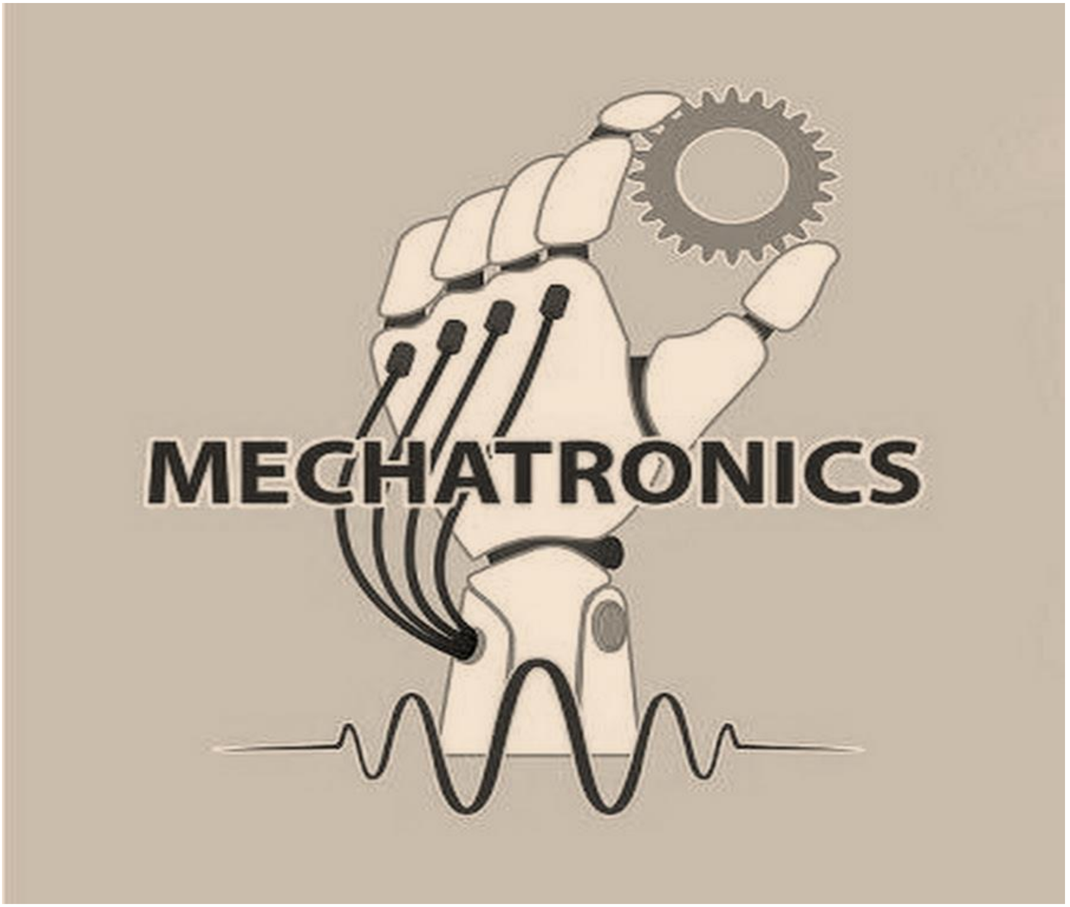

Mechatronics systems and applications

Code- ARA 204

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Faculty, USAR, GGSAIPU

Syllabus

S. No.	Contents
1	**Introduction**: Definition of mechatronics, measurement system, control systems, microprocessor based controllers, mechatronics approach.
2	**Sensors and Transducers**: Sensors and transducers, performance terminology, photoelectric transducers, flow transducers, optical sensors and transducers, semiconductor lasers, selection of sensors, mechanical / electrical switches, inputting data by switches.
3	**Actuators**: Actuation systems, pneumatic and hydraulic systems, process control valves, rotary actuators, mechanical actuation systems, electrical actuation systems.
4	**Signal Conditioning**: Signal conditioning, filtering digital signal, multiplexers, data acquisition, digital signal processing, pulse modulation, data presentation systems.
5	**Microprocessors and Microcontrollers**: Microcomputer structure, microcontrollers, applications, programmable logic controllers.
6	**Modeling and System Response**: Mathematical models, bond graph models, mechanical, electrical, hydraulic and thermal systems, dynamic response of systems, transfer function and frequency response, closed loop controllers.
7	**Design and Mechatronics**: Input/output systems, computer based modular design, system validation, remote monitoring and control, designing, possible design solutions, detailed case studies of mechatronic systems used in photocopier, automobile, robots.

Unit I [12]

Introduction: Introduction to Mechatronics System, Elements of mechatronics system, mechatronics in manufacturing, product and design, Measurement Systems, Control System, comparison between traditional and mechatronics approach.

Sensors and Transducers: Introduction, Performance terminology, static and dynamic characteristics of transducers, Displacement Measurement: Transducers for displacement, displacement measurement, potentiometer, LVDT. Strain Measurement: Theory of Strain Gauges, Bridge circuit, Strain gauge based load cells and torque sensors, Velocity and Motion: Electromagnetic tachometer, photoelectric tachometer, variable reluctance tachometer, Digital Encoders. Vibration and acceleration: Eddy current type, piezoelectric type; Accelerometer: Principle of working, practical accelerometers, strain gauge based and piezoelectric accelerometers. Pressure Measurement: Elastic pressure transducers viz. Bourdon tubes, diaphragm, bellows and piezoelectric pressure sensors. Flow Measurement: Bernoulli flowmeter, Ultrasonic flowmeter, Magnetic flow meter, Rotameter. Miscellaneous Sensors: Leak detector, Flame detector, Smoke detector, pH sensors, Conductivity sensors, Humidity sensors, Potentiometric Biosensors and Proximity sensors. Selection of sensors

Unit II [10]

Mechanical Actuation System: Cams, Gear trains, Ratchet and Pawl, Belt and chain drives, Bearings.

Hydraulic and Pneumatic Actuation System: Introduction to Hydraulic and Pneumatic Systems, Directional Control valves, Flow control valves.

Electrical Actuation System: Electrical systems, Solid State Switches, Solenoids, D.C. motors, A.C. motors, Stepper motors.

Unit III [12]

Microprocessors: Microprocessor systems, Microcontrollers, applications.

Programmable logic controllers: Programmable logic controllers (PLC) Structure, Input / Output Processing, principles of operation, PLC versus computer, Programming Languages, programming using Ladder Diagrams, Logic Functions, Latching, Sequencing, Timers, Internal Relays And Counters, Shift Registers, Master and Jump Controls, Jumps, Data Movement, Code Conversion, Data handling and manipulation, selecting a PLC.

Unit IV [8]

System Models: Mathematical models, Mechanical, Electrical, hydraulic and Thermal Systems, Modelling of dynamic systems.

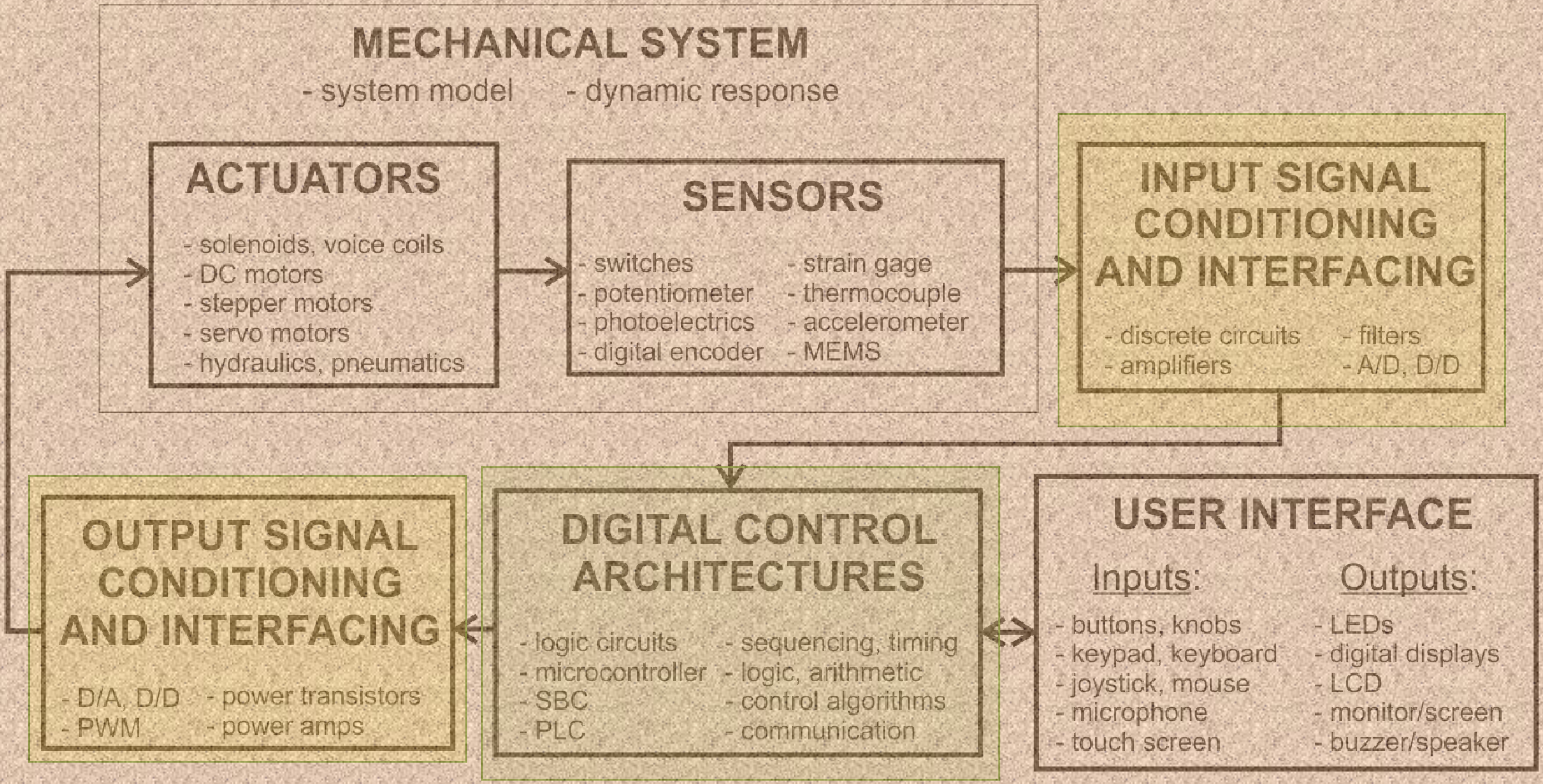
Design of Mechatronics systems: Stages in designing mechatronics system, Traditional and Mechatronic design.

Case studies of Mechatronics system: Mechatronic approach to design, Boat Auto pilot, Pick and place robots, high speed tilting train, automatic car park system, coin counter, engine management system, automated guided vehicle, autonomous mobile system, antilock brake system control, Auto-Focus Camera, Printer, Domestic Washing Machine, Optical Mark Reader, Bar Code Reader

Books

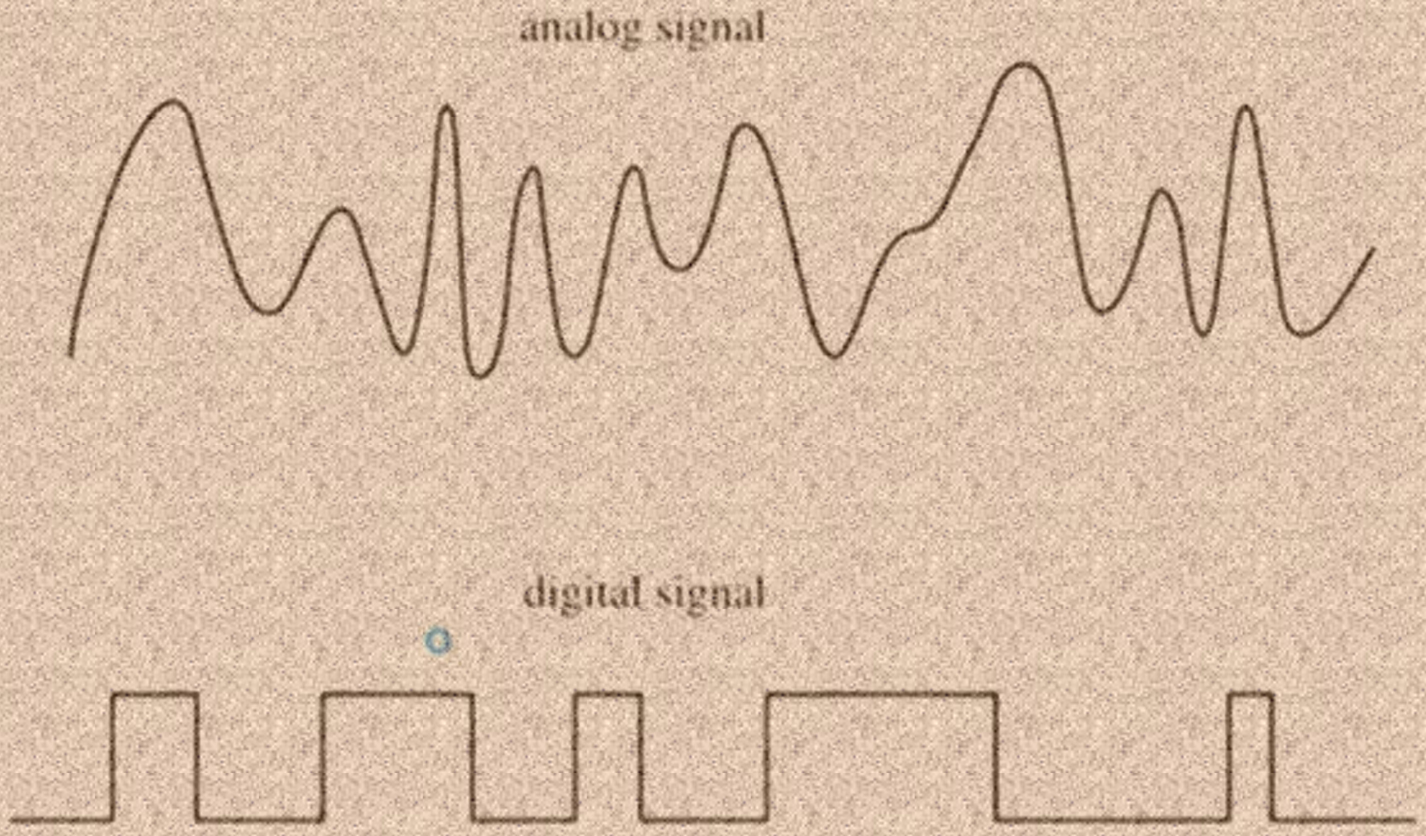
- Mechatronics: Bolton, W., Longman
- Introduction to Mechatronics: D.G. Alciatore & Michael B. Histand; Tata Mc Graw Hill
- Mechatronic system Design; Shetty Dedas, Kolk and Richard
- Mechatronic handbook: Bishop; CRC press
- Intelligent Mechatronic Systems: Modeling, Control and Diagnosis, R. Merzouki, A. K. Samantaray, P. M. Pathak, B. Ould Bouamama, Springer, London

Mechatronics system components



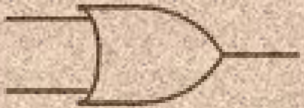
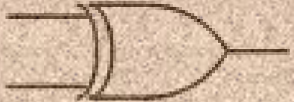
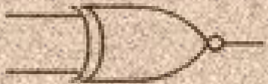
Analog & digital signals

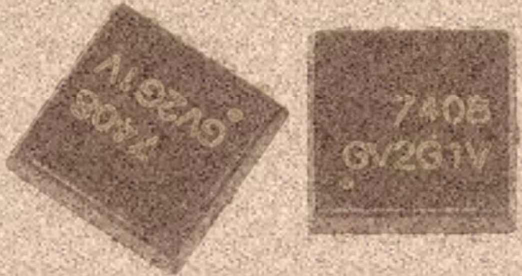
- Analog signal changes in a continuous manner
- A digital signal exists only at specific levels or states and changes its level in discrete steps



Digital Logics

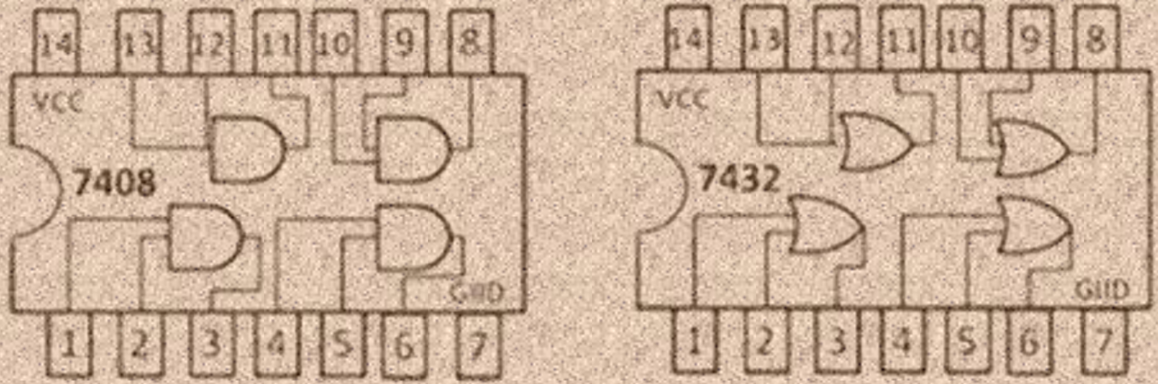
- These are controls which involves only two possible signal levels.
- Digital circuitry is the basis of digital computers and microprocessor controlled systems.
- This circuitry evolved from the transistor circuits which is being able to output one of the two voltage levels depending on the levels at its inputs.
- The two levels namely 5V and 0V are the high and low signals and represented by 1 and 0.
- The two levels of 0 and 1 may represent
- 1 |ON | Open |Yes|True |+5V
- 0 |OFF|Closed|No |False|0 V

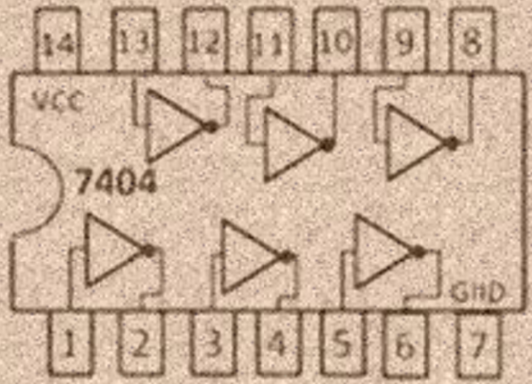
Logic Gate	Symbol	Description	Boolean
AND		Output is at logic 1 when, and only when all its inputs are at logic 1,otherwise the output is at logic 0.	$X = A \cdot B$
OR		Output is at logic 1 when one or more are at logic 1.If all inputs are at logic 0,output is at logic 0.	$X = A + B$
NAND		Output is at logic 0 when,and only when all its inputs are at logic 1,otherwise the output is at logic 1	$X = \overline{A \cdot B}$
NOR		Output is at logic 0 when one or more of its inputs are at logic 1.If all the inputs are at logic 0,the output is at logic 1.	$X = \overline{A + B}$
XOR		Output is at logic 1 when one and Only one of its inputs is at logic 1. Otherwise is it logic 0.	$X = A \oplus B$
XNOR		Output is at logic 0 when one and only one of its inputs is at logic1.Otherwise it is logic 1. Similar to XOR but inverted.	$X = \overline{A \oplus B}$
NOT		Output is at logic 0 when its only input is at logic 1, and at logic 1 when its only input is at logic 0.That's why it is called and INVERTER	$X = \overline{A}$

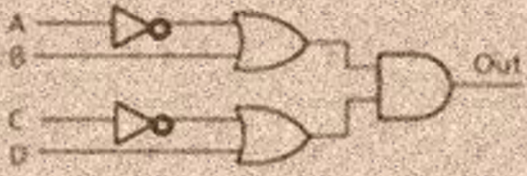


Integrated Circuits

- Logic gates are available as integrated circuits
- Circuits with their 74XX number are transistor-transistor logic(TTL) cct and are based on the use of transistors and operate between 0 to 5V level.







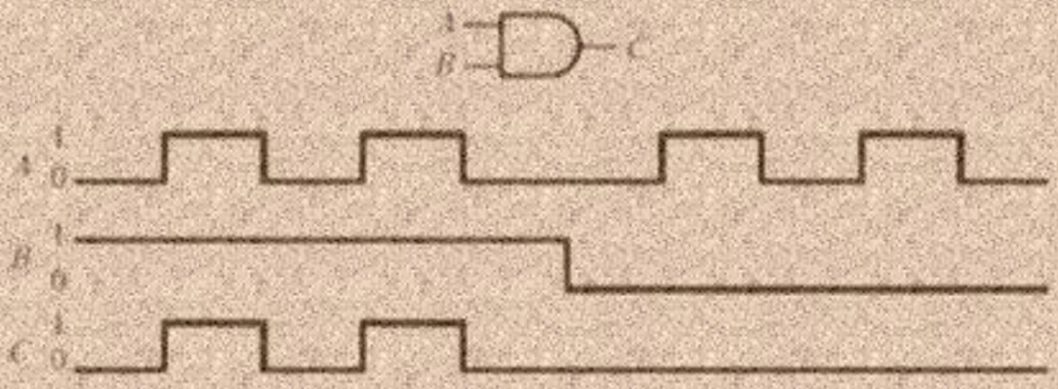
$$Out = (\bar{A} + B)(\bar{C} + D)$$

Combining Gates

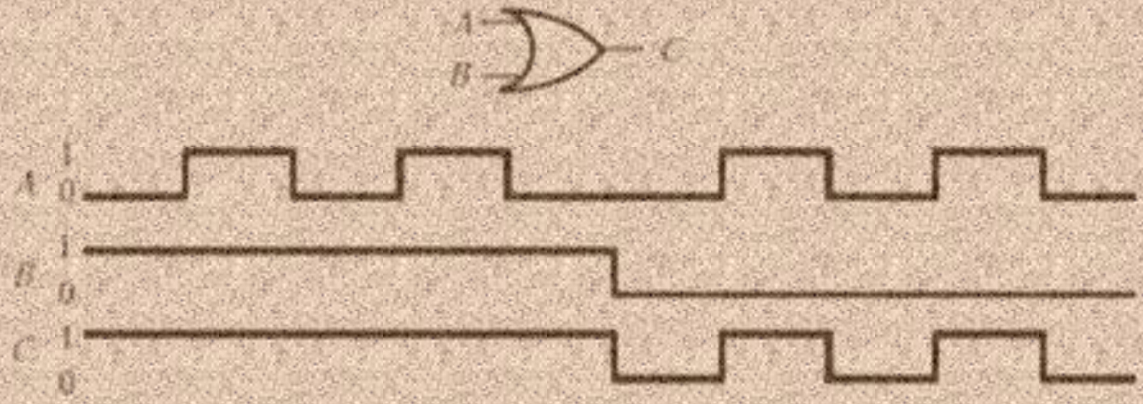
- All the gates are manufactured as IC where transistors, resistors and diodes exists in a single chip of silicon.
- There are two families of digital integrated circuits,
- TTL or transistor transistor logic: They have no's 74XX
- CMOS for complementary metal-oxide semiconductors.
- Voltage levels define logic low (0) and logic high (1) at the inputs and outputs.
- CMOS have nos 40XX
- High speed CMOS family have no 74HCXX

Timing Diagrams

- It shows simultaneous levels of the inputs and outputs in a circuit vs. time.
- The timing diagram can be used to illustrate every possible combination of input values and corresponding outputs, providing a graphical summary of the input/output relationships.



AND gate timing diagram



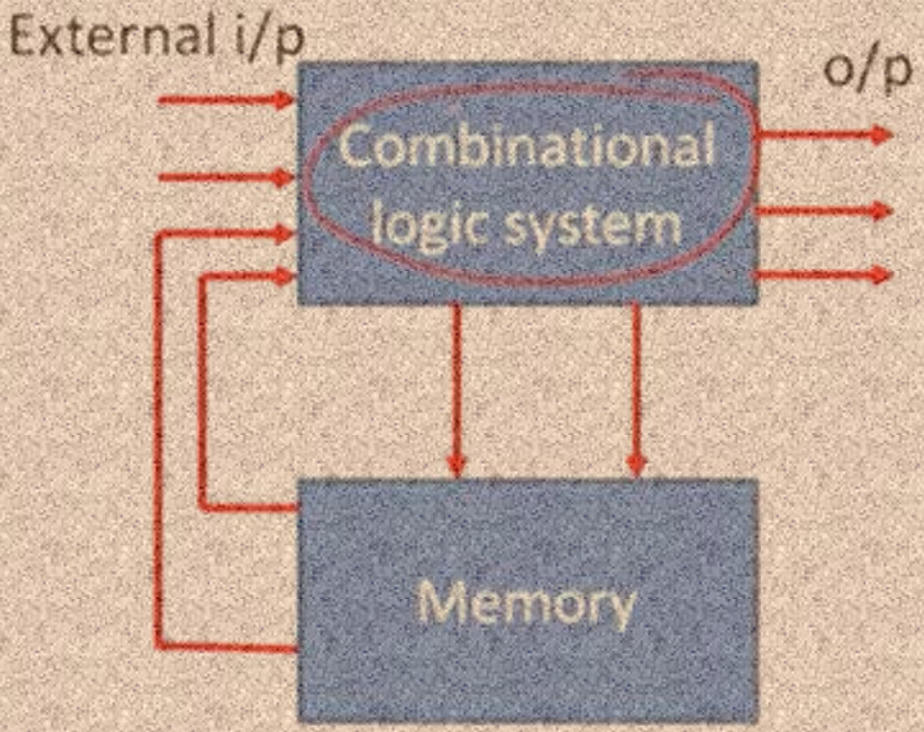
OR gate timing diagram

Design of Logic Networks

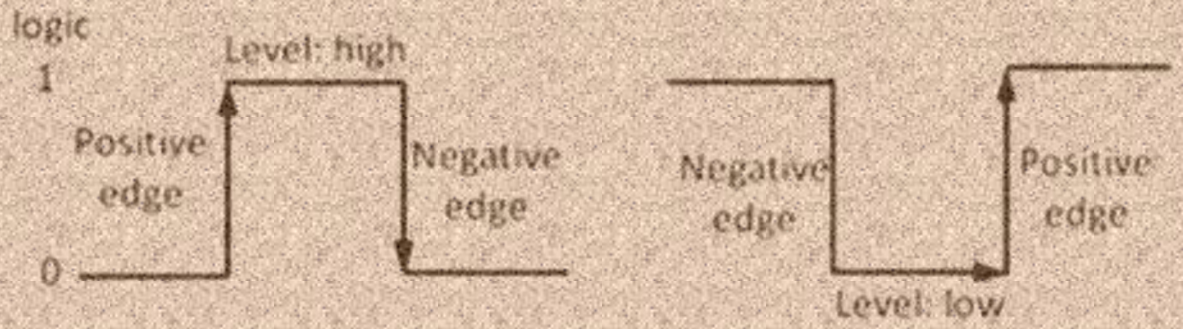
- Define the problem in words.
- Write quasi-logic statements in English that can be translated into Boolean expressions.
- Write the Boolean expressions.
- Simplify and optimize the Boolean expressions, if possible.
- Write an all-AND, all-NAND, all-OR, or all-NOR realization of the circuit to minimize the number of required logic gate IC components.
- Draw the logic schematic for the electronic realization of the circuit.

Sequential Logic

- In combinational logic system the o/p is determined by combination of the i/p variables at a particular instant of time.
- When a system requires an o/p which depends on earlier values of the i/p a sequential logic system is required.
- Thus a sequential logic system requires a memory.



- Sequential logic devices usually respond to inputs when a separate trigger signal transitions from one level to another.
- The trigger signal is usually referred as the **clock** (CK) signal.
- The clock signal can be a periodic square wave or an aperiodic collection of pulses.

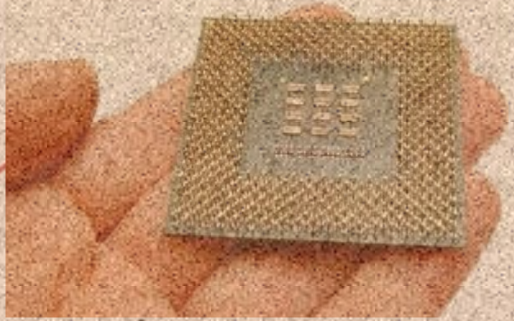


Clock Pulse Edge

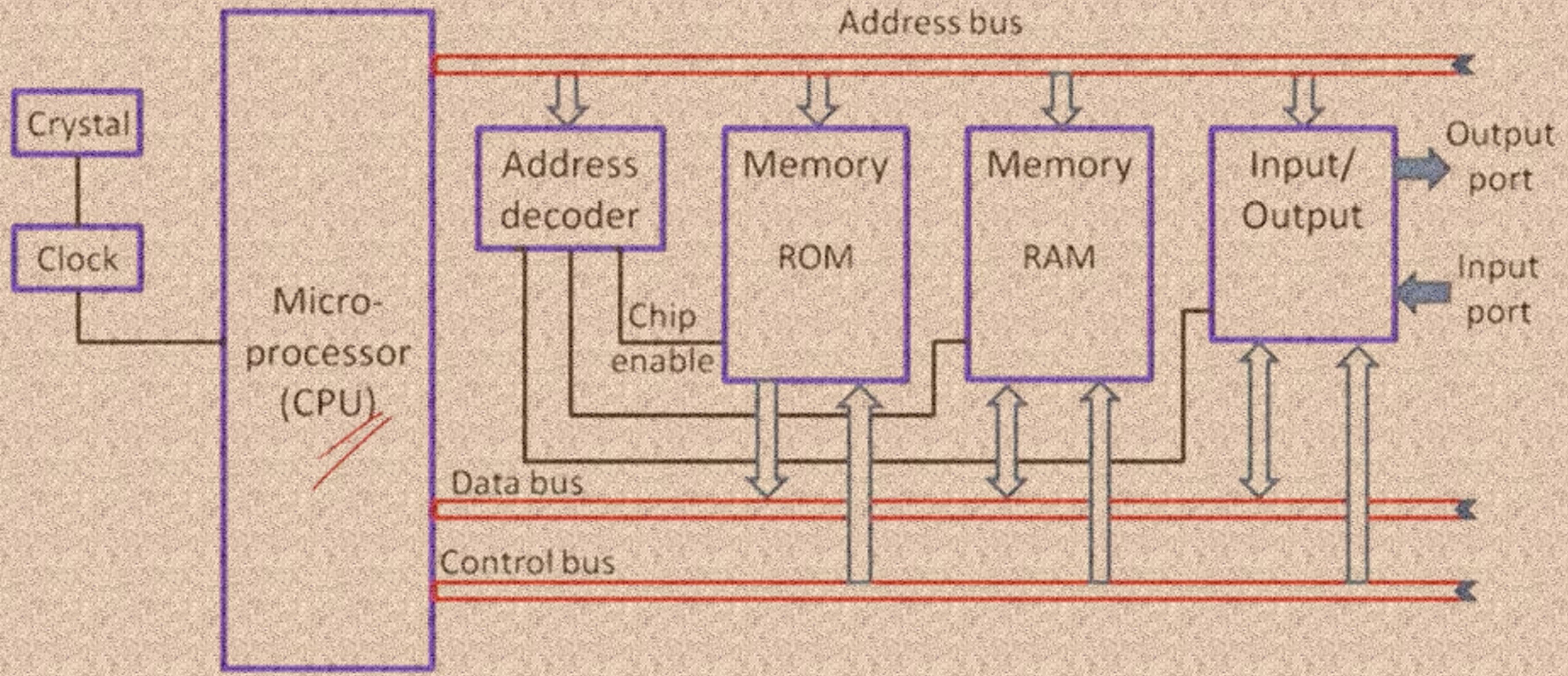
Introduction

- Simple control problem, can be solved by an electronic control system using combinational and sequential logic integrated circuits.
- However, with complex situation there might be many more variables to control in a more complex control sequence.
- With combinational and sequential logic IC wired connections are used to connect.
- For complex situations microprocessor are used and software is used to make the interconnections.

Microprocessor System



- Microprocessor system has three parts namely Central Processing Unit (CPU), Input & Output interfaces and Memory
- CPU recognise and carry out program instructions (this part of microprocessor system uses the microprocessor)
- I/P & O/P interfaces handle communications between the microprocessor and the outside world
- Memory hold the program instructions and data
- Microprocessor having memory, input & output arrangements all on same chip are microcontrollers



General form of a microcontroller system

Buses

- Digital signals moves from one section to another along paths called buses.
- Typically a bus may have 16 or 32 parallel connections so that each can carry 1 bit of a data word simultaneously.

- Types of bus available in a microprocessor system are
  1. Data bus
  2. Address bus
  3. Control bus

Data bus

- It carries data associated with processing function of CPU
- Used to transport a word to or from the CPU and the memory or the input/output interfaces.
- Each bit being carried by a separate wire in the bus
- More wire means longer word length
- For example: For a word of length 4 bits, the number of values it can have are $2^4 = 16$.

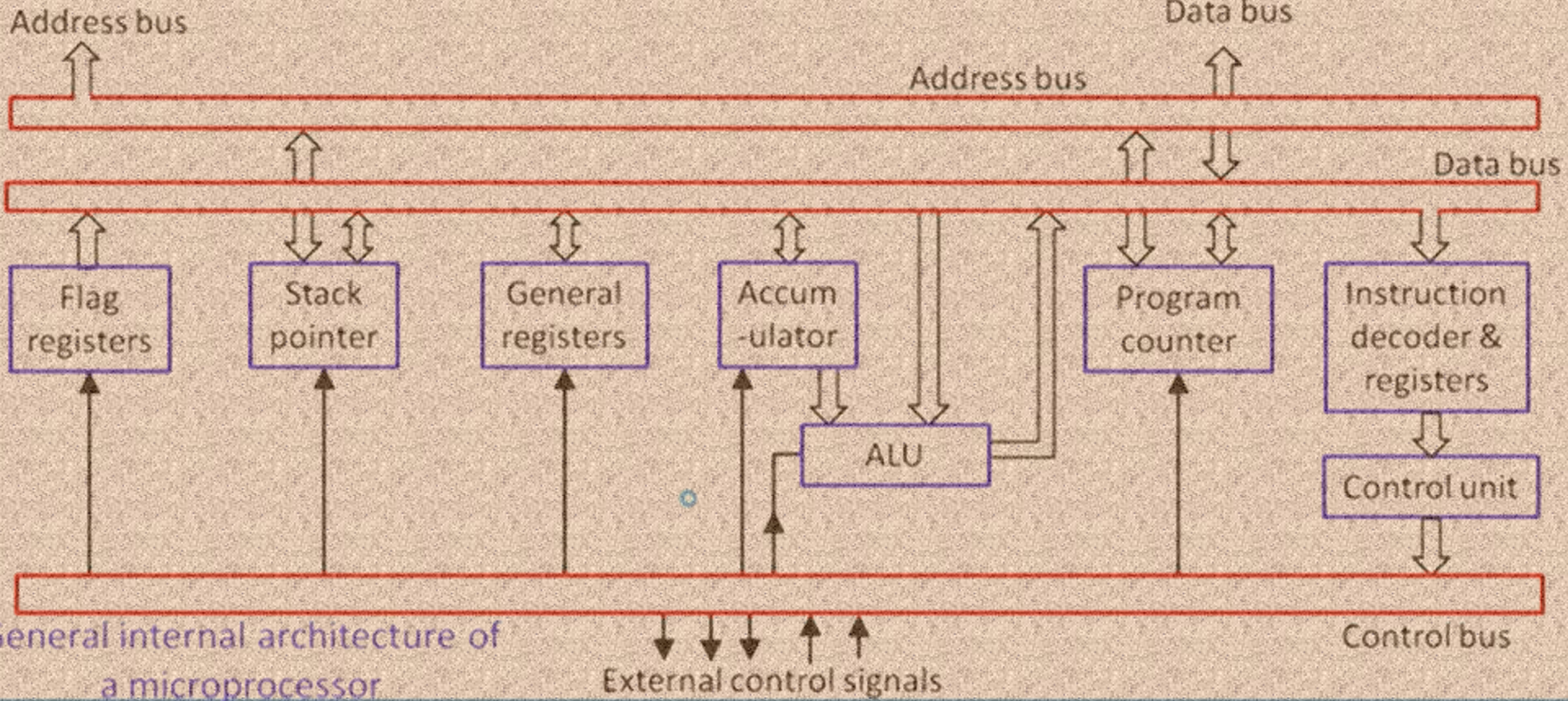
Address bus

- It carries signal which indicates where data is to be found.
- A computer with an 8-bit data bus has typically a 16-bit-wide address bus, i.e. 16 wires.
- This size of address bus enables 2^{16} locations to be addressed.
- 2^{16} indicates 65536 locations and is usually written as 64K, where K is equal to 1024.

Control Bus

- It carries signals related with control actions (e.g. operation of i/p, o/p devices).
- **READ** is used for receiving a signal.
- **WRITE** for sending a signal.
- The control bus is also used to carry the system clock signals to synchronize all the actions of the microprocessor system.

Microprocessor



General internal architecture of a microprocessor

Constituents parts of the microprocessor

1. Arithmetic and logic unit (ALU)- performs the data manipulations
2. Registers- are memory locations with in the microprocessor and used to store information involved in programme execution.
3. Control unit- determines the timing and sequence of operations.

Registers

1. Accumulator register- temporary holding register for data to be operated on by ALU and after operation holds the results.
2. Status register/flag register-
   - carries information concerning the results of the latest process carried out in ALU.
   - It carries individual bits called flags.
   - Used to indicate whether the last operation resulted in a negative result, a zero result, a carry output occurs, an overflow occurs or the program is allowed to be interrupted.

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
S	Z		AC		P		CY

- Common flags in status register

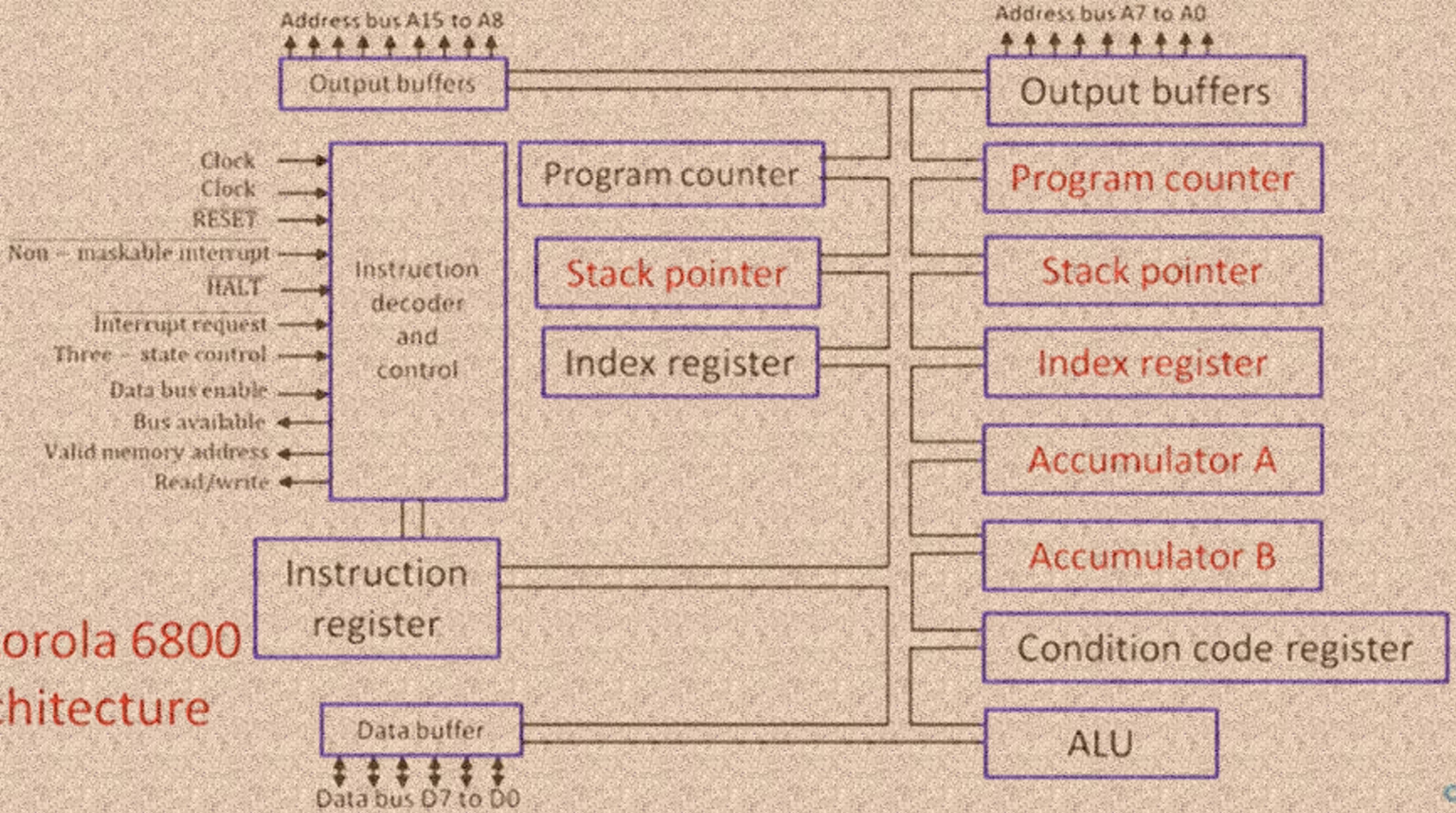
Flag	Set, i.e. 1	Reset, i.e. 0
Z	Result is zero	Result is not zero
N	Result is negative	Result is not negative
C	Carry is generated	Carry is not ignored
V	Overflow occurs	Overflow does not occur
I	Interrupt is ignored	Interrupt is processed normally

3. Programme counter register-

- It allows the CPU to keep track of its position in the program.
- Contains the address of the memory location that contains the next program instruction.
- The program counter is incremented each time so that the CPU executes instructions sequentially until, JUMP or BRANCH, changes the program counter out of that sequence.

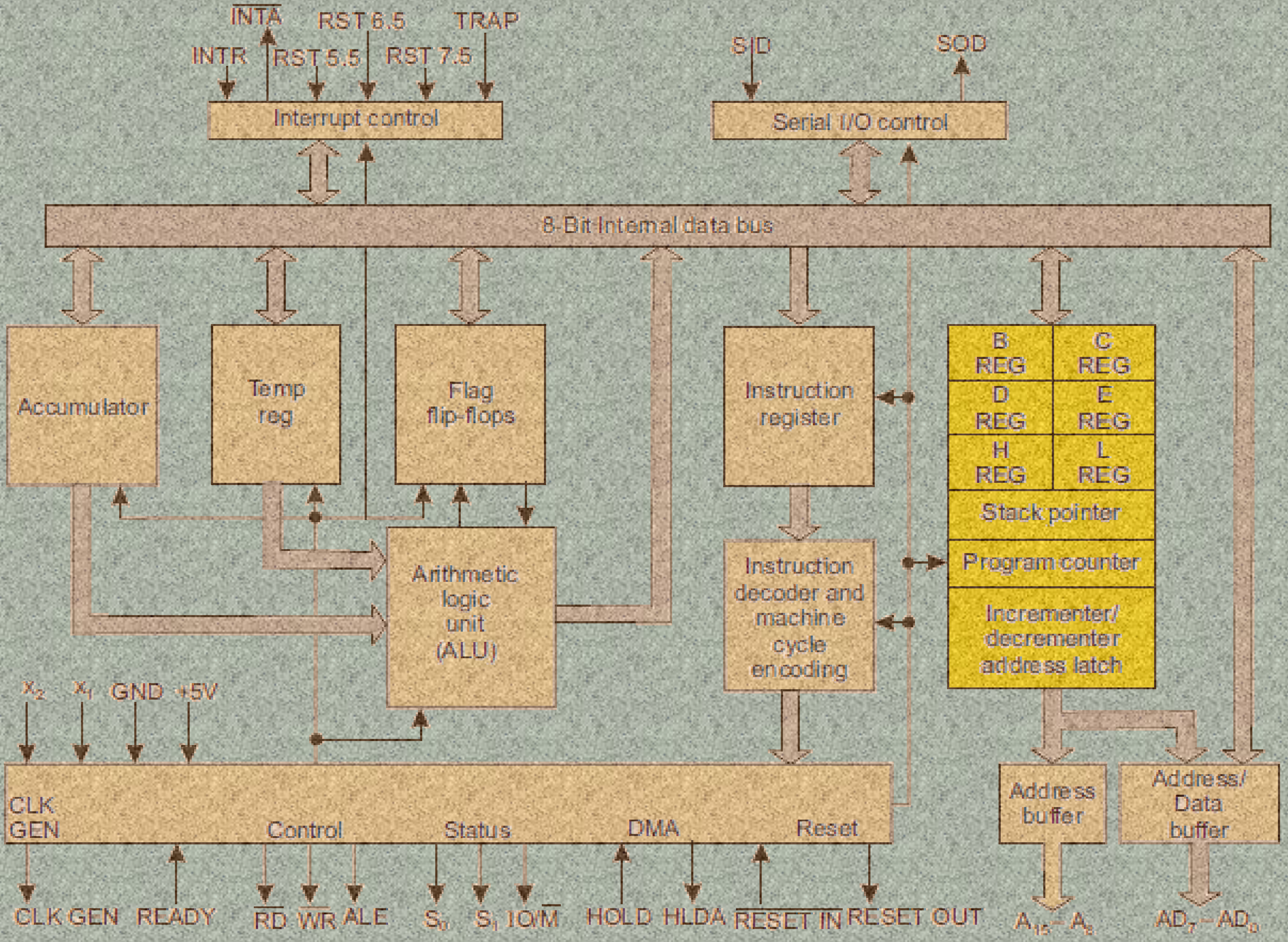
4. Memory address register- contains the address of data.
5. Instruction register - stores instructions.
6. General purpose register - temporary storage of data or addresses, involved in the transfer between registers.
7. Stack pointer register
   - Content of this register form an address which defines the top of stack in RAM.
   - Stack is a special area of the memory in which program counter values can be stored when a subroutine part of program is being used.

- The number and form of the registers depends on the microprocessor.
- For example, the Motorola 6800 microprocessor has two accumulator registers, a status register, an index register, a stack pointer register and a program counter register.



Motorola 6800 architecture

Microprocessor 8085 architecture



Architecture of 8085

Memory

- Memory units store binary data.
- Size of memory determined by the number of wires in the address bus.
- Memory unit consists of large number of storage cells with each cell capable of storing 0 or 1 bit.
- Storage cells grouped into a location with each location storing a word.
- In order to access the stored word each location is identified by a unique word.
- Size of memory specified in terms of no. of memory locations available. 1 K is 2^{10} =1024 (4K memory has 4096 locations.)

Forms of memory

1. ROM (Read only memory)-
   - permanent storage of data that CPU can read but CPU cannot write data on ROM.
   - ROM does not require a power supply to retain its data so called non volatile memory.
   - programmed with the required contents during the manufacture of the integrated circuit.

2. RAM (Random access memory)-

- can be read from or written to at any time provided power is there.
- Data is considered volatile because it is lost when power goes.
- Static RAM- retains data in flip flop as long as memory is powered.
- Dynamic RAM-consists of capacitor storage of data that must be refreshed (rewritten) periodically because of the charge leakage.

3. EPROM (Erasable programmable ROM)-

- Data stored can be erased with ultraviolet light through a transparent window at the top of the EPROM IC.
- Then new data can be stored on the EPROM.
- Other type of EPROM is electrically erasable (EEPROM)
- Data in this is electrically erasable and rewritten through its data line.

Input/Output

- Communication to and from the microprocessor occurs through I/O devices connected to the bus.
- External computer peripheral I/O devices are keyboards, printers, displays, modems, network device.
- For mechatronic applications A/D, D/A and digital I/O(D/D) provides interfaces to switches, sensors and actuators.
- Since the speed and characteristic of the peripheral devices differ with microprocessor, microprocessor are connected via an interface chip.

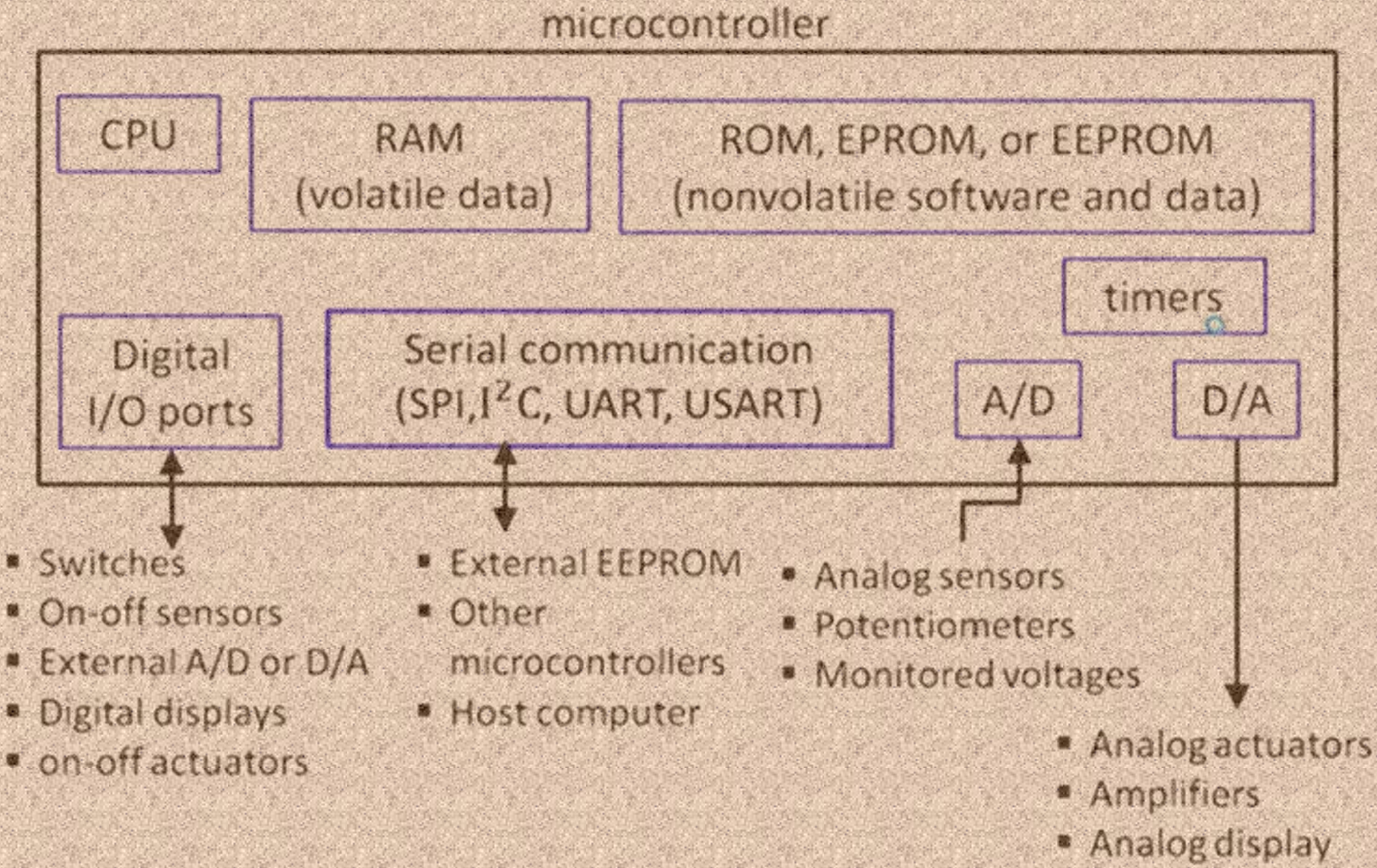
- Microprocessor accept valid data from interface chip which is indicated by the interrupt or polling (status bit set to 1).
- Polling is the process of repeated checking each peripheral device to see if it is ready to send or accept a new byte of data.

Microprocessor Programming

- Instructions executed by CPU are defined on binary code called machine code.
- Microprocessor can be programmed using assembly language having mnemonic command corresponding to each instructions.
- Assembly language converted to machine code using assembler.
- When set of instructions are small microprocessor is called RISC (reduced instruction set computer) microprocessor.

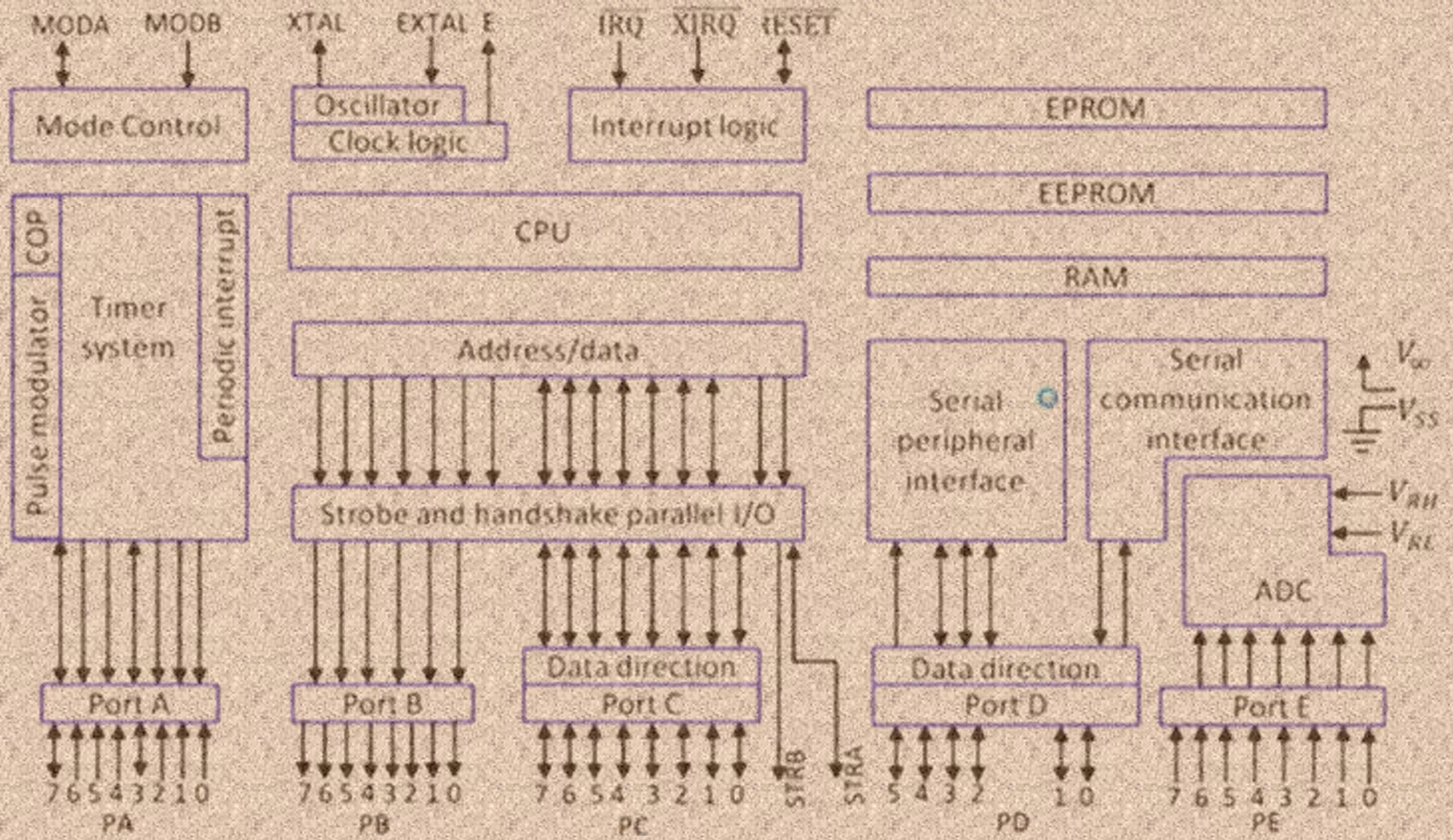
Microcontroller

- Microcontroller is the integration of a microprocessor with memory and input/output interfaces, and other peripherals such as timers, on a single chip.
- Microcontrollers have limited amounts of ROM and RAM and are widely used for embedded control systems.
- A microprocessor system with separate memory and input/output chips is more suited to processing information in a computer system.

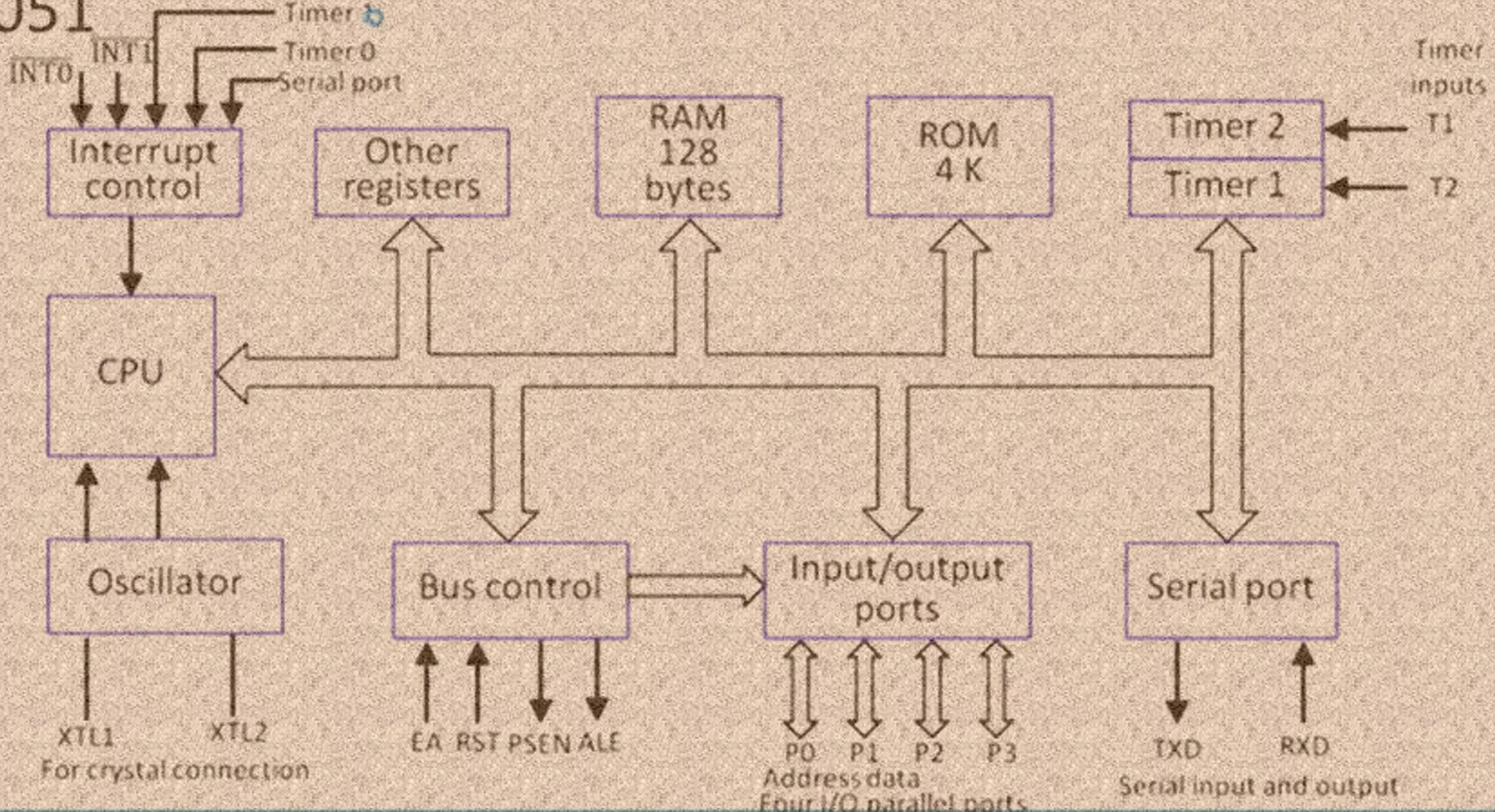


- SPI-serial peripheral interface
- I^{2}C -interintegrated circuit.
- UART-universal asynchronous receiver transmitter
- USART-universal synchronous asynchronous receiver transmitter

Motorola M68HC11



Intel 8051



INT0
INT1
Timer
Timer 0
Serial port
Interrupt control
Other registers
RAM 128 bytes
ROM 4 K
Timer 2
Timer 1
Timer inputs
T1
T2
CPU
Oscillator
Bus control
Input/output ports
Serial port
XTL1
XTL2
For crystal connection
EA RST PSEN ALE
P0 P1 P2 P3
Address data
Four I/O parallel ports
TXD
RXD
Serial input and output

	8051	PIC	AVR	ARM
Bus width	8-bit for standard core	8/16/32-bit	8/32-bit	32-bit mostly also available in 64-bit
Communication Protocols	UART, USART,SPI,I2C	PIC, UART, USART, LIN, CAN, Ethernet, SPI, I2S	UART, USART, SPI, I2C, (special purpose AVR support CAN, USB, Ethernet)	UART, USART, LIN, I2C, SPI, CAN, USB, Ethernet, I2S, DSP, SAI (serial audio interface), IrDA
Speed	12 Clock/instruction cycle	4 Clock/instruction cycle	1 clock/ instruction cycle	1 clock/ instruction cycle
Memory	ROM, SRAM, FLASH	SRAM, FLASH	Flash, SRAM, EEPROM	Flash, SDRAM, EEPROM
ISA	CLSC	Some feature of RISC	RISC	RISC
Memory Architecture	Harvard architecture	Von Neumann architecture	Modified	Modified Harvard architecture
Power Consumption	Average	Low	Low	Low
Families	8051 variants	PIC16,PIC17, PIC18, PIC24, PIC32	Tiny, Atmega, Xmega, special purpose AVR	ARMv4,5,6,7 and series
Community	Vast	Very Good	Very Good	Vast
Manufacturer	NXP, Atmel, Silicon Labs, Dallas, Cyprus, Infineon, etc.	Microchip Average	Atmel	Apple, Nvidia, Qualcomm, Samsung Electronics, and TI etc.
Cost (as compared to features provide)	Very Low	Average	Average	Low
Other Feature	Known for its Standard	Cheap	Cheap, effective	High speed operation Vast
Popular Microcontrollers	AT89C51, P89v51, etc.	PIC18fXX8, PIC16f88X, PIC32MXX	Atmega8, 16, 32, Arduino Community	LPC2148, ARM Cortex-M0 to ARM Cortex-M7, etc.

AVR	ARM
AVR micro controller refers to Advanced Virtual RISC (AVR).	ARM micro controller refers to Advanced RISC Micro-controller (ARM).

RISC (Reduced Instruction Set Computer)

To reduce the numbers of clock cycles

Tiva ARM Cortex M4 Microcontroller: Features

Feature	Description
Performance	
Core	ARM Cortex-M4F processor core
Performance	80-MHz operation; 100 DMIPS performance
Flash	256 KB single-cycle Flash memory
System SRAM	32 KB single-cycle SRAM
EEPROM	2KB of EEPROM
Internal ROM	Internal ROM loaded with TivaWare™ for C Series software
Security	
Communication Interfaces	
Universal Asynchronous Receivers/Transmitter (UART)	Eight UARTs
Synchronous Serial Interface (SSI)	Four SSI modules
Inter-Integrated Circuit (I^2C)	Four I^2C modules with four transmission speeds including high-spee mode
Controller Area Network (CAN)	Two CAN 2.0 A/B controllers
Universal Serial Bus (USB)	USB 2.0 OTG/Host/Device
System Integration	
Micro Direct Memory Access (μDMA)	ARM® PrimeCell® 32-channel configurable μDMA controller
General-Purpose Timer (GPTM)	Six 16/32-bit GPTM blocks and six 32/64-bit Wide GPTM blocks
Watchdog Timer (WDT)	Two watchdog timers
Hibernation Module (HIB)	Low-power battery-backed Hibernation module
General-Purpose Input/Output (GPIO)	Six physical GPIO blocks
Advanced Motion Control	
Pulse Width Modulator (PWM)	Two PWM modules, each with four PWM generator blocks and a control block, for a total of 16 PWM outputs.
Quadrature Encoder Interface (QEI)	Two QEI modules
Analog Support	
Analog-to-Digital Converter (ADC)	Two 12-bit ADC modules, each with a maximum sample rate of one million samples/second
Analog Comparator Controller	Two independent integrated analog comparators
Digital Comparator	16 digital comparators
JTAG and Serial Wire Debug (SWD)	One JTAG module with integrated ARM SWD
Package Information	
Package	64-pin LQFP
Operating Range (Ambient)	Industrial (-40°C to 85°C) temperature range Extended (-40°C to 105°C) temperature range

Tiva ARM Cortex M4 Microcontroller: Features

TM4C123GH6PM