TI Designs
Passive NFC Temperature Patch Reference Design

TI Designs

TI Designs provide the foundation that you need including methodology, testing and design files to quickly evaluate and customize the system. TI Designs help *you* accelerate your time to market.

Design Resources

TIDA-00721	Design Folder
LMT70	Product Folder
RF430CL330H	Product Folder
ADS1113	Product Folder
MSP430G2403	Product Folder

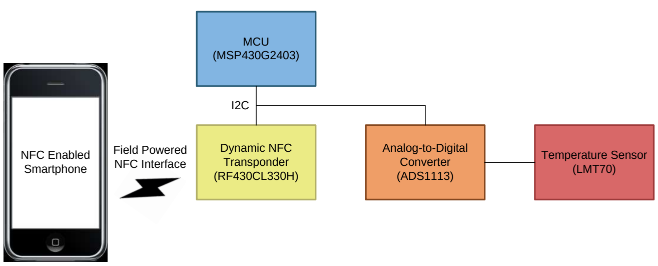
TI E2E™ Community — ASK Our E2E Experts

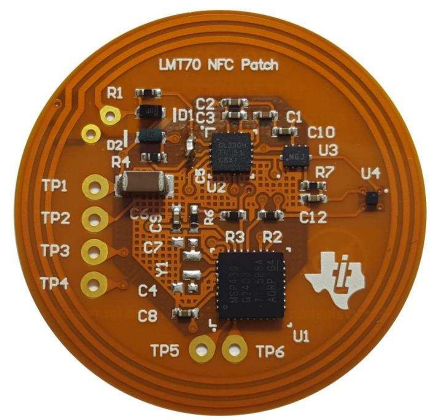
Design Features

- High Accuracy (< 0.2°C) Temperature Sensing System
- Battery-less/Passive NFC Tag
- RF430CL330H NFC Dynamic Tag Type 4B Compliant Communication
- Data Read Back From Any NFC Reader
- Integrated PCB Antenna

Featured Applications

- Skin Temperature Measurement
- Battery-Less Temperature Monitoring





Android is a trademark of Google Inc.

1 Key System Specifications

Table 1 shows the key system specifications.

Table 1. Key System Specifications

PARAMETER	SPECIFICATIONS AND FEATURES	DETAILS
Operating power supply range	2.0 V to 3.0 V	Section 3.1
Operating temperature	–40°C to 85°C	Section 7.1
RF Protocol	ISO4443B	Section 3.1.2
NFC operating frequency	13.56 MHz	Section 3.1.2
Form factor	22 mm diameter round flex PCB	Section 5.1
Sensors	Sensor: Temperature (LMT70) Operating Temperature Range: –55°C to 150°C Temperature Accuracy: 0.13°C (max) 20°C to 42°C 0.36°C (max) –55°C to 150°C	Section 3.1.1

2 System Description

The Passive NFC Temperature Patch Reference Design measures local temperature and transmits the data from the NFC tag to a NFC reader such as an NFC enabled smart phone.

Temperature is measured with the LMT70 high accuracy analog temperature sensor that interfaces with the 16-bit ADS1113 analog-to-digital converter (ADC). After the temperature data is digitized, the data is sent to the MSP430G2403 microcontroller which stores the data and then sends it to the RF430CL330H NFC transponder. The RF430CL330H bundles the data into the NFC protocol and sends it to a NFC reader.

The Passive NFC Temperature Patch Reference Design is a passive NFC tag that is powered by harvesting the NFC RF field. The NFC Temperature Patch is only functional within the RF field of the NFC reader.

3 Block Diagram

Figure 1 shows the system block diagram.

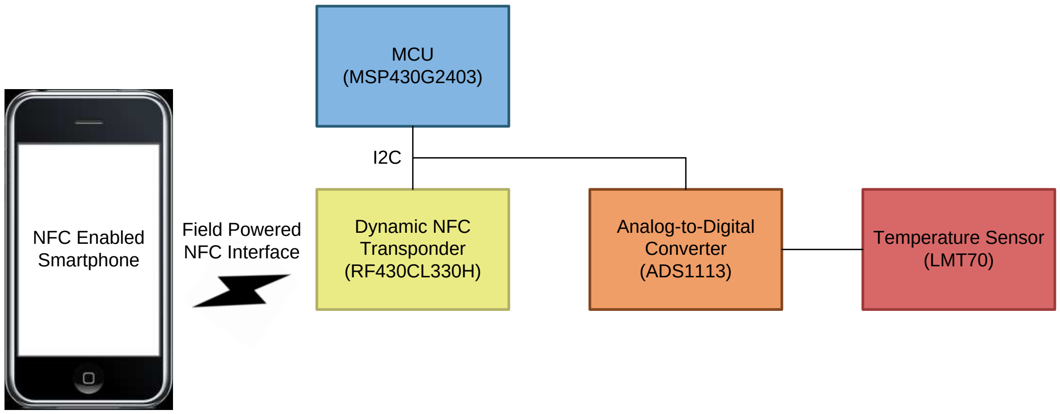


Figure 1. System Block Diagram

3.1 Highlighted Products

The Temperature Sensor NFC Patch Reference Design features the following devices:

- LMT70
  – High accuracy analog temperature sensor
- RF430CL330H
  – Dynamic NFC interface transponder
- ADS1113
  – 16-bit Sigma-Delta ADC with built in reference
- MSP430G2403
  – Low-power mixed signal microcontroller

For more information on each of these devices, see their respective product folders at www.ti.com.

3.1.1 LMT70 Description

The LMT70 is a high accuracy analog output temperature sensor with an output enable pin. This temperature sensor has a linear output with a slope of –5.19mV/°C. The LMT70 has an accuracy is 0.13°C between the human body temperature range of 20°C to 42°C and 0.36°C over the full operating temperature range of –55°C to 150°C. The part comes in a small chip scale package (WCSP), measuring 0.88 mm x 0.8 mm.

Figure 2 shows the LMT70 block diagram.

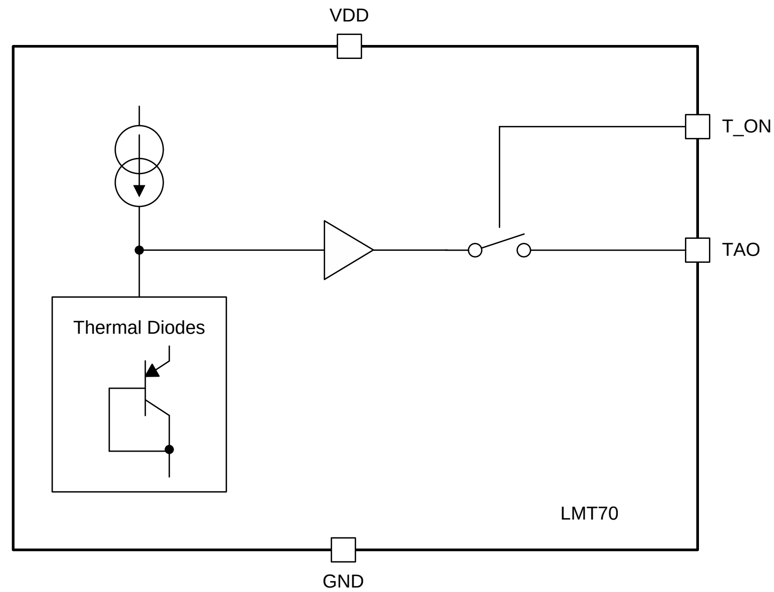


Figure 2. LMT70 Block Diagram

3.1.2 RF430CL300H Description

The RF430CL330H Dynamic NFC Interface Transponder is an NFC Tag Type 4B device that combines a wireless NFC interface and a wired SPI or I2C interface to connect the device to a host. The NDEF message in the SRAM can be written and read from the integrated SPI or I2C serial communication interface and can also be accessed and updated wirelessly through the integrated ISO14443B-compliant RF interface that supports up to 848 kbps. The RF430CL330H allows for a low cost, dual interface (wired and wireless) transponder which allows for communication to and from a host controller. This functionality is not possible with a standard passive NFC transponder (wireless only).

Figure 3 shows the RF430CL330H block diagram.

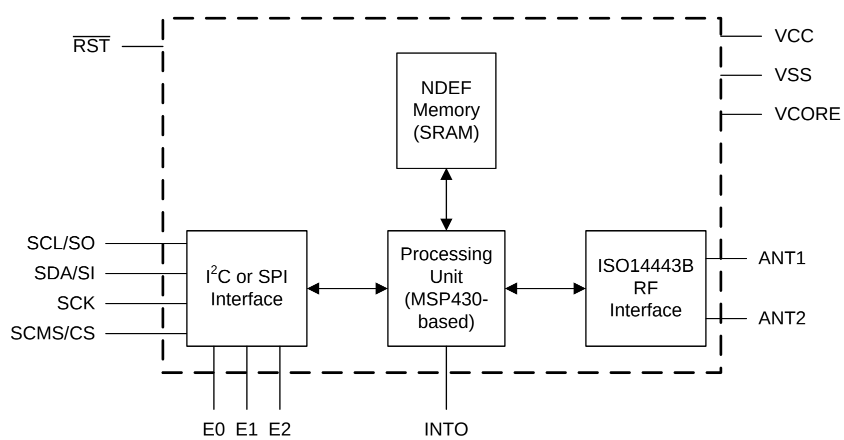


Figure 3. RF430CL330H Block Diagram

3.1.3 ADS1113 Description

The ADS1113 is a 16-bit sigma-delta analog-to-digital converter (ADC) with an integrated voltage reference and oscillator. The power supply of the ADS1113 ranges from 2.0 V to 5.5 V and draws 150 uA in continuous mode and 500 nA in power down mode. The ADS113 communicates with a host through an I2C interface and features four hard programmable addresses. The precision ADC samples at a maximum of 860 samples per second and can either operate in continuous or single-shot modes.

Figure 4 shows the ADS1113 block diagram.

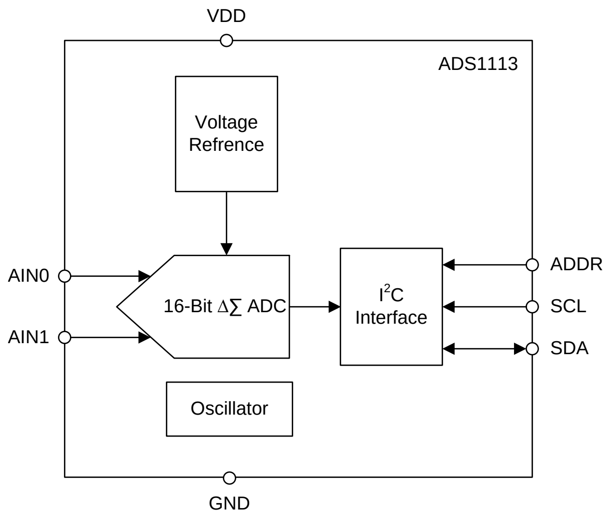


Figure 4. ADS1113 Block Diagram

3.1.4 MSP430G2403 Description

The MSP430G2403 is included in the low cost and ultra-low-power family of MSP430 microcontrollers. The low-power features make it ideal for energy strained systems. The various peripherals such as timers and serial communication protocols allow flexibility in system designs.

Figure 5 shows the MSP430G2403 block diagram.

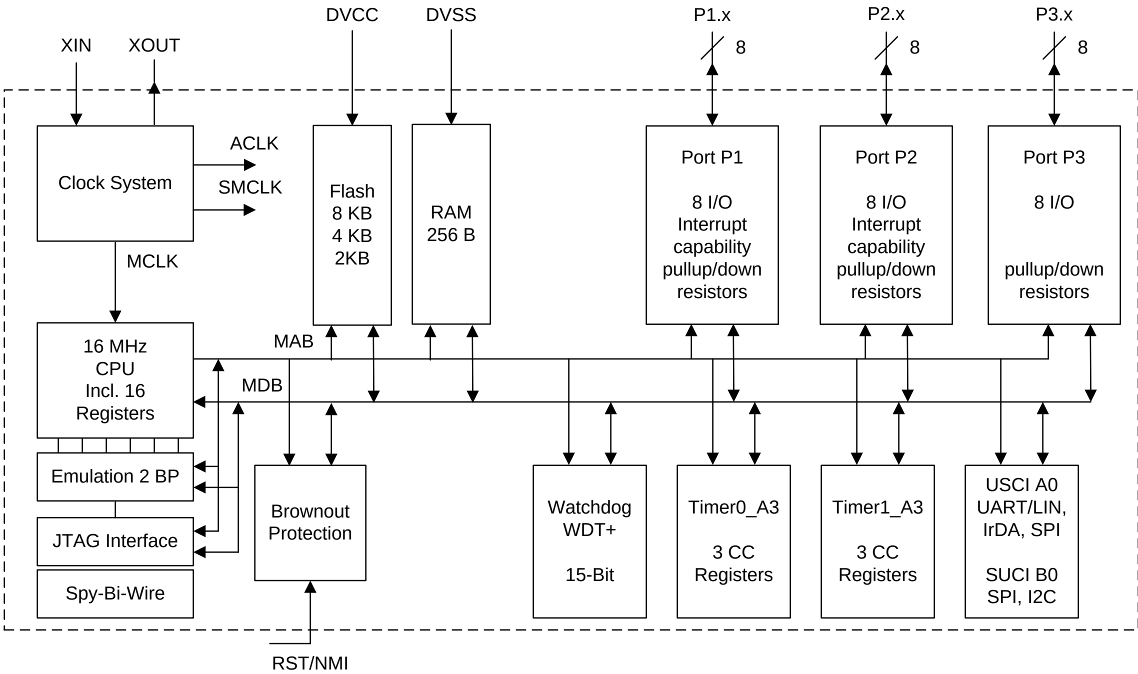


Figure 5. MSP430G2403

4 System Design Theory

4.1 Component Selection

4.1.1 Analog Temperature Sensor

The LMT70 was chosen for this TI Design for its high accuracy specifications of 0.05°C (typical) and 0.13°C (max) in the human body temperature range of 20-42°C and 0.36°C (max) over the full operational range of –55°C to 150°C. The power supply range of the LMT70 is between 2.0 V and 5.5 V which makes it useable for battery powered or RF energy harvested applications. The LMT70 comes in a 0.88 mm x 0.88 mm chip scale WCSP, which is optimal for space constrained boards.

4.1.2 Dynamic Interface Transponder

The RF430CL330H Dynamic NFC Interface Transponder is an NFC Tag Type 4B device that combines a wireless NFC interface and a wired I2C interface to connect the device to a host. The device utilizes a 3KB SRAM buffer to receive commands from an NFC enabled reader/writer and also communicate back the response. The integrated ISO14443B-compliant RF interface supports data rates from 106 kbps to 848 kbps. The RF430CL330H was chosen to allow for a low cost, dual interface (wired and wireless) transponder which allows for communication to and from a host controller. This functionality is not possible with a standard passive NFC transponder (wireless only).

4.1.3 Analog-to-Digital Converter

The ADS1113 16-bit sigma-delta analog-to-digital converter was chosen to interface with the LMT70 for its precision specifications. The ADC also comes with a built-in voltage reference which reduces both the BOM count and space on the board.

4.2 Microcontroller Selection

The MSP430G2403 was primarily chosen to interface with the LMT70, RF430CL300H, and ADS1113 through the I2C interface. Because few IO’s and peripherals were used, the low pin count and package version of this MSP430 was selected. This microcontroller includes low-power modes for low-power applications.

5 Getting Started Hardware

5.1 Hardware Overview

The NFC Temperature Patch Reference Design is shown in Figure 6. This reference design contains a round flex PCB (FPC) form factor with a diameter of 32 mm.

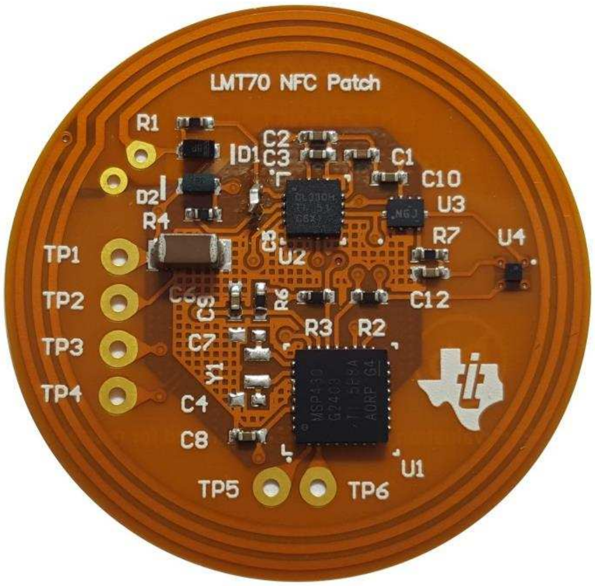


Figure 6. NFC Temperature Patch Reference Design

The board comes with 6 vias/pads that allow programming the onboard MSP430G2403 microcontroller.

Table 2 shows the test point functionality of the system.

Table 2. Test Point Functionality

TEST POINT	FUNCTION
TP1	VDD
TP2	GND
TP3	SBWTDIO
TP4	SBWTCK
TP5	UART_RX
TP6	UART_TX

All components are located on the top side of the board. The antenna coil wraps around the perimeter of the board on both the top and bottom layers.

5.2 Programming the Board

An MSP-FET must be used to program the Reference Design board. The appropriate connections between the Reference Design hardware and the MSP-FET programming tool are shown in Table 3. For convenience, the pinout diagram of the MSP-FET debugger is shown in Figure 7. Once the electrical connections between the board and the MSP-FET are made, then Code Composer Studio may program the board.

Table 3 shows the TIDA-00721 test points to the MSP-FET pinout.

Table 3. TIDA-00721 Test Points to MSP-FET Pinout

TIDA-00721 TEST POINT	TIDA-00721 TEST POINT NAME	MSP-FET PIN NUMBER	MSP-FET PIN NAME
TP1	VDD	2	VCC_TOOL
TP2	GND	9	GND
TP3	SBWTDIO	1	TDO/TDI
TP4	SBWTCK	7	TCK

Figure 7 shows the MSP-FET JTAG connector pinout.

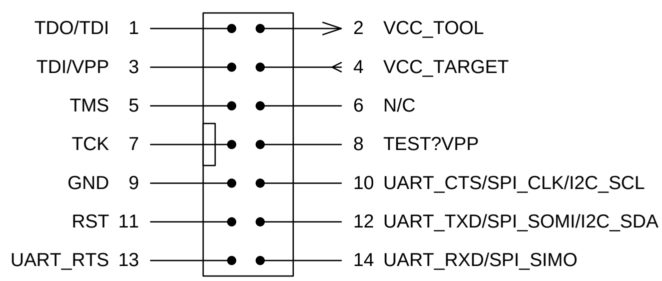


Figure 7. MSP-FET JTAG Connector Pinout

5.3 Reading the Temperature Data

The Passive NFC Temperature Patch Reference Design comes pre-programmed and ready to use. Install any app that can read NFC NDEF messages. For this document and reference design, the Android™ OS system reads NDEF data from the Passive NFC Temperature Patch. After installing the NFC application, enable NFC connectivity, then hover near the Passive NFC Temperature Patch Reference Design with the phone. The following must appear on the screen:

Figure 8 shows the temperature data.

Figure 8. Temperature Data

6 Getting Started Firmware

6.1 Subsection

The firmware for the Passive NFC Temperature Patch Reference Design may be found in the firmware download link located at TIDA-00721.

Figure 9 shows the firmware flow design.

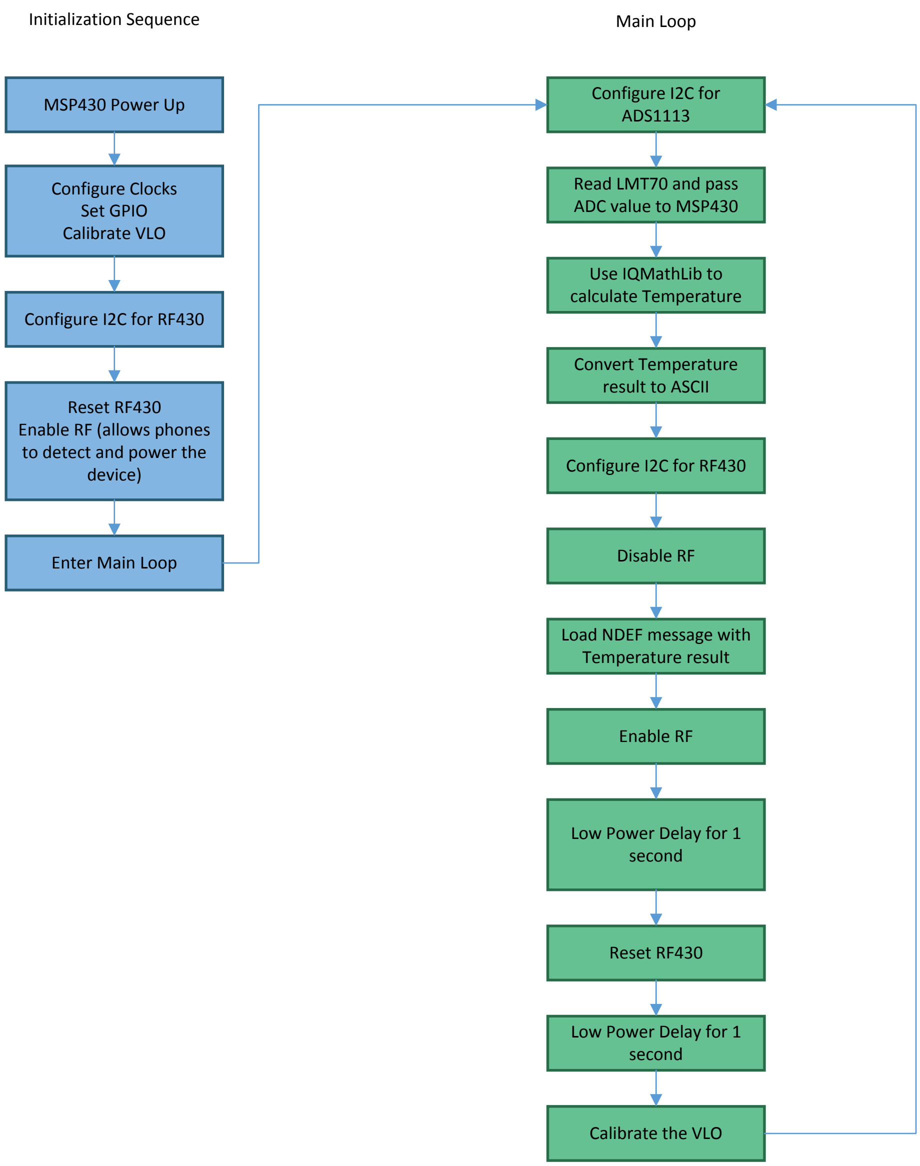


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Figure 9. Firmware Flow Design

6.2 NFC Overview

The NFC Forum defines a data format for NFC messages called NDEF (NFC Data Exchange Format). Utilization of a common data format allows for all NFC compliant devices to exchange data in a well known format. NDEF allows for different record types including text records, URL, Vcard, and Bluetooth Connection Handover. In this application, text records display the measurements.

Figure 10 shows an example of a NDEF tag application mapping.

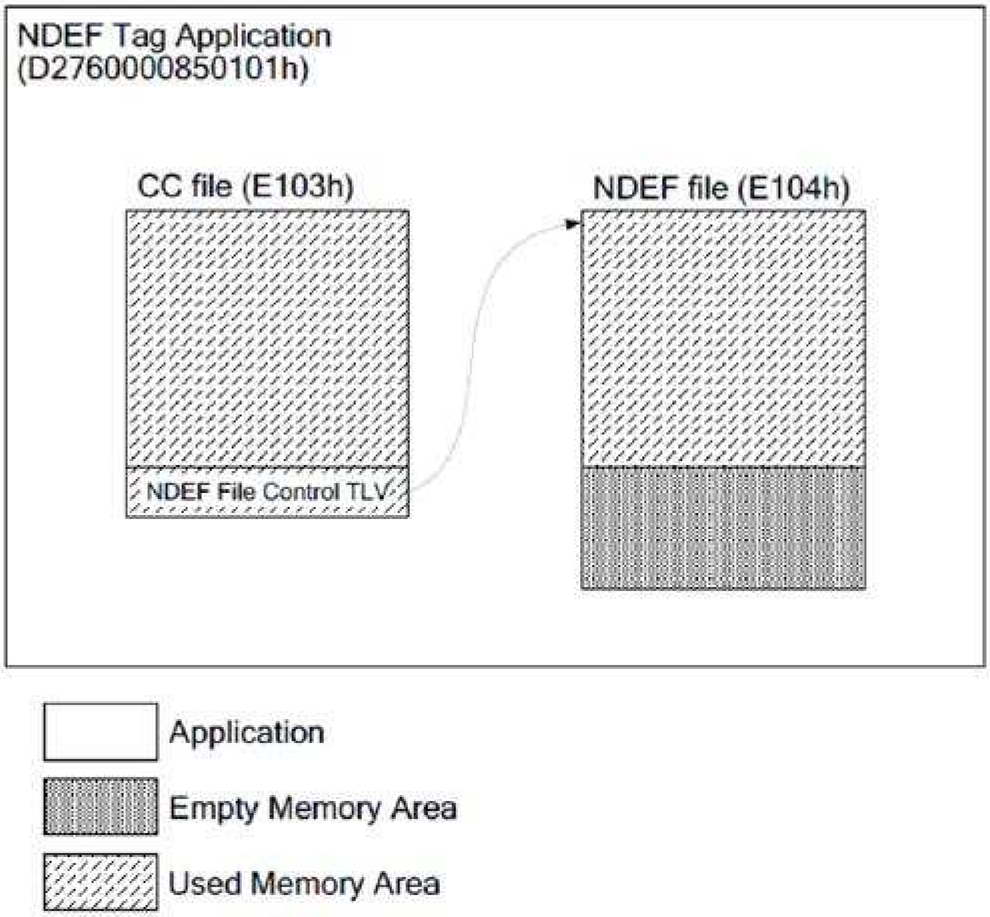

Figure 10. NDEF Tag Application Mapping Example

A state machine in the NFC stack that emulates this NDEF memory structure. The RF430CL330H generates requests for each file as required to respond to the NFC reader. The RF430CL330H supports files up to 64 KB. This enables streaming of all the measurements in a single NDEF message, preventing tapping the phone more than once or needing custom applications.

7 Test Setup

7.1 Temperature Characterization

Typical temperature characterization cannot be used. Instead a temperature controlled oil bath measured an accurate temperature. Ovens (which are typically used) have turbulent air flows with gradients of various temperatures within the chamber which is not ideal for accurate temperature testing. A temperate controlled oil bath involves placing an object in a hot or cool oil based liquid. Once dipped into the oil, a controlled medium surrounds the object. Additionally, a high accuracy RTD probe was used as a temperature reference.

The Passive NFC Temperature Patch Reference Design was designed to measure human skin temperature (20°C — 42°C).

Figure 11 shows the NFC temperature sensor patch accuracy at human body temperature.

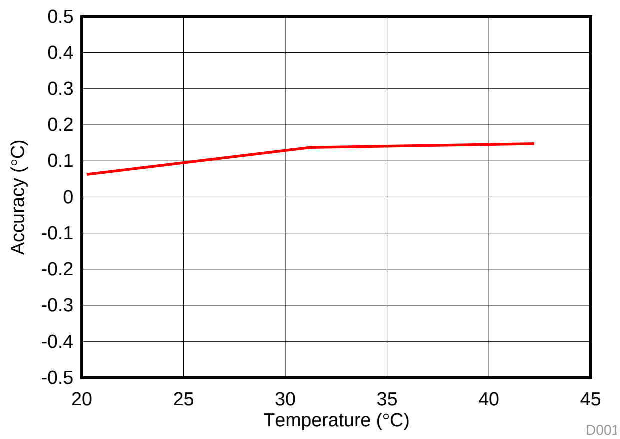

Figure 11. NFC Temperature Sensor Patch Accuracy at Human Body Temperatures

The Passive NFC Temperature Patch is not limited to measuring human skin temperature. It may be placed anywhere where temperature must be measured. An accuracy plot of the operating temperatures of –40°C to 85°C is shown in Figure 12.

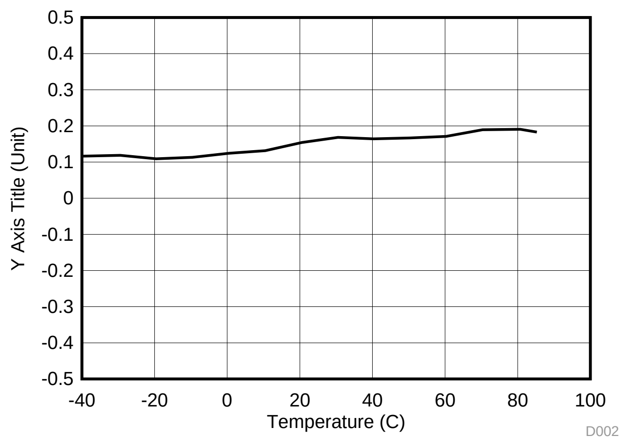

Figure 12. NFC Temperature Sensor Patch Accuracy at Full Temperature Range

7.2 Read/Write Distance

The measured communication range of NFC enabled smartphones is shown in Table 4. This data assumes a parallel orientation between the reader antenna and the tag antenna that provides the maximum magnetic field coupling.

Table 4. Communication Range

DEVICE	DISTANCE
Samsung Galaxy S6	2.2 cm
Samsung Nexus S	2.8 cm

7.3 Antenna Characteristics

The frequency response of the antenna is shown in Figure 13. Antenna tuning is necessary to keep the antenna resonant or close to the NFC operating frequency of 13.56 MHz to maximize data and power transfer. The average Q value for 300 boards is 24.63.

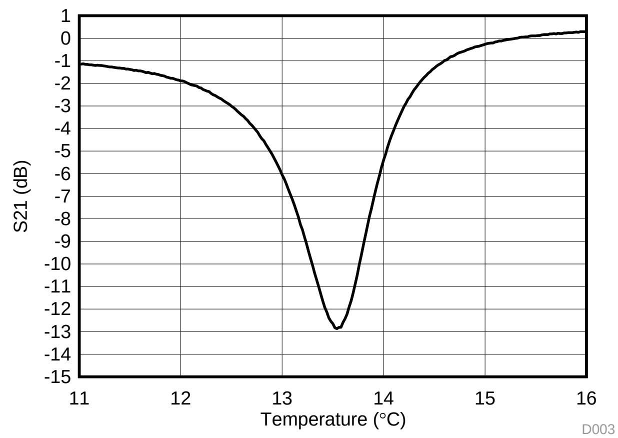

Figure 13. Frequency Response of TIDA-00721

8 Design Files

8.1 Schematics

To download the schematics for each board, refer to the design files at TIDA-00721.

Figure 14 shows the TIDA-00721 schematic.

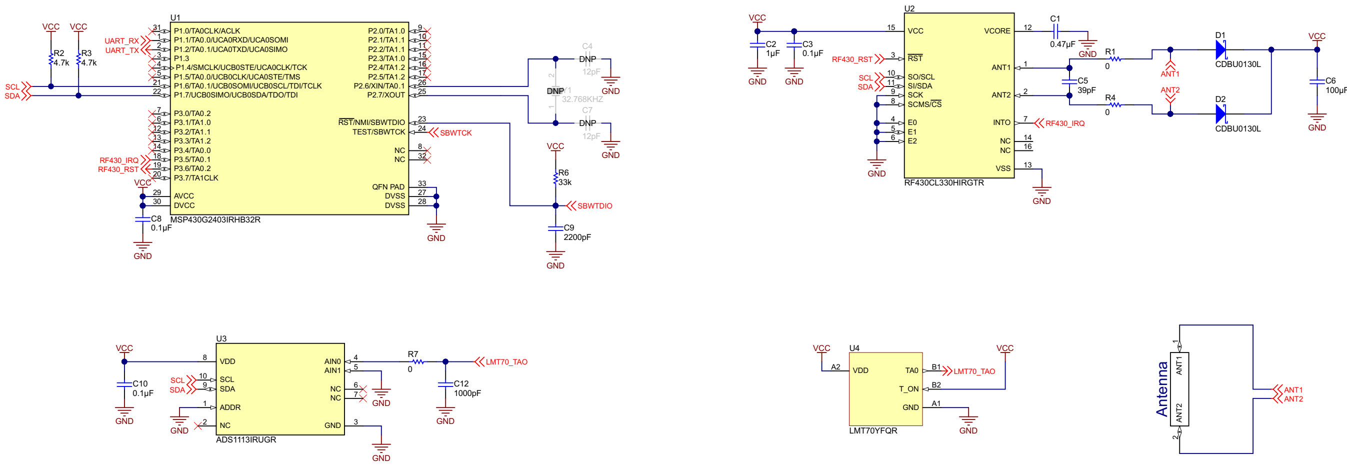

Figure 14. TIDA-00721 Schematic

8.2 Bill of Materials

To download the bill of materials (BOM) for each board, refer to the design files at TIDA-00721.

8.3 PCB Layout Recommendations

This TI Design contains devices with a BGA, because of the flexibility of flex PCB boards, and can pop off the board. A hatched VDD and ground pour covers the top and bottom layers of the flex PCB to provide rigidity.

The TI Design board includes an integrated PCB antenna which resonates at 13.56 MHz. To maintain a high Q value, TI recommends not placing any devices or traces within 4 mm of the antenna.

8.3.1 Layout Prints

To download the Layout Prints for each board, refer to the design files in TIDA-00721.

8.4 Altium Project

To download the Altium project files for each board, refer to the design file at TIDA-00721.

8.5 Layout Guidelines

Figure 15 shows the layout guidelines.

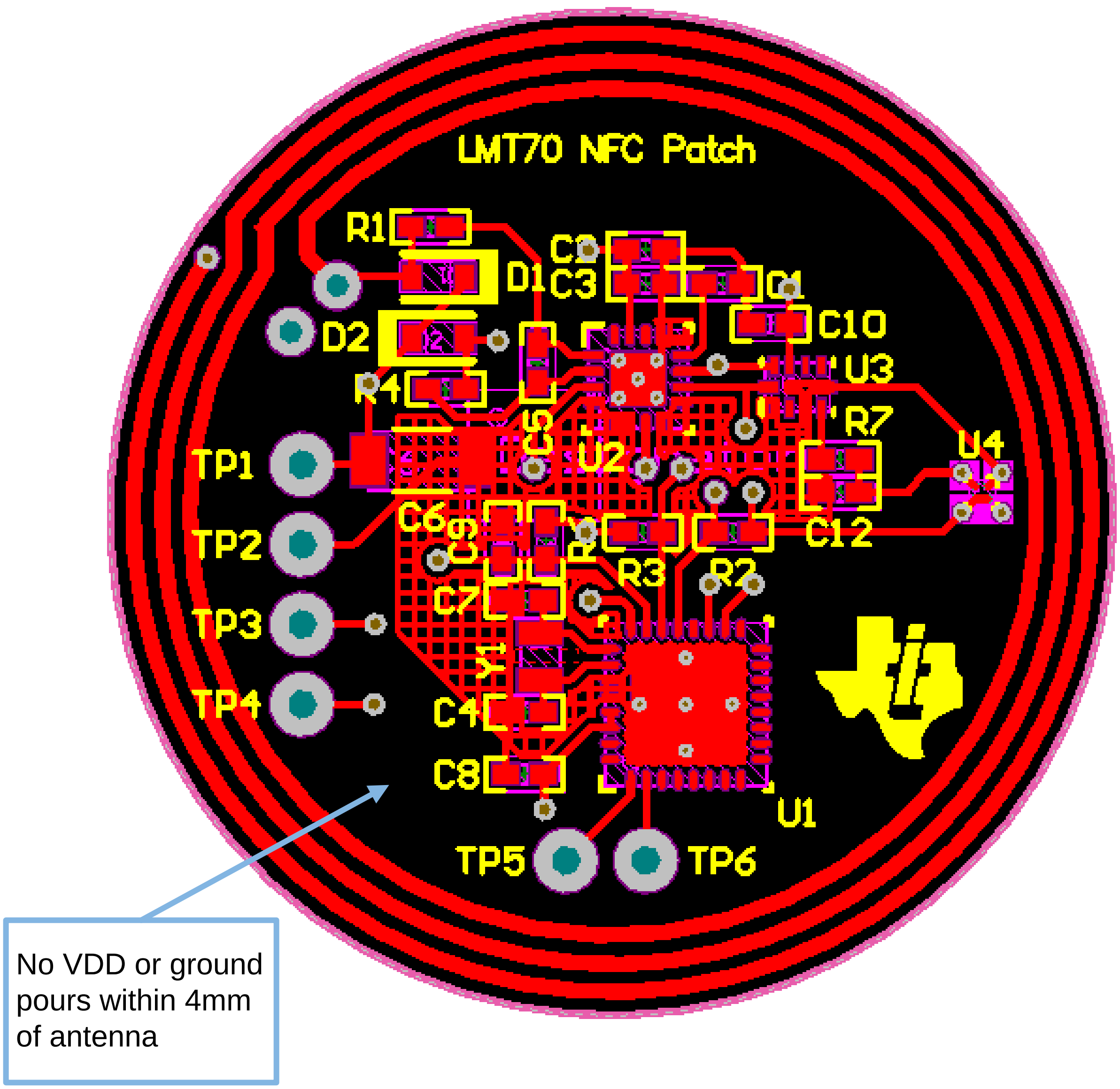

Figure 15. Layout Guidelines

9 Software Files

To download the software files for this reference design, refer to the software files at TIDA-00721.

10 References

1. LMT70 Datasheet (SNIS187)
2. RF430CL330H Datasheet (SLAS916)
3. ADS1113 Datasheet (SBAS444)
4. MSP430G2403 Datasheet (SLAS734)

11 About the Author

MICHAEL WONG is a Temperature Sensor Applications Engineer at TI where he is responsible for developing reference designs and supporting customer applications for the temperature sensor market. Michael brings to this role experience in temperature sensor system design and sensor validation. Michael earned his Masters of Science (MS) in Electrical Engineering from Santa Clara University and a Bachelor of Science (BS) in Electrical Engineering from San Jose State University.

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RALPH JACOBI is an Applications Engineer at TI working on the NFC/RFID applications team. He is focused on developing embedded firmware and application software for devices across TI's NFC/HF RFID portfolio using a variety of TI microcontrollers. Ralph also works with field sales and application teams to provide customer support, and is actively involved on TI's E2E forums. Ralph holds a BS in Electrical Engineering from the University of Florida and he is an Eagle Scout. Ralph has been at TI since 2014.

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