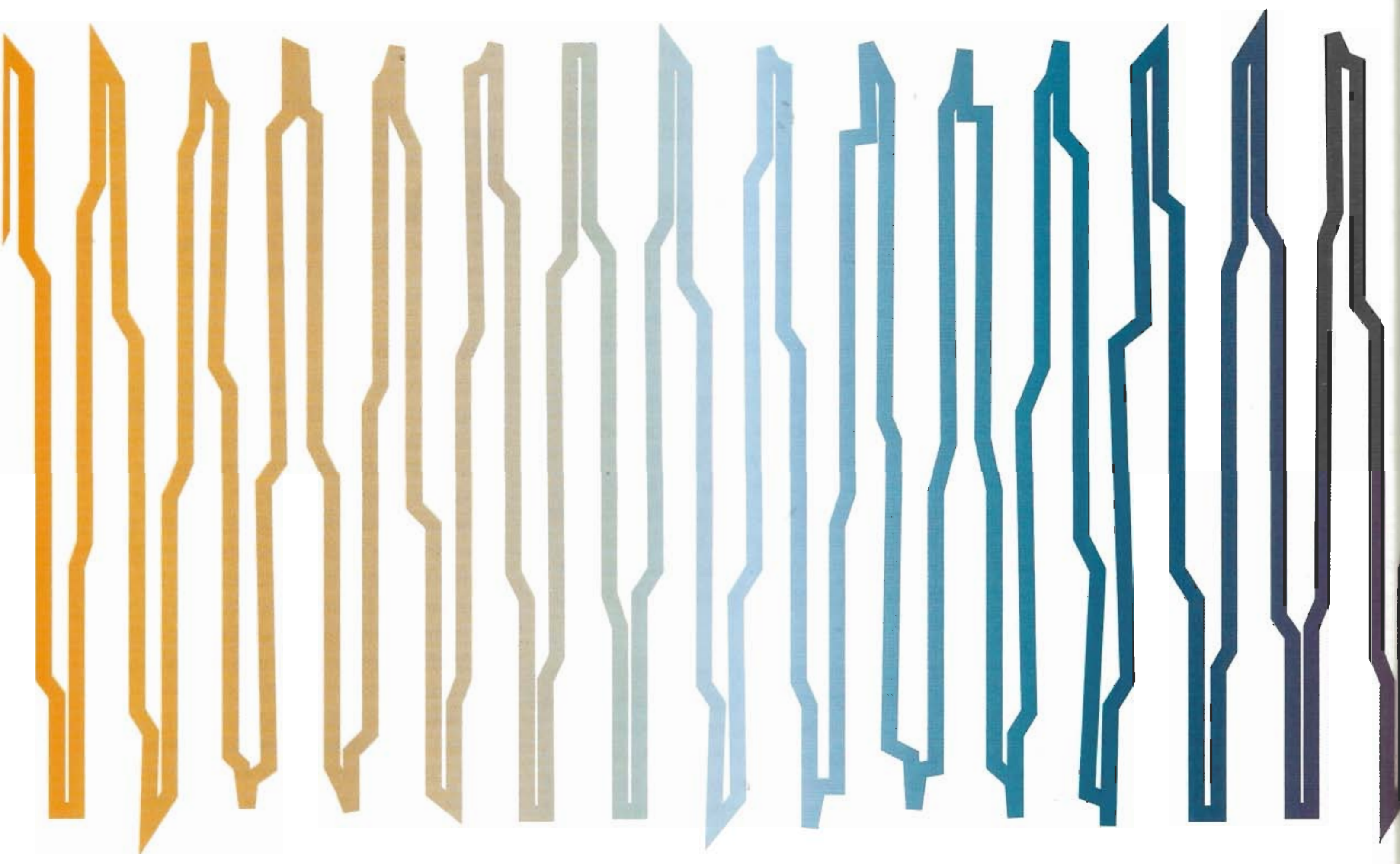

# Energy harvesting and Low Power RF radio technology

Source: Texas Instruments

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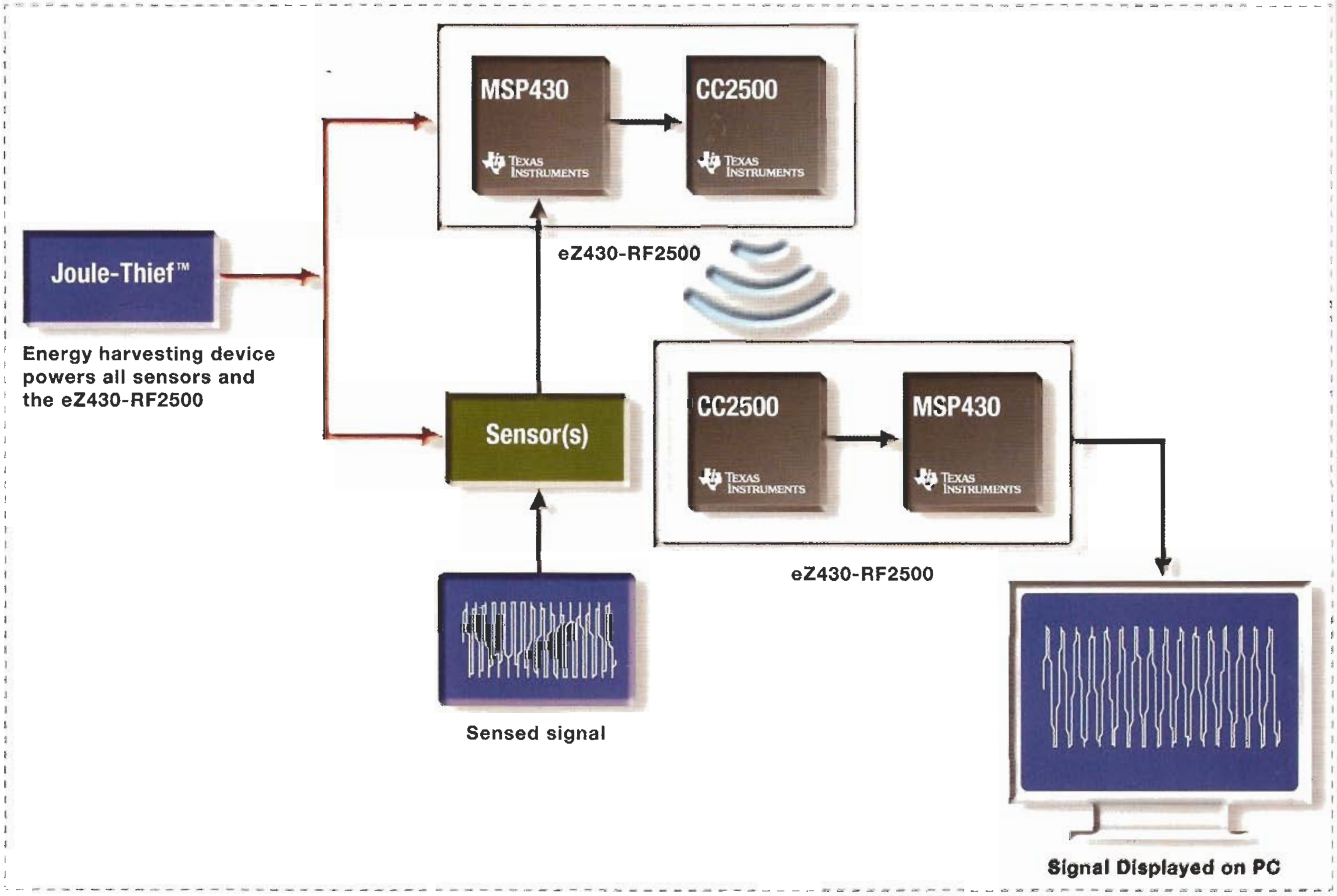
According to the Darnell Group, the potential worldwide market for energy harvesting solutions used in wireless sensor systems could reach approximately 164 million units by 2013, a compound annual growth rate of nearly 65 percent. Energy harvesting is an important emerging area of low power technology that can provide energy not only for large-scale needs through wind and solar systems, but also for smaller-scale needs such as sensor networks, utilizing the vibrations inherent in structures, vehicles and machinery to create power, or harvest energy, that can drive sensors while eliminating the need for wires and batteries.




Supplying power to a network of sensor-transmitters has traditionally required expensive wiring installation or routine battery changes. Gathering data from difficult or dangerous-to-reach locations using wired sensors may be impossible and/or even compromise the safety of personnel who install wiring and replace batteries. Energy harvesting is a solution that allows these sensor transmitters to operate for up to 20 years using a battery.

This article will review practical applications for this new technology and discuss the best way to incorporate low power RF radio technology to power wireless sensors in a simple point-to-point, star or device mesh network.

Numerous industrial and commercial markets - including building automation, transportation infrastructure and medical device alarm monitoring - have already developed energy harvesting products that are available today.

Building automation is a key application area. Commercial building occupancy sensors, thermostats and light switches can be installed with mechanical or solar energy harvesting devices that can eliminate the control wire from existing installations. A wireless network with energy harvesting technology can tie all the sensors together and reduce lighting and HVAC costs, by switching off power to non-essential functions when the building is not occupied.

Another industrial application is transportation infrastructure such as road, rail and bridge strain gauges. By pairing strain gauges with a wireless radio and relying on the continuous energy of surface vibration, wind, or solar energy to power the strain sensors, the sensors are able to transmit exception-based data when a key component of the infrastructure starts to deflect (hopefully) before it breaks.

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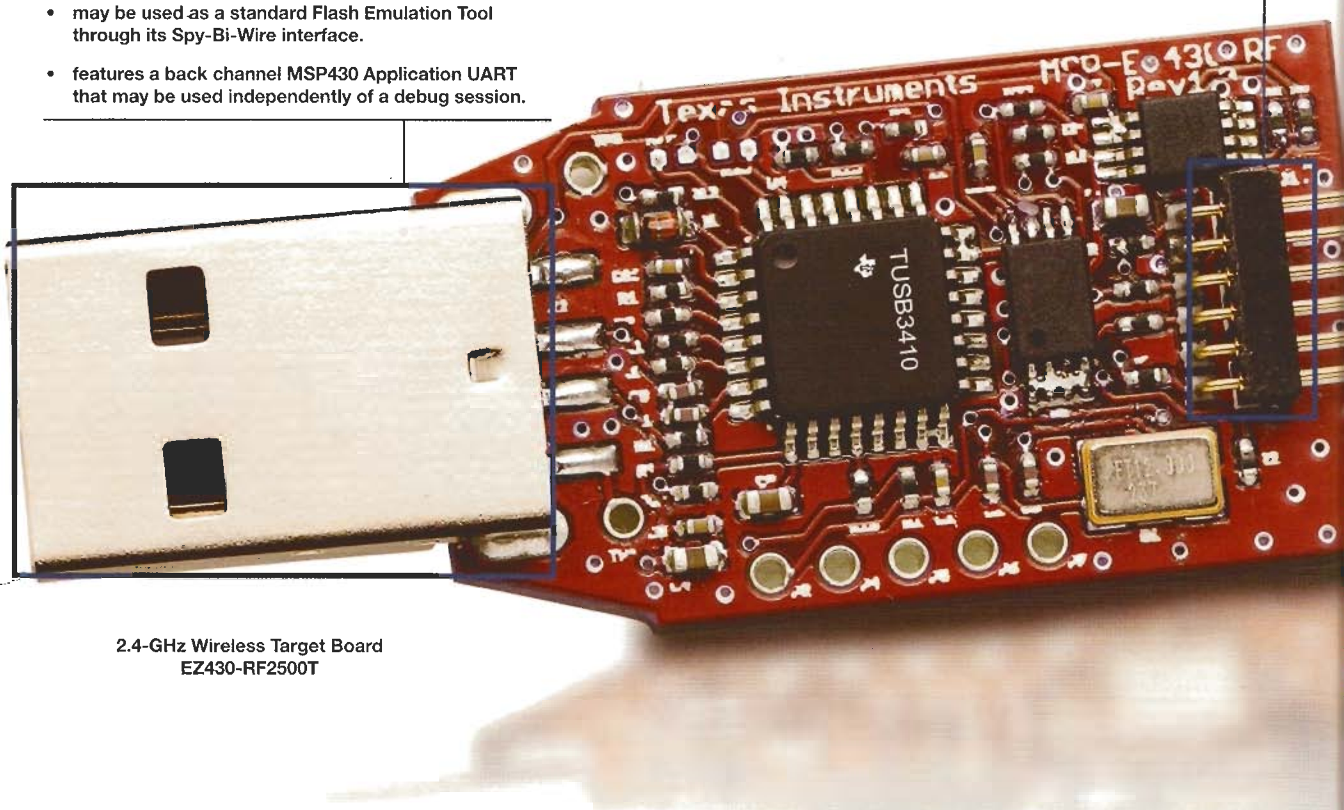
EZ430-RF USB debugging interface

- may be used as a standard Flash Emulation Tool through its Spy-Bi-Wire interface.
- features a back channel MSP430 Application UART that may be used independently of a debug session.

Spy Bi-Wire & MSP430 Application UART

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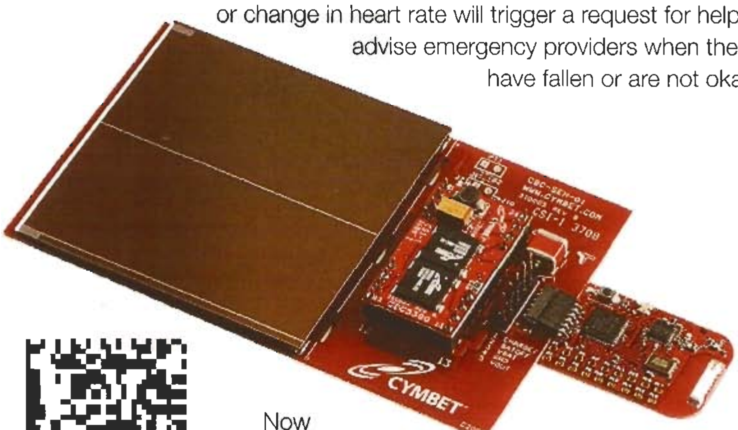
2.4-GHz Wireless Target Board EZ430-RF2500T

Energy harvesting is also being used in commercial applications. For example, medical devices designed for the elderly in-home or outpatient market are equipped with accelerometers and medical sensors running on heat or body movement energy harvesting technology. A sudden fall or change in heart rate will trigger a request for help to advise emergency providers when they have fallen or are not okay.




Solar Harvesting Kit EZ430-RF2500-SEH

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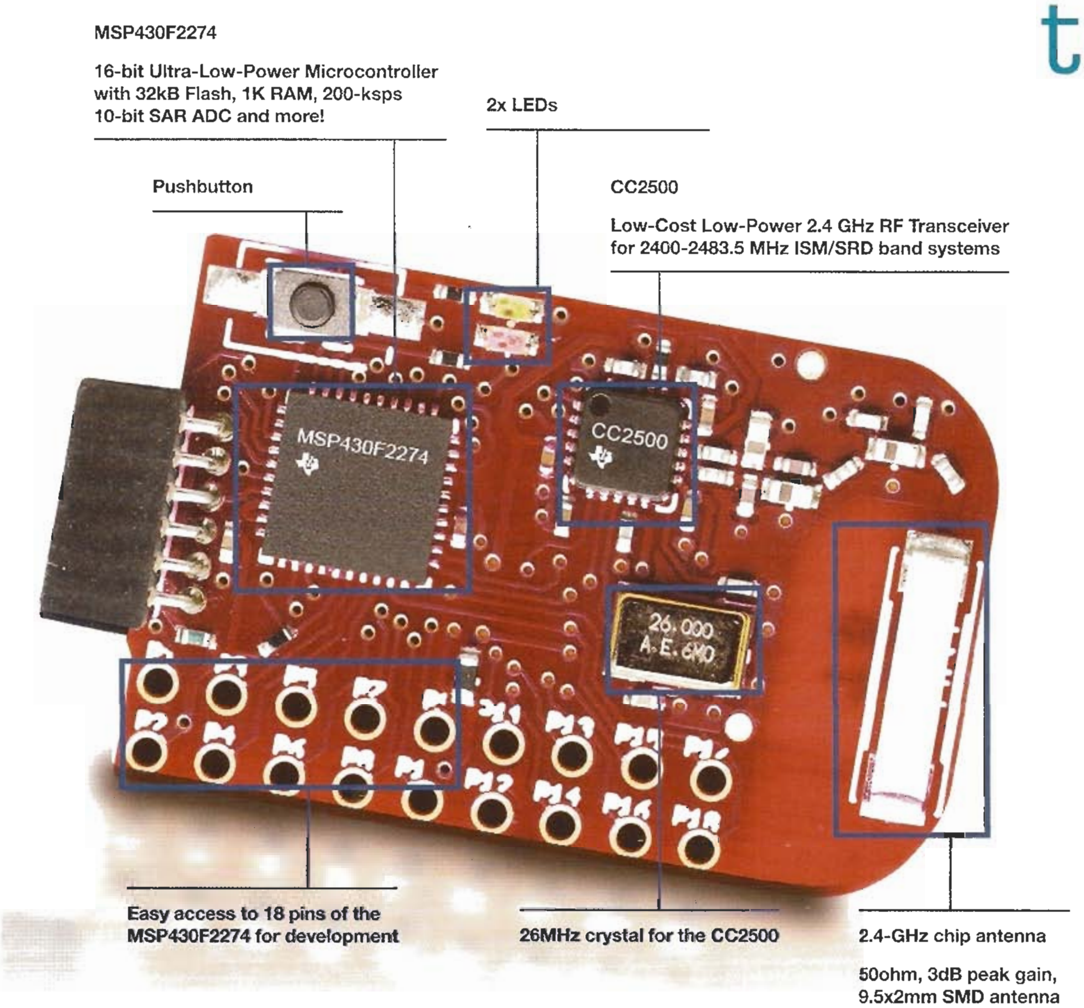
Now let's consider the best way to add energy scavenging technology with a radio and take advantage of existing features to develop product in which it's not necessary to keep changing batteries once the product is deployed. When discussing low power radios, we will focus on radios that have the following capabilities or features: they can go to sleep mode and be off 95% of the time; they can go from deep sleep to ready to transmit in 300ms or less; they consume less than 500$\mu$A of current in the transition phase and typically consume less than 16mA when transmitting and 20mA when receiving data.

The following best practices will accelerate the development process of products featuring energy harvesting and RF technology:

1. Use the lowest possible duty cycle. Send your data only when needed and do not send more data than necessary. A large amount of sensor activity is exception-based messages. Only send the message when the sensor value has gone out of limits set up for the application.

2. Minimize the receive window length of your radio in applications testing. This window length can be adjusted adaptively. The default is to use a narrow window and increase the window when packets are missed as a result of receive timeout.

3. Use the built-in receive signal strength indicator (rssi) feature of the radio to reduce the transmit power or receive sensitivity in your point-to-point product, so that the radio can dynamically adjust based upon the other devices operating in the vicinity of your radio. There is




no need to increase your transmit power and shout across the room when you can talk or whisper and get your message through the first time. The difference in transmit mode current can be as much as 10 ma between using output levels of-12dBm and 0dbm.

4. Use the lowest possible voltage setting. RF devices have reduced current draw at low voltages and use the on chip regulator with low quiescent current to maximize battery lifetime

5. When you do have data to send, use the FIFO buffer function of the RF-IC to store the data. Use the buffer read/write mode to minimize SPI operations. SPI communications consume power.

6. When you receive incoming messages, discard false packets that are not intended for your product that are possibly coming from another unwanted radio system. Minimize the time in RX processing false packets by checking the carrier sense, valid preamble, valid sync word, valid byte length and valid address feature options built into today's radio technology. Once you have done that, then and only then, wake up the MCU and use the automatic CRC check and discard the packet if the CRC fails. Interrupt the MCU if the CRC is okay.

7. Spend time selecting a crystal that takes into consideration clock drift between the two devices. Increased drift means increased time in the receiver to ensure packet reception. The receiver must be turned early, especially in polling mode architectures. The problem with turning on early means an increased probability of receiving false packets that require additional receiver time, where we are driving to maximum sleep time for battery life.

8. Spend time squeezing every possible electron from transition states of the radio. For example, spend time drilling into the state diagrams of the data sheet. Develop a power budget spreadsheet which includes the typical values for power down, crystal oscillator start up, PLL startup, full TX_RX time and power down for your application. For two way protocols, go as quickly as possible from transmit to receive mode or vice versa.

## A practical example

AdaptivEnergy has developed a demonstration kit using Joule-Thief technology to harvest energy and power and Texas Instruments' ultra-low power MSP430 MCU and CC2500 RF transceiver to collect data, control the operation of a system or send sensed data to central collection sites. The Joule-Thief energy harvesting device is based on AdaptivEnergy's Ruggedized Laminated Piezo technology, which enables compact energy harvesting modules to power applications, such as wireless sensors. These wireless sensors could be used to gather ambient intelligence to detect and report critical conditions in factories, automobiles, office buildings, homes and other environments - without wiring or batteries.

The RLP Smart Energy Beam allows up to ten times more strain to be applied to the piezoceramic than other piezoelectric energy harvesting devices, creating more converted electric power for system use. In addition to directly sensing movement, the design accepts inputs from external sensing elements that can help detect strains in bridges and high-rise buildings, equipment fatigue in factories, excessive temperatures, the presence of dangerous chemicals, unsafe events in automobiles and a variety of other environmental conditions.

TI's MSP430F2274 microcontroller and a CC2500 RF transceiver allows the Joule-Thief design to gain as much processing and transmission as possible from the charge stored in a capacitor. The MSP430 microcontroller provides a fast wake-up time of less than a microsecond for a preferable low power/high performance solution. ■

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