Technical Article

Real-time Temperature Sensing with Dual-mode Connectivity

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Today, there are many applications that require accurate and continuous temperature sensing to protect a product or improve system performance. Temperature sensors now have the ability to deliver accurate measurements wirelessly and in real-time thanks to advancements in connectivity technology. In many applications, the ability to monitor and control a system from a remote location is a key requirement. By combining long-range Sub-1 GHz networking with *Bluetooth® low energy* (2.4 GHz) connectivity opens up a world of possibilities for temperature measurement. Here we will discuss how the use of these technologies together can enhance systems where temperature measurement is critical.

Some Example Applications - Cold Chain Management and Home Automation

Temperature sensing is used in many applications and below we will look at two examples:

- Cold chain management
- Home automation

Cold Chain Management

Cold chain management is deployed to monitor and track products that are sensitive to temperature. A typical example is fresh food being shipped from a farmer and tracked all the way to the supermarket. The temperature of pallets or individual boxes is monitored to ensure the quality of the produce. While monitoring solutions exist today, the combination of Sub-1 GHz and Bluetooth low energy in a single device plus a high quality temperature sensor enables new functionality. For example, the long-range, Sub 1 GHz network enables coverage of a large area like a storage facility and the Bluetooth connectivity enables an operator (truck driver, shop assistant) to communicate directly with the pallet/box using a smartphone to check if the product has been kept at the right temperature for the duration of its journey. These technologies also allow a smartphone to be used as an Internet gateway in places where a Sub 1 GHz network cannot be implemented – for example during the truck transport. In this case the truck driver's smartphone could be the gateway without any intervention from the driver apart from running a smartphone app in the background. This would allow remote systems to continue monitoring the temperature of cargo.

Home Automation

Localized temperature control is important for maintaining a pleasant indoor climate. By wirelessly connecting sensors with ventilation/cooling/heating, it is also possible to optimize comfort while at the same time making sure energy consumption is kept at a minimum. Many home automation systems use Sub-1 GHz technology today for its long range and low power consumption. In these solutions, temperature sensing is used in heating, air-condition and ventilation systems (windows/blinds). At the same time, Bluetooth connectivity allows users to access to the information via smartphones and tablets. Using a single device for both connection methods, such

as the SimpleLink™ dual-band CC1350 wireless microcontroller (MCU), allows for simple, cost-effective systems to be developed.

Building a Dual-band, Temperature Monitoring System

TI's SimpleLink dual-band CC1350 wireless MCU is a new wireless system-on-chip solution (SoC) that offers both the long range RF connectivity of the Sub-1 GHz frequency band, in addition to the simple connectivity of *Bluetooth*® low energy (2.4 GHz). The small size of the CC1350 solution and its low power consumption make it ideal for building the systems described earlier. In addition, its interfaces allow for adding a temperature sensor directly without additional circuitry.

Figure 1 shows a block diagram of the CC1350 wireless MCU. For a digital sensor like TMP18x (±0.3 degrees) single wire temperature sensor for in temperature controlled vehicles, or TMP112 (±0.5 degrees), and TMP114 (±0.3 degrees) from TI, a digital interface like the I^2C or the SMBus™ can be used for sensor configuration and collecting temperature data. Assuming that the I^2C is used, there are two main ways of connecting the CC1350 wireless MCU to the temperature sensor:

1. Using the I^2C interface that is directly controller by the ARM® Cortex®-M3 application processor. The I^2C module has a dedicated driver library function that is integrated as a part of the TI RTOS (real-time operating system). The I^2C software routine used to handle the sensor can be found here on ti.com. This can be used as an example to handle other I^2C temperature sensors as well.
2. Using the sensor controller on board the CC1350 device. The sensor controller has its own configuration tool called the Sensor Controller Studio that contains sample code for the I^2C interface. To access this code, download the Sensor Controller Studio and click on the I2C example on the front page.

Using the sensor controller will give the lowest current consumption. However, in most use cases, the temperature sensor is read out very infrequently (interval of ten seconds or more) – in these cases the difference with respect to average current consumption is negligible between the ARM Cortex-M3 and the sensor controller. A temperature read of every 10s can easily be designed to consume less than 1µA in total current consumption – including the stand-by (32kHz) sleep current consumption.

Connecting an Analog Temperature Sensor to a Dual-band Wireless MCU

Analog temperature sensors such as the LMT70 can be read by using the 12-bit analog-to-digital converter (ADC) inside the CC1350 device. As for digital sensors, a user has a choice of using the TI RTOS that includes an ADC software driver run by the ARM Cortex-M3, or using the sensor controller. Examples of how to read out analog sensors can be found in the Sensor Controller Studio.

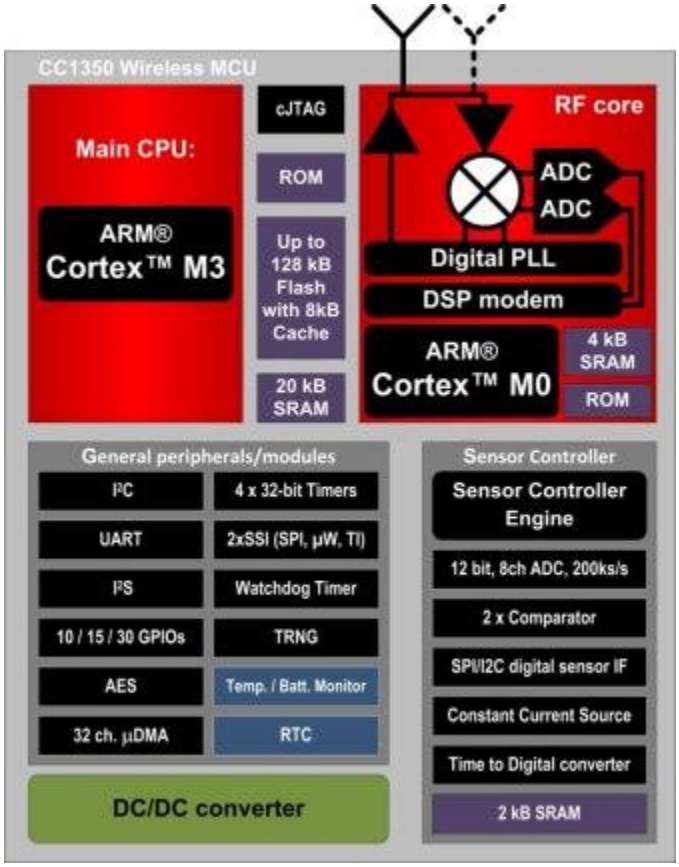

Figure 1. Block Diagram of the SimpleLink Dual-band CC1350 Wireless MCU

Additional Resources:

- Learn more about TI's sensor portfolio.
- Choose your temperature sensor.
- Get started with the SimpleLink dual-band CC1350 wireless MCU LaunchPad™ kit
- Download the TI 15.4-Stack, a Sub-1 GHz star network protocol based on IEEE 802.15.4g PHY.
- Want to learn more about how you can use the CC1350 wireless MCU? Read other parts of this technical article series:
  - How to manage wireless sensor networks with dual-band connectivity
  - Cold chain in the IoT

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