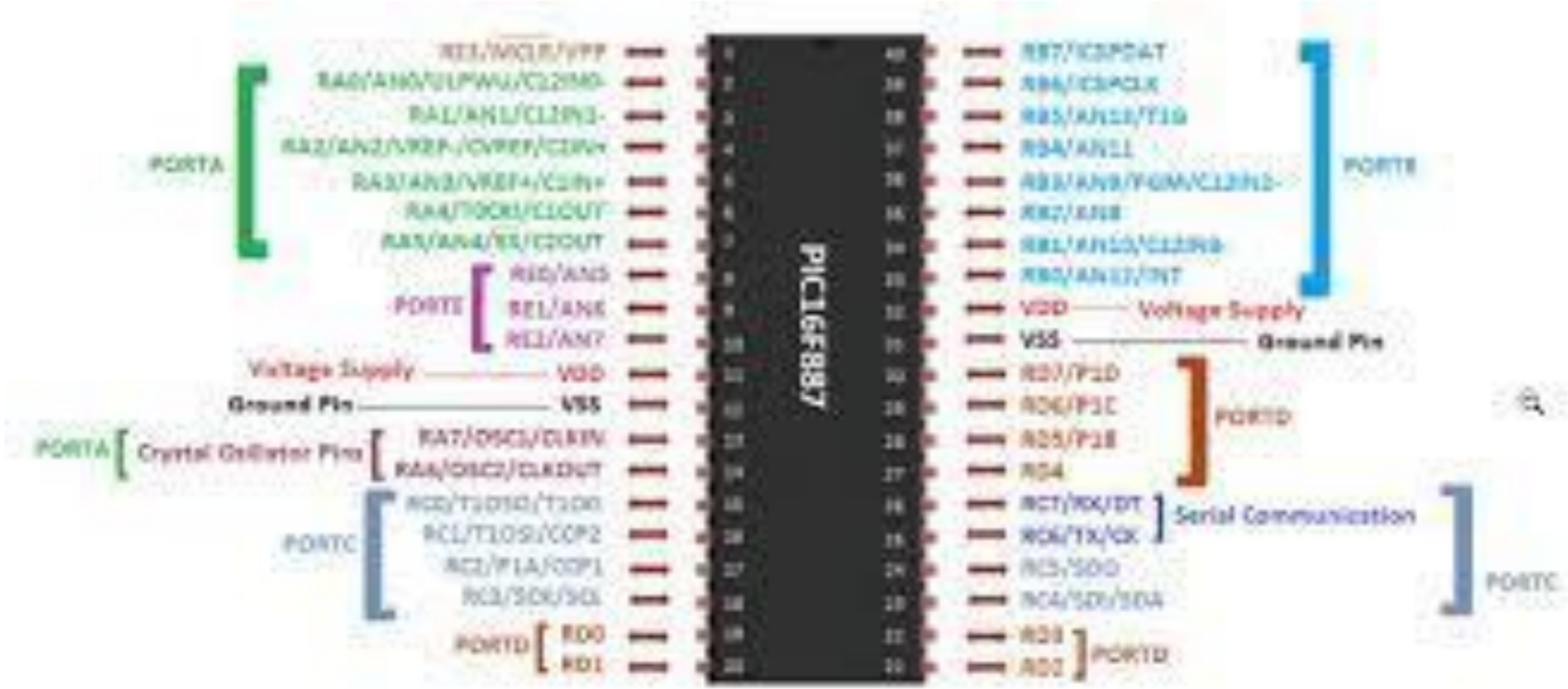
COE3062

Microcontrollers & Embedded Systems

Department of Computer Engineering

General Sir John Kotelawala Defence University.

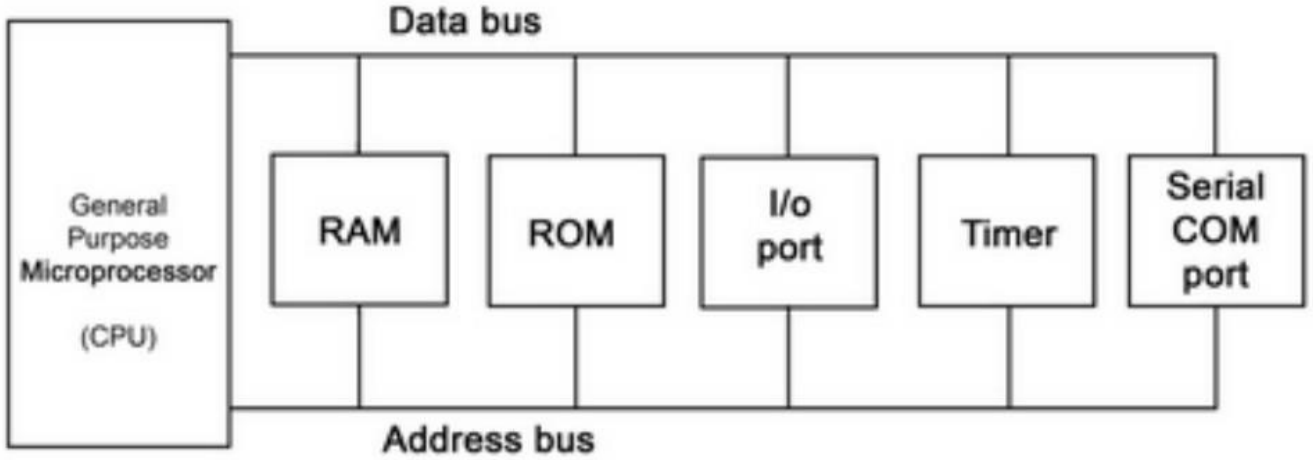
PIC Microcontroller



Micro-controllers - Introduction

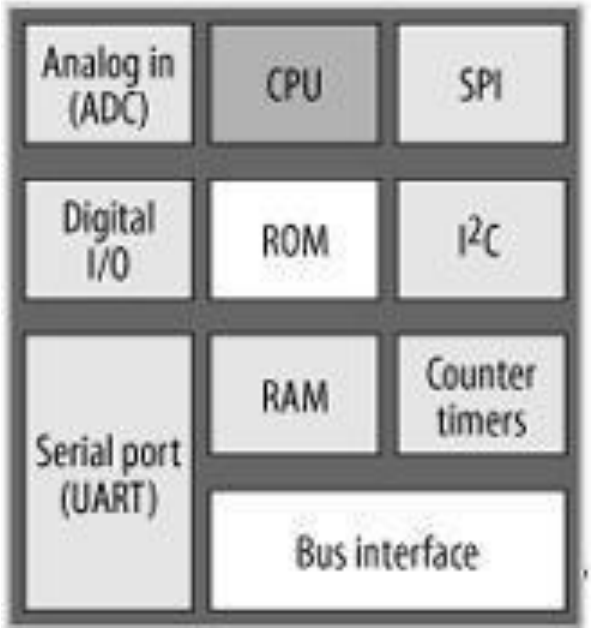
- Embedded System Hardware

- Microprocessor in a PC

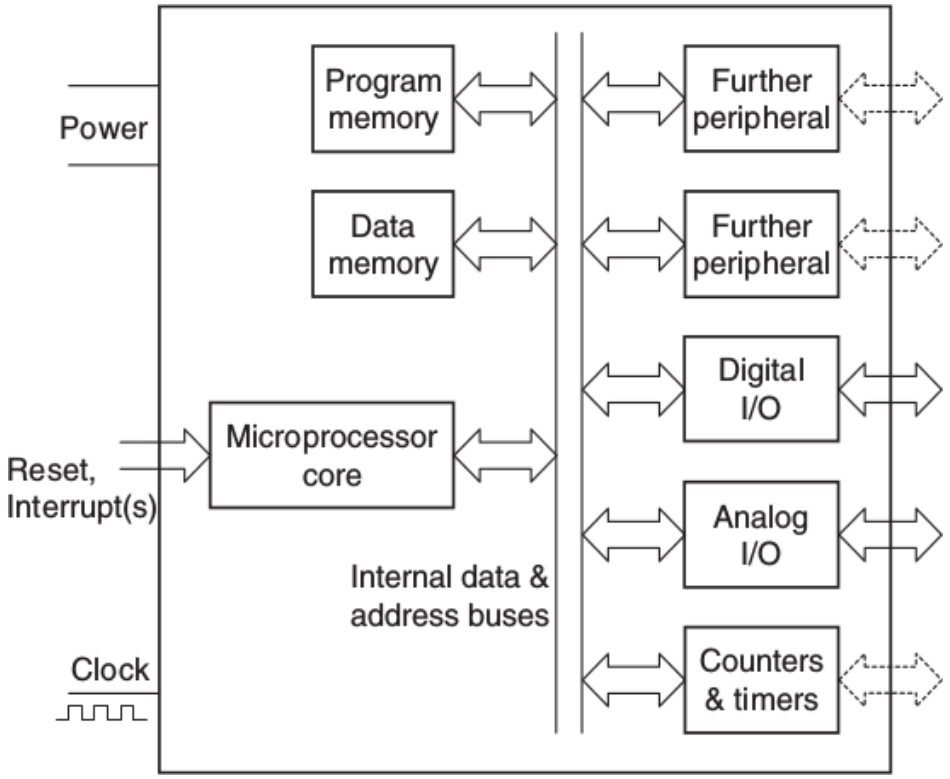


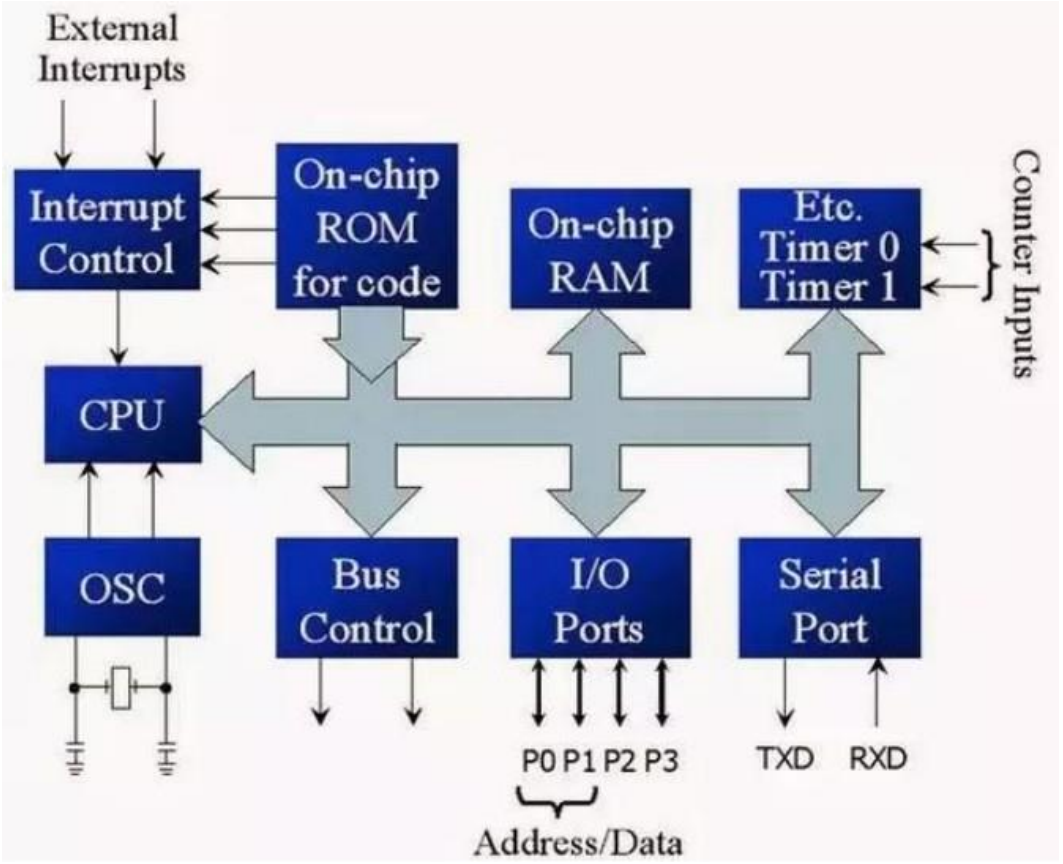
Micro-controllers - Introduction

- Smaller Embedded systems use micro-controllers
- All the components required for computer functionalities are incorporated in a single chip
- A micro-controller has minimum
  - A CPU
  - Small amount of internal memory
  - Some form of I/O
  - Interfaces to connect microcontrollers with external peripherals and host computers
    Serial, SPI, I2C, Bus Interface
  - Timers and counters



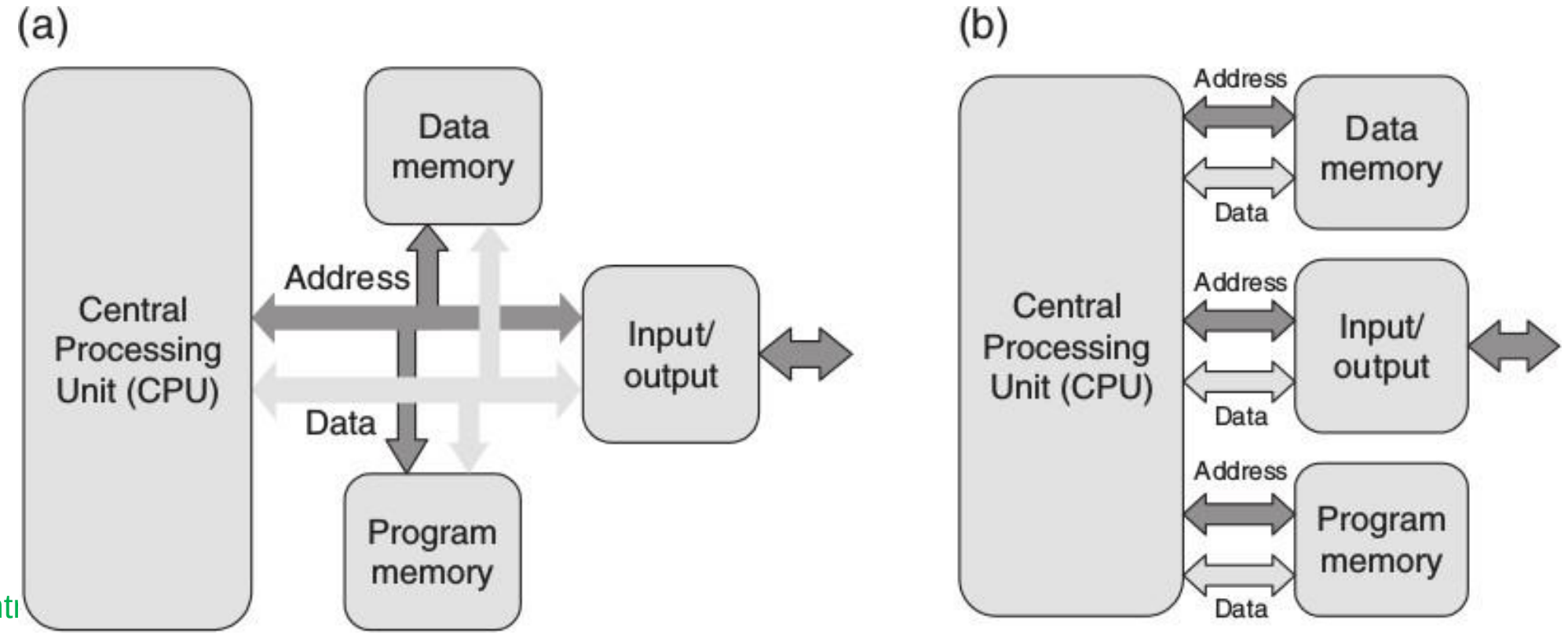
Generic Micro-controller





Micro-controller Architectures

- Memory Organization
  a) Von - Neumann
  b) Harvard



Micro-controller Architectures

- Memory Organization
  a) Von - Neumann
  - Simple and logical
  - Flexible in memory division with data and instructions
  - “one size fits all” approach (same word size for data and instructions)
  - Buses are shared for data , instructions

(b) Harvard
  - Flexible bus size for data and instructions
  - Increased complexity due to multiple busses
  - Enforces data and program separation

Micro-controller Architectures

- CISC
  - Complex Instruction Set Computer
  - Instructions provided for complex operations - closer to high level language
  - Instructions of different lengths and different formats
  - Many different addressing modes
  - Requires multiple clock cycles (varying number) for execution

Micro-controller Architectures

- RISC
  - Reduced Instruction Set Computer
  - Instructions provided only for simple operations
  - Instructions of fixed lengths (mostly consistent format)
  - Load store architecture
  - Requires fixed number of clock cycles (one or many) for execution

Micro-controller Architectures

- Complex Embedded systems like mobile phones uses a “Application Processor” with more powerful CPU, sub systems and interfaces
- Almost all mobile application processors are RISC processors
  - CISC processors generate more heat and consume more power
  - Smaller size of RISC processors
- Instruction Set Architectures (ISA)
  - ARM (Advanced RISC Machines) - ARM is the most popular. Nearly 80% high end embedded CPUs are ARM based
  - X86, A64, MIPS, SupperH, PowerPC
  - Lot of Mobile Application processor manufacturers reuse ARM processor cores from ARM Limited (www.arm.com)

Micro-controllers

- Many varieties of Micro-controllers are available, designer should choose micro-controller depending on design needs
  - Bits (Bus size)
  - Memory size (ROM/FLASH/RAM)
  - Number of I/O line
  - Packaging type
  - Power consumption
  - Supply voltage
  - Speed
  - Size
  - etc….

Micro-controllers

- Some Micro-controller types
  - Microchip-- PIC® Micro-controllers

    RISC architecture (reduced instruction set computer), Has sold over 2 billion as of 2002, Cost effective and rich in peripherals
  - Motorola now Freescale

    CISC architecture, Has hundreds of instructions, Examples: 68HC05, 68HC08, 68HC11
  - Intel now Marvell

    CISC architecture, Has hundreds of instructions, Examples: 8051, 8052 (Many manufacturers)
  - Atmel

    RISC architecture, Cost effective and rich in peripherals, AVR
  - Many more manufacturers

    Qualcomm, TI (OMAP) , AMD , Renesas (SuperH), Samsung ARM Cores, ST Micro STPC, MTK, etc...

PIC Micro-controllers

- PIC - “Peripheral Interface Controller” by General Instruments in late 1970’s
- PIC ® 1650 and 1655 processors.
  - completely stand-alone, was a RISC structure, with a single Working register and just 30 instructions.
  - The output pins could source or sink much more current than most other microprocessors of the time. (trademarks of the PIC)
  - were emerging – simplicity, stand-alone, high speed and low cost.
- General Instruments sold off its semiconductor division -> Microchip
- Microchip made their development tools simple and low cost or free

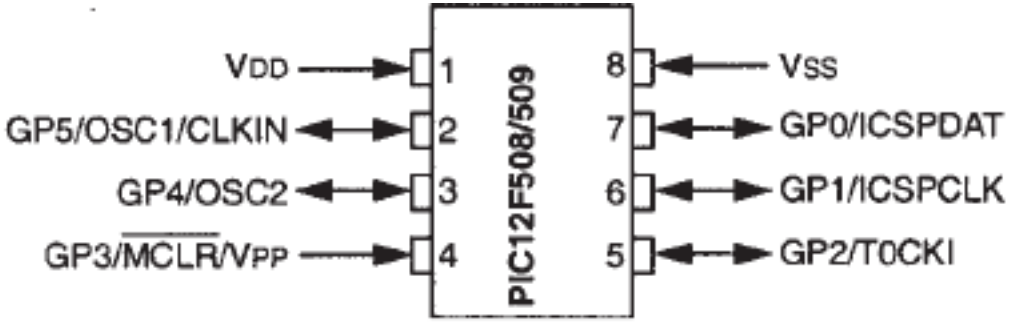
PIC Micro-controllers

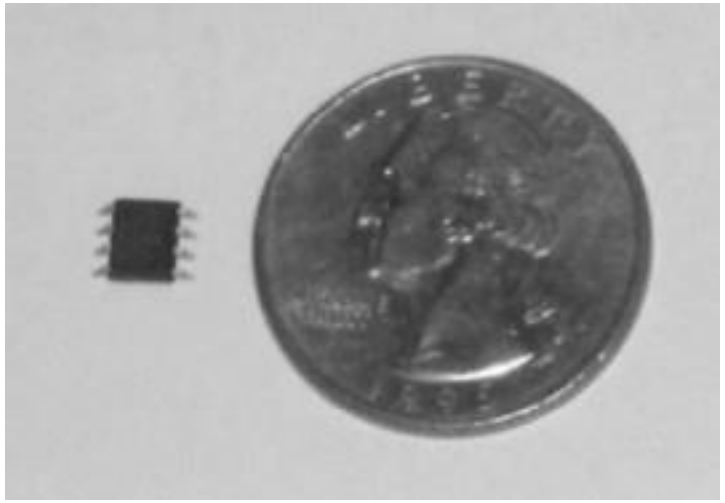
- Pic Micro-controller family

PIC family	Stack size (words)	Instruction word size	Number of instructions	Interrupt vectors
12CXXX/12FXXX	2	12- or 14-bit	33	None
16C5XX/16F5XX	2	12-bit	33	None
16CXXX/16FXXX	8	14-bit	35	1
17CXXX	16	16-bit	58, including hardware multiply	4
18CXXX/18FXXX	32	16-bit	75, including hardware multiply	2 (prioritised)

PIC Micro-controllers

- Example - 12 Series

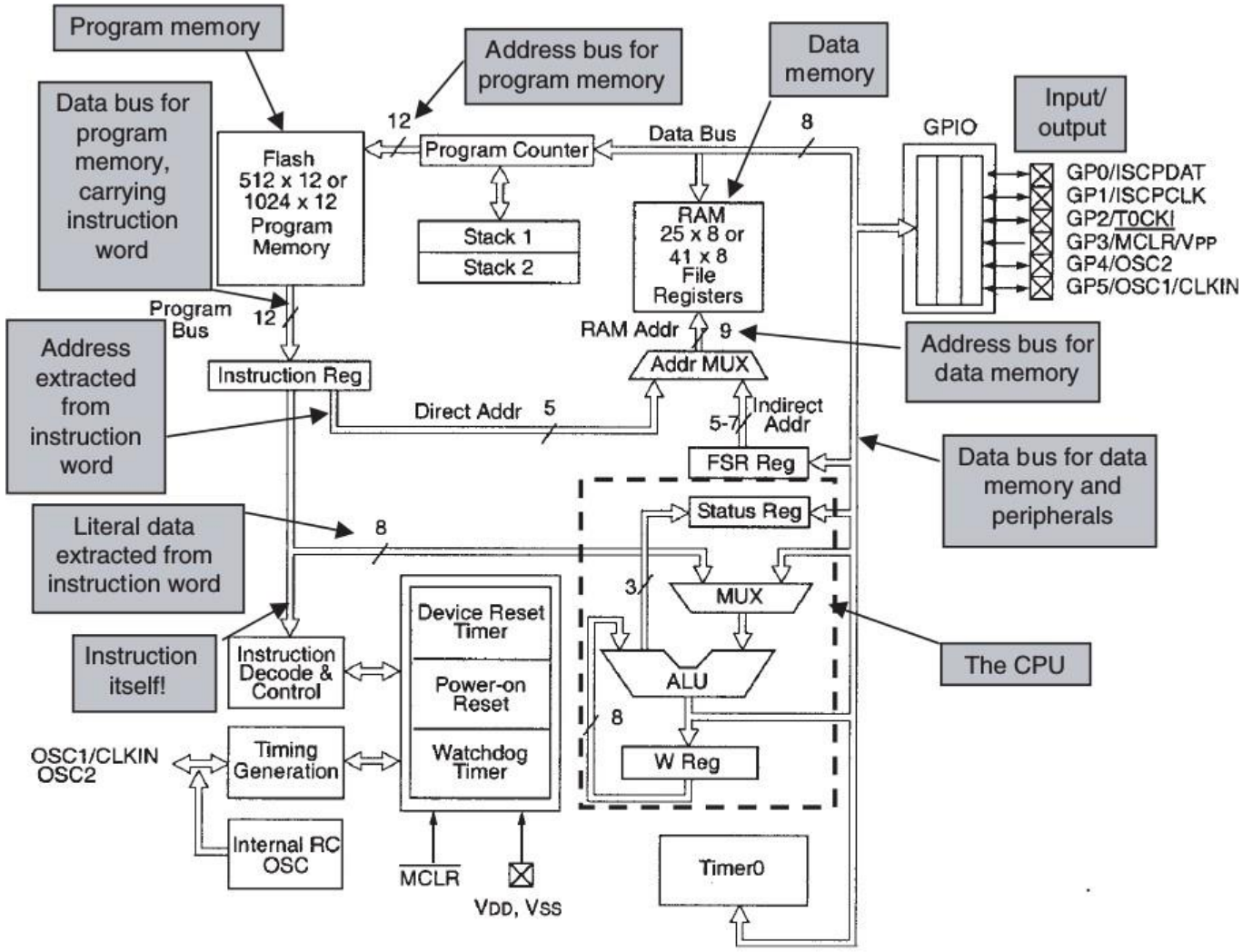




Key

V_{DD}:	Power supply	V_{SS}:	Ground
V_{PP}:	Programming voltage input	MCLR:	Master clear
OSC1, OSC2:	Oscillator pins	CLKIN:	External clock input
GP0 to GP5:	General-Purpose input/output pins (bidirectional except GP3)		
CSPDAT:	In-Circuit Serial Programming™ data pin.		
CSPCLK:	In-Circuit Serial Programming™ clock pin.		

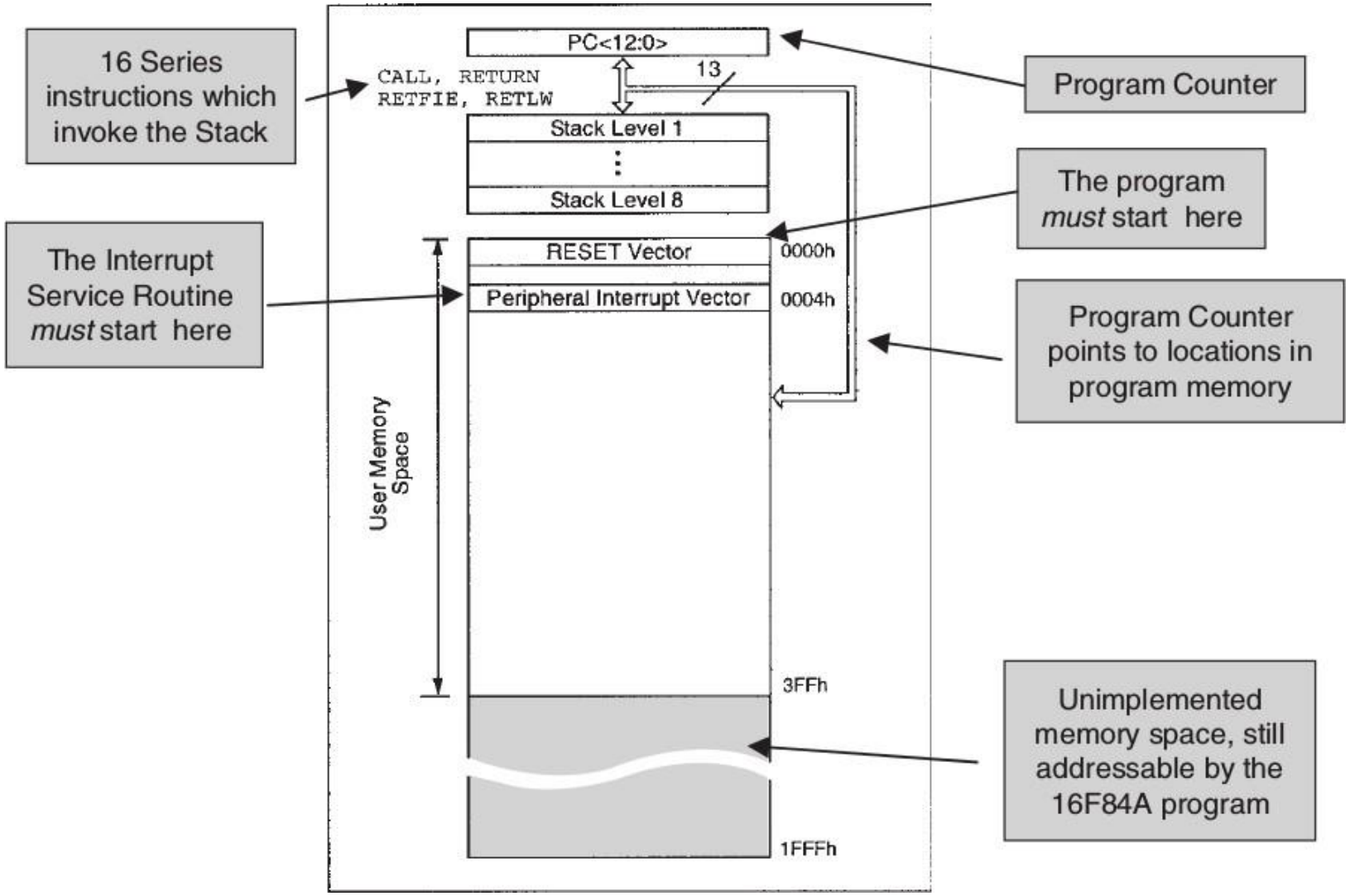
Micro-controllers - PIC



Key *(See also Key to Figure 1.11)*

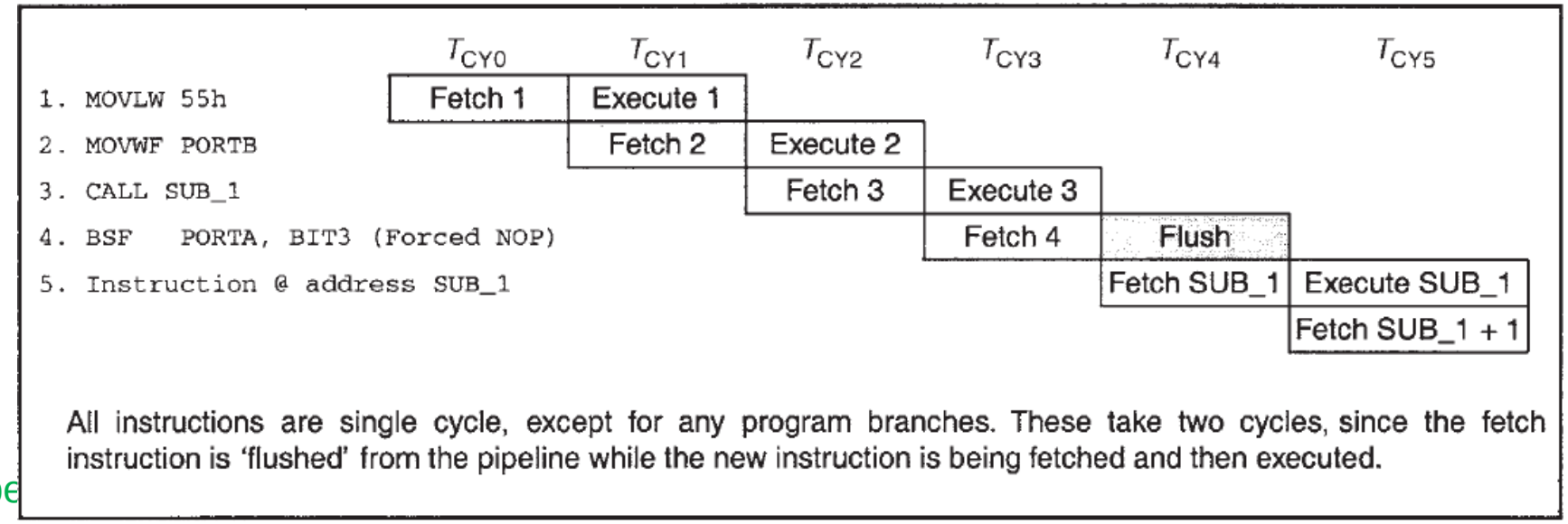
FSR:	File Select Register	GPIO:	General-Purpose Input/Output
MUX:	Multiplexer	RC:	Resistor capacitor
W reg:	Working register		

Micro-controllers - PIC



PIC Micro-controllers

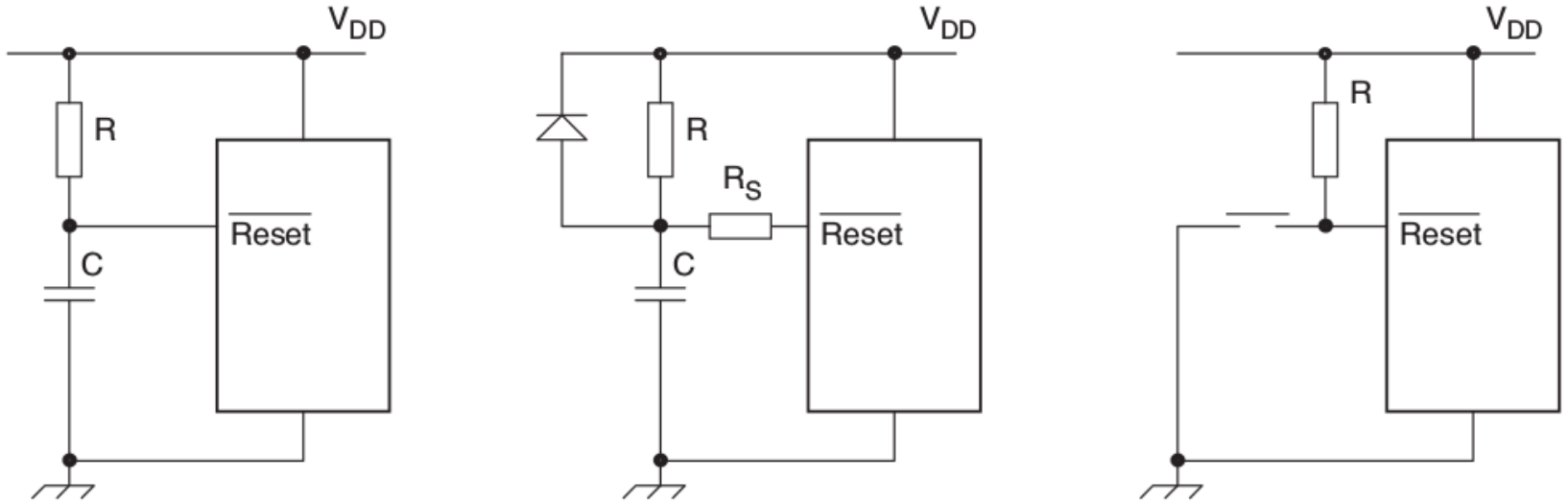
- Clock oscillator and instruction cycle
  - Within any microprocessor, the main clock signal is immediately divided down by a fixed value into a lower-frequency signal. Each cycle of this slower signal is called either a machine cycle or an instruction cycle.
  - In PIC 16 Series microcontrollers the main oscillator signal is divided by 4 to produce the instruction cycle time.
- Pipelining



All instructions are single cycle, except for any program branches. These take two cycles, since the fetch instruction is 'flushed' from the pipeline while the new instruction is being fetched and then executed.

PIC Micro-controllers

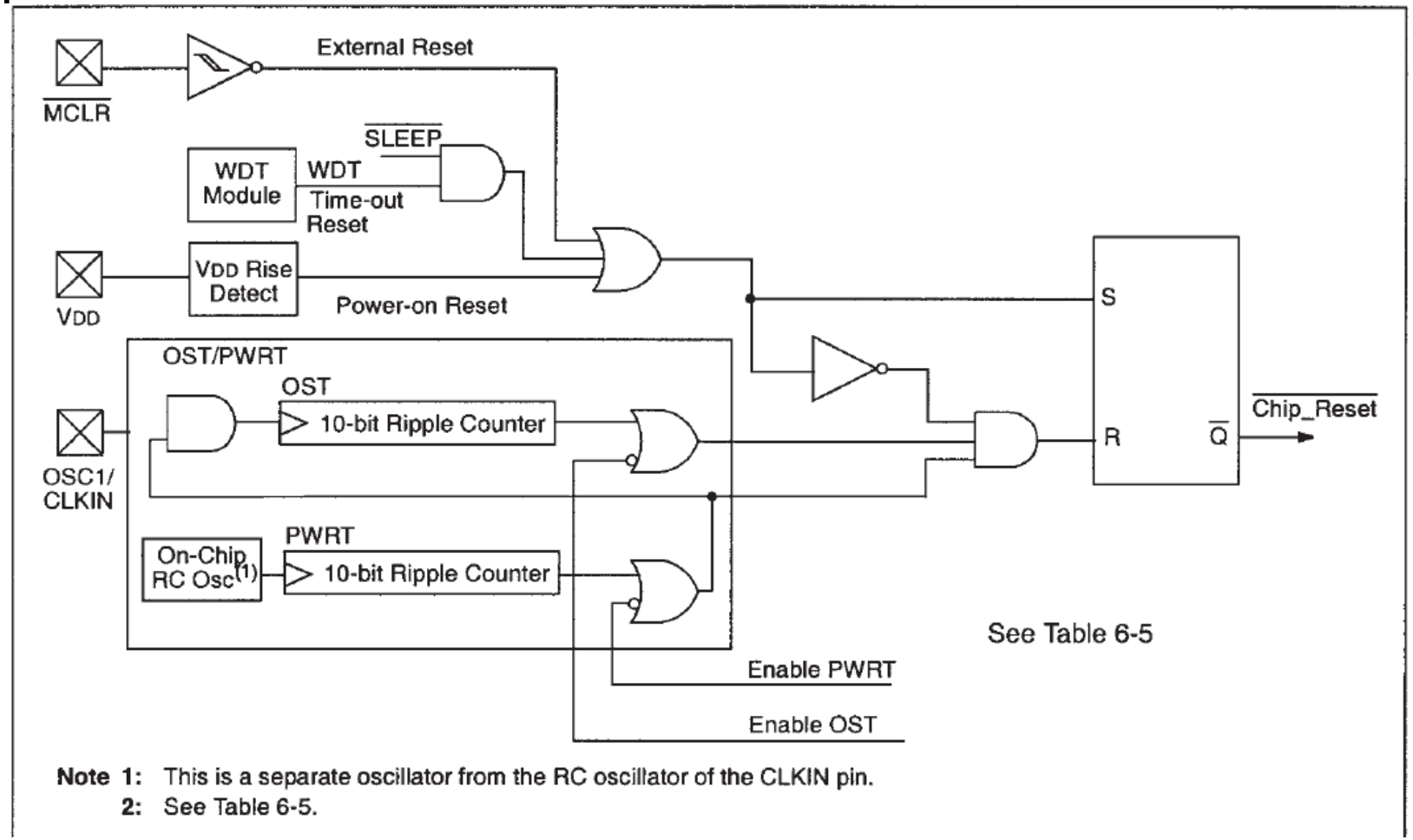
- Power-up and Reset
  - ‘ready-to-start’ condition is called Reset



  - 16F84A includes some sophisticated on-chip reset circuitry, which in many situations makes the components above unnecessary. A Power- up Timer (PWRT) is included on-chip,

PIC Micro-controllers

- Power-up and Reset



Note 1: This is a separate oscillator from the RC oscillator of the CLKIN pin.
2: See Table 6-5.

PIC Micro-controllers

- Digital I/O

  All micro-controllers have digital I/O pins (Ports) PIC 12F675 has 6 I/o Pins

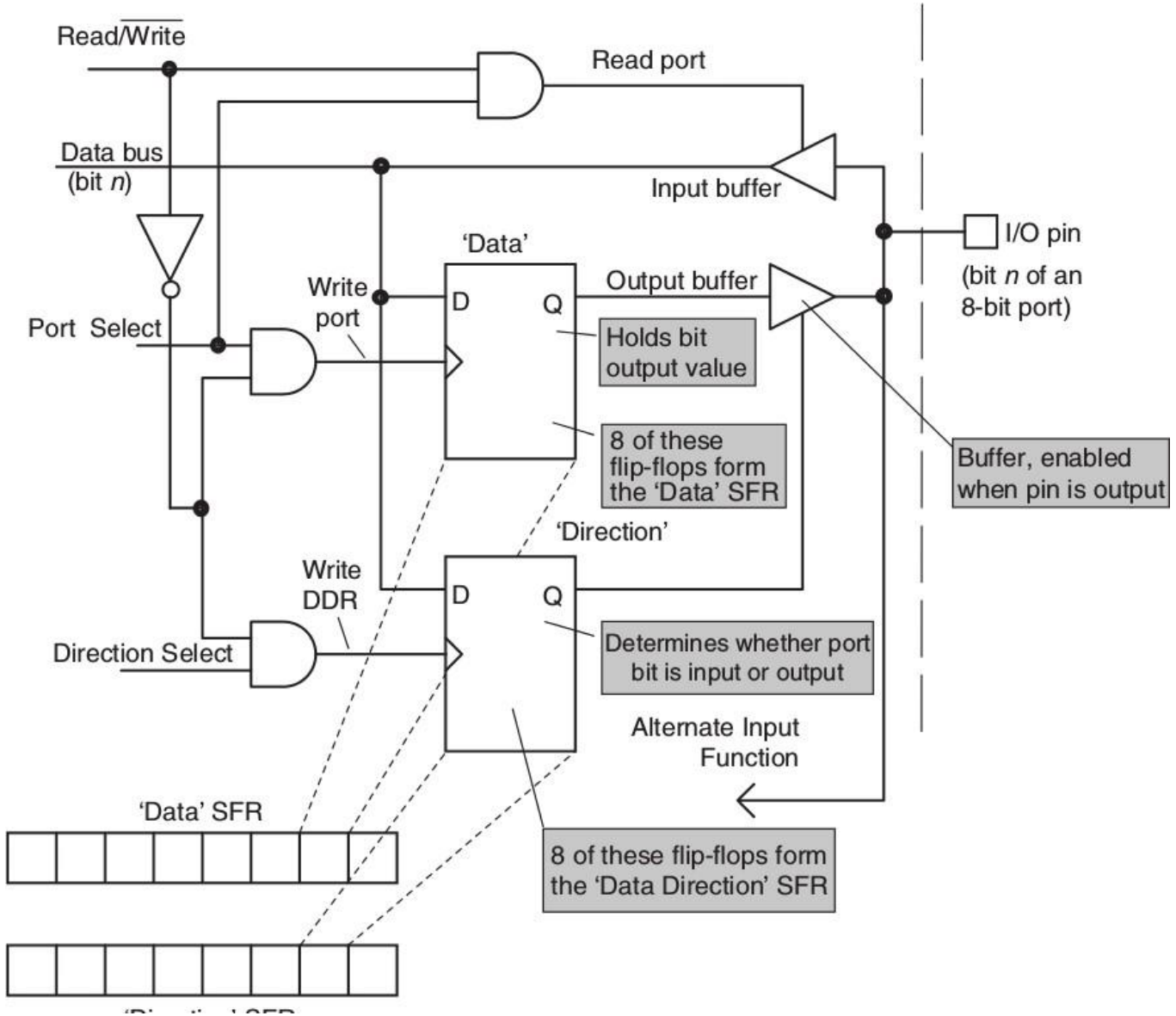
  PIC16F877A has 33 I/O Pins
  - Ports used to control and monitor external devices
  - They have 2 control registers

  TRIx sets whether each pin is input or output PORTx sets the output logic levels

  Most Pins can source or sink 25mA of current

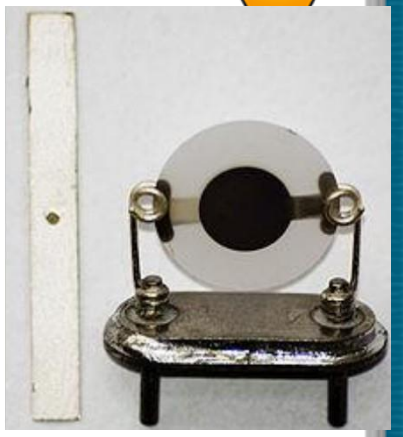
PIC Micro-controllers

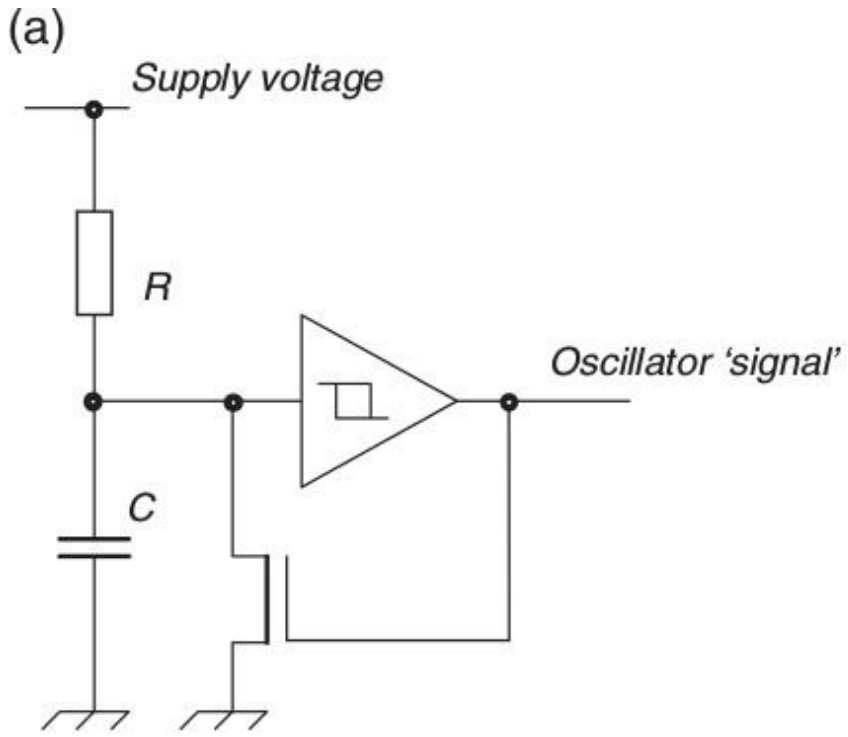
- Digital I/O

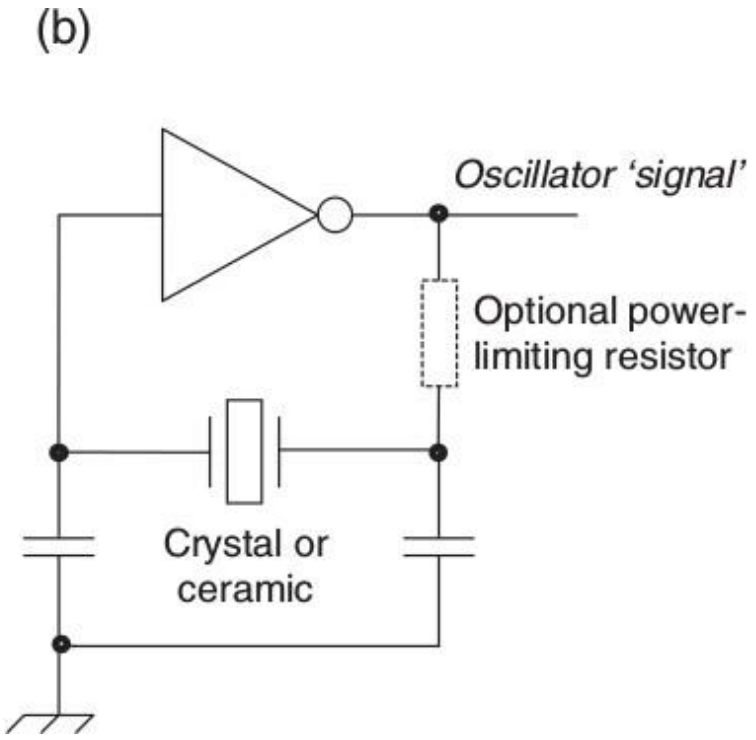


PIC Micro-controllers

- Clock





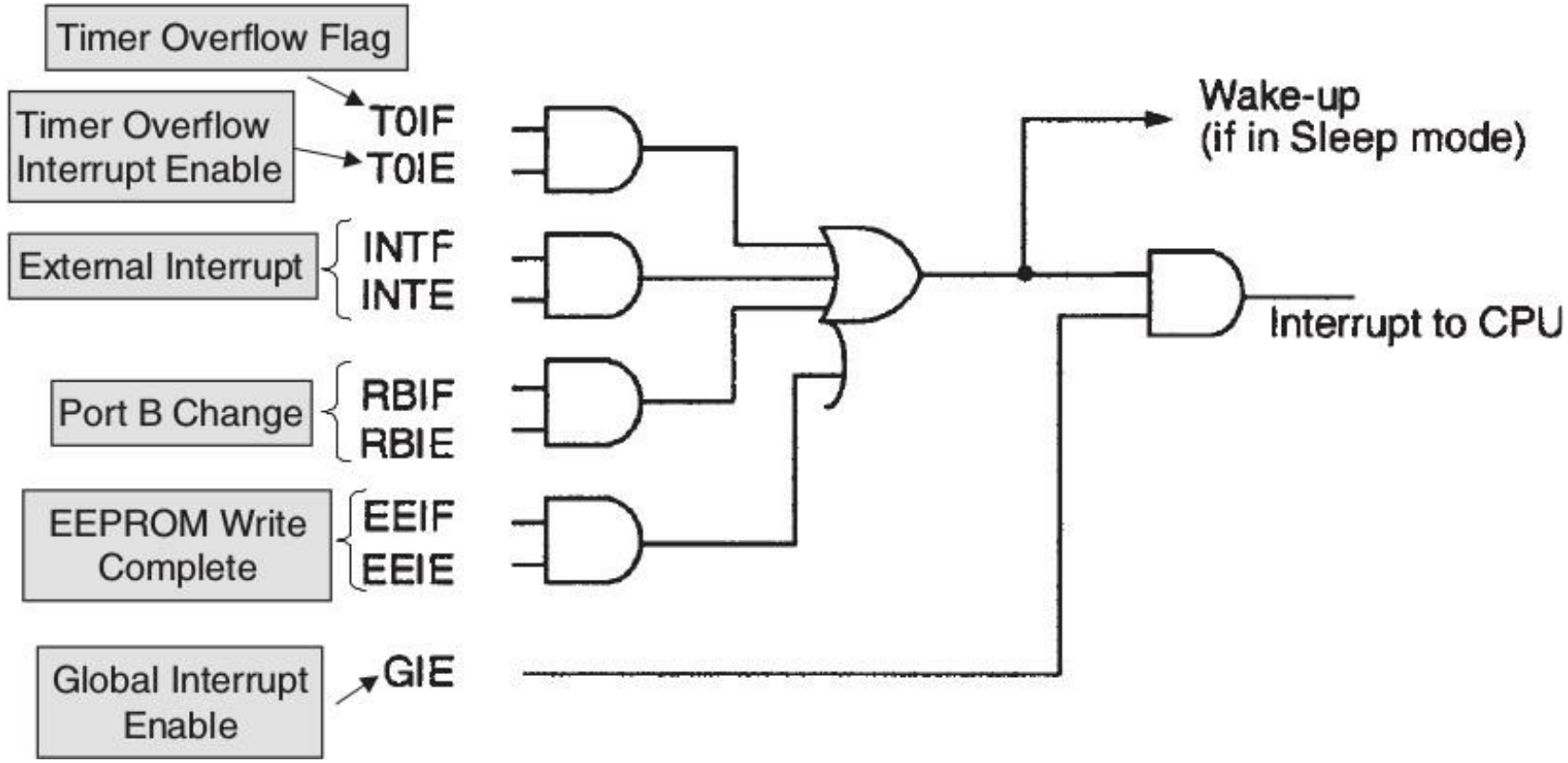


PIC Micro-controllers

- Interrupts
  - Any service request that cause the CPU to stop the current execution stream and to execute an instruction stream that service the interrupt
  - When the CPU finishes servicing the interrupt, it returns to the original execution stream at the point where it left off.
- PIC interrupts INT (PORT 0) interrupt
PORTB change interrupt (PB7:PB4)
Timer overflow interrupt
USART interrupt
A/D conversion interrupt

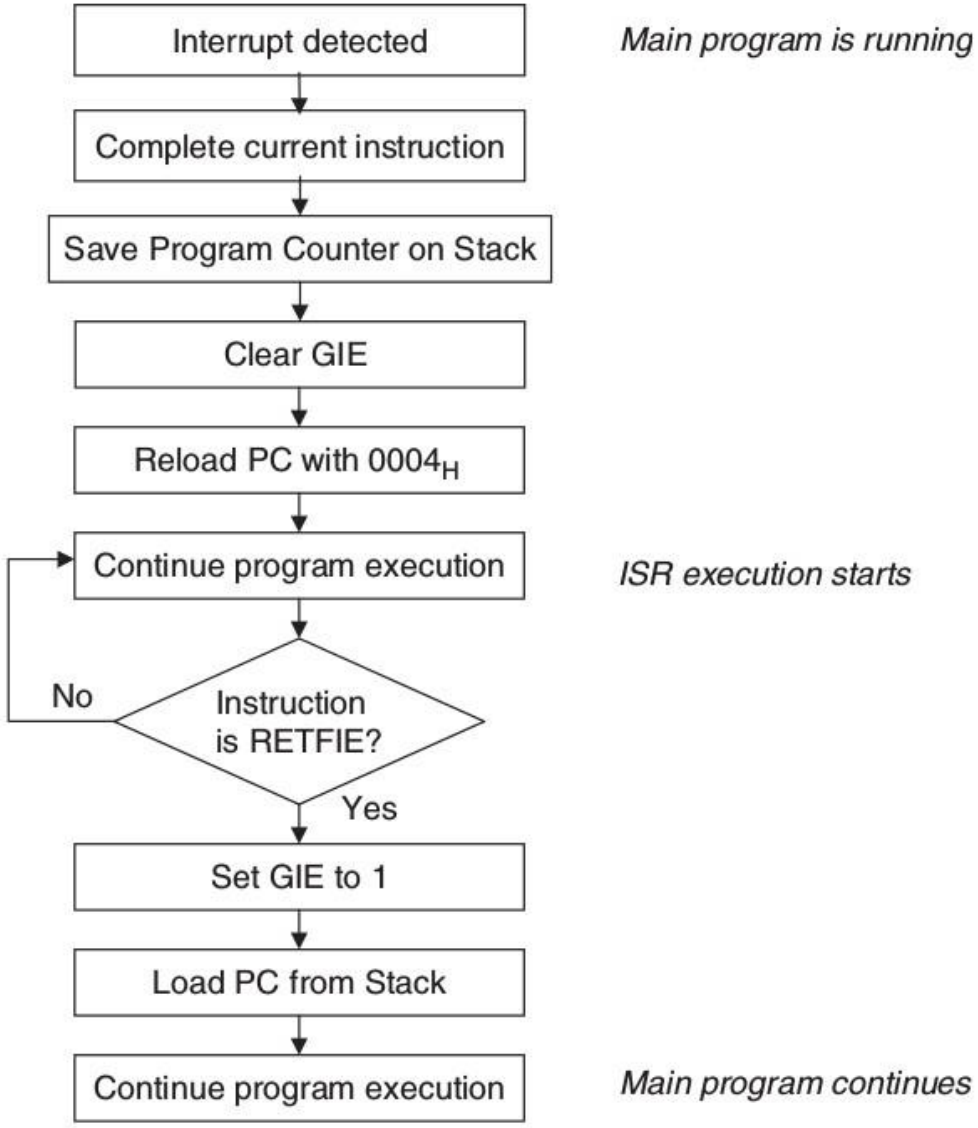
PIC Micro-controllers

- Interrupts



PIC Micro-controllers

- How Interrupts are handled
  - Start the ISR at the interrupt vector, location 0004
  - Enable the interrupt that is to be used, by setting the enable bit in the INTCON register
  - Set the Global Enable bit, GIE
  - Clear the interrupt flag within the ISR
  - End the ISR with a retfie instruction Ensure that the interrupt source, for example Port B or Timer 0, is actually set up to generate interrupts!

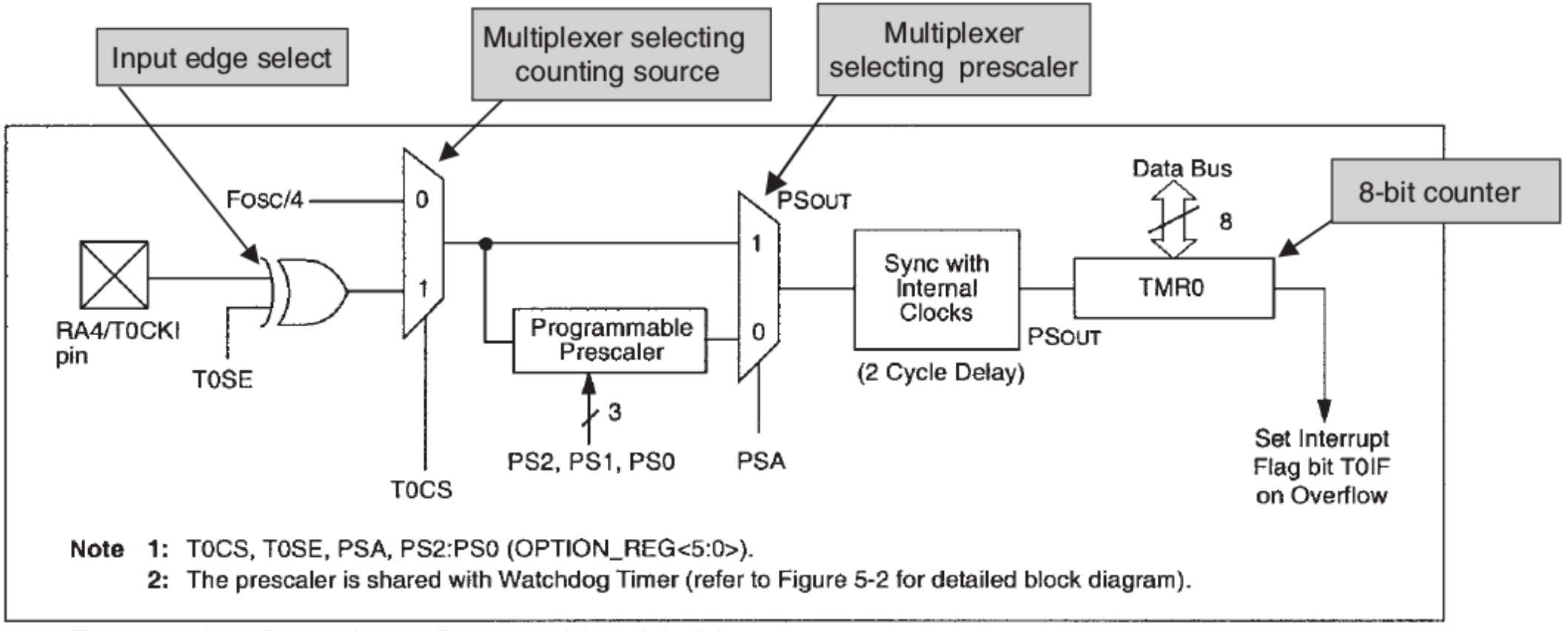


PIC Micro-controllers

- Timers
  - Available on most of the PIC Microcontrollers
  - Some 8 bits and some 16 bits
  - Some have presalers or postscalers
  - can use external pin as clock in or click outs
- Timer 0
  - 8 bit timer with prescaler
  - Readable and writable
  - 8bit software programmable prescaler
  - Can divide counter inputs by 2,4,8,16,32,64,128,256
  - Internal or external clock (PA4)
  - Interrupt on overflow from 0FFh to 00h
  - Edge select for external clock

PIC Micro-controllers

- Timer 0



PIC Micro-controllers

- Timer 1
  - 16 bit timer / counter Interrupt on overflow Read and writable Different operating modes
  - Programmable prescaler

- Timer 1 : operating Modes
  - Synchronous Timer
  - Increase every instruction cycle Synchronized Counter
  - Timer increases on rising edge of external clock External clock is synchronous with internal phase clock Asynchronous Counter
  - Timer increases independent of internal phase clock

PIC Micro-controllers

- PWM (Pulse Width Modulation)
  - Duty Cycle often expressed as a percentage of the period
  - Average DC voltage will be approximately the same percentage of the on voltage.
- Typically used

Intensity control

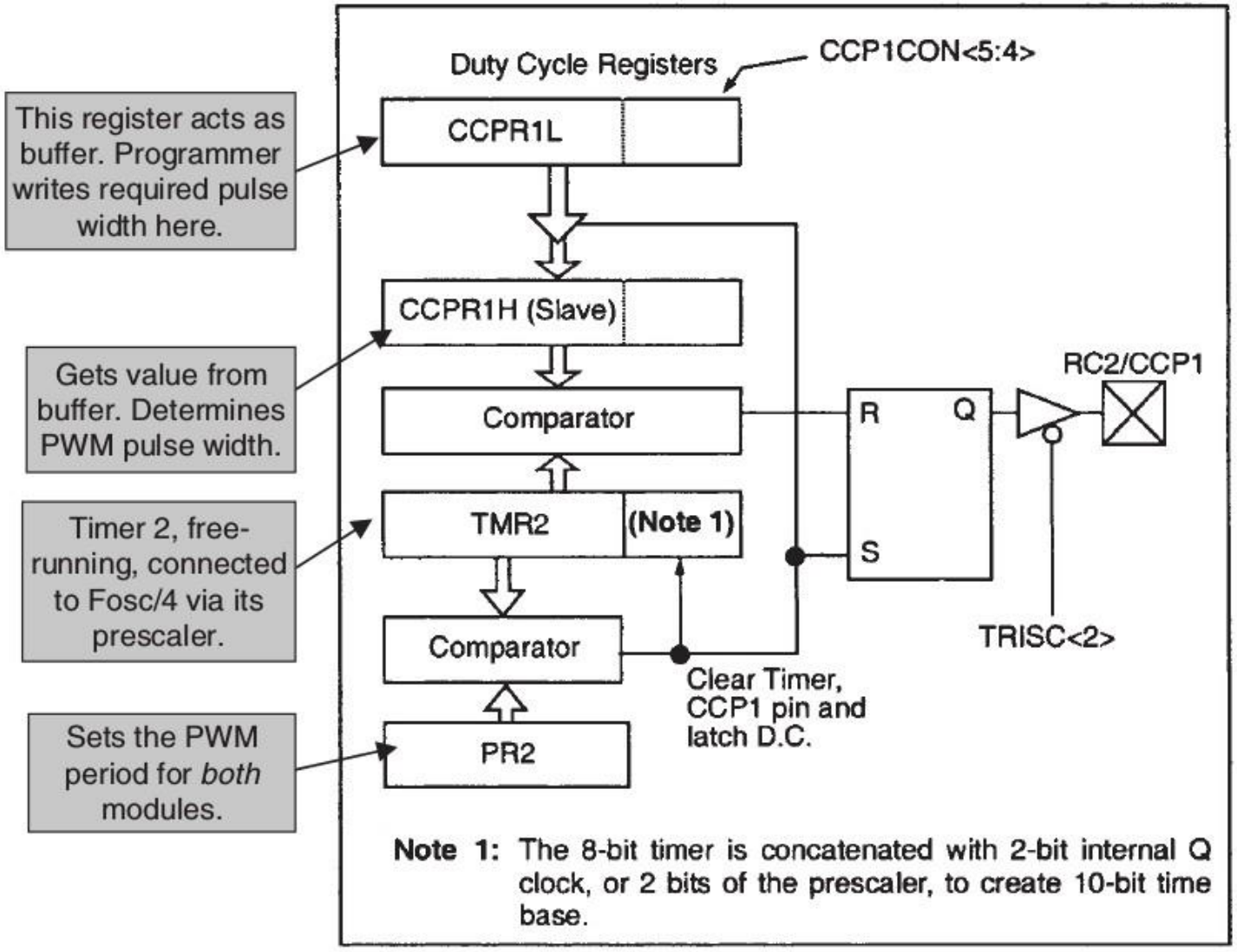
Motor controller

Temperature controller

- PWM mode
  - 10 bit resolution
  - Coupled with Timer 2 for producing output
  - Period and duty cycle of timer 2 output manipulated for obtaining desired PWM waveform

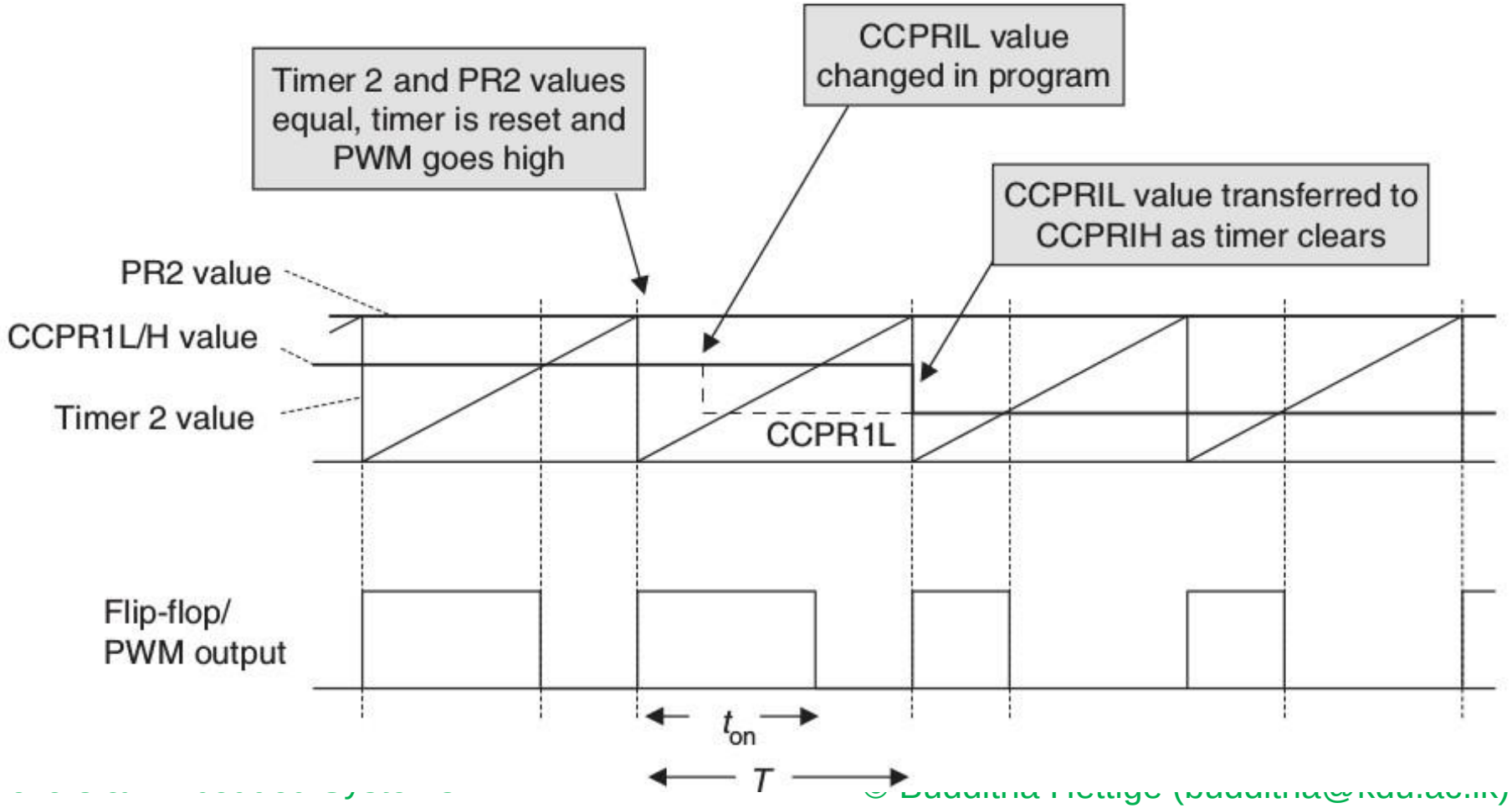
PIC Micro-controllers

- PWM



PIC Micro-controllers

- PWM

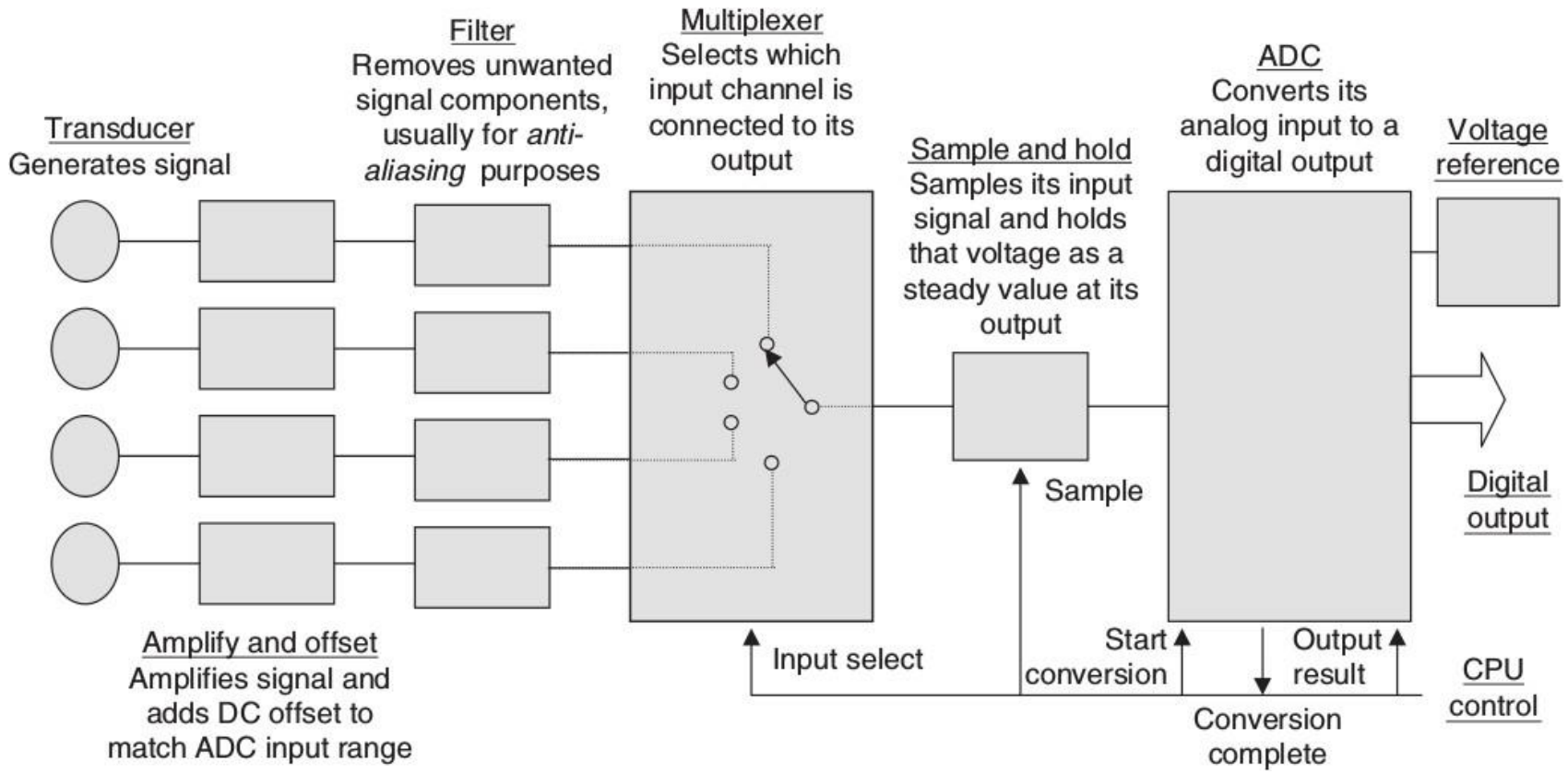


PIC Micro-controllers

- ADC (Analog to digital converter)
  - Convert analog inputs signals to 8bit or 10 bit digital values.
  - Input analog channel, conversion clock and analog reference voltage is software selected.
  - Can operate even when the device is in sleep mode
  - Can generate an interrupt when the process is finished.

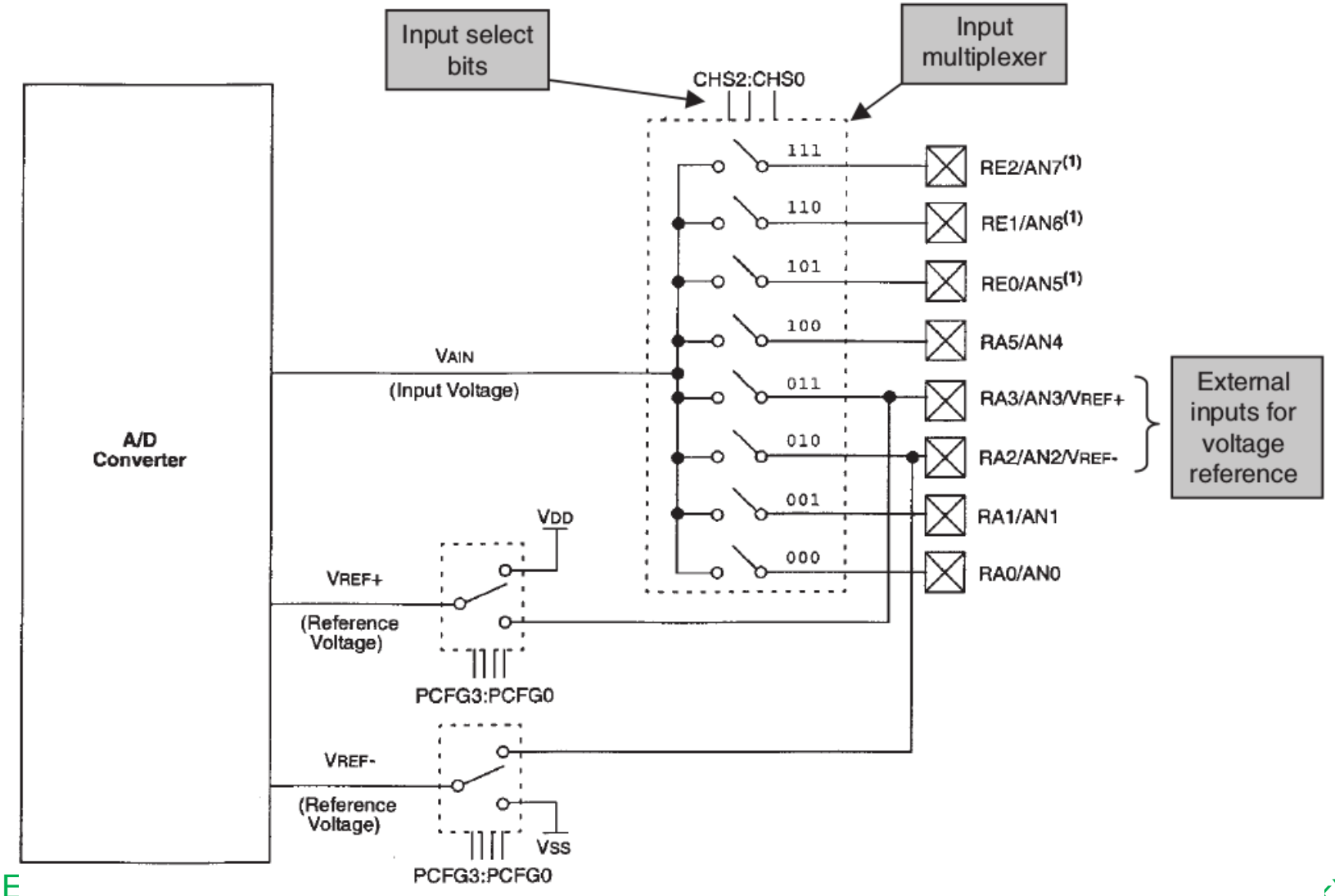
PIC Micro-controllers

- ADC - Typical Data Acquisition System



PIC Micro-controllers

- ADC



Note 1: Not available on 28-pin devices.

PIC Micro-controllers

- Synchronous Serial Port
  - Serial interface module for communicating with other devices or micro-controllers.
- Modules operates in one of two modes
  - Serial peripheral interface
  - Inter-integrated circuit (I2C)

Read PIC with Data sheet

PIC16F627A/628A/648A

Data Sheet

FLASH-Based

8-Bit CMOS Microcontrollers

PIC16F882/883/884/886/887

Data Sheet

28/40/44-Pin, Enhanced Flash-Based 8-Bit CMOS Microcontrollers with nanoWatt Technology

PIC18F2455/2550/4455/4550

Data Sheet

28/40/44-Pin, High Performance, Enhanced Flash, USB Microcontrollers with nanoWatt Technology

PIC12F508/509/16F505

Data Sheet

8/14-Pin, 8-Bit Flash Microcontrollers

Data Sheet

TABLE 1-1: PIC16F627A/628A/648A FAMILY OF DEVICES

		PIC16F627A	PIC16F628A	PIC16F648A	PIC16LF627A	PIC16LF628A	PIC16LF648A
Clock	Maximum Frequency of Operation (MHz)	20	20	20	4	4	4
Memory	FLASH Program Memory (words)	1024	2048	4096	1024	2048	4096
	RAM Data Memory (bytes)	224	224	256	224	224	256
	EEPROM Data Memory (bytes)	128	128	256	128	128	256
Peripherals	Timer module(s)	TMR0, TMR1, TMR2	TMR0, TMR1, TMR2	TMR0, TMR1, TMR2	TMR0, TMR1, TMR2	TMR0, TMR1, TMR2	TMR0, TMR1, TMR2
	Comparator(s)	2	2	2	2	2	2
	Capture/Compare/PWM modules	1	1	1	1	1	1
	Serial Communications	USART	USART	USART	USART	USART	USART
Features	Internal Voltage Reference	Yes	Yes	Yes	Yes	Yes	Yes
	Interrupt Sources	10	10	10	10	10	10
	I/O Pins	16	16	16	16	16	16
	Voltage Range (Volts)	3.0-5.5	3.0-5.5	3.0-5.5	2.0-5.5	2.0-5.5	2.0-5.5
	Brown-out Reset	Yes	Yes	Yes	Yes	Yes	Yes
	Packages	18-pin DIP, SOIC, 20-pin SSOP, 28-pin QFN	18-pin DIP, SOIC, 20-pin SSOP, 28-pin QFN	18-pin DIP, SOIC, 20-pin SSOP, 28-pin QFN	18-pin DIP, SOIC, 20-pin SSOP, 28-pin QFN	18-pin DIP, SOIC, 20-pin SSOP, 28-pin QFN	18-pin DIP, SOIC, 20-pin SSOP, 28-pin QFN

Sample

TABLE 1-1: PIC12F508/509/16F505 DEVICES

		PIC12F508	PIC12F509	PIC16F505
Clock	Maximum Frequency of Operation (MHz)	4	4	20
Memory	Flash Program Memory	512	1024	1024
	Data Memory (bytes)	25	41	72
Peripherals	Timer Module(s)	TMR0	TMR0	TMR0
	Wake-up from Sleep on Pin Change	Yes	Yes	Yes
Features	I/O Pins	5	5	11
	Input Pins	1	1	1
	Internal Pull-ups	Yes	Yes	Yes
	In-Circuit Serial Programming	Yes	Yes	Yes
	Number of Instructions	33	33	33
	Packages	8-pin PDIP, SOIC, MSOP	8-pin PDIP, SOIC, MSOP	14-pin PDIP, SOIC, TSSOP

Sample

TABLE 1-1: DEVICE FEATURES

Features	PIC18F2455	PIC18F2550	PIC18F4455	PIC18F4550
Operating Frequency	DC – 48 MHz	DC – 48 MHz	DC – 48 MHz	DC – 48 MHz
Program Memory (Bytes)	24576	32768	24576	32768
Program Memory (Instructions)	12288	16384	12288	16384
Data Memory (Bytes)	2048	2048	2048	2048
Data EEPROM Memory (Bytes)	256	256	256	256
Interrupt Sources	19	19	20	20
I/O Ports	Ports A, B, C, (E)	Ports A, B, C, (E)	Ports A, B, C, D, E	Ports A, B, C, D, E
Timers	4	4	4	4
Capture/Compare/PWM Modules	2	2	1	1
Enhanced Capture/ Compare/PWM Modules	00		1	1
Serial Communications	MSSP, Enhanced USART	MSSP, Enhanced USART	MSSP, Enhanced USART	MSSP, Enhanced USART
Universal Serial Bus (USB) Module	11		1	1
Streaming Parallel Port (SPP)	No	No	Yes	Yes
10-Bit Analog-to-Digital Module	10 Input Channels	10 Input Channels	13 Input Channels	13 Input Channels
Comparators	2	2	2	2
Resets (and Delays)	POR, BOR, RESET Instruction, Stack Full, Stack Underflow (PWRT, OST), MCLR (optional), WDT	POR, BOR, RESET Instruction, Stack Full, Stack Underflow (PWRT, OST), MCLR (optional), WDT	POR, BOR, RESET Instruction, Stack Full, Stack Underflow (PWRT, OST), MCLR (optional), WDT	POR, BOR, RESET Instruction, Stack Full, Stack Underflow (PWRT, OST), MCLR (optional), WDT
Programmable Low-Voltage Detect	Yes	Yes	Yes	Yes