VSM's
SOMASHEKHAR R KOTHIWALE INSTITUTE OF TECHNOLOGY, NIPANI

DEPT. OF ELECTRONICS & COMMUNICATION ENGINEERING.

EMBEDDED CONTROLLER LABORATORY [17ECL6]
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CONTENTS

1. INTRODUCTION TO ARM Cortex M3PROCESSOR

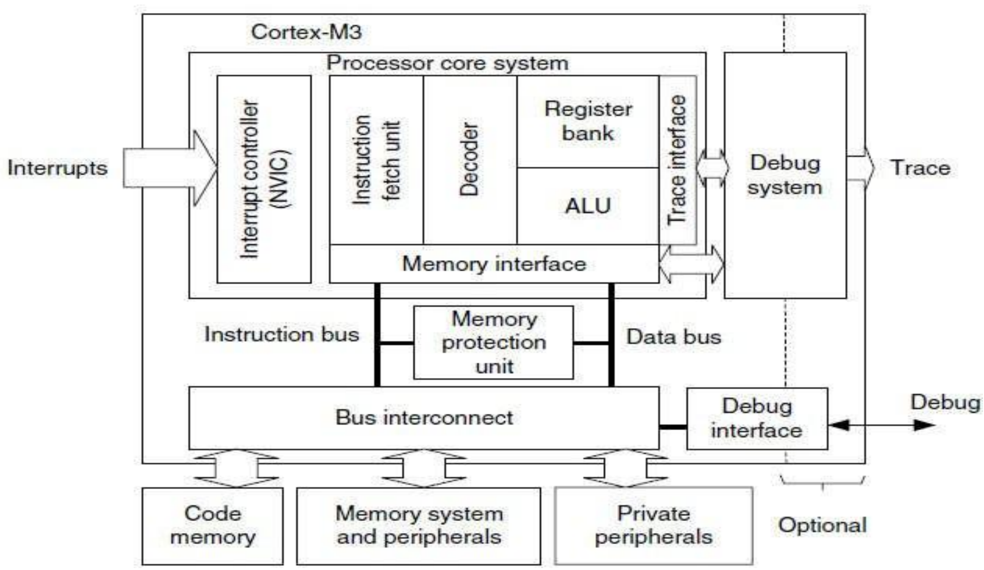
1.1 Introduction

The ARM Cortex-M3 is a general purpose 32-bit microprocessor, which offers high performance and very low power consumption. The Cortex-M3 offers many new features, including 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.

Pipeline techniques are employed so that all parts of the processing and memory systems can operate continuously. Typically, while one instruction is being executed, its successor is being decoded, and a third instruction is being fetched from memory.

The processor has a Harvard architecture, which means that it has a separate instruction bus and data bus. This allows instructions and data accesses to take place at the same time, and as a result of this, the performance of the processor increases because data accesses do not affect the instruction pipeline. This feature results in multiple bus interfaces on Cortex-M3, each with optimized usage and the ability to be used simultaneously. However, the instruction and data buses share the same memory space (a unified memory system). In other words, you cannot get 8 GB of memory space just because you have separate bus interfaces.

A simplified block diagram of the Cortex-m3 architecture is shown below



It is worthwhile highlighting that the Cortex-M3 processor is not the first ARM processor to be used to create generic micro controllers. The venerable ARM7 processor has been very successful in this market, The Cortex-M3 processor builds on the success of the ARM7processor to deliver devices that are significantly easier to program and debug and yet deliver a higher processingcapability.

1.2 Background of ARMarchitecture

ARM was formed in 1990 as Advanced RISC Machines Ltd., a joint venture of Apple Computer,Acorn Computer Group, and VLSI Technology. In 1991, ARM introduced the ARM6 processor family, and VLSI became the initial licensee. Subsequently, additional companies, including Texas Instruments, NEC, Sharp, and ST Microelectronics, licensed the ARM processor designs, extending the applications of ARM processors into mobile phones, computer hard disks, personal digital assistants (PDAs), home entertainment systems, and many other consumer products.

Nowadays, ARM partners ship in excess of 2 billion ARM processors each year. Unlike many semiconductor companies, ARM does not manufacture processors or sell the chips directly. Instead, ARM licenses the processor designs to business partners, including a majority of the world's leading semiconductor companies. Based on the ARM low-cost and power-efficient processor designs, these partners create their processors, micro controllers, and system-on-chip solutions. This business model is commonly called intellectual property (IP) licensing.

1.3 Architectureversions

Overtheyears,ARMhascontinuedtodevelopnewprocessorsandsystemblocks.Theseinclude the popular ARM7TDMI processor and, more recently, the ARM1176TZ (F)-S processor, which is used in high-end applications such as smart phones. The evolution of features and enhancements to the processors over time has led to successive versions of the ARM architecture. Note that architecture version numbers are independent from processor names. For example, the ARM7TDMI processor is based on the ARMv4T architecture (the *T* is for*Thumb* instruction modesupport).

The ARMv5E architecture was introduced with the ARM9E processor families, including the ARM926E-S and ARM946E-S processors. This architecture added "Enhanced" Digital Signal Processing (DSP) instructions for multimedia applications. With the arrival of the ARM11 processor family, the architecture was extended to the ARMv6. New features in this architecture included memory system features and Single Instruction–Multiple Data (SIMD) instructions. Processors based on the ARMv6 architecture include the ARM1136J (F)-S, the ARM1156T2 (F)-S, and the ARM1176JZ (F)-S.

Over the past several years, ARM extended its product portfolio by diversifying its CPU development,whichresultedinthearchitectureversion7orv7.Inthisversion,thearchitecture design is divided into threeprofiles:

- The ***A profile*** is designed for high-performance open applicationplatforms.
- The ***R profile*** is designed for high-end embedded systems in which real-time performance isneeded.
- The***Mprofile***isdesignedfordeeplyembeddedmicrocontroller-typesystems. Bit

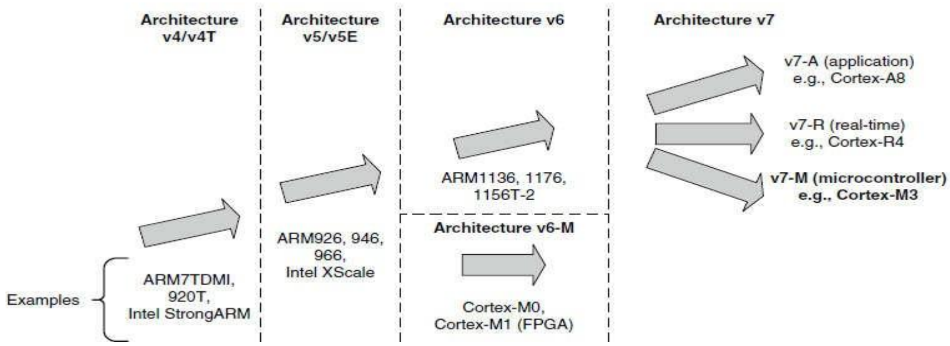
more details on theseprofiles

***A Profile (ARMv7-A)*:** Application processors which are designed to handle complex applications such as high-end embedded operating systems (OSs) (e.g., Symbian, Linux, and Windows Embedded). These processors requiring the highest processing power, virtual memory system support with memory management units (MMUs), and, optionally, enhanced Java support and a secure program execution environment. Example products include high-end mobile phones and electronic wallets for financial transactions.

***RProfile(ARMv7-R)*:**Real-time,high-performanceprocessorstargetedprimarilyatthehigher end of the real-time market, those applications, such as high-end breaking systems and hard drive controllers.

M Profile (ARMv7-M): Processors targeting low-cost applications in which processing efficiency is important and cost, power consumption, low interrupt latency, and ease of use are critical,aswellasindustrialcontrolapplications,includingreal-timecontrolsystems.TheCortex processor families are the first products developed on architecture v7, and the Cortex- M3 processor is based on one profile of the v7 architecture, called ARM v7-M, an architecture specification for micro controllerproducts.

Below figure shows the development stages of ARM versions



1.4 Instruction SetDevelopment

Enhancement and extension of instruction sets used by the ARM processors has been one ofthe key driving forces of the architecture's evolution. Historically (since ARM7TDMI), two different instruction sets are supported on the ARM processor: the ARM instructions that are 32 bits and Thumb instructions that are 16 bits. During program execution, the processor can be dynamically switched between the ARM state and the Thumb state to use either one of the instructionsets.TheThumbinstructionsetprovidesonlyasubsetofthe ARMinstructions,butit can provide higher code density. It is useful for products with tight memoryrequirements.

The Thumb-2 Technology and Instruction Set Architecture

The Thumb-2 technology extended the Thumb Instruction Set Architecture (ISA) into a highly efficient and powerful instruction set that delivers significant benefits in terms of ease of use, code size, and performance. The extended instruction set in Thumb-2 is a super set of the previous 16-bit Thumb instruction set, with additional 16-bit instructions alongside 32-bit instructions. It allows more complex operations to be carried out in the Thumb state, thus allowing higher efficiency by reducing the number of states switching between ARM state and Thumb state.

Focused on small memory system devices such as micro controllers and reducing the size ofthe processor, the Cortex-M3 supports only the Thumb-2 (and traditional Thumb) instruction set. Instead of using ARM instructions for some operations, as in traditional ARM processors, it uses the Thumb-2 instruction set for all operations. As a result, the Cortex-M3 processor is not backward compatible with traditional ARMprocessors.

Nevertheless, the Cortex-M3 processor can execute almost all the 16-bit Thumb instructions, including all 16-bit Thumb instructions supported on ARM7 family processors, making application porting easy. With support for both 16-bit and 32-bit instructions in the Thumb-2 instruction set, there is no need to switch the processor between Thumb state (16-bit instructions) and ARM state (32-bit instructions). For example, in ARM7 or ARM9 family processors, you might need to switchto ARM state if you want to carry out complex calculations or a large number of conditional operations and good performance is needed, whereas in the Cortex-M3 processor, you can mix 32-bit instructions with 16-bit instructions without switching state, getting high code density and high performance with no extracomplexity.The Thumb-2 instruction set is a very important feature of the ARMv7 architecture. Compared with the instructions supported on ARM7 family processors (ARMv4T architecture), the Cortex- M3 processor instruction set has a large number of new features. For the first time, hardware divide instruction is available on an ARM processor, and a number of multiply instructions are also available on the Cortex-M3 processor to improve data-crunching performance. The Cortex-M3 processor also supports unaligned data accesses, a feature previously available only inhigh-end processors.

1.5 Advantages of Cortex M3processors

The Cortex-M3 addresses the requirements for the 32-bit embedded processor 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 and in a known number of cycles
***Improved code density*:** ensuring that code fits in even the smallest memory footprints
***Easeofuse*:**providingeasierprogramminganddebuggingforthegrowingnumberof8-bitand 16-bit users migrating to 32bits
***Lower cost solutions*:** reducing 32-bit-based system costs close to those of legacy 8-bit and 16-bit devices and enabling low-end, 32-bit micro controllers to be priced at less than US$1 for the first time
***Wide choice of development tools*:** from low-cost or free compilers to full-featured development suites from many development tool vendors

Cost savings can be achieved by improving the amount of code reuse across all systems. Because Cortex-M3 processor-based micro controllers can be easily programmed using the C language and are based on a well-established architecture, application code can be ported and reused easily, and reducing development time and testing costs.

1.6 Applications of Cortex M3processors

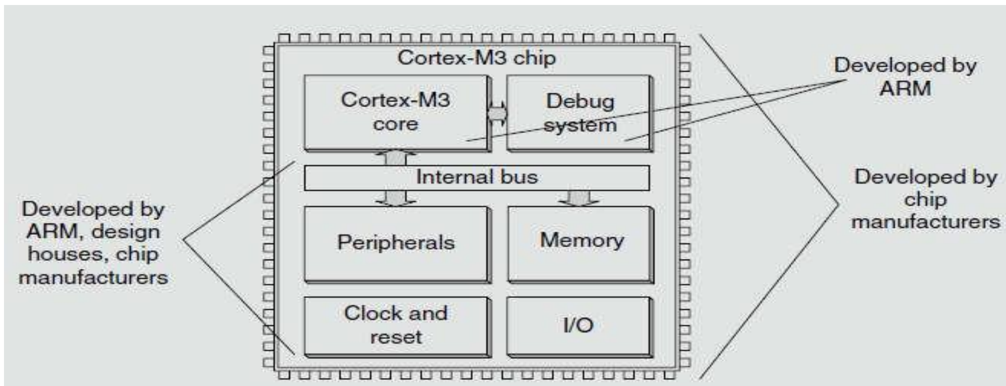
***Low-cost micro controllers*:** The Cortex-M3 processor is ideally suited for low-cost micro controllers, which are commonly used in consumer products, from toys to electrical appliances. It is a highly competitive market due to the many well-known 8-bit and 16-bit micro controller products on the market. Its lower power, high performance, and ease-of-use advantages enable embedded developers to migrate to 32-bit systems and develop products with the ARM architecture.

***Automotive*:** Another ideal application for the Cortex-M3 processor is in the automotive industry. The Cortex-M3 processor has very high-performance efficiency and low interrupt latency, allowing it to be used in real-time systems. The Cortex-M3 processor supports up to 240 external vectored interrupts, with a built-in interrupt controller with nested interrupt supports and an optional MPU, making it ideal for highly integrated and cost-sensitive automotive applications.

***Data communications*:** The processor's low power and high efficiency, coupled with instructions in Thumb-2 for bit-field manipulation, make the Cortex-M3 ideal for many communications applications, such as Bluetooth and ZigBee.

Industrial control*:** In industrial control applications, simplicity, fast response, and reliability are key factors. Again, the Cortex-M3 processors interrupt feature, low interrupt latency, and enhanced fault-handling features make it a strong candidate in this area.Consumer products*:** In many consumer products, a high-performance microprocessor (or several of them) is used. The Cortex-M3 processor, being a small processor, is highly efficient and low in power and supports an MPU enabling complex software to execute while providing robust memory protection.

1.7 TheCortex-M3ProcessorversusCortex-M3-BasedMicro Controllers



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.

2. INTRODUCTION TO MICRO CONTROLLERLPC1768

2.1 ArchitecturalOverview

The LPC1768FBD100 is an ARM Cortex-M3 based micro controller for embedded applications requiring a high level of integration and low power dissipation. The ARM Cortex-M3 is a next generation core that offers system enhancements such as modernized debug features and a higher level of support block integration. LPC1768 operate up to 100 MHz CPU frequency.

The peripheral complement of the LPC1768 includes up to 512 kilo bytes of flash memory, up to 64KB of data memory, Ethernet MAC, a USB interface that can be configured as either Host, Device, or OTG, 8 channel general purpose DMA controller, 4 UARTs, 2 CAN channels, 2 SSP controllers, SPI interface, 3 I2C interfaces, 2-input plus 2-output I2S interface, 8 channel 12-bit ADC, 10-bit DAC, motor control PWM, Quadrature Encoder interface, 4 general purpose timers, 6-output general purpose PWM, ultra-low power RTC with separate battery supply, and up to 70 general purpose I/O pins.

The LPC1768 use a multi layer AHB(Advanced High Performance Bus) matrix to connect the ARM Cortex-M3 buses and other bus masters to peripherals in a flexible manner that optimizes performance by allowing peripherals that are on different slaves ports of the matrix to be accessed simultaneously by different bus masters.

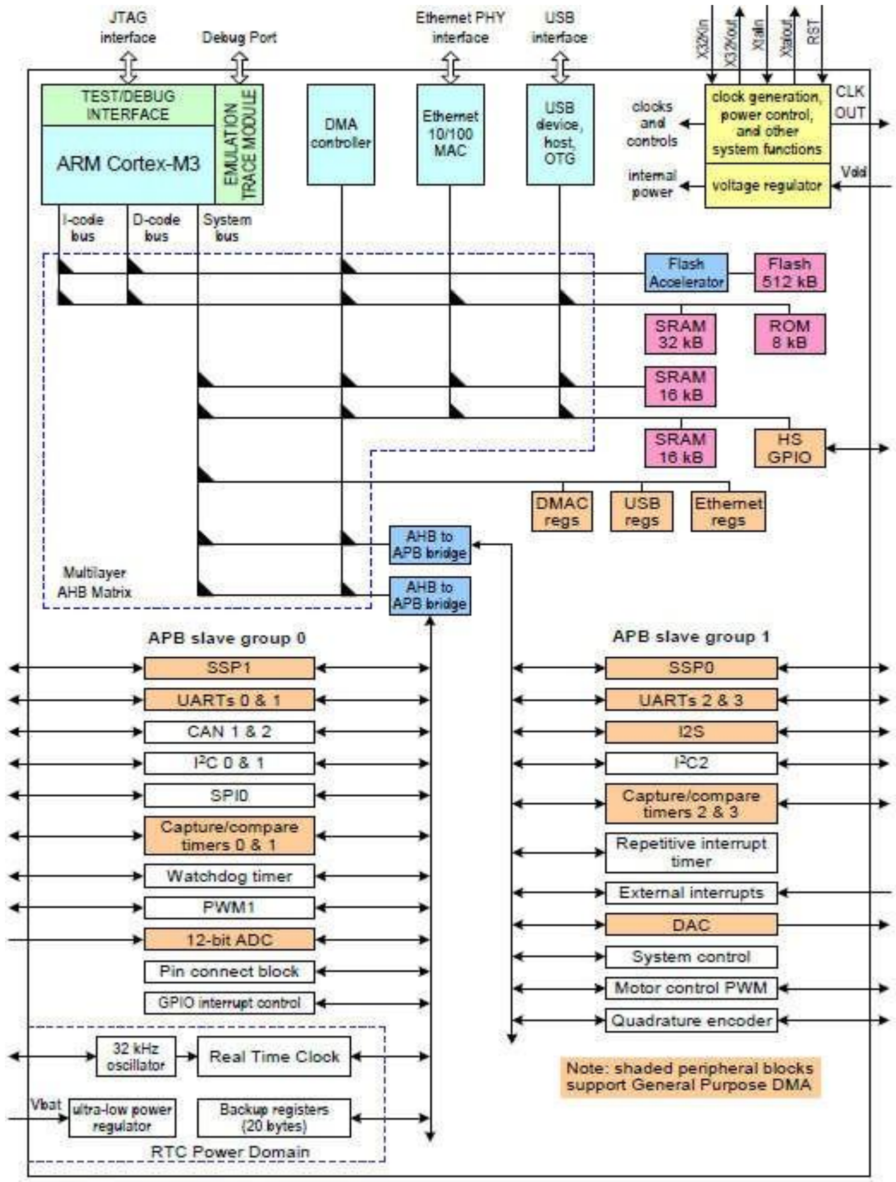
On-chip flash memory system

The LPC1768 contains up to 512 KB of on-chip flash memory. A flash memory accelerator maximizes performance for use with the two fast AHB Lite buses. This memory may be used for both code and data storage. Programming of the flash memory may be accomplished in several ways. It may be programmed In System via the serial port. The application program may also erase and/or program the flash while the application is running, allowing a great degree of flexibility for data storage field firmware upgrades, etc.

On-chip Static RAM

The LPC1768 contains up to 64 KB of on-chip static RAM memory. Up to 32 KB of SRAM, accessible by the CPU and all three DMA controllers are on a higher-speed bus. Devices containing more than 32 KB SRAM have two additional 16 KB SRAM blocks, each situated on separate slave ports on the AHB multilayer matrix. This architecture allows the possibility for CPU and DMA accesses to be separated in such a way that there are few or no delays for the bus masters.

2.2 Block Diagram ofLPC1768FBD10



2.3 A brief description of theblocks:

Nested vector interrupt controller

The NVIC is an integral part of the Cortex-M3. The tight coupling to the CPU allows for low interrupt latency and efficient processing of late arriving interrupts.

Features

- Controls system exceptions and peripheralinterrupts
- In the LPC1768, the NVIC supports 33 vectoredinterrupts
- 32 programmable interrupt priority levels, with hardware priority levelmasking
- Relocatable vectortable
- Non-Maskable Interrupt(NMI)
- Software interruptgeneration

Interrupt sources

Each peripheral device has one interrupt line connected to the NVIC but may have several interrupt flags. Individual interrupt flags may also represent more than one interrupt source.

Any pin on Port 0 and Port 2 (total of 42 pins) regardless of the selected function, can be programmed to generate an interrupt on a rising edge, a falling edge, or both.

General purpose DMA controller

The GPDMA (General Purpose Direct Memory Access) is an AMBA AHB (Advanced Micro controller Bus Architecture Advance high performance bus) compliant peripheral allowing selected peripherals to have DMA support.

TheGPDMAenablesperipheral-to-memory,memory-to-peripheral,peripheral-to-peripheral,and memory-to-memory transactions. The source and destination areas can each be either a memory region or a peripheral, and can be accessed through the AHB master. The GPDMA controller allows data transfers between the USB and Ethernet controllers and the various on-chip SRAM areas. The supported APB peripherals are SSP0/1, all UARTs, the I2S-bus interface, theADC,andtheDAC.TwomatchsignalsforeachtimercanbeusedtotriggerDMAtransfers.

Function Configuration block

Theselectedpinsofthemicrocontrollertohavemorethanonefunction.Configurationregisters control the multiplexers to allow connection between the pin and the on-chip peripherals. Peripheralsshouldbeconnectedtotheappropriatepinspriortobeingactivatedandpriortoany related interrupt(s) beingenabled.

Activity of any enabled peripheral function that is not mapped to a related pin should be considered undefined. Most pins can also be configured as open-drain outputs or to have a pull-up, pull-down, or no resistorenabled.

Fast general purpose parallelI/O

Device pins that are not connected to a specific peripheral function are controlled by the GPIO registers. Pins may be dynamically configured as inputs or outputs. Separate registers allow setting or clearing any number of outputs simultaneously. The value of the output register may be read back as well as the current state of the port pins.

USB interface

TheUniversalSerialBus(USB)isa4-wirebusthatsupportscommunicationbetweenahostand oneormore(upto127)peripherals.ThehostcontrollerallocatestheUSBbandwidthto attached devices through a token-based protocol. The bus supports hot plugging and dynamic configuration of the devices. All transactions are initiated by the host controller.

The USB interface includes a device, Host, and OTG controller with on-chip PHY for device and Host functions. The OTG switching protocol is supported through the use of an external controller.

USB device controller enables 12 Mbit/s data exchange with a USB Host controller. It consists of a register interface, serial interface engine, endpoint buffer memory, and a DMA controller. The serial interface engine decodes the USB data stream and writes data to the appropriate endpoint buffer. The status of a completed USB transfer or error condition is indicated viastatus registers. An interrupt is also generated if enabled. When enabled, the DMA controller transfers data between the endpoint buffer and the on-chipSRAM.

12-bit ADC

The LPC1768 contain a single 12-bit successive approximation ADC with eight channels and DMA support.

10-bit DAC

The DAC allows to generate a variable analog output. The maximum output value of the DAC is VREFP.

UART's

The LPC1768 contain four UART's. In addition to standard transmit and receive data lines, UART1 also provides a full modem control handshake interface and support for RS-485/9-bit mode allowing both software address detection and automatic address detection using 9-bit mode.

The UART's include a fractional baud rate generator. Standard baud rates such as 115200 Baud can be achieved with any crystal frequency above 2 MHz

SPI serial I/O controller

The LPC1768 contain one SPI controller. SPI is a full duplex serial interface designed to handle multiple masters and slaves connected to a given bus. Only a single master and a single slave can communicate on the interface during a given data transfer. During a data transfer the master always sends 8 bits to 16 bits of data to the slave, and the slave always sends 8 bits to 16 bits of data to the master.

SSP serial I/O controller

The LPC1768 contain two SSP controllers. The SSP controller is capable of operation on a SPI, 4-wire SSI, or Micro wire bus. It can interact with multiple masters and slaves on the bus. Only a single master and a single slave can communicate on the bus during a given data transfer. The SSP supports full duplex transfers, with frames of 4 bits to 16 bits of data flowing from the master to the slave and from the slave to the master. In practice, often only one of these data flows carries meaningfuldata.

I2C-bus serial I/O controllers

The LPC1768 each contain three I2C-bus controllers. The I2C-bus is bidirectional for inter-IC control using only two wires: a Serial Clock line (SCL) and a Serial DAta line (SDA). Each device is recognized by a unique address and can operate as either a receiver-only device or a transmitter with the capability to both receive and send information (such as memory).

Transmitters and/or receivers can operate in either master or slave mode, depending on whether the chip has to initiate a data transfer or is only addressed. The I2C is a multi-master bus and can be controlled by more than one bus master connected to it.General purpose 32-bit timers/external event counters

The LPC1768 include four 32-bit timer/counters. The timer/counter is designed to count cycles of the system derived clock or an externally-supplied clock. It can optionally generate interrupts, generate timed DMA requests, or perform other actions at specified timer values, based on four match registers. Each timer/counter also includes two capture inputs to trap the timer value when an input signal transitions, optionally generating an interrupt.

Pulse width modulator

The PWM is based on the standard Timer block and inherits all of its features, although only the PWM function is pinned out on the LPC1768. The Timer is designed to count cycles of the system derived clock and optionally switch pins, generate interrupts or perform other actions when specified timer values occur, based on seven match registers. The PWM function is in addition to these features, and is based on match register events.

Watchdog timer

The purpose of the watchdog is to reset the micro controller within a reasonable amount oftime if it enters an erroneous state. When enabled, the watchdog will generate a system reset if the userprogramfailsto‘feed’(orreload)thewatchdogwithinapredeterminedamountoftime.

RTC and backup registers

The RTC is a set of counters for measuring time when system power is on, and optionally when it is off. The RTC on the LPC1768 is designed to have extremely low power consumption, i.e. less than 1 uA. The RTC will typically run from the main chip power supply, conserving battery power while the rest of the device is powered up. When operating from a battery, the RTC will continue working down to 2.1 V. Battery power can be provided from a standard 3 V Lithium button cell.

An ultra-low power 32 kHz oscillator will provide a 1 Hz clock to the time counting portion of the RTC, moving most of the power consumption out of the time counting function.

Clocking and Power Control

Crystal oscillators
The LPC1768 include three independent oscillators. These are the main oscillator, the IRC oscillator, and the RTC oscillator. Each oscillator can be used for more than one purpose as required in a particular application. Any of the three clock sources can be chosen by software to drive the main PLL and ultimately the CPU.

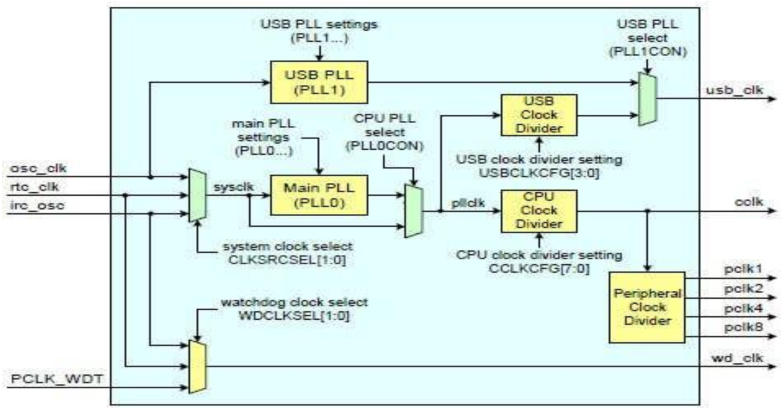
Following reset, the LPC1768 will operate from the Internal RC oscillator until switched by software. This allows systems to operate without any external crystal and the boot loader code to operate at a known frequency.

Power control

The LPC1768 support a variety of power control features. There are four special modes of processor power reduction: Sleep mode, Deep-sleep mode, Power-down mode, and Deep power-down mode. The CPU clock rate may also be controlled as needed by changing clock sources, reconfiguring PLL values, and/or altering the CPU clock divider value. This allows a trade-off of power versus processing speed based on application requirements. In addition, Peripheral Power Control allows shutting down the clocks to individual on-chip peripherals, allowing fine tuning of power consumption by eliminating all dynamic power use in any peripherals that are not required for the application. Each of the peripherals has its own clock divider which provides even better power control.

Integrated PMU (Power Management Unit) automatically adjust internal regulators to minimize power consumption during Sleep, Deep sleep, Power-down, and Deep power- down modes.The LPC1768 also implement a separate power domain to allow turning off power to the bulk of the device while maintaining operation of the RTC and a small set of registers for storing data during any of the power-down modes.

Clock generation block diagram for LPC1768 is shown below



System Control

Reset

Reset has four sources on the LPC1768: the RESET pin, the Watchdog reset, power-on reset (POR),andtheBrown-OutDetection(BOD)circuit.TheRESETpinisaSchmitttriggerinputpin. Assertion of chip Reset by any source, once the operating voltage attains a usable level, causes the RSTOUT pin to go LOW. Once reset is de-asserted, or, in case of a BOD- triggered reset, once the voltage rises above the BOD threshold, the RSTOUT pin goes HIGH. In other words RSTOUT is high when the controller is in its activestate.

Emulation and debugging

Debug and trace functions are integrated into the ARM Cortex-M3. Serial wire debug and trace functions are supported in addition to a standard JTAG debug and parallel trace functions. The ARM Cortex-M3 is configured to support up to eight breakpoints and four watch points.

Note: For further details on Controller blocks refer the User manual of LPC176x/5x – UM10360 available at www.nxp.com

3. TECHNICAL SPECIFICATIONS ofLPC1768

3.1 Specifications ofLPC1768:

- ARM Cortex-M3 processor runs up to 100 MHzfrequency.
- ARM Cortex-M3 built-in Nested Vectored Interrupt Controller(NVIC).
- Up to 512kB on-chip flash program memory with In-System Programming (ISP) and In-Application Programming (IAP) capabilities. The combination of an enhanced flash memory accelerator and location of the flash memory on the CPU local code/data bus provides high code performance fromflash.
- Up to 64kB on-chip SRAMincludes:
  - Up to 32kB of SRAM on the CPU with local code/data bus for high-performance CPU access.
  - Up to two 16kB SRAM blocks with separate access paths for higher throughput. These SRAM blocks may be used for Ethernet, USB, and DMA memory, as well as for general purpose instruction and datastorage.
- Eight channel General Purpose DMA controller (GPDMA) on the AHB multilayer matrix that can be used with the SSP, I2S, UART, the Analog-to-Digital and Digital-to-Analog converterperipherals,timermatchsignals,GPIO,andformemory-to-memorytransfers.
- Serialinterfaces:
  - Ethernet MAC with RMII interface and dedicated DMA controller.
  - USB 2.0 full-speed controller that can be configured for either device, Host, or OTG operation with an on-chip PHY for device and Host functions and a dedicated DMA controller.
  - Four UART's with fractional baud rate generation, internal FIFO, IrDA, and DMA support. One UART has modem control I/O and RS-485/EIA-485support.
  - Two-channel CANcontroller.
  - Two SSP controllers with FIFO and multi-protocol capabilities. The SSP interfaces can be used with the GPDMAcontroller.
  - SPI controller with synchronous, serial, full duplex communication and programmable data length. SPI is included as a legacy peripheral and can be used instead ofSSP0.
  - Three enhanced I2C-bus interfaces, one with an open-drain output supporting the full I2C specification and Fast mode plus with data rates of 1Mbit/s, two with standard port pins. Enhancements include multiple address recognition and monitormode.
  - I2S (Inter-IC Sound) interface for digital audio input or output, with fractional rate control. The I2S interface can be used with the GPDMA. The I2S interface supports 3-wire data transmit and receive or 4-wire combined transmit and receive connections, as well as master clockoutput.
- Otherperipherals:
  - 70 General Purpose I/O (GPIO) pins with configurable pull-up/down resistors, open drain mode, and repeater mode. All GPIOs are located on an AHB bus for fast access, and support Cortex-M3 bit-banding. GPIOs can be accessed by the General Purpose DMA Controller. Any pin of ports 0 and 2 can be used to generate aninterrupt.
  - 12-bit Analog-to-Digital Converter (ADC) with input multiplexing among eight pins, conversion rates up to 200 kHz, and multiple result registers. The 12-bit ADC can be used with the GPDMAcontroller.
  - 10-bit Digital-to-Analog Converter (DAC) with dedicated conversion timer and DMA support.
  - Four general purpose timers/counters, with a total of eight capture inputs and ten compare outputs. Each timer block has an external count input. Specific timer events can be selected to generate DMArequests.
  - One motor control PWM with support for three-phase motorcontrol.
  - Quadrature encoder interface that can monitor one external quadratureencoder.

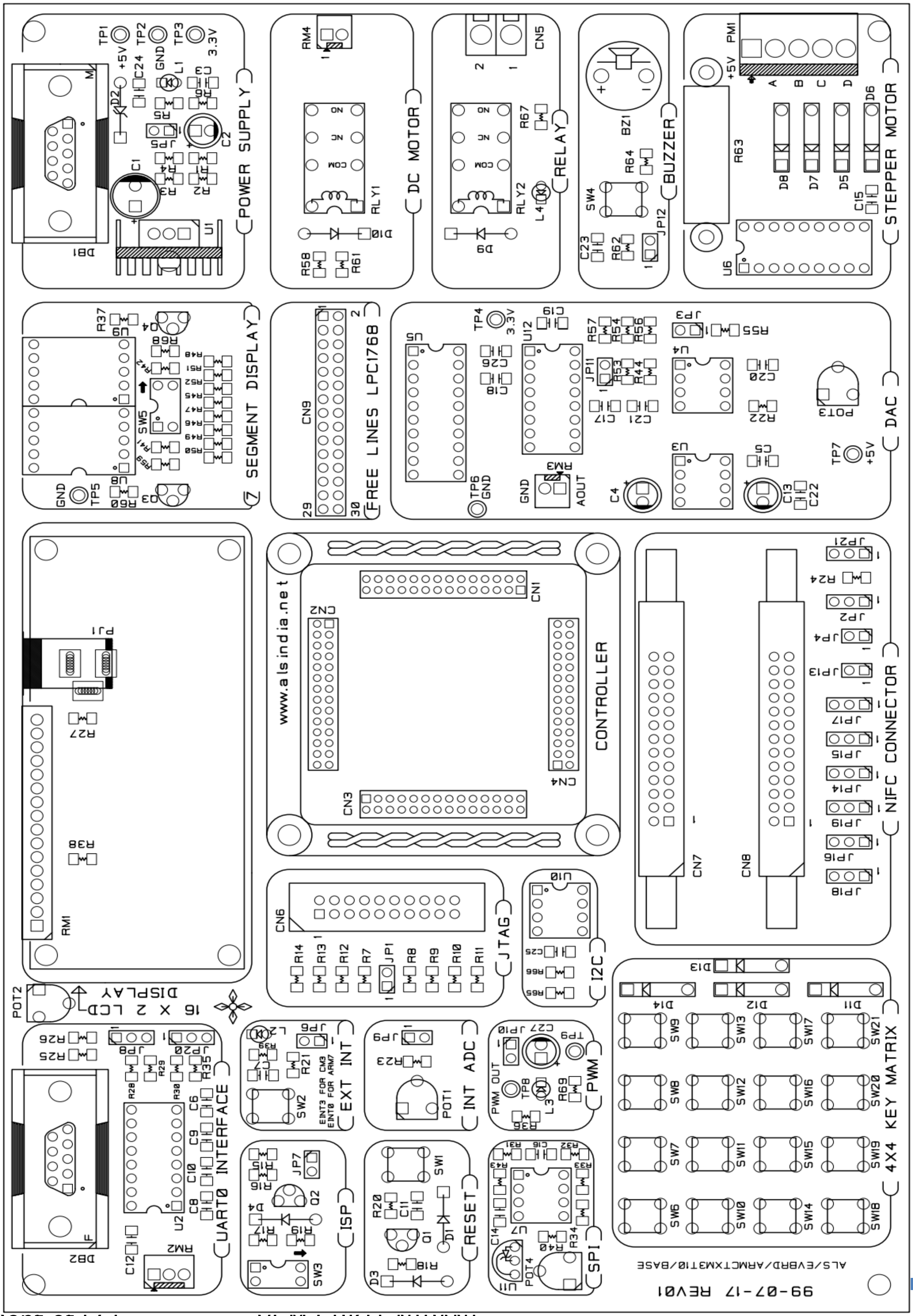
- One standard PWM/timer block with external countinput.
- Real-Time Clock (RTC) with a separate power domain. The RTC is clocked by a dedicated RTC oscillator. The RTC block includes 20 bytes of battery-powered backup registers, allowing system status to be stored when the rest of the chip is poweredoff. Battery power can be supplied from a standard 3 V Lithium button cell. The RTC will continue working when the battery voltage drops to as low as 2.1 V. An RTC interrupt can wake up the CPU from any reduced powermode.
- Watchdog Timer (WDT). The WDT can be clocked from the internal RC oscillator, the RTC oscillator, or the APBclock.
- Cortex-M3 system tick timer, including an external clock input option.
- Repetitive interrupt timer provides programmable and repeating timed interrupts.

- Standard JTAG test/debug interface as well as Serial Wire Debug and Serial Wire Trace Portoptions.
- Emulation trace module supports real-timetrace.
- Four reduced power modes: Sleep, Deep-sleep, Power-down, and Deeppower-down.
- Single3.3Vpowersupply(2.4Vto3.6V).Temperaturerangeof-40°Cto85 °C.
- Fourexternalinterruptinputsconfigurableasedge/levelsensitive.AllpinsonPORT0and PORT2 can be used as edge sensitive interruptsources.
- Non Maskable Interrupt (NMI)input.
- Clock output function that can reflect the main oscillator clock, IRC clock, RTC clock,CPU clock, or the USBclock.
- The Wake-up Interrupt Controller (WIC) allows the CPU to automatically wake up from any priority interrupt that can occur while the clocks are stopped in deep sleep, Power-down, and Deep power-downmodes
- Processor wake-up from Power-down mode via any interrupt able to operate during Power-down mode (includes external interrupts, RTC interrupt, USB activity, Ethernet wake-up interrupt, CAN bus activity, PORT0/2 pin interrupt, andNMI).
- Each peripheral has its own clock divider for further powersavings.
- Brownout detect with separate threshold for interrupt and forcedreset.
- On-chip Power-On Reset(POR).
- On-chip crystal oscillator with an operating range of 1 MHz to 25MHz.
- 4 MHz internal RC oscillator trimmed to 1% accuracy that can optionally be used as a systemclock.
- Anon-chipPLLallows CPUoperationuptothemaximum CPUratewithouttheneedfora high-frequency crystal. May be run from the main oscillator, the internal RC oscillator, or the RTCoscillator.
- A second, dedicated PLL may be used for the USB interface in order to allow added flexibility for the Main PLLsettings.
- Versatile pin function selection feature allows many possibilities for using on-chip peripheralfunctions.

3.2 SPECIFICATIONS OFALS-SDA-ARMCTXM3-06

- **LPC1768** is **ARM Cortex M3** based micro controllerwith
  - ✓ 512KB flash memory and 64KB SRAM In-System Programming (ISP) and In-Application Programming (IAP)capabilities.
  - ✓ Single 3.3 V power supply (2.4 V to 3.6V).
  - ✓ 70 General Purpose I/O (GPIO) pins with configurable pull-up/down resistors, open drain mode, and repeatermode.
  - ✓ 12-bit Analog-to-Digital Converter (ADC) and up to 8 analogchannels.
  - ✓ 10-bit Digital-to-Analog Converter (DAC) with dedicated conversiontimer.
  - ✓ Four general purpose timers/counters, with a total of eight capture inputs andten compareoutputs.
  - ✓ Four UART's with fractional baud rate generation, internal FIFO,IrDA.
  - ✓ SPI controller with synchronous, serial, full duplexcommunication.
  - ✓ Three enhanced I2C-businterfaces
  - ✓ Four reduced power modes: Sleep, Deep-sleep, Power-down, and Deep power-down.
  - ✓ Real-Time Clock (RTC) with a separate powerdomain.
  - ✓ Standard JTAG test/debug interface as well as Serial WireDebug.
  - ✓ Four external interrupt inputs configurable as edge/levelsensitive.
- 12MHz Crystal allows easy communicationsetup
- Oneonboardvoltageregulatorforgenerating3.3V.InputtothiswillbefromExternal +5V DC Power supply through a 9-pin DSUB connector
- Piggy Back module containing **LPC1768**controller
- Standard JTAG connector with ARM 2×10 pin layout for programming/debugging with ARM-JTAG
- Reset push-button for resetting thecontroller
- One RS232 interface circuit with 9 pin DSUB connector: this is used by the Boot loader program, to program **LPC1768** Flash memory without externalProgrammer
- DC motor interface with direction and speedcontrol
- Stepper motor interface with direction and speedcontrol
- 16×2 alphanumeric LCDDisplay
- On chip ADC interface circuit usingAD0.5(P1.31)
- 8-bit DACinterface
- 4x4 Key-Matrix connected to the port lines of thecontroller
- One External interrupt circuit with LEDindication
- Two-digit multiplexed 7-segment displayinterface
- Interface circuit for on board Buzzer, Relay and Led indication controlled through push button.
- SPI Interface: 2 channel ADC IC with POT and Temperaturesensor
- I2C Interface: NVROMIC
- Standard 26-pin FRC connectors to connect to **on-board interface** or some of **ALS standard ExternalInterfaces.**
- A number of software examples in 'C-language' to illustrate the functioning of the interfaces. The software examples are compiled using an evaluation version of KEIL4 'C' compiler forARM.
- Compact elegant plasticenclosure
- Optional USB to Serial interface (RS232)cable.

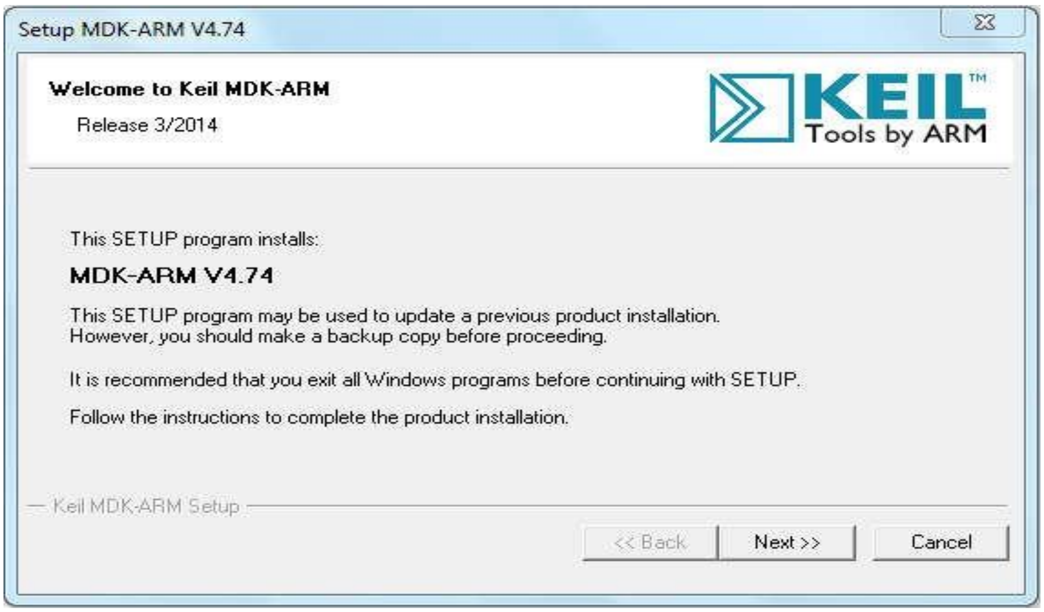
4. PLACEMENTDIAGRAM



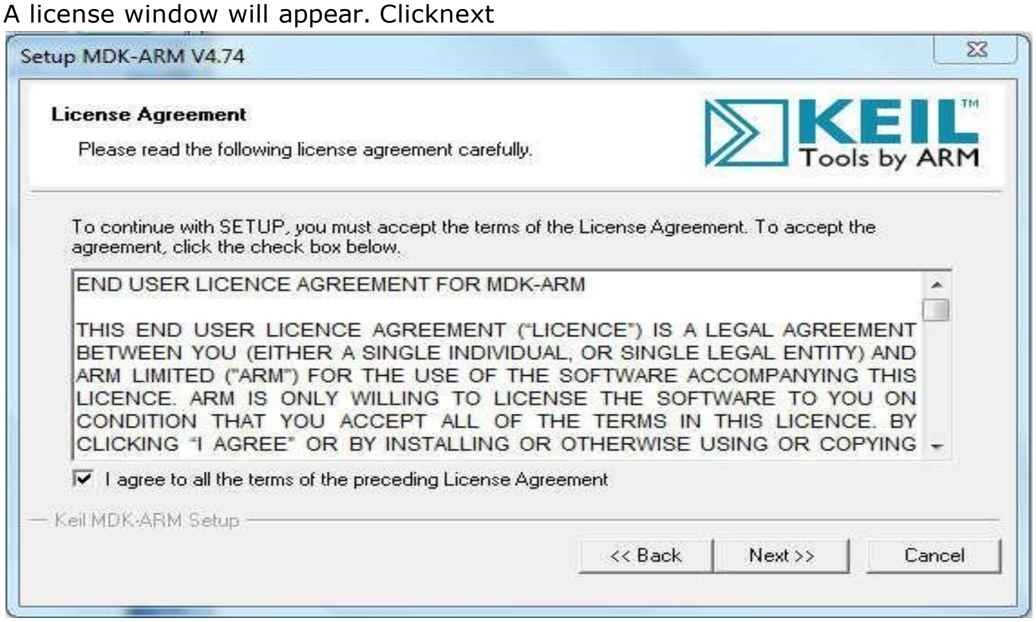
5. SOFTWARE/FIRMWARE

5.1 Keil uvision4 IDEInstallation:

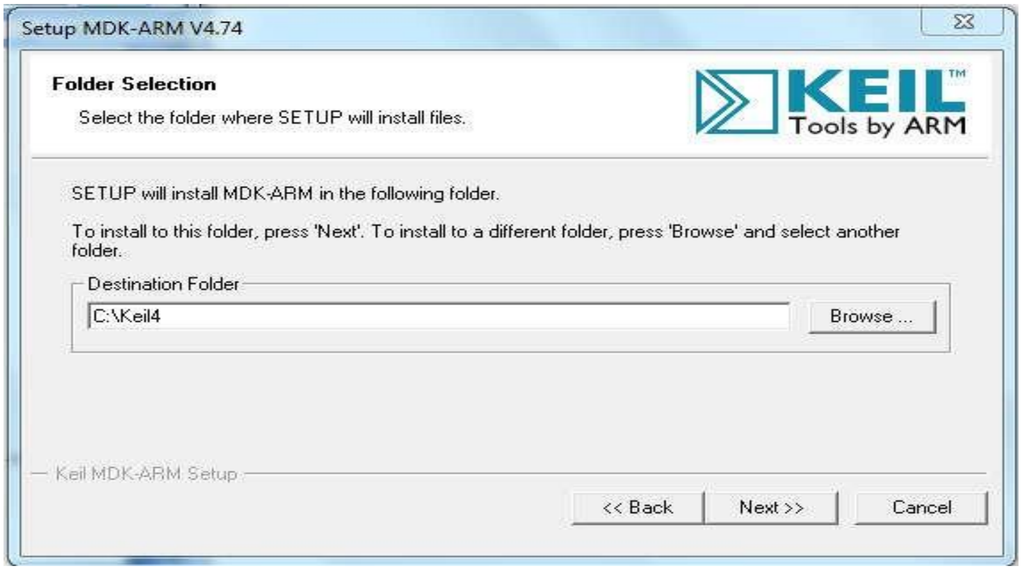
- Installation of keiluVision4 asfollows.
- Go to Software folder in the CD and run mdk474.exefile.
- A welcome window will appear. Click next onit



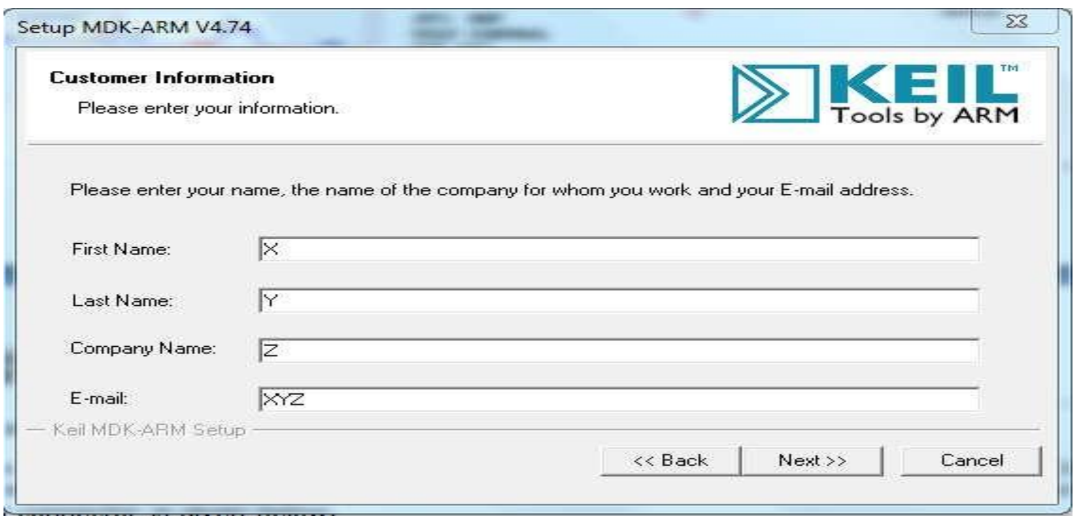
- A license window will appear. Clicknext



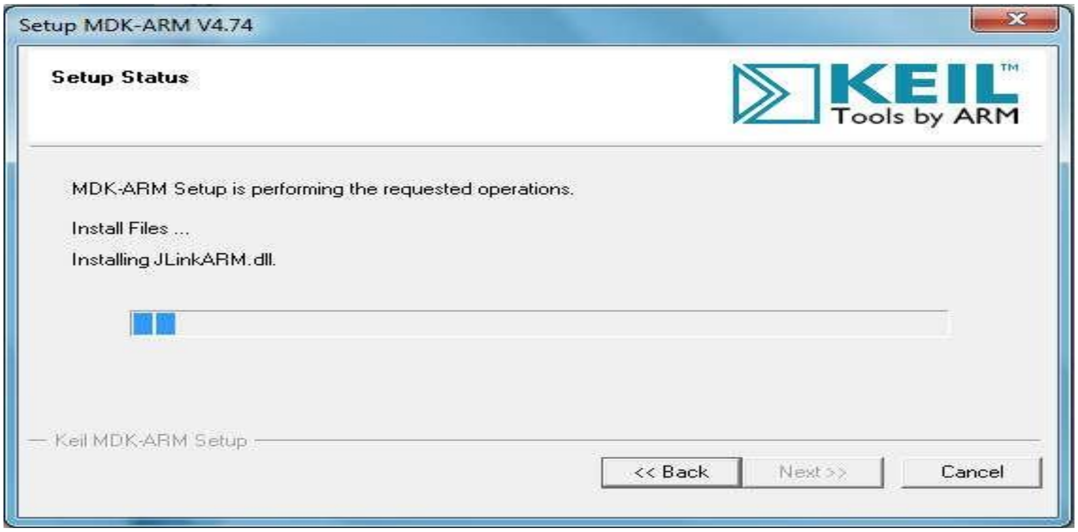
- Create a folder Keil4 at C drive to installsoftware



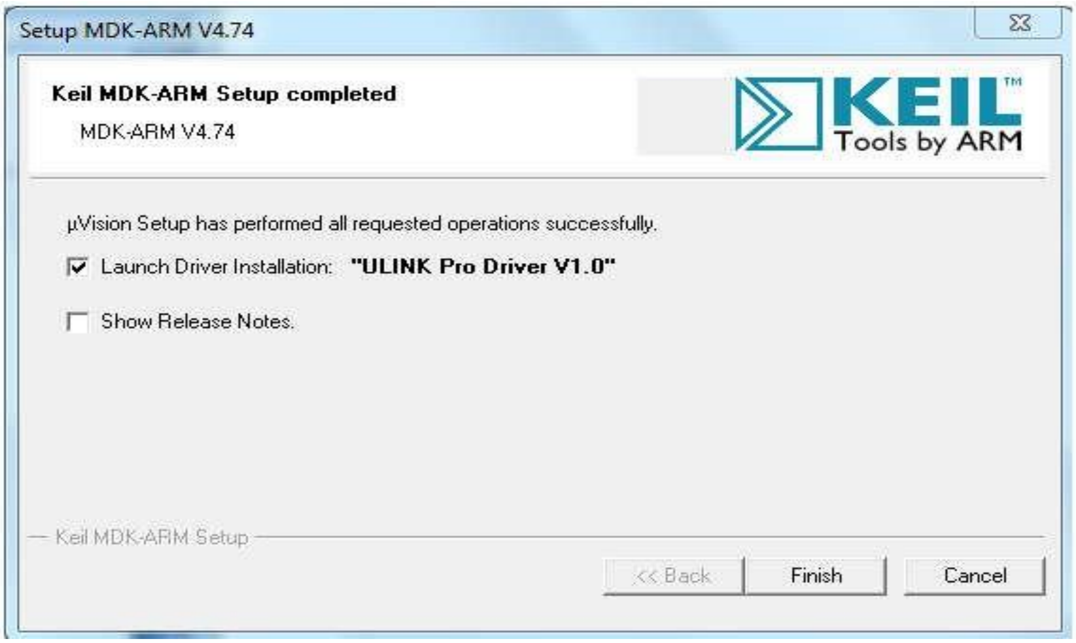
- Mention customer information against the tabsappear



- After clicking next a setup status willappear



- Click next andfinish



5.2 Settings to be done at configuration wizard of system_LPC17xx.cfile

- ✓ Beforeconfiguringtheclockregistersstudytheblockdiagramwhichisdescribedinthe Clocking and power control in chapter2.
- ✓ TherearethreeclocksourcesforCPU.SelectOscillatorclockoutofthree.Thisselection is done by CLKSRCSELregister.
- ✓ IfwedisablethePLL0SystemclockwillbebypasseddirectlyintoCPUclockdivider register.
- ✓ UseCCLKCFGregisterforchoosingthedivisionfactorof4toget3MHzoutof12MHz Oscillatorfrequency.
- ✓ For any other peripherals use the PCLK same asCCLK.Follow the below mentioned

procedure to do these settings.

Open uVisoin4 →under file tab open
C: Keil (4)\ARM\startup\NXP\LPC17xx\system_LPC17xx.c

- Double click on system_LPC17xx.c file at projectwindow
- Select the configuration wizard at thebottom
- Expand theicons
- Select Clockconfiguration
- Under System controls and Statusregisters
  OSCRANGE: Main Oscillatorrangeselect **1MHz to20MHz**
  OSCEN: Mainoscillatorenable **√**
- Under Clock source select register(CLKSRCSEL)
  CLKSRC: PLL clocksourceselection **Main oscillator**
- Disable **PLL0** configuration and **PLL1**configuration
- Under CPU Clock Configurationregister(CCLKCFG)
  CCLKSEL: Divide value for CPU clockforPLL0 **4**
- Under USB Clock configuration register(USBCLKCFG)
  USBSEL: Divide value for USB clockforPLL0 **4**
- Under Peripheral clock selection register 0 (PCLKSEL0) and 1(PCLKSEL1)
  Select Pclk = Cclk for all.
- Under Power control for peripherals(PCONP)
  Enable the power for requiredperipherals
- IfCLKOUTtobestudiedconfiguretheClockoutputconfigurationregisterasbelow
  CLKOUTSEL : **MainOscillator**
  CLKOUTDIV **1**
  CLKOUT_EN :**√**
- Call thefunctions

```
SystemInit ();
SystemCoreClockUpdate();
```

At the beginning of the main function without missing.These functions are defined in system_LPC17xx.c where actual clock and other system control registers configuration takes place.

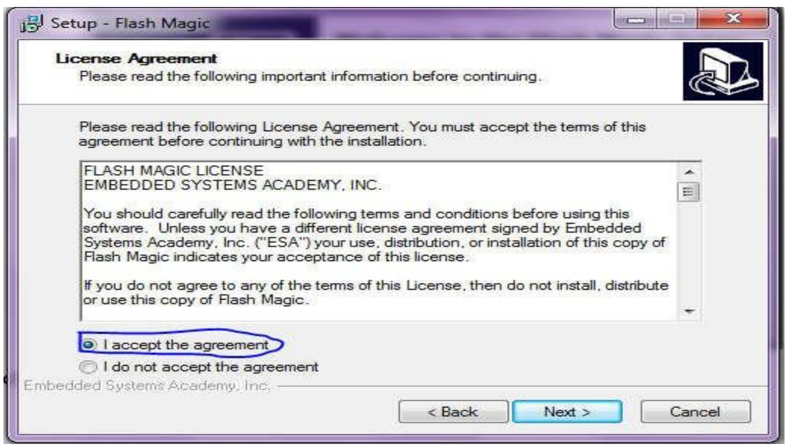
NOTE: System core clock (Peripheral CLK)/Operating frequency is calculated as below
Main Oscillator = XTAL = 12MHZ and (CCLKCFG+1) = 4 then
System core clock = Main Oscillator/ (CCLKCFG+1) = 12MHZ / 4 = 3MHZ.

5.3 Flash magic 6.01installations:

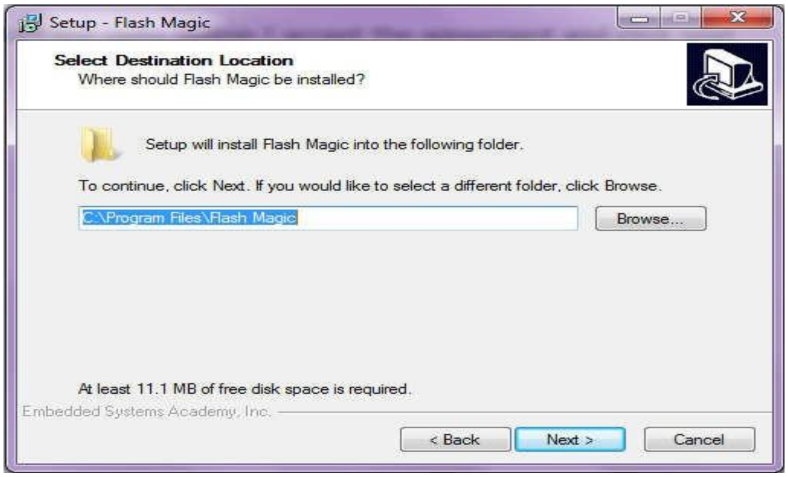
1.Go to Software folder in the CD and run FlashMagic.exe file.

2.Click next on Welcome wizard

3.Select the radio button I accept the agreement and click next



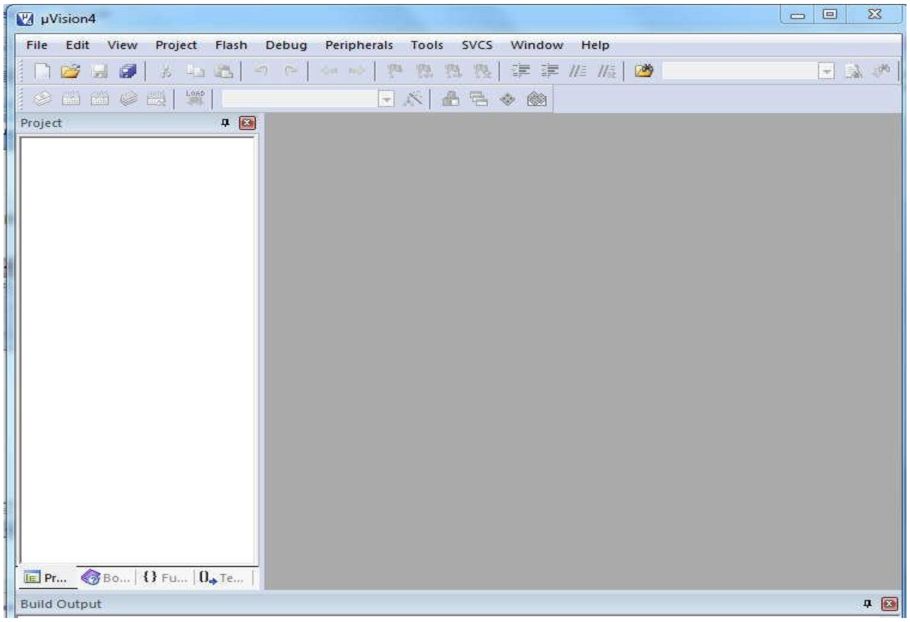
4.Choose a folder to install the files. Click next and choose the option create short cut icon and click next. Displays the options we have selected



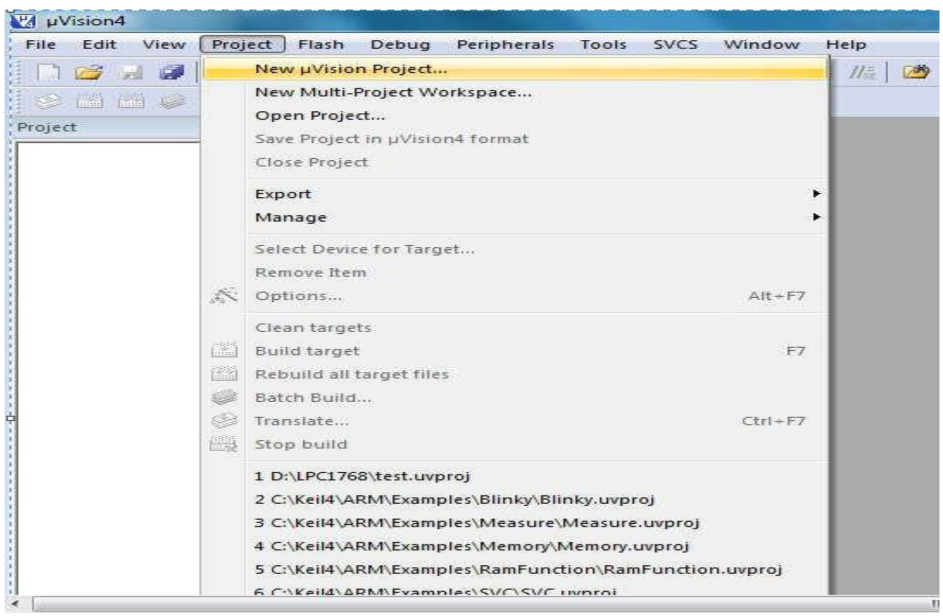
5.Click on install and finish

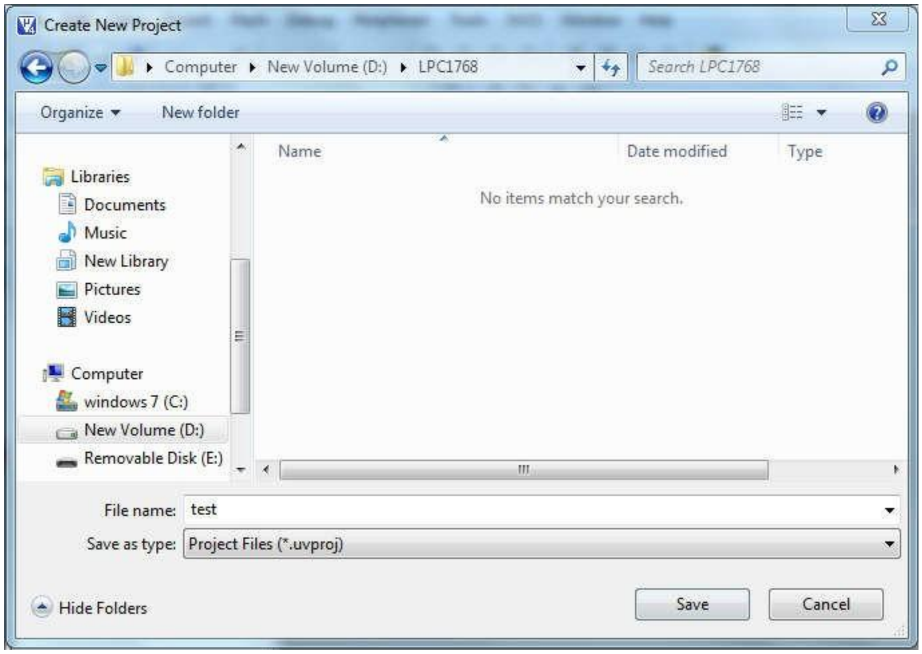
5.4 Project Creation in Keil uvision4IDE:

- ✓ Create a project folder before creating NEWproject.
- ✓ Use separate folder for eachproject
- ✓ Open Keil uVision4 IDE software by double clicking on "Keil Uvision4"icon.

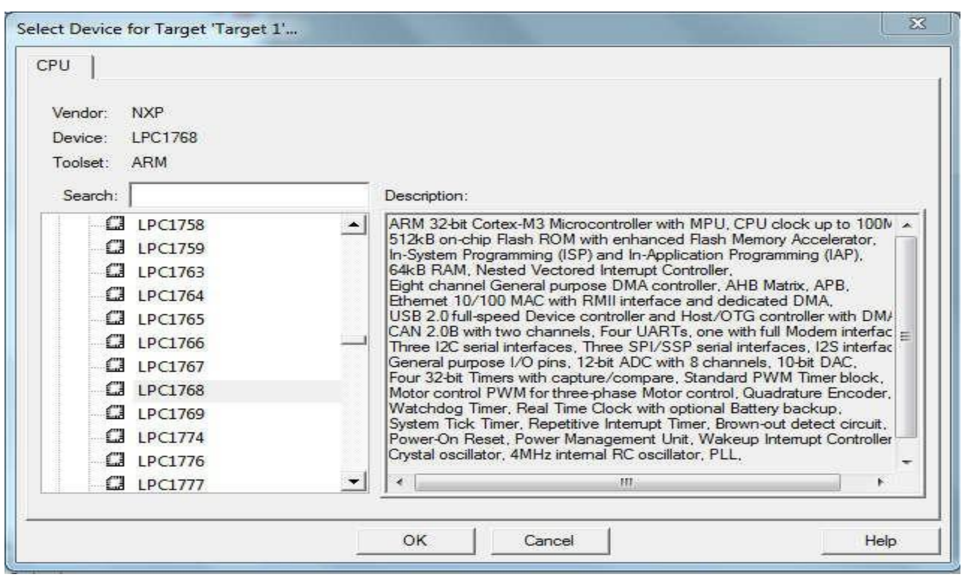


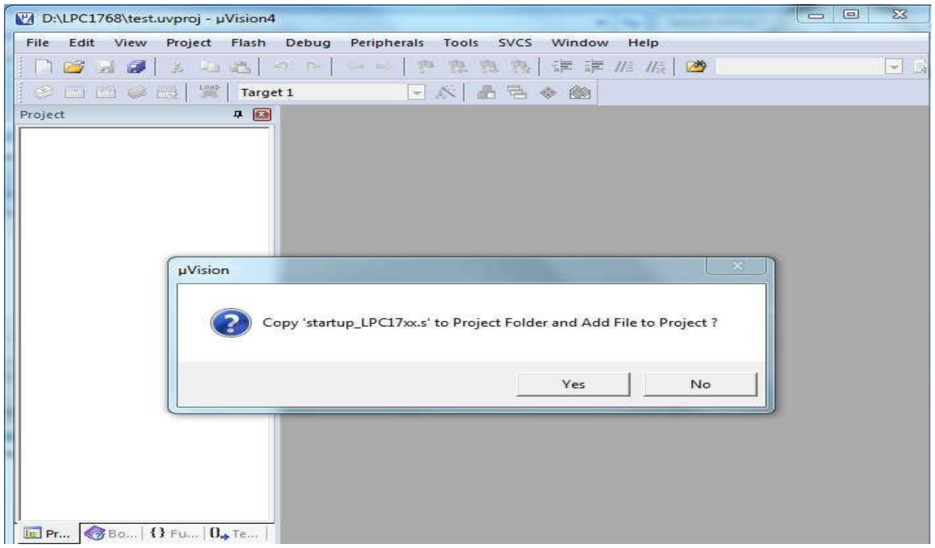
✓ Go to "Project" then to "New Project" and save it with a name in the Respective Project folder, already youcreated.

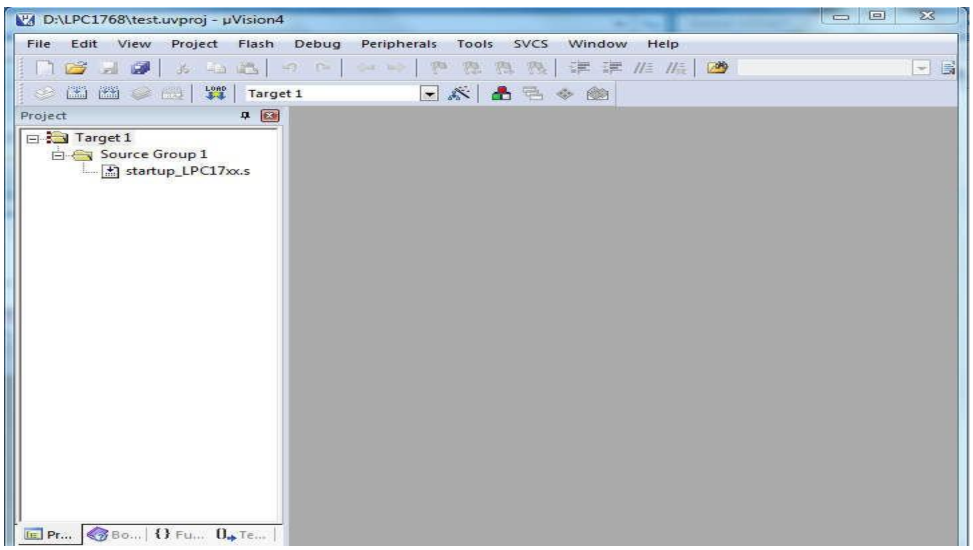




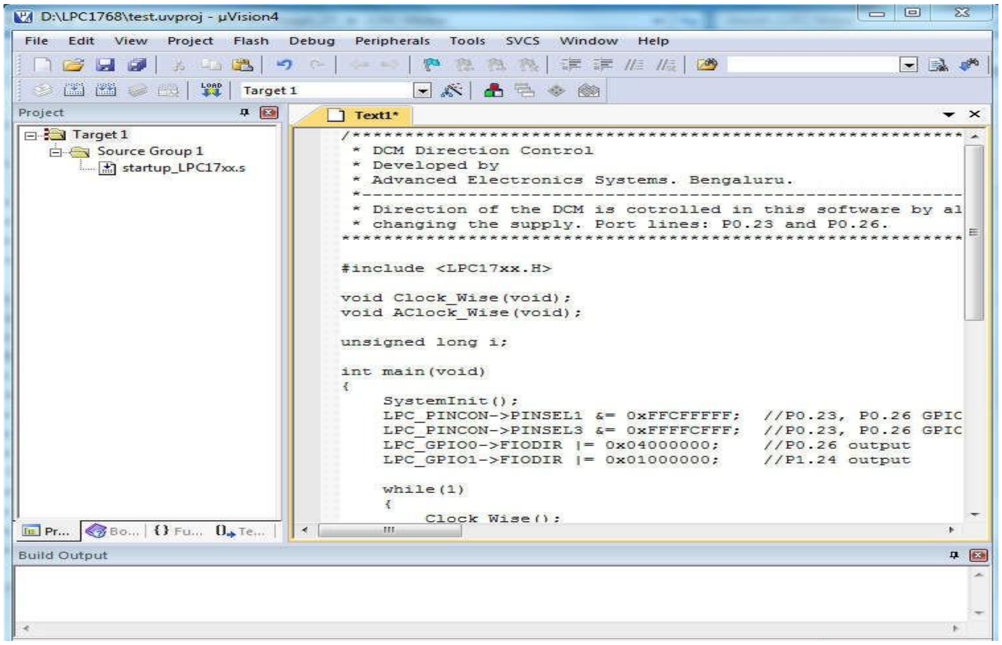
✓ Select the device as "NXP (founded by Philips)" In that "LPC1768" then Press OK and then press "YES" button to add "system_LPC17xx.s"file.







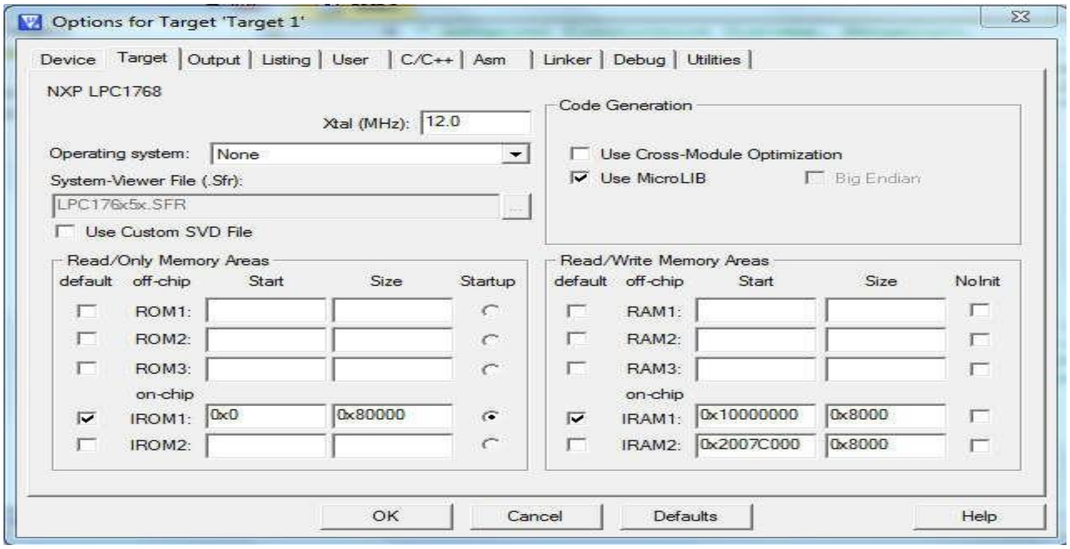
- ✓ Go to "File" In that "New" to open an editor window. Create your source file And use the header file "LPC17xx.h" in the source file and save the file. Color syntax highlighting will be enabled once the file is saved with a Recognized extension such as ".C".



- ✓ Rightclickon"SourceGroup1"andselecttheoption"Add FilestoGroup'SourceGroup 1' "add the. C source file(s) to thegroup.
- ✓ Again right click on Source Group 1 and select the option "Add Existing Files to Group 'Source Group 1' "add the file–C: Keil4\ARM\startup\NXP\LPC17xx\system_LPC17xx.c
- ✓ Any changes made to this file at current project will directly change the source system_LPC17xx.c file. So that other project settings may get altered. So it is recommended to copy thefile C: Keil (4)\ARM\startup\NXP\LPC17xx\system_LPC17xx.c to the project folder and add to the sourcegroup.
  Important: This file should be added at each project creation.
- ✓ Then go to "Project" in that "Translate" to compile the File(s).
- ✓ Go to "Project" in that "Build Target" for building all source files such as ".C",".ASM", ".h", files, etc…This will create the hex file if no warnings & noErrors.

5.5 Settings to be done in KEILUV4 for Executing Cprograms:

- ✓ In Project Window Right click "TARGET1" and select "options for target'TARGET1'
- ✓ Then go to option "Target" inthat
  1. Xtal 12.0MHz and UseMicroLIB
  2. Select IROM1 (starting 0×0 size0×8000).
  3. Select IRAM1 (starting 0×10000000 size0×8000).



- ✓ Then go to option"Output"
  - Select "Create Hexfile".
- ✓ Then go to option"Linker"
  - Select use memory layout from targetdialog

6. TEST SET UP & TESTPROCEDURE:

6.1 TEST SET UPREQUIREMENTS:

- ALS-SDA-ARMCTXM3-06 : 1No.
- Powersupply(+5V) : 1No.
- USB-to-SERIAL cable for programming andserialcommunication : 1No.
- Kiel uvision4 and flash magic6.01
- OneworkingCOMportinthehostcomputersystemandPCfordownloadingthe software.
- 1 numbers 26 core FRC cables of 2 inchlength

6.2 TEST SETUP:

- Connect +5V power cable toDB1.
- Do not insert the piggyback module into the board before testing the voltagelevels.
- Remove JP5 and then switch on the powersupply.
- Check+5VatTP1.IfvoltagesareatrightlevelthencheckifanyIC'sgettingwarm.
- Insert JP5 and check +3.3V atTP3
- Then switch off the power supply, insert the piggybackmodule.
- Also make sure the regulator output which is flowing into the controller is3.3V

6.3 FLASH PROGRAMMING

- Connect 9 pin DSUB USB-to-SERIAL cable from PC to DB2 at theboard.
- On the 2 way dip switch SW3 and Short jumperJP7.
- Open flash magic6.01**.**
- Some Settings in FLASHMAGIC:

Step1. Communications:

Device :LPC1768

ComPort : COM1 (Check theCOM here .**Computer**→right

Click→**Manage**→**DeviceManager**→**Ports**)

Baud Rate 19200
Interface : None (ISP)
Oscillator :12MHz

Step2. ERASE:
Select "Erase Blocks Used By Hex File".

Step3. Hex file:
Browse and select the Hex file which you want to download.

Step4. Options:
Select "Verify After Programming".
Go to **Options** ->**Advanced Options->communications**
Do not select **High Speed Communications**
Keep baud rate 115200.
Options ->**Advanced Options->Hardware config**
Select **Use DTR & RTS to control RST & ISP Pin**.
Select **Keep RTS asserted while COM Port open**.
T1 = 50ms. T2 = 100ms.

Step5. Start:
Click Start to download the hex file to the controller.

After downloading the code the program starts executing in the hardware, then switch off SW3 and remove the ISP jumper JP7.

7. HARDWAREDETAILS

7.1 CONNECTORDETAILS:

- **CN1CONNECTOR**:28pin14X2HEADERisconnectedtothecontroller.

Pin#	DESCRIPTION	PIN #	DESCRIPTION
1	TDO-JTAG	2	TDI-JTAG
3	TMS-JTAG	4	TRST-JTAG
5	TCK-JTAG	6	PC3
7	PC2	8	PC1
9	PC0	10	3.3V
11	GND	12	3.3V
13	NC	14	NC
15	GND	16	RTCX1
17	RESET	18	RTCX2
19	VBAT	20	ADC
21	CP1.30	22	NC
23	NC	24	C_P0.28
25	C_P0.27	26	NC
27	NC	28	NC

- **CN2CONNECTOR**:28pin14X2HEADERisconnectedtothecontroller.

Pin#	DESCRIPTION	PIN #	DESCRIPTION
1	NC	2	NC
3	C_P2.12	4	PWM
5	3.3V	6	C_P0.29
7	C_P0.30	8	GND
9	C_P1.18	10	C_P1.19
11	ROW0	12	ROW1
13	ROW2	14	ROW3
15	C_P1.24	16	C_P1.25
17	NC	18	GND
19	3.3V	20	C_P1.27
21	C_P1.28	22	C_P1.29

23	C_P0.0	24	C_P0.1
25	PB6	26	PB7
27	EINT	28	NC

- **CN3CONNECTOR**:28pin14X2HEADERisconnectedtothecontroller.

PIN #	DESCRIPTION	PIN #	DESCRIPTION
1	NC	2	NC
3	ILED	4	EINT1
5	ISP	6	3.3V
7	GND	8	PA7*
9	PA6	10	PA5
11	PA4	12	PA3
13	PA2	14	PA1
15	PA0	16	LD7/CON
17	LD6	18	LD5
19	LD4	20	LEN
21	LRS	22	PC7
23	3.3V	24	GND
25	PC6	26	PC5
27	PC4	28	NC

CN4 CONNECTOR: 28 pin 14 X 2 HEADER is connected to thecontroller.

PIN #	DESCRIPTION	PIN #	DESCRIPTION
1	PB5	2	PB4
3	PB3	4	PB2
5	PB1	6	PB0
7	C_P4.28	8	GND
9	3.3V	10	C_P4.29
11	C_P1.17	12	C_P1.16
13	C_P1.15	14	C_P1.14
15	C_P1.10	16	C_P1.4
17	C_P1.8	18	C_P1.9
19	C_P1.1	20	C_P1.0
21	3.3V	22	GND
23	TXD0	24	RXD0
25	RTCK-JTAG	26	NC
27	NC	28	NC

- **CN5 CONNECTOR**: 2 pin MKDSN connector for RELAYinterface

PIN #	DESCRIPTION
1	Connected to POL1 of Rly2
2	Connected to NO contact of Rly2

- **CN6 CONNECTOR**: 20 pin FRC connected to the controller, Standard JTAG connector for programming/debuggingwithARM-JTAGdebugger.SHORTjumperJP1for JTAGtowork.

PIN #	DESCRIPTION	PIN #	DESCRIPTION
1	+3.3V	2	+3.3V
3	TRST	4	GND
5	TDI	6	GND
7	TMS	8	GND
9	TCK	10	GND
11	RTCK	12	GND
13	TDO	14	GND
15	RST	16	GND
17	R10 ONE END	18	GND
19	R11 ONE END	20	GND

- **CN7 CONNECTOR**: 26 pin FRC connected to the controller, which is compatiblewith **ALS Standard External Interfaces**. SHORT jumper JP4 to connect External Interfaces.

PIN #	DESCRIPTION	PIN #	DESCRIPTION
1	PC4(P2.0)	2	PC5(P2.1)
3	PC2(P0.25)	4	PC3(P0.26)
5	PC0(P0.23)	6	PC1(P0.24)
7	PB6(P0.10)	8	PB7(P0.11)
9	PB4(P0.8)	10	PB5(P0.9)
11	PB2(P0.6)	12	PB3(P0.7)
13	PB0(P0.4)	14	PB1(P0.5)
15	PA6(P0.21)	16	PA7(P0.22)
17	PA4(P0.19)	18	PA5(P0.20)
19	PA2(P0.17)	20	PA3(P0.18)
21	PA0(P0.15)	22	PA1(P0.16)
23	PC6*(P2.2 2nd PIN OF JP13)	24	PC7(P2.3)
25	+5V THROUGH JP4	26	GND

- **CN8CONNECTOR**:26pinFRCconnectedtothecontroller,whichiscompatiblewith

ALS Standard External Interfaces.

PIN #	DESCRIPTION	PIN #	DESCRIPTION
1	*PC4	2	*PC5
3	*PC2	4	*PC3
5	*PC0	6	*PC1
7	*PB6	8	*PB7
9	*PB4	10	*PB5
11	*PB2	12	*PB3
13	*PB0	14	*PB1
15	*PA6	16	*PA7
17	*PA4	18	*PA5
19	*PA2	20	*PA3
21	*PA0	22	*PA1
23	*PC6	24	*PC7
25	+5V THROUGH JP4	26	GND

7.2 DSUB CONNECTORDETAILS:

- **DB1 CONNECTOR**: 9-Pin D-type Male Powerconnector.

Pin Number	Description
1,2,3,6,7,8	No Connection
4	GND
5	GND
9	+5V

- **DB2 CONNECTOR**: **(UART0)** 9-Pin D-type Female connector connects to the COM port of host PC for In System Programming (ISP) application and transferring the data between controller device and host computer. Use a cross cable to connect to PC. NOTE: DTR and RTS lines arerequired.

Pin Number	Description
1,6,8,9	NC
3	R0IN
2	T0OUT
5	GND
4	DTR
7	RTS

7.3 POWERMATEDETAILS:

- **PM1**:5 Pin Power mate (High Current Output Lines for StepperMotor).

Pin Number	Description
1	+5V
2	OUT1(A)
3	OUT2(B)
4 5	OUT3(C) OUT4(D)

7.4 JUMPERDETAILS:

JUMPERS	CONNECTION	DESCRIPTION
JP1 (1,2)	Closed	To enable JTAG Programming.
JP2 (1,2)	Closed	CN7-16 to P0.22.
JP2 (2,3)	NC	NA
JP3 (1,2)	Closed	Ref Volt applied to DAC
JP4(1,2)	Closed	5V supply to connector
JP5 (1,2)	Closed	Connects 3.3v to board
JP6 (1,2)	Closed	External Interrupt (INT3) is given through SW2.
JP7 (1,2)	Closed	ISP signal to the controller
JP8 (1,2)	Closed	NA
JP8 (2,3)	Closed	To Test UART1(TXD1) of LPC1768
JP9 (1,2)	Closed	Enable internal ADC circuit
JP10 (1,2)	Closed	Enable PWM circuit
JP11(1,2)	Closed	The output wave form is Uni-Polar
JP11(1,2)	Open	The output wave form is Bi-Polar
JP12(1,2)	Closed	General Purpose Switch is given through SW4.
JP13(1,2)	Closed	To connect CN3.25 to CN7.23.
JP14(2,3)	Closed	To connect SCK to CN3.14.
JP15(2,3)	Closed	To connect MISO to CN3.13.
JP16(2,3)	Closed	To connect MOSI to CN3.12.
JP17(2,3)	Closed	To connect SSEL to CN3.15.
JP18(2,3)	Closed	To connect SCL to CN3.10.
JP19(2,3)	Closed	To connect SDA to CN3.11.
JP20(1,2)	Closed	NA
JP20(2,3)	Closed	To Test UART1(RXD1) of LPC1768
JP21(2,3)	Closed	To Operate DC motor of 1768

7.5 TESTPOINTS:

TEST POINTS	DESCRIPTION
TP1,TP7	+5V
TP3, TP4	+3.3V
TP2, TP5,TP6	GND
TP8	PWM OUTPUT

7.6 SWITCHDETAILS:

SWITCH	DESCRIPTION
SW1	RESET SWITCH
SW2	External Interrupt connected to P2.13 of Controller.
SW3	2-WAY Dipswitch to control RTS & DTR lines for ISP.
SW4	General Purpose Switch
SW5	2-WAY dip switch to enable each 7-segment display.
SW6 – SW21	4x4 Keypad switches.

7.7 POTDETAILS:

- POT1: 10K ANVI POT for testing **INTERNAL ADC** ofCONTROLLER.
- POT2: 50K ANVI POT for **LCD**Contrast.
- POT3: 5K ANVI POT for **DAC0800** interface circuit (To control Vref forDAC).
- POT4: 10K ANVI POT for SPI ADCCircuit

7.8 ICDETAILS:

IC's	DESCRIPTION
U1	**LM317** VOLTAGE REGULATOR (3 PIN)
U2	**MAX3232** RS232 LINE DRIVER(16 PIN)
U3	**ICL7660S** SUPER VOLTAGE Converter (8 PIN)
U4	**LM358** DUAL OP AMP (8 PIN)
U5	**74HCT244** OCTAL BUFFER (20 PIN)
U6	**ULN2803** DRIVER 8 Darlington array(18 PIN)
U7	**MCP3202** SPI ADC(8 PIN)
U8,U9	**LT543** SEVEN SEGMENT DISPLAY (10 PIN)
U10	**AT24C16** I2C NVROM IC
U11	**LM335** Temperature sensor
U12	**DAC0800** Digital to Analog (16 PIN)

7.9 RELIAMATEDETAILS:

1. RM1: 16 pin Single female Berg for LCDInterface.

PIN #	DESCRIPTION	PIN #	DESCRIPTION
1	GND	9,10	NO CONNECTION
2	+5V	11	DATA LINE D4(P2.6)
3	50K ANVI POT (POT2)	12	DATA LINE D5(P2.7)
4	RS(P2.4)	13	DATA LINE D6(P2.8)
5	GND	14	DATA LINE D7(P2.9)
6	CSE(P2.5)	15	+5V(Backlight)
7,8	NO CONNECTION	16	GND

2. RM2: UART1Interface

Pin Number	Description
1	TX
2	RX
3	GND

2. RM3: DAC 0800Interface

Pin Number	Description
1	Connected to DAC O/P
2	GND

3. RM4: DCMOTOR

Pin Number	Description
1	Connected to POLE1 of Rly1
2	Connected to POLE2 of Rly1

8. CABLEDETAILS

8.1 APPLYINGPOWER:

Use the following procedure to apply power. Connect a 9-pin DSUB Female Connector to a 9-pin DSUB Male connector **DB1** provided on the Evaluation Board. The color code for the supply is shown in table below:

PINNUMBERS	**POWER**
9	+5V
4,5	GND

8.2 SERIAL COMMUNICATION:

TheRS232Crosscableconnectionsrequiredforestablishingcommunicationbetween Evaluation Board and a display terminal/host computer system is givenbelow (ON BOARD it is DB2).

Open the Hyper Terminal & set the host computer system baud rate to **9600**, data length to **8 bit**, parity bit to **none** and stop bits to **1**.

DB2 PIN **NO.** (9 PIN MALE)	**COMPUTER** (COM PORT) **PIN NO.** (9-PIN FEMALE)
2-TXD	2-RXD
3-RXD	3-TXD
4-DTR	4-DTR
7-RTS	7-RTS
5-SIGNAL GND	5-SIGNAL GND
1,6,8,9	NC

9. ONBOARDINTERFACES

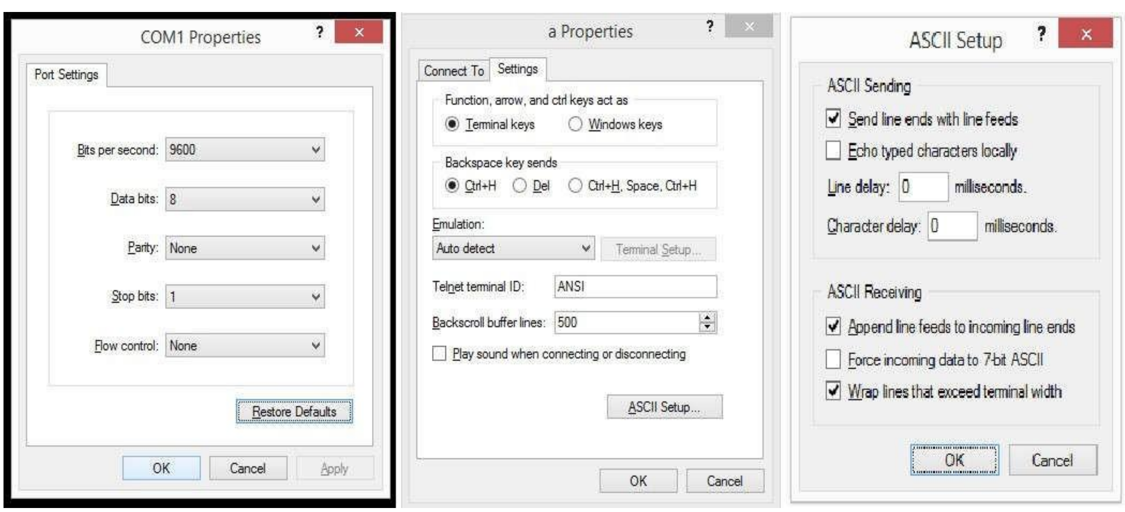
9.1 UART0 interfaceblock:

If you are connecting this Evaluation board to a computer, you have to use Hyper Terminal or Any other UART communication package. This package allows the user to use computer as a simple display terminal for Evaluation board and to transfer data between computer and Evaluation board. To set Hyper terminal communication package refer the following steps.

NOTE: USER MUST DOWNLOAD THE HYPERTERMINAL SOFTWARE FROM INTERNET.

Follow the sequence as **Start** -> A**ll Programs** ->**Accessories** ->**Communications** -> **Hyper Terminal**.

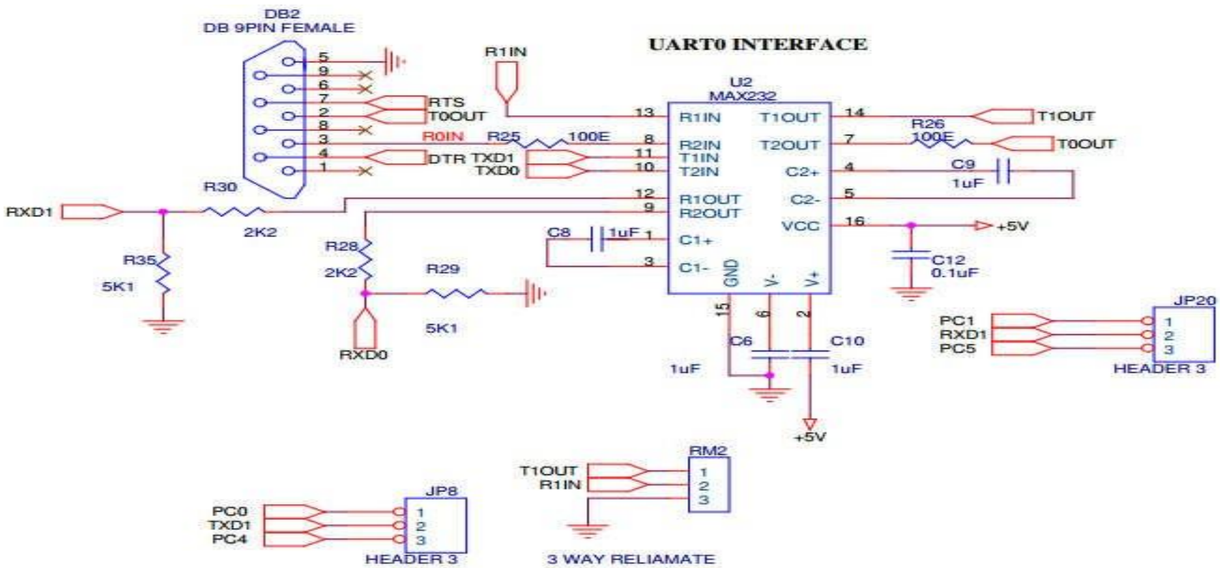
- Give the name for Hyper Terminal and then press**OK**.
- The window "**Connect To**" will appear, Select the COM port you are using in "**Connect Using**"option.
- Go to **FILE MENU** click on **properties** then click on**Configure.**
  Select the" **Port Settings**"
  Bits per Sec : 9600 (Depends on application software)
  Databits 8
  Parity :None
  Stopbits 1
  Flow control : None
  Then **Press** ->**OK**
  Go to "**File**" -> "**Save**"
- After opening the window **"Disconnect"** it by clicking on Call → Disconnect or just clicking on disconnecticon.
- Now go to File → Properties. Select 'Settings'. Select ASCII setup. A new window will come. In that select these 2options:
  ASCII Sending → Send line ends with line feeds
  ASCII Receiving → Append line feeds to incoming line ends
  Click OK. Now Call (Call → Call) again.
- Bring the Shortcut icon for Hyper Terminal on the Desktop of yourcomputer.
  Use **USB-to-SERIAL Cable** from 9-pin DSUB Female connector to the PC Com port.



UART0 is used for the boot loader purpose. Also can be used for interfacing with PC for any communication purpose. DB2 has the TXD and RXD of UART0 along with the handshaking lines RTS and DTR. MAX232 is used between this connector and controller. Hence the signals at DB2 will be in RS232 level. These lines cannot be used directly for TTL interface. A conversion must be done from RS232 to TTL level at other side if they have to be used with TTL lines.

DB2 - **(UART0)** 9-Pin D-type Female connector connects to the COM port of host PC for In System Programming (ISP) application and transferring the data between controller device and host computer. If UART0 is used for the flash programming on the switch SW3. Off the SW3 if UART0 is used for communication purpose. Note that there is an interfacing RS232 USB-to-SERIAL device between the connector and the device pins listed below

Pin Number at CN9	Pin LPC1768	Description
1,6,8,9	-	NC
3	99(P0.3)	R0IN – RXD0
2	98(P0.2)	T0OUT – TXD0
5	-	GND
4	17(RESET)	DTR
7	53(P2.10)	RTS

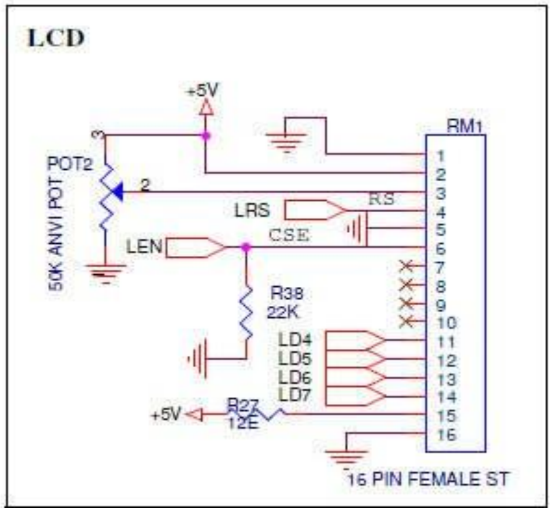


9.2 AlphanumericLCD:

A **16×2 alphanumeric LCD** can be used to display the message from controller. 16 pin small LCD has to be mounted to the connector RM1. Only higher 4 data lines are used among the 8 LCD data lines. Use POT2 for contrast adjustment.

Pin no RM1	Description
1	Ground
2	+5V
3	LCD contrast
4	RS
5,7,8,9,10	NC
6	En

11 to 14	Data 4 to 7
15	Back light anode
16	Back light cathode



9.3 Relay buzzer and Motors controlblock:

It is a high Current applications block where a stepper motor, a Dc motor and a relay are interfaced through the high current driver ULN2803 (U6). These lines will have high current (max 300 mA) with low voltage level of 0.7V.

The Stepper motor can be interfaced to the board by connecting it to the Power Mate PM1. The direction of the rotation can be changed through software. The DC Motor can also beinterfacedtotheboardbyconnectingittotheReliamateRM4.Thedirectionoftherotation can be changed throughsoftware.

The Relay RLY2 is switched between ON and OFF state. The LED L2 will toggle for every relay switch over. The contact of NO & NC of the relay can be checked at the MKDSN connector CN5 pins 1 & 2 using a Digital Multi meter – these contacts can be connected to externaldevices.

By connecting 26 pin FRC cable from CN7 to CN8 this block can be interfaced and the port lines details are given in the table.

CN8 Pin #	**Description**
1, 2, 23, 24	Buffered from U6 used for stepper motor control
3	Buffered from U6 & connected to RLY2 coil. coil other end is connected to +5V
5	Connected to pin 1 of U6; corresponding output of U6 is taken to NO and NC contacts of relay RLY1
4	One end of coil of relay RLY1
6	Controls the buzzer

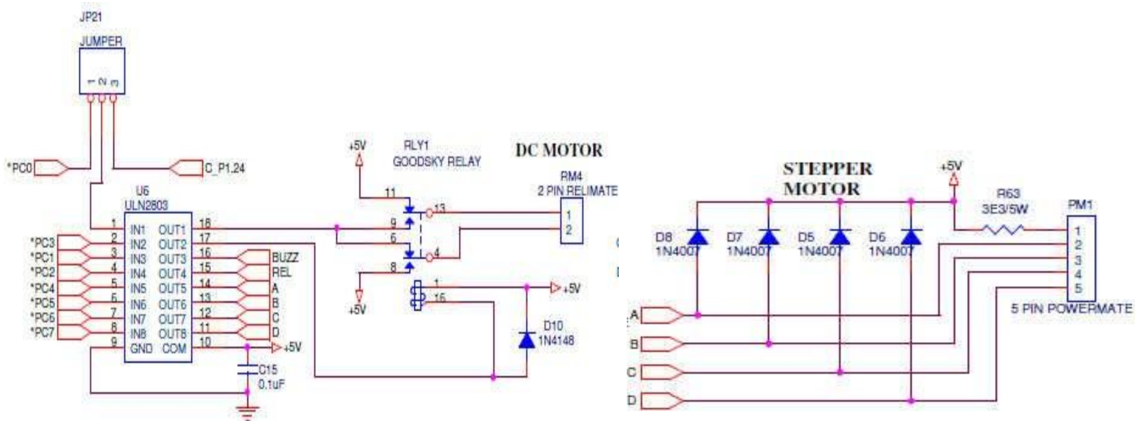
CN5 – 2 pin MKDSN connector provides the RLY2 relay output for external use.
Pin 1 – COM of the relay.
pin 2 – NO of the relay.

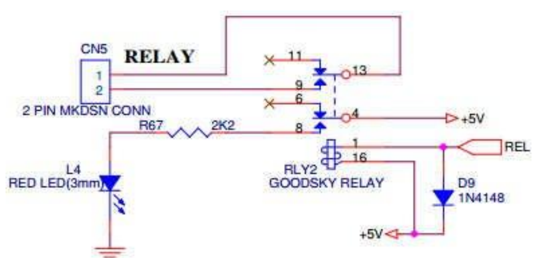
RM4 – it's a 2 pin straight male reliamate. COM pins of relay RLY1 are terminated here. It is used to run and direction control of DC motor.

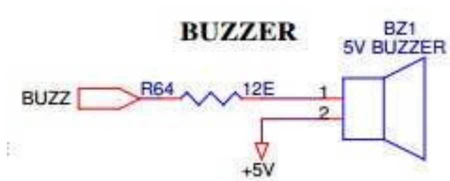
PM1 – it's a 5 pin straight male power mate.

Pin no	Description
1	+5v supply
2	Phase A
3	Phase B
4	Phase C
5	Phase D

Pin 2 to 5 are phase A to D output for the stepper motor respectively.

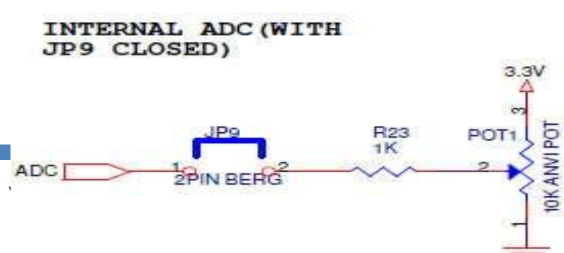






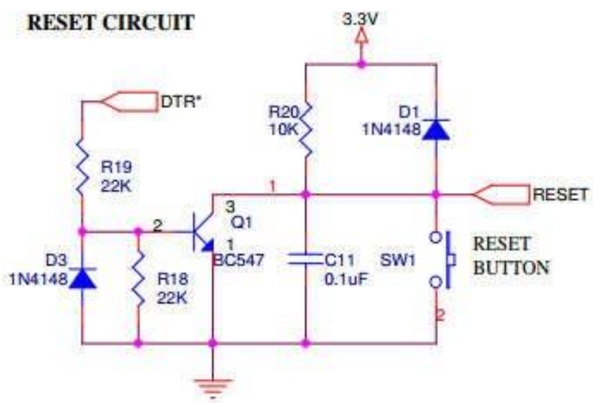
9.4 Internal ADCinterface:

On board there is one interface for internal ADC. AD0.5 (pin P1.31) of controller is used to convert the analog input voltage varied using POT1 to digital value. A 0 to 3.3V is the input voltagerange.000toFFFistheconverteddigitalvoltagerangehere.ShortJP9(1,2)tousethis interface.



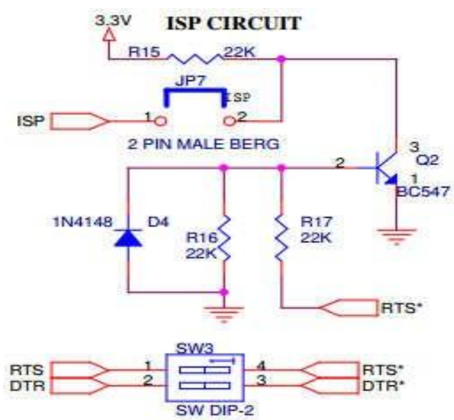
9.5 Reset Circuit:

It's an active high input to the controller. A low level on this pin causes the controller to be in reset mode. Switch-SW1 to be used for the purpose of resetting the controller.



9.6 ISP Circuit:

A LOW level after reset at pin P2.10 is considered an external hardware request to start the ISP command handler. Assuming that power supply pins are on their nominal levels when the rising edge on RESET pin is generated, it may take up to 3 ms before P2.10 is sampled and the decision on whether to continue with user code or ISP handler is made.



During programming the controller using Flash magic software, jumper – JP7 needs to be shorted. This jumper connects the ISP line P2.10 to ground level during the Flash magic attempt to program theflash.

NOTE: For more details RTS and DTR signals you must refer the ISP circuit and RESET circuit.

ProgrammingMode:

RunMode:

SW3 – is to isolate the hand shaking signals from board signals (RTS, DTR) and connector. Keep this switch ON before programming the controller flash memory with the application code. Keep it open to Run the loaded program and reset. Especially if UART0 is using for any communication purpose, user must keep these switch open to execute UART0 relatedcode.

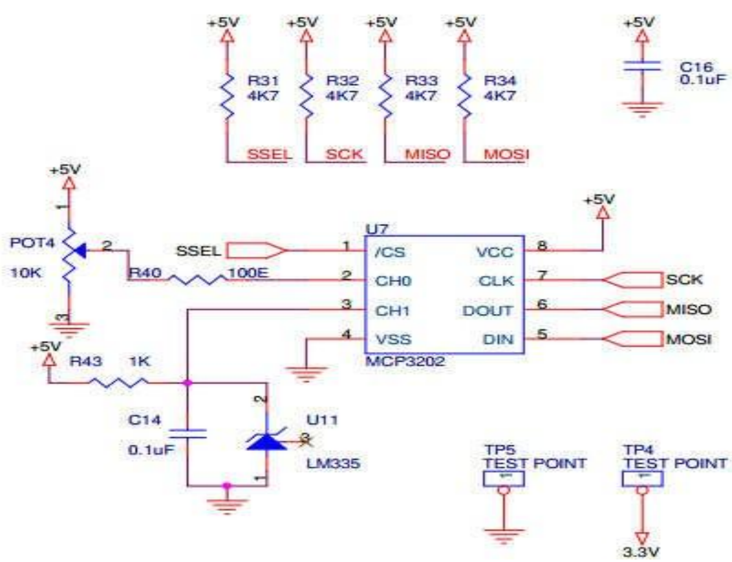
RTS – Controls the ISP line of the controllerP2.10

DTR – Used to interface controllerreset.

9.7 Serial peripheralInterface:

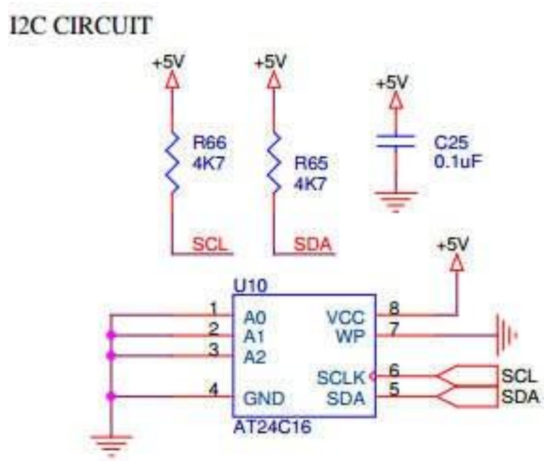
This block has a 2 channel SPI ADC. Channel 0 input is POT4 and channel 1 input is Temperature sensor LM335. While interfacing this block do not connect 26 pin FRC cable from CN7 to CN8 and short the Pins 2&3 at the jumpers JP14, JP15, JP16, JP17. Port lines used are P0.15 – SCK, P0.16 – SSEL, P0.17 – MISO, P0.18 –MOSI.

SPI CIRCUIT



9.8 I2C Interface:

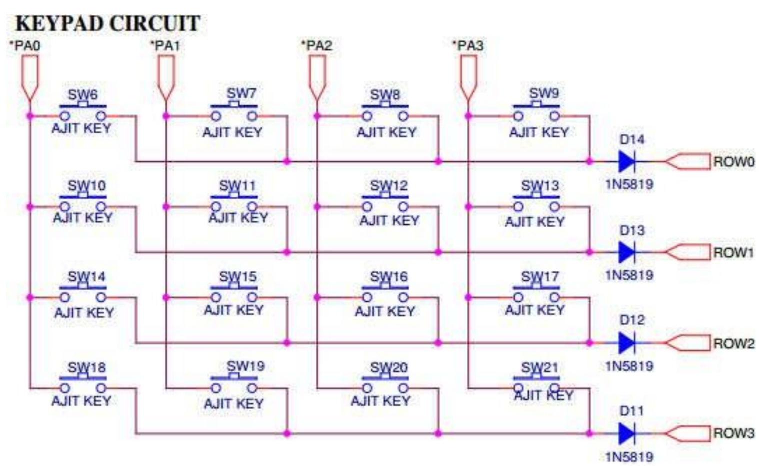
This block has I2C NVROM IC. Can be communicated using I2C1. To interface this block short pin2&3atthejumpersJP18andJP19.Donotconnect26pinFRCcablefromCN7 toCN8.Port lines used are P0.19 – SDA1, P0.20 –SCL1.



9.9 4×4 key matrixInterface:

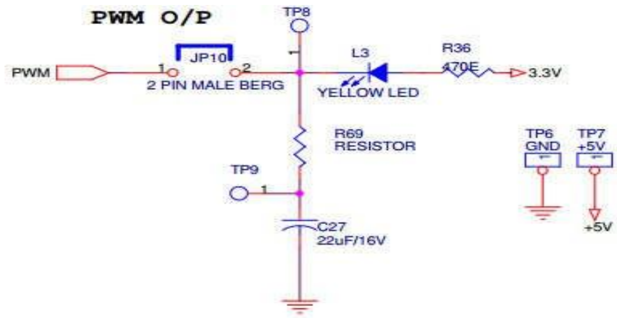
The switches SW14 to SW29 are organized as 4 rows X 4 columns matrix. One end of all the switches are configured as columns. The other end of the matrix configured as rows. A row line will be always an output from the controller. Column lines are inputs. A low level sent from the row will appear at column end if the switch ispressed.

Connect 26 pin FRC cable from CN7 to CN8 for interfacing this block with controller.



9.10 PWM Interface:

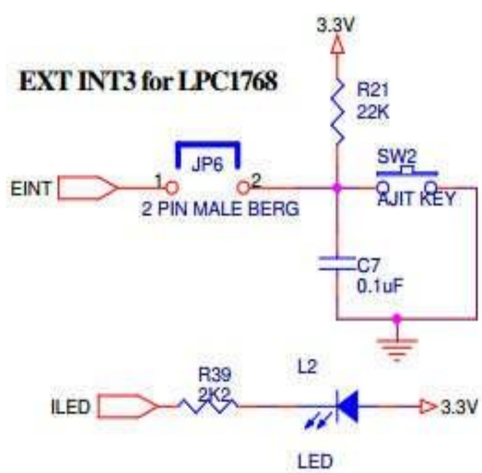
A PWM output from the controller can be observed as an intensity variation of the LED L3. Pulses on the CRO can be observed at TP8. Short JP10 to interface this block. Port line P3.25.



9.11 External interrupts:

An external interrupt EINT3 to the controller is generated using the switch SW2. Pressing the switch generates edge triggered interrupt to the controller.

Short JP6 to use EINT3. Port lines EINT3 – P2.13.



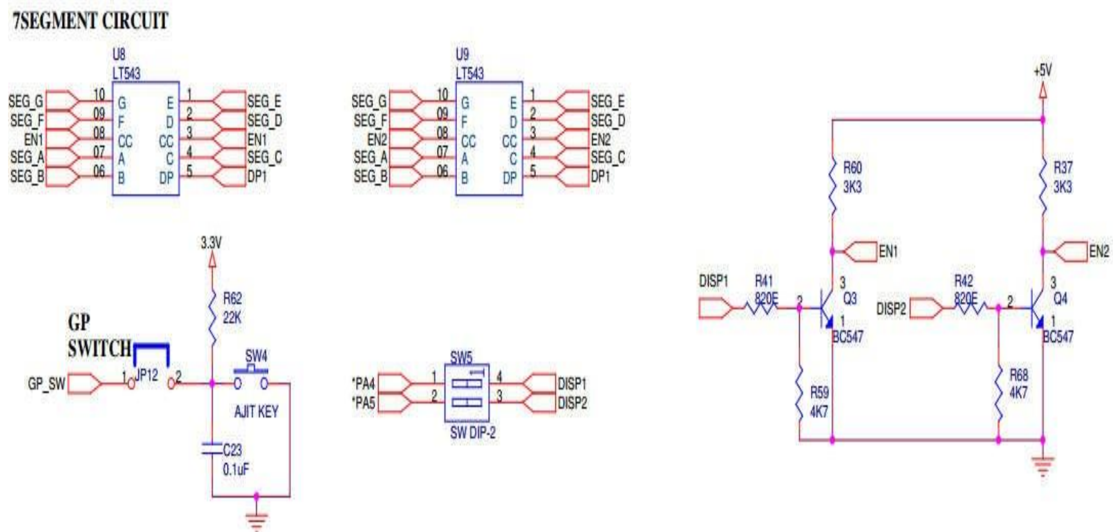
9.12 Seven segment display interface:

There are two multiplexed 7-segment display units (**U8, U9**) on the board. Each display has 8-inputs SEG_A (Pin-7), SEG_B (Pin-6), SEG_C (Pin-4), SEG_D (Pin-2), SEG_E (Pin-1), SEG_F (Pin-9), SEG_G (Pin-10) and SEG_H (Pin-5) and the remaining pins pin-3 & pin-8 are Common Cathode CC. These segments are common cathode type hence active high devices.

At power on enable of all the segments are pulled up. A two bits input through SW5 is used for multiplexing operation. A high level on these lines enables the corresponding display. Connection of these enable lines are shown below.

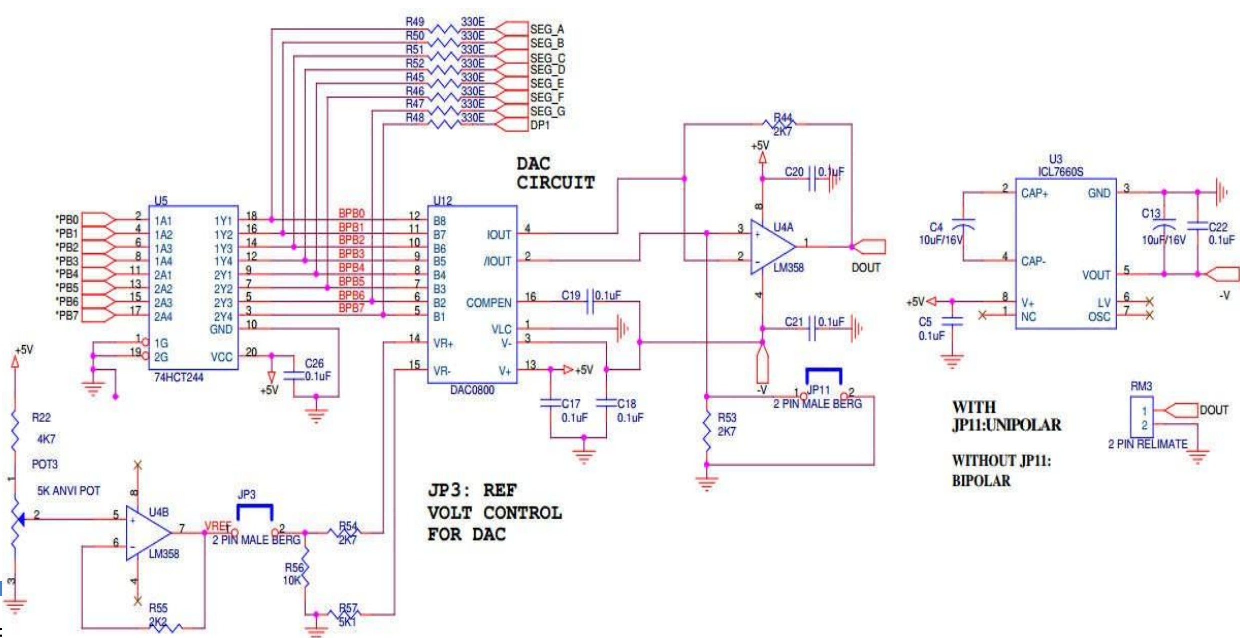
CN8 pin 17 → SW5 pin 1 → EN1 (U8)
CN8 pin 18 → SW5 pin 2 → EN2 (U9)
Data lines:
CN8 pin 13 → SEG A

CN8 pin 14 → SEG B
CN8 pin 11 → SEG C
CN8 pin 12 → SEG D
CN8 pin 9 → SEG E
CN8 pin 10 → SEG F
CN8 pin 7 → SEG G
CN8 pin 8 → Decimal points



9.13 ExternalDAC:

DAC0800 is used to convert the digital data into analog signals. Digital data from specified port lines is given to DAC input. Amplitude of output waveform can be varied by varying **POT3** (5K) that is by varying the reference voltage of DAC0800. JP11 (1,2) closed output is uni-polar and JP11(1,2) open output is bi-polar. Port lines used for DAC are P0.4 – P0.11. Connect FRC cable from CN7 to CN8 to use this block.



9.14 Spareconnector:

Few unused lines of the board are terminated at a connector – CN9. It's a 30 pin 15×2 male straight berg. These lines can be used for any external interface if required. A pin descriptionof this connector is given below.

PIN #	Description	PIN #	Description
1	P0.27/SDA0/USB_SDA	2	P0.28/SCL0/USB_SCL
3	P2.12//EINT2/I2STX_WS	4	P1.18/USB_UP_LED/PWM1.1/CAP1.0
5	P1.19/MCOA0/USB_PPWR/CAP1.1	6	P1.24/MCI2/PWM1.5/MOSI0
7	P1.25/MCOA1/MAT1.1	8	P1.27/CLKOUT/USB_OVRCR/CAP0.1
9	P1.28/MCOA2/PCAP1.0/MAT0.0	10	P1.29/MCOB2/PCAP1.1/MAT0.1
11	P0.0/RD1/TXD3/SDA1	12	P0.1/TD1/RXD3/SCL1
13	P4.28/RX_MCLK/MAT2.0/TXD3	14	P4.29/TX_MCLK/MAT2.1/RXD3
15	P1.0/ENET_TXD0	16	P1.1/ENET_TXD1
17	P1.4/ENET_TX_EN	18	P1.8/ENET_CRS
19	P1.9/ENET_RXD0	20	P1.10/ENET_RXD1
21	P1.14/ENET_RX_ER	22	P1.15/ENET_REF_CLK
23	P1.16/ENET_MDC	24	P1.17/ENET_MDIO
25	P0.29/USB_D+	26	P0.30/USB_D
27	RTCX1	28	RTCX2
29	VBAT	30	Ground

10. DEMO PROGRAMS IN KEIL UVISION4IDE

For all the SYLLABUS or demo programs make sure that the corresponding settings have to be made:

- Both Switches of SW3 should be in ON position for ISPprogramming.
- Short JP7 for ISPprogramming.
- Short JP5 to connect +3.3v into thecircuit.
- Short JP4 to connect +5v to InterfaceBoard.
- Connect the 26 core FRC cable **CN7** to **CN8** to connect to **On-boardinterfaces**.
- Connect **CN7** for **ExternalNIFC's**.

DEMO PROGRAMS:

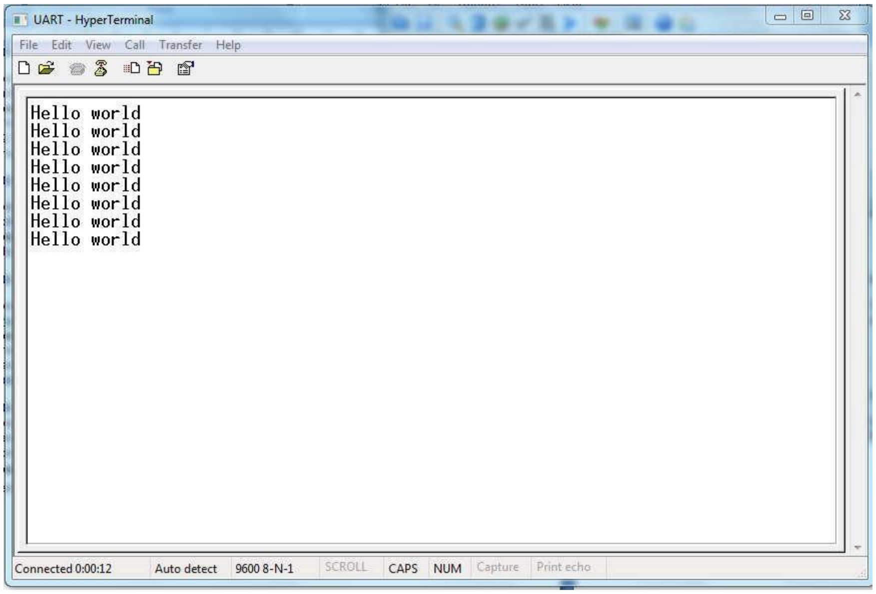
NOTE: Do not short any Jumpers JP14, JP15, JP16, JP17, JP18 and JP19 when 26 pin FRC cable is connected from CN7 to CN8. While using SPI and I2C do not connect 26 pin FRC cable from CN7 to CN8.

10.1 Test UART0test:

Download the file "UART0_test.hex" to trainer using Flash Magic 6.01 version.
Switch off SW3, Un-short JP7. Press the reset switch (SW1) to run the program.

Result:

Open the hyper terminal, the Constant string "**Hello World"** will be displayed on the hyper terminal.



10.2 Test DC Motor:

A) DC Motor Speed control using on chipPWM:

Download the file "dcm_speed_control.hex" to trainer using Flash Magic 6.01 version.
Connect the Female Reliamate of the DC motor to the male Reliamate RM4 present on the board. Short JP21/2&3 ,Switch off SW3, Un-short JP7. Press the reset switch (SW1) to run the program.

Result:

Observe the rotation of the dc motor (Controlled by On chip PWM) Varies from slow speed to higher speed and Vice Versa. This rotation of the motor will be continuously in loop.

B) DC Motor directionControl:

Download the file "dcm_direction.hex" to trainer using Flash Magic 6.01 version.
Connect the Female Reliamate of the DC motor to the male Reliamate RM4 present on the board. Short JP21/2&3 and Connect the 26pin FRC between CN7 and CN8. Switch off SW3, Un-short JP7. Press the reset switch (SW1) to run the program.

Result:

Observe the Clockwise and Anti-Clockwise rotation of the dc motor with respect On/Off of Relay RLY1. This rotation of the motor will be continuously in loop.

10.3 Test Stepper Motor

Download the file "steppermtr.hex" to trainer using Flash Magic 6.01 version.
Connect the Female Power mate of the stepper motor to the male Power mate PM1 present on the board. Jumper JP13 (1, 2) should be shorted and all the other jumpers should be removed. Switch off SW3, Un-short JP7. Press the reset switch (SW1) to run the program.

Result:

Observe the stepper motor rotation it should rotate **Clockwise** &**Anti Clockwise** direction. This rotation of the motor will be continuously in loop.

10.4 Test Internal ADC:

Download the file "Int_ADC.hex" to trainer using Flash Magic 6.01 version.
Jumper JP9 should be shorted and all the other jumpers should be removed. Switch off SW3, Un-short JP7. Press the reset switch (SW1) to run the program.

Result:

This routine is used to study the internal Feature of the LPC1768 Microcontroller. Vary the POT1 (10K) and observe the corresponding analog (0-3.30V) & digital value (0-fff) on LCD.

10.5 TestDAC0800:

A) SineWave:

Download the file "SINE.hex" to trainer using Flash Magic 6.01 version.
Jumper JP3 should be shorted. Jumper JP11 should be open for **bipolar** mode. Jumper JP11 should be short for **unipolar** mode and all the other jumpers should be removed. Switch off SW3, Un-short JP7. Press the reset switch (SW1) to run the program.

Result:

Observe the Analog output waveform at the Pin-1 of RM3 using Oscilloscope (CRO) with respect to GND pin-2 of RM3.

NOTE: POT3 is provided to control the Reference voltage for DAC output (Vref).User will get maximum 2.5V peak to peak for uni-polar and 5V peak to peak for Bipolar.

B) SquareWave:

Download the file "Square.hex" to trainer using Flash Magic 6.01 version.
Jumper setting are same as sine wave.

Result:

Observe the Analog output waveform at the Pin-1 of RM3 using Oscilloscope (CRO) with respect to GND pin-2 of RM3.

NOTE: POT3 is provided to control the Reference voltage for DAC output (Vref).User will get maximum 2.5V peak to peak for uni-polar and 5V peak to peak for Bipolar.

C) Triangle Wave:

Download the file "Triangle.hex" to trainer using Flash Magic 6.01 version.
Jumper setting are same as sine wave.

Result:

Observe the Analog output waveform at the Pin-1 of RM3 using Oscilloscope (CRO) with respect to GND pin-2 of RM3.

NOTE: POT3 is provided to control the Reference voltage for DAC output (Vref).User will get maximum 2.5V peak to peak for uni-polar and 5V peak to peak for Bipolar.

10.6 Test Keypad (4X4Matrix):

Download the file "KEY_LCD.hex" to trainer using Flash Magic 6.01 version. Switch off SW3, Un-short JP7. Press the reset switch (SW1) to run the program.

Result:

Press the keys SW6 to SW21 and the Corresponding outputs '0 to F' will be displayed on the LCD.

10.7 Test Pulse Width Modulation(PWM):

Downloadthefile"PWM.hex"totrainerusingFlashMagic6.01version.
Jumper JP10 should be shorted all the other jumpers should be removed. Switch off SW3, Un-short JP7. Press the reset switch (SW1) to run the program.

Result:

Observe the output on CRO at TP8 and also LED L3 (intensity of LED will vary).

10.9 Test ExternalInterrupt:

Download the file "EXINT.hex" to trainer using Flash Magic 6.01 version.
Jumper JP6 should be shorted, all the other jumpers should be removed. Switch off SW3, Un-short JP7. Press the reset switch (SW1) to run the program.

Result:

When switch SW2 pressed the port line goes low & the external interrupt occurs at port line P2.13. To show the external interrupt has been occurred LED L2 has been used (Toggle for each Press).

10.10 TEST 7 SegmentDisplay:

Download the file "Seven_seg.hex" to trainer using Flash Magic 6.01 version.
Both pins of SW5 should be in ON position. Switch off SW3, Un-short JP7. Press the reset switch (SW1) to run the program.

Result:

Observe display changing from 00 to FF. This process is continuously in loop
Control RELAY\BUZZER\LED ThroughSwitch:

Download the file "RELAY.hex" to trainer using Flash Magic 6.01 version.
Short jumper JP12.

Result:

Press SW4 on the buzzer section, see that Relay RLY2, Led L4 and Buzzer BZ1 are On and when user releases the push button the Relay RLY2, L4 and Buzzer should be in Off condition. Relay **Common** and **NO** are brought out to CN5 connector.

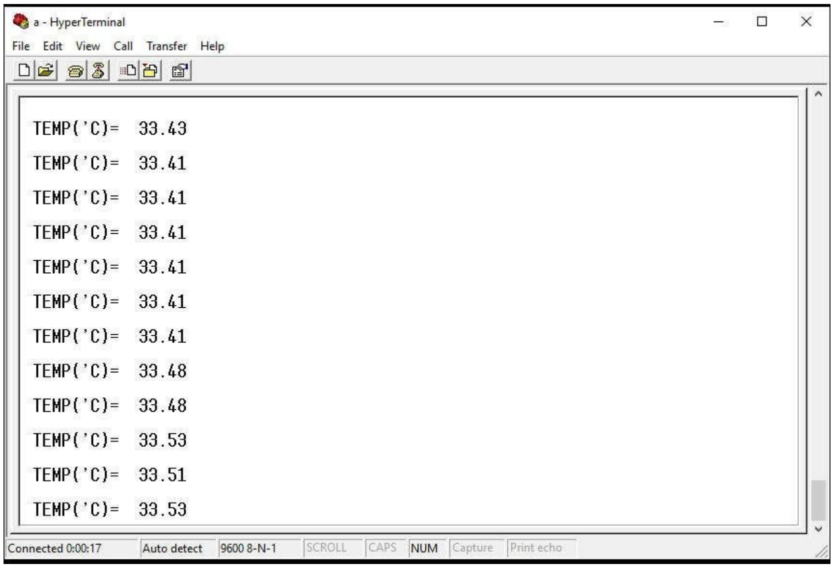
10.11 SPI TemperatureSensor

Download the file "SENSOR.hex" to trainer using Flash Magic 6.01 version.
Remove inter connected cable CN7 and CN8. Short JP14 JP15 JP16 JP17/2&3. Do the serial communications set up with hyper terminal with baud rate of 9600. Switch off SW3, Un-short JP7. Press the reset switch (SW1) to run the program.

NOTE: While doing this experiment user must measure the voltage of the Power Supply. That measured voltage will be considered as your Vref for LM335 interface. In software you must alter the defined value of Vref (for more details refer the description of the program).

Result:

Temperature value will display on hyper terminal.



11. DEMO ASSEMBLYPROGRAMS

11.1 ALP to multiply two 16bit binarynumbers.

Download the file "16_bit_mul/mul.hex" to trainer using Flash Magic 6.01 version.
Here two 16 bit Numbers used for the multiplication are **0x706F and 0x7161.User can change the inputs.** Switch off SW3, Un-short JP7. Press the reset switch (SW1) to run the program.
Result:
Multiplied result is displayed on the LCD.

11.2 ALP to find the sum of first 10 integernumbers.

Download the file "sum_of_1_to_10/sum.hex" to trainer using Flash Magic 6.01 version.
Here **first 10 natural numbers are 01 to 10 so sum will be 55.** Switch off SW3, Un-short JP7. Press the reset switch (SW1) to run the program.
Result:
Added result is displayed on the LCD.

12. TROUBLESHOOTING

1. **PowerSupply:**
   - ✓ Short jumper **JP5 to** connect**+3.3V.**
2. **In System Programming / Download(ISP):**
   - ✓ **In System Programming** or download could not be established properly then check out whether the following conditions aremet
   - ✓ The cable used for communication should be **USB-to-SERIALcable**.
   - ✓ Dipswitch ON 1 & 2 switches of the SW3 **DTR** and **RTS** for serial communication.
   - ✓ IC MAX232 is in good condition.
3. **JTAG Programming /Download:**
   - ✓ Short jumper **JP1 (RTCK)** forcommunication.
   - ✓ Dip Switch ON 1 &2 pins of the SW3 **DTR** and **RTS** for serial communication.
4. **GeneralProblems:**
   - ✓ Make Proper Jumper Connections as mentioned in HardwareDetails**.**
   - ✓ Make Proper Connections as mentioned in Demo Programs Setup.

13. QUICKREFERENCE

PORT LINE DETAILS – Used for on board interfaces

SL No.	PROGRAM NAME	PORT LINE
1	LCD	P2.4 - P2.9
2	7SEG DISPLAY	P0.4 - P0.11 & P0.19 - P0.22
3	STEPPER MOTOR	P2.0 – P2.3
4	DC MOTOR	P1.24& P0.26
5	RELAY	P0.25
6	BUZZER	P0.24
7	EXT-INTERRUPT0	P2.13
8	DAC0800	P0.4 – P0.11
9	PWM	P3.25
10	Internal ADC	P1.31
11	4X4 KEY MATRIX	P1.16 – P1.23
12	SPI	P0.17,P0.18,P0.19,P0.20

```
/**********************************************************
 * EXP1 : UART0 test Demonstration(To display HELLO WORLD)

 --------------------------------------------------------------------------------
 * Controller : LPC1768
* Description        : In this example fixed string "HELLO WORLD" is displayed
 * on the Hyperterminal using Uart0 Feature.
 --------------------------------------------------------------------------------
*****************************************************************/

#include<LPC17xx.h>

void delay(unsigned int r1);
void UART0_Init(void);
void UART0_IRQHandler(void);

unsigned long int r=0, i = 0;
unsigned char tx0_flag=0;
unsigned char *ptr, arr[] = "Hello world\r";

int main(void)
{
	SystemInit();
	SystemCoreClockUpdate();
	UART0_Init();
	while(1)
	{
		ptr = arr;
		while ( *ptr != '\0'){
			LPC_UART0->THR = *ptr++;
			while(tx0_flag == 0x00);
			tx0_flag = 0x00;
			for (i=0; i<200; i++);
		}
		for (i=0; i<500; i++)
		delay(625);
	}
}

void UART0_Init(void)
{
	LPC_SC->PCONP |= 0x00000008;			//UART0 peripheral enable
	LPC_PINCON->PINSEL0 |= 0x00000050;
	LPC_UART0->LCR = 0x00000083;			//enable divisor latch, parity
disable, 1 stop bit, 8bit word length
	LPC_UART0->DLM = 0X00;
	LPC_UART0->DLL = 0x13;				//select baud rate 9600 bps
```

```
        LPC_UART0->LCR = 0X00000003;
        LPC_UART0->FCR = 0x07;
        LPC_UART0->IER = 0X03;              //select Transmit and receive interrupt

        NVIC_EnableIRQ(UART0_IRQn);                         //Assigning channel
}

void UART0_IRQHandler(void)
{
        unsigned long Int_Stat;
        Int_Stat = LPC_UART0->IIR;                          //reading the data from
interrupt identification register
        Int_Stat = Int_Stat & 0x06;                         //masking other than txmit
int & rcve data indicator

        if((Int_Stat & 0x02)== 0x02)                //transmit interrupt
                tx0_flag = 0xff;
}

void delay(unsigned int r1)
{
        for(r=0;r<r1;r++);
}
```

```
/*******************************************************************
 * EXP2A:DC MOTOR CONTROL USING ON CHIP PWM

  ---------------------------------------------------------------------------
 * Controller : LPC1768
  * Description       : Port line P1.24 used for the PWM feature.When T0TC matches
 * the MR0 counts interrupt is generated
 * and Duty cycle will be changed.Depends upon the Duty cycle Motor speed is also
changes.
 * PWM 1.5 is used. Match register 0 is used for count purpose. PWM 1
 * match register 5 is increamented or decreamented at each interrupted.
 ---------------------------------------------------------------------------

*******************************************************************/

#include <lpc17xx.h>

void pwm_init(void);
void PWM1_IRQHandler(void);

unsigned long int i,j;
unsigned char flag,flag1,flag2;

int main(void)
{
	SystemInit();
	SystemCoreClockUpdate();
	pwm_init();

	while(1)
	{
		for(i=0;i<=1000;i++);			// delay

   }//end of while
}//end of main

void pwm_init(void)
{
	LPC_SC->PCONP |= (1<<6);			//PWM1 is powered
	LPC_PINCON->PINSEL3 |= 0x00020000; //pwm1.5 is selected for the pin P1.24

	LPC_PWM1->PR  = 0x00000000;		//Count frequency : Fpclk
	LPC_PWM1->PCR = 0x0002000;   //select PWM5 single edge & PWM5 o/p is enb
	LPC_PWM1->MCR = 0x00000003;		//Reset and interrupt on PWMMR0
	LPC_PWM1->MR0 = 30000;			//setup match register 0 count
	LPC_PWM1->MR5 = 0x00000100;		//setup match register MR5
	LPC_PWM1->LER = 0x000000FF;		//enable shadow copy register
```

```
        LPC_PWM1->TCR = 0x00000002;       //RESET COUNTER AND PRESCALER
        LPC_PWM1->TCR = 0x00000009;       //enable PWM and counter

        NVIC_EnableIRQ(PWM1_IRQn);
        return;
}

void PWM1_IRQHandler(void)
{
        LPC_PWM1->IR = 0xff;                          //clear the interrupts

        if(flag == 0x00)
    {

                LPC_PWM1->MR5 += 100;
                LPC_PWM1->LER = 0x000000FF;


                                if(LPC_PWM1->MR5 >= 37000)
                                        {
                                flag1 = 0xff;
                                flag = 0xff;
                                LPC_PWM1->LER = 0x000000fF;
                                        }
         for(i=0;i<8000;i++);
        }

    else if(flag1 == 0xff)
    {

                LPC_PWM1->MR5 -= 100;
                LPC_PWM1->LER = 0x000000fF;

                if(LPC_PWM1->MR5 <= 0x500)
                {
                        flag  = 0x00;
                        flag1 = 0x00;
                        LPC_PWM1->LER = 0X000000fF;
                }
         for(i=0;i<8000;i++);
        }
}
```

```
/*******************************************************************
 * EXP2B.DCM Direction Control
  *----------------------------------------------------------------------------
 * Controller : LPC1768

 * Description       :Direction of the DCM is cotrolled in this software by alternatively inter-
 * changing the supply with the help Relay.   Port lines: P1.24 and P0.26.
 * Port line P1.24 used for the PWM feature.When T0TC matches
 * the MR0 counts interrupt is generated
 * and Duty cycle will be changed.Depends upon the Duty cycle Motor speed is also changes.
 * PWM 1.5 is used. Match register 0 is used for count purpose. PWM 1
 * match register 5 is increamented or decreamented at each interrupted.
 ---------------------------------------------------------------------------

*******************************************************************/

#include <LPC17xx.H>

void Clock_Wise(void);
void AClock_Wise(void);

unsigned long i;

int main(void)
{
	SystemInit();
	LPC_PINCON->PINSEL1 &= 0xFFCFFFFF;	//P0.26 GPIO, P0.26 controls dir
	LPC_PINCON->PINSEL3 &= 0xFFFFCFFF;	//P1.24 GPIO
	LPC_GPIO0->FIODIR |= 0x04000000; //P0.26 output
	LPC_GPIO1->FIODIR |= 0x01000000; //P1.24 output

	while(1)
	{
		Clock_Wise();
		for(i=0;i<200000;i++);
		AClock_Wise();
		for(i=0;i<200000;i++);

	}		//end while(1)
}			//end main

void Clock_Wise(void)
{
	LPC_GPIO1->FIOCLR = 0x01000000;		//P0.23 Kept low to off DCM
	for(i=0;i<10000;i++);		//delay to componsate inertia
```

```
        LPC_GPIO0->FIOSET = 0x04000000;          //coil is on
        LPC_GPIO1->FIOSET = 0x01000000;          //motor in on
        return;
}                                                //end void Clock_Wise(void)

void AClock_Wise(void)
{
        LPC_GPIO1->FIOCLR = 0x01000000;          //P0.23 Kept low to off DCM
        for(i=0;i<10000;i++);                    //delay to componsate inertia
        LPC_GPIO0->FIOCLR = 0x04000000;          //coil is off
        LPC_GPIO1->FIOSET = 0x01000000;          //Motor is on
        return;
}                                                //end void AClock_Wise(void)
```

```
/*********************************************************************
 * EXP3.Stepper motor Direction control
 *------------------------------------------------------------------------------
 * Controller : LPC1768
  * Description:A stepper motor direction is controlled by shifting the voltage across
 * the coils. Port lines : P2.0 to P2.3.
 *------------------------------------------------------------------------------
*********************************************************************/

#include <LPC17xx.H>

void clock_wise(void);
void anti_clock_wise(void);
unsigned long int var1,var2;
unsigned int i=0,j=0,k=0;

int main(void)
{
	SystemInit();
	SystemCoreClockUpdate();

	LPC_PINCON->PINSEL4 = 0x00000000;	//P2.0 to P2.3 GPIO
	LPC_GPIO2->FIODIR = 0x0000000F;		//P2.0 to P2.3 output

	while(1)
	{
		for(j=0;j<50;j++)	//50 times in Clock wise Rotation
			clock_wise();

		for(k=0;k<65000;k++);		//Delay to show  anti_clock Rotation

		for(j=0;j<50;j++)		//50 times in  Anti Clock wise Rotation
			anti_clock_wise();

		for(k=0;k<65000;k++);		//Delay to show clock Rotation
	}						//End of while(1)
}							//End of main

void clock_wise(void)
{
	var1 = 0x00000001;				//For Clockwise
   for(i=0;i<=3;i++)			//for A B C D Stepping
	{
	  LPC_GPIO2->FIOCLR =  0X0000000F;
	  LPC_GPIO2->FIOSET =  var1;
		var1 = var1<<1;				//For Clockwise
      for(k=0;k<15000;k++);			//for step speed variation
```

```
   }
}

void anti_clock_wise(void)
{
       var1 = 0x0000008;                                 //For Anticlockwise
   for(i=0;i<=3;i++)                              //for A B C D Stepping
   {

          LPC_GPIO2->FIOCLR =  0X0000000F;
              LPC_GPIO2->FIOSET =  var1;
              var1 = var1>>1;                            //For Anticlockwise
      for(k=0;k<15000;k++);                       //for step speed variation
   }
}
```

```
/*****************************************************************
 * Alphanumeric LCD

 *------------------------------------------------------------------
 * Controller : LPC1768
* Port lines used: Data1 to Data4 - P0.23 to P0.26
 * En - P0.28. RS - P0.27, RW - Ground
 * Connection : CND to CNAB

*****************************************************************/

 #include <lpc17xx.h>

 #include "AN_LCD.h"

 unsigned long int temp1=0, temp2=0 ;


 //lcd initialization
 void lcd_init()
 {
        /* Ports initialized as GPIO */
   LPC_PINCON->PINSEL4 &= 0xFFF000FF;  //P2.4 to P2.9

        /* Setting the directions as output */
   LPC_GPIO2->FIODIR |= DT_CTRL;
        LPC_GPIO2->FIODIR |= RS_CTRL;
        LPC_GPIO2->FIODIR |= EN_CTRL;

   clear_ports();
        delay_lcd(3200);

        temp2 = (0x30<<2);
        wr_cn();
        delay_lcd(30000);

        temp2 = (0x30<<2);
        wr_cn();
        delay_lcd(30000);

        temp2 = (0x30<<2);
        wr_cn();
        delay_lcd(30000);

        temp2 = (0x20<<2);
        wr_cn();
        delay_lcd(30000);
```

```
        temp1 = 0x28;
        lcd_com();
        delay_lcd(30000);

        temp1 = 0x0c;
        lcd_com();
        delay_lcd(800);

        temp1 = 0x06;
        lcd_com();
        delay_lcd(800);

        temp1 = 0x01;
        lcd_com();
        delay_lcd(10000);

        temp1 = 0x80;
        lcd_com();
        delay_lcd(800);
    return;
}

void lcd_com(void)
{
        temp2 = temp1 & 0xf0;//move data (26-8+1) times : 26 - HN place, 4 - Bits
        temp2 = temp2 << 2;//data lines from 23 to 26
        wr_cn();
        temp2 = temp1 & 0x0f; //26-4+1
        temp2 = temp2 << 6;
        wr_cn();
        delay_lcd(1000);
    return;
}

// command nibble o/p routine
void wr_cn(void)                        //write command reg
{
        clear_ports();
        LPC_GPIO2->FIOPIN = temp2;          // Assign the value to the data lines
    LPC_GPIO2->FIOCLR = RS_CTRL;            // clear bit RS
        LPC_GPIO2->FIOSET = EN_CTRL;        // EN=1
        delay_lcd(25);
        LPC_GPIO2->FIOCLR = EN_CTRL;                            // EN =0
    return;

}
```

```
// data o/p routine which also outputs high nibble first
// and lower nibble next
void lcd_data(void)
{
  temp2 = temp1 & 0xf0;
  temp2 = temp2 << 2;
  wr_dn();
  temp2= temp1 & 0x0f;
  temp2= temp2 << 6;
  wr_dn();
  delay_lcd(1000);
  return;
}

// data nibble o/p routine
void wr_dn(void)
{
      clear_ports();

      LPC_GPIO2->FIOPIN = temp2;          // Assign the value to the data lines
      LPC_GPIO2->FIOSET = RS_CTRL;        // set bit  RS
      LPC_GPIO2->FIOSET = EN_CTRL;        // EN=1
      delay_lcd(25);
      LPC_GPIO2->FIOCLR = EN_CTRL;        // EN =0
  return;
}

void delay_lcd(unsigned int r1)
{
      unsigned int r;
      for(r=0;r<r1;r++);
  return;
}

void clr_disp(void)
{
      temp1 = 0x01;
      lcd_com();
      delay_lcd(10000);
  return;
}
void clear_ports(void)
{
  /* Clearing the lines at power on */
      LPC_GPIO2->FIOCLR = DT_CTRL; //Clearing data lines
      LPC_GPIO2->FIOCLR = RS_CTRL;  //Clearing RS line
```

```
        LPC_GPIO2->FIOCLR = EN_CTRL; //Clearing Enable line

    return;
 }

 void lcd_puts(unsigned char *buf1)
 {
    unsigned int i=0;

    while(buf1[i]!='\0')
    {
        temp1 = buf1[i];
         lcd_data();
                i++;
        if(i==16)
                {
         temp1 = 0xc0;
                        lcd_com();
                }

       }
    return;
 }
```

```
// program to generate square wave with DAC interface
/*******************************************
 * EXP5:External DAC interface (Square Wave)

 *-----------------------------------------------------------------
 * Controller : LPC1768

 * Description         : This example explains about how Sqaure Wave is generated.P0.4
to P0.11 are used to get the Digital values.


       0xff  ________
          |                    |                              |
          |                    |                              |
          |                    |                              |
                                     |                        |
              |
                    0x00 |                         |_________|


*****************************************************************
******/
#include <LPC17xx.H>

void delay(void);

int main ()
{
             LPC_PINCON->PINSEL0 &= 0xFF0000FF ;
       // Configure P0.4 to P0.11 as GPIO
   LPC_GPIO0->FIODIR  |= 0x00000FF0 ;

       while(1)
   {
       LPC_GPIO0->FIOPIN  = 0x00000FF0 ;
      delay();
      LPC_GPIO0->FIOCLR  = 0x00000FF0 ;
      delay();
   }
}

void delay(void)
{
       unsigned int i=0;
       for(i=0;i<=9500;i++);
}
```

```
// program to generate Triangular wave with DAC interface
/*****************************************************************
 * EXP5:External DAC interface (Triangle Wave)
 *-----------------------------------------------------------------
 * Controller : LPC1768
* Description       : This example explains about how Triangular Wave is
generated.P0.4 to P0.11 are used to get the Digital values.

      0xff
             /\        /\
            /  \      /  \
           /    \    /    \
          /      \  /      \
                                              /       \  /       \
                              0x00  /                    \/        \

 *****************************************************************/
#include <LPC17xx.H>

int main ()
{
        unsigned long int temp=0x00000000;
        unsigned int i=0;

  LPC_PINCON->PINSEL0 &= 0xFF0000FF ;                                    //
Configure P0.4 to P0.11 as GPIO
        LPC_GPIO0->FIODIR  |= 0x00000FF0 ;

    while(1)
    {
        //output 0 to FE
       for(i=0;i!=0xFF;i++)
       {
        temp=i;
        temp = temp << 4;
        LPC_GPIO0->FIOPIN = temp;
       }
        // output FF to 1
       for(i=0xFF; i!=0;i--)
       {
        temp=i;
        temp = temp << 4;
        LPC_GPIO0->FIOPIN = temp;
       }
        }//End of while(1)
}//End of main()
```

```
/*******************************************************************
 * EXP5:External DAC interface (Sine Wave)

 *-------------------------------------------------------------------
 * Controller : LPC1768
* Description        : This example explains about how Sine Wave is generated. Here Y
= Asin(@) since 48 samples are
 used to generate the sine wave so 360/48 = 7.5 degree/sample.
 for example for 15deg Y = 1.25 + Asin(@) = 1.25 + 1.25sin(15)  = 1.5735

                        for 2.5V    -----------------> 0xff
                   then  1.5735V -----------------> 0xA1


                   |0xff            .  .
                                                                      --|2.5V
for Uni polar
                   |     .        .
                                                                 |
                   |   . 15           .
                                                            |
                   | .                 .
                                                       |
0x7f   |-------------------------------------------------            |1.25V
                   |                     .
         .                                    |
                   |                       .
    .                                         |
                   |                          .        .
    |
    _____|_______________________________________.____.____________________--|0V
                   |0x00

******************************************************************/

#include <LPC17xx.H>

int count=0,sinevalue,value;
unsigned char sine_tab[49]=
        { 0x80,0x90,0xA1,0xB1,0xC0,0xCD,0xDA,0xE5,0xEE,0xF6,0xFB,0xFE,
     0xFF,0xFE,0xFB,0xF6,0xEE,0xE5,0xDA,0xCD,0xC0,0xB1,0xA1,0x90,
     0x80,0x70,0x5F,0x4F,0x40,0x33,0x26,0x1B,0x12,0x0A,0x05,0x02,
     0x00,0x02,0x05,0x0A,0x12,0x1B,0x26,0x33,0x40,0x4F,0x5F,0x70,0x80};

int main(void)
{
        LPC_PINCON->PINSEL0 &= 0xFF0000FF ;                                    //
```

```
Configure P0.0 to P0.15 as GPIO
   LPC_GPIO0->FIODIR  |= 0x00000FF0 ;

        count = 0;
        while(1)
        {
                for(count=0;count<48;count++)
                {
                        sinevalue = sine_tab[count];//+0X10 ;
                        value= 0x00000FF0 & (sinevalue << 4);
                        LPC_GPIO0->FIOPIN = value;
                }
        }
}
```

```
/****************************************************************
 * Alphanumeric keypad LCD

 *------------------------------------------------------------
 * Controller : LPC1768
  * Port lines used: Data1 to Data4 - P0.23 to P0.26
 * En - P0.28. RS - P0.27, RW - Ground
 * Connection : CND to CNAB

*****************************************************************/

 #include <lpc17xx.h>

 #include "AN_LCD.h"

 unsigned long int temp1=0, temp2=0 ;


 //lcd initialization
 void lcd_init()
 {
        /* Ports initialized as GPIO */
   LPC_PINCON->PINSEL4 &= 0xFFF000FF;  //P2.4 to P2.9

        /* Setting the directions as output */
   LPC_GPIO2->FIODIR |= DT_CTRL;
        LPC_GPIO2->FIODIR |= RS_CTRL;
        LPC_GPIO2->FIODIR |= EN_CTRL;

   clear_ports();
        delay_lcd(3200);

        temp2 = (0x30<<2);
        wr_cn();
        delay_lcd(30000);

        temp2 = (0x30<<2);
        wr_cn();
        delay_lcd(30000);

        temp2 = (0x30<<2);
        wr_cn();
        delay_lcd(30000);

        temp2 = (0x20<<2);
        wr_cn();
        delay_lcd(30000);
```

```
        temp1 = 0x28;
        lcd_com();
        delay_lcd(30000);

        temp1 = 0x0c;
        lcd_com();
        delay_lcd(800);

        temp1 = 0x06;
        lcd_com();
        delay_lcd(800);

        temp1 = 0x01;
        lcd_com();
        delay_lcd(10000);

        temp1 = 0x80;
        lcd_com();
        delay_lcd(800);
    return;
}

void lcd_com(void)
{
        temp2 = temp1 & 0xf0;//move data (26-8+1) times : 26 - HN place, 4 - Bits
        temp2 = temp2 << 2;//data lines from 23 to 26
        wr_cn();
        temp2 = temp1 & 0x0f; //26-4+1
        temp2 = temp2 << 6;
        wr_cn();
        delay_lcd(1000);
    return;
}

// command nibble o/p routine
void wr_cn(void)                        //write command reg
{
        clear_ports();
        LPC_GPIO2->FIOPIN = temp2;          // Assign the value to the data lines
    LPC_GPIO2->FIOCLR = RS_CTRL;            // clear bit RS
        LPC_GPIO2->FIOSET = EN_CTRL;        // EN=1
        delay_lcd(25);
        LPC_GPIO2->FIOCLR = EN_CTRL;                                // EN =0
    return;

}
```

```
// data o/p routine which also outputs high nibble first
// and lower nibble next
void lcd_data(void)
{
  temp2 = temp1 & 0xf0;
  temp2 = temp2 << 2;
  wr_dn();
  temp2= temp1 & 0x0f;
  temp2= temp2 << 6;
  wr_dn();
  delay_lcd(1000);
  return;
}

// data nibble o/p routine
void wr_dn(void)
{
      clear_ports();

      LPC_GPIO2->FIOPIN = temp2;          // Assign the value to the data lines
      LPC_GPIO2->FIOSET = RS_CTRL;        // set bit  RS
      LPC_GPIO2->FIOSET = EN_CTRL;        // EN=1
      delay_lcd(25);
      LPC_GPIO2->FIOCLR = EN_CTRL;        // EN =0
  return;
}

void delay_lcd(unsigned int r1)
{
      unsigned int r;
      for(r=0;r<r1;r++);
  return;
}

void clr_disp(void)
{
      temp1 = 0x01;
      lcd_com();
      delay_lcd(10000);
  return;
}
void clear_ports(void)
{
  /* Clearing the lines at power on */
      LPC_GPIO2->FIOCLR = DT_CTRL; //Clearing data lines
      LPC_GPIO2->FIOCLR = RS_CTRL;  //Clearing RS line
```

```
        LPC_GPIO2->FIOCLR = EN_CTRL; //Clearing Enable line

    return;
 }

 void lcd_puts(unsigned char *buf1)
 {
    unsigned int i=0;

    while(buf1[i]!='\0')
    {
        temp1 = buf1[i];
         lcd_data();
                 i++;
        if(i==16)
                 {
         temp1 = 0xc0;
                         lcd_com();
                 }

       }
    return;
 }
```

```
/*********************************************************************
****
 * EXP8 : Ext interrupt 3

 * ----------------------------------------------------------------------
 * Controller : LPC1768
 * Project           : ALS-SDA-ARMCTXM3-06

 * Description       :This example senses the extenal interrupt 3 through the pin P2.13
 * caused through the switch SW10. Toggeles the LED L10 if there is an
 * interrupt. Port line: EX INT - P2.13 and LED - P2.13
*********************************************************************
****/

#include<LPC17xx.h>

void EINT3_IRQHandler(void);

unsigned char int3_flag=0;

int main(void)
{
	unsigned char flag=0;

	SystemInit();
	SystemCoreClockUpdate();


	LPC_PINCON->PINSEL4 |= 0x04000000;			//P2.13 as EINT3

	LPC_PINCON->PINSEL4 &= 0xFCFFFFFF;			//P2.12 GPIO for LED
	LPC_GPIO2->FIODIR = 0x00001000;				//P2.12 is assigned
output
	LPC_GPIO2->FIOSET = 0x00001000;				//Initiall LED is kept
on

	LPC_SC->EXTINT = 0x00000008;				//writing 1 cleares the
interrupt, get set if there is interrupt
	LPC_SC->EXTMODE = 0x00000008;				//EINT3 is initiated as
edge senitive, 0 for level sensitive
	LPC_SC->EXTPOLAR = 0x00000000;				//EINT3 is falling
edge sensitive, 1 for rising edge
								//above
registers, bit0-EINT0, bit1-EINT1, bit2-EINT2,bit3-EINT3
	NVIC_EnableIRQ(EINT3_IRQn);				//core_cm3.h

	while(1)
```

```
	{
		while(int3_flag == 0x00);				//wait till interrupt
		int3_flag = 0x00;

		if(flag == 0x00)					//when flag is '0' off
the LED
		{
			LPC_GPIO2->FIOCLR = 0x00001000;
			flag = 0xFF;
		}								//when
flag is FF on the LED
		else
		{
			LPC_GPIO2->FIOSET = 0x00001000;
			flag = 0x00;
		}
	}
}

void EINT3_IRQHandler(void)
{
	int3_flag = 0xff;
	LPC_SC->EXTINT = 0x00000008;				//cleares the interrupt
}
```

```
/*****************************************************************
************
 * EXP9 : SEVEN SEGMENT DISPLAY

 *-----------------------------------------------------------------------------
 * Controller : LPC1768
 * Project              : ALS-SDA-ARMCTXM3-06

 * Description          :\\\\\\\\\\\\\\DISPLAY ARE CONNECTED IN COMMON CATHODE
MODE\\\\\\\\\\\\\\\\\\\\
        Port0 Connected to data lines of all 7 segement displays
          a
         ----
        f|  g |b
         |----|
        e|    |c
         ----  . dot
          d
        a = P0.04
        b = P0.05
        c = P0.06
        d = P0.07
        e = P0.08
        f = P0.09
        g = P0.10
        dot = P0.11


        Select lines for two 7 Segments
        DIS1  P0.19
        DIS2  P0.20
*/

#include <LPC17xx.h>
unsigned int delay, count=0, Switchcount=0,j;

unsigned int Disp[16]={0x000003f0, 0x00000060, 0x000005b0, 0x000004f0,
0x00000660,0x000006d0,
                                        0x000007d0, 0x00000070, 0x000007f0,
0x000006f0, 0x00000770,0x000007c0,
                                        0x00000390, 0x000005e0, 0x00000790,
0x00000710 };

#define ALLDISP  0x00180000                         //Select all display
#define DATAPORT 0x00000ff0                         //P0.16 to P0.23 : Data lines
connected to drive Seven Segments
```

```
int main (void)
{
        LPC_PINCON->PINSEL0 = 0x00000000;
        LPC_PINCON->PINSEL1 = 0x00000000;
        LPC_GPIO0->FIODIR =   0x00180ff0;

        while(1)
        {
                LPC_GPIO0->FIOSET |= ALLDISP;
                LPC_GPIO0->FIOCLR =   0x00000ff0;          // clear the data lines to 7-
segment displays
                LPC_GPIO0->FIOSET = Disp[Switchcount];            // get the 7-segment
display value from the array

                        for(j=0;j<3;j++)
                        for(delay=0;delay<30000;delay++);   // 1s delay

                                Switchcount++;
                                if(Switchcount == 0x10)  // 0 to F has been displayed ? go
back to 0
                          {
                                 Switchcount = 0;
                                 LPC_GPIO0->FIOCLR  =        0x00180ff0;

                          }

        }
}
```

```
/********************************************************************
 * EXP 10:Relay/buzzer/Led test

 *-------------------------------------------------------------------
 * Controller : LPC1768

 * Description        : Coil of the relay is pulled up at one side and other side is
controlled
 * by the controller via ULN2803 an inverting buffer. When Switch SW4 is Pressed
,high is sent
 * from the controller for Relay, current flows through the coil. LED gets on and
 * CN5 pin 1 and 2 gets short as well and low is sent from the controller then Buzzer
will ON
********************************************************************/

#include <LPC17xx.H>
unsigned int count=0;
int main(void)
{
	unsigned int i;
	SystemInit();
	SystemCoreClockUpdate();

	LPC_PINCON->PINSEL1 &= 0xFFF0FFFF;		//P0.25 GPIO
	LPC_GPIO0->FIODIR |= 0x03000000;	//P0.25 output
  while(1)
  {
	if(!(LPC_GPIO2->FIOPIN & 0x00000800))
	{
		for(i=0;i<10;i++)
		{
		LPC_GPIO0->FIOSET = 0x03000000;  //relay on
		for(i=0;i<10000;i++);

		}

  }
	else
	{
	  LPC_GPIO0->FIOCLR = 0x03000000;	//relay off
	  for(i=0;i<100000;i++);
	}
	}					//end int main(void)
```

```
/**************************************************************
 * SPI.c for testing SPI

 *---------------------------------------------------------------------------------
 * Controller : LPC1768
 * Its a generalr SPI init and ISR code to  be used at necessary points by including
 * SPI.h file. SSEL of SPI is not considered for initialisation. Its user option to
 * select any port line as Ss line. Other than that port lines used are - P0.15 - SCK,
 * MISO - P0.17, MOSI - P0.18
*****************************************************************
*************/
#include <LPC17xx.h>
#include "SPI.h"
unsigned char spi_flag = 0, temp=0;

void SPI_Init(void)
{
//	LPC_SC->PCONP |= (1<<8);	//Enable the peripheral SPI
	LPC_PINCON->PINSEL0 |= 0xC0000000;	//P0.15 as SCK
	LPC_PINCON->PINSEL1 |= 0x0000003C;	//select MISO-P0.17,MOSI-P0.18

	LPC_SPI->SPCCR = 0x1E; //  SPI CLOCK SELECTED AS 100KHZ
	LPC_SPI->SPCR = 0xA0; //8 bit data, actve high clk, master SPI mode,SPI Int
enable
			// Master mode and SCK line is active high
	LPC_SPI->SPINT  = 0x01; //clear the interrupt flag
	NVIC_EnableIRQ(SPI_IRQn);
}

void SPI_IRQHandler(void)
{
   spi_flag = 1;
   temp = LPC_SPI->SPSR;   // To clear SPIF bit we have to read status register.
   temp = LPC_SPI->SPDR;   // Then read the data register(optional)
   LPC_SPI->SPINT = 0x01;  // To clear the SPI interrupt
}
```

```
/*****************************************************************
 * EXP7  :PWM Test

 * ------------------------------------------------------------------
 * Controller : LPC1768
  * Description      : PWM 1.2 is used. Match register 0 is used for count purpose.
PWM 1
 * match register 2 is increamented or decreamented at each interrupted.
 * Port line P3.25.
*****************************************************************/

#include <LPC17xx.H>
void pwm_init(void);
void PWM1_IRQHandler(void);

unsigned long int i;
unsigned char flag,flag1;

int main(void)
{
	SystemInit();
	SystemCoreClockUpdate();
	pwm_init();

	while(1)
	{
		for(i=0;i<=1000;i++);			// delay
   }//end of while
}//end of main

void pwm_init(void)
{
	LPC_SC->PCONP |= (1<<6);			//PWM1 is powered
	LPC_PINCON->PINSEL7 |= 0x000C0000;	//pwm1.2 is selected for the pin
P3.25

	LPC_PWM1->PR  = 0x00000000;	//Count frequency : Fpclk
	LPC_PWM1->PCR = 0x00000400;	//select PWM2 single edge
	LPC_PWM1->MCR = 0x00000003;	//Reset and interrupt on PWMMR0
	LPC_PWM1->MR0 = 30000;		//setup match register 0 count
	LPC_PWM1->MR2 = 0x00000100;	//setup match register MR1
	LPC_PWM1->LER = 0x000000FF;	//enable shadow copy register
	LPC_PWM1->TCR = 0x00000002;	//RESET COUNTER AND PRESCALER
	LPC_PWM1->TCR = 0x00000009;	//enable PWM and counter

	NVIC_EnableIRQ(PWM1_IRQn);
```

```
        return;
}

void PWM1_IRQHandler(void)
{
        LPC_PWM1->IR = 0xff;                            //clear the interrupts

        if(flag == 0x00)
    {
                LPC_PWM1->MR2 += 100;
                LPC_PWM1->LER = 0x000000FF;

                if(LPC_PWM1->MR2 >= 27000)
                {
        flag1 = 0xff;
        flag = 0xff;
        LPC_PWM1->LER = 0x000000fF;
                }
        }
    else if(flag1 == 0xff)
    {
                LPC_PWM1->MR2 -= 100;
                LPC_PWM1->LER = 0x000000fF;

                if(LPC_PWM1->MR2 <= 0x500)
                {
                        flag  = 0x00;
                        flag1 = 0x00;
                        LPC_PWM1->LER = 0X000000fF;
                }
        }
}
```