EEE4020

Embedded System Design

Project Report

Interfacing STM32 Discovery board with Current and Voltage Sensor Using I2C Protocol

Name: Pratik Sunil Khandelwal

Reg no. 20BEI0065

Slot: F1

Faculty: Dr. Selvakumar K

Abstract:

Voltage and current sensing are one of the most important aspects in working with sensors and other circuits, these are the basis of measurements. In this project we worked with INA 219 voltage and current sensing module, we interfaced it with STM32 Discovery board to read the values from the sensing module using I2C protocol, the code was written in Bare metal programming. Different sensors give their output in form of voltage across them or the amount of current that they generate depending upon change in resistance, so sensing these values is important for calibration and correlating it with what sensor is measuring.

Introduction:

Voltage Sensing: There are different reasons why voltage sensing is important:

- Voltage Sensing: Voltage sensing allows for precise control of the voltage levels in a circuit. This is important in many applications, such as in power supplies and motor control circuits, where voltage regulation is critical for proper operation.
- Safety: Voltage sensing helps to ensure that the voltage levels in a circuit are safe for the components and users. By monitoring the voltage, it is possible to detect and prevent dangerous situations such as overvoltage or voltage spikes that could damage the circuit or harm people.
- Monitoring: Voltage sensing can be used to monitor the performance of a circuit over time. By tracking changes in voltage levels, it is possible to identify trends and patterns that could indicate problems or opportunities for improvement.

Current Sensing: There are different reasons why current sensing is important:

- Current sensing is important in electronic circuits to ensure that components are not being overdriven, which can cause damage or malfunction. Current sensing can also be used for feedback control in power supplies, amplifiers, and other electronic devices.

- Current sensing is crucial in battery management systems to monitor the charging and discharging of batteries. This is important for maintaining battery health and ensuring safe operation.

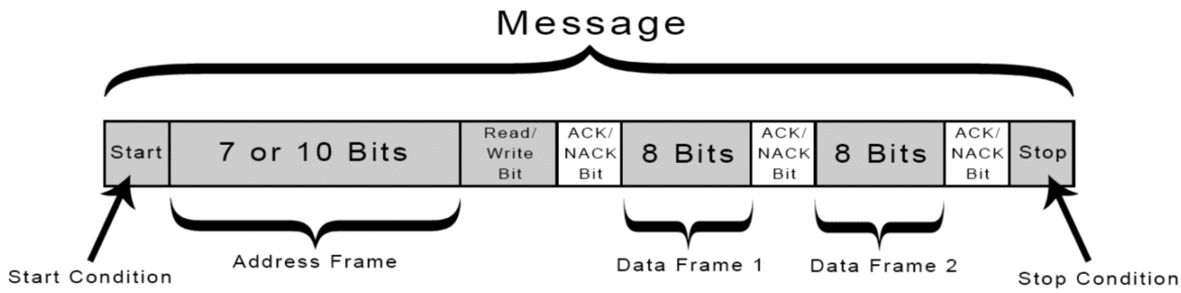
INA 219, can sense two types of voltages, first is bus voltage that is (Vin-)-GND and shunt voltage which is (Vin+ - Vin-), the range that it can measure is from 0 to 26 volts. The range of current is between 0 to 3.2 A.

I2C communication:

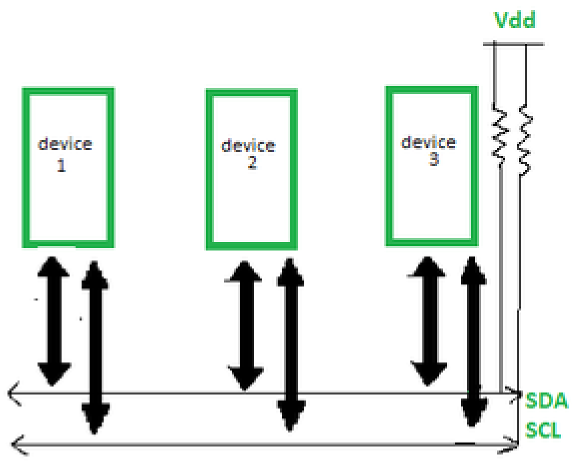
I2C stands for Inter-Integrated Circuit. It is a bus interface connection protocol incorporated into devices for serial communication. It was originally designed by Philips Semiconductor in 1982. Recently, it is a widely used protocol for short-distance communication. It is also known as Two Wired Interface (TWI). The wires are:

Serial Data (SDA) – Transfer of data takes place through this pin.

Serial Clock (SCL) – It carries the clock signal.

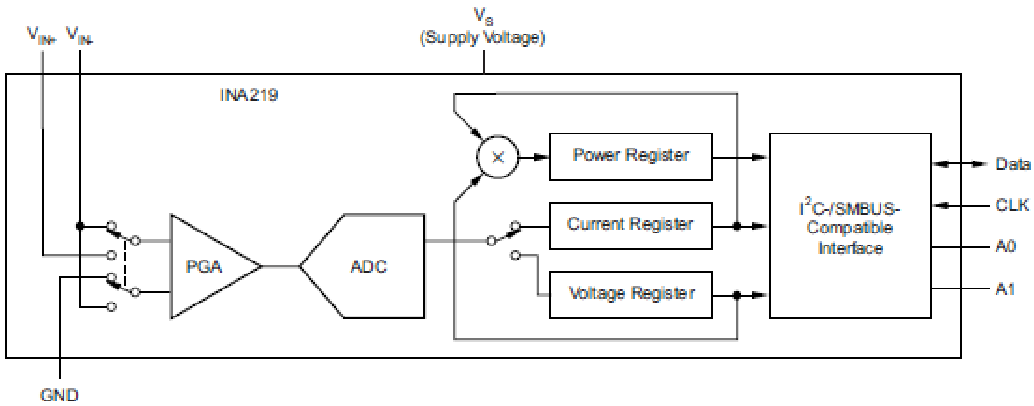


I2C Data Frame



I2C Bus Communication Circuit

INA 219 Current sensor:



The INA219 is a current shunt and power monitor with an I2C- or SMBUS-compatible interface. The device monitors both shunt voltage drop and bus supply voltage, with programmable conversion times and filtering. A programmable calibration value, combined with an internal multiplier, enables direct, readouts of current in amperes. An additional multiplying register calculates power in watts. The I2C- or SMBUS-compatible interface features 16 programmable addresses.

Application and interfacing it with I2C communication

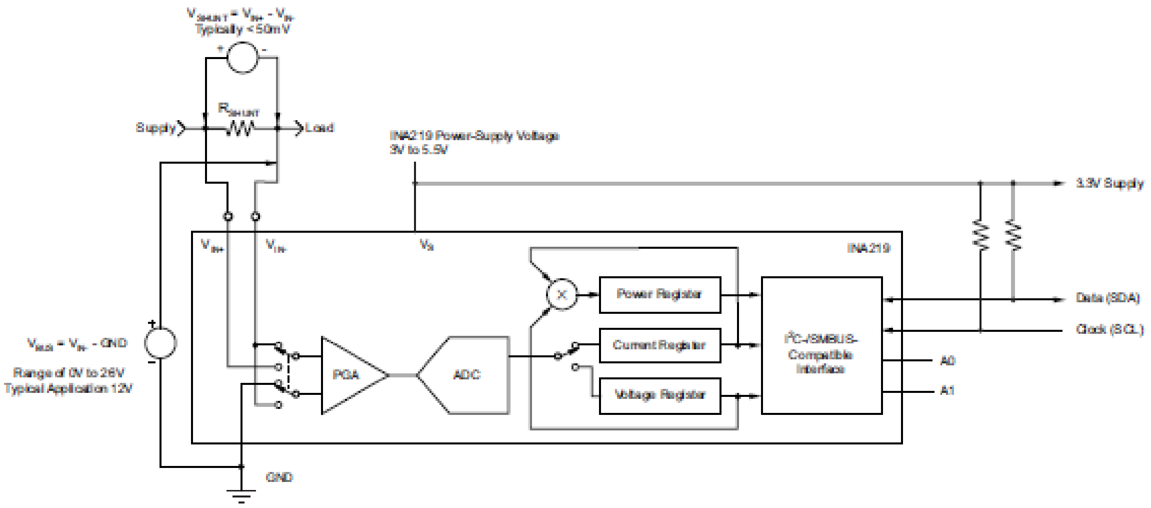


Figure 13. INA219 Configured for Shunt and Bus Voltage Measurement

Methodology:

We used STM32F407 Discovery board as a master in I2C communication and INA219 sensor acts as a slave. The Vin+ and Vin- of the sensor is attached across the shunt resistor to get the shunt voltage and to sense the current across it.

Discovery board has 3 I2C blocks, we are going to use I2C-1 to do the communication, here are the steps followed for interfacing:

1) Setting discovery board in master mode, and configuring the I2C protocol.
   a. Enabling Clock to I2C1 using bus APB1.
   b. Enabling clock access to GPIOB pin, through AHB1 bus.
   c. Setting PB6 and PB7 to alternate function mode as PB6 is SCL and PB7 is SDA.
   d. Setting PB6 and PB7 to pull up pins
   e. Setting both to open drain configuration.
   f. Setting both to high speed mode using OSPEEDR register.
   g. Setting the alternate function for PB6 and PB7

2) Setting I2C
   a. Enter the reset mode in CR1 register and then coming out of it.
   b. Set peripheral clock frequency of 16MHz.
   c. Setting I2C to standard mode 100kHz clock
   d. Setting the rise time in TRISE resistor.
   e. Enabling the I2C1 module at the end.

Reading and writing the data from INA219

There are 5 resistors to either read or write from or both, they are:

Table 2. Summary of Register Set

POINTER ADDRESS	REGISTER NAME	FUNCTION	POWER-ON RESET		TYPE[1]
HEX			BINARY	HEX	
00	Configuration	All-register reset, settings for bus voltage range, PGA Gain, ADC resolution/averaging.	00111001 10011111	399F	R/$\overline{W}$
01	Shunt voltage	Shunt voltage measurement data.	Shunt voltage	—	R
02	Bus voltage	Bus voltage measurement data.	Bus voltage	—	R
03	Power[2]	Power measurement data.	00000000 00000000	0000	R
04	Current[2]	Contains the value of the current flowing through the shunt resistor.	00000000 00000000	0000	R
05	Calibration	Sets full-scale range and LSB of current and power measurements. Overall system calibration.	00000000 00000000	0000	R/$\overline{W}$

(1) Type: **R** = Read only, **R/$\overline{W}$** = Read/Write.
(2) The Power register and Current register default to 0 because the Calibration register defaults to 0, yielding a zero current value until the Calibration register is programmed.

- Here, we have to set the values in Configuration register to change the ADC resolution and the averaging, the standard is 12-bit resolution with a conversion time of 523 micro seconds. The first 3 bits are for operating mode, depending upon which mode the user want he can change the bits:

Table 6. Mode Settings[1]

MODE3	MODE2	MODE1	MODE
0	0	0	Power-down
0	0	1	Shunt voltage, triggered
0	1	0	Bus voltage, triggered
0	1	1	Shunt and bus, triggered
1	0	0	ADC off (disabled)
1	0	1	Shunt voltage, continuous
1	1	0	Bus voltage, continuous
1	1	1	Shunt and bus, continuous

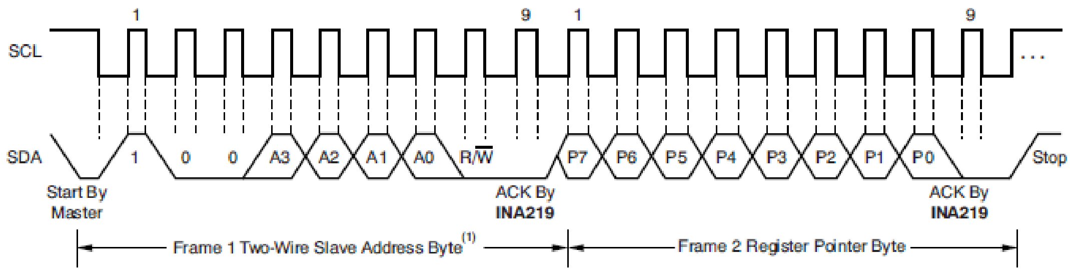
(1) Shaded values are default.

We here are keeping the configuration register to its default value to get good resolution of 12 bits and a good range of shunt register from +-320mV.

Configuration of calibration register is also an important part when you want to sense current and power, without configuring the calibration register you cannot get the value of power and current. Those resistors when read will show value 0.

Reading the data from INA219. (Bus Voltage) (Vin- - GND)

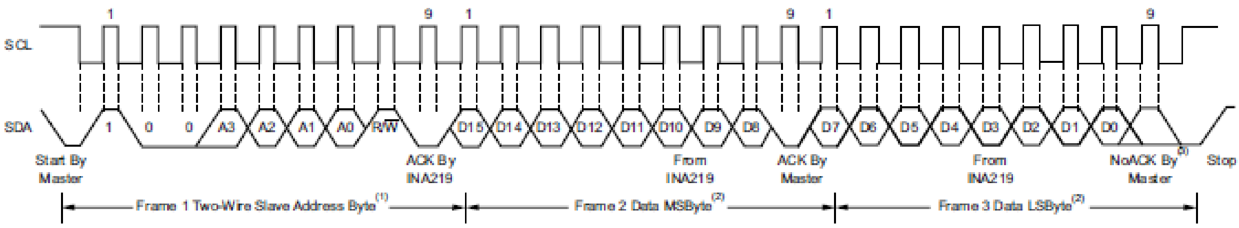
Step 1: select the register that you are going to read the value from. (Setting Register Pointer)



NOTE (1): The value of the Slave Address Byte is determined by the settings of the A0 and A1 pins. Refer to Table 1.

Figure 18. Typical Register Pointer Set

Step 2: Read the value from your resistor (16 bit) (0x02)



NOTES: (1) The value of the Slave Address Byte is determined by the settings of the A0 and A1 pins. Refer to Table 1.
(2) Read data is from the last register pointer location. If a new register is desired, the register pointer must be updated. See Figure 19.
(3) ACK by Master can also be sent.

Figure 16. Timing Diagram for Read Word Format

Step 3: The storing it in a variable, as the first 3 bits (LSB) of the Bus Voltage resistor is not use we shift the value towards right and then multiply by 0.004 to convert it into voltage as 1 bit is equal to 4mV.

Figure 24. Bus Voltage Register

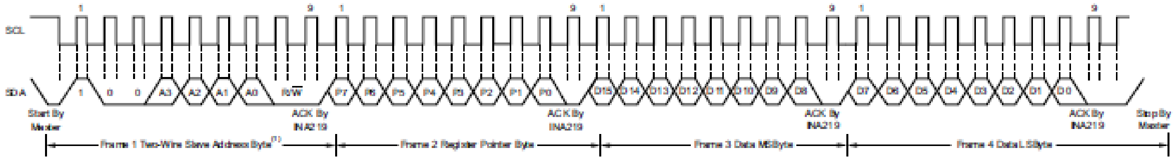
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
BD12	BD11	BD10	BD9	BD8	BD7	BD6	BD5	BD4	BD3	BD2	BD1	BD0	—	CNVR	OVF

At full-scale range = 16 V (decimal = 4000, hex = 0FA0), and LSB = 4 mV.

Setting the configuration register and getting the current value:

1) Step 1: configure the configuration register based upon the maximum current that should be sensed.

2) Step 2: Write the value into configuration register.



NOTE (1): The value of the Slave Address Byte is determined by the settings of the A0 and A1 pins. Refer to Table 1.

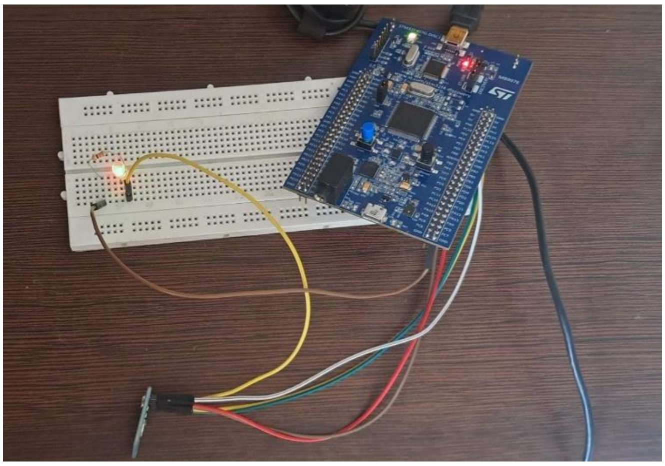
Figure 15. Timing Diagram for Write Word Format

3) Step 3: Read the value from the resistor, follow the same procedure as in case of bus voltage, use it in case of current register (0x04).

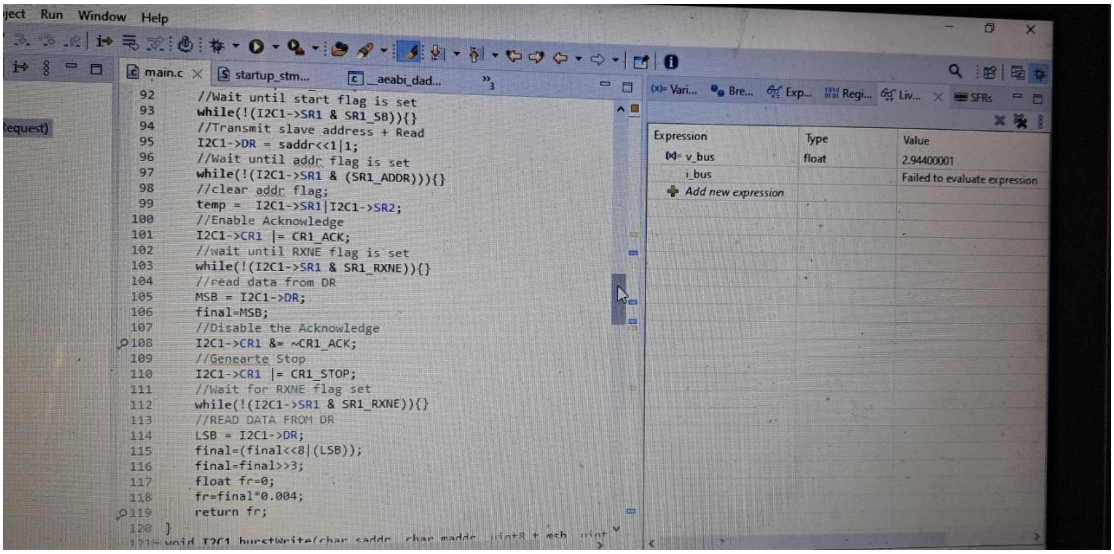
Result:

Bus voltage

Input to be sensed: 3.0V



Setup



Output = 2.94400001 V

Conclusion:

This sensor has many applications from monitoring to control and so on. We were able to use I2C communication protocol and work with this sensor to get the output. We can use and LED display connected with I2C module to get the output displayed real-time on the screen.

This sensing application has many advantages, this can be later modified into a full fletched sensor, in which you depending upon your choice can choose the configuration and the range by yourself and get the final values.

Voltage and current sensors are commonly used in electrical systems to measure the electrical characteristics of a circuit. They provide information about the amount of voltage and current in a circuit, which can be used to monitor and control the circuit's performance.

A voltage sensor measures the voltage level of an electrical signal, while a current sensor measures the amount of current flowing through a circuit. Both sensors are essential in controlling electrical circuits and ensuring that they operate within safe and efficient limits.

Voltage sensors are used to monitor the voltage levels of a power source, such as a battery or an AC power supply. They are also used to measure the voltage drop across a load, such as a resistor or a motor. Voltage sensors can help prevent overvoltage conditions that could damage electrical equipment or cause a safety hazard.

Current sensors are used to measure the amount of current flowing through a circuit. They are commonly used in motor control applications, where the current flowing through a motor is monitored to ensure that it is operating within safe limits. Current sensors can also be used in power monitoring applications to measure the power consumption of a device or circuit.