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FPGA BASED 3D MOTION SENSOR

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ABSTRACT

The main objective of this paper is to explain the functioning of a device, designed to sense the real time motion changes of an object. This motion sensing device Digital Accelerometer can be used to sense any change in the position of an object with respect to its original position, all along the three axes. This Digital accelerometer is to be put into its function controlled by a Field Programmable Gate Array (FPGA). The above motion sensing device connected with the FPGA will also be useful in reducing complexity factors such as area consumption, cost, etc in installing the objects and at the same time, the device could also be introduced in an easier way. This paper is mainly to deal with the experimental procedure in detecting such changes using this motion sensing device Digital Accelerometer.

KEYWORDS: *Digital Accelerometer, Field Programmable Gate Array, MicroBlaze Processor, Spartan6.*

1. INTRODUCTION

Nowadays, usage of motion sensor plays a vital role in the day to day life in many fields. It is used to detect the motion or any change in the position of an object to which it is attached. Sensors used in those days, were capable of sensing the position of an object on two dimensional basis only [1]. But this is quite insufficient now a days in many fields with the advanced developments in technology, and it has become much essential to detect such changes occurred in the position of an object three dimensionally.

In previous days, in order to sense the position of an object three dimensionally, more than one accelerometer was used. But it is quite obvious that maintaining more than one accelerometer at a time is a cumbersome process. To overcome this difficulty, usage of a triaxial Digital Accelerometer is hereby suggested and the details of the same are dealt with, in this paper.

A triaxial Digital Accelerometer with FPGA [2] is more suitable and much precise too, in sensing any change in the position of an object all along the three axis since the sensor is going to be monitored by a PC that has been connected with this device.

Generally FPGA based device are easier for implementation in many applications. These FPGA based devices are mostly preferred as they improve performance of the device as well as it became a Reprogrammable device, so the future improvement regarding this project can be implemented easily.

Through this paper, we are to introduce the high performance and low cost FPGA with Digital Accelerometer to detect the motions of the object with which it was attached.

2. OVERVIEW OF THE PROJECT

MMA8452Q triaxial Digital Accelerometer is used to sense motion of the object along the entire three axis. This Digital Accelerometer is controlled by a Xilinx Spartan 6 MicroBlaze soft processor. This MicroBlaze Processor sends the requests to the Digital Accelerometer to read the position of the object which is to be monitored.

This Digital Accelerometer is connected with a MicroBlaze Processor through I2C Controller [3]. This controller will act as the master and the slave is the accelerometer. The MicroBlaze Processor send request to the slave Digital Accelerometer via I2C controller and also the slave

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will respond to that by transferring the respect co ordinates to the master through the I2C serial Bus.

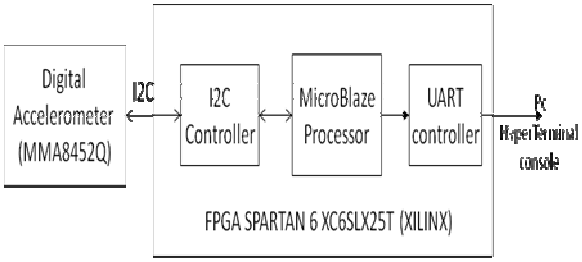

Fig 1: Block Diagram of FPGA Based 3D Motion Sensor

The co ordinates obtained by the MicroBlaze Processor will be monitored by PC which is connected to that controller through UART controller. The UART controller will convert the parallel data to serial and transfer in serial format.

3. ARCHITECTURE AND ITS IMPLEMENTATION

The device has been designed with Spartan 6 (XC6SLX25T) family of package FGG484. (These settings are to be adopted accordingly with the standards of the available board details).

3.1 Controller / Processor

Xilinx Soft MicroBlaze Processor is implemented in Spartan 6 FPGA is the controller as well as acts as a master for the entire design. The fully orthogonal architectural processor is a 32-bit general purpose registers with reduced instruction set Computer (RISC) which is more optimal for Xilinx Field Programmable Gate Arrays (FPGA).

The internal Error Correction Code (ECC) in MicroBlaze Processor provide a complete flexible solution to select any combination of embedded peripherals, memory management unit, and bus-interfaces features on a single FPGA at lowest cost.

Here the IP interface is made with PLB (Processor Local Bus) that lead to usage of big endian reverse format. Generally Spartan 6 uses a dedicated LMB bus to reduce the other buses loading for accessing the local-memory (FPGA BRAM), of the processor.

The Digital Accelerometer is connected to MicroBlaze processor through I2C bus. The data, signals etc. will get transferred through I2C bus between MicroBlaze Processor and Digital Accelerometer. According to the software settings the MicroBlaze Processor get co ordinates from the Accelerometer that it reads.

The Processor will compare the newly obtained co-ordinates with the previously obtained co-ordinates, and if it observes any changes with respect to any of the co-ordinates, then it will transfer the co-ordinates to display on the Hyper-Terminal screen in the PC (Personal Computer). Actually the Processor will transfer the co-ordinates to the Hyper-Terminal screen through a UART Controller.

3.2 I2C Bus

The in-built I2C Bus developed by Xilinx with PLB clock frequency of 50 MHz is used to connect the MicroBlaze Processor with the Digital Accelerometer. The master I2C Bus, transfer data between the processor and the Digital Accelerometer which functioning with an output frequency of SCL is 100 kHz and responds to 7 bit slave address.

Function involved in I2C Bus data transfer are : first start the I2C Bus, then set the slave address which is the address of the device that is going to be connected to the processor, receive or send data between slave and the master, after finishing entire data transfer, stop the I2C Bus.

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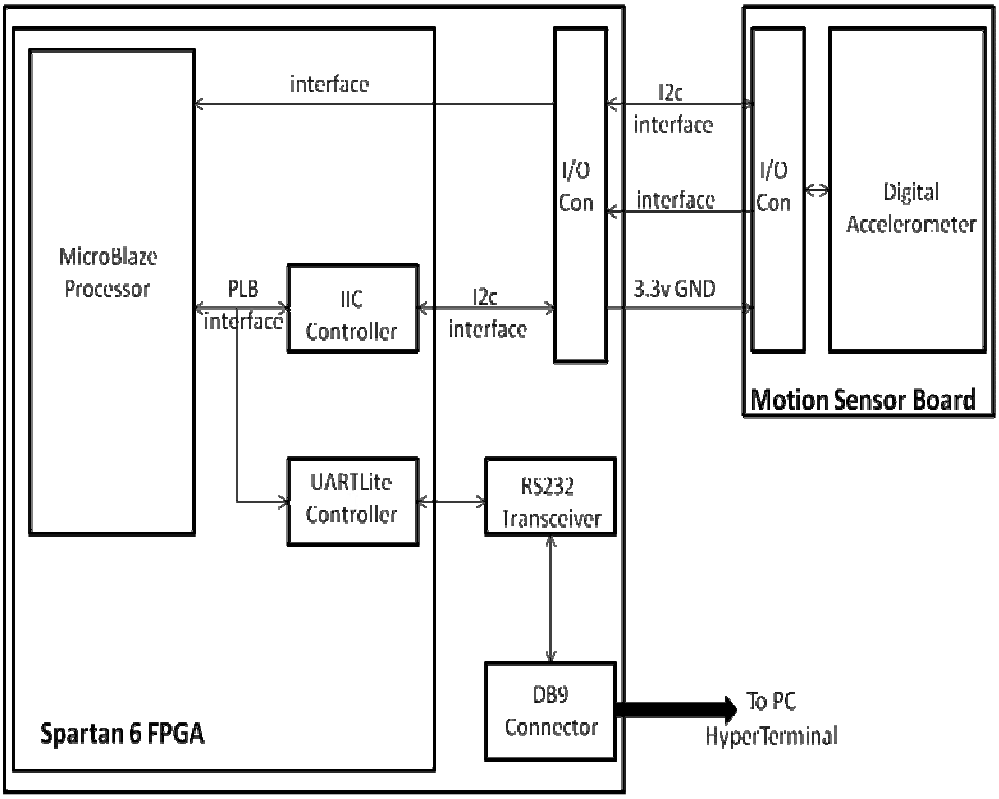

Fig 2: Architecture of FPGA Based 3D motion Sensing Device

3.3 UART Controller

UART Controller designed by the Xilinx is to be utilized for our design. It is to perform parallel to serial connection in data transfer. It is to transfer 8 bit data along with 1 stop bit. It internally consists of 16-character Transmit FIFO and 16-character Receive FIFO.

UART Controller is used to connect the Processor with the PC to display the received data. The obtained data will be displayed in the Hyper-Terminal screen.

3.4 Accelerometer

Accelerometer is a device to convert the mechanical signals to digital signal [4]. This electromechanical device is to measure acceleration forces that the force may be a static force or that could be dynamic force.

In this design three axis MMA8452Q Digital Accelerometer of capacitive Micromachine designed by Freescale Semiconductor is used to senses the motion of the body with which it is rigidly attached. It is available with the user's dynamically selectable scales of ±2g (Gravitational force) acceleration. Digital Accelerometer output is intercepted by I2C Bus that will operate on 2.25 MHz along with required kΩ external pull-up resistor.

The MMA8452Q is16 pin QFN which is available in the size of 3 mm x 3 mm x 1 mm. It will automatically remain in the inactive mode with low power. During active mode it requires a supply voltage of 1.95v to 3.6v.

The MMA8452Q is optimized with low power mode or high resolution mode for output data. Synchronously data transfer Digital Accelerometer which provides 12 bit digital output data (Co ordinates). In that 12 bit data, first 8 bit to the Processor represent the MSB of the acceleration value and the remaining 4 bit is LSB part of the acceleration value.

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3.4.1 Auto-Wake/Sleep Mode

The main advantage of using this Auto-Wake/Sleep mode is that the system will automatically get switched over to higher sampling rate (high current consumption) when it gets any interrupt otherwise it remains in the sleep mode (with low current consumption).

The Accelerometer will go to automatic sleep mode when it does not receive any of the interrupt for a longer time. Due to this, the device will transmit to specified lower sample rate which triggers the device to inactive mode with low current consumption.

3.4.2 Free Fall and Motion Detection

The Freefall/Motion Detection interrupts will make the devices to wake up from the sleep mode. MMA8452Q Accelerometer is more flexible to process the freefall or motion detection [5], [6]. The selection of freefall or motion detection is basically depends on the threshold value which the user sets according to their requirement.

Freefall is any of the motion of the object triggered along with the gravitational force acting on it. It is of examining X, Y, and Z axis of the object when it obtains the request from the Processor.

4. EXPERIMENTAL RESULT

The Digital Accelerometer attached physically to the body of the object can be moved in all the directions. According to the changes in the body of the object the respective changes in co-ordinates will be displayed on the Hyper-Terminal screen. Some of the samples of the co-ordinates displayed on the Hyper-Terminal screen are added here.

From the below table we can view the changes in the co-ordinates from the previous co-ordinates according to the changes in position of the object.

Table 1: Sample of co-ordinates during changes in object position

X_Axis	Y_Axis	Z_Axis
244	252	63
207	250	36
197	251	21
247	244	60
63	0	7
63	244	5
11	251	64
154	168	231
78	169	240
5	68	39
79	37	19
224	244	55
197	230	15
28	245	57
28	234	235

5. CONCLUSION

In this study of FPGA based Motion Sensor, for our analysis the small Digital Accelerometer has been fixed on a small board. We analysis the motion/freefall along all the three axis of the board on which the Digital Accelerometer was fixed and the changes in position of this board are monitored by using a PC. In future, the scope of the project can be expanded in such ways, that they can be utilized in many developing fields, like detecting the motion of the human beings by making small device, detecting the motion/falling of HDD (Hardware Disk Drive) which is going to attach with that, auto-sleep and auto-wake intended for cell phones screens, PDA (personal digital

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assistant), GPS (Global Positioning System), gaming etc.

The combination of FPGA with accelerometer makes it much easier to be implemented in many fields and also it requires very small space and as well consumes less power.

In order to reduce the area utilize for this project, LCD is going to implement for co-ordinates display instead of PC. Already lot of studies shown that, the accelerometer was implemented in many fields to achieve good resolution over the object position.

6. ACKNOWLEDGMENT

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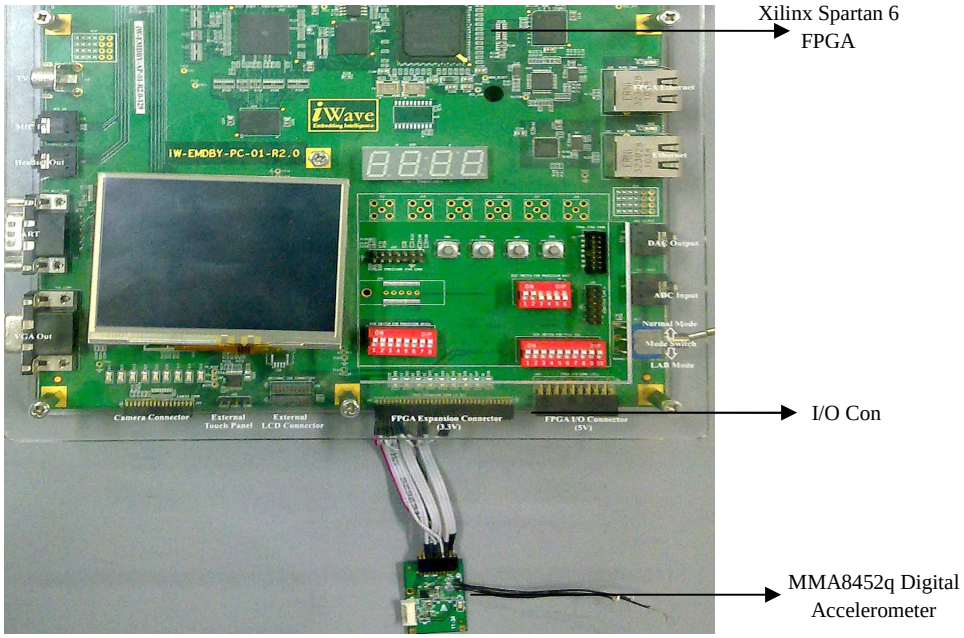

Fig 3: MMA8452q Digital Accelerometer board with Xilinx Spartan6 FPGA

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