TI Solutions for Cold Chain

Daniel Mar: Product Marketing Temperature Sensors
Ali Anwar: Product Marketing MSP430

Texas Instruments

Agenda

- What is Cold Chain?

- TI Solutions for Cold Chain
  - Temperature sensors
  - Humidity sensors
  - Optical sensors
  - MSP430 FRAM

- TI Reference Designs for Cold Chain
  - Ultralow Power Multi-sensor Data Logger with NFC Interface Reference Design (TIDA-00524)
  - Humidity & Temp Sensor Node for Star Networks Enabling 10+ Year Coin Cell Battery Life Ref Design (TIDA-00374)
  - Humidity & Temp. Sensing Node for Sub-1 GHz Star Networks Enabling 10+ Year Coin Cell Battery Life (TIDA-00484)
  - Dynamic Field-Powered NFC Reference Design for Data Logging, Access Control, and Security Applications (TIDA-00217)

What is Cold Chain?

Texas Instruments

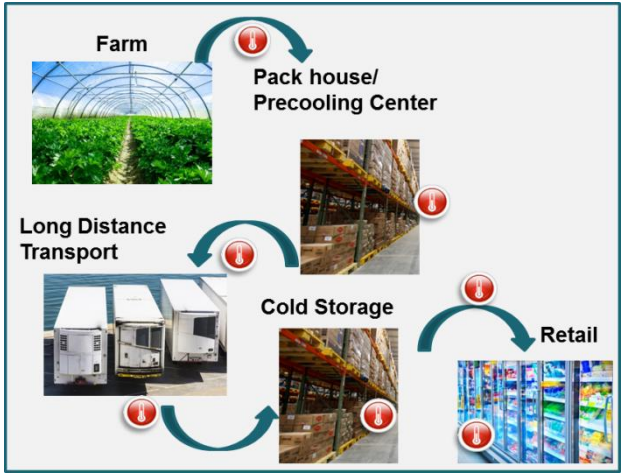
What is Cold Chain?

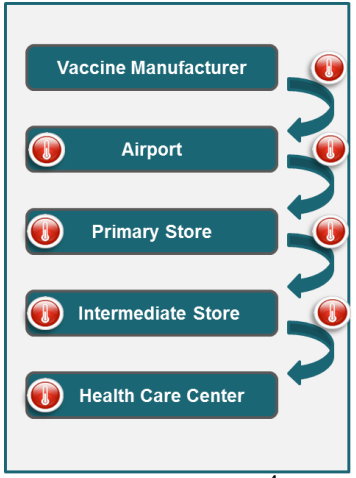
Cold chain management includes all of the means used to ensure a constant temperature for a product that is not heat stable from the time it is manufactured or farmed until the time it is used.

Industries Involved:

- Food
- Retail
- Medical: (hospitals, transplants, blood)
- Pharmaceutical
- Refrigeration
- Transportation (air, ship, truck, train)
- Fleet Management
- Warehousing
- Packaging

Examples Cold Chains?

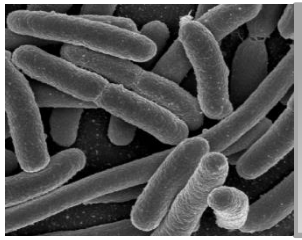




Cold Chain Facts

$167B was spent on Food Storage and Transportation (2015)
-> $235B by 2020

Wastage:
43 Billion Pounds of Food are thrown out annually by US grocery stores (10% of the food supply)



Safety:
48 Million People get sick annually in the use due to foodborne illness

- 128,000 are hospitalized
- 3000 die

Beyond Food:
In a Department of Health and Human Services study, 76% of the providers had stored vaccines at incorrect temperatures for at least 5 hours during the two-week period measured.

Market Drivers

- Increasing Safety Regulations
  - 40 Countries with GDP (Good Distribution Policies)
    - FDA Food Safety Modernization Act (FSMA)
    - EU Commission
    - World Health Organization
- Liability
  - Determining liability should a shipment have a temperature excursion
- Costs
  - Better tracking allows for cheaper transportation methods (Air -> Truck / Ship)
- Reduce Carbon Foot Print
  - Reduce Air Freight

Types of Equipment

- **Indicators**
  - Single Event: excursion outside temp/time window
  - Typically disposable
  - Either chemical or electronic

- **Electronic Data Loggers** (disposable, reusable, fixed infrastructure)
  - Temperature, Humidity, Light, Vibration data is stored
  - Real Time Options (Zigbee, Wifi, Cellular, Satellite)
  - Data loggers w/ or w/o integrated sensors
    - Wired and wireless communication between Data Logger and sensors

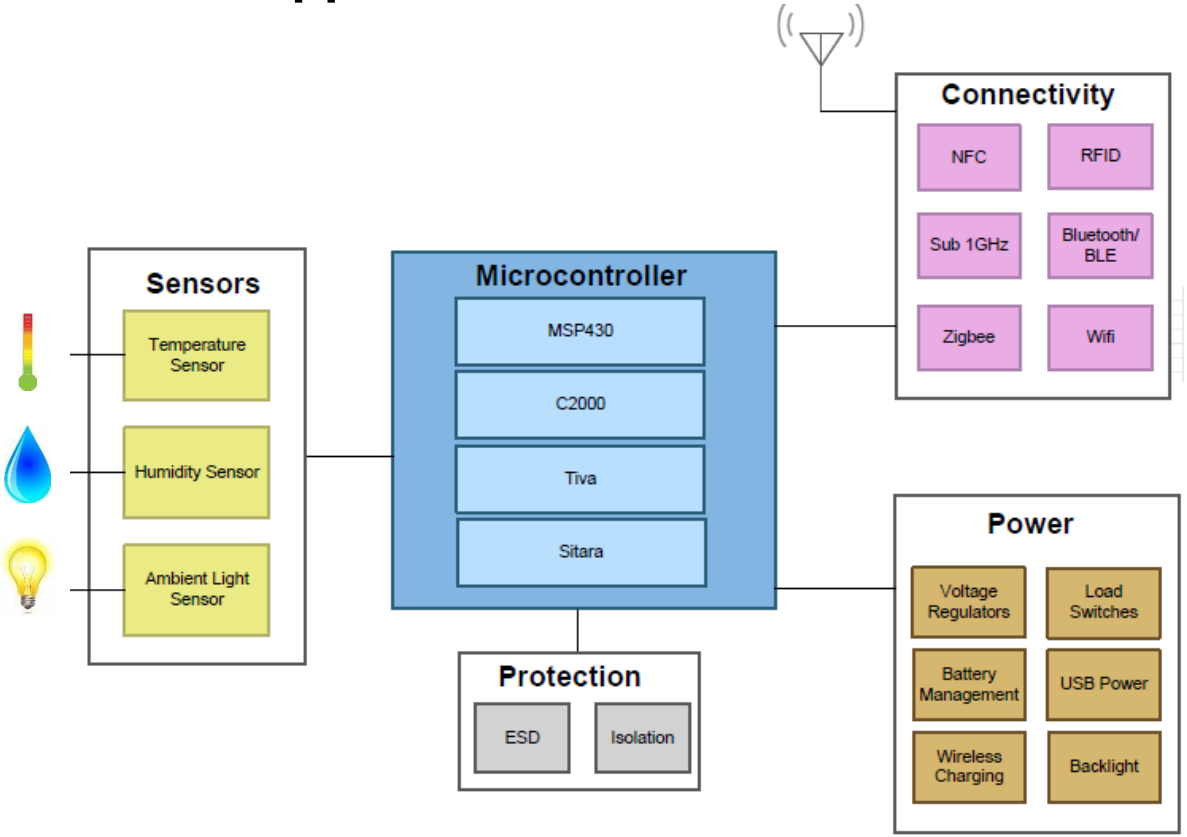
Common Terms

- **GDP** (**Good Distribution Practices):** Government or Corporate guidelines for the proper distribution of medicinal products for human use. GDP is a quality warranty system, which includes requirements for purchase, receiving, storage and export of drugs intended for human consumption.
- **HACCP (Hazard Analysis, Critical Control Point**): Systematic approach to safety but preventing hazards. See ISO 22000 FSMS 2005 for HACCP
- **NIST Traceability:** The National Institute of Standards and Technology maintains the U.S. national standards for temperature. Traceability can be defined as an unbroken record of documentation ("documentation traceability") or an unbroken chain of measurements and associated uncertainties ("metrological traceability").
- **EN12830:** EU Standard for Temperature-measuring instruments, Temperature measurement, Temperature, Refrigerating plant, Cold storage, Vehicles, Freight transport, Food products, FrozENfoods, Ice cream, Working range, Recording instruments (measurement), Data recording, Chart records.
- **FSMA**: Food Safety Modernization Act. US Law passed in 2011. It aims to ensure the U.S. food supply is safe by shifting the focus from responding to contamination to preventing it.

TI Temperature Sensors Solutions for Cold Chain

TI offers complete monitoring solution

for the Cold Chain applications



TI Temperature Sensor for Cold Chain

TI Temp Sensor vs Thermistor

Advantages of an IC Temp sensor

Simplicity:
- No additional circuitry required
- Better PSRR & Noise Immunity
- Easier to layout
- No curve fitting or lookup table
- Eliminate polling for over / under temp detection

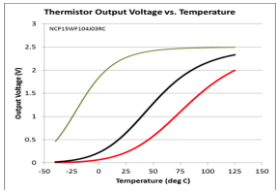
Wide range of interfaces
- Analog, I2C, SPI, 1-wire, UART, Pulse Counter
- Cabled / Probe interfaces

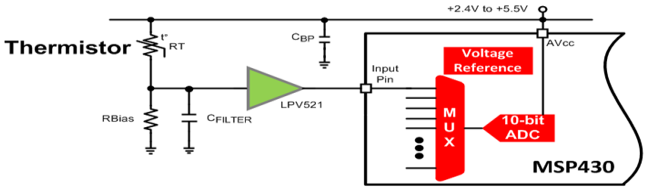
Accuracy:
- Accuracy is guaranteed (zero calibration needed)
- Analog outputs are linear
- Little to no self heating

Power
- Digital Interface options down to 4.8uW
- Built-in low power modes
- Programmable wake->sample->sleep>repeat mode

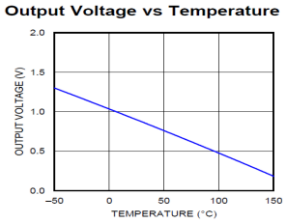
Cost
- Can be very competitively priced compared to total thermistor solution (thermistor + components & calibration)

Thermistor





IC Sensor



Featured Local Temperature Sensors

	TMP112	TMP75C	TMP275	LMT70
Interface	I2C w/Alert			Analog
Supply Range	1.4V to 3.6V		2.5V to 5.5V	
I2C Addresses Available	8			N/A
Accuracy: -20°C to +90°C 0°C to +65°C –20°C to +85°C –40°C to +125°C –55°C to 150°C	0.5°C max 3.0°C max	1.0°C max 2.0°C max 3.0°C max	0.5°C max 1.0°C max	0.2°C max 0.36°C max
Resolution	12-Bit			-5.18 mV/°C
Quiescent Current (max)	10 uA	85uA		12uA
Shutdown Current	1uA	3uA		50nA
Package Footprint	SO T-563 1.6 x 1.6mm	SO-8 (3.0mm x 4.9mm) MSOP-8 (4.9mm x 6.0mm)		WCSP 0.8x0.8mm

NIST

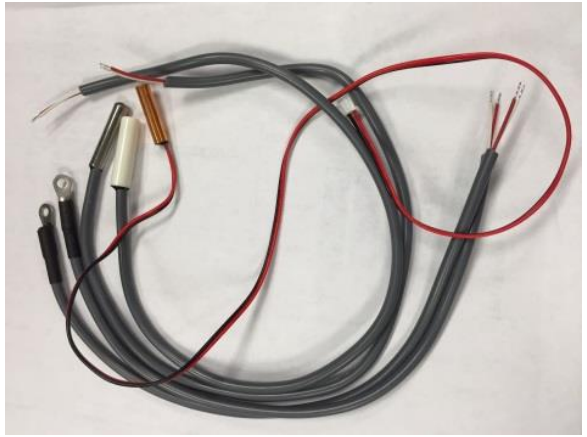
Probes

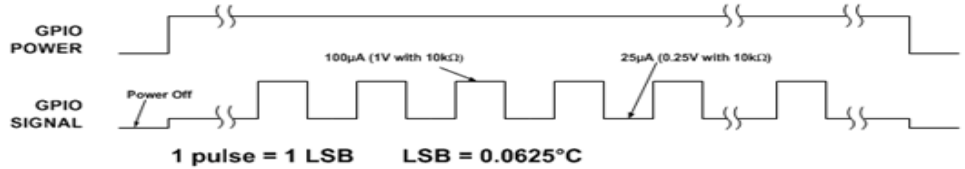
Traditional Method: Thermistors

- 2 wire
- Star topology
- Requires Calibration & Non-Linear
- Sensitive to environmental factors

TI Advantage: LMT01

- 2 Wires- mechanically compatible
- Digital - Pulse Counter Interface
- Noise Immunity
- Guaranteed +/-0.5°C Accuracy
- Insensitive to humidity and shock





$$Temp = \left(\frac{NP}{4096} \times 256°C\right) - 50°C$$

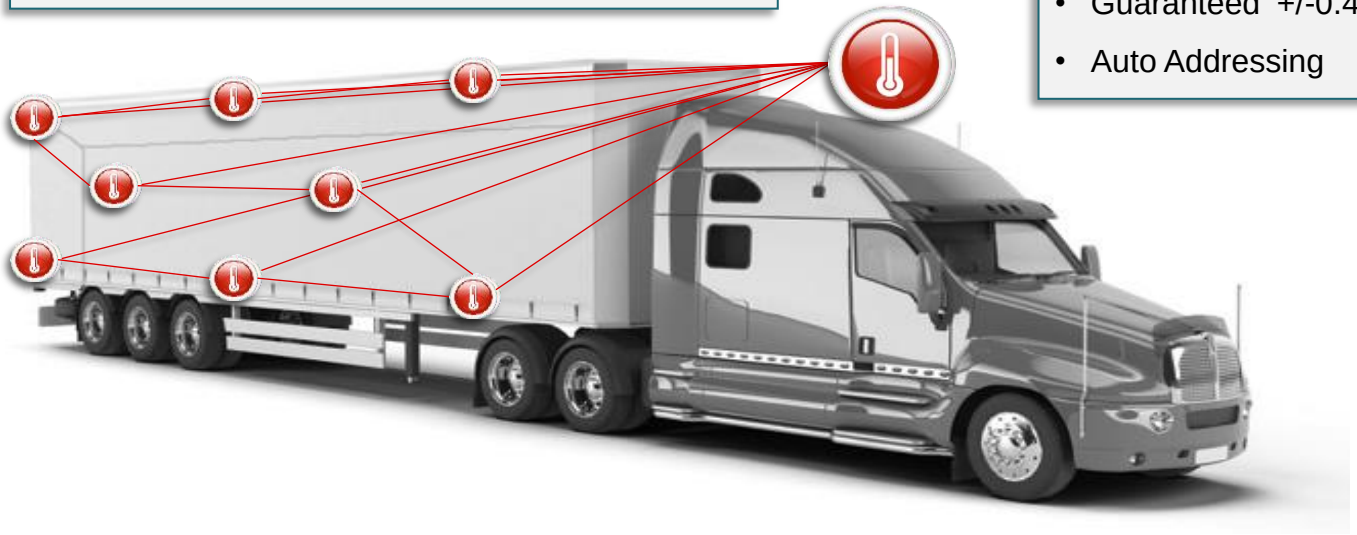
Multi-Location Thermal Monitoring

Traditional Method: Thermistors

- 2 Wires for every location
- Complicated Assembly
- Calibration
- Non-Linear

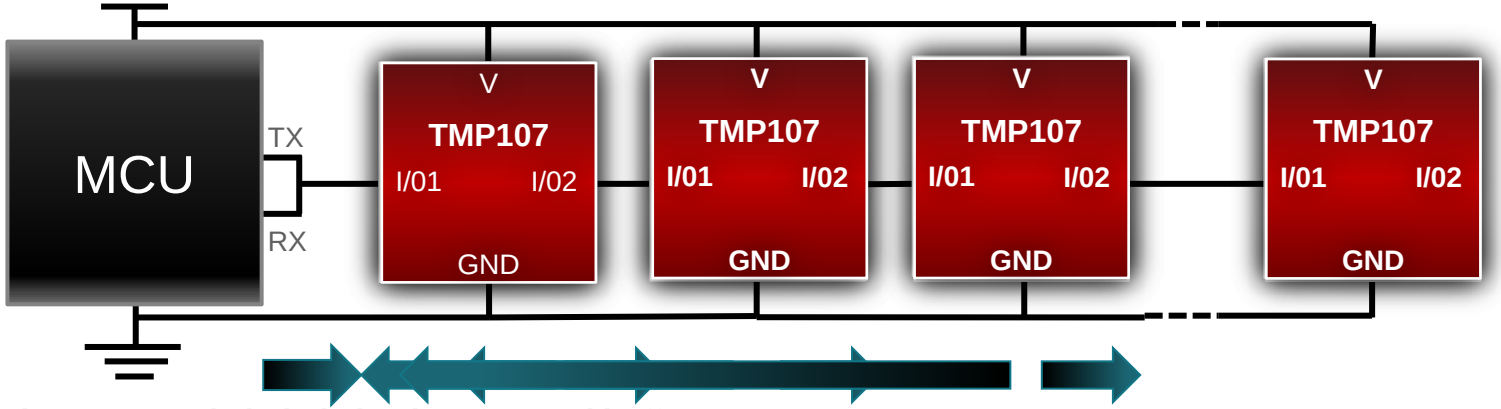
TI Advantage: TMP107

- 3 Wires (PWR, GND, Comm)
- Daisy Chain Topology
  - Saves copper
  - Faster installation
- Guaranteed +/-0.4°C Accuracy
- Auto Addressing



TMP107: SMAART Wire™ Interface

- ½ Duplex UART interface
- Auto addressing based upon location in the chain
- Non-volatile memory is available to store address & programming



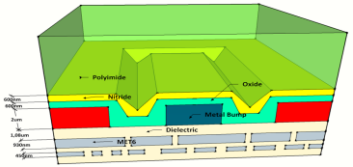
Bus Times out and chain is back to forward buffer

All the devices know their position in the bus for any further reads and writes

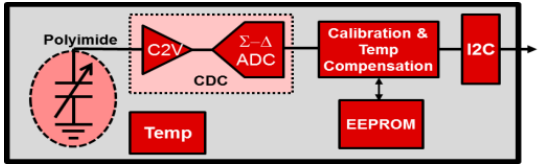
TI Humidity Sensors Solutions for Cold Chain

TI – Humidity sensor package option

HDC1010 – HDC1080



- TI Humidity sensor family are based on integrated sensor and dedicate Analog Front End
- HDC family is fully calibrated in TI fab and temperature compensated

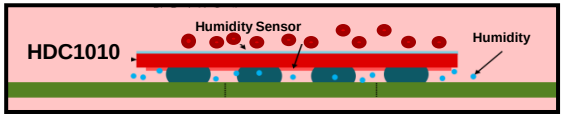


- **HDC is available in two packages**
  - WLCSP-8 package
  - WSON-6 plastic package

WLCSP-8

Humidity sensor on bottom

Dust

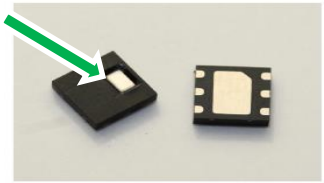


Unique sensor location greatly reduces impact of dust & dirt

HDC1010

PWSON-6

Humidity sensor on top



Industry Standard Pinout

HDC1080

HDC1010
Humidity & Temperature Sensor

Features

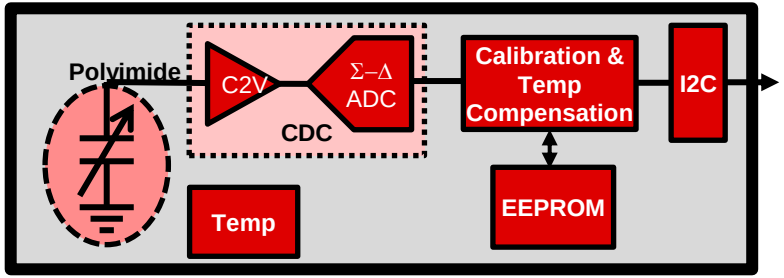
Relative Humidity Range	0% to 100%
Humidity Accuracy	±2%
Typical Drift	< 0.5%/yr
Supply Current (Measuring)	180uA
Avg Supply Current (@1sps)	1.3uA
Temperature Accuracy	±0.2ºC (typ)
Temperature Range (Operating)	-20ºC to +85ºC
Operating Voltage	2.7V to 5.5V
Package	
▪ 8 pin WLCSP (1.59mm x 2.04mm)	

Applications

- HVAC
- White goods (dryer, fridge, microwave, dishwasher)
- Printers
- Handheld Meters
- Camera Defog
- Smart Thermostats and Room Monitors
- Medical Devices

Benefits

- Completely integrated humidity and temperature IC provides guaranteed performance
- Fully calibrated sensor enables quick time-to-market
- Very low power consumption
- Small package size supports compact designs



HDC1080
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Avg Supply Current (@1sps)	1.3uA
Temperature Accuracy	±0.2ºC (typ)
Temperature Range (Operating)	-20ºC to +85ºC
Operating Voltage	2.7V to 5.5V
Package	
▪ 6 pin PWSON (3.0mm x 3.0mm)	

Applications

- HVAC
- White goods (dryer, fridge, microwave, dishwasher)
- Printers
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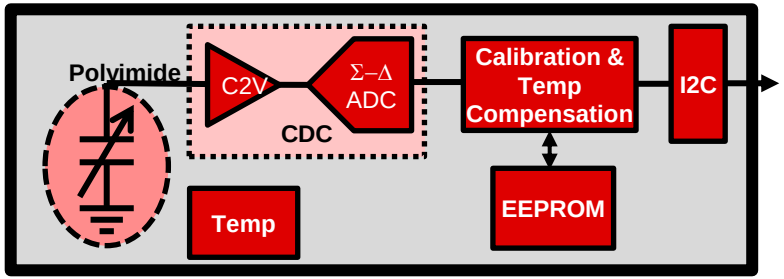


Tools to Win – HDC design resources

EVMs, Reference Designs, App Notes

EVMs

HDC1010EVM - HDC1080EVM

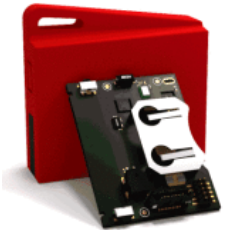
- Evaluate HDC1010 - HDC1080 Humidity and temperature sensor
- User friendly OneGUI interface
- Powered by USB

Application Notes/ Training

- HDC1xxx application note
- HDC1010EVM - HDC1080EVM user guide
- Wireless Sensor Node

TI Designs

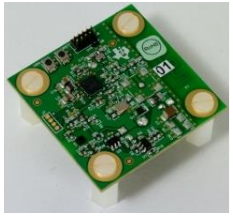
TIDC-CC2650STK-SENSORTAG



- 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 kit from anywhere
- Multi-standard support enables ZigBee or 6LoWPAN through a simple firmware upgrade

TI Designs

TIDA-00374 **Humidity & Temp Sensor Node for Star Networks Enabling 10+ Year Coin Cell battery life**

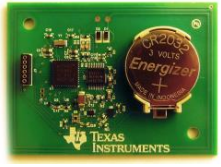


- Use of Nano-Power System Timer to Duty-Cycle the System Results in 10+ Year Battery Life from CR2032 Coin Cell
- Configurable System Wakeup Interval
- Extremely Low Off-State Current (183 nA for 59.97 seconds)
- Ultra Low On-State Current Due to Low Active Processor and Radio Transmit Currents (4.04 mA for 30 ms)
- ±2% Relative Humidity Accuracy
- ±0.2°C Temperature Accuracy

TIDA-00488 **Humidity & Temp Sensor Node for Sub-1GHz Star Networks Enabling 10+ Year Coin Cell battery life**

- 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 (270 nA for 59.97 seconds)
- Ultra-Low On-State Current Due to Low Active Processor and Radio Transmit Currents (3.376 mA for 30 ms)
- ±2% Relative Humidity Accuracy
- ±0.2°C Temperature Accuracy

TIDA-00524 **Ultralow Power Multi-sensor Data Logger with NFC Interface Reference Design**



- 5 Year Battery Life on a CR-2032 coin cell
- RF430 NFC Dynamic Tag Type 4B Compliant Communication
- NFC configuration and data read back
- Multiple Sensor Options
  - Temperature (TMP112)
  - Ambient Light (OPT3001)
  - Humidity + Temperature (HDC1000)
- Up to 64KB of non-volatile FRAM memory
- Data is Date/Time stamped using RTC

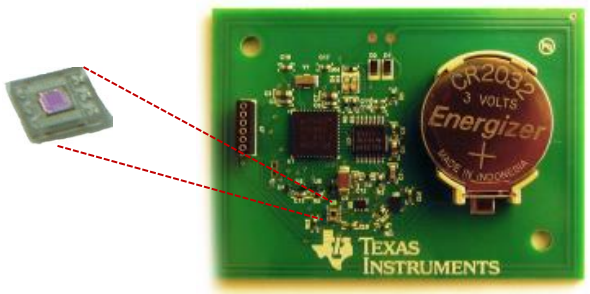
TI Optical Sensors Solutions for Cold Chain

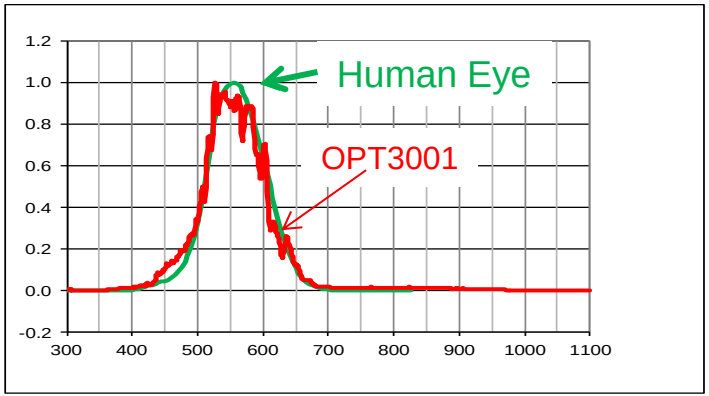
Optical Sensors

TI's Ambient Light

OPT3001: Precision Human Eye Matching

Features:
- >99% IR Rejection
- 23-Bit Effective Resolution
- 0.01 Lux to 83K Lux
- 2.5uA (max) Quiescent Current
- 2.0 x 2.0mm





MSP430 Microcontrollers

- TI MCU Overview
- MSP430 FRAM Advantages
- TI MCU Solutions for Cold Chain

Industry-Leading MCU Portfolio

Low-Power MCUs

- More than 500 low-power MCUs
- Industry's lowest power MCU
- The world's only embedded FRAM MCU family
- Combines smart analog with low system power to fit any power budget
- Broad range of applications include smart grid, wearables, sensors and cold chain

Performance MCUs

- More than 275 high-performance MCUs
- Specialize in control loop and functional safety applications
- Includes support for functional safety standards like IEC61508 and ISO 26262
- Broad range of applications include motor control, industrial drives, digital power, functional safety and transportation

Wireless MCUs

- Support for more than 14 wireless connectivity technologies – focus on ease of use and low power
- Enable faster IoT designs to connect everything
- Broad range of applications include building automation, wearables, sensors and smart grid

TI Confidential – NDA Restrictions

TI's Low-Power Microcontroller Solutions

16-bit MSP430 MCUs

- The industry leader in ultra-low-power, rich peripherals and analog integration.
- World's only portfolio of ultra-low-power embedded FRAM MCUs.
- Growing portfolio of more than 500 low-power MCUs

32-bit MSP432 MCUs

- Industry's lowest power ARM® Cortex®-M4F MCUs. Period.
- High performance MCUs without sacrificing power consumption.
- Sampling 256KB today.

SimpleLink Wireless MCUs

- Focus on ease of use and low power.
- Support for more than 14 Bluetooth Smart, Sub-1 GHz, 6LoWPAN, ZigBee and more.
- Portfolio includes SimpleLink Wi-Fi and new ultra-low power platform.

MSP430 FRAM Advantages

Texas Instruments

New Design Challenges

Application Energy	Designers adding functionality with a reduced or equivalent energy budget
Debugging	Designers spend 75+ percent of their time figuring out where power is “leaking” in their system
Complexity	Embedded software is becoming more complex, increasing memory requirements, energy budget and time to market
Future Development	Designers depend on a scalable portfolio to leverage hardware and software investments in future projects

Introducing the FRAM Advantage

Low power and fast writes

- Because you spend so much time in standby, current consumption as low as 350 nA
- When your application wakes up, 100µA/MHz active mode current for efficient operation
- Write quicker to save power; 13 KB in milliseconds, not seconds

Smart designs and cost saving

- Adjust to changing memory requirements with flexible non-volatile FRAM; store your application, data or both
- Restore your system state after power failure with two lines of code and no backup power source
- Update your system over the air with on-the-fly, bit level data writes and no buffering or pre-erase required

Reliability and robustness

- Log data continuously with 10^{15} write endurance and proven 10 year data retention at 85° C
- Prevent unauthorized memory and data communication access with IP encapsulation and hardware AES
- Diminish data loss with undetectable soft error rates and other inherent security advantages of FRAM

All-in-one: FRAM Delivers Max Benefits

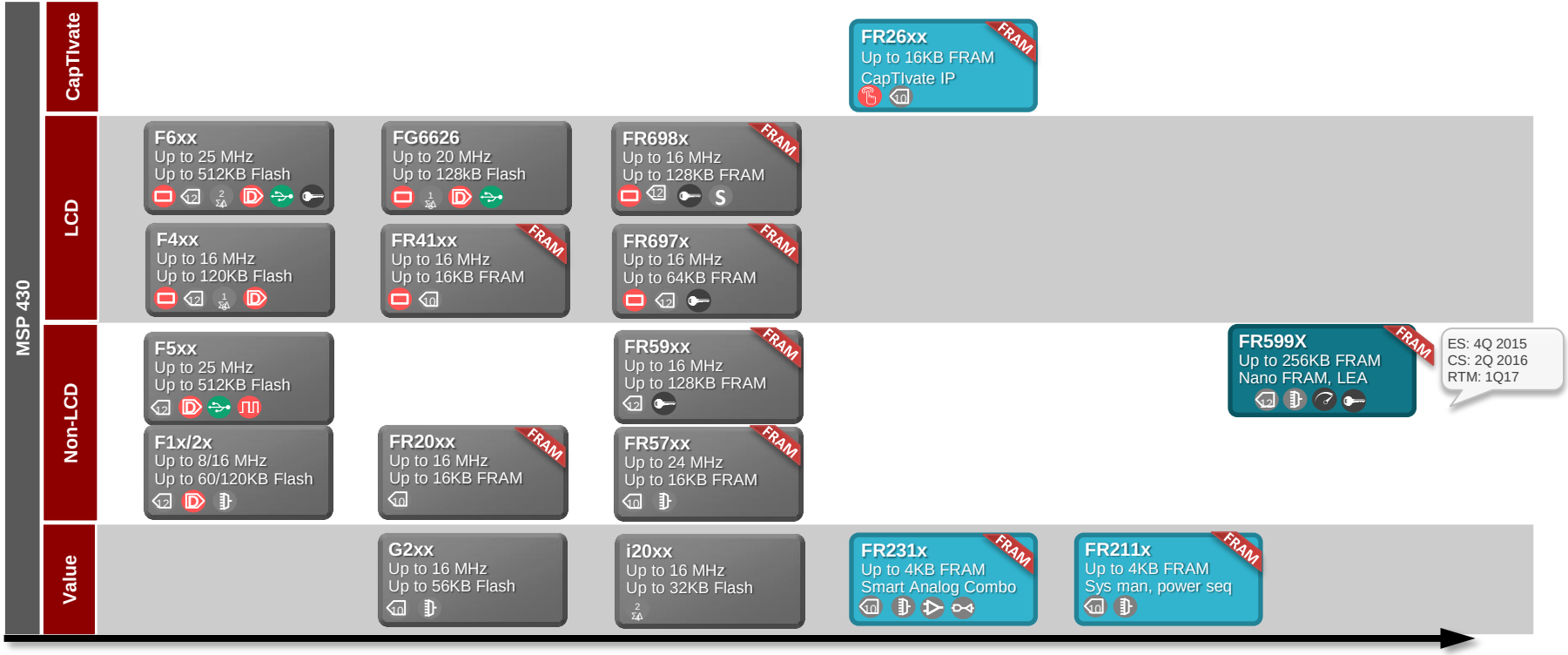
All-in-one: FRAM MCU delievers max benefits				
Specifications	**FRAM**	**SRAM**	**EEPROM**	**Flash**
Non-volatile *Retains data w/o power*	Yes	No	Yes	Yes
Write speed *(13 KB)*	10ms	<10ms	2 secs	1 sec
Average active Power [µA/MHz] *16 bit word access by the CPU*	100	<60	50,000+	230
Write endurance	10^{15}	Unlimited	100,000	10,000
Soft Errors	Below Measurable Limits	Yes	Yes	Yes
Bit-wise programmable	Yes	Yes	No	No
Unified Memory *Flexible code and data partitioning*	Yes	No	No	No

Customers can learn more at: www.ti.com/fram

MSP430 Roadmap

Sensing & Measurement portfolio

Concept
Development
Sampling
Production



Datalogging

Asset Tracking – MSP430FR5969

- Integrated Low-power RTC
  - Wake-up at precise intervals and pull information
- Over-the-air System Updates
  - Write data on-the-fly: no buffering & no pre-erase
- 64kB of Non-volatile FRAM
  - Log data quickly and over extended periods of time

System Management and Data Buffering

Electronic Labels – MSP430FR5869

- Low-power system management
  - Only wakeup when needed
- Fast Non-volatile Writes for Screen Refresh
  - Update displays quickly
- Unified Memory
  - Reduce MCU cost when industry standard Flash to RAM ratios are not ideal

TIDesign for Cold Chain Applications

get ahead of competition with TI complete reference solutions

Ultralow Power Multi-sensor Data Logger with NFC Interface Reference Design (TIDA-00524)

For Cold Chain Management

TIDesigns

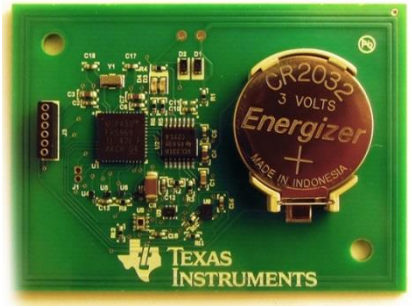
Solution Features

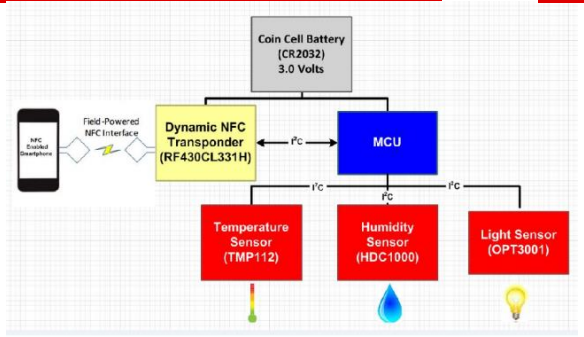
- MSP430 FRAM has unified memory, low power writes, faster writes, high endurance, security, etc.
- RF430 NFC Dynamic Tag Type 4B Communication
- Multiple Sensor Options & Configurations
  - Temp (TMP112)**
  - Temp + Humidity (HDC1000)
  - Ambient Light (OPT3001)
- 5 Year battery life

Solution Benefits

- Encrypted Memory
- NFC:
  - Transform Smartphone in portable data log reader
  - Potential for hermetically sealed enclosures
  - Retrieve data log even when battery is dead
- Mix / Match sensors to achieve the desired power/price point.

System Level View

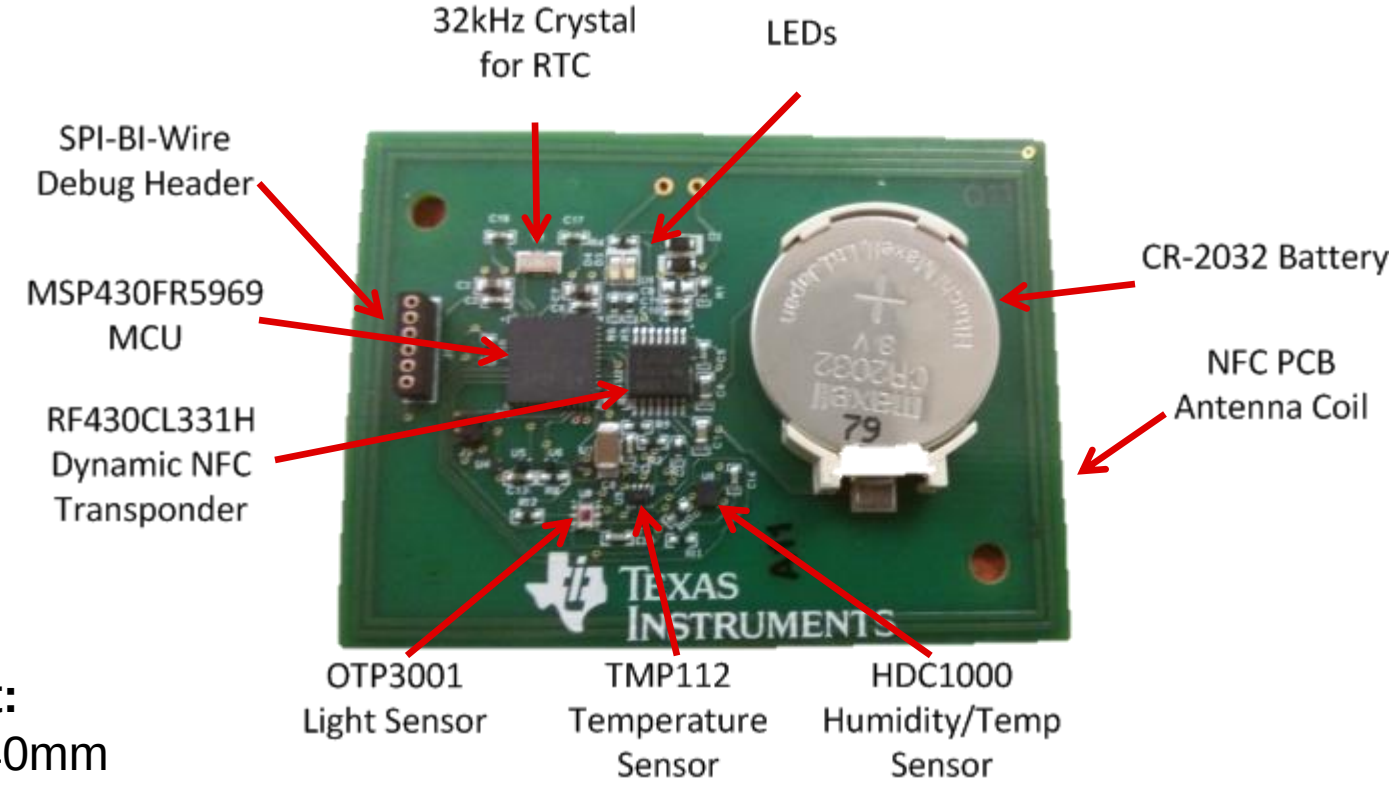




Resources

- Check out TIDA-00524 here
- Check out video here
- Order EVM here
- Download Datasheet here

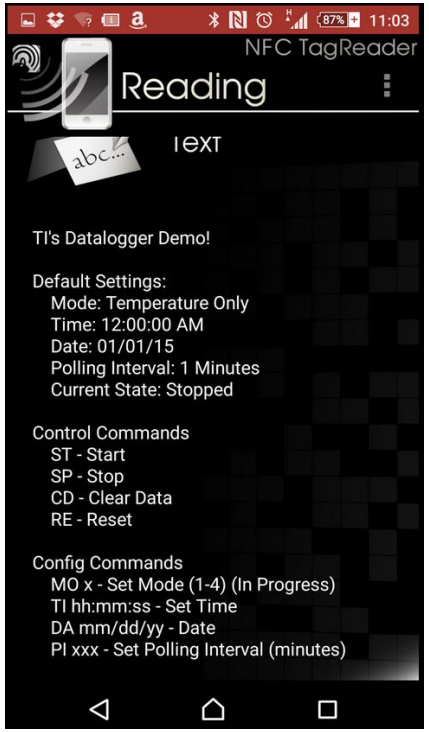
Hardware



Footprint:
55mm x 40mm

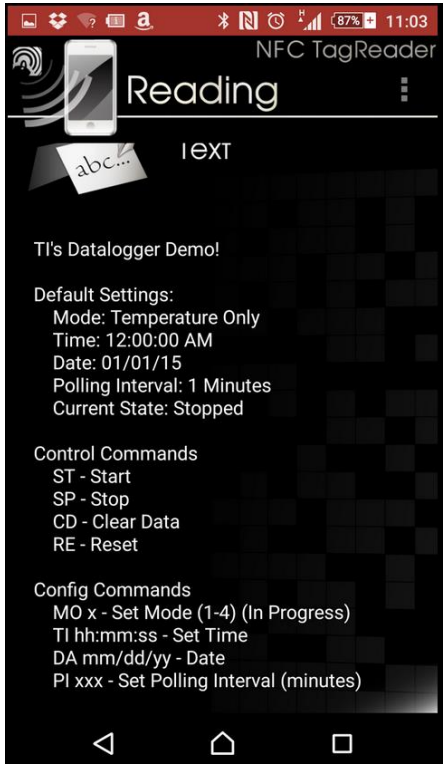
Design Features

- Communicates with NFC enabled phone using existing Reader/Writer applications(phone must support Reader/Writer mode)
- “Over the air” Configuration
- Data is Date/Time stamped using RTC
- CR-2032 Battery life of >5 Years
- Read Data stored in FRAM even when battery is depleted(RF energy harvesting)



Configuration Options

- **Control Commands**
  - ST – Start Measurements
  - SP – Stop Measurements
  - CD – Clear Measurement Data
  - RE – Reset all configurations, Measurement data, and Date/Time
- **Configuration Commands**
  - MO x – Set Mode(Temp, Light, Temp+Light, Humidity + Temp)
  - TI hh:mm:ss – Set Time
  - DA mm/dd/yy – Set Date
  - PI xxx – Set Polling Interval(minimum: 1min)



Command list is displayed when reading data logger

Dynamic Field-Powered NFC Reference Design for Data Logging, Access Control, and Security Applications

TI Designs Number: TIDA-00217

TIDesigns

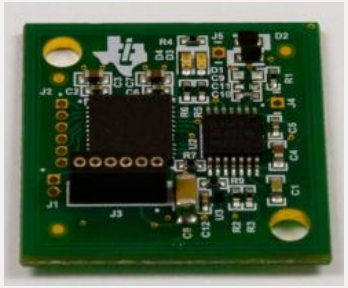
Solution Features

- RF430CL330H dynamic NFC transponder enables static tag emulation
- NFC type 4B compliant
- NFC/RFID protocol handled in ROM code
- Wireless sensor interface
- Low power: NFC reader provides transmission power
- Uses either field or bus power

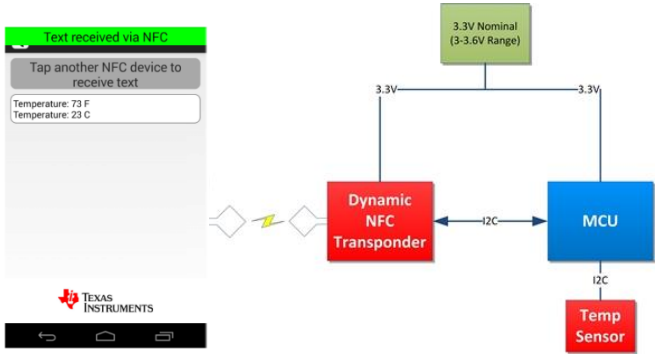
Solution Benefits

- User can receive updated information from a field unit including part authentication, sensing data, data logging, or security applications
- NFC devices in most modern cellphones
- Small size allows tags to be embedded in wrist straps, bracelets, key cards, etc.
- Battery-less sensor interface

Tools & Resources



- **TIDA-00217 Tools Folder**
- **User Guide**
- **Video**
- **Device Datasheets**:
  - RF430CL330H
  - MSP430FR5969
  - TMP103
  - TPD1E10B06



Humidity & Temp. Sensing Node for 2.4-GHz Star Networks Enabling 10+ Year Coin Cell Battery Life

TI Designs Number: TIDA-00374

TIDesigns

Solution Features

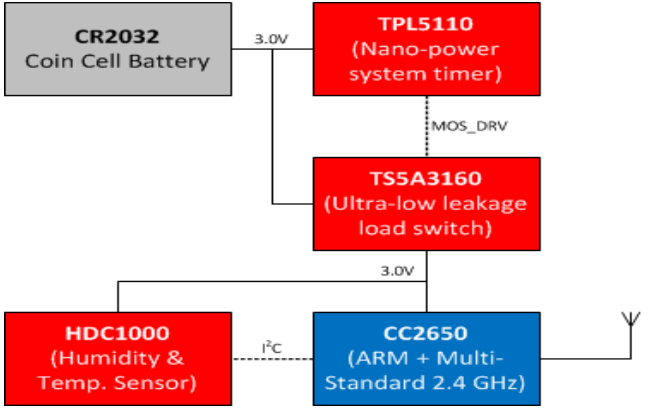
- Configurable System Wakeup Interval
- Extremely low off-state current (183 nA for 59.97 s)
- Ultra low on-state current due to low active processor and radio transmit currents (4.04 mA for 30 ms)
- ±3% Relative Humidity Accuracy
- ±0.2°C Temperature Accuracy
- Multi-standard 2.4 GHz radio

Solution Benefits

- Use of Nano-Power System Timer to Duty-Cycle the System Results in 10+ year battery life from CR2032 coin cell
- Small, integrated solution size due to the integrated sensor and radio SoC

Tools & Resources

- **TIDA-00374 Tools Folder**
- **User Guide**
- **Device Datasheets**:
  - HDC1000
  - TPL5110
  - TS5A3160
  - CC2650



Humidity & Temp. Sensing Node for Sub-1 GHz Star Networks Enabling 10+ Year Coin Cell Battery Life

TI Designs Number: TIDA-00484

TIDesigns

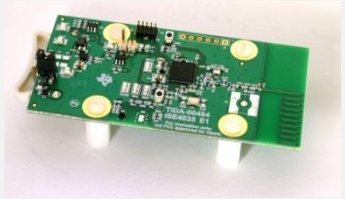
Solution Features

- Configurable System Wakeup Interval
- Extremely low off-state current (270 nA for 59.97 s)
- Ultra low on-state current due to low active processor and radio transmit currents (3.376 mA for 30 ms)
- Extended transmit range due to Sub-1 GHz radio
- ±3% Relative Humidity Accuracy
- ±0.2°C Temperature Accuracy

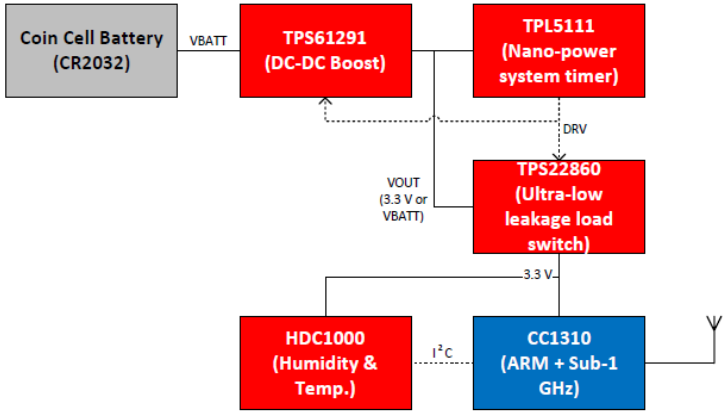
Solution Benefits

- Use of Nano-Power System Timer to Duty-Cycle the System Results in 10+ year battery life from CR2032 coin cell
- Small, integrated solution size due to the integrated sensor and radio SoC

Tools & Resources



- TIDA-00484 Tools Folder
- User Guide
- **Device Datasheets**:
  - HDC1000
  - TPL5111
  - TPS22860
  - TPS61291
  - CC1310



Your one stop shop for Cold Chain

- Sensors (Temperature, humidity, light, and more…)
- Low power microprocessors
- Non-Volatile FRAM memory
- Broad range of RF technologies
- More (power, ADCs, protection, isolation…)

- Accelerate your projects with TIDesigns

Thank You!

Texas Instruments