Hall Effect Sensor for Energy Measurement

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Abstract: The demand for energy is increasing since the people use more home appliances. So energy measurement plays an important role in smart home. One key element for measuring energy is the sensor. In this proposed paper the Hall Effect sensor and the comparison of different current sensing techniques is discussed. The Hall Effect sensor has huge applications in field of industrial and automotive. Depending on performance and some common applications comparison of different current sensing is proposed. Current sensor is used in many applications such as control, measuring, detecting of changed current, monitoring and power management.

Keywords: Hall Effect, MSP430 controller, Energy, Sigma-Delta ADC, Current.

Introduction

Nowadays, the demand for energy is increasing since the people use more home appliances and each device require more power. These demands are not met by the traditional power grid hence smart grid came into existence. The goal of this keen matrix is to move from one route correspondence into two way correspondence. The applications of smart grid are generation, transmission, and distribution. Smart meter, smart socket are the common form of the smart grid technology. Current measurement is necessary for monitoring, control, power management and protection. There are different techniques for current sensing, for example, ohms law of resistance, faradays law of induction, magnetic field sensor and faradays effect. Based on these techniques shunt resistor, current transformer, rogowski coil, magneto resistor, Hall Effect and flux gate sensors are classified.

Literature survey

Silvio Ziegler et.al.[4], this paper deals with fundamental understanding of different current sensing techniques for current monitoring and understanding the performance and drawbacks of each techniques. The comparison between different current sensing techniques is discussed in this paper. Shunt resistor and trace sensing resistor are based on ohm's law of resistances.Due to the increase in size and high power losses shunt resistors becomes difficult at the higher currents. Hall Effect sensors are used in the different applications like home appliances, automotive and energy distribution. The popular techniques such as current transformer and rogowski coil are widely used in energy distribution and for measuring the alternative currents.

Jignesh V. Patel et.al.[2], analog to digital converters converts analog signals which are the real world signals into digital signals. This paper presents the most popular methods of analog to digital converters such as flash, pipelined, successive approximations and sigma-delta. The different architectures of analog to digital converters such as flash, pipeline, successive approximation and sigma-delta ADCs and comparison between these A/D converters are discussed. Sigma-delta converters are a good choice because of its high integration, high resolution and low cost.

Honeywell book et.a.l.[9], in this book basic principle of Hall Effect, basic information desired to apply for Hall Effect gadgets and also the applications and design for Hall Effect systems is discussed. The most essential applications and viable methods for using the Hall Effect detecting gadgets are illustrated. The general ideas of Hall Effect detecting data and the application cases are given in this book.

MSP430 is a mixed signal microprocessor which is well-known for metering and sub-metering purpose/applications. Because of inexpensive, sufficient mixed signal peripherals, low power modes and I/O channels the MSP430 processor is the best choice.

Nattachart Tamkittikhun et al.[10] power monitoring of each and every appliances in the home is necessary for energy saving and planning purpose. This paper focuses on single phase home appliances for energy measurement. In this paper power meter is designed by using current and voltage transformers and Arduino computing platform. The developed meter is to monitor RMS voltage, and current, real, apparent power and power factor in real time. The principle of power meter is to sense current and voltage signals, therefore the current and voltage sensors are required. There are many different techniques for current and voltage measurement based on different principles. In this design they have chosen current and voltage transformers based current and voltage sensor. The programming using arduino is done since it is highly available. Here only one ADC is integrated in Arduino has some flaws for phase shifting.

Hall Effect principle

The rule of Hall Effect sensor is the point at which a current conveying conductor is set into a magnetic field, a voltage will be produced which is opposite to both the current and the magnetic field.

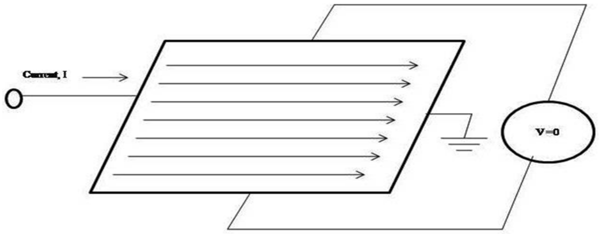

Figure 1. When no magnetic field is present

Consider the thin sheet of a semiconducting material through which current is passed. The current distribution is uniform when magnetic field is not present as shown in above figure 1, there is no potential difference produced across the output. The force called Lorentz force is exerted on a current, when perpendicular magnetic field is present as shown in below figure 2. This force disturbs the flow of current, resulting in the potential difference that is voltage is seen across the output. The voltage which is produced across output is called as hall voltage (V_H).

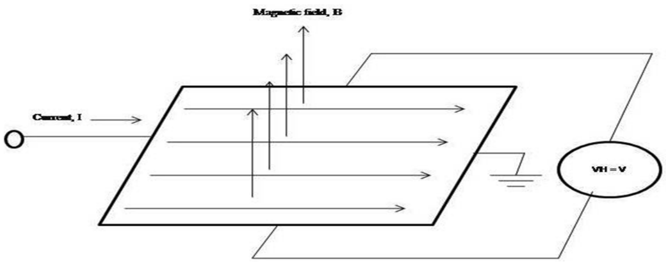

Figure 2. When magnetic field is present

ACS712 Hall effect current sensor

ACS712 is a current sensor based on Hall Effect technology. This component gives precise and economical solutions for communication, commercial and industrial systems, load detection management, universal power supply, over current fault detection and motor control are the application where it can be applied. The specifications of this sensor are ratio metric linear output, supply voltage 5Vdc, measuring range is -5 to +5 Amps and sensitivity of 180-190mV/A.

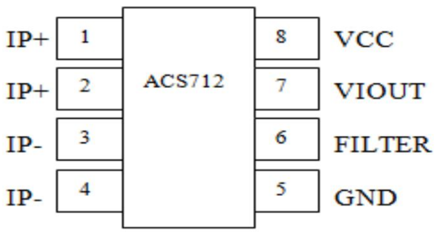

Figure 3: Pin diagram of ACS712

There are three versions of ACS712 sensor such as 5A, 20A, and 30A. 5VDC is required to power on the module, when there is no current the output will be 2.5V that is $\frac{VCC}{2}$. There are eight pins in ACS712 sensor i.e. IP+, IP-, GND, FILTER, VIOUT and VCC.

Comparative Study of Different Current Sensing Techniques

The major role of current sensor is for monitoring, control and protection. Shunt resistors, rogowski coil, current transformer, fluxgate sensor, and Hall Effect sensor are the different current sensors applied in the power systems. The comparison of different current sensing techniques is listed in the table 1 as shown in below, with accuracy and some common applications.

Table 1: Comparison for Different Current Sensing Techniques

Parameters	**Shunt resistors**	**Current transformer**	**Rogowski coil**	**Hall Effect sensor**
Current type	AC and DC	AC	AC	AC and DC
Measuring range	<100A	100A-1000A	0-10kA	10mA-25000A
Cost	Low	Medium	Medium	High
Efficiency	High	Medium	Low	High
Accuracy	High	Medium	Low	Medium
Inherent isolation	No	Yes	Yes	Yes
Power consumption	High	Low	Medium	Low
Frequency range	kHz - MHz	0.05 – 10kHz	0.1 – 100MHz	1MHz
Advantages	Size, speed	No offset voltage	Low sensitivity to parameter variations	No insertion loss, handles high current

Basic methods for current measurement are shunt and trace sensing resistors based on ohms law of resistance; shunt resistor becomes difficult at high currents due to high power losses and increase in size. Copper trace sensing provides low cost and low power losses. Current transformer and rogowski coil are bigger in size; hence due to the size constraints these are not used for measurement. Hall Effect sensor has good linearity, current measuring range is high, and relatively high accuracy hence it is one of the best current sensor for current measurement. Hall Effect sensor also provides galvanic isolation, good accuracy and low losses.

Results

The implementation of 16 bit Sigma-Delta ADC initialization and conversion process is done by considering some test signals with inputs like 50mv, 100mv, and so forth with frequency of 50Hz. The sigma delta ADC internal reference voltage is 1.2V.

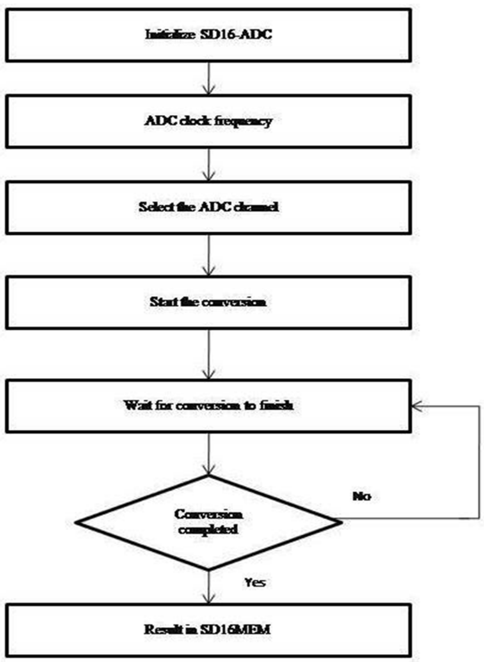

Figure 4. Flow chart for implementation of SD16-ADC initialization and conversion

The MSP430 is an ultralow-power microcontroller from the Texas instruments. MSP430F4xx is designed for energy metering applications. The MSP430F47197 has inbuilt 16-bit sigma delta analog to digital converter (SD16-ADC). The first

step is to compute SD16-ADC with the clock frequency of 32 kHz. This MSP430F47197 has seven independent sigma delta channels, start the conversion after initializing and selecting SD channel. The digital output values are stored in memory once the conversion is finished. If the conversion is not finished wait until the conversion to finish and store the result in SD16MEM. The above figure 4 shown is the flow chart for implementing SD16-ADC initialization and conversion process.
The IAR embedded workbench is used to develop application software. The IAR embedded workbench is an arrangement of improvement devices for building and investigating the implanted applications utilizing constructing agent, C, and C++. The 16 bit MSP430 gadgets from Texas Instruments are bolstered by the IAR apparatus. The IAR advancement apparatus can produce a twofold document that can be downloaded on the microcontroller.

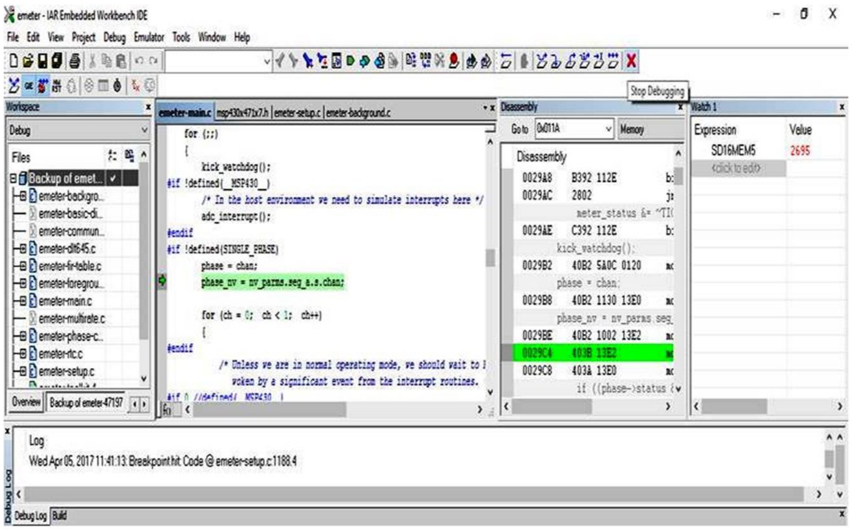

Figure 5. Test signal for input 50mV

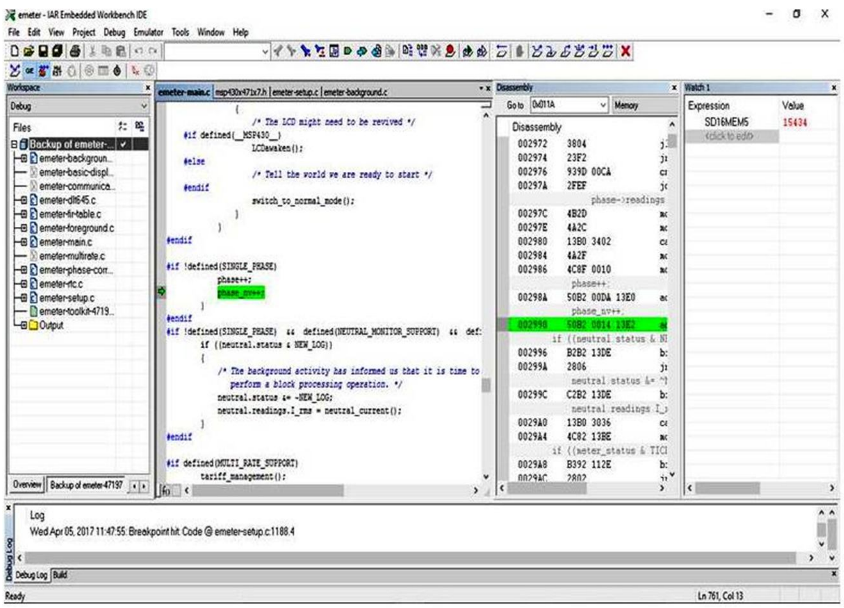

Figure 6. Test signal for input 300Mv

The MSP430 consists of SD16 ADC is differential and needs input voltages at the pins do not exceed +500 to -500 with gain is 1. Resolution is defined as how many parts the maximum signal can be divided into. The resolution is calculated using formula 2^n, where n is the number of bits for example the resolution for 16-bit is 2^16 i.e. 65535 discrete voltage levels.

Table 2. Test signals comparison for different inputs with different loads

Loads (watts)	Analog input (mV)	ADC Resolution for 16-bit (2^n) where n=16	ADC voltage resolution (mV)	Theoretical digital output values	Practical digital output values
11	50	65535	0.7629	2730	2695
20	100	65535	1.5258	5461	5343
35	150	65535	2.2888	8192	8073
40	250	65535	3.8146	13653	12047
50	300	65535	4.5776	16384	15434
70	400	65535	6.1035	21845	20301
80	450	65535	6.8664	24576	23456
100	500	65535	7.6293	27306	25789

The ADC voltage resolution is given by ADC voltage resolution = $(Analog\ input\ )/(ADC\ resolution\ )$. The digital output values are calculated using, digital output values = $(Analog\ input\ )/V\_(ref\ )\ *2\text{^}n$, where n is number of bits and V_{ref} is the reference voltage.

Conclusion

The Hall Effect current sensor plays a major role in measurement issues. The Hall Effect sensor has advantages of cost, performance, high sensitivity, and availability, which make it the most promising for current measurement especially in distributed transmission lines. With different input signals the SD16 ADC digital output discrete values are tested and compared with the theoretical values. For future scope these SD16-ADC samples are triggered to gather current sample. These current sample values are accumulated in register and further processed.

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