

Development of ARM and CPLD Based Multi Controller Board

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ABSTRACT

Over the course of the last ten years, the number of researchers, academicians, and industry people participating in development boards has significantly increased. In order for product development departments to realize their objective of generating higher-quality items, it is vital for them to integrate the processes of developing both hardware and software. The fundamental concept that supports a multi-controller board which incorporates ARM and CPLD cores has been materialized into a working product. There is not yet a version of a Multi-Controller Boards that is currently available in the marketplace that incorporates both CPLD and ARM into such a single board at the same time. This is the case despite the fact that such a board would be desirable. Creating a board that can accommodate many controllers is the primary objective of this endeavor. In addition to a switching circuit, this board will feature an ARM chipset as well as a CPLD chipset as its primary components. In order to transition between the two chipsets, the switching circuitry have been utilized.

Keywords: *ARM (Advanced Risc Machine), Development boards, CPLD (Complex Programmable Logic Device), PCB (Printed Circuit Board).*

1.0 Introduction

Development boards play an important and productive role in the improvement of engineering practices, the improvement of the quality of engineering training, and the assistance of students in broadening their design ideas, among other things. Hobbyists and students need a kit which can be used as either one CPLD or even an ARM on a single board; this is necessary despite the fact that multi-controller boards are readily available on the market. When combined on a single board, the programmable combination of CPLD & ARM may sometimes be more cost-effective than using two separate boards. Complex Programmable Logic Device is an acronym for EEPROM-based CPLD. A CPLD is a logic system with macro cells and completely programmable AND/OR arrays. The fundamental building blocks of a CPLD are macro cells, which feature dynamic logic operations and logic for applying dependent variable form expressions. AND/OR arrays can be reprogrammed entirely and are used to execute a variety of logic operations. Frequently, macro cells are blocks of functionality that carry out sequential or combinatorial logic.

An ARM processor is a type of central processing unit that was developed by Advanced RISC Machines and belongs to the RISC (reduced instruction set computer) family of CPUs (ARM). In addition to central processing units (CPUs) and intellectual property cores, ARM also provides full software development tools. These tools, which include Keil and DS-5, make it possible to build whole systems using ARM microcontrollers and systems on chips.

In the beginning, the purpose of development boards was to educate the public. Its use has expanded beyond instructional reasons and into industrial applications as modern development boards that are more cheap have been available [1]. In 1984, Altera Corporation, which had been established the previous year, released a CPLD [2]. There is not yet a model of the a Multicontroller Board available on the market that incorporates both CPLD & ARM into a single component at this time. Numerous power system elements of MAX II portable systems are useful. The MAX II device features two primary power options. The unit with an integrated core voltage regulator is the most practical [2]. As a result of this discovery made by designers, microcontrollers with hundreds of inputs and outputs are no longer as small and cost-effective as they once were. It is not unusual for a tiny form factor CPLD to contain more than 50 I/Os. A CPLD does not often compete with a microcontroller, but when it does, it makes an ideal companion

With the debut of CPLDs, designers learned that CPLD can be utilized to replace or supplement microcontroller-implemented functionalities in portable applications [3] because modern CPLDs consume less power than their predecessors, the relevance of thermal control & power usage in battery-powered devices has decreased [4]. CPLDs are manufactured by a number of different companies, including Intel (Altera), Lattice Semiconductor, Microchip Technology (Atmel), Silego Technology, and Xilinx [5]. In 1978, Cambridge University was responsible for the introduction of the first ARM processor. In 1985, the Acorn Computer Company was responsible for the construction of the very first ARM processor. ARM was established in 1990 and rose to prominence quite quickly after its inception [6].

In the previous works, ARM has shipped 6.4 billion Arm-based chips, including a record-breaking 4.2 billion Cortex-M processors [7]. With CPLD solutions from Xilinx, low-power, high-performance, or a combination of the two are all feasible. Xilinx's CPLD is suited for potential design difficulties. Xilinx CPLD family are industry-leading [5] because to their high-performance, low-power, nonvolatile characteristics.

When building circuits, protection circuits for microcontrollers, it is essential to take care of the fundamentals first. This means that any digital pins that link to conductors and are exposed to large currents must be secured by protection circuits. The PCB is created from scratch for the current inquiry. A logic design can be described using the hardware description language known as VHDL. This language can also be utilized. The VHDL logic design can then be read by software tools in order to generate a configuration file, which can subsequently be loaded into a CPLD in order to implement a logic design on the CPLD.

Automatic identification and data capture (AIDC) technology is required under the Unique Device Identification System final rule (UDI Rule). It is the PCB's unique system number that provides information about its manufacture. A bootloader is a piece of code that enables the updating of user application code. Alternative download mechanisms, such as a USB stick or a network port, are available for obtaining the new code. After the boot ROM is executed, the bootloader is executed and, if necessary, will do the update before executing the end-user programme. This work also employs a flash programmer, a gadget that allows us to programme the flash memory of a microcontroller. Transferring, compiling, and sending the programme to the microcontroller for execution is possible.

2.0 Methodology

Both the hardware and the software can be separated into their own portions on the board. The component known as the hardware can be subdivided even further into two parts: the first contains the chipset and the control, and the second is made up of the resources and the peripherals. The CPLD chipset, the switching circuit, and the ARM chipset are the individual components that come together to form the hardware part. The Quartus tool is used for the design of CPLDs, whereas STM32CubeMX & Keil uVision are used for the programming of ARM devices, respectively. USB Blaster and ST Link V2 programmers are used to programme CPLD and ARM chipsets. The power supply jacks and the voltage regulator are also included in the hardware resources. The direct current voltage on the input is controlled by a voltage regulator, and then it is distributed to the various components according to their individual needs. IO pins, LEDs, and user switches are the types of peripherals that have been integrated onto the board.

The CPLD and ARM chipset were created with the KiCad software, and the resulting schematic diagram may be shown in Figure 1. Both the CPLD chipset and the ARM chipset are made up of a variety of components in order to fulfill their respective functions. The ICs that were used include ALTERA MAX II EPM240T100C5 for the CPLD chipset and STM32F103C8T6 for the ARM chipset. This information can be seen in the schematic. Figure 2 shows the Block diagram for the Implementation of CPLD and ARM.

2.1 ARM Schematic

The schematic for ARM is shown in Figure 3. Because of the ease of availability in the local market, the availability of software as open source, and the compatibility of the ICs to meet the technical specifications and best suit for the design, EPM240T100C5 are chosen for the CPLD chipset, while STM32F103C8T6 is chosen for the ARM chipset. Both of these chipsets are chosen in order to meet the requirements of the design. It has been determined that the ICs, in addition to any and all other required components, have been procured. KiCad is the software application that is utilized throughout the process of designing the printed circuit board. It is manufactured using JLC PCB, and each component is inserted onto the PCB only after the continuity check has been completed. Proposed Methodology which includes Procurement of components, Designing, Fabrication and finally testing the board.

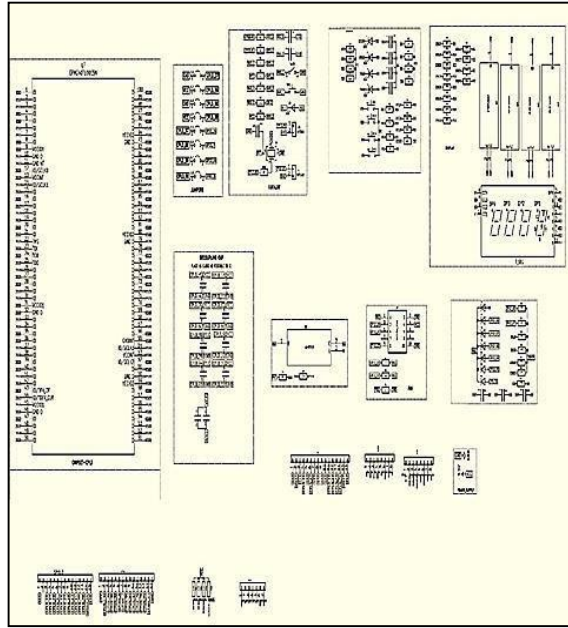


Figure 1: CPLD schematic

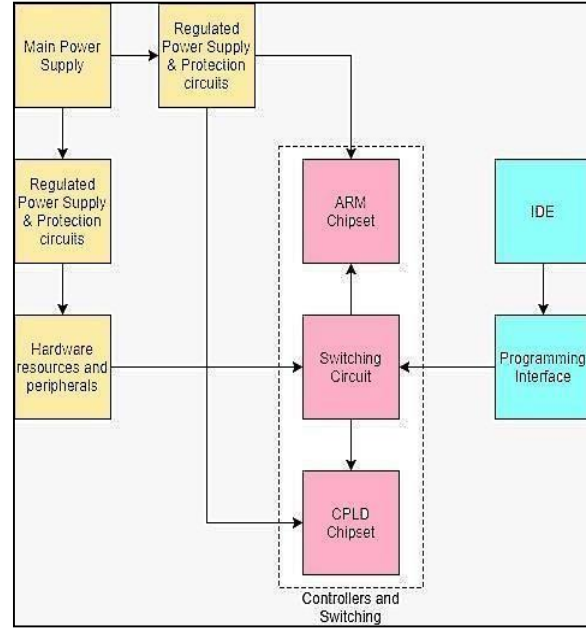


Figure 2: Block diagram

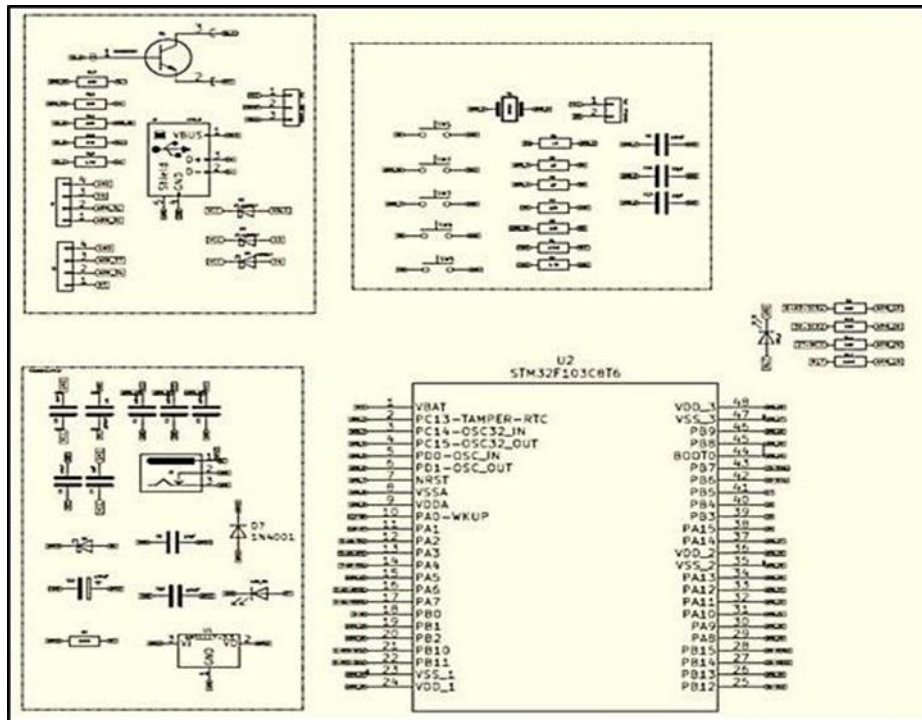


Figure 3: ARM schematic

After the development of a number of applications, the source code of those applications is then put into the integrated circuits so that the functionality of the board can be tested. The procedure of loading the programme into ARM chipset requires the use of the ST Link V2 programmer, as well as the software packages STM32CubeMX and Keil uVision. The purpose of doing this is to get the desired result. On the other hand, in uploading the code into CPLD chipsets, the Quartus & ModelSim packages, in combination with USB Blaster, are used. This is done in order to test the code before it is really implemented.

2.2 Tools used

KiCad is a free electrical design automation software programme that may be used for the design of printed circuit boards (PCBs). The creation of electrical circuit schematics as well as their translation to PCB designs is both made easier by this feature. KiCad was first conceived upon and developed by Jean-Pierre Charras. It comes with a PCB layout design environment and an integrated schematic capture. In the testing of CPLDs, Quartus and ModelSim are utilised: The programme was formerly called as Quartus Prime and Altera Quartus II before Intel completed its purchase of Altera. Quartus Prime gives developers the ability to build their designs, do timing analysis, examine RTL drawings, simulate a structure's response to a variety of stimuli, and configure a target system with the help of the programmer by utilizing HDL. Quartus Prime is equipped with both VHDL and Verilog implementations, allowing for hardware overview, visual modification of logic circuits, & vector waveform modelling, respectively. ModelSim is indeed a multi-language environment developed by Mentor Graphics. It gives users the ability to mimic hardware description languages such as VHDL, Verilog, and SystemC, in addition to doing C debugging. ModelSim is compatible with Xilinx ISE, as well as Xilinx Vivado and Intel Quartus Prime. To use a graphical user interface, the simulation may be run manually or automatically. Both methods are available (GUI).

STM32CubeMX & KeilVision are testing platforms for ARM. STM32CubeMX is really a graphical tool that walks you through the process of configuring STM32 microcontrollers & microprocessors in a step-by-step manner. It also generates the corresponding initializing C code for such Arm® Cortex®-M core or even a partial Linux® System Tree for Arm® Cortex®-A core. STM32CubeMX can be downloaded for free from the ST website [8-10].

The KeilVision software development framework is a window-based environment that provides users with a robust and up-to-date editor, in addition to a project manager and even a create facility feature. It includes all of the tools that are necessary to construct embedded programmes, such as a C/C++ compiler, a macro assembler, a linker/locator, and a HEX file generator. The use of vision enables the acceleration of the development process for embedded applications.

The uVision IDE & Debugging tools is at the forefront of a Keil development toolchain, and so it comes equipped with a number of capabilities that make it simpler for programmers to design embedded programmes that are both effective and decisive. The Keil tools were simple to utilize and will make it easier for you to achieve the design goals and targets you set for yourself. Programming: Quartus with VHDL and also the ARM Integrated Development Environment [11-12].

2.3 IC Specifications

CPLD chipset is shown in Figure 4. ALTERAMAXIIEPM240T100C5: Manufacturer: Intel, seriesEPM240, Stand by current: 25uA, Multi volt I/Ointerfacesupporting3.3V, ISP circuitry complaint with IEEEStd.1532, Maximum Operating frequency: 304MHz, Maximum Operating Temperature: 70⁰ C, Operating Supply Current: 55mA, Number of Logic array blocks: 24, Moisture sensitive: Yes.

2.4 ARM Chipset: STM32F103C8T6

Figure 5 presents an illustration of an ARM chipset. Cortex®-M3 ARM® 32-bit Architecture The highest frequency of the CPU Core is F72 MHz, and it has a performance of 1.25 DMIPS/MHz (Dhrystone 2.1) at 0 wait state memory access. Multiplication and division performed in a single cycle using hardware Clock, reset, and supply management, as well as 64 or 128 kilobytes of flash memory and 20 kilobytes of static random access memory (SRAM). I/Os and an application supply ranging from 2.0 to 3.6 V, a crystal oscillator operating at 16 MHz, PLL for the CPU clock, a 32 kHz oscillator for both the RTC with calibration, an internal 8 MHz RC that has been factory-trimmed, an internal 40 kHz RC, and so on. Modes that use less power include Sleep, Stop, and Standby, VBAT power supply for the backup registers and the RTC, 2 A/D converters each of 12 bits and 1 second (up to 16 channels), The range of the conversion is from 0 - 3.6 V, Dual-sample capabilities, as well as a hold mode, Temperature sensor, DMA: 7-channel DMA controller, Timers, ADC, SPIs, I2Cs, and USARTs are some of the peripherals that are supported. With upto to 80 fast I/O ports, 26/37/51/80 I/Os, all of which are mappable on 16 external interrupt vectors, and virtually all of which are 5 V-tolerant, this chip offers a lot of flexibility. Interfaces for serial wire debug (SWD) and JTAG, an incremental encoder input, and a debug mode are included in this mode. PWM timer for motor control with dead-time generation & emergency stop, as well as two watchdog timers of 16 bits each (Independent and Window), As many as nine different communication interfaces, Up to two x I2C interfaces (SMBus/PMBus), as well as PMBus and SMBus. As many as three USARTs (ISO 7816 interface, LIN, IrDA capability, modem control), Up to 2 SPIs with a data transfer rate of 18 Mbit/s, a CAN interface with 2.0B active, a USB 2.0 full-speed interface, a CRC calculation unit, and 96 bits of a unique identifier [9-12].

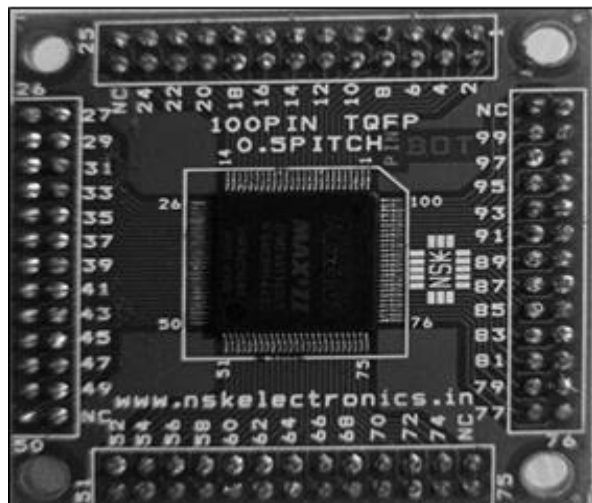


Figure 4: CPLD Chipset

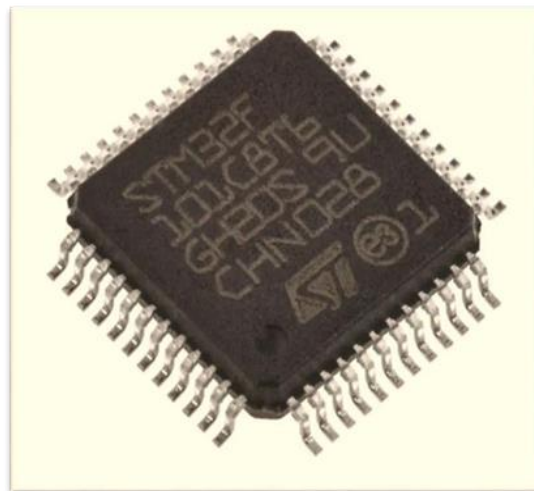


Figure 5: ARM Chipset

2.5 Printed Circuit Board Design and Fabrication

The abbreviation PCB stands for "printed circuit board." It's a piece of equipment called a circuit board, and it has lines and pads that connect various spots. Rigid PCBs constitute roughly 90 percent of the total quantity of PCBs that are produced at this time and are therefore the predominant type used in manufacturing. Some printed circuit boards (PCBs) are versatile and allow circuitry to be twisted and folded into form. These PCBs are frequently used in situations in which the flexible circuit must be able to resist hundreds of thousands of bend cycles without failing. PCBs that can serve many purposes make up about ten percent of the market.

Printed electronics is a rapidly developing PCB technology that is distinct from the ones described above. Printed electronics circuits are typically very simple and very low-cost, and they help reduce the amount of money spent on electronic packaging to the point where electronic solutions can be created to solve problems that have never been considered before. Because they are frequently utilized in electronics, such as portable computer systems or disposable computing devices, this paves the way for a wide variety of design opportunities for electrical engineers. Because of the complexity of commercial development programmes, there is a wide selection of computer-aided design (CAD) software and hardware solutions that may be purchased. There is a wide variety of high-quality software that may be downloaded for free or at a low cost by individuals, including students and others who have hobbies. Before moving on to the full PCB design and layout, it is crucial to obtain a general idea of where the components will go and determine whether there will be enough room on the board to contain all of the necessary circuitry. This may be done by drawing a schematic of the board. This will allow for judgements to be made regarding the required number of layers for the board, as well as whether or not there is sufficient capacity to fit all of the electronic components.

After a basic estimate of the space and approximate placements of the components has been produced, it will be possible to develop a more detailed component layout for the PCB design. This can contain information on prospective radio frequency (RF) issues as well as other information, such as the closeness of different pieces of equipment that might need to communicate with one another. In order for components to ever be incorporated into the PCB design, all pertinent information must first be associated with them. This will include the footprint for the pads on the printed circuit board, as well as any drilling details, no-go zones, and other similar information. After the PCB has been completed, the data that was created for it will be utilized in a number of different stages of the production process. Not only will the files be used to construct the actual printed circuit board (PCB), but they will also be utilized in other aspects of the manufacturing process.

They can be utilized to generate a pick and place programme, as well as a PCB solder mask, which is employed to apply solder paste to the board before components are installed. The PCB is ready where the pins are soldered with proper connections and hence, ARM and CPLD can be integrated on the PCB. As of now, the ARM integration is performed and the various programs were tested.

2.6 Integration of ARM and CPLD on PCB

Both the CPLD set and the ARM chipset have been included into the printed circuit board (PCB). As a result, the finished printed circuit board (PCB) looks like the one shown below, with the top view of the PCB displayed in

Figure 6, and the bottom view of the PCB after assembly shown in Figure 7. Both the CPLD and the ARM chipsets are included into the printed circuit board.



Figure 6: PCB top view after assembly

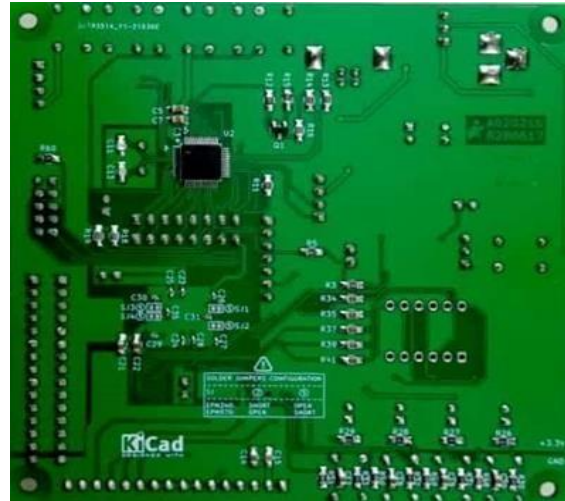


Figure 7: PCB bottom view after assembly

2.7 Software Testing

CPLD Testing: Verilog is the programming language that is utilized, while USB blaster, Quartus, as well as Modelsim are indeed the configuration tools that are used for the CPLD Chipset., Verilogcode is converted to symbol, the pin planner is used to assign input and output pins, the symbol (bdf) file is compiled, the compiled file is transferred to Chipset via USB blaster.

2.8 CPLD Testing using QUATUS for a sample code of counter : Sample Verilog Code for Counter

```
module counter (clk, out);
```

```
    input clk;
```

```
    output out;
```

```
    reg out;
```

```
    reg[23:0] count;
```

```
    always @ (posedge clk)
```

```
        begincount <= count +
```

```
        1'b1;
```

```
        out <= count[23];
```

```
    end
```

```
endmodule
```

3.0 Results and Discussions

The printed circuit board (PCB) is successfully produced after having been correctly designed with Ki Cad and having all of the necessary criteria. Onto the printed circuit board (PCB) are assembled the CPLD chipset ALTERA MAX II EPM240T100C5, the ARM chipset STM32F103C8T6, and the hardware resources. The board was put through its paces while it was being soldered. The ARM chipset is evaluated with the help of STM32CubeMX and KeilVision, whilst the CPLD chipset is evaluated with the assistance of Quartus and Modelsim tools. Following figures 8 , 9 & 10 shows the screenshots taken during the execution of Quartus prime tool which includes Compilation and logic block.

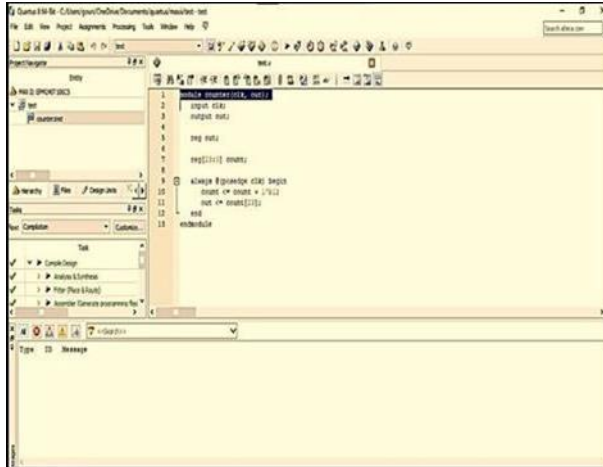


Figure 8: Sample code typed in Quartus II for testing CPLD

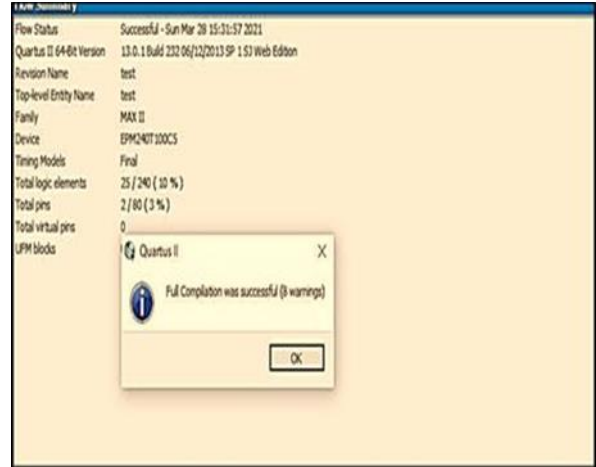


Figure 9: Successful compilation using Quartus II

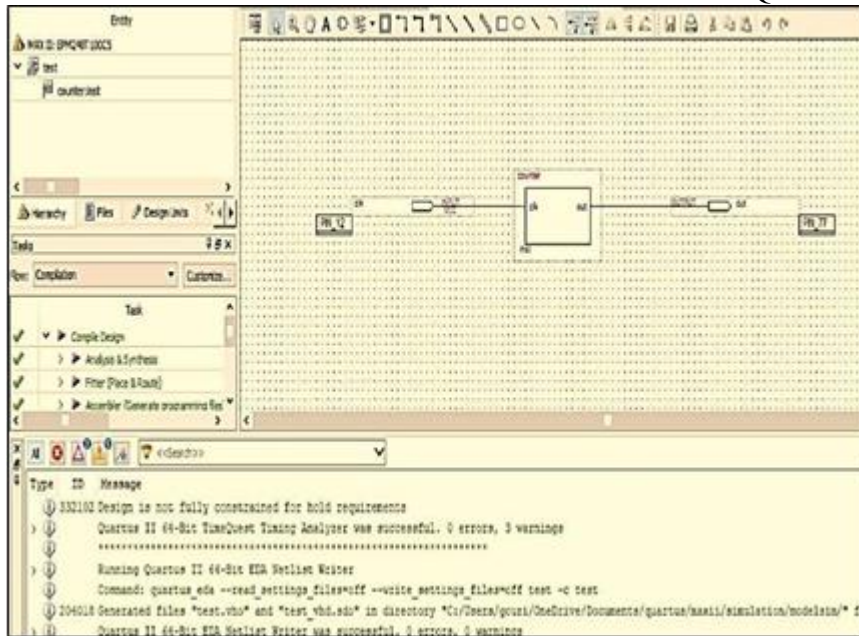


Figure 10: Logic Block of Counter

3.1 ARM Testing

In the STM32CubeMX software, the LQFP48 package of the STM32F103C8 IC is chosen; the clock is set to zero; the pin PA 1 is set to GPIO Output; the code is produced; the project is opened in the Keil uVision5 software after the needed project settings are established; the main, C file is opened; and after making the required modifications to the code, it is built and loaded into the IC with the assistance of the After the circuit board (PCB) has been accurately developed using Ki Cad and meets all of the essential requirements, it is successfully manufactured. The CPLD chip ALTERA MAX II EPM240T100C5, with ARM chip STM32F103C8T6, and even the hardware resources are all placed into the printed circuit boards (PCB). While the board was being soldered, this was put throughout its paces with various tests. The ARM chipset was assessed with the aid of STM32CubeMX & Keil uVision, whereas the CPLD chip is evaluated with help of Quartus & Modelsim tools. uVision is a graphical user interface developed by Keil.

Output of Obstacle detection

Emulating an instructional kit that may be used for the development of almost any design depends on CPLD with ARM is the purpose of this body of work. In order to put the board through its paces, the applications listed below were carried out. ARM: Using an infrared sensor and a buzzer to detect proximity and obstacles, the flashing of serial LEDs with a configurable delay may be seen, as illustrated in figures 11 and 12.

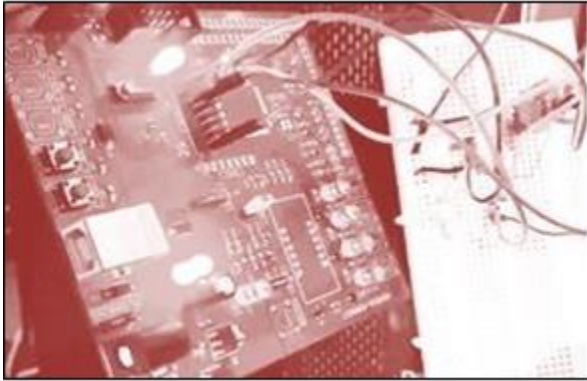


Figure 11: IR setup

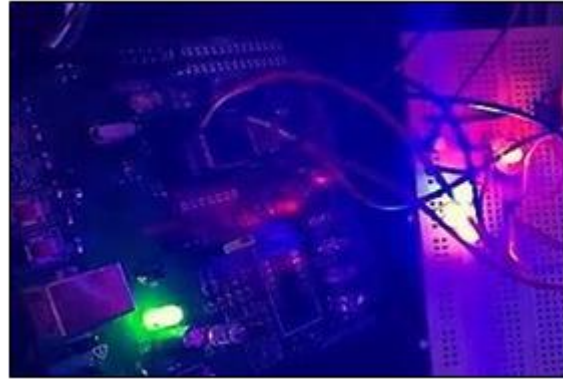


Figure 12: Output of Obstacle detection

4.0 Conclusions

Both the CPLD and the ARM chipsets have been successfully included onto the printed circuit board (PCB). Applications such as a proximity sensor that make use of ARM and counters, adders, and multiplexers that make use of CPLD have been created successfully. This board has the potential to be utilized as an instructional kit, allowing for the development of any project based on CPLD or ARM without the usage of standard boards. It is possible to implement both the SPI and UART communication protocols.

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