address.
- TI is also launching the **SimpleLink Sub-1 GHz CC1310 wireless MCU** and the **SimpleLink ZigBee RF4CE CC2620 wireless MCU** in 2015.

Getting started

To simplify development, TI provides a broad range of tools and software that offer flexibility between technologies. All kits for 2.4-GHz operation are based on the multi-standard CC2650 wireless MCU. The CC2650DK includes two SmartRF06 evaluation boards, two CC2650 evaluation modules and can be customized with the appropriate software stacks for Bluetooth Smart, 6LoWPAN or ZigBee operation. The CC2650STK SimpleLink SensorTag is a rapid prototyping and development tool designed to shorten the design time for CC26xx development from months to hours.

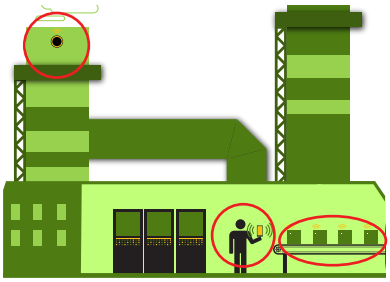
Application areas

The SimpleLink ultra-low power wireless MCU platform is designed for use in multiple applications including:

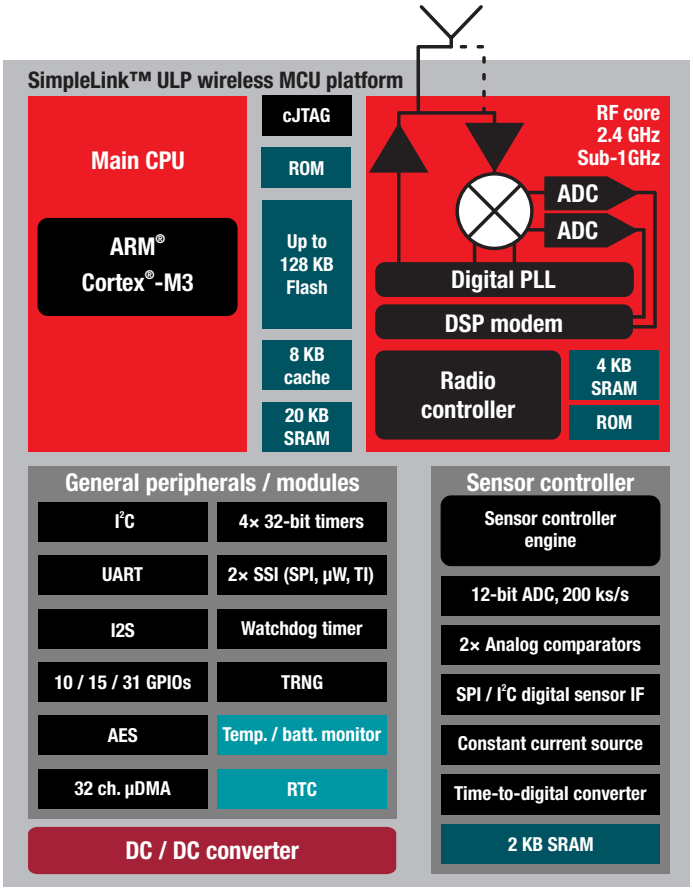
Health and Fitness

Home and Building Automation

Industrial



Block diagram



Hardware

CC2650DK $299	CC2650EMK $99	CC2650STK $29
Complete 2.4-GHz hardware, software and RF development platform for Bluetooth Smart, ZigBee and 6LoWPAN	Two optimized plug-in boards to easily test RF performance with more nodes in a CC2650DK network The EMK comes in 4×4-mm, 5×5-mm and 7×7-mm options	**Low-power development kit for IoT applications** Start sensor development in the cloud in three minutes. Expandable with debugger and DevPacks to customized your IoT application. Powered by the CC2650 wireless MCU and 10 low-power sensors

Software

SmartRF Studio 7	Sensor Controller Studio	SmartRF Flash Programmer 2	CCS Uniflash
PC application that helps designers of radio systems easily evaluate the RF-IC at an early stage in the design process	Development environment to implement sensor controller task algorithms and rapid development	PC application for programming CC26xx devices	Flash programmer with Windows® and Linux™ support

For more information on the SimpleLink ultra-low power wireless MCU platform, please visit **www.ti.com/simplelinkulp**

Texas Instruments

SimpleLink™ Wi-Fi® Family

CC3100 / CC3200 Internet-on-a-chip™ Solutions

TEXAS INSTRUMENTS

Save time and resources developing with CC3100 and CC3200 Wi-Fi® CERTIFIED™ chips and modules

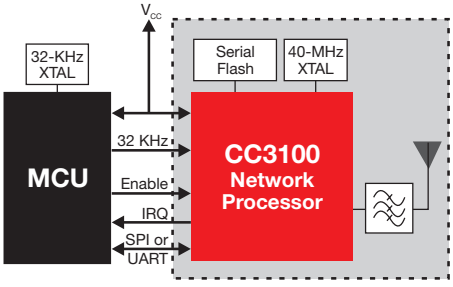
Overview

TI makes connectivity even easier with the next-generation SimpleLink Wi-Fi solutions. The product family features Internet-on-a-chip™, Wi-Fi CERTIFIED™ solutions solving industry challenges for broad embedded applications. With SimpleLink CC3100 and CC3200 pin-to-pin-compatible solutions you can:

- Program applications on the industry's first Internet-on-a-chip solution with user-dedicated MCU
- Power Wi-Fi battery-operated designs for more than a year on two AA batteries
- Start quickly, no Wi-Fi experience needed

CC3100 Wireless Network Processor

The CC3100 device is a Wi-Fi, self-contained network processor with on-chip web server and embedded TCP/IP stack that connects

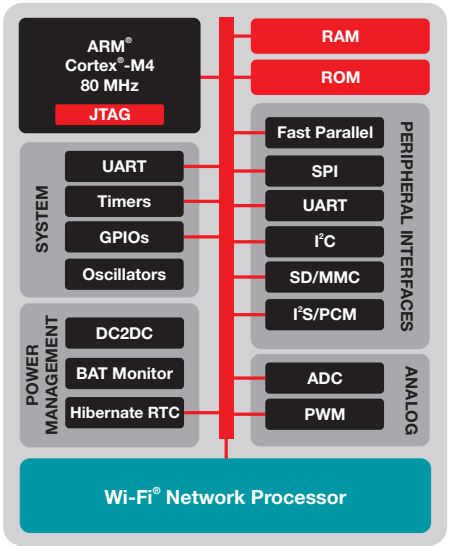


easily to any low-cost and low-power microcontroller (MCU) such as the MSP430F5529 or MSP430FR5969, due to a simple UART or SPI driver and host memory footprint as low as 7kB of code to reside on the MCU. Hardware design flexibility includes a 64-pin 9×9 mm QFN package or upcoming certified CC3100 module. Flexible connection methods (provisioning) include Access Point Mode, WPS, SmartConfig™ Technology and others. On the security side, an embedded hardware cryptography engine allows establishing TLS secure Link in 200 ms.

Interfacing to any MCU, designed with low-power radio and advanced low-power modes, the SimpleLink Wi-Fi family makes sensor-to-the-cloud connectivity possible. Moreover, the solution contains several Internet protocols in ROM including mDNS, DNS, SSL/TLS and HTTP server.

CC3200 Wireless MCU

The SimpleLink Wi-Fi CC3200 solution capitalizes on the CC3100 benefits and integrates an 80-MHz ARM® Cortex®-M4 MCU and peripherals enabling application development with a Wi-Fi CERTIFIED device or module. Developers can fully access the MCU portion with more than 200kB of application code fully independent from the Wi-Fi processing. The peripheral set includes parallel camera,



I²S audio, SDMMC, ADC, SPI, UART, I²C, PWM, I/Os, built-in power management and RTC enabling connection to the cloud.

CC3200 certified modules, coming soon, provide easier Wi-Fi integration by lowering manufacturing costs, reducing development time and simplifying procurement and certification. The modules have complete antenna reference designs for streamlined integration.

Software and Support

Both CC3100 and CC3200 solutions are supported by a software development kit (SDK) including software drivers, sample applications, API guide, user documentation and a world-class support E2E™ community. On the integrated Cortex-M4, all sample applications in the SDK are supported with Code Composer Studio™ Integrated Development Environment and no RTOS. A few of the applications support IAR, GCC, Free RTOS, TI-RTOS.
Example applications:

- Internet-on-a-chip sample applications
  - Email from SimpleLink Wi-Fi solution
  - Information Center – get time and weather from Internet
  - http server – host a web page on SimpleLink Wi-Fi solution
  - XMPP – Instant Message chat client
  - Serial interface
- Wi-Fi sample apps
  - Easy Wi-Fi configuration
  - Station, AP modes
  - TCP/UDP
  - Security – Enterprise/Personal, TLS/SSL
- MCU peripheral samples apps

Getting started: SimpleLink™ CC3100 and CC3200 hardware development kits

	Kit name	Description	When to buy this?
SimpleLink Wi-Fi C3200 Internet-on-a-chip wireless microcontroller (MCU)			
	**CC3200-LAUNCHXL** $29.99 USD	• CC3200 Launchpad • Single-chip Internet of Things solution with integrated MCU	Want to use Wi-Fi® wireless MCU – single-chip Internet-on-a-chip™
SimpleLink Wi-Fi CC3100 Internet-on-a-chip wireless network processor			
	**CC3100BOOST-CC31XXEMUBOOST-EXP430F5529LP** $49.99 USD	• CC3100 BoosterPack + Advanced emulation board + MSP430F5529 Launchpad	Want to evaluate all CC3100 sample apps, using TI's ultra-low-power MSP430™ MCU family
	**CC3100BOOST-CC31XXEMUBOOST** $36.99 USD	• CC3100 BoosterPack + flashing and advanced debug capability • Compatible LaunchPads (sold separately)	Want to use CC3100 with any other MCU. Need one EMUBOOST board for flashing, using radio tool, using SimpleLink Studio (MCU development on PC) or advanced debug
	**CC3100BOOST** $19.99 USD	• CC3100 BoosterPack	If buying additional CC3100BOOST boards – assuming you already have CC31XXEMUBOOST for flashing, radio tool and possible advanced debug
	**CC3100BOOST-MSP-EXP430FR5969** $34.00 USD	• CC3100 BoosterPack + MSP430FR5969 LaunchPad	Want to evaluate CC3100 with TI's low power FRAM device MSP430FR5969

Growing cloud of ecosystem partners

The TI IoT cloud ecosystem helps manufacturers using TI technology to easily and rapidly connect more to the IoT. Open to cloud service providers with a differentiated service offering and value-added services running on one of TI's IoT solutions, the TI cloud ecosystem provides options to meet individual manufacturer needs. **www.ti.com/simplelinkwificloud**

2lemetry™ ARRAYENT EXOSITE IBM® xively™ by LogMeIn

TI Design Library: Wi-Fi and IoT development with SimpleLink Wi-Fi reference designs

TIDesigns

Jump start system design and speed time to market with our comprehensive Wi-Fi reference designs. Each design includes schematic or block diagram, BOM and design files. Created by experts with deep system and product knowledge, the designs span across TI's portfolio of analog, embedded processor and connectivity products.

- **SimpleLink Wi-Fi Antenna Selection** enables evaluation and development of end applications requiring antenna diversity
- **Smart Plug with Remote Disconnect and Wi-Fi Connectivity** quickly creates networked load control devices for industrial building and home automation applications
- **Wi-Fi Audio Streaming Application** enables the capture, streaming and playback of audio from a digital microphone or a stereo/mono audio jack to another Wi-Fi-enabled device
- **SimpleLink Wi-Fi Connectivity in a Smart Electric Meter** implements a three-phase energy meter with Wi-Fi connectivity

Texas Instruments

WiLink™ 8 Wi-Fi®+ *Bluetooth*®/BLE Modules

Certified high-performance combo modules from TI for fast and easy time-to-market

TEXAS INSTRUMENTS

Key Features and Benefits

- High-performance Wi-Fi
  - 802.11 a/b/g/n 2.4- and 5-GHz Radio/Baseband/MAC
  - 20- and 40-MHz channels
  - 2×2 MIMO
  - Up to 100 Mbps (UDP) of throughput
  - MRC for 1.4× extended range
  - Station and access point
  - Wi-Fi direct, multi-channel multi-role
  - Personal and enterprise security
  - Linux™, Android™ and RTOS drivers
- Dual-mode *Bluetooth*
  - *Bluetooth* and BLE (BT 4.0 compliant)
  - On-chip SBC encode and decode
  - Royalty-free certified TI *Bluetooth* Stack™ based on Bluetopia®
- Wi-Fi/*Bluetooth* single antenna co-existence
- Built-in power management
- Direct connection to battery (integrated DC2DC)
- Advanced low-power modes
- Host interfaces
  - SDIO for Wi-Fi and UART for BT
- Temperature ranges:
  - 20°C to +70°C
  - –40°C to +85°C
- Small form factor: 13.4 × 13.3 × 2 mm

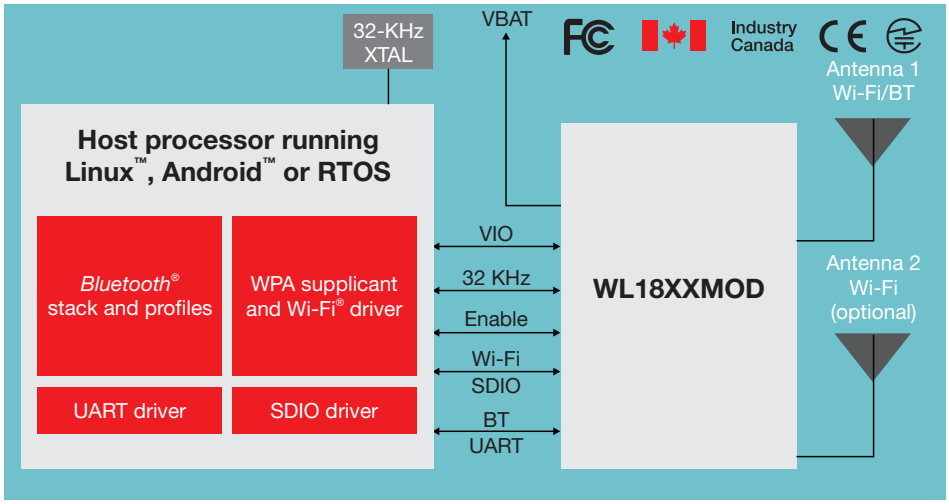
Overview

The TI WiLink 8 module family enables manufacturers to easily add fully integrated 2.4- and 5-GHz versions of Wi-Fi and dual-mode *Bluetooth* 4.0 solutions to embedded applications. The new highly integrated module family offers high throughput and extended industrial temperature range with robust Wi-Fi and *Bluetooth* coexistence. WiLink 8 modules are perfect for power-optimized designs for home and building automation, smart energy, gateways, wireless audio, enterprise, wearables and many more industrial and Internet of Things (IoT) applications. The WiLink 8 modules and software are compatible and pre-integrated with many processors including TI's Sitara™ processors. As a module, less hardware and RF design is needed, making development easier and faster. Wi-Fi and *Bluetooth* software stacks and sample applications are provided, and the modules are FCC/IC/ETSI/Telec certified. WiLink 8 solutions also provide sample applications, API guide, user documentation and a world-class support community.

The modules are pin-to-pin compatible enabling new use cases and better user experiences including:

- Extended temperature range of –40°C to 85°C for industrial applications

WiLink 8 block diagram



- 5-GHz module for high-performance solutions in a less noisy frequency band
- Wi-Fi, *Bluetooth* and **ZigBee®** coexistence for **Smart energy and home gateways**
- 1.4× the range and up to 100 Mbps throughput with WiLink 8 MRC

(maximal ratio combining) and MIMO (multiple-input and multiple-output) technology

- Low-power applications with low idle connect current consumption
- **Audio streaming** with both Wi-Fi and dual-mode *Bluetooth*/Bluetooth low energy

Applications

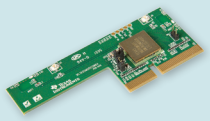
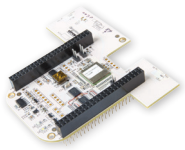
- Internet of Things
- Industrial and home automation
- Home electronics
- Home appliances and white goods
- Gateways
- Wireless audio
- Video camera and security
- Wearables

WiLink™ 8 Wi-Fi®+ *Bluetooth*®/BLE Modules

TI Modules

Product Number	Wi-Fi®			*Bluetooth* v4.0 Bluetooth low energy	Industrial temperature
	2.4 GHz	5 GHz	MIMO		
WL1801MOD	•				
WL1805MOD	•		•		
WL1807MOD	•	•	•		•
WL1831MOD	•			•	
WL1835MOD	•		•	•	
WL1837MOD	•	•	•	•	•

Development Tools

Product Number	Description	Availability
WL1835MODCOM8 	The 2.4-GHz WL1835-based evaluation board is compatible with the Sitara™ AM335x and AM437x EVMs as well as several other TI EVMs and reference designs	TI eStore and authorized distributors
WL1835MOD Cape 	WiLink 8 module-based cape offered by CircuitCo for fast development with BeagleBone Black and BeagleBone open source computer	BoardZoo.com and CircuitCo distributors
WL1837MODCOM8 	The 5-GHz WL1837-based evaluation board is compatible with Sitara AM335x and AM437xEVMs as well as several other TI EVMs and reference designs	TI eStore and authorized distributors

Other tools

- TI provides a fully integrated and validated WiLink 8 add-on software for Sitara AM335x Linux™ ezSDK – **www.ti.com/wilink8**
- TI's unique SmartConfig™ technology is a one-step Wi-Fi setup process that allows multiple in-home devices to connect to Wi-Fi networks quickly and efficiently – **www.ti.com/tool/smartconfig**

WiLink resources

- Learn more: **www.ti.com/wilink8**
- E2E Forum: **www.ti.com/wiconforum**
- WiLink 8 Wiki: **www.ti.com/wilink8wiki**

TI *Bluetooth*® CC256x Solutions

Dual-mode *Bluetooth* 4.1 controller available in certified modules with integrated audio capabilities

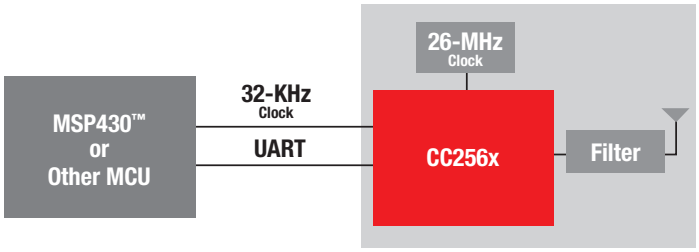
Texas Instruments

Overview

TI single- and dual-mode CC256x solutions are complete *Bluetooth*® BR/EDR/LE HCI or *Bluetooth* + *Bluetooth* Low Energy solutions that reduce design effort and enable fast time to market.

A royalty-free software *Bluetooth* stack available from TI is pre-integrated with TI's MSP430™ and ARM® Cortex®-M4 MCUs. The stack is also available for MFi solutions and on other MCUs. Examples of profiles supported today include: serial port profile (SPP), human interface device (HID), A2DP (Advanced Audio Distribution Profile), AVRCP (Audio/Video Remote Control Profile) and several BLE profiles (profiles can vary based on the supported MCU).

In addition to software, reference designs are available with a low BOM cost. For example, TI's Audio Sink solution uses the *Bluetooth*® device for audio processing, an MSP430™, audio DAC and USB charger. TI's Audio Source solution is also available. For more information, visit **TI Designs**.



▲ *CC256x block diagram*

Key Features

- Single-chip *Bluetooth* solution integrating *Bluetooth* Basic Rate (BR)/Enhanced Data Rate (EDR)/ Low Energy (LE) features fully compliant with the *Bluetooth* 4.1 specification up to the HCI layer
- BR/EDR features include:
  - CC2560 provides an assisted mode for HFP1.6 wideband speech (WBS) profile or A2DP profile to reduce host processing and power
- LE supports up to 10 CC2564 simultaneous connections
- Flexibility for easy stack integration and validation into various microcontrollers, such as MSP430 and ARM Cortex-M4 MCUs
- Highly optimized for low-cost designs:
  - Package footprint: 76 pins, 0.6-mm pitch, 8.10-mm × 8.10-mm mrQFN
- Best-in-class *Bluetooth* (RF) performance (TX power, RX sensitivity, blocking)
  - Class 1.5 TX power up to +12 dBm
  - Provides longer range, including 2× range over ther *Bluetooth* low energy-only solutions
- Advanced power management for extended battery life and ease of design
- Physical interfaces:
  - Standard HCI over H4 UART (4 wire)
  - Standard HCI over H5 UART (2 wire)
  - Fully programmable digital PCM-I²S codec interface

Benefits

- Best-in-class link budget extends application range
- Simplified hardware and software development
- Reduced development time and costs
- Enables simultaneous operations of *Bluetooth* with *Bluetooth* low energy

www.ti.com/bluetooth

CC256x Products

Devices/ Modules	Description	Technology supported			Assisted modes	
		BR/EDR	LE	Ant™	HFP 1.6 (WBS)	A2DP
CC2560	*Bluetooth*® 4.1 (with EDR)	•			•	•
CC2564*	*Bluetooth* 4.1 + BLE	•	•		•	•
	Bluetooth 4.1 + ANT	•		•	•	•

** The device does not support simultaneous operation of LE, ANT or assisted modes. Any of these modes can run simultaneous to Bluetooth BR/EDR.*

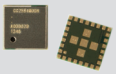
Applications

- Cable replacement
- Smart watches, activity trackers
- Mobile device accessories
- Industrial control
- Audio streaming solutions
- Point of sale

Bluetooth® CC256x Resources

- Learn more at: **www.ti.com/bluetooth**
- E2E™ Forum: **www.ti.com/wiconforum**
- CC256x Wiki: **www.ti.com/cc2564wiki**

Development Tools and Software

Product Number	Description	Availability
CC256x modules from TI 	TI-certified modules based on the CC2564 devices	Available through TI and TI authorized distributors
CC2564MODEM 	CC2564 Module Evaluation board Intended for evaluation purposes of the CC2564 module. Works with processor platforms such as TI's ultra-low-power MSP430 and the performance TM4C ARM® Cortex®-MF microcontrollers.	TI Store and authorized distributors
***Bluetooth* and MSP430™ Audio Sink Reference Design** 	Enables *Bluetooth* audio (SBC encode/decode) with CC2560 and the ultra-low power MSP430F5229 and digital input speaker amplifier (TAS2505) and USB charge management device (BQ24055). Reference design is a cost-effective audio implementation, with full design files provided for application and end product development. Software supported includes TI *Bluetooth* stack (certified and royalty free) based on Bluetopia.	*Download at TI Designs* Boards are orderable through TI Store
***Bluetooth* and MSP430 Audio Source Reference Design** 	Enables *Bluetooth* audio (SBC encode/decode) with CC2560 and the ultra-low power MSP430F5229 and digital DAC plus USB charge management device (BQ24055). Reference design is a cost-effective audio implementation, with full design files provided for application and end product development. Software supported includes TI *Bluetooth* stack (certified and royalty free) based on Bluetopia.	*Download at TI Designs* Boards are orderable through TI Store
CC256x BoosterPack	*Bluetooth* BoosterPack evaluation kit has flexibility to work with ultra-low power microcontrollers such as the TI MSP430 and TM4C Series LaunchPad evaluation kits	Coming soon: Boards will be orderable through TI Store
CC256xQFNEM 	CC256x *Bluetooth*® / dual-mode QFN device evaluation module	TI Store and authorized distributors

SimpleLink™ CC2540T 2.4-GHz *Bluetooth*® Low Energy Wireless MCU

1 Device Overview

1.1 Features

- True Single-Chip BLE Solution: CC2540T Can Run Both Application and BLE Protocol Stack, Includes Peripherals to Interface with Wide Range of Sensors, and so forth.
- Operating Temperature up to 125°C
- 6-mm × 6-mm Package
- RF
  - *Bluetooth* Low Energy Technology Compatible
  - Excellent Link Budget (up to 97 dB), Enabling Long-Range Applications Without External Front End
  - Accurate Digital Received Signal-Strength Indicator (RSSI)
  - Suitable for Systems Targeting Compliance with Worldwide Radio Frequency Regulations: ETSI EN 300 328 and EN 300 440 Class 2 (Europe), FCC CFR47 Part 15 (US), and ARIB STD-T66 (Japan)
- Layout
  - Few External Components
  - Reference Design Provided
  - 6-mm × 6-mm QFN40 Package
- Low Power
  - Active Mode RX Down to 19.6 mA
  - Active Mode TX (–6 dBm): 24 mA
  - Power Mode 1 (3-µs Wake-Up): 235 µA
  - Power Mode 2 (Sleep Timer On): 0.9 µA
  - Power Mode 3 (External Interrupts): 0.4 µA
  - Wide Supply Voltage Range (2 V–3.6 V)
  - Full RAM and Register Retention in All Power Modes
- TPS62730 Compatible
  Low Power in Active Mode
  - RX Down to 15.8 mA (3-V Supply)
  - TX (–6 dBm): 18.6 mA (3-V Supply)
- Microcontroller
  - High-Performance and Low-Power 8051 Microcontroller Core
  - 256-KB In-System-Programmable Flash
  - 8-KB SRAM
- Peripherals
  - 12-Bit ADC with Eight Channels and Configurable Resolution
  - Integrated Ultralow-Power Comparator
  - General-Purpose Timers (One 16-Bit, Two 8-Bit)
  - 21 General-Purpose I/O (GPIO) Pins (19×4 mA, 2×20 mA)
  - 32-kHz Sleep Timer with Capture
  - Two Powerful USARTs with Support for Several Serial Protocols
  - Full-Speed USB Interface
  - IR Generation Circuitry
  - Powerful Five-Channel DMA
  - AES Security Coprocessor
  - Battery Monitor and Temperature Sensor
  - Each CC2540T Contains a Unique 48-Bit IEEE Address
- *Bluetooth* v4.0 Compliant Protocol Stack for Single-Mode BLE Solution
  - Complete Power-Optimized Stack, Including Controller and Host
    - GAP – Central, Peripheral, Observer, or Broadcaster (Including Combination Roles)
    - ATT / GATT – Client and Server
    - SMP – AES-128 Encryption and Decryption
    - L2CAP
  - Sample Applications and Profiles
    - Generic Applications for GAP Central and Peripheral Roles
    - Proximity, Accelerometer, Simple Keys, and Battery GATT Services
  - Multiple Configuration Options
    - Single-Chip Configuration, Allowing Application to Run on CC2540T
    - Network Processor Interface for Applications Running on an External Microcontroller
  - BTool – Windows PC Application for Evaluation, Development, and Test
- Development Tools
  - CC2540T Mini Development Kit
  - SmartRF™ Software
  - Supported by IAR Embedded Workbench™ Software for 8051

1.2 Applications

- 2.4-GHz *Bluetooth* Low Energy Systems
- Lighting
- Motor Monitoring
- Proximity Sensing
- Cable Replacement
- Power Tools
- Maintenance
- Wireless HMI and Remote Display
- USB Dongles
- Smart Phone Connectivity

1.3 Description

The CC2540T is a cost-effective, low-power, true wireless MCU for *Bluetooth* low energy applications. It enables robust BLE master or slave nodes to be built with very low total bill-of-material costs, and can operate up to 125°C. The CC2540T combines an excellent RF transceiver with an industry-standard enhanced 8051 MCU, in-system programmable flash memory, 8-KB RAM, and many other powerful supporting features and peripherals. The CC2540T is suitable for systems where very low power consumption is required. Very low-power sleep modes are available. Short transition times between operating modes further enable low power consumption.

Combined with the *Bluetooth* low energy protocol stack from Texas Instruments, the CC2540TF256 forms the market's most flexible and cost-effective single-mode *Bluetooth* low energy solution.

Table 1-1. Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE
CC2540TF256RHAR	RHA (40)	6.00 mm × 6.00 mm
CC2540TF256RHAT	RHA (40)	6.00 mm × 6.00 mm

(1) For more information, see Section 8, *Mechanical Packaging and Orderable Information*.

1.4 Functional Block Diagram

Figure 1-1 shows the functional block diagram of the device.

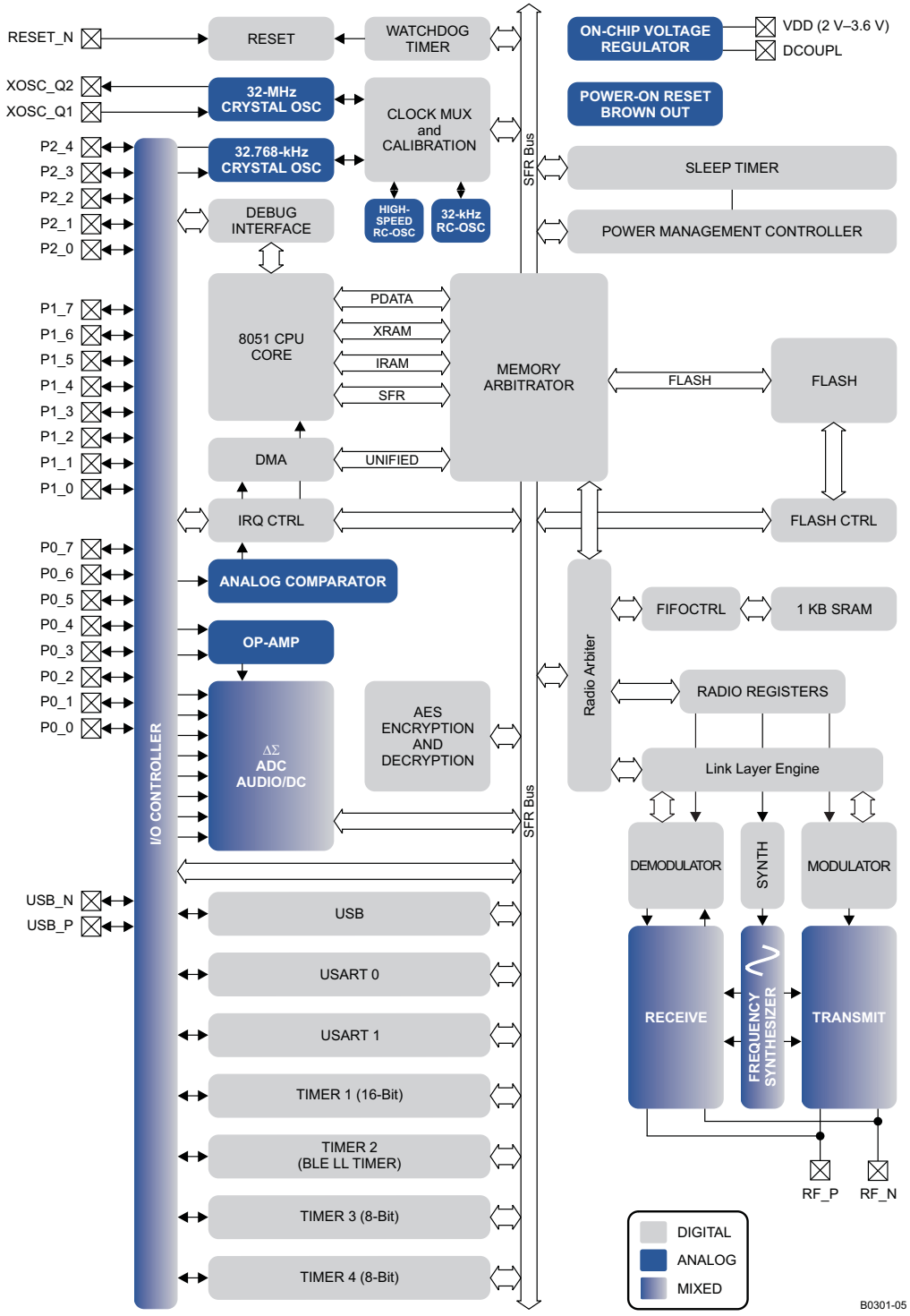


Figure 1-1. Functional Block Diagram

SWRY016

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as “components”) are sold subject to TI’s terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI’s terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers’ products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers’ products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI’s goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or “enhanced plastic” are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have ***not*** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

Products		**Applications**	
Audio	www.ti.com/audio	Automotive and Transportation	www.ti.com/automotive
Amplifiers	amplifier.ti.com	Communications and Telecom	www.ti.com/communications
Data Converters	dataconverter.ti.com	Computers and Peripherals	www.ti.com/computers
DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy
Clocks and Timers	www.ti.com/clocks	Industrial	www.ti.com/industrial
Interface	interface.ti.com	Medical	www.ti.com/medical
Logic	logic.ti.com	Security	www.ti.com/security
Power Mgmt	power.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Applications Processors	www.ti.com/omap	**TI E2E Community**	e2e.ti.com
Wireless Connectivity	www.ti.com/wirelessconnectivity		

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265