Smart Pill Bottle

MAXREFDES1150

Introduction

The MAXREFDES1150 is Maxim's smart pill bottle design for medical and broad IoT applications. This design uses an accurate weight scale and modern IoT communications to provide a complete system for patients and doctors to accurately and safely monitor their medicine intake. Furthermore, users can extend this concept to any consumable requiring refill and/or replenishment. The MAXREFDES1150 accepts an initial load of pills or tablets. The application then prompts the user for the quantity of pills and the frequency and amount of each dose. Automatic measurements validate that medicine is taken at the right time, or notifications are sent if medicine has not been taken. The design also includes an audible buzzer if the smart pill bottle is left on its side or upside down.

The 16-bit ADC MAX11213 lies at the heart of MAXREFDES1150, providing accurate measurement of the pill bottle load cell. The design conveniently works with Arduino and Arm® Mbed Enabled™ platforms and Bluetooth low energy (BLE)-enabled modules. The MAXREFDES1150 is suitable for a wide variety of IoT measurement applications requiring accurate analog-signal measurement and communication. It can be powered with a USB port to an Mbed® platform and then to the MAXREFDES1150 board, which is powered by the MAX6071 reference chip, so it can enhance the system accuracy. The reference design also includes an Android APK with HMI technology. The APK can be used to configure the pills parameter and be updated, if needed.

The MAXREFDES1150 reference design block diagram (Figure 1) demonstrates how it works. When the pill bottle is placed on the MAXREFDES1150 board's load-cell sensor, it captures and measures the results, then updates them to the APK. The MAXREFDES1150 includes microcontroller source files to enable developers to quickly evaluate and customize the design for their specific applications with minimal firmware or hardware changes. The board is designed in a compact form factor for rapid evaluation or installation.

Other features include the following:

- Low Power
- High Accuracy
- Bluetooth Module
- Mbed Platform

Hardware Specification

Input Range: 0g to 100g

Resolution: System should be capable of measuring a pill as low as 50mg mass.

Button: Calibration "CAL" button and Reset "RST" button.

Output: LED for tilt indication, alarm for incorrect information.

Interface: Android APP for device.

Power Consumption: Not including platform, shall not exceed 30mW during peak operation.

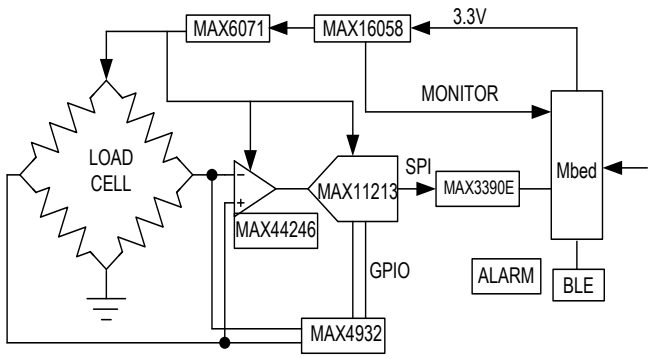

Figure 1. MAXREFDES1150 block diagram.

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Designed–Built–Tested

This document describes the hardware shown in Figure 2, Figure 3, and Figure 4. It provides a detailed systematic technical guide to design a smart pill box system, including load cell, signal conditioner, ADC and related firmware, APP. The system can measure less than 50mg pills with repeat accuracy. The system has been built and tested, details of which follow later in this document.

Note: The MAXREFDES1150 replaces the MAXREFDES141.

Design Procedure for Smart Pill Bottle

Step 1: Select the Load Cell

Because the input measure range is up to 100g, and we need high accuracy, we selected the 100g load cell. For this load cell, full range is 1.8mV at 3V power supply. The sensor max error is approximately 50mg.

For 50mg input, the output is approximately:

1.8mV/(100g/50mg) = 0.9µV, above the ADC floor noise (0.57µV at 10sps)

Count max: 100g/50mg = 2k pcs

Step 2: Select the ADC (MAX11213)

Because the requirement for our measure range is 0~100g, resolution = 50mg, we select the MAX11213.

For the MAX11213:

570nV$_{RMS}$ noise at 10sps, far below the least input requirement.

1 LSB = 3V/(2^{16} - 1) = 45.8µV, so gain = 45.8µV/0.9µV = 51 needed.

The MAX11213 has integrated gain up to 128.

Step 3: Design the Signal Chain

Once we determine the sensor and ADC, we can design the whole signal chain and interface as well as the power supply. See Figure 1.

Step 4: Select a Platform

Because the Mbed platform is popular and required, we selected the most used STMicroelectronics Mbed board based on the STM32F103.

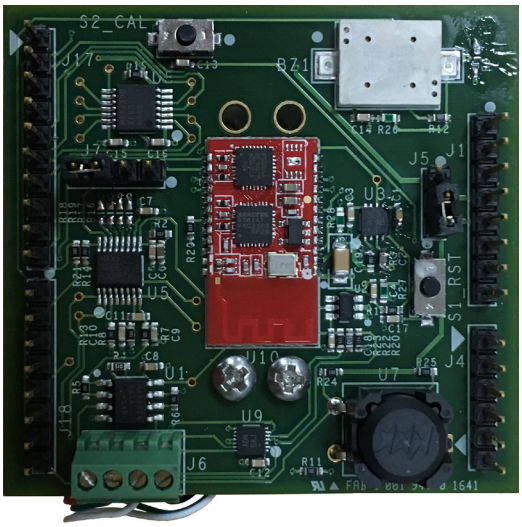

Figure 2. MAXREFDES1150 board layout—component side.

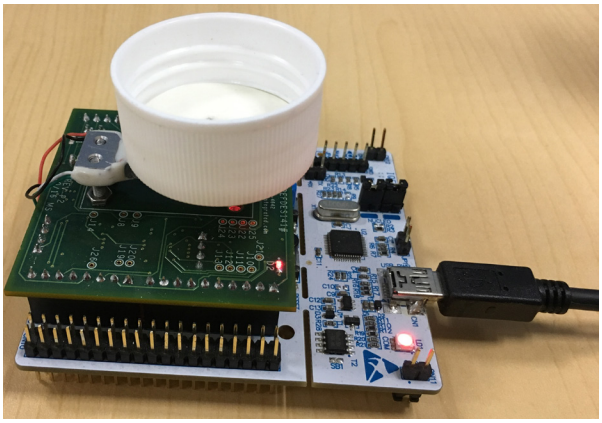

Figure 3. MAXREFDES1150 board layout—total assembled view.

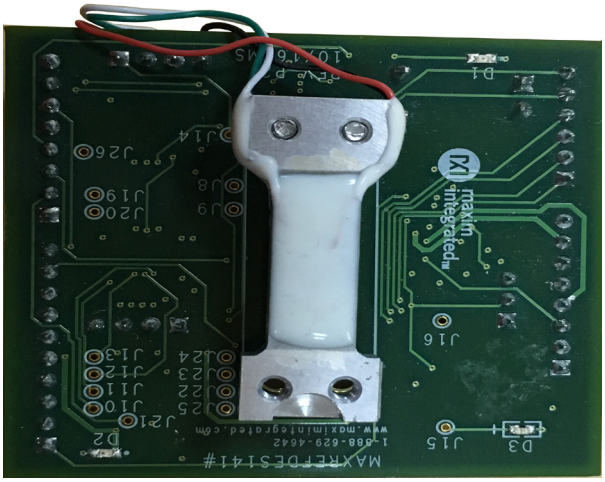

Figure 4. MAXREFDES1150 board layout—load cell side.

Detailed Description of Hardware

The MAXREFDES1150 consists of a load-cell sensor, differential gain, 16-bit ADC, SPI level translator, standard Mbed board, BLE module, power monitor, accurate reference power supply and calibration, and alarm circuit. A USB port provides power supply to the whole system.

When the pill bottle or weight is placed on the load cell, the load cell outputs electrical signals to the MAX44246 amplifier and differential amplifies to the MAX11213 ADC, then to microcontroller M3. The microcontroller filters the data to analyze what happened to the bottle based on the accuracy weight change. Combined with the user pill dose configuration and time calculation, the microcontroller can justify when pills eaten, more pills eaten, less pills eaten, repeat eaten, forgot eaten, bottle tilt, bottle empty, bottle not placed, and give related alarm information through the LED/buzzer/message.

The reset switch (SW1) resets the board, and the calibration switch (SW2) is used to start a calibration procedure.

The green light-emitting diode (LED) indicates the power supply is good. The red/yellow LEDs indicate the alarm and procedure. See Table 1 for the LED status descriptions.

Table 1. LED Status Meaning

LED STATUS	DESCRIPTION
Green On	Power is connected
Red On+Buzzer	Pills finished, refill fills
Yellow On+Red On+Buzzer	Bottle tilt
Yellow On+Buzzer	No bottle placed
Red Flash+Yellow Flash+Buzzer	Forget to take pills
Yellow Flash+Buzzer	Taken less pills
Red Flash+Buzzer	Repeat taken pills/taken more pills

MAX11213

The MAX11213 lies at the center of the system. The device is a 1-channel, differential input, 16-bit delta-sigma ADC that achieves exceptional performance while consuming very low power (< 300µA active current), with precision DC measurements. The MAX11213 communicates through an SPI serial interface and is available in a small 16-pin QSOP package.

The device offers a low noise solution (570nV_{RMS} noise at 10sps, ±3.6V_{FS} input) with a programmable gain amplifier (gain settings from 1x to 128x), four SPI-controlled GPIOs for external mux control, optional input buffers on both signal and reference inputs and 100dB (min) 50Hz/60Hz rejection.

It can operate from a single 2.7V to 3.6V analog supply, 1.7V to 3.6V digital, and I/O power supply.

In this smart pill-bottle design, the MAX11213 is configured as follows:

- V_{AVDD} = 3.3V, V_{AVSS} = 0V, V_{DVDD} = 3.3V, V_{REFP} - V_{REFN} = 3.3V
- ADC sampling rate = 50sps
- PGA gain = 1
- Continuous conversion mode
- REF buffer is disabled
- Signal buffer is enabled

Designers can easily change the configurations to their specific requirements using the provided firmware.

Strain-Gauge Load Cell

The strain-gauge load cell is excited by a 3.3V voltage reference and with the ADC reference voltage. When the strain-gauge load cell is deformed by the load acting on it, the load-cell electrical resistances change, meaning the load cell outputs a voltage changed proportional to the load. The load-cell capacity is 100g with a rated output of 0.6mV/V. The nonlinearity is 0.05% max FS. Depending on the specific application and accuracy requirement, different load cells can be selected and replace the load cells mounted on the board.

Note: Do not overload the load cells for more than 10 seconds and no more than 20% capacity.

Power Supplies and Voltage References

A micro-USB cable connected to a PC or other socket is used to power the MAXREFDES1150. The MAX16058 monitors the power supply and watchdog system. The MAX6071 3.3V output, low-noise, high-precision series voltage reference excites the load cells and drives the MAX11213 ADC REF/AVDD/DVDD.

Microprocessor and the BLE Module

The MAXREFDES1150 reference design uses an STM32F103 Mbed platform as the controller board. The processor controls the ADC and BLE module, and performs all calculations. The BLE module is BM88, which is a dual-mode Bluetooth module that complies with the 4.0 version. With the BLE module, the microcontroller communicates with a mobile device using APK tools and updates the pill bottle status and user new configuration.

Detailed Description of Software

The MAXREFDES1150 firmware is based on an infinite loop design model. After power-up, the microprocessor configures the power domains, clock domains, BLE module, RS-232 port, vector, SPI interface, timer, ADC, and other housekeeping tasks. Then the microprocessor goes into a loop, measuring the load cell and processing the data. The results are analyzed and showed on an Android mobile application. Figure 5 shows the MAXREFDES1150 firmware main function flowchart. Refer to the source files for firmware details, which include the following:

- Main.c—main code
- MAX11213drv.c—ADC MAX11213 driver code
- myexti.c—interrupt code
- stm32_spi.c—SPI code
- stm32_usart1.c—UART code for BLE module

Detailed Description of GUI

The MAXREFDES1150 board can work with the GUI application that runs on an Android mobile phone. The application conveniently provides measured results on a mobile phone, allowing a user to configure the pill bottle parameters using the mobile phone. Figure 6 and Figure 7 show MAXREFDES1150 GUI application screenshots.

Before connecting the MAXREFDES1150 board to a mobile phone, the user should install the Android APK on his mobile phone. To install the Android APK, download the file **SmartPillBottle_v01.apk** from the MAXREFDES1150 webpage, and click it to install (see the *Design Resources* section). Then open the APP and power the board. The APP searches for and matches the BLE module. When the BLE module is connected, the APP shows the parameter configure interface. After configuration, the APP and system begin to work.

Test the MAXREFDES1150 board to ensure it can meet the hardware requirements. The board can measure in the 0g to 100g range with a 12mg resolution. Refer to the test results.

Design Resources

Download the complete set of **Design Resources** including the schematics, bill of materials, PCB layout, and test files.

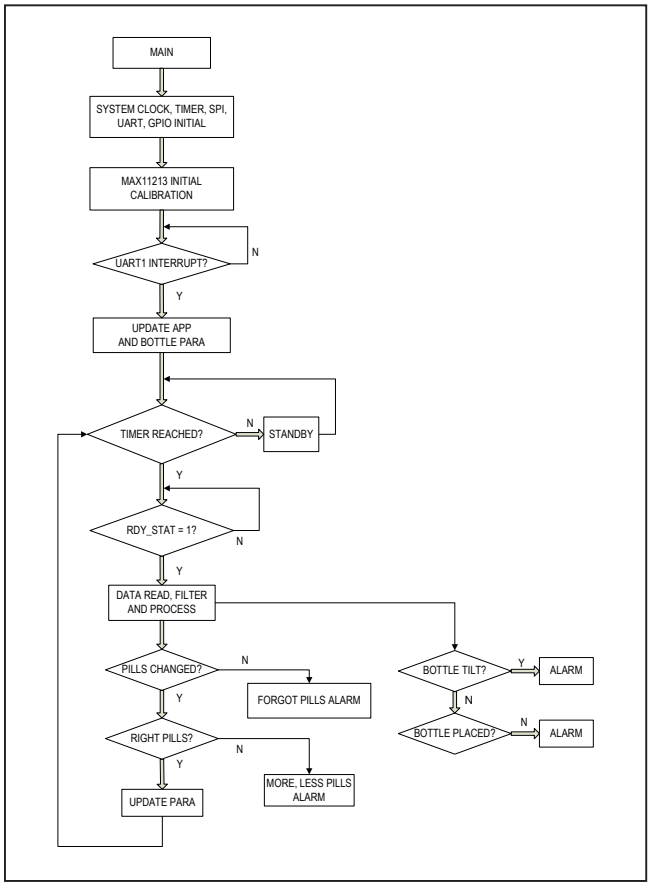

Figure 5. MAXREFDES1150 firmware flowchart.

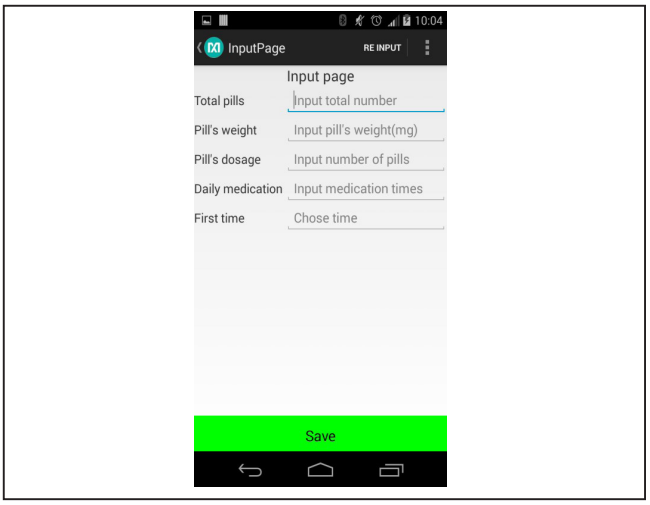

Figure 6. MAXREFDES1150 GUI—input page.

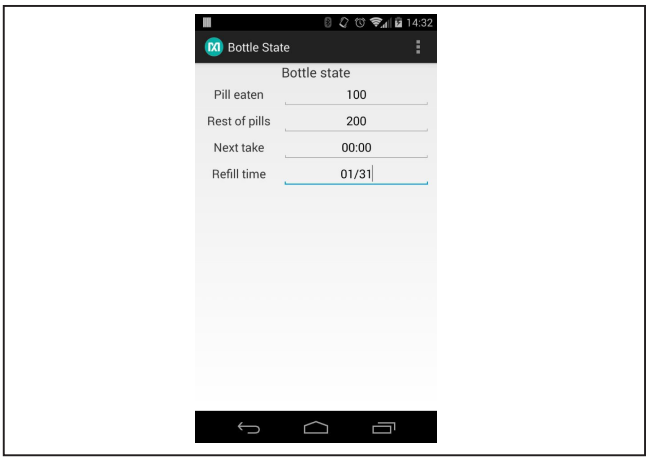

Figure 7. MAXREFDES1150 GUI—bottle state.

Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	2/18	Initial release	—