

# **AN-2254 MSP430 Interface to LMP91200 Code Library**

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## **ABSTRACT**

The MSP430™ is an ideal microcontroller solution for low-cost, low-power precision sensor applications because it consumes very little power. The LMP91200 is a configurable sensor analog front end (AFE) for use in low power analytical sensing applications. This library provides functions to facilitate the interfacing of any MSP430 device to a LMP91200. Any device within the MSP430 family can be used with this library, made possible by hardware abstraction. Similarly, any SPI-capable interface module within the MSP430 family is supported by the library. This allows the designer maximum flexibility in choosing the best MSP430 device for the application. This document provides descriptive information and instructions for using the library either for demonstration purposes or implementation into a project. This is the recommended starting point for developing software for the LMP91200 and MSP430 combination. The software examples have been developed for the MSP430F5528 breakout board, but can easily be ported to another hardware platform.

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## 1 Introduction

This application report describes different ways to interface and use the TI LMP91200 devices with an MSP430. The accompanying software contains a function library allowing quick prototyping of sensor AFE setup and control. The software provided in this library is a starting point for developers wanting to get the most out of the MSP430 and the LMP91200 sensor AFE devices.

The LMP91200 is a configurable sensor AFE for use in low power analytical sensing applications. It provides all of the functionality needed to detect changes based on a delta voltage at the sensor. With its extremely low input bias current it is optimized for use with pH sensors. The LMP91200 is equipped with a slave SPI port, through which it can communicate with an MSP430 and is an optimal match for the MSP430 ultra low power microcontrollers. The MSP430 is a great fit for applications where power conservation is a priority. The many power-saving mechanisms designed into the MSP430 make it ideal for such applications.

## 2 Purpose and Scope

To aid in interfacing these devices, TI has produced a code library that significantly reduces the need to write low-level interface functions. It provides a boost in the development of an MSP430/LMP91200-based product, saving time and allowing quick progression to the application-specific aspects of the project. This library is designed to be used with any MSP430 device. Since a SPI master can be implemented using one of many peripherals within the MSP430 family, and since the peripherals available may differ by device and application, library calls are provided for each of these interfaces. The chosen interface is selected by assigning a value to a system variable, which causes the compiler to conditionally include the appropriate function calls. As such, application code utilizing the library remains portable between various MSP430 devices, with minimal modification required.

Several complete example application projects are provided with the library. The purpose of these projects is to demonstrate use of the library. It is not intended as a comprehensive guide to using the LMP91200, and it does not make use of all the features of these devices. It does, however, use all the register access functions provided by the library.

## 3 File Organization

The library has been implemented with modular hardware abstraction. There is a header file specific to each of the hardware components (LMP91200, MSP430, and the board). The hardware definition header files are shown in [Table 1](#). [Table 2](#) shows the library code files and its header, and [Table 3](#) shows the demonstration applications that accompanies the library.

**Table 1. Hardware Definition Files**

Filename	Description
<i>TI_LMP91200.h</i>	Definitions specific to the LMP91200 device, including register bit definitions and commonly-used masks for use with these registers.
<i>TI_MSP430.h</i>	Definitions specific to the MSP430 device; primarily, the pins used in the SPI interface. Definitions for USART0/1, USCI_A0/1/2/3, USCI_B0/1/2/3, USI and bit banging are included. Also, labels are defined for use with the system variable <i>TI_LMP91200_SER_INTF</i> . This label selects the modules to be used for accessing the LMP91200 SPI interface.
<i>TI_MSP430_hardware_board.h</i>	Definitions specific to the board being used; that is, the connections between the MSP430 and the LMP91200EVAL, such as the SPI connections to the onboard ADC141S626 and GPIO pins. SPI connections to the LMP91200 are not defined here because they are defined inherently within <i>TI_MSP430.h</i> . The system variable <i>TI_LMP91200_SER_INTF</i> is defined in this file.

**Table 2. Library Code**

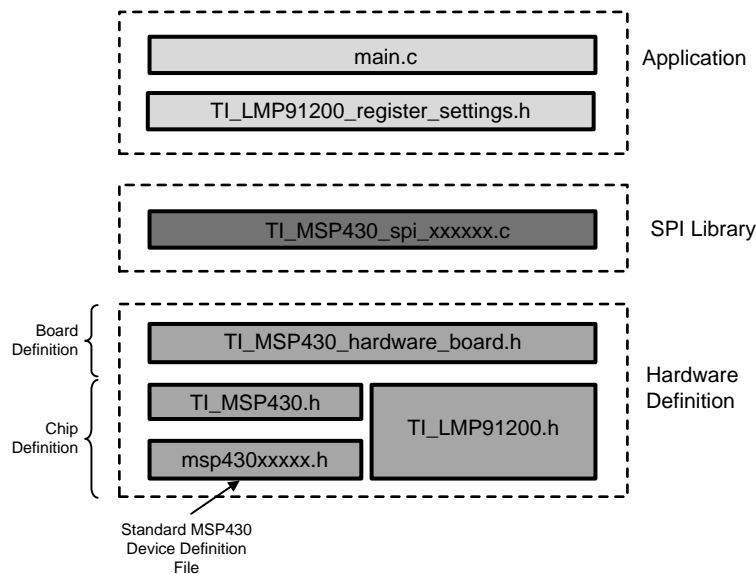
Filename	Description
<i>TI_MSP430_spi_USCIA0_5xx.c</i>	Function for accessing the LMP91200 registers via SPI_USCIA0 module from the MSP430 5xx family
<i>TI_MSP430_other_spi_modules\</i>	Functions for accessing the LMP91200 registers via other MSP430 SPI modules like SPI_USART0, SPI_USART1, SPI_USCIA1, and so forth.
<i>TI_MSP430_spi_USCIA1_5xx.c</i>	
<i>TI_MSP430_spi_USCIA2_5xx.c</i>	
<i>TI_MSP430_spi_USCIA3_5xx.c</i>	
<i>TI_MSP430_spi_USCIB0_5xx.c</i>	
<i>TI_MSP430_spi_USCIB1_5xx.c</i>	
<i>TI_MSP430_spi_USCIB2_5xx.c</i>	
<i>TI_MSP430_spi_USCIB3_5xx.c</i>	
<i>TI_MSP430_spi_USCIA0.c</i>	
<i>TI_MSP430_spi_USCIA1.c</i>	
<i>TI_MSP430_spi_USCIB0.c</i>	
<i>TI_MSP430_spi_USCIB1.c</i>	
<i>TI_MSP430_spi_USART0.c</i>	
<i>TI_MSP430_spi_USART1.c</i>	
<i>TI_MSP430_spi_USI.c</i>	
<i>TI_MSP430_spi_BITBANG.c</i>	
<i>TI_MSP430_spi.h</i>	Function declarations for <i>TI_MSP430_spi_*.c</i>

**Table 3. Demo Applications Included With the Library**

Demo Application	Filename	Description
Application1: Read/Write LMP91200 Registers	<i>demo-app01\main.c</i>	Application code with functions to demonstrate read and write of the LMP91200 register
	<i>demo-app02\ TI_LMP91200_register_settings.h</i>	Application specific initialization values for the LMP91200 registers
Application2: 1-step temperature measurement using the onboard ADC141S626	<i>demo-app02\main.c</i>	Application code with functions to demonstrate the 1-step temperature measurement described in the LMP91200 data sheet
	<i>demo-app02\adc14s626.c</i>	Application code with functions to initialize and read the ADC141S626 data output
	<i>demo-app02\ TI_LMP91200_register_settings.h</i>	Application specific initialization values for the LMP91200 registers
Application3: 2-step temperature measurement using the onboard ADC141S626	<i>demo-app03\main.c</i>	Application code with functions to demonstrate the 2-step temperature measurement described in the LMP91200 data sheet
	<i>demo-app03\adc14s626.c</i>	Application code with functions to initialize and read the ADC141S626 data output
	<i>demo-app03\ TI_LMP91200_register_settings.h</i>	Application specific initialization values for the LMP91200 registers
Application4: 3-step temperature measurement using the onboard ADC141S626	<i>demo-app04\main.c</i>	Application code with functions to demonstrate the 3-step temperature measurement described in the LMP91200 data sheet
	<i>demo-app04\adc14s626.c</i>	Application code with functions to initialize and read the ADC141S626 data output
	<i>demo-app04\ TI_LMP91200_register_settings.h</i>	Application specific initialization values for the LMP91200 registers
Application5: 2-step temperature measurement using the ADC12 module in MSP430F5528	<i>demo-app05\main.c</i>	Application code with functions to demonstrate the 2-step temperature measurement described in the LMP91200 data sheet
	<i>demo-app05\ TI_LMP91200_register_settings.h</i>	Application specific initialization values for the LMP91200 registers

**NOTE:** The register settings values for *TI\_LMP91200\_register\_settings.h* can easily be obtained from the “Register configuration file” saved from the Sensor AFE Software [2]. The demo application code reads the values stored in the register settings file to initialize the LMP91200 device register.

Figure 1 shows a stack diagram of the library. Note that one of the files displayed in the stack is the standard definition file for the specific MSP430 device being used. This file is included with the development environment being used to create the MSP430 software.



**Figure 1. Code Library Stack**

## 4 Functions

Table 4 shows the SPI register-access functions provided in the library, with a brief description.

**Table 4. Register Access and Control Functions Provided by the Library**

Function Name	Description
<code>void TI_LMP91200_SPISetup (void)</code>	Configures the SPI port assigned by the <code>TI_LMP91200_SER_INTF</code> system variable. Must be called before calling any of the other functions.
<code>uint16_t TI_LMP91200_SPIWriteReg (uint16_t value)</code>	Writes “value” to the LMP91200 configuration register. It returns the 16-bit value stored in the configuration register before the write.

A version of these functions is provided for all MSP430 peripherals that are capable of communicating using the SPI protocol.

These peripherals are:

- USART0 for 1xx, 2xx, and 4xx families
- USART1 for 1xx, 2xx, and 4xx families
- USCI\_A0 for 5xx and 6xx families
- USCI\_A1 for 5xx and 6xx families
- USCI\_A2 for 5xx and 6xx families
- USCI\_A3 for 5xx and 6xx families

- USCI\_B0 for 5xx and 6xx families
- USCI\_B1 for 5xx and 6xx families
- USCI\_B2 for 5xx and 6xx families
- USCI\_B3 for 5xx and 6xx families
- USCI\_A0 for 2xx and 4xx families
- USCI\_A1 for 2xx and 4xx families
- USCI\_B0 for 2xx and 4xx families
- USCI\_B1 for 2xx and 4xx families
- USI for G2xx value series family
- Bitbang using GPIO pins

## 5 Using the Software

### 5.1 Prerequisites

To successfully compile, download and run the software described in this document, the following materials are needed:

- MSP430 Target Board MSP-TS430RGC64USB Board
- LMP91200 Evaluation Board LMP91200EB
- MSP430 USB Debugging Interface MSP430-FET430UIF
- IAR Embedded Workbench or TI Code Composer Studio™ for MSP430

The software can be adapted to run on other MSP430 hardware boards as well. For instructions, see [Section 5.3](#).

A free, code size limited, but fully functional edition of IAR Embedded Workbench (IAR Kickstart) is available from the IAR Systems website ([www.iar.com](http://www.iar.com)) or from the TI MSP430 software tools page:

[http://www.ti.com/lstds/ti/microcontroller/16-bit\\_msp430/msp430\\_software\\_landing\\_page](http://www.ti.com/lstds/ti/microcontroller/16-bit_msp430/msp430_software_landing_page).

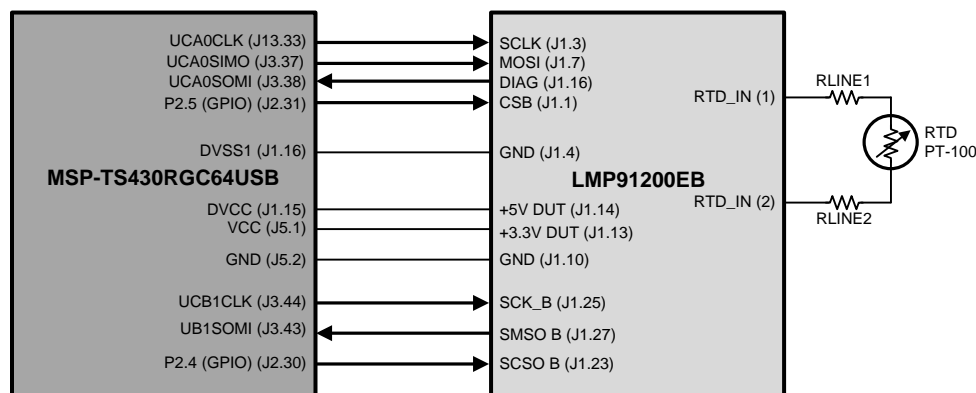
As an alternative to IAR Embedded Workbench, it would be possible to use Code Composer Studio. A trial edition of the Code Composer Studio is available from the TI MSP430 software tools page.

### 5.2 Getting Started

Follow these simple steps to get your application up and running:

1. Install IAR Workbench.
2. Download the source code for this application report and unzip the files to your working directory.
3. Open IAR Embedded Workbench and create a new project:
  - (a) Select Project → Create new project.
  - (b) Select tool chain MSP430
  - (c) Base the project on the empty project template
  - (d) Save (you will also be asked to save the current workspace)
4. Add following C files to the project from the software that you downloaded and unzipped in step 2:
  - (a) All C files from the *codeVlibrary* folder
  - (b) All C files from the *codeVlibrary\TI\_MSP430\_other\_spi\_modules* folder
  - (c) All C files from the *code\demo-application-examples\demo-app01* folder

5. Open the "options" dialog for the new project by right clicking the project name in the workspace window. A window should appear:
  - (a) Under "General options", select the MSP device. For the MSP-TS430RGC64USB target board, use MSP430F5528.
  - (b) Under "C/C++ compiler", click on the preprocessor pane.
    - (i) The "Ignore standard include directories" tick box should not be ticked.
    - (ii) In the "Additional include directories", add include paths telling the compiler where to find the header files included by the C files. You should add the `$PROJ_DIR$\code\include` folder.
  - (c) Under "Debugger", select "FET Debugger" from the "Driver" drop down list.
  - (d) Under "FET Debugger", in the "Connection" section, choose the connection type of the FET tool (Texas Instruments USB-IF). Leave the rest of the settings as is.
6. Click "OK" to close the options window.
7. Select "Project → Rebuild All". There should be no errors or warnings when IAR rebuilds the executables (if not done already, you will also be asked to save the current workspace).
8. The configuration of the hardware definition files in the library as distributed by TI is for an MSP430F5528 equipped board. The system variable `TI_LMP91200_SER_INTF` defined within `TI_hardware_board.h` identifies USCIA0 as the connected SPI port to control the LMP91200. Peripheral pinouts can change slightly between individual MSP430 devices and families. For this reason `TI_MSP430.h` identifies the pins which correspond to a peripheral for any given device.
9. Connect the LMP91200 Evaluation Board SPI interface lines to the MSP430 target board SPI port as shown in Figure 2. Note that the USCIA0 pins of the MSP430 are used to control the LMP91200 SPI pins.
10. Also, connect the ADC141S626 SPI interface lines of the LMP91200EB to the MSP430 target board SPI port as shown in Figure 2. Note that the USCIB1 pins of the MSP430 are used to control the ADC141S626 SPI pins.



**Figure 2. LMP91200 to MSP430 Connection Diagram**

11. The LMP91200 Evaluation Board jumper connections can be seen in Figure 3 and Table 5. Jumpers not shown can be left unpopulated.

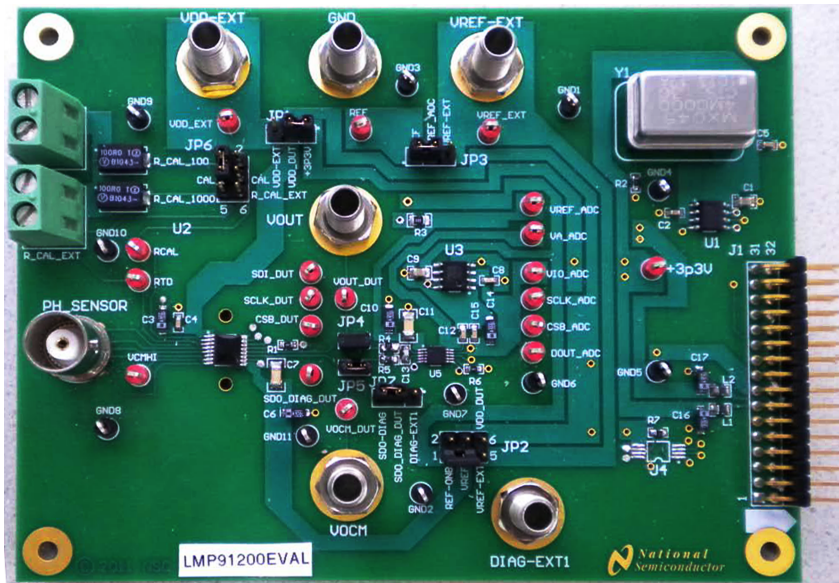


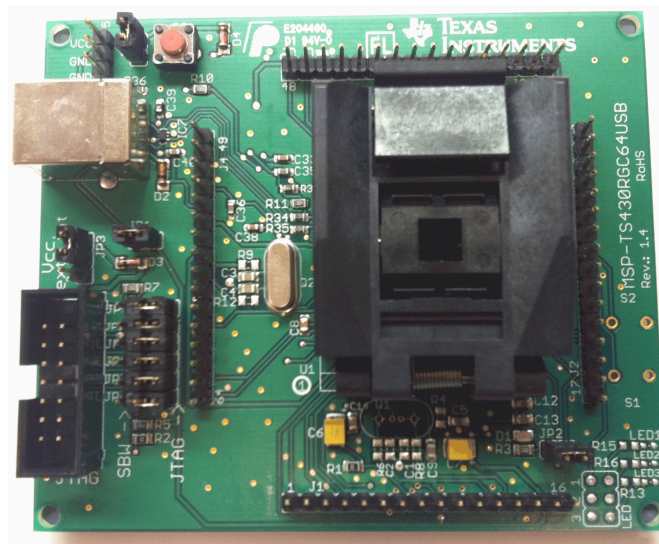
Figure 3. LMP91200EB Jumper Settings

Table 5. LMP91200EB Jumper Settings

Jumpers	Configuration	Purpose
JP1	1-2 shorted	Supply voltage (3.3 V) of the LMP91200 provided from the SPIO4 connector
JP2	1-3 shorted	Connect the onboard voltage reference (2.5 V) to the VREF pin of the LMP91200
JP3	1-2 shorted	Voltage reference provided by onboard voltage reference
JP4	shorted	Connect the VOUT pin of the LMP91200 to the onboard ADC141S626 input
JP5	shorted	Connect the VCM pin of the LMP91200 to the onboard ADC141S626 input
JP6	1-3 shorted	Reference resistor = 100 Ω and a Pt100 is connected to the board
JP7	2-3 shorted	Connect the SDO_DIAG pin to the bidirectional MUX U4

12. Attach the MSP430 FET to your PC. If you are running Windows and using the USB FET tool for the first time, you will be asked to install some drivers for the tool. For Windows, they are located in `$IAR_INSTALL_DIR$1430\drivers\TIUSBFET`.
13. Attach the MSP430 FET to the MSP430 target board using the JTAG connector. The  $V_{CC}$  power select jumper JP3 should be set to 1-2 (int), where the board is powered from the FET alone.

14. The MSP430 target board jumper connections can be seen in [Figure 4](#).



**Figure 4. MSP-TS430RGC64USB Jumper Settings**

15. Select Project → Debug. IAR will now establish a connection with the target MCU, download the application, and program the MSP430. The debugger will be started, halting the target at *main* ().
16. Demo\_app01 is a simple example that demonstrates the SPI calls to write and successfully read back the LMP91200 register. The onboard LED on the MSP430 target board is setup to blink continuously if the value read back matches the value written.
17. Steps 3 to 15 can be followed to exercise other demo applications included with the library as well.

### 5.3 Adapting the Demo Project to Other Hardware

The procedure for adapting this code to other hardware is as follows:

1. Edit the pin assignments within *TI\_MSP430.h* for the interface modules being used. It is not necessary to modify the pins for the interfaces not selected for use with the SPI bus, as they will not be referenced by the library. The labels being referenced in the `#define` assignments will be drawn from the standard definition file (*msp430.h*) listed at the top of *TI\_MSP430.h*.
2. Edit the pin assignments in *TI\_MSP430\_hardware\_board.h*, taking into account all the necessary connections on the board being used. The assigned labels are drawn from the standard definition file (*msp430.h*) listed at the top of *TI\_MSP430.h*.

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**NOTE:** The onboard ADC141S626 SPI interface lines are defined here.

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3. Assign the proper values to *TI\_LMP91200\_SER\_INTF* in *TI\_MSP430\_hardware\_board.h*. The labels available for assignment can be found at the bottom of *TI\_MSP430.h*.
4. Appropriately set up the function to configure the system clock source and clock rate. This depends on your hardware and the particular MSP430 MCU in use.
5. The default setup is to use the onboard ADC141S626 for converting the LMP91200 output. If the ADC141S626 is not used, appropriately set up the functions to configure and convert the LMP91200 output. This depends on your hardware and the particular MSP430 MCU in use.
6. Make sure the physical hardware connections between the MSP430 target board and the LMP91200EB are modified according to the pin assignments above.

After making these changes, rebuild the project and download the code image. The application should function as described earlier.



## 5.4 Using the Library With an Application

The same procedure as described in [Section 5.3](#) should be applied in order to adapt the library to the new hardware.

The function `TI_LMP91200_SWIFSetup()` should always be called after a POR event within the MSP430. After this the access of registers is straightforward.

## 6 References

1. *LMP91200: Configurable AFE for Low-Power Chemical Sensing Applications Data Sheet* ([SNAS571](#))
2. *LMP91200 Sensor AFE Software Download* ([SNAC005](#))
3. *LMP91200 Evaluation Board User Guide* ([SNAU122](#))
4. *MSP430F551x/MSP430F552x Mixed Signal Microcontroller Data Sheet* ([SLAS590](#))
5. *MSP430x5xx/MSP430x6xx Family User's Guide* ([SLAU208](#))
6. MSP430F55xx 64-Pin Target Board MSP-TS430RGC64USB
7. MSP430 USB Debugging Interface MSP-FET430UIF

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Consumer Electronics	<a href="http://www.ti.com/consumer-apps">www.ti.com/consumer-apps</a>
Energy and Lighting	<a href="http://www.ti.com/energy">www.ti.com/energy</a>
Industrial	<a href="http://www.ti.com/industrial">www.ti.com/industrial</a>
Medical	<a href="http://www.ti.com/medical">www.ti.com/medical</a>
Security	<a href="http://www.ti.com/security">www.ti.com/security</a>
Space, Avionics and Defense	<a href="http://www.ti.com/space-avionics-defense">www.ti.com/space-avionics-defense</a>
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