Interfacing a DAC with ARM cortex M3 Microcontroller LPC1768

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***Abstract*—**The ARM cortex M3 is a next generation core that offers system enhancements such as modernized debug features and a high level of support block integration. The ARM cortex M3 based microcontrollers are versatile and has numerous well developed features, thereby finding applications in various embedded applications. High performance, low cost and ease of use are the salient features of the ARM cortex M3 microcontrollers. The ARM cortex M3 microcontroller LPC1768 is a 32 bit microcontroller with advanced features. The state of the art presented in this paper is the interfacing of a Digital to Analog converter (DAC) with the ARM cortex M3 Microcontroller LPC1768. The Analog output waveforms in the form of triangular wave and square wave was displayed on the CRO as a result of this interfacing.

Keywords*—Arm cortex M3 microcontrollers, embedded applications, 32 bit microcontroller, interfacing, Digital to Analog converter, analog output waveforms, triangular wave, square wave.*

I. INTRODUCTION

The ARM cortex M3 is a general purpose 32 bit microcontroller. This microcontroller has high performance and requires very less power consumption. Apart from this, it offers many new features such as a Thumb 2 instruction set, low interrupt latency, hardware divide, interruptible/ continuable multiple load and store instructions, automatic state save and restore for interrupts, tightly integrated interrupt controller with wake up interrupt controller and multiple core buses capable of simultaneous accesses. In these microcontrollers pipelining techniques are employed so that all parts of processing and memory systems can operate continuously. Typically, while one instruction is being executed, the next instruction (its successor) is being decoded while the third instruction is being fetched from the memory [1].

The Cortex-M3 processor is the central processing unit (CPU) of a micro controller chip. In addition, a number of other components are required for the whole Cortex-M3 processor-based micro controller. After chip manufacturers license the Cortex-M3 processor, they can put the Cortex-M3 processor in their silicon designs, adding memory, peripherals, input/output (I/O), and other features. Cortex-M3 processor-based chips from different manufacturers will have different memory sizes, types, peripherals, and features.

The cortex M3 microcontroller addresses the requirements for the 32 bit embedded market in the following ways

- Greater performance efficiency: allowing more work to be done without increasing the frequency or power requirements.
- Low power consumption: enabling longer battery life, especially critical in portable products including wireless networking applications.
- Enhanced determinism: guaranteeing that critical tasks and interrupts are serviced as quickly as possible in a known number of cycles.
- Improved code density: ensuring that the code fits even in the smallest memory footprints.
- Ease of use: providing easier programming and debugging for the growing number of 8 bit and 16 bit users migrating to 32 bits.
- Lower cost solutions: reducing the 32 bit based microcontroller system costs close to those of legacy 8 bit and 16 bit devices [1], [2], 3].

The rest of the paper is organized in to sections as follows: section II includes the overview of ARM cortex M3 microcontroller LPC1768. Section III focuses on the system design. Results and discussions are reported in section IV. Finally section V summarizes the paper and presents the concluding remark.

II. ARM CORTEX M3 MICROCONTROLLER LPC1768 OVERVIEW

The LPC1768 is an ARM cortex M3 microcontroller used in embedded applications and requires high level of integration and less power consumption. The LPC1768 can operate up to 100 MHz CPU frequency. The peripheral components of the LPC1768 possesses up to 512 kilo bytes of flash memory, up to 64 kilo bytes of data memory, Ethernet medium access control (MAC), a USB interface which can be configured either as host device or OTG, 8 channel general purpose Direct memory access (DMA) controller, 4 Universal asynchronous receiver transmitter (UART's), 2 controller area network (CAN) channels, 2 system service processors (SSP), serial peripheral interface (SPI), 3 I2C interfaces, 2- input plus 2- output I2S interface, 8 channel 12 bit Analog to Digital converter (ADC), 10 bit Digital to Analog converter (DAC), motor control pulse width modulation (PWM), quadrature encoder interface, 4 general purpose timers, 6 output general purpose PWM, ultra-low power real time clock (RTC) with separate battery supply, and up to 70 general purpose Input /output (I/O) pins.

The LPC1768 makes use of a multi-layer AHB (Advanced High Performance Bus) matrix for connecting the ARM cortex M3 buses as well as other bus master peripherals in a flexible way which optimizes performance by allowing peripherals which are located on different slave ports of the matrix to be accessed simultaneously by different bus masters [4].

III. SYSTEM DESIGN

A. Technical Specifications of the ALS SDA ARM cortex M3 LPC1768 evaluation board

The following are the salient features of the ARM cortex M3 LPC1768 evaluation board.

- It has 512KB flash memory, 64KB SRAM, In system programming (ISP) and In application programming (IAP) capabilities.
- It possesses Single 3.3 volt power supply (2.4v to 3.6v).
- There are 70 general purpose I/O pins (GPIO) with configurable pull up/ pull down resistors, open drain mode and repeater mode.
- There are 12-bit Analog to Digital converter (ADC) and up to 8 analog channels.
- 10-bit Digital to Analog converter (DAC) with dedicated conversion timer is also available.
- There are 4 general purpose timers/counters, with a total of eight capture inputs and ten compare outputs.
- Three enhanced I2C bus interfaces are also available.
- Serial peripheral interface (SPI) controller with synchronous, serial, full duplex communication.
- There are four reduced power modes: sleep mode, deep sleep mode, power down mode and deep power down mode.
- It has a Real time clock (RTC) with a separate power domain.
- A 12 MHz crystal allows easy communication set up.
- Four external interrupt inputs configurable as edge/level sensitive.
- There is an on board voltage regulator for generating 3.3 volt. Input to this is through the external +5volt DC power supply through a 9 pin DSUB connector.
- The LPC1768 controller is contained in the piggy back module.
- There is a Reset push button for resetting the controller.
- One RS232 interface circuit with 9 pin DSUB connector.
- DC motor interface with direction and speed control.
- Stepper motor interface with direction and speed control.
- 16x2 alphanumeric display is available on the board for the purpose of LCD interfacing.
- On chip ADC interface circuit using AD0.5 (P1.31)
- 8-bit DAC interface is also available.
- 4x4 key matrix connected to the port lines of the controller.
- For LED indication there is an external interrupt circuit.
- Two digit multiplexed seven segment display interface is also available.
- Interface circuit for on board buzzer, relay and LED indication controlled through push button.
- SPI interface: Two channel ADC IC with POT and Temperature sensor.
- Standard 26 pin FRC connectors to connect to on board interface.

B. System specifications

The system specifications are illustrated in table 1.

TABLE I. SYSTEM SPECIFICATIONS

Sl. No	System specifications
1.	Domain: Microprocessors and Microcontrollers, Embedded systems
2.	Microcontroller used: Arm cortex M3 Microcontroller LPC1768 from NXP founded by Philips.
3.	Microcontroller data capacity: 32bit RISC microcontroller.
4.	Desktop computer: Pentium 4, 1GB RAM , Processor speed 2.5 GHz.
5.	Programming language: Embedded C.
6.	Software: Keil µ vision 4.
7.	Cathode ray oscilloscope (CRO).
8.	Adapter cable, USB cable, connecting probes for CRO.
9.	Port line: P0.4-P0.11
10.	Digital to Analog converter: DAC0800 (16 bit).
11.	In system programming (ISP): flash magic software is used to download the hex files to the flash magic of the controller.
12.	Serial communication: RS 232 cross cable connections required for establishing communication between the evaluation board and a display terminal/ host computer.
13.	Applications: waveform generation such as sine wave square wave and triangular wave and display on CRO.

C. DAC 0800

The term DAC refers to Digital to Analog conversion. Digital to Analog conversion is a process in which the Digital signal is converted into an equivalent Analog signal (voltage). In other words it can be said that, the DAC process involves the translation of Digital information into equivalent Analog information. The DAC allows generating variable analog output [6], [7]. The DAC0800 is a 16 pin IC which is used in the Arm cortex M3 LPC1768 evaluation board to convert the Digital data into Analog signal [9].

D. System set up

The system set up was done in embedded system and Microcontroller lab. Desktop computer, Arm cortex M3 LPC1768 evaluation board and a CRO were used in the system. The adapter cable was plugged in the socket to give the power supply and the adapter pin was connected to the ARM cortex M3 LPC1768 evaluation board. The mandatory hardware connections were done by connecting the USB cable to the USB port of the desktop computer and the other end of the USB cable was connected to the female connector of the RS 232 cable and the male connector of the RS232 cable was connected to the female connector provided on the ARM cortex M3 LPC1768 evaluation board. The CRO connections were done by connecting the positive probe (red color) at pin 1 of RM3 and negative probe (black color) at pin 2 of RM3 of the ARM cortex M3 LPC1768 evaluation board.

The keil µ vision 4 software was used to write the C program for DAC interfacing to obtain a triangular analog waveform. The keil µ vision 4 software located on the desktop was opened by double clicking it [5]. The project option was clicked and new µ vision project was chosen as shown in figure 1.

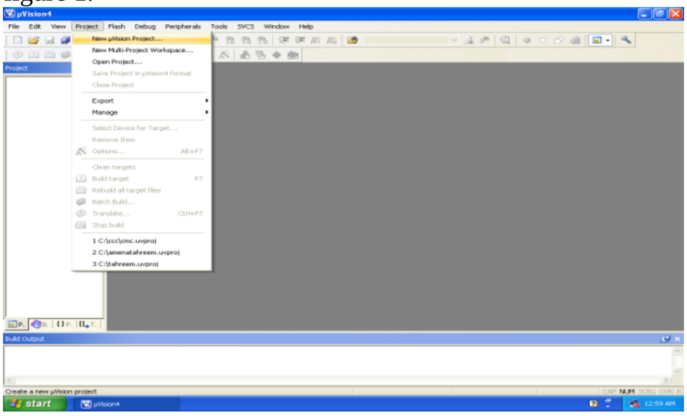

Figure 1 Selecting the new µ vision project

Create New project window appeared on the screen. A new and separate folder was created on the desktop and was named as waveforms. A file named TRIANGULAR was saved in the folder as illustrated in figure 2.

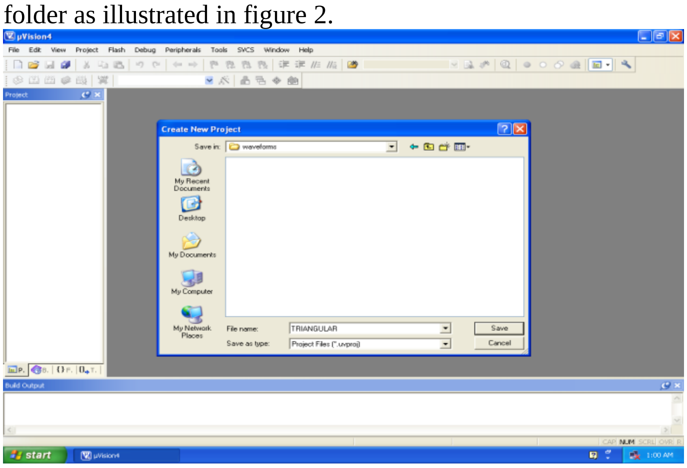

Figure 2 Folder creation and file naming

A new window named Select Device for Target 'Target1'appeared on the screen. In the search column of this window nxp was written so as to select the desired microcontroller from this nxp series founded by Philips. The ARM cortex M3 microcontroller LPC1768 was selected and the description of this microcontroller was displayed and ok option was chosen as illustrated in figure 3.

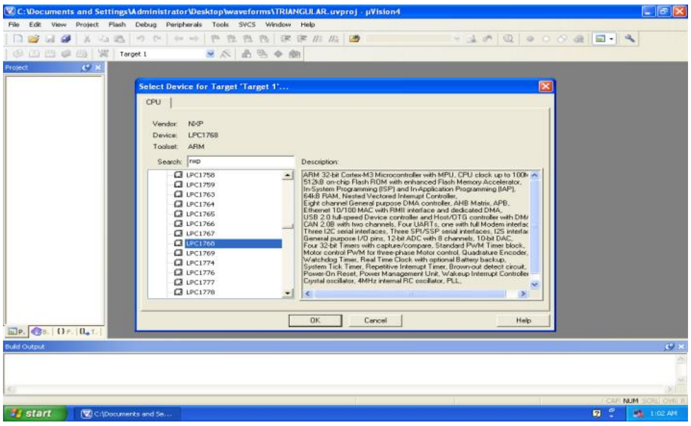

Figure 3 Selection of the ARM cortex M3 microcontroller LPC1768

Another new window named µ vision with two options Yes and No appeared and the option Yes was chosen to add "system_LPC17xx.s" as depicted in figure 4.

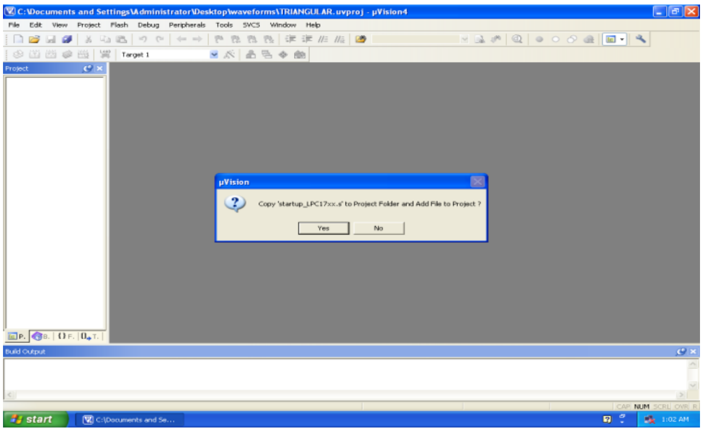

Figure 4 Choosing the Yes option

In the project window target was created as 'Target1'. The + sign of the target was clicked due to which source group 1 was shown below the target as depicted in figure 5.

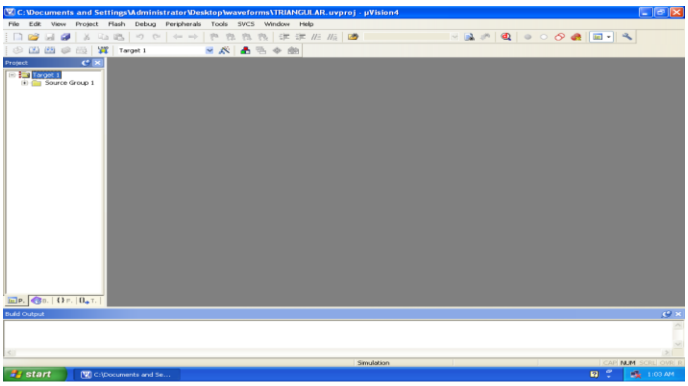

Figure 5 Creation of source group 1

After the project is created go to file option and select new option to open the editor window as shown in figure 6.

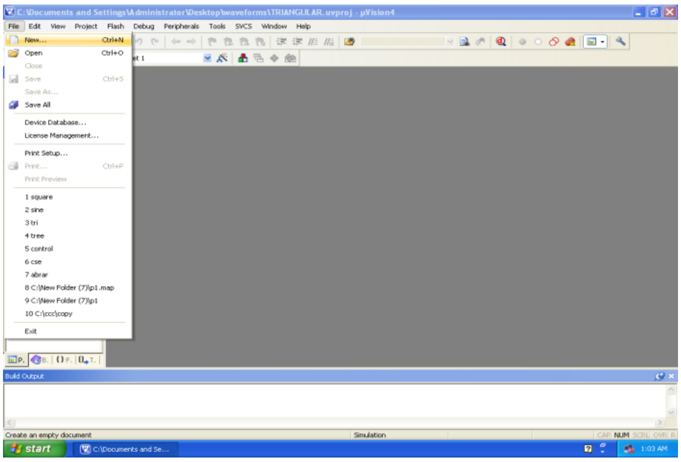

Figure 6 Selection of new file

The program was written in embedded C language for the DAC interfacing to generate a triangular waveform and the program was saved by clicking on the save icon as illustrated in figure 7.

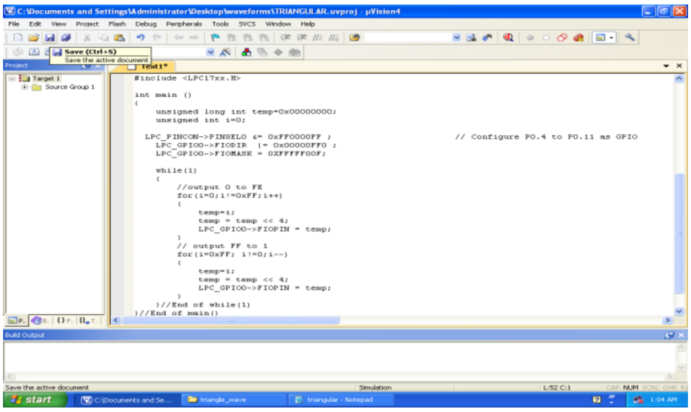

Figure 7 Saving the program

A new window named SaveAs appeared where the file was saved as TRIANGULAR .c. The file extension .c is necessary. This is illustrated in figure 8.

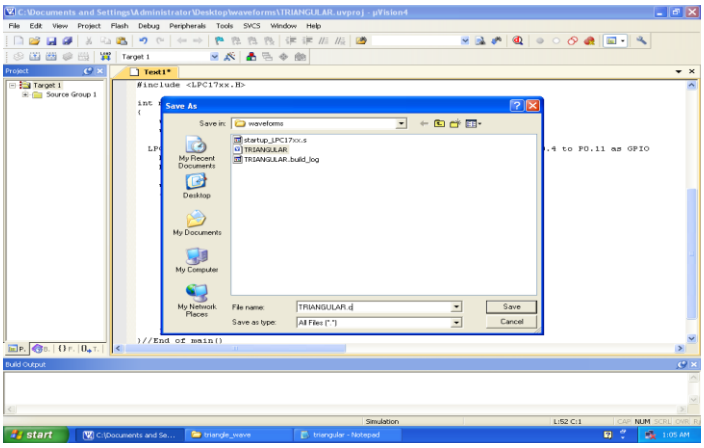

Figure 8 Naming the file as TRIANGULAR.c.

Color syntax highlighting was enabled after the file TRIANGULAR.c was saved. The source group 1 located below the Target 1 in the project window was right clicked and the option Add existing files to group 'Source group 1' was selected to add the .c source file to the group as shown in figure 9.

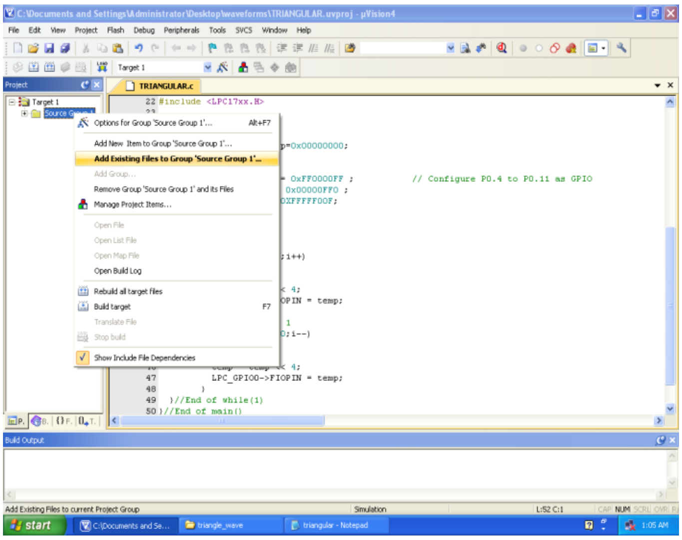

Figure 9 Adding the existing files to group source group 1.

A new window appeared with the name Add files to group 'Source Group 1' where the file TRIANGULAR.c was selected and then the Add and close option was clicked one after the other as depicted in figure 10.

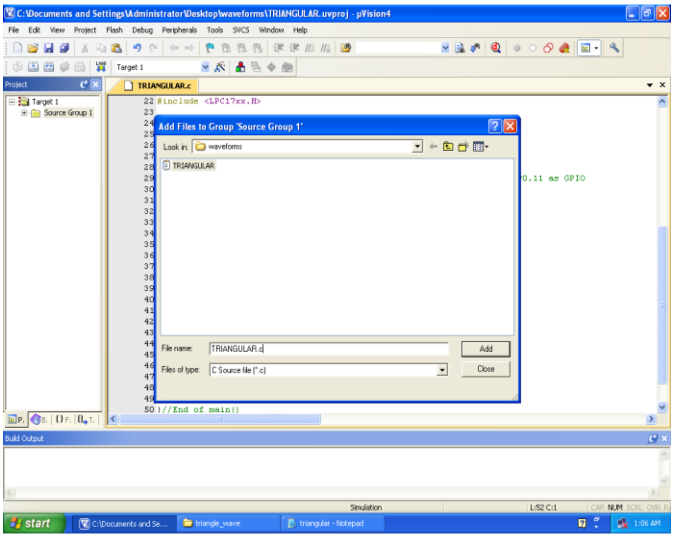

Figure 10 Choosing the file TRIANGULAR.c

The same window Add files to group 'Source Group 1' appeared once again. Here the startup file folder was clicked and in it the NXP was chosen then LPC17xx folder was opened and finally system_LPC17xx was selected as shown in figures 11, 12 and 13 respectively.

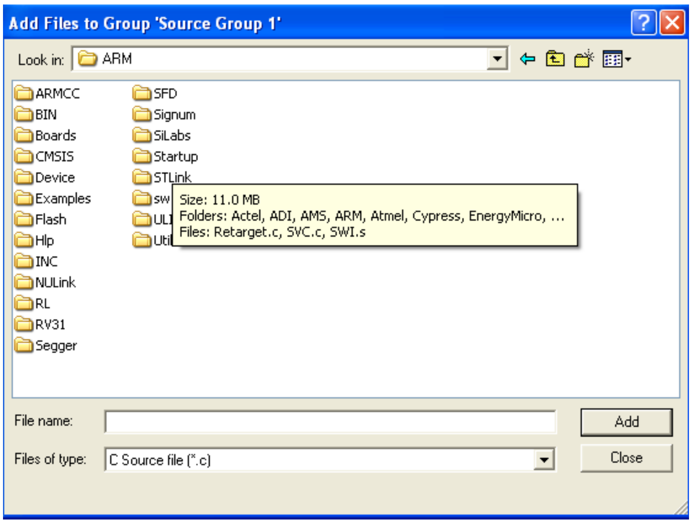

Figure 11 clicking startup folder

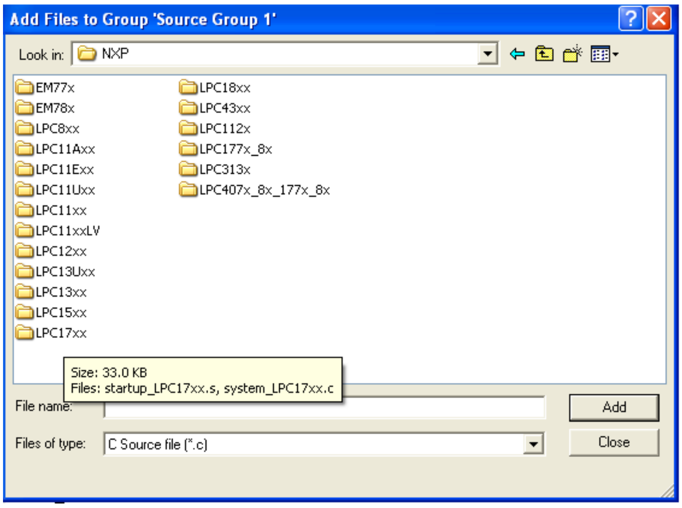

Figure 12 Opening the folder LPC17xx

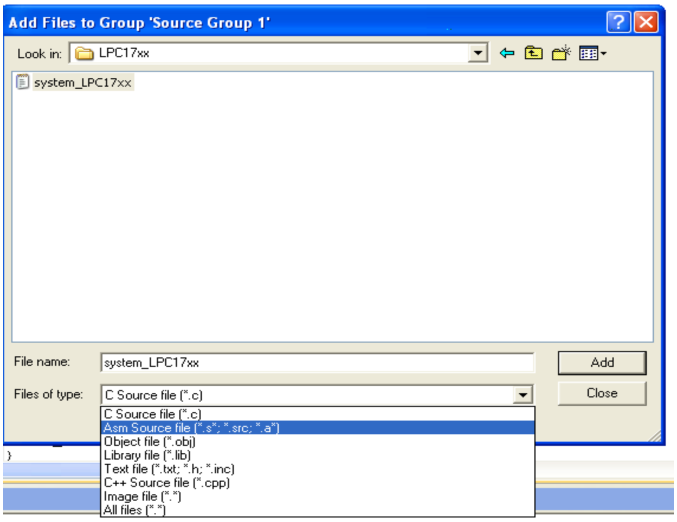

Figure 13 Selecting system_LPC17xx

The next important task was to compile the files. For this purpose build icon was clicked as shown in figure 14.

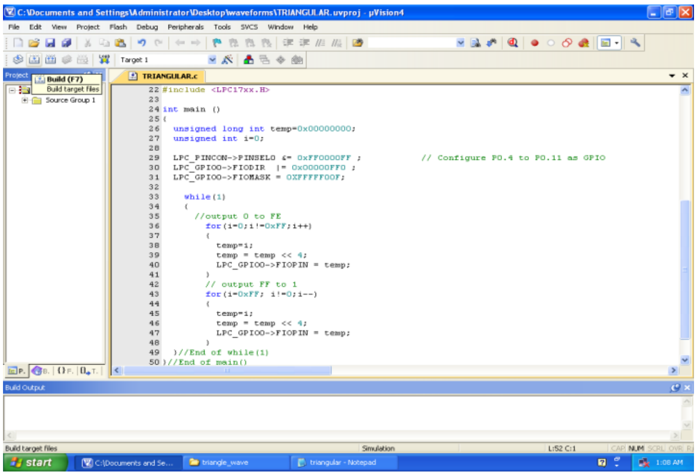

Figure 14 Choosing the build icon for compilation

After this step, the build output window was checked where the message TRIANGULAR.axf 0 Error(s), 0 warning(s) was displayed which ensured that the program was without errors. This is illustrated in figure 15.

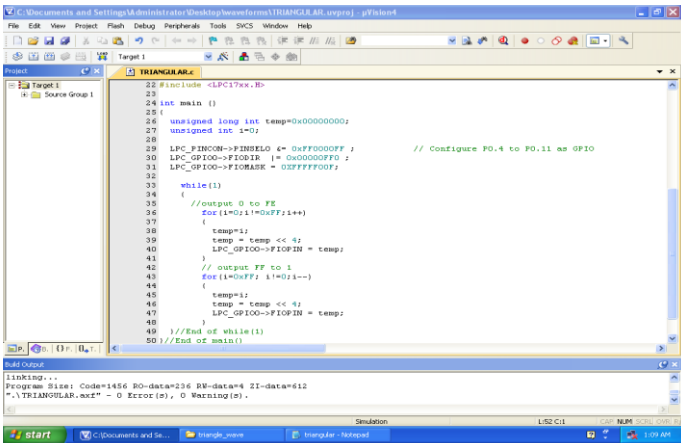

Figure 15 Getting the error free program with 0 errors and 0 warnings

In the project window Target 1 option was right clicked and then options for Target 'Target 1' was chosen as shown in figure 16

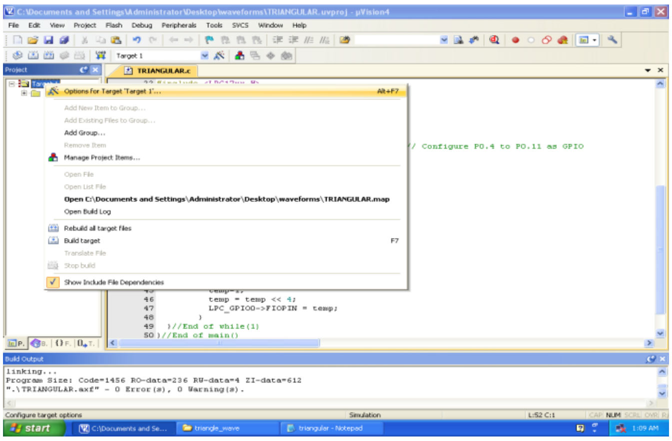

Figure 16 Selecting options for Target Target 1

A new window named options for Target 'Target 1' appeared where the output option was clicked and then create hex file option was enabled as shown in figure 17.

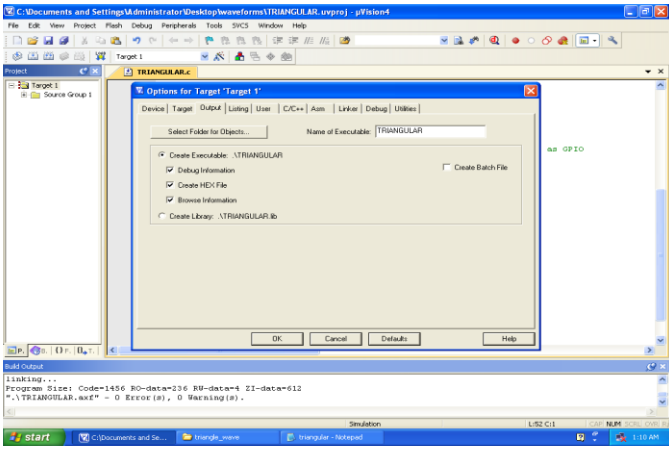

Fig 17 Enabling create hex file option

in the same window the linker option was cliked and then the option use memory layout from target dialog was enabled as shown in figure 18

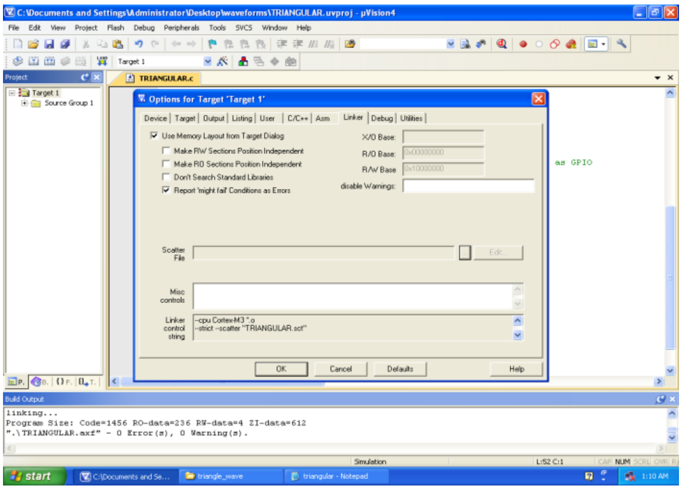

Figure 18 Enabling the option use memory layout from target dialog.

Lastly to come out of this window ok option was clicked.Finally rebuild icon was clicked in order to rebuild the target files as depicted in figure 19.

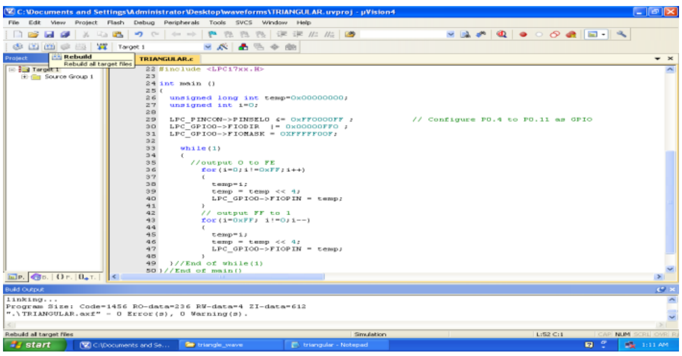

Figure 19 Choosing the Rebuild icon to build target files.

This created the hex file with 0 Error(s) and 0 warning(s) as displayed in the build output window. This is shown in figure 20.

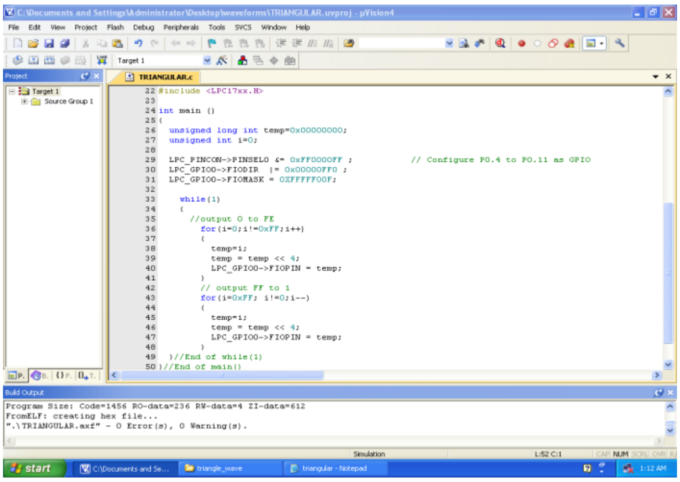

Fig 20 Creation of Hex file.

IV. EXPERIMENTAL RESULTS AND DISCUSSION

The analog output waveform in the form of Triangular wave was observed on the CRO by connecting the positive probe at pin-1 of RM3 with respect to the ground pin-2 RM2 by connecting the negative probe on the ARM cortex M3 LPC1768 evaluation board. In order to obtain this final output flash magic software was used to download the hex files to the controller. The flash magic software located on the desktop was double clicked and five steps were carried out sequentially to get the required output.

STEP 1: COMMUNICATION

In this step the following selections were made

- Device: LPC1768
- Com port: COM5 (as the USB cable is connected to this port).
- Baud rate: 19200
- Interface : None (ISP)
- Oscillator (MHz): 12

STEP 2: ERASE
In this step, the option erase blocks used by the hex file was enabled by selecting it.

STEP 3: HEX FILE
In step 3, browse option was clicked to download the hex files. In the proposed system the hex file named TRIANGULAR.hex was located in a folder named WAVEFORMS on the desktop.

STEP 4: OPTIONS
The option verify after programming was enabled in this step by selecting this particular option.

STEP 5: START
In step 5, start option was clicked so as to download the hex file to the controller on the Arm cortex M3 LPC1768 evaluation board.

The steps 1 to 5 are illustrated by the photographic view as shown in figure 21

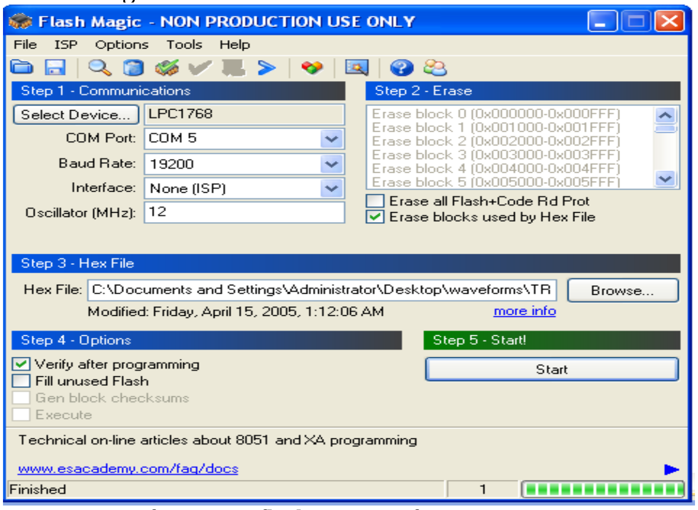

Figure 21 Performing 5 flash magic software steps

As step 5 was completed, a triangular output waveform was obtained on the CRO as illustrated by the photographic view as shown in figure 22. The complete system setup for triangular output waveform is depicted in figure 23.

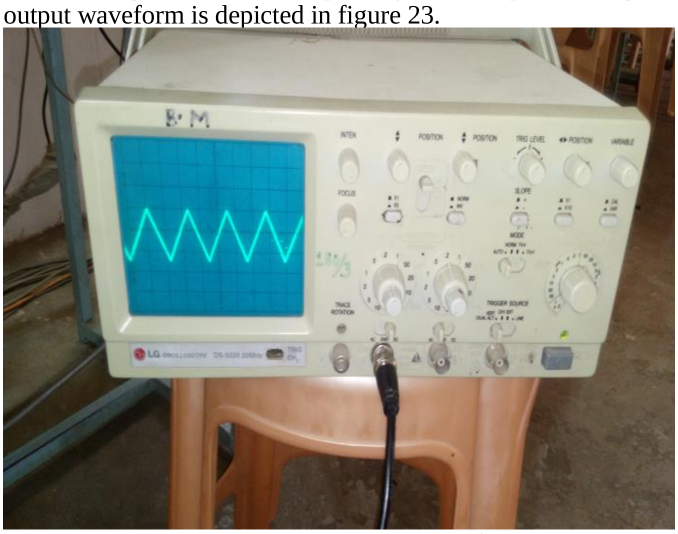

Figure 22 Getting the triangular output waveform.

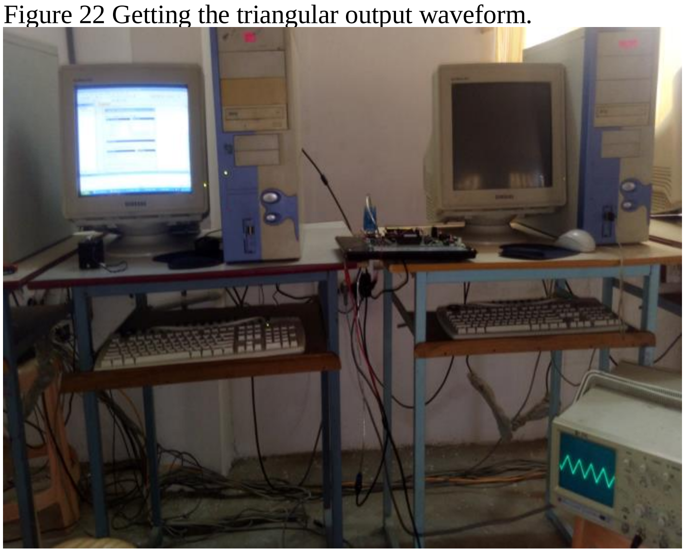

Figure 24 Photographic view of triangular output waveform set up

Following the same procedure, the experiment was performed to get a square wave. The complete interfacing and the square wave output are illustrated by the photographic view as shown in figure 24 and 25.

Figure 24 photographic view of square output waveform

Figure 25 Getting the square output waveform.

V. CONCLUSION

In this paper the interfacing of a DAC with the ARM cortex M3 microcontroller LPC1768 was presented. The hardware and software features of Digital to Analog conversion with Analog output waveforms are presented using the ARM cortex M3 microcontroller LPC1768 Two experiments were performed with respect to the DAC interfacing. The first experiment output was a triangular waveform and the second experiment output was a square waveform. The complete interfacing system was comprised of ALS-SDA ARM cortex M3-06 evaluation board, desktop computer, and a CRO. The interfacing was carried out very smoothly by making proper hardware connections. Keil µ vision 4 and flash magic software's were used in this interfacing. The entire system was very simple, stable, reliable and easy to implement and use.

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