Low-Power Fault Indicators

MAXREFDES1171

Introduction

The MAXREFDES1171 uses Maxim® low-power chips for power grid fault indicators based on the low-power Arm® Cortex®-M4 processor. The MAXREFDES1171 is a high accuracy, low power, small and easily implanted design that can monitor the power status on the power grid line. Power grid coverage is widening in cities and the country-side, so power grid reliability and a short power-off time are important. The key requirements for a fault indicator are accuracy and very low power. One specification is that the unit must work for at least five years when in battery mode.

Main features and benefits:

- Ultra-low power
- Small size
- High accuracy

Hardware Specification

Table 1 provides an overview of the design specification.

Table 1. Design Specification

PARAMETER	SYMBOL	MIN	MAX
Battery Voltage	V_{BAT}	3.1V	4.2V
Super Cap Voltage	V_{CAP}	2.5V, ±10%	
Standby Current	$I_{STANDBY}$	80µA	
Accuracy Error	Error	1%	
Sample Rate	SR	4000sps per channel	
Input Range	V_{IN}	-16.5V	+16.5V

Designed–Built–Tested

This document describes the hardware shown in Figure 1. It provides a detailed systematic technical guide to design in a small, low-power, high-accuracy fault indicator. The design has been built and tested, details of which follow later in this document.

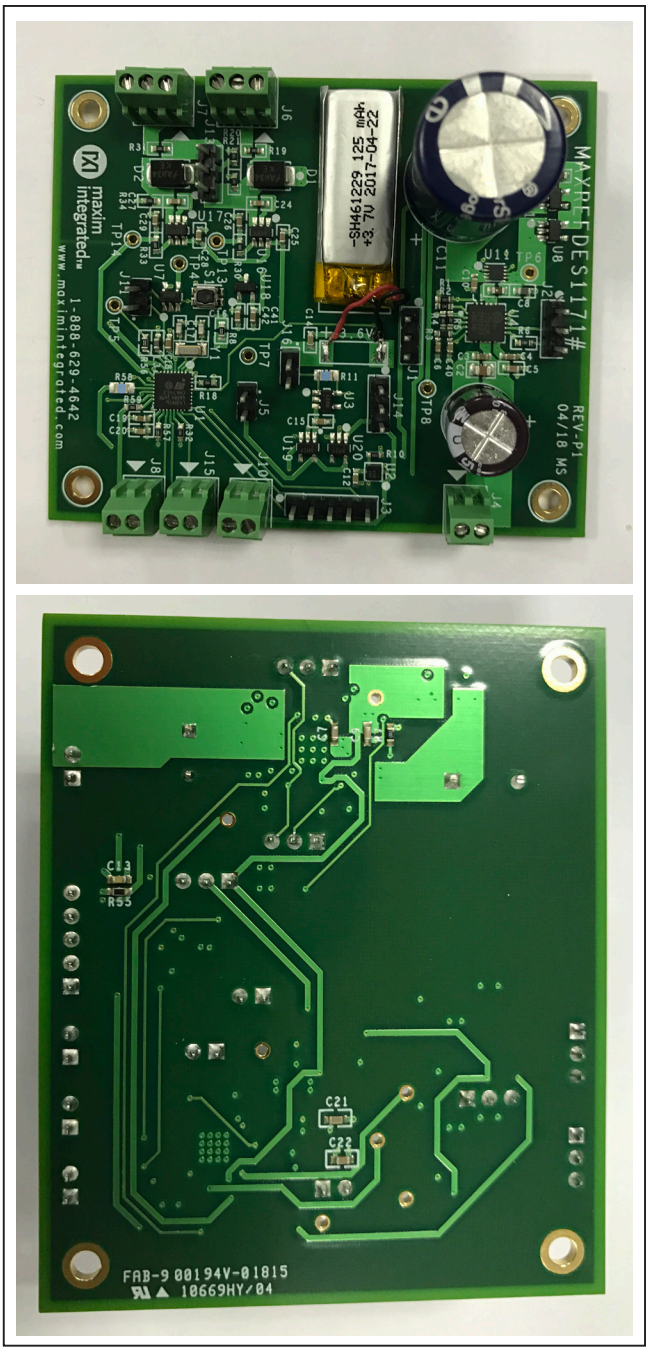

Figure 1. MAXREFDES1171 hardware top (above) and bottom (below).

Hardware Overview

The reference design block diagram (Figure 2) demonstrates how the MAXREFDES1171 works. When the power line is powered on, the board is powered from the power line. When the power line is powered off, the board is powered from the battery. When using the battery, the board goes into standby mode to save power and monitors the power line status. When power is restored to the power line, the board switches to normal mode and is powered from the power line. The MAXREFDES1171 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.

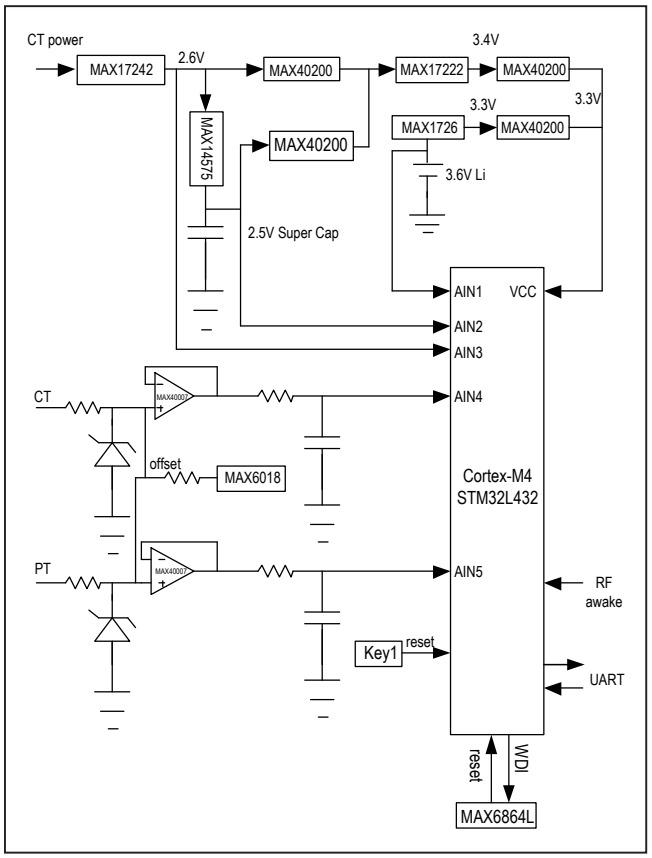

Figure 2. MAXREFDES1171 block diagram.

Design Considerations

The fault indicator has a critical requirement for low power. In battery standby mode, the standby current must be less than 80µA for the whole board. In measure mode, the sample rate must be equal to or higher than 80 points/channel at one cycle of the power line within 1% accuracy.

Detailed Description of Hardware

Microcontroller

The MAXREFDES1171 uses the STM32L432KC from STMicroelectronics® as its microcontroller unit (MCU). This chip is popular, especially in the in low-power-application market for portable applications. This Arm Cortex-M4 is small, uses low power, and has a large memory to perform to our requirements.

Signal Chain

The MAX40007 is a single operational amplifier that is ideal for battery-powered applications such as portable instrumentation and portable medical equipment. This CMOS op amp features an ultra-low supply current of only 700nA (typical), ground-sensing inputs, and rail-to-rail outputs. The MAX40007 operates from a single 1.7V to 5.5V supply, which allows the amplifier to be powered by the same 1.8V, 2.5V, or 3.3V nominal supply that powers the microcontroller. We used the MAX40007 as an input buffer and then used the internal ADC in the MCU to sample the input signal.

The MAX6018 is a precision, low-voltage, low-dropout, micropower voltage reference. The MAX6018 voltage reference consumes less than 5µA (maximum) of supply current and can source and sink up to 1mA of load current. The low-dropout voltage and the ultra-low, supply voltage-independent supply current make the MAX6018 ideal for battery-monitoring systems. We used the MAX6018 as an offset for the MAX40007.

Power Supply

Because power is key for this reference design, we selected Maxim chips that support very low power and standby current.

The MAXREFDES1171 can be supplied by power line and battery or by supercapacitor. The supercapacitor is charged when the power line is powered on. The charge current is controlled by the MAX14575C. The external reset IC, MAX6864, monitors the input power supply voltage of the MCU. The pushbutton S1 can manually reset the MCU.

The MAX17242 high-efficiency, synchronous step-down DC-DC converters with integrated MOSFETs operates over a 3.5V to 36V input voltage and can operate in drop-out conditions by running at 99% duty cycle. The converter delivers up to 2A output current and generates fixed output voltages of 3.3V/5V, along with the ability to program the output voltage between 1V to 10V. The converter's low 15µA (typical) quiescent current makes the MAX17242 suitable for low-power applications.

The MAX17222 is an ultra-low quiescent current boost (step-up) DC-DC converter with a 0.5A peak inductor current limit and True Shutdown™. True Shutdown disconnects the output from the input with no forward or reverse current. The output voltage is selectable using a single standard 1% resistor. The 500mA peak inductor current limit allows flexibility when choosing inductors. The MAX17222 has post-startup enable transient protection (ETP), which allows the output to remain regulated for input voltages down to 400mV, depending on load current. The MAX17222 offers ultra-low quiescent current, small total solution size, and high efficiency throughout the entire load range. The MAX17222 is ideal for battery applications where long battery life is a must.

The MAX40200 is an ideal diode current-switch that drops so little voltage that it approaches an order of magnitude better than Schottky diodes. When forward-biased and enabled, the MAX40200 conducts with as little as 85mV of voltage drop while carrying currents as high as 1A. Typical voltage drop is 43mV at 500mA, with the voltage drop increasing linearly at higher currents. The MAX40200 thermally protects itself, and any downstream circuitry, from overtemperature conditions.

The MAX6864 ultra-low-current (170nA, typical) microprocessor (µP) supervisory circuit combines voltage monitor, watchdog timer, and manual reset input functions in a 5-pin SOT23 package. This device asserts a reset signal whenever the monitored voltage drops below the factory trimmed reset threshold voltage, the manual reset is asserted, or the watchdog timer expires.

The MAX14575C programmable current-limit switch features internal current limiting to prevent damage to devices due to faulty load conditions. This current-limit switch features a low 32mΩ (typical) on-resistance and operates from a +2.3V to +5.5V input voltage range. The current limit is adjustable from 250mA to 2.5A, making the MAX14575C ideal for charging a large load capacitor as well as for high-current load switching applications. We used the MAX14575C to control the supercapacitor charge current.

The MAX1726 are ultra-low supply current, low-dropout linear regulators intended for low-power applications that demand the longest possible battery life. Unlike inferior PNP-based designs, the MAX1726's PMOS pass elements maintain an ultra-low 2µA supply current throughout their entire operating range and in dropout. We use the MAX1726 to regulate battery output.

Operation Overview

Standby Mode and Measure Mode

The MAXREFDES1171 works in two modes: standby mode and operation mode. When there is no power in the power line, it works in standby mode. When power is restored to the power line, it enters measure mode. The total current in standby mode is 12µA.

Program Download Interface

Download new programs into the MCU with the ST-Link. The J3 header is reserved for ST-Link, which is a device from STMicroelectronics.

Main Loop

The MAXREFDES1171 firmware is based on an infinite-loop design model. After power-up, the MCU configures itself and configures the communication function. If there is power in the power line, the MAXREFDES1171 goes into measure mode and measures the CT/PT value. When the power line is powered off, the MAXREFDES1171 is powered by the battery and goes into standby mode to monitor the power line status. When power is recovered to the power line, the MAXREFDES1171 returns to measure mode.

Figure 3 shows the main function flowchart.

True Shutdown is a trademark of Maxim Integrated Products, Inc.

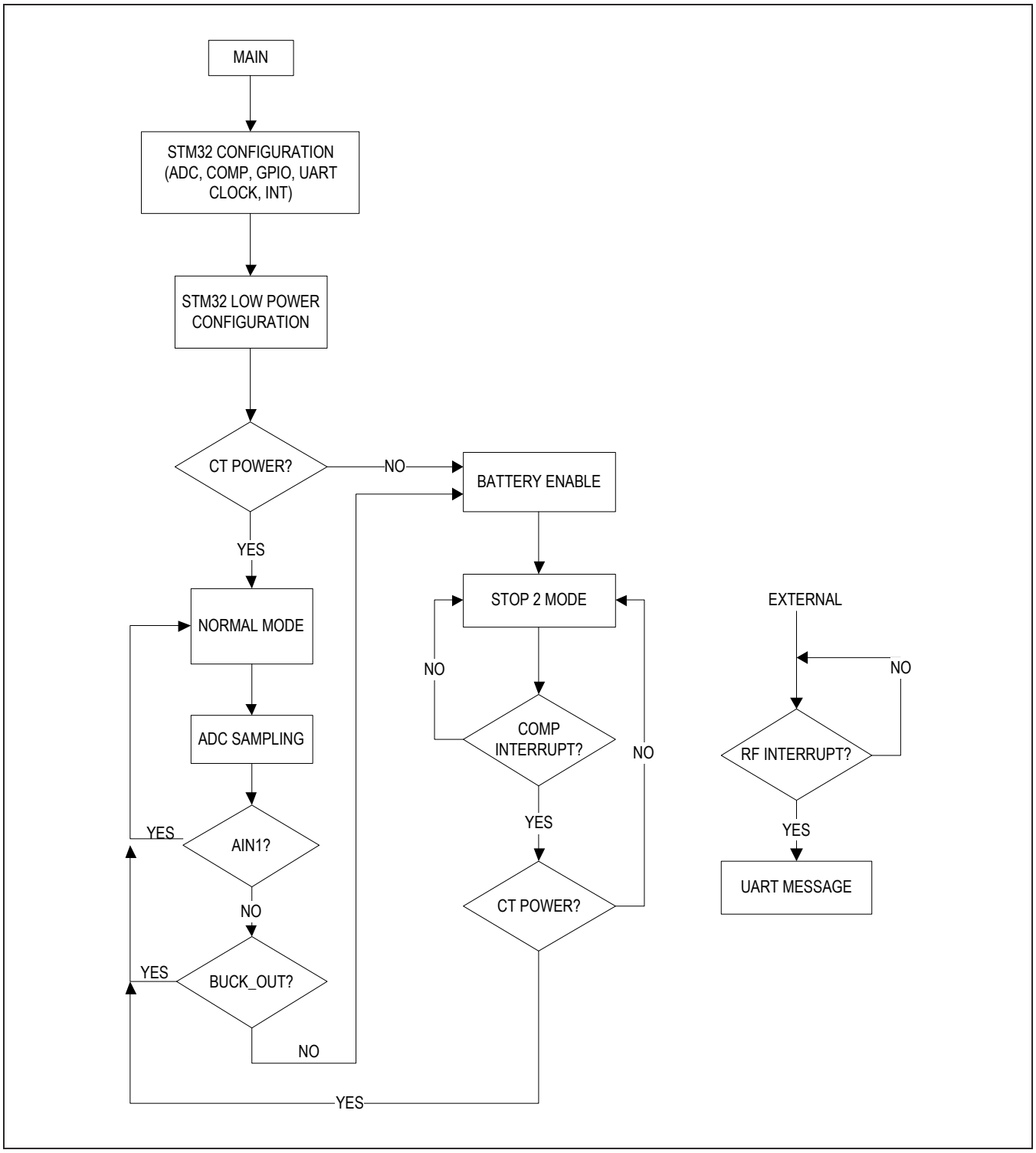

Figure 3. Main function flowchart.

Low Power Configuration

To have low power in standby mode, we must configure each component independently as discussed in the following sections.

Microcontroller

Because the microcontroller consumes a large percentage of system power, especially if the chip is working in a high MHz frequency, the operation frequency should be decreased to 100kHz before the MCU sleeps. Note that when the frequency drops, the MCU slows down dramatically, so decreasing the frequency must be the last step before the system goes to sleep.

The GPIO configuration is also important. The GPIO should be configured as Analog Input mode. UART and the ADC should be de-initialized. The unused function should be disabled.

Battery Power supply

When the power line has power, the battery does not work. To save power, disable the MAX40200(U19) by pulling down the EN pin during working mode.

Graphical User Interface

There is no dedicated GUI for MAXREFDES1171. The reference design provides support for the UART interface to communicate with a PC in a common serial port program (e.g., Serial port utility, Realterm, or Tera Term). When the UART command is sent, the MAXREFDES1171 sends out the measured value.

Design Resources

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

Trademarks

Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	8/18	Initial release	—