Related Parts

SUBSYSTEM BOARD 5723

SONOMA (MAXREFDES14#): ISOLATED ENERGY MEASUREMENT SUBSYSTEM REFERENCE DESIGN

Oct 25, 2013

Abstract: The Sonoma (MAXREFDES14#) subsystem reference design performs accurate AC energy measurement while utilizing a unique, low-cost galvanic isolation architecture. The Sonoma meets the high-accuracy and low-cost needs of energy-measurement applications. This small form-factor design is available for purchase. Hardware, firmware design files, and lab measurements provide complete system information for rapid prototyping and development.

Introduction
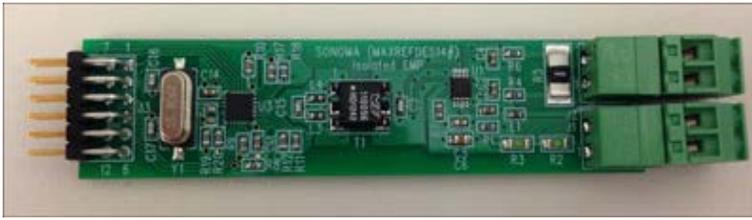
[More detailed image](#) (JPG)

AC measurement applications often require [galvanic isolation](#) to protect the system and user from high voltages. This is typically accomplished by either using bulky voltage/current transformers for sensors or by isolating the data and power interface to the measurement subsystem. These approaches, however, consume a considerable amount of space and come with hidden costs and design challenges.

The Sonoma ([MAXREFDES14#](#)) energy measurement subsystem reference design provides galvanic isolation from the system with a single pulse [transformer](#) while using resistors as the sensing elements. The result is a small, cost-optimized board.

The Sonoma design utilizes an isolated energy measurement processor ([MAX78615+LMU](#)); a multichannel, precision analog-to-digital converter ([ADC](#)) ([MAX78700](#)); a pulse transformer; optional 20MHz crystal oscillator, and the appropriate sense resistors for converting AC voltage and current into measurable signals. With the embedded load monitoring unit (LMU) firmware and nonvolatile storage of calibration and configuration data, Sonoma is a complete measurement subsystem ready for integration into any design.
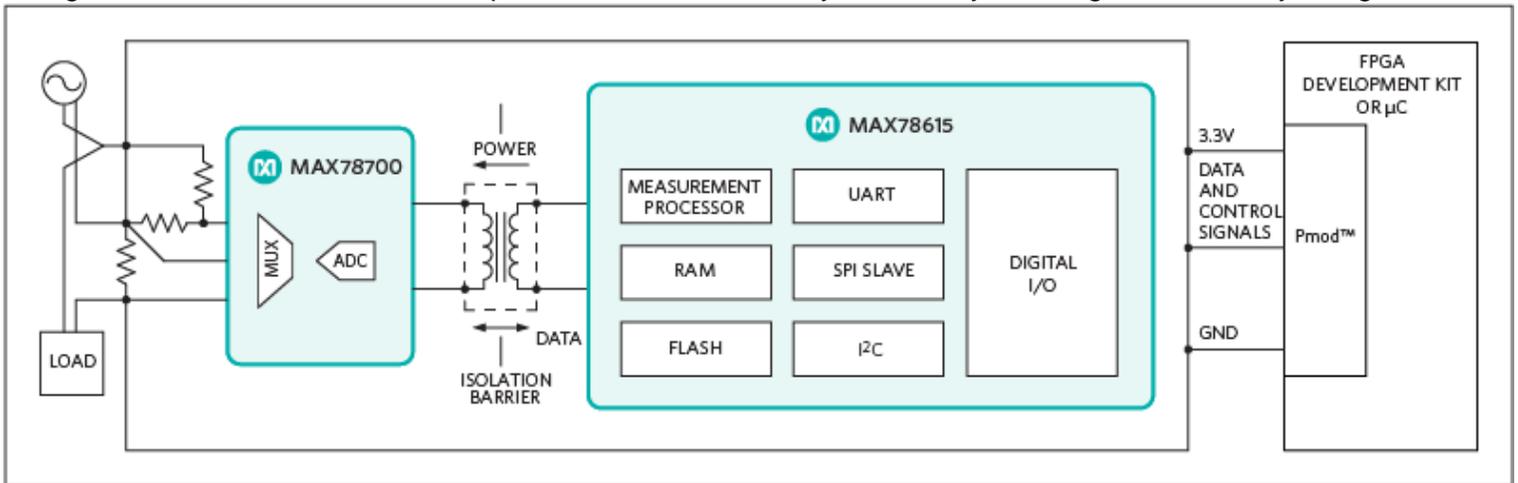

Figure 1. The Sonoma subsystem design block diagram.

Features

- High-accuracy power measurement
- High-voltage galvanic isolation
- Preset gain/offset parameters
- On-board 4mΩ [current sensing](#) resistor with a good temperature coefficient
- On-board voltage sensing resistor divider with a ratio of 2667:1 with good temperature coefficient
- Universal AC [input voltage range](#) from 90 to 264VAC
- Pluggable terminals for AC (8A max)
- Small printed-circuit board (PCB) area
- Device drivers
- Example C [source](#) code
- Configuration files for Xilinx® LX9 and ZedBoard™ platforms
- Pmod™-compatible form factor

Applications

- Lighting control systems
- Commercial and industrial automation
- Renewable energy systems
- Electric vehicle charging systems
- Smart home applications

Competitive Advantages

- On-chip nonvolatile storage of calibration and configuration parameters
- Full galvanic isolation with a single transformer
- Small board size
- Lower BOM cost

Detailed Description of Hardware

Sonoma connects to Pmod-compatible field-programmable gate array (FPGA)/microcontroller development boards. The Pmod specification allows for both 3.3V and 5V modules as well as various pin assignments. Sonoma requires a supply voltage of 3.3V from the Pmod connector and uses the SPI pin assignments as illustrated here.

Table 1 shows the power requirements. **Table 2** shows currently supported platforms and ports.

Table 1. Power Requirement for the Sonoma Subsystem Reference Design

Power Type	Input Voltage (V)	Input Current (mA, typ)
On-board power	3.3	8.4

Table 2. Supported Platforms and Ports

Supported Platforms	Ports
LX9 platform (Spartan®-6)	J5
ZedBoard platform (Zynq®-7020)	JA1

Figure 1 shows the block diagram of the Sonoma reference design. The system utilizes the isolated MAX78615+LMU measurement processor, a single MAX78700 data converter, and resistive sensors for measuring 2-wire AC loads up to 8A.

The MAX78615+LMU energy measurement processor sits in the isolated domain of the system, simplifying integration into existing low-voltage domains found in many embedded systems. Pages of the internal flash memory are reserved for storing configuration and calibration data.

The MAX78700 analog-to-digital data converter (ADC) connects to the MAX78615+LMU processor through a single pulse transformer. The MAX78700 receives timing, configuration data, and power from the MAX78615+LMU, across the isolation barrier, utilizing Maxim's unique remote sensor technology. The MAX78700 responds with converted data samples of the voltage, current, and die temperature.

The All Design Files section contains schematics, layout files, Gerbers, and firmware necessary for immediate porting to your system. The board is configured for an SPI interface between the MAX78615+LMU and the host system and design files support this mode. Removing R10 places the device in UART mode. For more information, refer to the MAX78615+LMU data sheet on host interface options and protocols if using the UART interface is necessary.

The MAX78615+LMU device on the Sonoma contains a fixed set of preprogrammed scaling factors (optimized for a given bill of materials) in the nonvolatile memory to perform proper voltage, current, and power calculations. The resulting measurement accuracy in this case is directly related to the initial tolerance of the passive components found in the sense circuit. The Sonoma reference design utilizes fixed gain coefficients and offsets that were derived from looking at ten (10) initial units. Refer to the scaling registers section in the MAX78615+LMU data sheet for more information.

- Scaling Factors Used by Host:
  - Full Scale Voltage (VFSCALE) = 667Vpk
  - Full Scale Current (IFSCALE) = 50Apk
- Gain/Offset Parameters (value)
  - Offset for die temperature (0x3F88)
  - Gain for voltage sensor (0x208907)
  - Gain for current sensor (0x28BB1E)
  - RMS (noise) offset for IRMS (0x735)

Use the formulas below to calculate the RMS voltage, RMS current, and power.
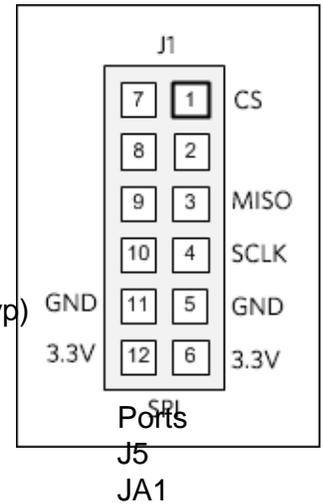
$$\text{RMS Voltage (Source A)} = \frac{VA\_RMS}{2^{23}} \times VFSCALE$$

$$\text{RMS Current (Source A)} = \frac{IA\_RMS}{2^{23}} \times IFSCALE$$

$$\text{Watts (Source A)} = \frac{WATT\_A}{2^{23}} \times VFSCALE \times IFSCALE$$

Detailed Description of LX9/ZedBoard Firmware

Table 2 shows the currently supported platforms and ports. Support for additional platforms may be added periodically under Firmware Files in the All Design Files section.

The Sonoma firmware released for the LX9 development kit targets a Microblaze™ soft core microcontroller placed inside a Xilinx Spartan®-6 FPGA. The Sonoma firmware also supports the ZedBoard kit and targets an ARM® Cortex® -A9 processor placed inside a Xilinx Zynq system-on-chip (SoC).

The firmware allows for immediate interfacing to the MAX78615+LMU, for register read and write commands.

Figure 2 shows the simple process flow. The firmware is in C, developed using the Xilinx SDK tool, based on the Eclipse™ open-source standard. Custom Sonoma-specific design functions (driver in the maximDeviceSpecificUtilities.c file) were created utilizing the standard Xilinx XSpi core version 3.03a.
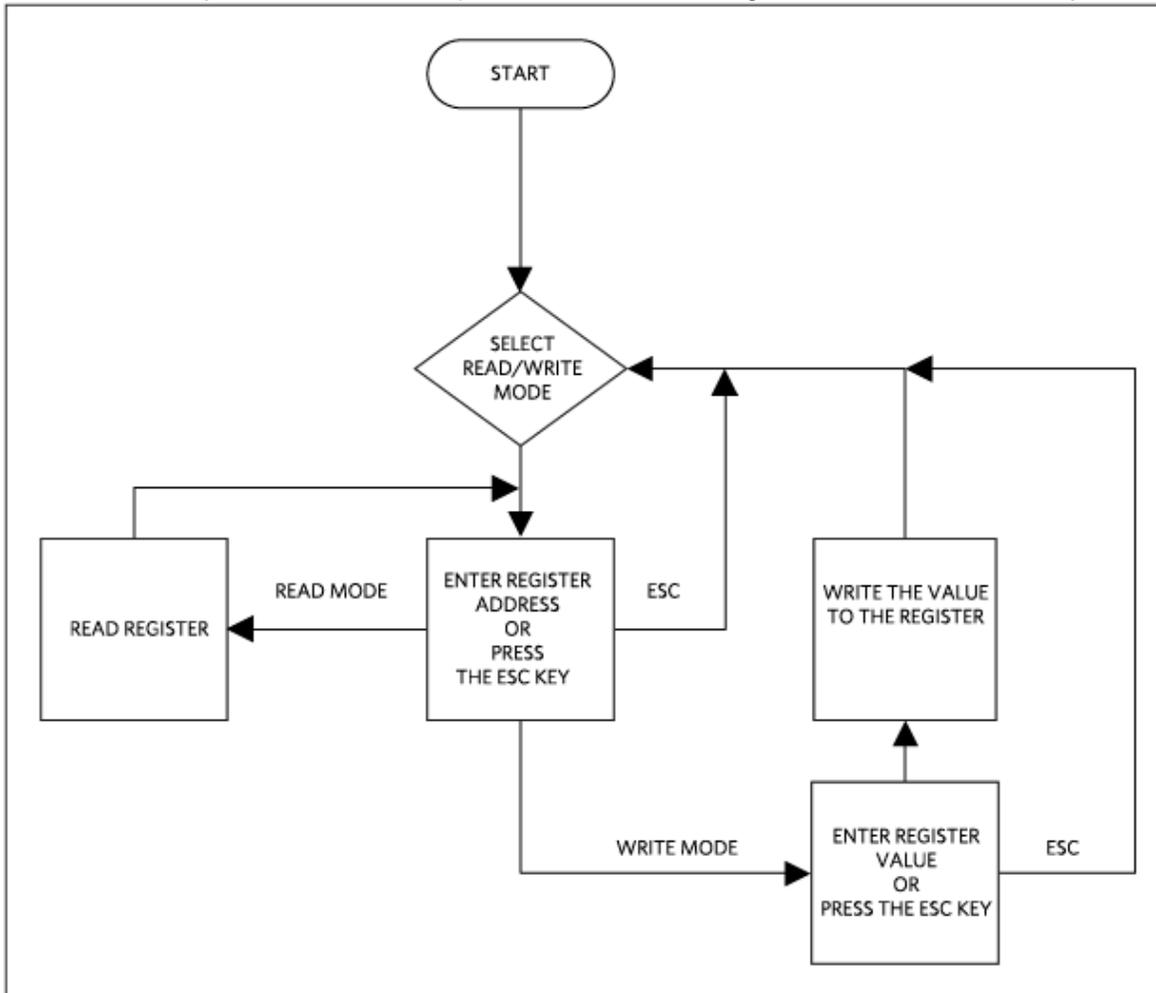

Figure 2. The Sonoma firmware flowchart.

The firmware accepts register read or write commands. The complete source code is provided to speed customer development. Code documentation can be found in the corresponding firmware platform files.

Quick Start

Required equipment:
- Windows® PC with two USB ports

- 120V AC outlet or a test equipment that can generate 120VAC (e.g., Fluke 6100A)
- An AC load
- Sonoma (MAXREFDES14#) board
- Sonoma-supported platform (i.e., LX9 development kit or ZedBoard kit)

Download, read, and carefully follow each step in the appropriate Sonoma Quick Start Guide:
Sonoma (MAXREFDES14#) LX9 Quick Start Guide
Sonoma (MAXREFDES14#) ZedBoard Quick Start Guide

Lab Measurements

Equipment:
- Fluke 6100A electrical power standards
- Fluke true RMS multimeters
- Windows PC
- Sonoma (MAXREFDES14#) board

Take special care and use proper equipment when testing the Sonoma design. Duplication of the presented test data requires an AC source with high accuracy.
Figure 3 shows the measured power accuracy of a random Sonoma board over load current. The error is less than ±3% with a fixed set of gain/offset coefficients for the sensors. Calibration of the sensors would achieve higher accuracy. Lower current levels produce higher errors, because the measurable signal is closer to the noise level. Averaging multiple data reads or increasing the accumulation interval of the MAX78615+LMU reduces the relative error.
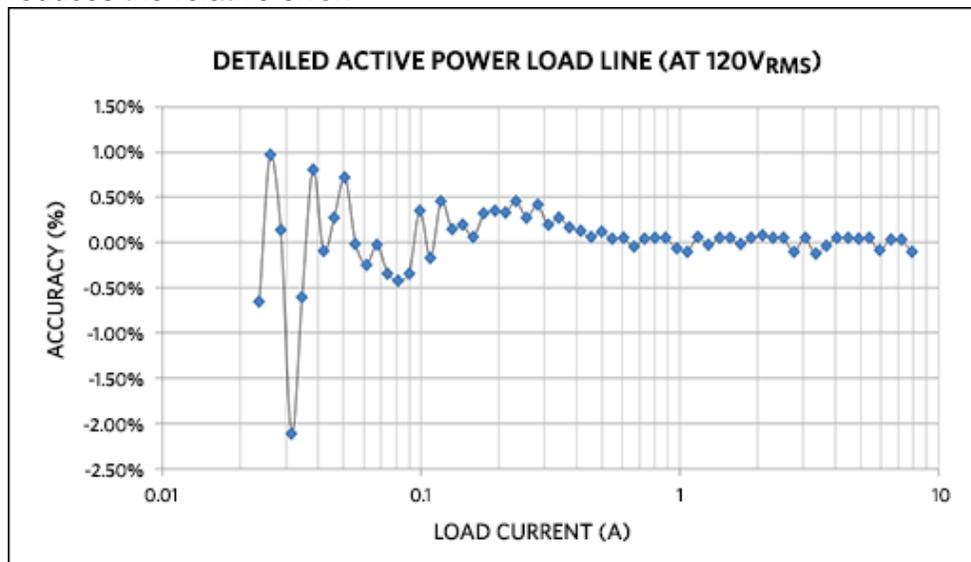

Figure 3. Power accuracy, 23.5mA to 7.9A at 120V$_{RMS}$/60Hz and room temperature.

All Design Files

Download All Design Files
Hardware Files

Schematic
Bill of materials (BOM)
PCB layout
PCB Gerber
PCB CAD (PADS 9.0)
Firmware Files

LX9 MicroBoard Platform (Spartan6)
ZedBoard Platform (Zynq-7000)

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ZedBoard is a trademark of ZedBoard.org.

Zynq is a registered trademark of Xilinx, Inc.

Related Parts

MAX78615+LMU	Isolated Energy Measurement Processor for Load Monitoring Units	Free Samples
MAX78700	Multichannel, Isolated, Precision ADC	Free Samples
MAXREFDES14	Sonoma (MAXREFDES14#): Isolated Energy Measurement Subsystem Reference Design	

Next Steps

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APP 5723: Oct 25, 2013
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