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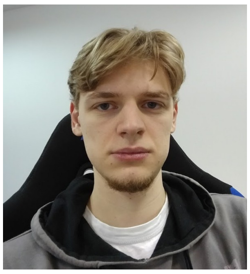


Measuring and representing electric current in the audio spectrum

Summary

In this project we hope to design and implement an electric current measuring device that will represent the information is a form other than visual, that form being auditory. For this purpose, we use a current sensor based on the Hall effect, which communicates on a serial interface with a microprocessor.

The microprocessor then calculates the effective value of the current, based on which a PWM signal in the audio spectrum is generated on one of its pins. The last stage of the design is an amplifier which drives this PWM signal on to a pair of headphones.

Introduction

Generalities

The measurement of electric current entails the successive conversion of a physical unit into an analogic unit and then a digital unit, for the end purpose of being represented in some way, as to inform an interested human agent. The first conversion is usually done using a current sensor, in this case one based on the Hall effect. The second one typically uses a ADC (analog-digital converter) that can be implemented in a number of ways. This representation of information is generally done with the help of an LED matrix display, but there is nothing stopping us from doing it in any other way from which a human can readily extract usable data (ex. Auditory, tactile etc.).

A development board is usually developed around a preexisting microcontroller and offers many functionalities like digital I/O, analog I/O, timers, PWM generators, serial and parallel communications etc. Amplifiers are digital or analogical electronic components made with the purpose of raising the amplitude of a signal given as an input, with as little distortion and error as possible, to be used by other components that require signals of heightened energy (ex. Audio speakers).

Utility

A device such as this could be used for example by people with certain disabilities, which lack the physical capabilities to employ a conventional measurement device. Alternatively, people working in an environment in which current measurement needs to be done in parallel with other measurements that require the undivided attention of the visual cortex could benefit from this apparatus.

Resources

In the construction of this device we have used the current sensor produced by Infineon, TLI4970-D050T4, based on the Hall effect, which can measure alternative or direct current in the range of -50/50Amperes. This sensor offers a good measuring precision in a wide range of temperatures and across its lifespan. (max 1.6%). The offset error is relatively small (under 25mA) and the sensor also offers a rapid method with which to signal an overcurrent state. Galvanic isolation is guaranteed for electric potentials in excess of 2.5kV. Measurement is done with an effective precision of 13 bits, sent over SPI for example to a microcontroller.

The current sensor comes included on a development board, also offered by Infineon, TLI4970050 2 GO KIT, which contains the XMC1100 microprocessor, based on the efficient ARM Cortex M0 architecture. We also employ the use of an audio amplifier, to drive the PWM signal generated by the development board on a pair of Sennheiser HD 449 headphones.

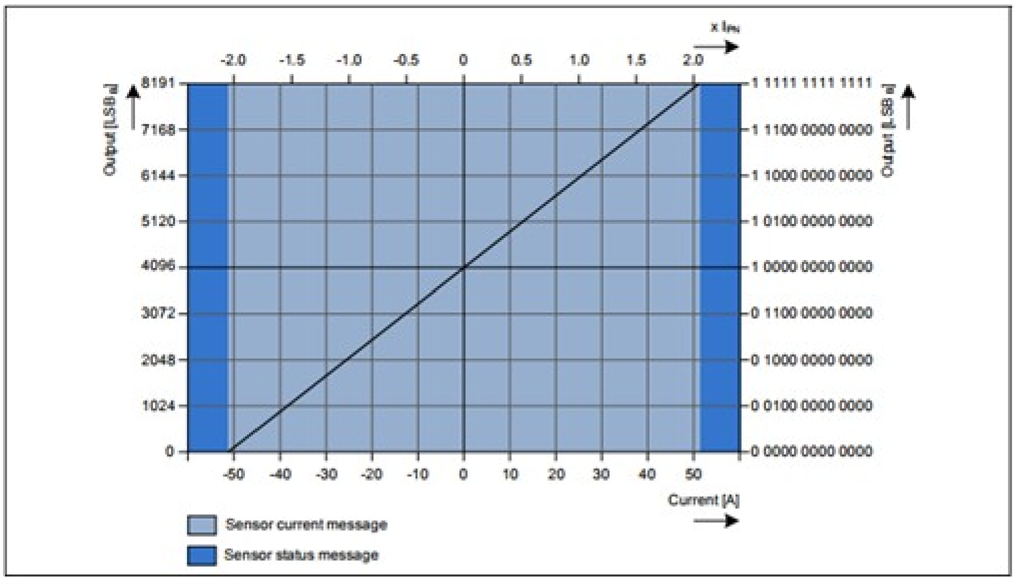
Implementation details

The current sensor(slave) communicates over the SPI protocol with the XMC1100 microprocessor(master) by sending two byes of data on every request initiated by the latter. Based on a transfer function specified in the current sensor spreadsheet, we can calculate the effective value of the current in Amperes, based on data received from it. The formula is as follows:

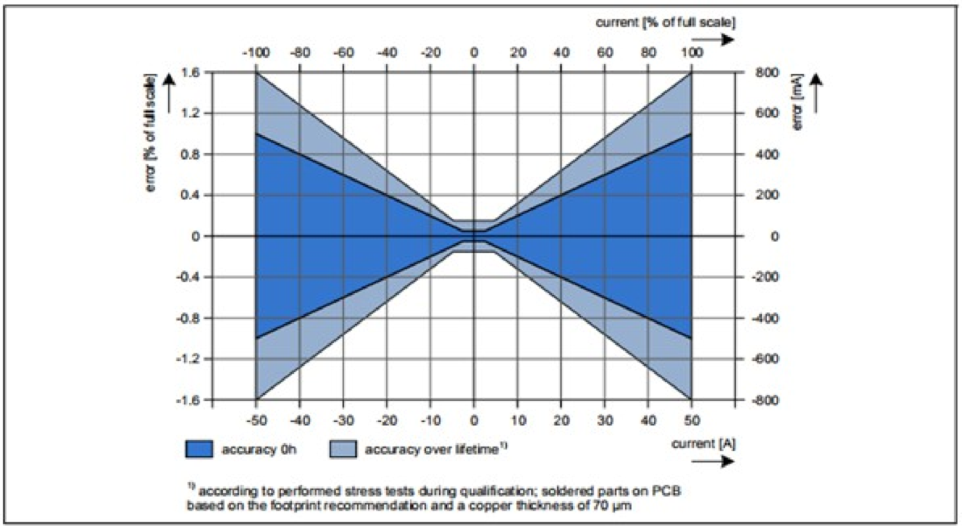
$$I_{out}[A] = \frac{out[LSB_D] - 4096[LSB_D]}{80[\frac{LSB_D}{A}]}$$

$$out[LSB_D] = I[A] \cdot 80[\frac{LSB_D}{A}] + 4096[LSB_D]$$

The caracteristic of this function is liniar, as we can observe in the manufacturer provided graph below, in which measured current valued is plotted against bits returned by the sensor:



The following graph illustrates the maximum value of the measurement error as a function of the measured current:



All SPI frames sent by the sensor are comprised of a 16-bit word. One parity bit is sent with every frame to provide easy error detection in the case of 1bit errors, thusly improving security and reliability in the measured data. Data transmission is initiated by asserting the CS (chip select) pin, ACTIVE LOW. On the next 16 clock positive edges (SCLK), the data frame is transmitted bit by bit on the output pin(DOUT). Betwixt two successive measurements, it is imperative that we deactivate the CS pin.

Two types of data frames can be sent by the sensor on a request, these being differentiated by the status bit (MSB, 1-state/0-measurement). The next bit is one of parity, calculated in such a manner that the parity of the whole word is odd. In the case of the data word, bits 13:0 contain information relevant to the present state of the sensor, while the measurement word with bits 12:0 encodes information about the current value, with bit 13 representing the overcurrent state. The state word offers relevant information with regard to possible hardware errors, out of bounds current, temperature and communication errors and so on.

VALUE — Offset: 01_H — Reset Value: 4000_H

Value of the actual current measurement

15	14	13	12 … 0
0	PAR	OCD	CURRENT
r	r	r	r

STATUS — Offset: 02_H — Reset Value: 8000_H

Sensor status message

15	14	13	12	11	10	9 … 0
1	PAR	HW	OL	OT	COM	RESERVED
r	r	r	r	r	r	r

The development board was programmed using the free IDE framework provided free of charged by Infineon, namely DAVE. In the following code, we instantiated a SPI communications module and a PWM signal generation module. The base value for the audio signal is 200Hz and it is correlated to a current of 0A. Using an infinite loop, the program requests the reading of two bytes from the current sensor, on the SPI interface. Every such operation entails the automated call to an event handler in which data is received as a parameter.

```
void SpiReceive()
{
        if(spi_rx.STAT==0)
        {
        if((spi_rx.STAT ^ spi_rx.OCD ^ spi_rx.PAR ^ spi_rx.CUR12 ^ spi_rx.CUR11 ^
spi_rx.CUR10 ^ spi_rx.CUR9 ^ spi_rx.CUR8  ^ spi_rx.CUR7 ^ spi_rx.CUR6 ^ spi_rx.CUR5 ^
spi_rx.CUR4 ^ spi_rx.CUR3 ^ spi_rx.CUR2 ^ spi_rx.CUR1 ^ spi_rx.CUR0)==1)
        {
                current=spi_rx.spi_word & 0x1FFF;
                current-=4096;
                current/=80;
                sprintf(line,"Current is: %f.",current);
                if(abs((spi_rx.spi_word & 0x1FFF)-(old.spi_word & 0x1FFF))>10)
                {
                pwm_setfreq_status=PWM_SetFreq(&PWM_0,current*1000+200);
                old=spi_rx;
                }
        }
        else
        {
                line="Parity error.";
        }
        }
}
```

First, we verify that the received word is relevant, by checking that the state bit signifies that the information is a measurement. Then, we check for errors by inspecting the parity bit and comparing it with the calculated parity. If the two do not match, then we ignore the message under scrutiny.

The effective value of the current is calculated based on the provided transfer function. To filter out the excessive variance of the audio signal, we ignore in this step all values which do not have a sufficient delta compared to de last valid read value.

Finally, we set the PWM frequency (initially programmed with a duty cycle of 50%) to an appropriate value from the audio spectrum. For this, we chose a linear mapping with a slope of 1000 and an offset of 200Hz. This corresponds to 200Hz for a current value of 0A and 10200Hz for 10A, values which are situated well within the human hearing range (20-20000Hz).

Bibliography

[1] https://www.infineon.com/dgdl/Infineon-TLI4970-D050T4-DS-v01_01-EN.pdf?fileId=5546d4625607bd1301562c43e04f38ad

[2] https://www.infineon.com/cms/en/product/sensor/magnetic-current-sensor/tli4970050-2-go-kit/

[3] https://www.infineon.com/dgdl/DAVE+Quick+Start+PresentationTutorial+v2-1.pdf?fileId=db3a304344d727a80144d99976b2002b