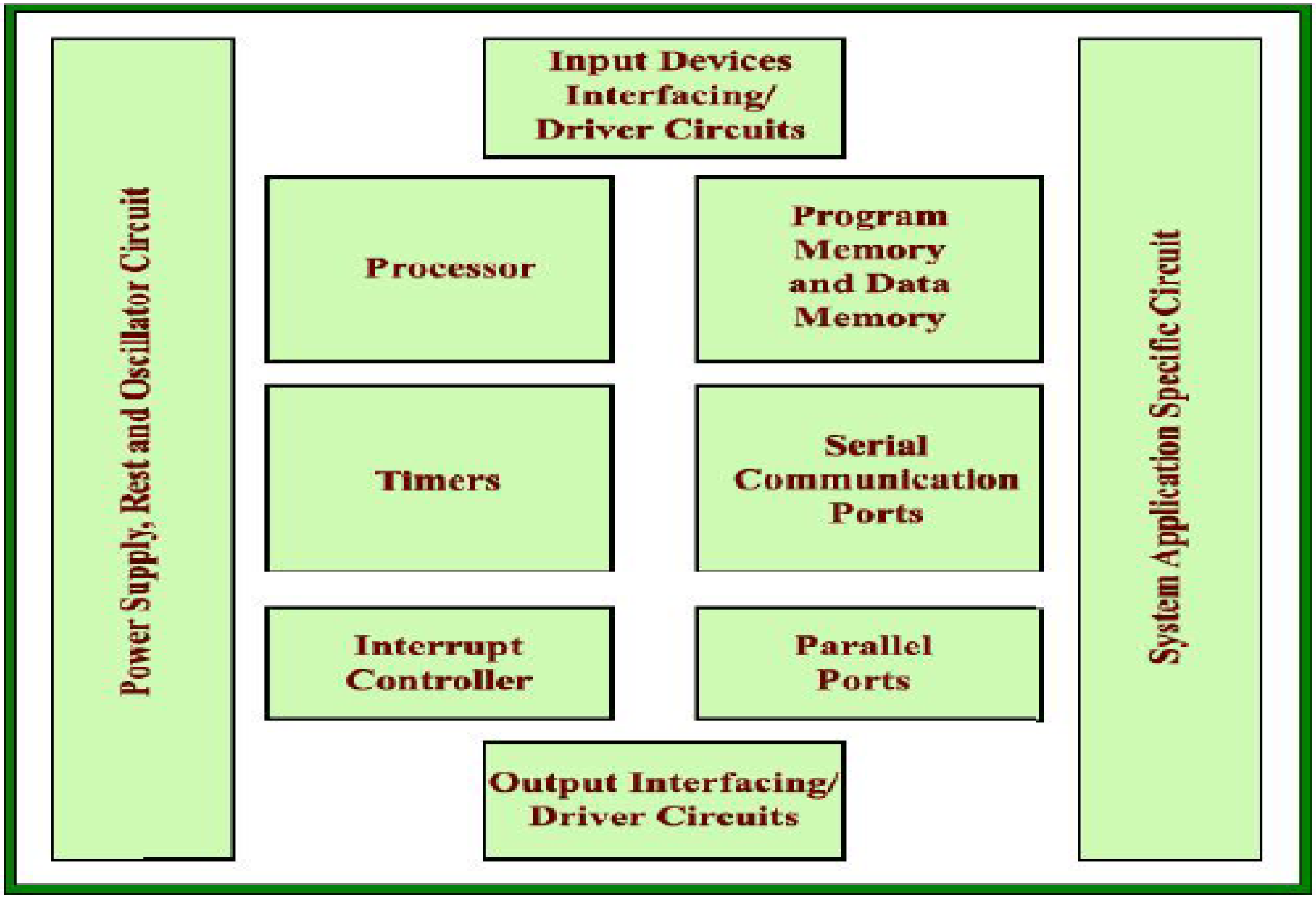
CHAPTER-2

EMBEDDED SYSTEM ARCHITECTURE

Learning objectives:

1. To know about hardware architecture of embedded system
2. Understand the ARM Cortex M0+ Hardware Overview
3. Explain about serial and parallel communication
4. Explain ATmega32 microcontroller Architecture
5. Describe Assembly language Programming with ATmega32 Instruction Set
6. Discuss about Interface peripherals, port, Interrupts, ISR and Timers

EMBEDDED SYSEM HARDWARE



ARCHITECTURE OF AN EMBEDDED SYSTEM

Typical embedded system mainly has two parts i.e., embedded hardware and embedded software.

Embedded hardware are based around microprocessor and microcontrollers, also include memory, bus, Input/Output, Controller, where as embedded software includes embedded operating systems, different applications and device drivers. Basically these two types of architecture i.e., Havard architecture and Von Neumann architecture are used in embedded systems.

The main part of Embedded System hardware architecture:

Architecture of the Embedded System includes Sensor, Analog to Digital Converter, Memory, Processor, Digital to Analog Converter, and Actuators etc.

The figure on next slide illustrates the overview of basic architecture of embedded systems:

ARCHITECTURE OF AN EMBEDDED SYSTEM

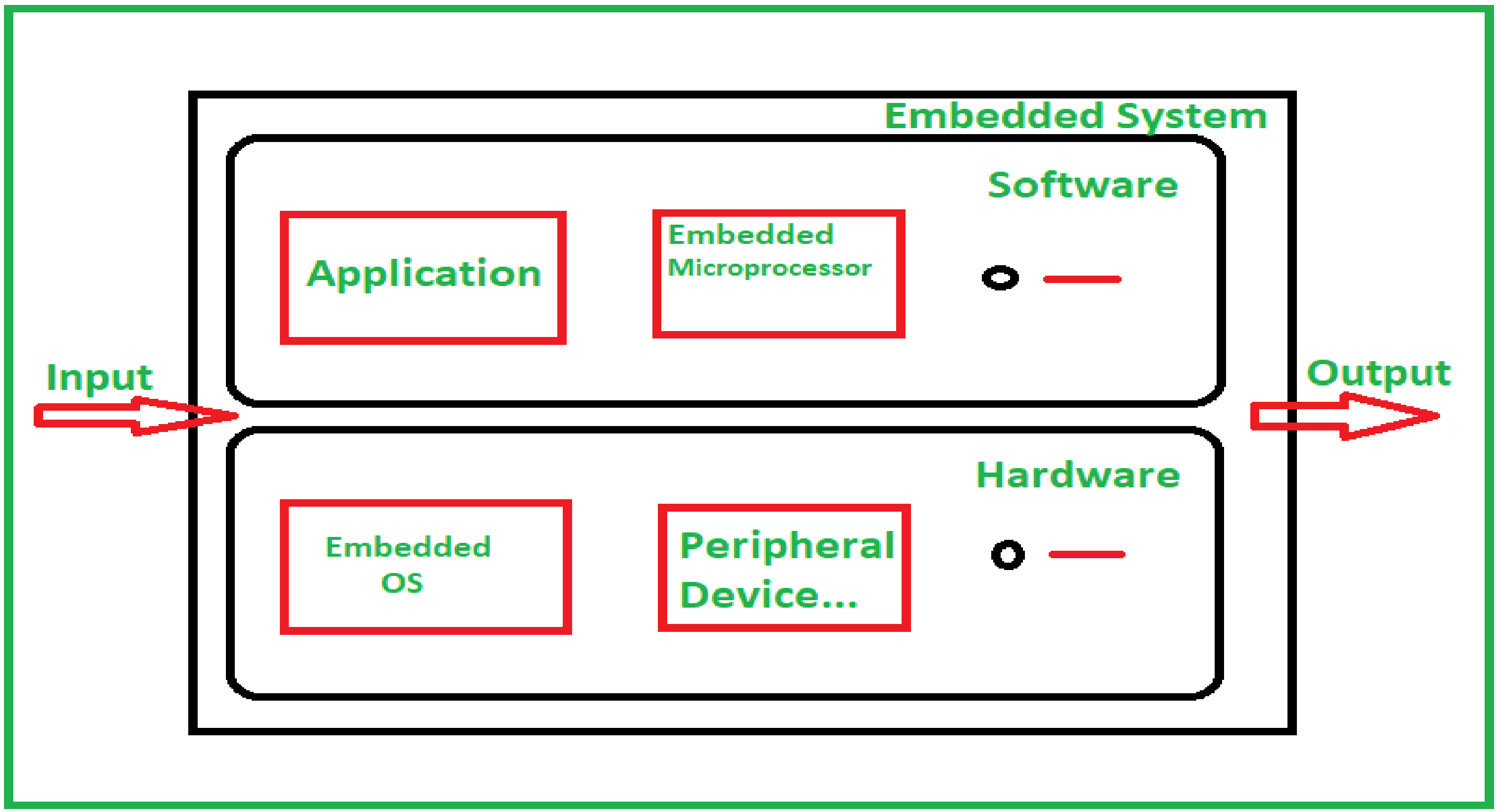


Fig: Basic architecture of embedded systems

Embedded Systems - Architecture Types

Hardware architecture for embedded system:

Basically these two types of architecture i.e., Havard architecture and Von Neumann architecture are used in embedded systems. Architecture of the Embedded System includes Sensor, Analog to Digital Converter, Memory, Processor, Digital to Analog Converter, and Actuators etc.

The 8051 microcontrollers work with 8-bit data bus. So they can support external data memory up to 64K and external program memory of 64k at best. Collectively, 8051 microcontrollers can address 128k of external memory.

When data and code lie in different memory blocks, then the architecture is referred as Harvard architecture. In case data and code lie in the same memory block, then the architecture is referred as Von Neumann architecture.

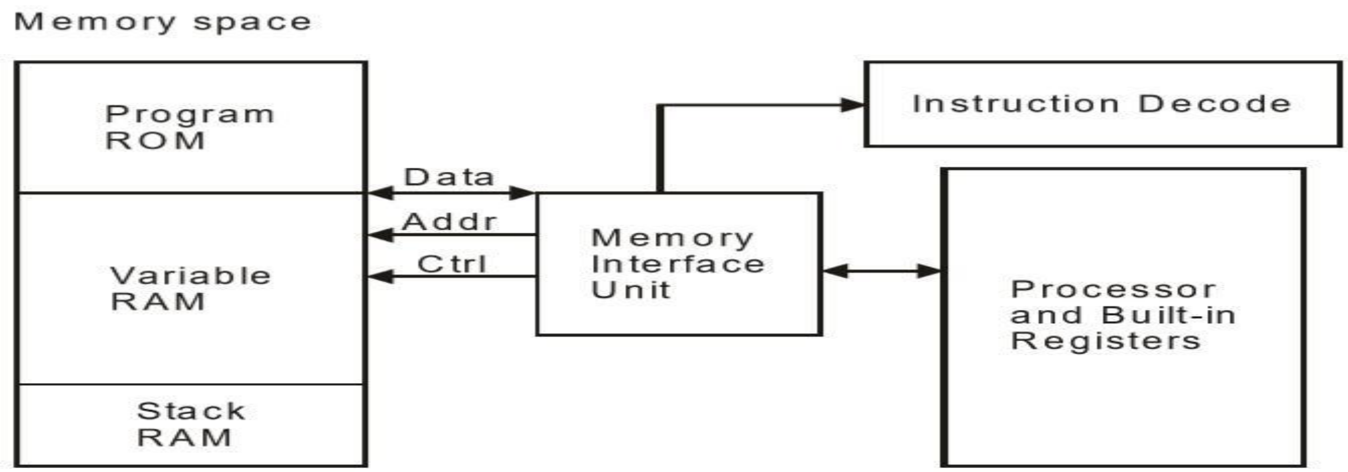
Von Neumann architecture :

In a normal computer that follows Von Neumann architecture, instructions and data both are stored in the same memory. So same buses are used to fetch instructions and data. This means the CPU cannot do both things together (read the instruction and read/write data).

Embedded Systems - Architecture Types....contd (Von Neumann Architecture)

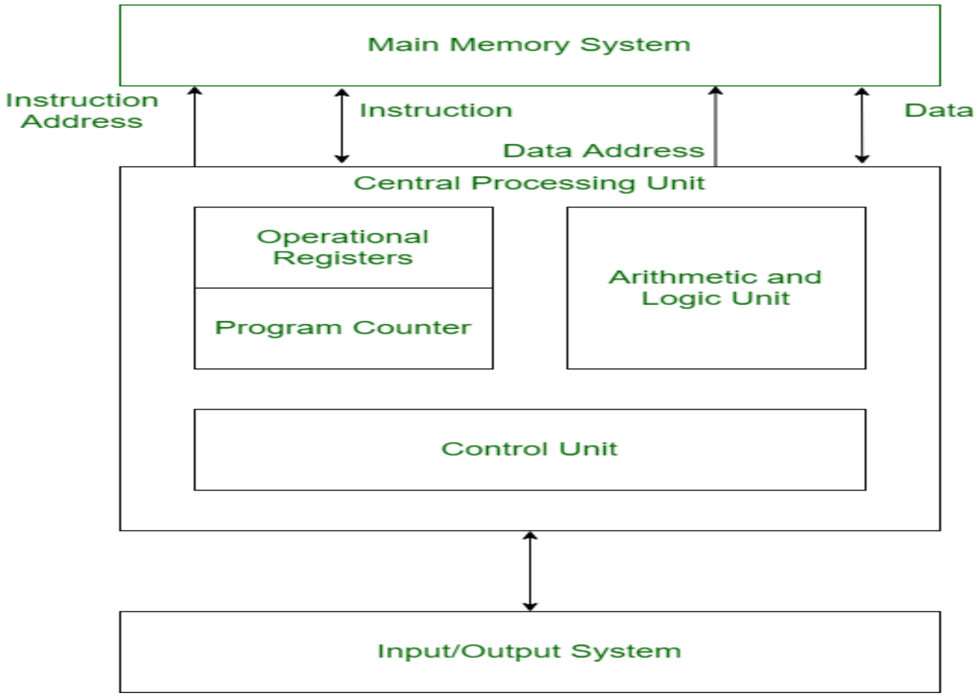
Von Neumann Architecture:

The Von Neumann architecture was first proposed by a computer scientist John von Neumann. In this architecture, one data path or bus exists for both instruction and data. As a result, the CPU does one operation at a time. It either fetches an instruction from memory, or performs read/write operation on data. So an instruction fetch and a data operation cannot occur simultaneously, sharing a common bus.



Von-Neumann architecture supports simple hardware. It allows the use of a single, sequential memory. Today's processing speeds vastly outpace memory access times, and we employ a very fast but small amount of memory (cache) local to the processor.

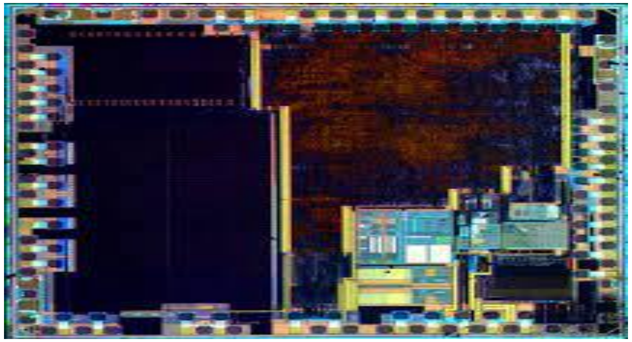
Embedded Systems - Architecture Types....contd
Structure of Harvard Architecture



Harvard Architecture is the computer architecture that contains separate storage and separate buses (signal path) for instruction and data. It was basically developed to overcome the bottleneck of Von Neumann Architecture. The main advantage of having separate buses for instruction and data is that the CPU can access instructions and read/write data at the same time.

ARM Cortex-M0+

The ARM Cortex-M is a group of 32-bit RISC ARM processor cores licensed by Arm Holdings. These cores are optimized for low-cost and energy-efficient integrated circuits, which have been embedded in tens of billions of consumer devices.



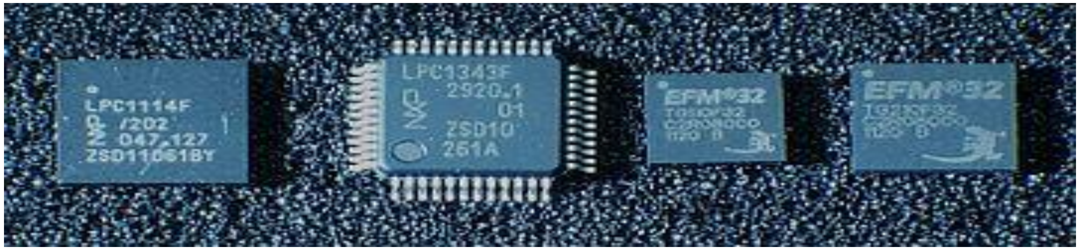
ARM based Microcontrollers (MCU) contain a 32-bit wide data bus. An ARM MCU is developed by ARM Holdings that contains an ARM processor core developed based on Advanced RISC Machine (ARM) architecture with32-bit RISC (reduced instruction set computer) instruction set in it.

ARM Cortex-M0+ ....contd

The ARM Cortex-M0+ processor is the most energy efficient ARM processor available for embedded applications with design constraints.

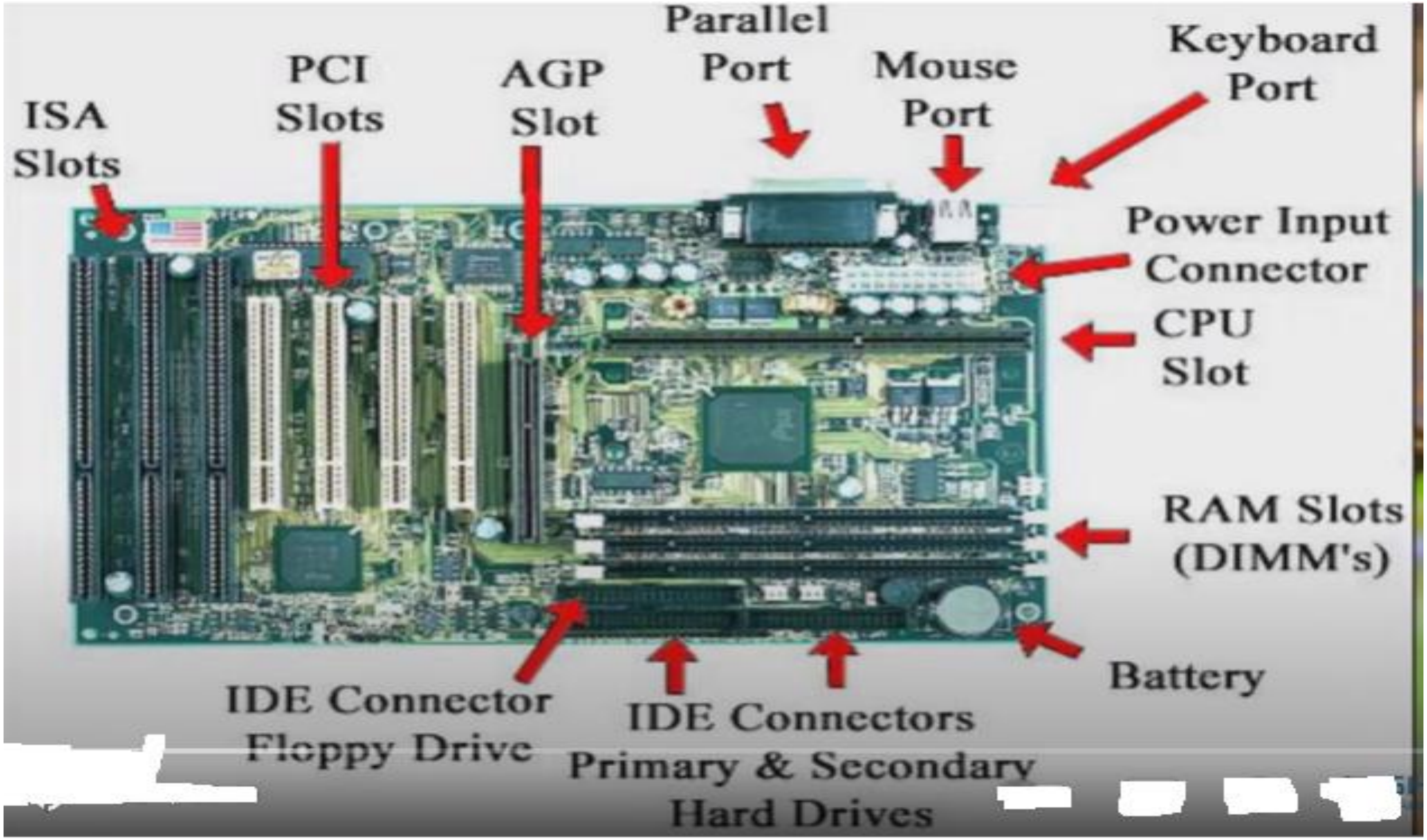
ARM-An ARM processor is one of a family of CPU based on the RISC(reduced instruction set computer) architecture developed by advanced RISC machine(ARM). ARM processor are extensively used in consumer electronic devices. Such as smart phone, tables, multimedia players.

32-bit	
Year	Core
2004	Cortex-M3
2007	Cortex-M1
2009	Cortex-M0
2010	Cortex-M4
2012	Cortex-M0+
2014	Cortex-M7
2016	Cortex-M23
2016	Cortex-M33
2018	Cortex-M35P
2020	Cortex-M55

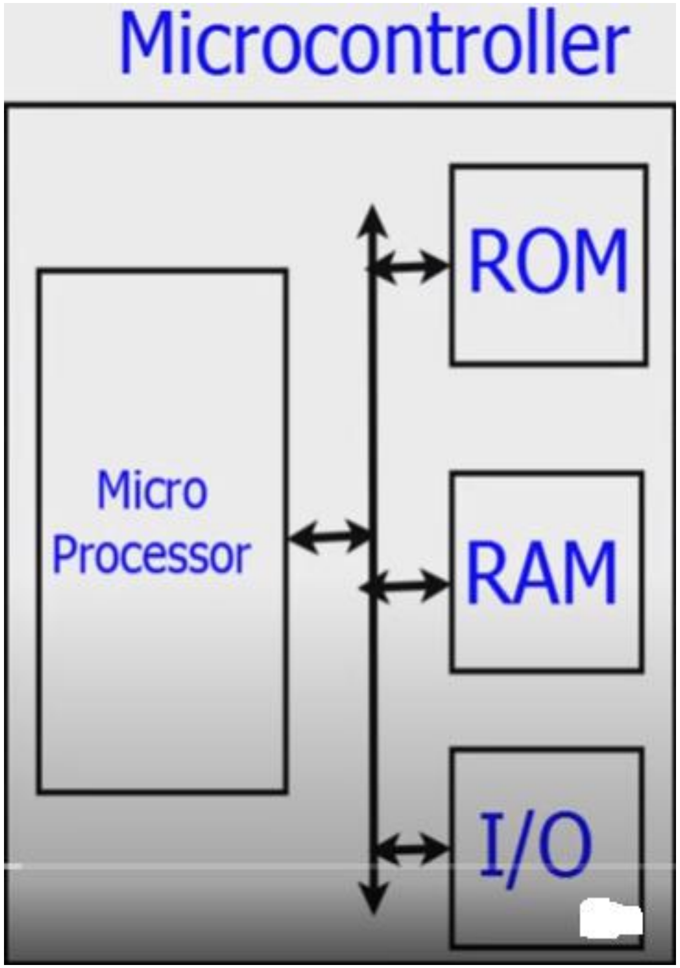


ARM Cortex-M0 and Cortex-M3 microcontroller ICs from NXP and Silicon Labs

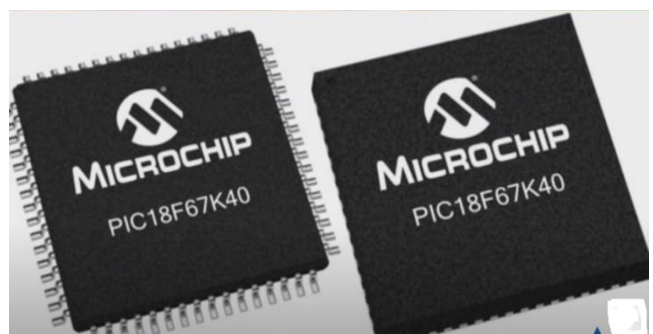
Microprocessor(µP)



Micro-controller(µC)



Microcontroller concept came in 1970.Motorola is the first company who launched microcontroller and more than 200 company making it at present time. And more than 100,000 variety of microcontroller is available in the market.



PORT

A port-a device

1. To receive the bytes from external peripheral(s) [or device(s) or processor(s) or controllers] for reading them later using instructions executed on the processor or

2. To send the bytes to external peripheral or device or processor using instructions executed on processor

✓Connects to the processor using address decoder and system buses

✓Port-Register addresses for programming the port functions or modes, reading port status and for writing or reading bytes.

Port in embedded: PORT is used to set the output value. • If the pin is set as output, then a PORT value of 1 will set voltage at that pin to 5V. If PORT value is 0, then voltage is set to 0.

PORT….contd

Parallel Port input- single bit :

✓Completion of a revolution of a wheel,

✓Achieving preset pressure in a boiler,

✓Filling of a liquid up to a fixed level.

Parallel Port Output- single bit:

✓A d.c. motor control

✓Pulses to an external circuit

✓Control signal to an external circuit

Parallel Port Input- multi-bit

✓ADC input from liquid level measuring sensor or temperature sensor or pressure sensor or speed sensor or d.c. motor rpm sensor

✓Encoder inputs for bits for angular position of a rotating s

PORT….contd

Parallel Port Output- multi-bit

✓LCD controller for Multilane LCD display matrix unit in a cellular phone to display on the screen the phone number, time, messages, character outputs or pictogram bit-images for display screen or e-mail or web page

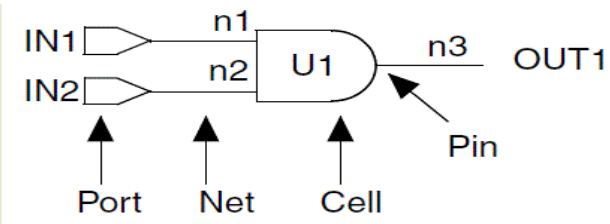
✓Print controller output

✓Stepper-motor coil driving bits

Parallel Port Input-Output

✓PPI 8255

✓Touch screen in mobile phone



Ports and pins?

A pin is a physical connection for a single net. In schematics and HDLs, pin and terminal are used interchangeably to represent the point where the connection to a network is made. A port is a group of pins representing a standard interface. In the physical world, a port is usually more than one pin.

Register

A register is a temporary storage area built into a CPU. It is used to quickly accept, store, and transfer data and instructions that are being used immediately by the CPU.

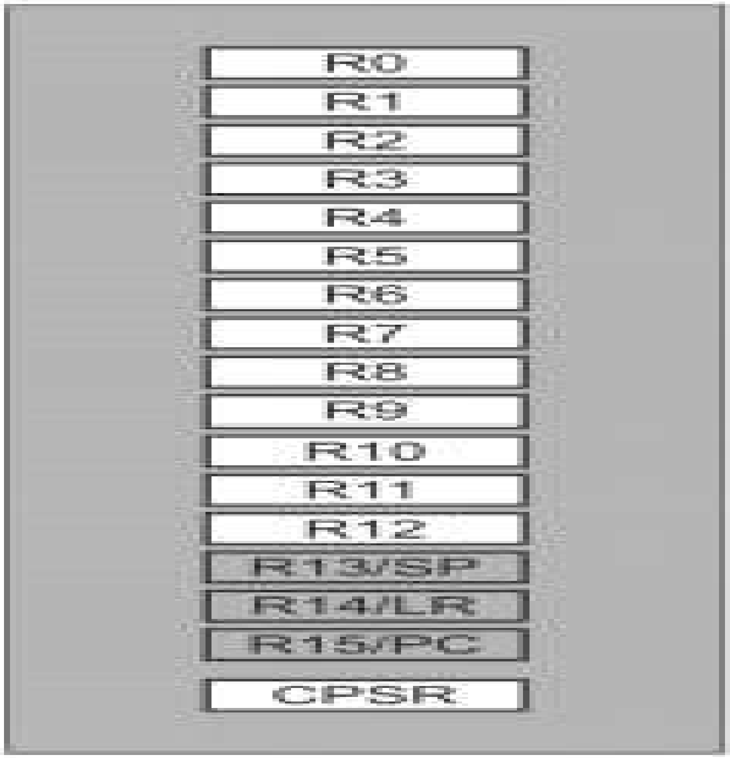
Register are for temporary data storage within processor architecture as shown in fig, ARM processor has sixteen number of general purpose register,R0-R15 and a current program status register(CPSR) defined for user mode of operation. Each of these register is of 32-bits.Out of these register R13,R14 and R15 have special purpose.

R13: Used as the stack pointer(a small register that stores the address of the last program request in a stack) that holds the address of the top of the stack in the current processor mode.

R14: Used as the link register(a special-purpose register which holds the address to return to when a function call completes) that save the content of program counter on control transfer due to the occurrence of exceptions or using the branch instructions in the program.

Register....contd

R15: Used as the program counter that points to the next instructions to be executed. In ARM state, all instructions are of 32-bits(four bytes).



User mode register set

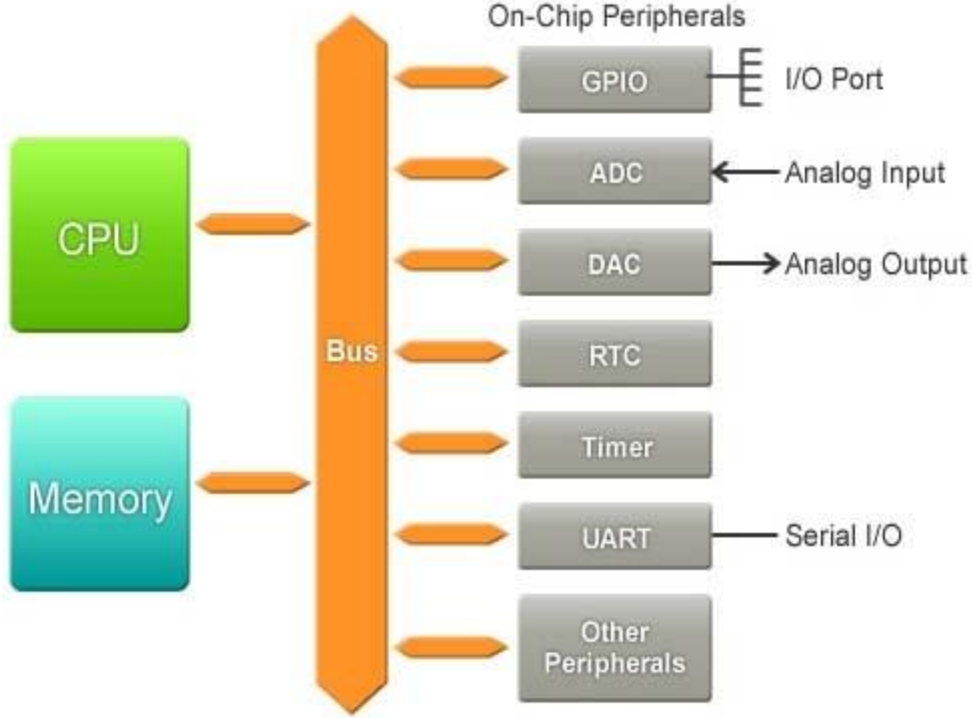
GPIO

GPIO stand for General Purpose Input/Outputs, meaning that it's a module capable of receiving and transmitting signals. They work with digital signals but can be mixed to use the pins with other peripheral fonctions (ADC, SSI, UART, etc).
A GPIO port handles both incoming and outgoing digital signals. As an input port, it can be used to communicate to the CPU the ON/OFF signals received from switches, or the digital readings received from sensors.

The GPIO peripheral provides dedicated general-purpose pins that can be configured as either inputs or outputs. When configured as an output, you can write to an internal register to control the state driven on the output pin.

Purpose of GPIO pins:
A GPIO (general-purpose input/output) port handles both incoming and outgoing digital signals. As an input port, it can be used to communicate to the CPU the ON/OFF signals received from switches, or the digital readings received from sensors.

GPIO….contd



Peripheral: GPIO

ADC and DAC

ADC and DAC:

As its name implies, an analog-to-digital converter (**ADC**) takes an analog wave as an input and converts this wave to a digitally represented output form (Fig. A).

A digital-to-analog converter (**DAC**) essentially does the reverse, converting a digital representation into an analog form (Fig. B).

The Digital to Analogue Converser (DAC) is a device that converts a binary representation of a number to an actual analogue voltage on an external pin.

ADC and DAC….contd

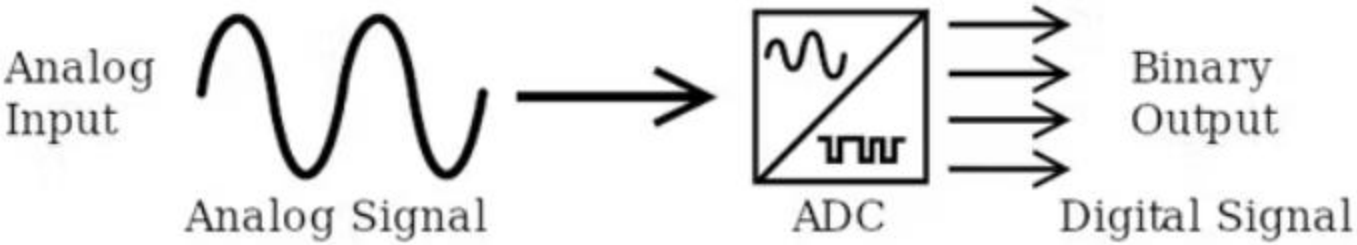


Fig: A- Schematic shows basic ADC functionality

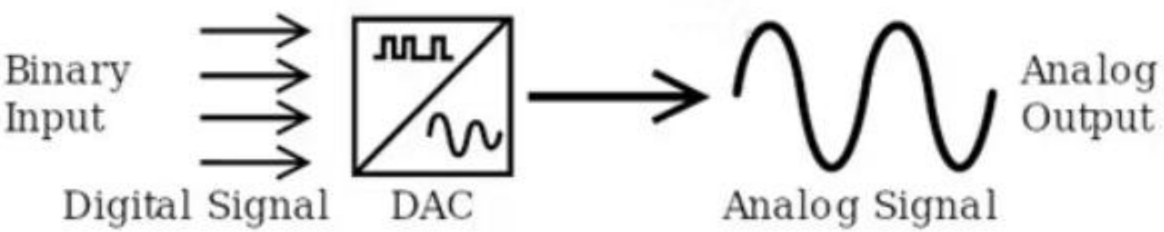


Fig: B- Schematic shows basic DAC functionality

Serial and Parallel Communication

Wired (UART, USART, SPI, I2C and Ethernet) at Physical-Data Link layer communication technologies

Serial and Parallel Communication

- Serial means one bit after another in successive time intervals over a wire

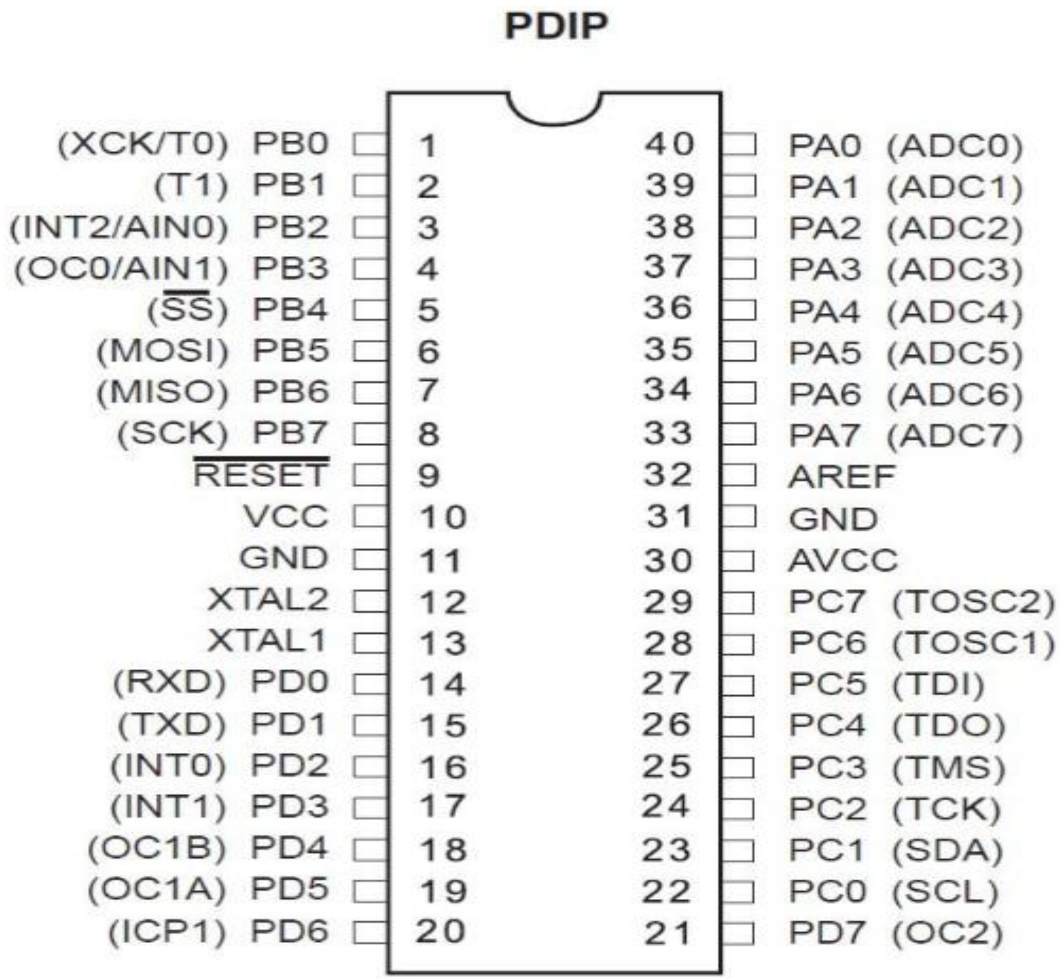
- Parallel all bits in a word at the same times communicate at different wires

ATmega32 MICROCONTROLLER ARCHITECTURE

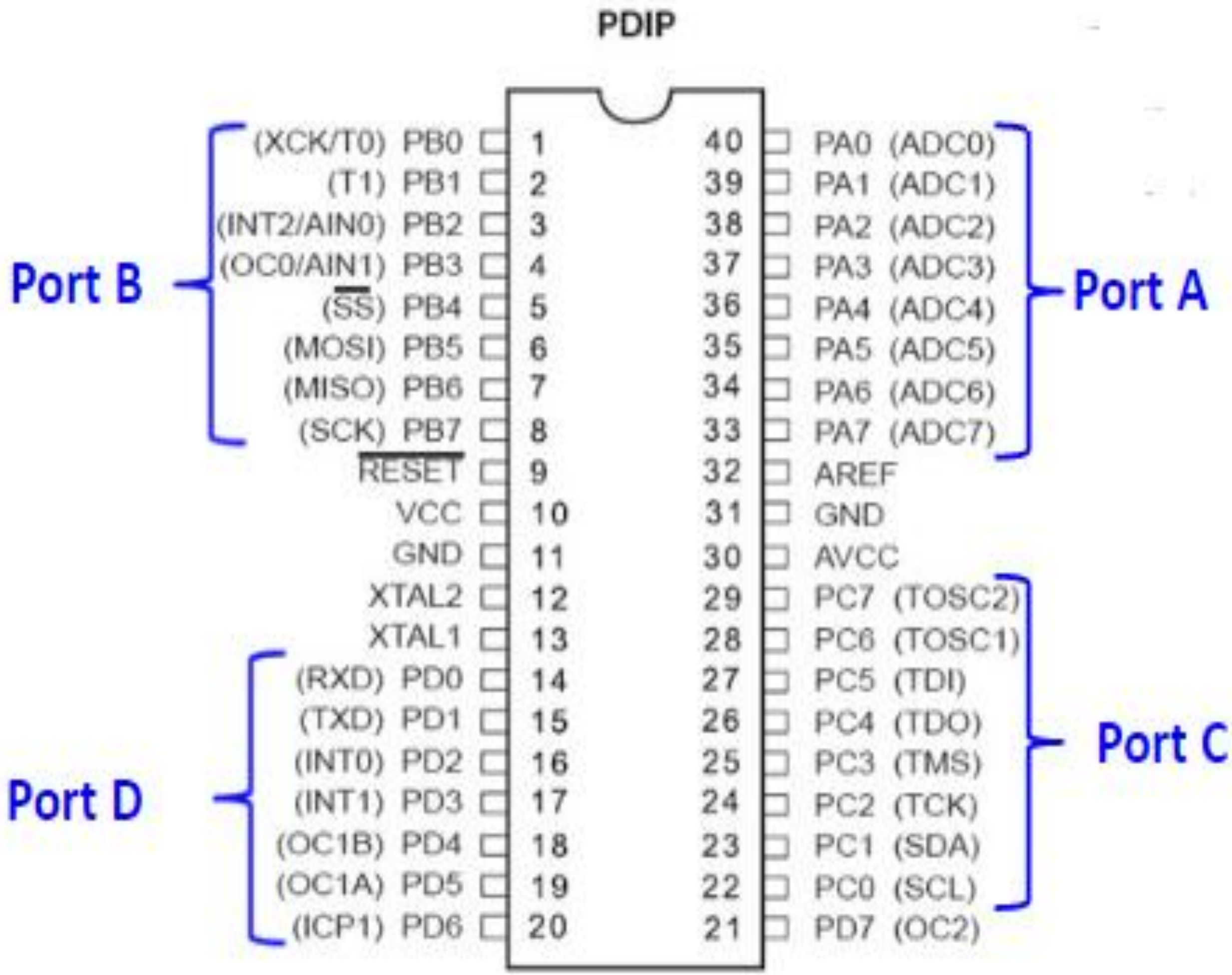
ATmega32 is a low power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. Due to RISC, AVR can execute 1 million instructions per second if cycle frequency is 1MHz. Key Features: 32 x 8 general working purpose registers.

By executing powerful instructions in a single clock cycle, the ATmega32 achieves throughputs approaching 1 MIPS per MHz allowing the system designer to optimize power consumption versus processing speed.

ATmega32 Microcontroller Pin Diagram



ATmega32 Microcontroller Pin Diagram….contd



ATmega32 Microcontroller Pin Descriptions

Port A (PA7-PA0): Port A serves as analog inputs for A/D converter. It also acts as an 8-bit bidirectional I/O port if the A/D converter is not used internally.

Port B (PB7-PB0) and Port D (PD7-PD0): These ports are 8-bit bidirectional I/O ports. Their output buffers have symmetrical drive characteristics with high source and sink capability. As inputs, these are pulled low if the pull-up resistors are used. It also provides various special functional features of the ATmega32.

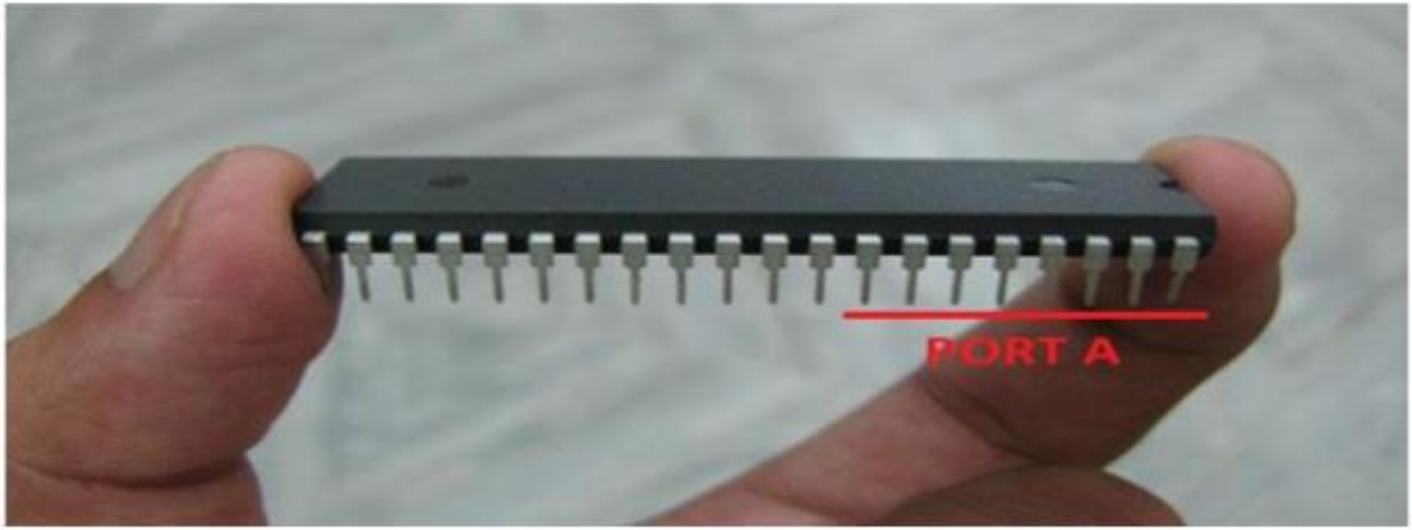
Port C (PC7-PC0): Port C is an 8-bit bidirectional I/O port. If the Joint Test Action Group (JTAG) interface is enabled, the pull-up resistors on pins PC2 (TCK), PC3 (TMS), and PC5 (TDI) will be activated.

ATmega32 Microcontroller Pin Descriptions….contd

Vcc: Digital voltage supply
GND: Ground
RESET: It is a RESET pin which is utilized to set the microcontroller ATmega32 to its primary value. During the beginning of an application the RESET pin is to be set elevated for two machine rotations.
XTAL1: It is an input for the inverting oscillator amplifier and input to an internal clock operating circuit.
XTAL2: It is an output from an inverting oscillator amplifier.
AVcc: It is a supply voltage pin for A/D converter and Port A. It must be connected with Vcc.
AREF: AREF is an analog signal reference pin for the analog to digital converter.

ATmega32 PIN OUT &DESCRIPTION

Digital IO is the most fundamental mode of connecting a MCU to external world. The interface is done using what is called a PORT. **A port is the point where internal data from MCU chip comes out or external data goes in.** They are present is form of PINs of the IC. Most of the PINs are dedicated to this function and other pins are used for power supply, clock source etc . ATMega32 ports are named PORTA, PORTB, PORTC, and PORTD.



Timers

Timers:

✓Real time clock-system clock, on each tick SysClkIntr interrupts

✓Based on each SysClkIntr interrupts— there are number of OS timer functions

✓Timer are used to message the elapsed time of events for instance , the kernel has to keep track of different times

The following functions calls are provided to manage the timer

- ✓Get time
- ✓Set time
- ✓Time delay(in system clock)
- ✓Time delay(in sec.)
- ✓Reset timer

THANK YOU