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APPLICATION FOR MEMS COMPONENTS TESTING
APLIKACE PRO TESTOVÁNÍ MEMS KOMPONENT

Abstract

The paper is dealing with description of accelerometer and gyroscope work. The application is designed for communication testing with master system. Testing application uses communication of microcontroller and digital gyroscopes and cooperates with LCD touch screen through USB bus. Application is created for property gyroscopes testing, data acquisition and its other processing to implement these components in inertial systems. This contribution describes method of data transfer from MEMS component to PC, design and realization of communication between tri-axis gyroscope system and computer. One of contribution chapters is dealing with design of measuring chain and its technical support. The following part describes application, which was created at Control Web 5 environment. The application provides monitoring of actual values from particular axis of gyroscopes.

Abstrakt

Příspěvek popisuje práci s akcelerometry a gyroskopy. Zabývá se popisem navržené aplikace pro komunikaci těchto prvků s nadřazeným systémem. Testovací aplikace využívá komunikaci s mikrokontrolérem, digitálními gyroskopy a dotykovým LCD panelem pomocí sběrnice USB. Aplikace je vytvořena pro testování gyroskopů, akcelerometrů, sběru dat a jejich zpracování pro implementaci těchto MEMS komponent v inerciálních systémech. Tento příspěvek popisuje způsob přenosu dat z MEMS systémů do PC, návrh a realizaci přenosové cesty mezi tříosým gyroskopem a PC. Část příspěvku se věnuje návrhu měřicího řetězce a použitým technickým prostředkům. Další část příspěvku popisuje aplikaci vytvořenou v systému Control Web 5 určenou pro monitorování aktuálních hodnot z jednotlivých os tříosého gyroskopu.

1 Introduction

Micro-Electro-Mechanical Systems (MEMS) is the integration of mechanical elements, sensors, actuators, and electronics on a common silicon substrate through micro fabrication technology. Tri-axis system of gyroscope has been used for application. Application provides transfer of measured data through SPI interface. System includes 3 pieces of gyroscope and allows measuring of angular speed at all three axis(x,y,z). These values are measured by 12 bits converters. 8 bits registers are defined for particular axis, in which upper and bottom byte of particular converters are stored. Applied circuit contains control registers, which allow configuring concrete measured system. Here is required a possibility of connection of SCADA/MMI system for other data processing. Standalone PIC chip is used as a “bridge”. Personal computer or notebook contains USB as a standard interface and therefore we need to implement RS232/USB converter. Another requirement was to minimize the whole system that is why SMD component was used. Implementation of various numbers of components is quite difficult and this solution requires technical equipment support.

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It is necessary to use following technical equipment for testing and realization of this solution. These allow testing and debugging of communicating protocols on the both side of communication: microchip <–> three-axis gyroscope system and microchip <–> PC. Logic analyzer ETC M611 was used for real time debugging of data transfer. It can be connected through the USB or LPT interface. For SPI signal evaluation (/CS, CLOC, DI, DO) M611 software (shipped with analyzer) was used. USB interface was used for debugging. Oscilloscope Tektronix TDS 210 was also used for communication monitoring between communication unit and PC. There is a possibility to use for monitoring any kind of software, which allows service of serial interface [Zolotová 2006].

2 Characteristics of digital gyroscope AND KIONIX tri-axis accelerometer

These high-performance silicon micro machined linear accelerometer and inclinometer consist of a sensor element and an ASIC packaged in a 3x5x0.9mm Land Grid Array (LGA). The KXPS5 series is designed to provide a high signal-to-noise ratio with excellent performance over temperature. These sensors can accept supply voltages between 1.8V and 5.25V. Sensitivity is factory programmable allowing customization for applications requiring from ±1.5g to ±6.0g ranges. Sensor bandwidth is user-definable. Interrupts can be generated for acceleration on any axis above a threshold value (Motion Interrupt) or for acceleration on all three axis below a threshold value (Free-fall Interrupt). Voltage is digitized by an on-board A/D converter and is accessed via an inter-integrated circuit (I2C) bus or serial peripheral interface (SPI) [Kionix 2007].

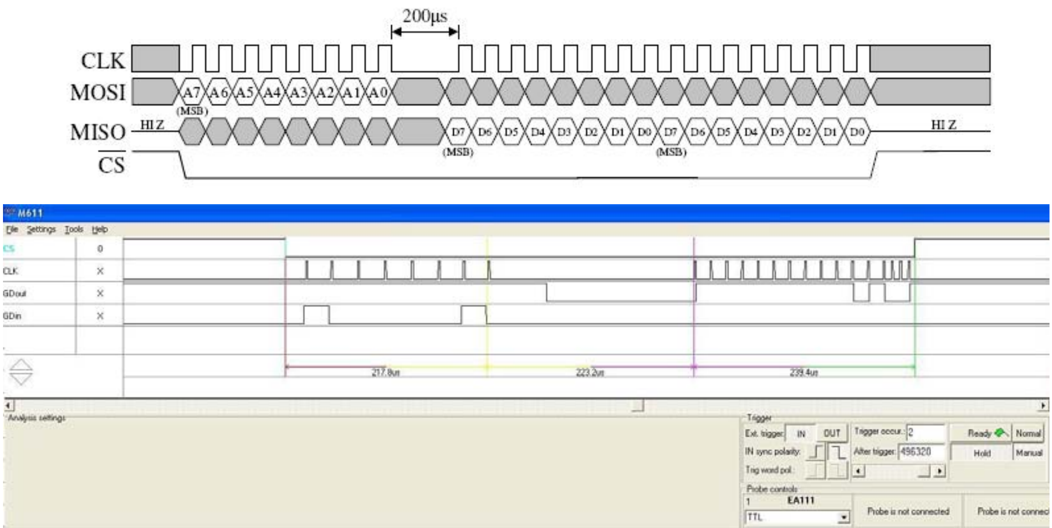

Fig.1: Timing diagram for A/D conversion and read operation (upper), testing of 4 accelerometer signal running by logic analyzer (bottom).

Gyroscope is a complete angular rate sensor with internal temperature sensor that uses the Analog Devices surface-micromachining process to make a functionally complete angular rate sensor with SPI interface.

The digital data available at the SPI port is proportional to the angular rate about the axis normal to the top surface of the device, which is in an 8.2 mm × 8.2 mm × 5.2 mm, 16-terminal, peripheral LGA package [Analog Devices 2007].

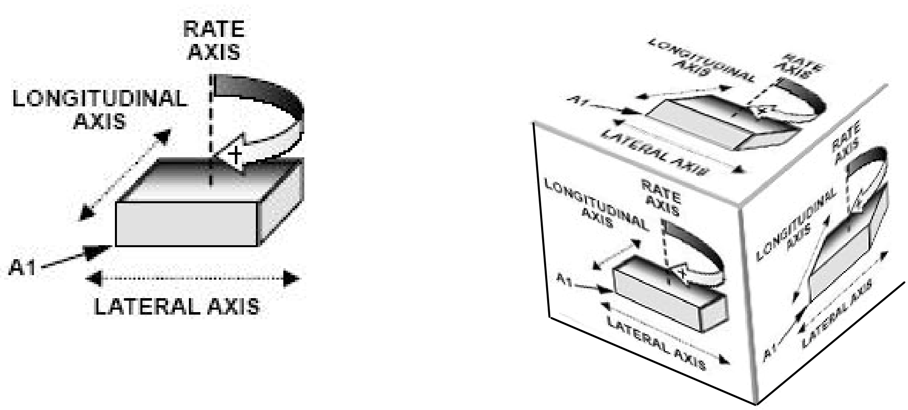

Fig.2: Principle of one-axis rate-sensing gyroscope and our design of 3D cube with 3 gyroscopes

3 Design of connection tri-axis system of gyroscopes and PC

This measuring chain consists of three parts. The first part is the evaluation board with 3-axis gyroscopes system, which allows data providing through SPI interface. Second part of this measuring chain consists of a control unit based on standalone microcontroller PIC [Hrbáček 2002]. The signals for SPI interface are generated here. Initialization, configuration for development board of the 3-axis gyroscopes system, and data processing for transferring data sent to serial interface and PC. The measured data are then processed in a computer for further presentation in the Control Web 5 environment.

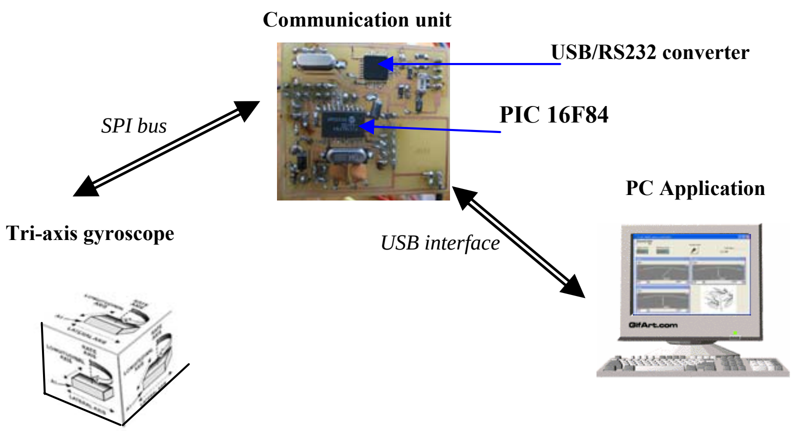

Fig.3 Block scheme of measuring chain

The basis of communication unit is a standalone microcontroller PIC (PIC16F84A - SMD) [Vacek 2007]. Tri-axis gyroscope system evaluation board of is connected to communication unit through SPI interface with four line wires:

/CS – chip select., CLOC – external clock generated by communication unit, DI – data line wire for data transfer from communication unit to board with 3-axis gyro system and DO – data line wire for data transfer from 3-axis gyro system board to communication unit.

The control words are necessary to be configured for all of three axes before their own measurement. Then we can read measured values at particular axis.

Communication protocol was created at C language compiler for microcontroler with embedded assembler support. Timing of protocol is depended on external clock crystal.

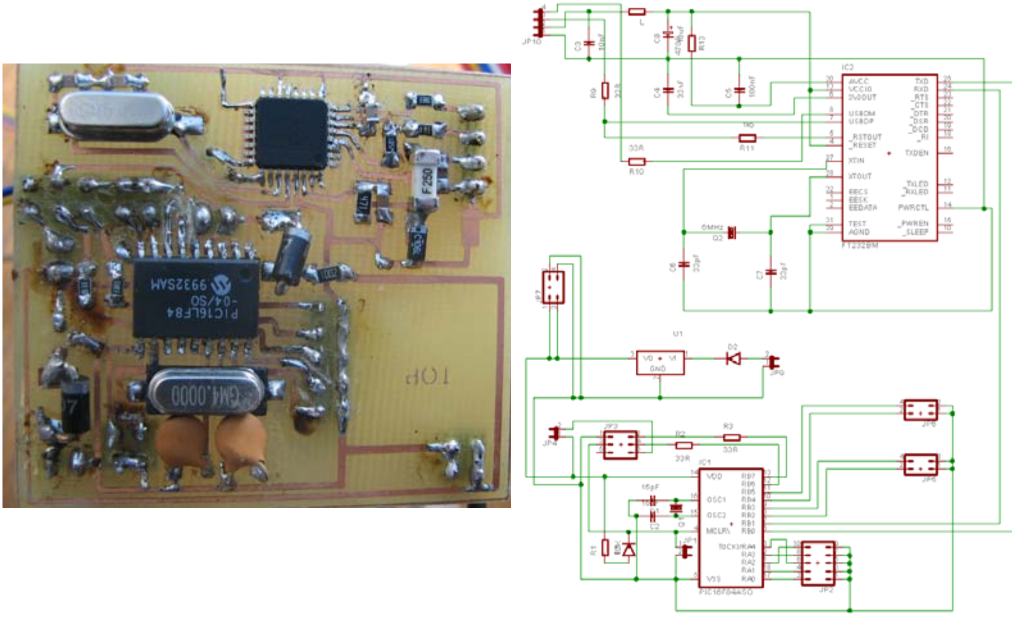

Fig. 4 Communication unit with standalone microcontroller

It was necessary to keep timing according to MEMS component specification (convert time, delay between adress of registry sending and value reading, etc). After having received string processing information from SPI interface, data are sent to PC by RS232/USB convector. So USB interface is the physical layer between communication unit and computer.

This converter is used at virtual COM mode. Scheme of communication unit is described at figure 4. The communication unit answers on request from superior computer by form of string, in which particular values from 12 bit converters of separated axis are encoded. Verified speed of this serial interface is 19200 Bps.

4 Testing Application

Described system above was realized only helping by analog gyroscopes in former times. In this project will be used the newest gyroscopes with digital output from Analog Devices company. Further the final module will be extending with accelerometers, which will communicate with gyroscopes through the common bus.

Methods of project solution:

- Choice of suitable sensors and standalone computer for solution of goals of the project.
- Testing of communication of particular gyroscopes and accelerometers through the SPI bus.
- Design of communication protocol between main control module including microcontroller and particular gyroscopes and accelerometer.
- Design and specification of communication interface between main module and touch screen panel or PDA, IPC etc.
- Design of general ordering of particular sensors in the module which enable sensing of values in three axes.
- Realization of particular printed circuit with a view to possibilities of common bus at the circuit level.
- Realization of prototype of three axis sensing module, which contains gyroscopes with digital output.
- Final testing of module in real operation.

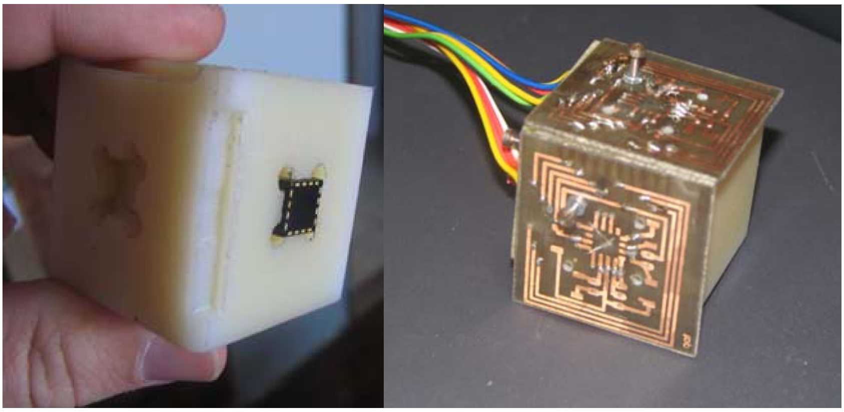

Fig.5: 3D Cube including 3 pieces of gyroscopes

The first step was to test the gyroscope and connect it with master controller through SPI bus. Design and the realization of 3D cube followed. It took fixing gyroscopes to all 3 of axis measurement. This step also required connection of 3 gyroscopes and put them on the same common bus, which communicate with master microchip. Master microchip is connected with LCD touch screen through the USB bus then. This realization is described in the following contribution. Realization of 3D cube is shown at the figure 5.

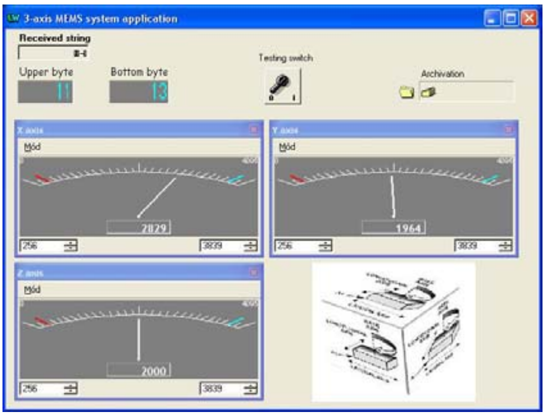

Fig.6 An application window in Control Web 5

The application was created in Control Web 5 environment, which allows monitoring and archiving of measured data [Control Web 2007]. Standard delivered driver was used for data transfer to serial interface. Although USB interface is used as the physical layer, it is possible to use ASCII driver for data transfer using virtual port. The computer controls communication and defines precise moments of measured data transfer. Monitoring is done with the help of SCADA/MMI standard components. An Application window for monitoring and archiving measured values in all three axes is shown at Fig. 6.

5 Conclusions

Design and possibility of communication of three axis gyroscopes system board through SPI bus was tested at the department of control systems and instrumentation and it has been described in this contribution. Standalone microcontroller has been used for signal processing. It generates commands in the form of signals through the SPI bus for three axis system evaluation board. This communication unit is connected to the computer with help of USB interface, which is equipped with converter chip RS232/USB. In this case Control Web 5 environment is a real time monitoring system and it allows archiving of measured data.

Design of application for testing of digital gyroscopes is described in this paper. 3D cube model has been created and equipped with 3 pieces of gyroscopes which allows measure and data acquisition from 3 of gyroscopes simultaneously. Data are provided by the common bus and are under the control of microchip and this one provides data to LCD touch screen or PC through the USB bus after data processing. Another step of project is to connect and test accelerometer, which is implemented into the whole system. The presented results have been obtained during the solving o research project GACR 101/07/1345 supported by the Czech Science Foundation.

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