Wireless Communication Between FPGA and Microcontroller

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***Abstract*— This paper offers a new method to the design and implementation of wireless communication between an FPGA device and a microcontroller. Wireless Bluetooth communication is utilized, as the Bluetooth modules are low-cost compared to other wireless modules and provide easy interfacing with both the FPGA and microcontroller. FPGAs have a higher parallel processing ability and can accomplish very precisely timed continuous and simultaneous tasks. This is done using UART protocol, as a means to exchange the data. With these predominate abilities, FPGAs can be crafted into a central unit for processing. By using the FPGA to take on some of the processing tasks, it improves system performance and frees up the MCU from cycle-intensive tasks. In this display of wireless communication, the microcontroller and sensors are mounted remotely. Communication between the microcontroller and FPGA is attained through Bluetooth, that operates in the 2.4 GHz frequency. UART protocol is utilized for interfacing the Bluetooth module with both the microcontroller and FPGA. As FPGAs do not have any dedicated logic to communicate with microcontrollers, a UART module was designed and implemented with an FPGA using a state machine design. The paper discusses several ways for these implementations.**

Keywords—FPGA, Microcontroller, Bluetooth, UART, Wireless Communication

I. INTRODUCTION

Microcontroller based embedded systems have been used in several projects for decades. They are comparatively inexpensive, versatile and easy to interface with various modules, thus making it popular within embedded systems. However, there are a wide variety of tasks in which a microcontroller cannot do efficiently. In these scenarios, FPGAs could be considered the best fit. The FPGA is a collection of several digital logic elements with configurable interconnections. While using these interconnections, an FPGA can be programmed to perform multiple concurrent functions. In addition, soft microprocessors can be implemented on an FPGA, by taking advantage of software development. The parallel processing in an FPGA makes it superior to other processors. In these other processors, the tasks are performed in a sequential manner [1]. However some hinderances that the FPGA imposes are, that complex algorithms can be impractical and its expensive price.

Selection of an FPGA or a microcontroller is done on the basis of project requirement. One solution is to use both an FPGA and microcontroller. This is done to utilize the advantages of both devices. The scope of this project is to utilize both devices by setting up wireless communication between them. In this solution, an FPGA is used to do tasks that demand precise timing and low latency while the microcontroller takes care of the remaining tasks.

Table 1: Comparison of FPGA only, Processor only and FPGA + Processor [2]

Platform	Advantages	Disadvantages
FPGA only	Precise timing Deterministic behavior	Tedious design Cost Hard debugging
Processor only	Easy implementation of the control algorithm Easy debugging	Interrupt latencies Size and cost for high performance DSPs
Processor + FPGA	Precise timing Deterministic behavior Easy implementation of the control algorithm Easy debugging	Development requires knowledge of software and FPGA design

II. DESIGN

In this project, a BASYS-3 board is used for the FPGA, a MSP432 launchpad is used for the microcontroller, and a HC05 Bluetooth module for a wireless Bluetooth module. The block diagram for the overall system can be seen in Fig 1.

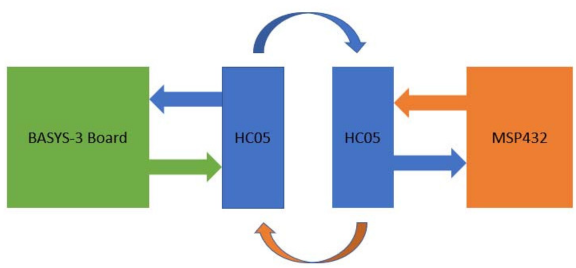

Fig 1: Block diagram of overall system

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The Bluetooth module is interfaced with the microcontroller and FPGA through UART protocol.

The MSP432 launchpad is equipped with built-in UART support, while the FPGA uses a state machine design to configure UART. This state machine diagram of the transmitter and receiver is shown in the in Fig 2 and 3. Along with the state machine design, the microcontroller is resynchronized to the FPGA clock domain, due to the asynchronous communication between the two modules.

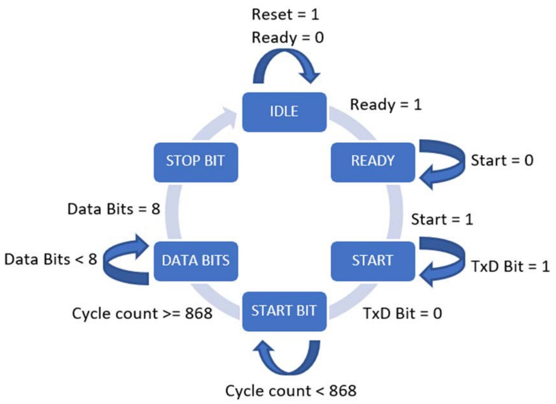

Fig 2: State diagram of the Transmitter

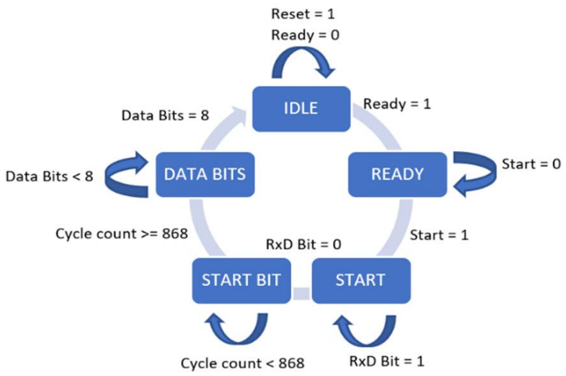

Fig 3: State diagram of the Receiver

As mentioned, the MSP432 is equipped with **eUSCI_A** (Enhanced Universal Serial Communication Interface A) module which is needed for UART mode. Two interrupts handlers were used: ***EUSCIA0_IRQHandler*** and ***EUSCIA2_IRQHandler,*** for Serial Terminal and Bluetooth respectively.

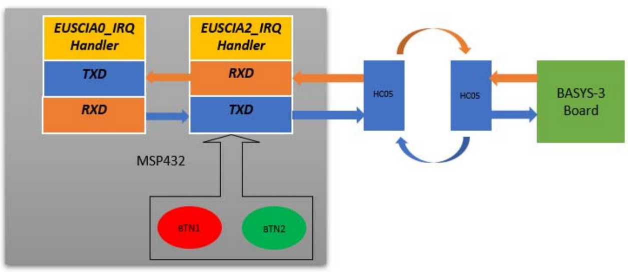

Fig 4: Use of eUSCI_A modules on MSP432

III. Implementation

After the designs were ready for both FPGA and Microcontroller, they were incorporated in the project. First, the two HC-05 Bluetooth modules were paired, allowing for automatic exchange of data when powered on and within range. This was achieved by using interfacing the modules using I2C communication. The Bluetooth modules were configured as Master and Slave by putting them into AT mode and using their physical address to bind them together.

Once the Bluetooth modules were configured, they were interfaced with the FPGA and Microcontroller. The connection between the FPGA and Bluetooth module can be seen in Fig 5.

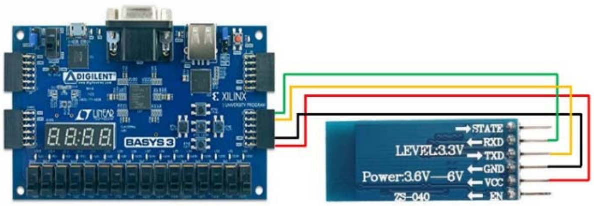

Fig 5: Wiring diagram of BASYS-3 and HC05 module

The interface between the MSP432 with the Bluetooth module along with the peripheral devices used in the project is shown in Fig 6.

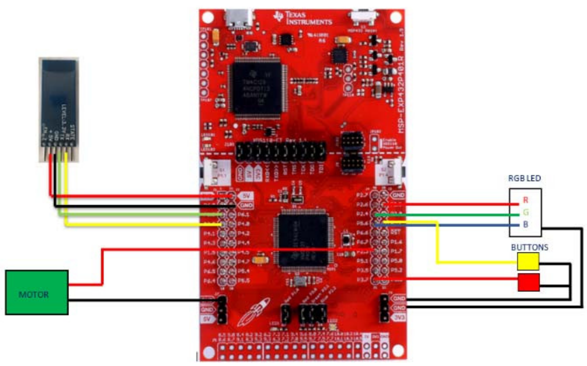

Fig 6: Wiring diagram of MSP432 and HC05 module along with peripheral devices

Once the Bluetooth modules were interfaced with and FPGA and Microcontroller, the two separate configurations were combined together. To ensure that the project was working as designed, a proof-of-concept method was made for larger applications. The application demonstrated was simple, allowing for the verification of bi-directional communication between the FPGA and Microcontroller. Pushbuttons, switches and LEDs were used on FPGA side, whereas pushbuttons, RGB LED and DC motor were used on Microcontroller side. These peripheral devices were used to verify the communication between the two Bluetooth modules, and demonstrate a simple application that this project can be used for.

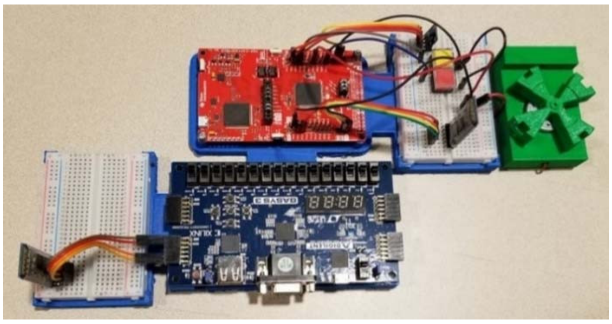

Fig 8: Final project

IV. Application

This project can be used for various tasks within different fields. For example, within the automotive industry vehicles are equipped with heavy electronic equipment that require high processing computation that can be done by a FPGA. Moreover, the use of FPGA helps build innovative safety applications such as adaptive cruise control, driver assistance, collision avoidance, and blind-spot detection.

Vehicle-to-vehicle communications are expected to have a greater impact on road safety. Vehicles could be connected using the communication protocol described above. Wi-Fi can also be used in place of Bluetooth. If this method is chosen, the core system and UART would remain the same. Fig 7 depicts the overall system of vehicle-to-vehicle communication using the implantation described.

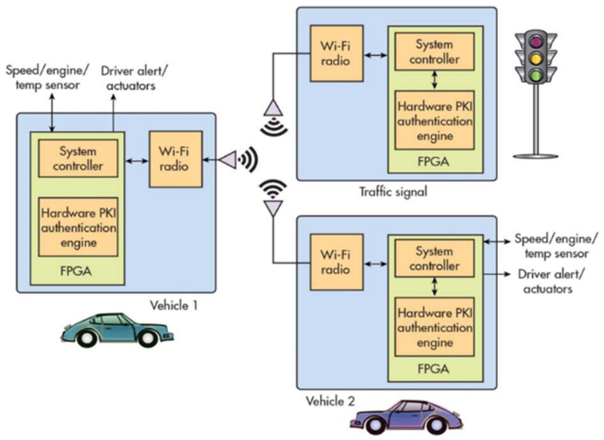

Fig 7: Vehicle-to-Vehicle Communication [9]

Another application of this project can be Industrial Automation Systems, where the field is heading towards wireless communication. Many Automated Storage and Retrieval Systems (ASRS) in warehouses still uses trailing cables which are prone to physical wear, require regular maintenance and replacement. This causes unnecessary time and money allotted for maintenance [10]. Switching to a wireless communication system could be a serviceable and cost-effective solution. The latest Bluetooth version can support up to 5mbps of data transfer within 200 meters (around 800 feet). This would be ideal for warehouse environments to establish wireless communication between ASRS and PLCs.

Similarly, the project proposed can be also be implemented in the field of home security and automation. Sensors used in this field such as, temperature and motion sensors, and video surveillance systems can be mounted remotely and interfaces with the microcontroller. Using Bluetooth, the data that needs to be processed can be transferred over to FPGA, keeping microcontroller free for running other main applications, such as alarms systems. This is likely to improve the overall system performance of microcontroller-based home-automation and security projects.

Combined FPGA-microcontroller can be applicable in real time systems such as, Network Security. Secure transaction of information is one of the most important tasks among networking. Encryption/Decryption is required to facilitate the secure transaction. This process can be accelerated using FPGA as coprocessor alongside the microcontroller.

IV. CONCLUSION

To conclude, wireless communication between thee FPGA (BASYS-3) and Microcontroller (MSP432) using Bluetooth (HC-05) and UART as communication protocol is successfully established. This paper proposes an approach to implement wireless communication for FPGA/Microcontroller based embedded system. The project presented is used to perform tasks that need high computation using the FPGA. Using the FPGA alone will increase the cost, power and development time. Thus, by interfacing the microcontroller with the FPGA, has a more user-friendly learning curve, the simpler task can be done and it can transfer data to the FPGA for further processing. Using the Bluetooth protocol gives the extra flexibility to use wireless communication. This system also allows for more adaptability, due to being able to interchange the Bluetooth device used.

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