MSP430 Code Library
Low-Power Wireless Applications

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Agenda

- MSP430 and CC1101 key features
- Software for MSP430 + CC1101
- MSP430 + CC1101 Applications

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This presentation will give a brief introduction to the MSP430 and the CC1101, focusing on aspects making them suitable for low power applications. Then, we will highlight some of the features in a newly developed library containing interface code for MSP430 + CC1101 and applications examples. In the last section, several applications using CC1101 and MSP430 will be presented.

MSP430 Key features

- Ultra-low-power architecture extends battery life:
  - 0.1-µA RAM retention
  - 0.8-µA real-time clock mode
  - 250-µA/MIPS active
- Wide range of integrated intelligent peripherals offloads the CPU
- Modern 16-bit RISC CPU enables new applications at a fraction of the code size

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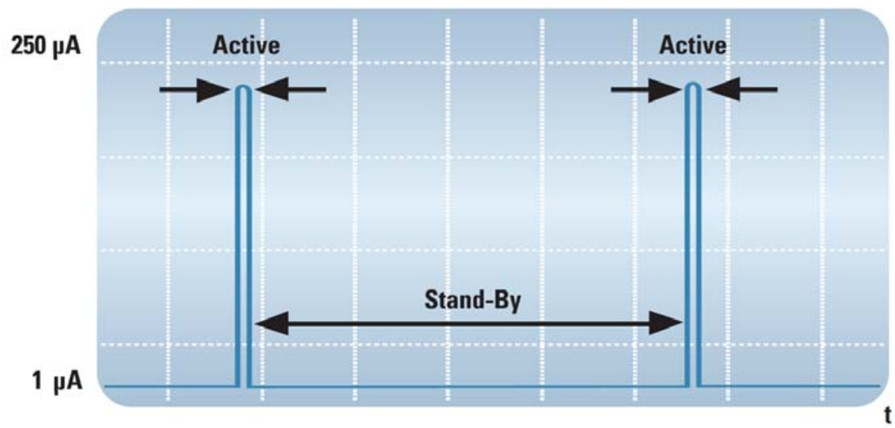
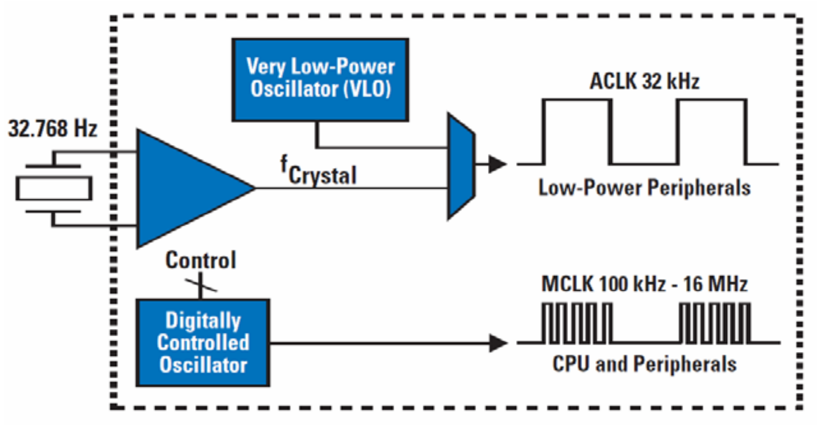
Ultra low power



Ultra-fast 1-µs DCO start-up allows MSP430-based systems to remain in low-power modes for the longest possible interval—extending battery life. The DCO is fully user programmable.

Multiple Oscillator Clock System



Flexible clock system

MSP can operate without using external crystall (only using the internal DCO (digitally controlled oscillator))

Wide variety of peripherals

- 10-/12-/16-bit ADC
- 12-bit DAC
- Comparator
- LCD driver
- Supply Voltage Supervisor (SVS)
- Operational amplifiers
- 16-bit and 8-bit timers
- Watchdog timer
- UART/LIN
- I2C
- SPI
- IrDA
- Hardware multiplier
- DMA controller
- Temperature sensor

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The large number of peripherals makes it possible to develop systems with very few external components.

MSP430 Family

- MSP430x1xx
  - Wide range of capabilities - from a simple low power controller
  - with a comparator, to complete systems on a chip including high-performance data converters, interfaces and multiplier

- MSP430x2xx
  - New ultra-low-power MSP430 generation.
  - Increased performance up to 16 MHz.
  - Integrated ±1% on-chip digitally controlled oscillator.
  - Increased number of analog inputs.

- MSP430x4xx
  - Integrated LCD controller for low power metering and medical applications.
  - Several devices offer application based peripherals to provide single-chip solutions for flow and electricity metering.

- MSP430x5xx
  - New core. Up to 25 MHz

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CC1101 Key features

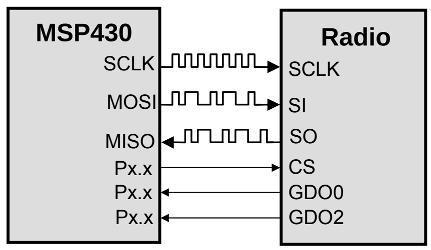
- RF transceiver for the sub 1 GHz ISM frequency band
- Powerful digital features making it easy to build a high-performance RF system using an inexpensive microcontroller
- Excellent RF performance

CC1101 Key features (cont.)

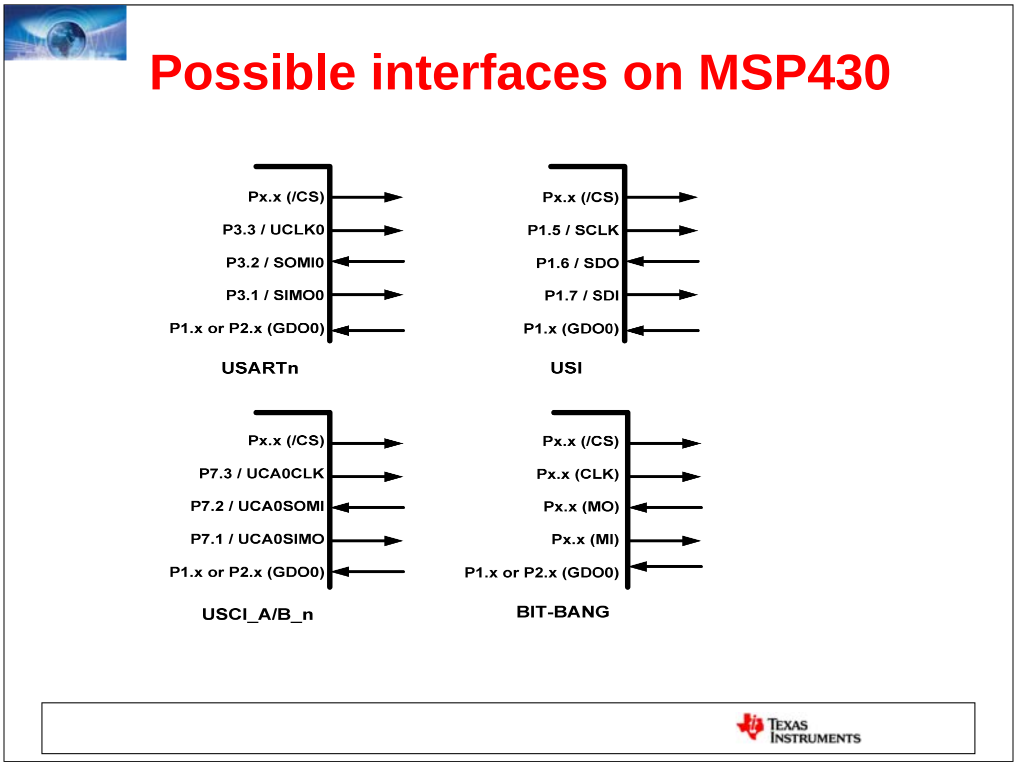
- Burst mode data transmission with high over-the-air data rate reduces current consumption.
- Low Current Consumption:
  - 14.7 mA in RX,1.2 kBaud, 868 MHz
  - 32.3 mA in TX at +10 dBm output power
  - 200 nA (typical) in Power Down
- Automatic RX polling using Wake-on-RadioHigh sensitivity (-111 dBm at 1.2 kbps, 868 MHz)
- Programmable data rate from 1.2 - 500 kbps
- Excellent selectivity and blocking performance

MSP430/CC1101 Interface

- The radio is configured via a simple 4-wire SPI compatible interface where the radio is the slave and the MCU is the master



- 2 generic digital outputs can be used for waking up the MSP430, triggering interrupts



The various ways in which the MSP430 can interfaced to the SPI bus are shown here, with their respective connections. Connections listed with "Px.x" mean that any available I/O pin can be used. Connections listed with specific pins mean that only the designated pin for that device and interface can be used, but the exact pin may vary by device (i.e., UCLK0 on the USARTn interface is not always P3.3).

The diagrams above show the MSP430 connection for this signal to be P1 or P2, as opposed to other Px I/O ports. This is because these are the only two capable of generating interrupts corresponding to an input transition. Interrupt capability is not necessary for every usage scenario involving GDOn.

USI is typically found on low pin-count devices that likely do not have a P2, such as the F20xx, hence the USI example only indicates P1.

MSP430/CC1100 Matching

- USART, USCI or USI needed to support the CC1101 SPI interface
- Carefully consider the need for RAM in your protocol. RAM is typically needed when storing packets for retransmission.

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Note that bit banging over the SPI interface is also possible, although this is not very efficient.

MSP430 for Wireless

MSP430 MCU + Chipcon RF ICs
=
perfect fit for low power wireless solutions

- Designed for low power
- Vcc = 1.8V ... 3.6V
- Simple connection through SPI
- Market leading RF transceivers

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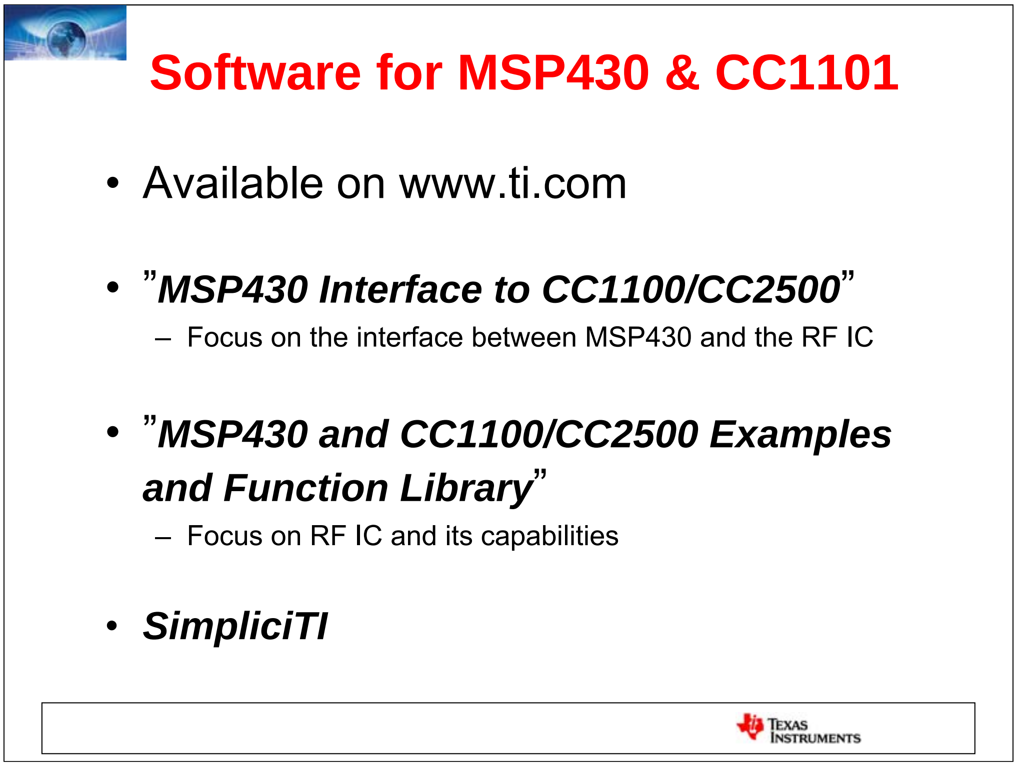
- MSP430 in LPW Applications



Both of the mentioned libraries are good starting points for developing software for the MSP430 + CC1101 combination. Whereas the first focuses on how to set up and use the SPI interface on the whole range of MSP430s, the second focuses on the capabilities of the CCxx00, and how to take advantage of them using the MSP430. The Examples Library has been developed for the MSP430 Experimenter’s Board, but can easily be ported to another hardware platform.

SimpliciTI is a simple protocol for a star network or point to point communication.

MSP430 and CC1100/CC2500

- Examples and Function Library

Picture showing one MSP430 Experimenter board with a CC2500 sending packets to another MSP430 Experimenter board with a CC2500. In this particular application, the receiving unit is displaying the RSSI of last the incoming packet/signal.

What you need to get started

- 2 MSP430 Experimenter Boards.
- 2 CC1100EMs or CC2500EMs with appropriate antennas.
- An MSP430 Debug Interface (e.g. MSP430-FET430UIF).
- IAR Embedded Workbench for MSP430.
- Software.
- Batteries (for the boards)

- Alternatively the eZ430-RF2500 kit

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A free, code size limited, but fully functional edition of IAR Embedded Workbench (IAR Kickstart) is available from the IAR Systems website (www.iar.com) or from the TI MSP430 homepage www.ti.com/msp430 (Tools & Software). As an alternative to IAR Embedded Workbench, it would be possible to use Code Composer Essentials 3. Minor modifications of the software handling interrupts would be necessary. A trial edition of Code Composer is available from the same location.

The MSP430 Experimenter Board can be ordered from the MSP430 homepage under Tools & Software.

The software is available from the MSP430 Experimenter Board webpage and from the CC1100 and CC2500 webpages.

MSP430 and CC1101/CC2500

- Examples and Function Library
  - Provides functions for easy access to the CC1101/CC2500
  - All the software you need to start building your own RF protocol

```
// Reset chip and send packet
halRfReset();
halRfSetup(...);
halRfWriteFifo(data, length);
halRfStrobe(CC1100_STX);
```

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The software provided in this library is a starting point for developers wanting to get the most out of the MSP430 and the Chipcon RF devices. It shows how to communicate with the CC1100/CC2500EM using the SPI interface and how to use various features of the chips for packet transmission and reception.

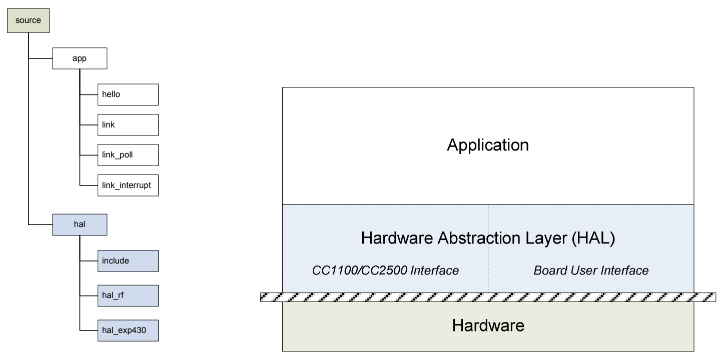
Note that CC1100 and CC2500 are identical seen from the MCU.

MSP430 and CC1101/CC2500

- Examples and Function Library
  - Hides MCU details – lets you focus on your application and the RF protocol
  - Gives examples on how to send and transmit packets, using different features of the RF ICs.
  - Does not offer a ready to use protocol
  - Not optimized for minimal code size or reduced function call overhead

SW Architecture

- The software is using clean interfaces between the layers to simplify portability and enhance readability
- Source code organized according to the layered software architecture



The Hardware Abstraction Layer (HAL) is divided in two parts. The CC1100/CC2500 part (hal_rf) contains basic functions for accessing the CC1100 or the CC2500 RF IC. It contains chip specific header files containing register and command strobe definitions, in addition to a common interface to most of the functions needed for successfully starting developing applications and experimenting with the RF devices. The second part (hal_exp430) contains all board specific software needed for direct access to hardware, that is digital input and output, LEDs, LCD, serial interfaces (UART, SPI) etc. The HAL has a generic, board independent interface.

Note that the registers and strobes for the CC1100 and the CC2500 are identical. The RF ICs are thus identical from a software perspective.

The Application layer contain example code for transmitting and receiving packets using various features of the chips.

Setting up the CC1101

- The libary provides a function for this purpose.

```
halRfSetup(HAL_RF_CONFIG* config, ...)
```

- Get the register settings by using SmartRF® Studio.

SmartRF® Studio

- Converts user inputs to register values
  - RF frequency
  - Data rate
  - Output power
  - Deviation
  - Modulation
  - RX filter bandwidth

- Offers export/import of register settings and C-code structure

- Allows remote configuration, control and performance testing of EMs and prototype board when connected to SmartRF04EB

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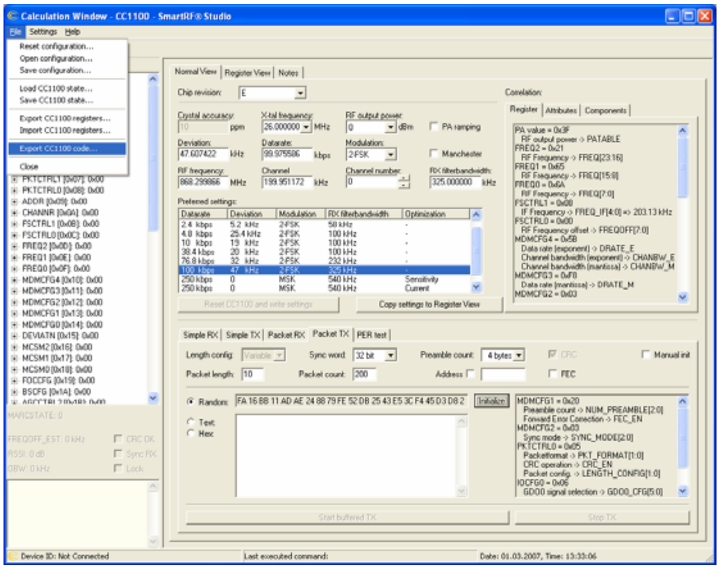
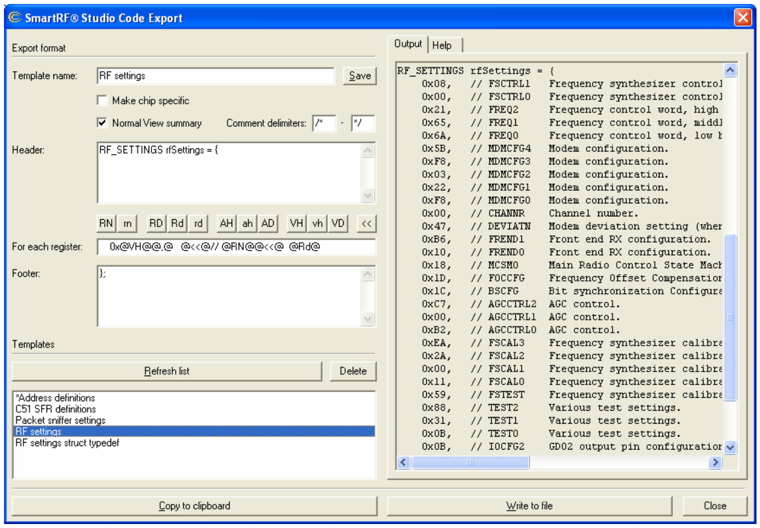
SmartRF® Studio



TEXAS INSTRUMENTS

Use the ”Export CC1101 code...” function in SmartRF Studio after selecting your preferred radio options.

SmartRF® Studio



TEXAS INSTRUMENTS

The Code Exporter can directly export a structure of the registers you need in order to configure the RF IC. Simply copy them to the clipboard and past them in an appropriate file included by your software.

Example applications

“link”	Transmit or receive variable length packets, but shorter than the size of the internal FIFO, using interrupts to signal the MCU when the packet is transmitted/received.
“link_poll”	Transmit or receive variable length packets (up to 255 bytes) using state information from chip.
“link_interrupt”	Transmit or receive variable length packets (up to 255 bytes) using packet complete and FIFO threshold interrupts.

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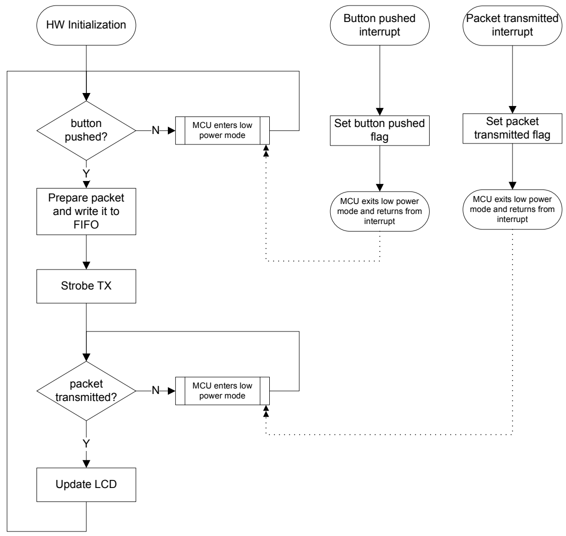
The software comes complete with a set of example applications, showing how to use some of the many digtal features of the CC1101.

Simple packet transmission



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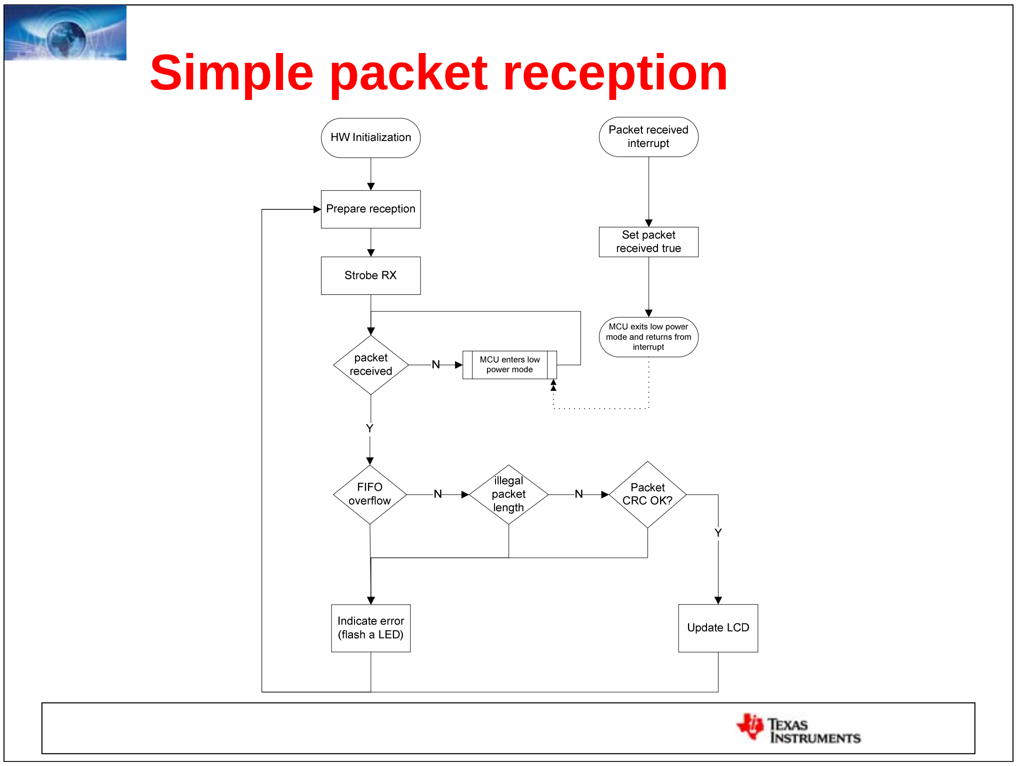
Transmitting data in the link example



Receiving data in the link example

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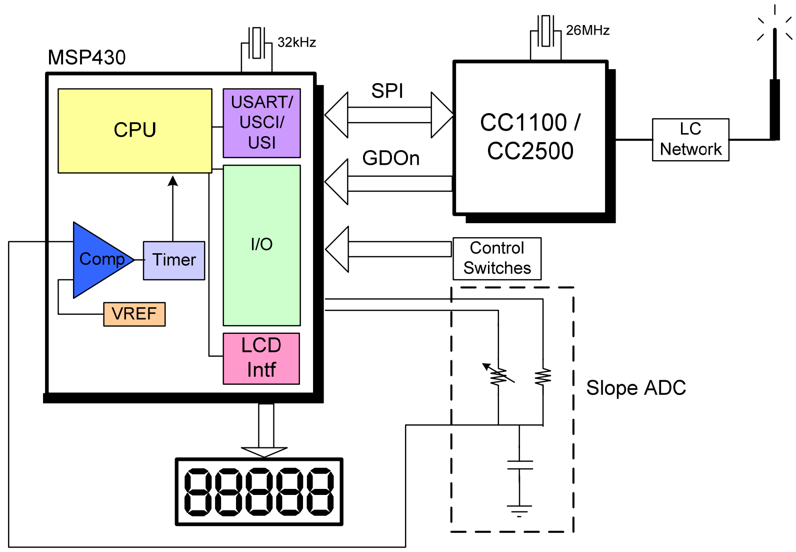
Wireless Thermostat



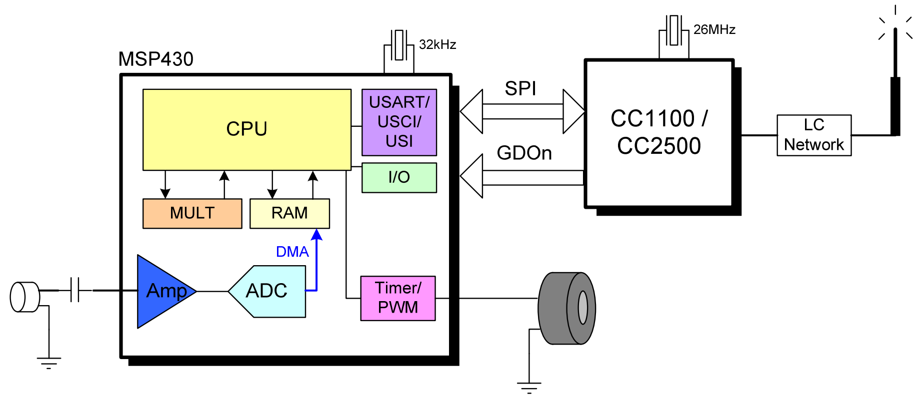
There are many applications for battery-powered wireless technology. Shown here is a wireless thermostat. Such a thermostat can be placed anywhere in the house, as opposed to only being located where the wires were fixed in the walls. It could be used as a stand-alone thermostat, or part of a home automation scheme with a central controller (perhaps the home PC).

Here, slope analog-digital conversion is used. This type of conversion uses a comparator with some discrete components, in place of a specialized ADC module. A capacitor is charged through a varistor, which varies resistance with temperature, and the time to charge to the reference voltage is measured with a capture/compare register (CCR), part of the timer module. It is also charged through a reference resistor of known, fixed resistance, and the varistor charge time is normalized to this reference value. The resulting charge time is used to identify a corresponding temperature. This type of conversion is accurate enough for residential thermostat applications.

The reference for the comparator is programmable. It can be some derivative of Vcc, or one of the integrated precision reference voltages. If these are not accurate enough for a given application, an external reference can be used as well.

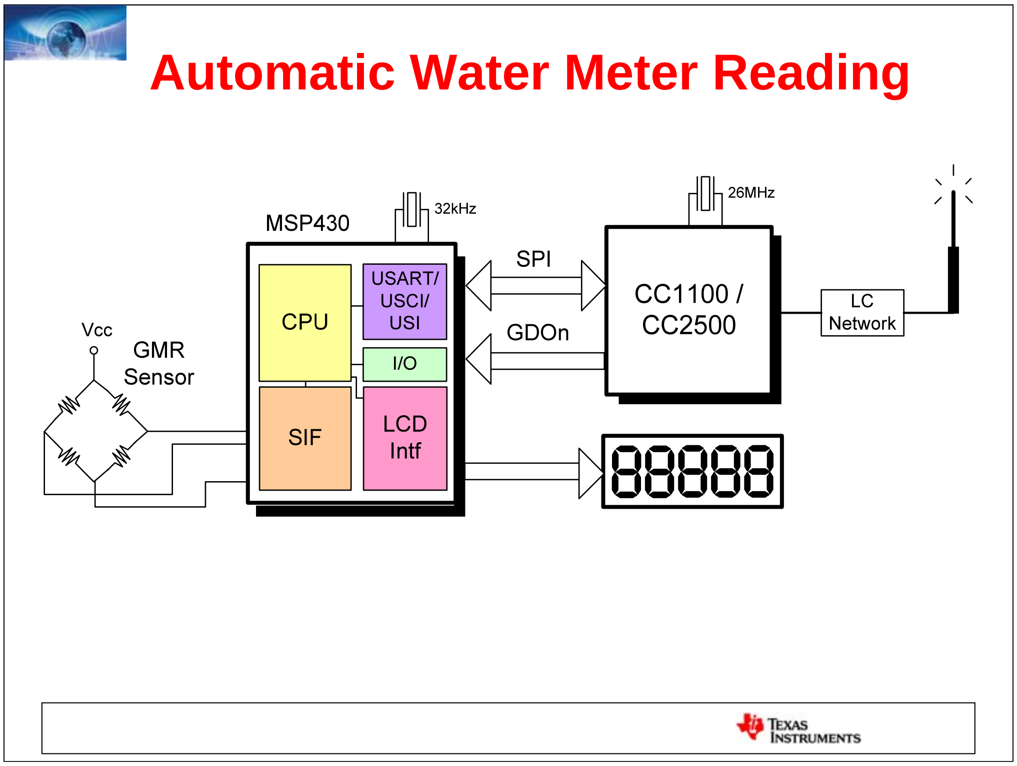
Control switches can be used to set the target temperature. Comparing the target temperature against the actual temperature, the CPU decides whether the room needs heating or cooling, and activates the appropriate equipment via the wireless link.

Glass Breakage Detector



A glass breakage detector is commonly used in residential alarm systems. This design utilizes the MSP430's integrated op amps in conjunction with a microphone to obtain the acoustic signature of the signal to be analyzed. The data is DMA'ed to RAM (CPU can power down during this operation, saving power), where the CPU analyzes it with digital filtering, made easier with the MSP430's hardware multiply/accumulate module.

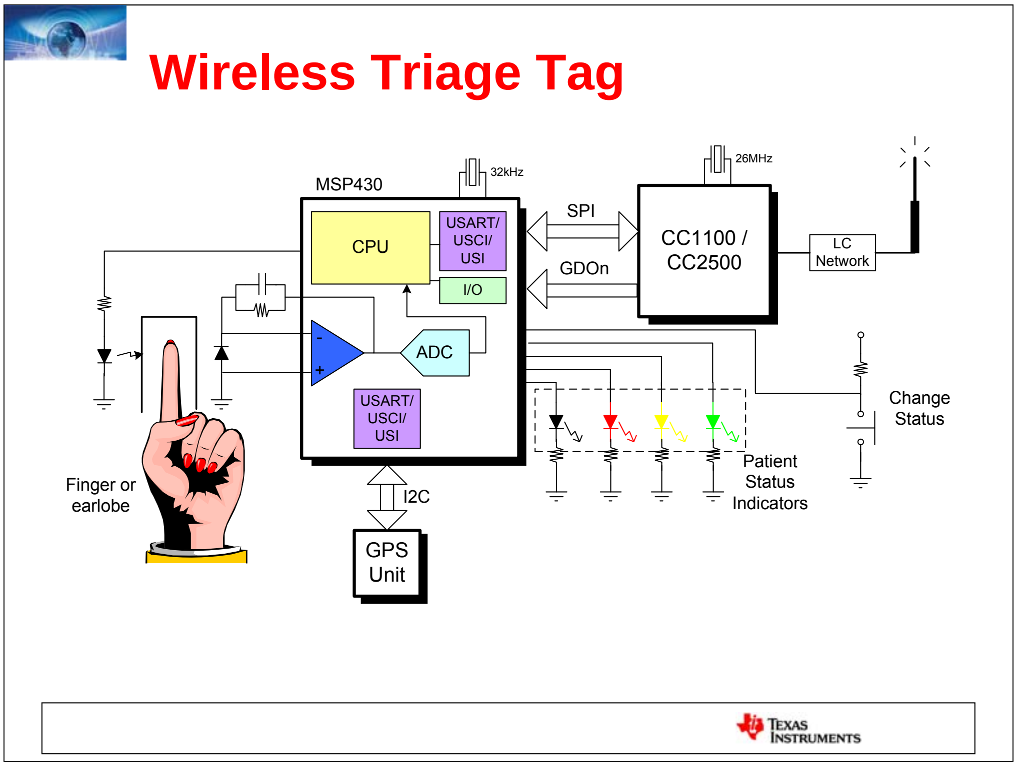
If it decides that the sound was indeed glass breakage, then it transmits the signal via wireless and generates a PWM signal to drive the alarm. The MSP430 CPU can configure a timer to output a PWM signal of any duty cycle with just a few instructions, and then power down the CPU while the PWM is driven, again saving power.



Automatic Meter Reading is a fast-growing market. In some residential applications, the data is transmitted to a worker who travels to an area and measures all the meters within range, in a single sitting. A more advanced method is to wire utilities with ethernet, and have a base station obtain the readings from all meters within range and transmit them to a central facility via ethernet.

A GMR (Giant Magneto-Resistive) sensor measures a magnetic field, similar to a Hall effect sensor. It is a newer technology with more sensitivity and stability. A magnet in the mechanical portion of the meter rotates as water flows through it. The sensor pulses as the magnet passes. The Scan Interface in the “FW” series of MSP430 processors can detect and interpret these pulses without CPU intervention, providing an ultra-low-power method of tracking rotation. As necessary, the CPU wakes up and updates the LCD display. On some period, on the order of a few seconds, the CPU transmits its data over the wireless interface.

Depending on the application and GMR sensor used, a separate op-amp may be necessary to gain the signal.

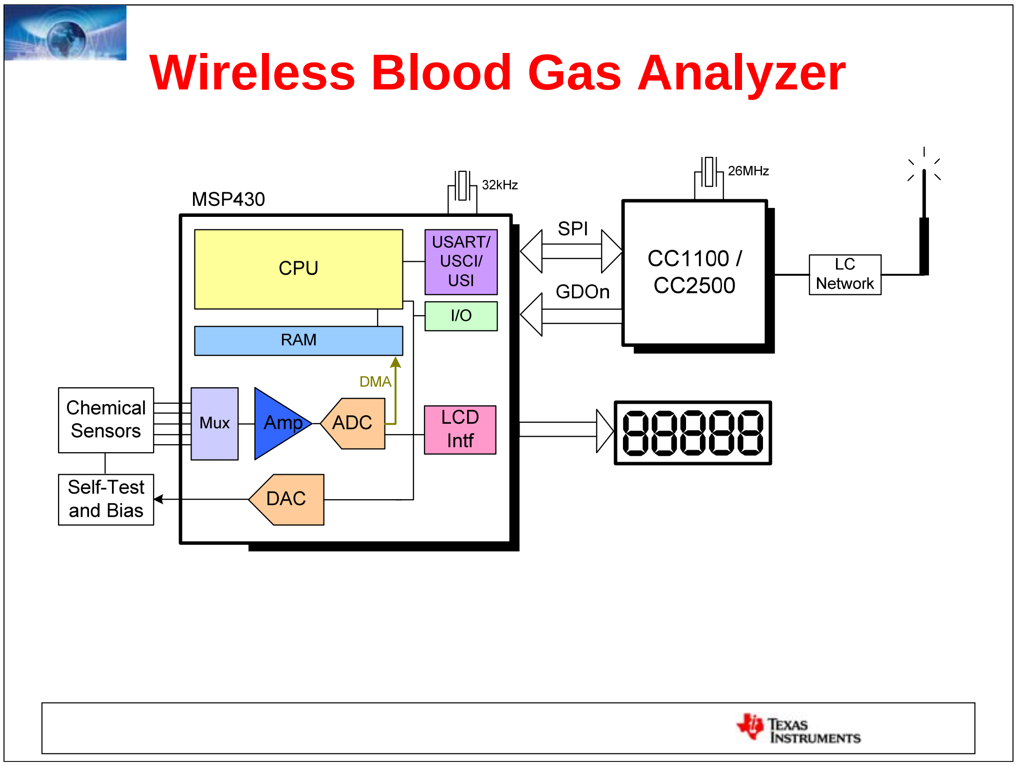


A traditional “triage tag” is a non-electronic device used by paramedics at sites with multiple victims in order to tag their status for other paramedics/doctors on-site. A system of four colors is used to quickly identify their state of health.

An electronic triage tag can serve this function, but also monitor vitals, such as pulse oximetry, EKG, and blood pressure. Then, this data can be transmitted to a base station that monitors status and alerts the paramedics if someone’s vitals turns for the worse. The mobile nature of this solution allows it to be taken across accident sites. The units can form a mesh network that links the devices together over an area wider than would be possible between a single unit and base station.

For large accident sites, a GPS unit can be added to identify physical location.

Pulse oximetry is performed by clipping a device over a person’s finger or earlobe. A photodiode is transmitted through the tissue to a sensor, and a transimpedance amplifier measures the current generated in the sensor. The traditional triage tag function is shown at the lower right.



A portable blood gas analyzer is an instrument used for measuring partial pressures of oxygen, carbon dioxide, carbon monoxide, and nitrogen in blood.

Multiple chemical sensors are directed into the op amp module of the MSP430, where they are amplified, then passed to the ADC module to be digitized for processing. Multiple inputs are available to the op amps. The MSP430's DMA can be used to shuttle the converted data to RAM. After initialization, the entire process can take place with the CPU powered down, saving power.

The CPU analyzes the results, updates the display, and sends the data to a base station. The DAC provides a bias voltage to the analog detection circuitry.

Additional information

TI Low Power Wireless

http://www.ti.com/lpw

TI MSP430

http://www.ti.com/msp430

TI Support

http://support.ti.com

TI Community

http://community.ti.com

Thank you for your attention!

QUESTIONS?