Embedded Systems Design

(630470)

Lecture 3

Microcontroller Architecture

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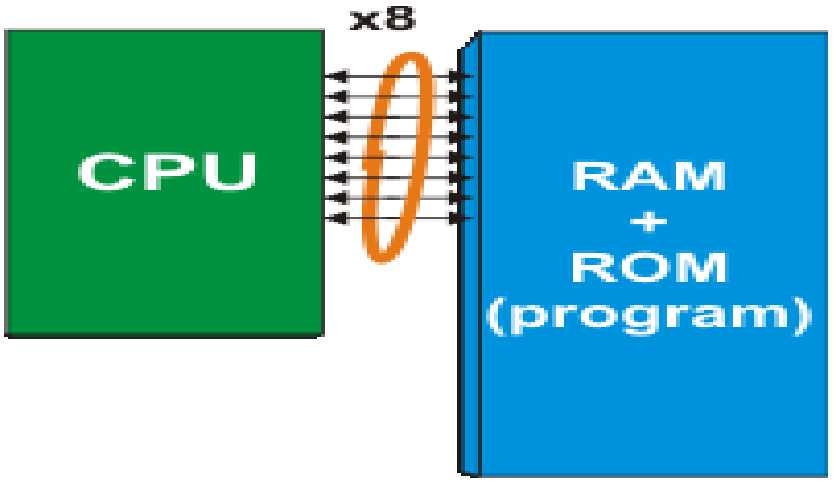
INTERNAL ARCHITECTURE

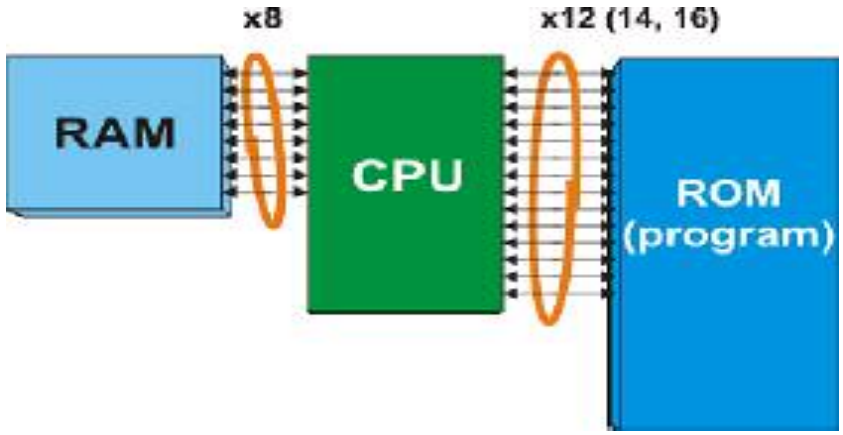
- All MCs use one of two basic design models:

  Harvard Architecture and v*on-Neumann* architecture.

- They represent two different ways of exchanging data between CPU and memory.
- **VON-NEUMANN ARCHITECTURE:**

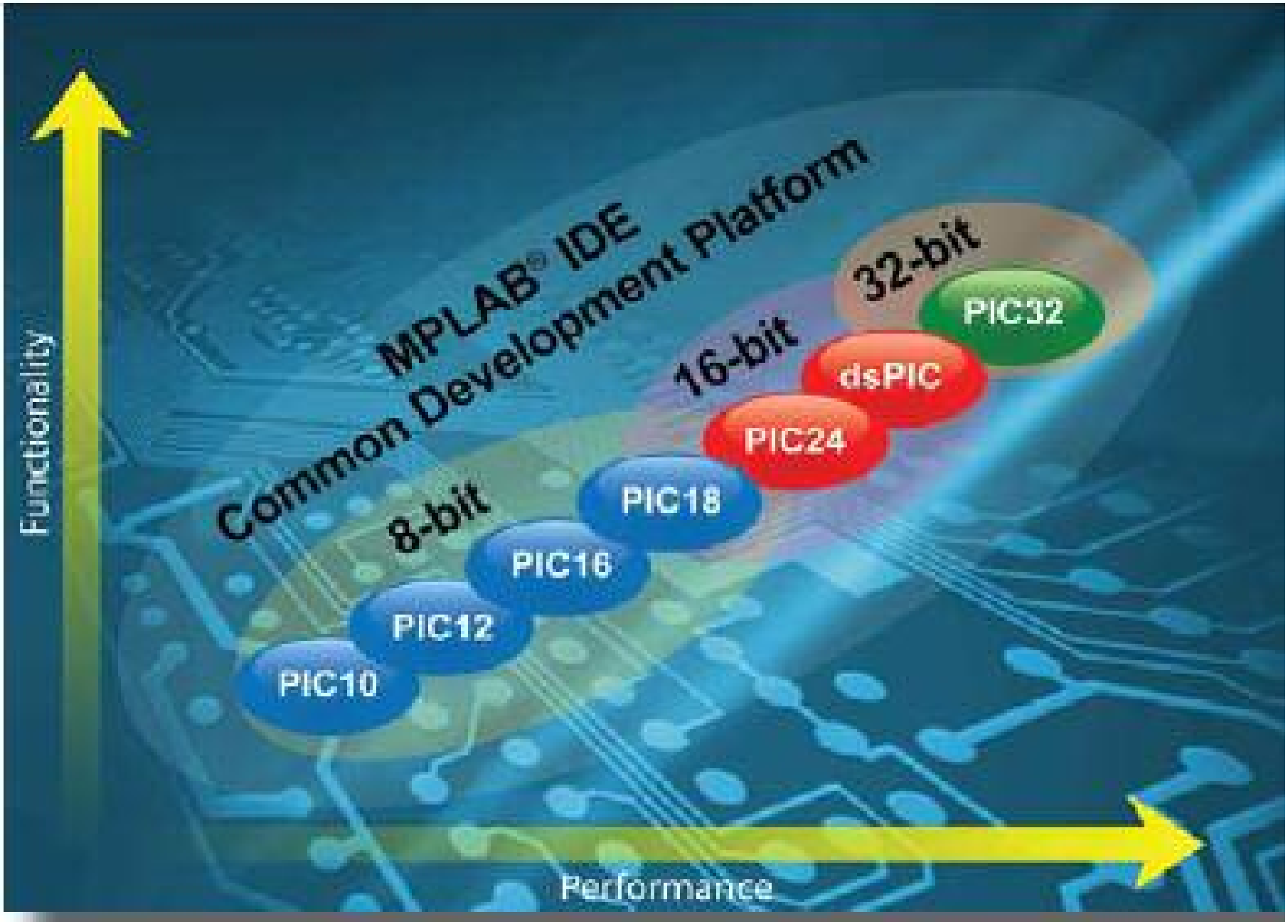


- **HARVARD ARCHITECTURE:**



CISC and RISC

- MCs with Harvard architecture are called "RISC MCs". MCs with von-Neumann's architecture are called 'CISC microcontrollers'.
- The PIC16F84 MC has a RISC architecture.
- Harvard architecture is a newer concept than von-Neumann's.
- In Harvard architecture, data bus and address bus are separate. Thus a greater flow of data is possible through the CPU, and of course, a greater speed of work.
- PIC16F84 uses 14 bits for instructions which allows for all instructions to be one word instructions.
- It is also typical for Harvard architecture to have fewer instructions than von-Neumann's, and to have instructions usually executed in one cycle.
- The PIC16F84 MC has 35 instructions. All of these instructions are executed in one cycle except for jump and branch instructions.


Functionality
MPLAB® IDE
Common Development Platform
8-bit
16-bit
32-bit
PIC10
PIC12
PIC16
PIC18
PIC24
dsPIC
PIC32
Performance

Popular PIC MCU Families

PIC10: Extremely small footprint, 6-pins

PIC12: Low-cost, easy-to-use, 8-pins

PIC16: NEW Enhanced Mid-Range core optimized for C with simplified memory map

PIC18: High 8-bit performance optimized for C with advanced communication peripherals, low-power, up to 128 KB Flash and 80-pins

PIC24: 16-bit families for more memory and faster peripherals including low power and high performance

dsPIC® DSCs: Digital signal control with motor control and power conversion peripherals, seamless migration with PIC24 MCUs

PIC32: Up to 80 MHz of 32-bit performance, compatible with 8- & 16-bit devices

- **Broad portfolio of more than 550 PIC microcontrollers**
  - From .5K to 512 KB Flash
  - From 0.5 to 80 MIPS performance
  - Multiple package options from 6- to 100-pins
  - nanoWatt XLP™ for eXtreme Low Power, <20 nA Sleep mode
- **Comprehensive technical documentation and free software**
  - Easy to get your designs done fast
  - Free software for USB, TCP-IP, ZigBee®, touch sensing, display and more
  - Leverage thousands of app notes, code examples and software libraries
- **MPLAB® IDE is absolutely free and the MPLAB tool suite supports ALL of Microchip's 8-, 16- and 32-bit microcontrollers**
  - Easy code migration
  - Free C Compiler without code size limitations
  - User-friendly, inexpensive programming and debug tools
  - Low-cost demo boards help speed up prototyping efforts
- **Easy-to-Use, Faster Time-to-Market**
  - C-code friendly with industry-leading code efficiency
  - PIC Architecture is easy to learn, easy to use
- **Easy migration with pin and code compatibility**
  - One MCU platform for all of your applications

- **Wide product availability and shortest lead times in the industry**
  - Worldwide fulfillment channels
  - Long product life cycles – we are still manufacturing the original PIC MCUs
- **The only supplier to bring USB, LCD, Ethernet, Touch Sensing and CAN to the 8-bit market**
  - Industry-leading integrated peripherals
  - Integrated nanoWatt XLP technology
  - Communication peripherals (SPI, I²C™, UART, USB, wireless)
  - Analog (8-, 10- and 12-bit ADC, comparators)
- **World-class, 24/7 technical support and training**
  - World-wide field application engineers
  - Built to support over 60,000 customers
  - Comprehensive web seminars, videos, hands-on training, "Lunch & Learns" and customer conferences
  - Leverage on-line community support from other developers on the Microchip Forums

Family	ROM [Kbytes]	RAM [bytes]	Pins	Clock Freq. [MHz]	A/D Inputs	Resolution of ADC	Comparators	8/16 – bit Timers	Serial Comm.	PWM Outputs	Others
Base-Line 8 - bit architecture, 12-bit Instruction Word Length											
PIC10FXXX	0.375-0.75	16 - 24	6 - 8	4 - 8	0 - 2	8	0 - 1	1 x 8	-	-	-
PIC12FXXX	0.75 - 1.5	25 - 38	8	4 - 8	0 - 3	8	0 - 1	1 x 8	-	-	EEPROM
PIC16FXXX	0.75 - 3	25 - 134	14 - 44	20	0 - 3	8	0 - 2	1 x 8	-	-	EEPROM
PIC16HVXXX	1.5	25	18 - 20	20	-	-	-	1 x 8	-	-	Vdd = 15V
Mid-Range 8 - bit architecture, 14-bit Instruction World Length											
PIC12FXXX	1.75 - 3.5	64 - 128	8	20	0 - 4	10	1	1 - 2 x 8 1 x 16	-	0 - 1	EEPROM
PIC12HVXXX	1.75	64	8	20	0 - 4	10	1	1 - 2 x 8 1 x 16	-	0 - 1	-
PIC16FXXX	1.75 - 14	64 - 368	14 - 64	20	0 - 13	8or 10	0 - 2	- 2 x 8 1 x 16	USART I2C SPI	0 - 3	-

MICROCHIP

PIC16F84A

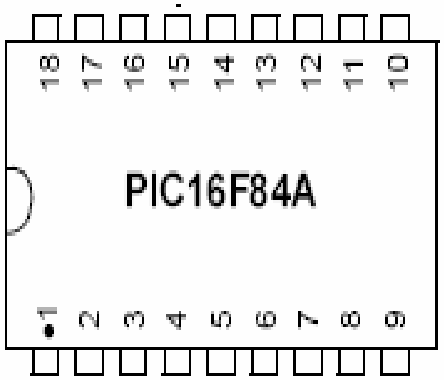
18-pin *Enhanced* FLASH/EEPROM 8-Bit Microcontroller

High Performance RISC CPU Features:

- Only 35 single word instructions to learn
- All instructions single-cycle except for program branches which are two-cycle
- Operating speed: DC - 20 MHz clock input
- 1024 words of program memory
- 68 bytes of Data RAM
- 64 bytes of Data EEPROM
- 14-bit wide instruction words
- 8-bit wide data bytes
- 15 Special Function Hardware registers

Peripheral Features:

- 13 I/O pins with individual direction control
- High current sink/source for direct LED drive
  - 25 mA sink max. per pin
  - 25 mA source max. per pin
- TMR0: 8-bit timer/counter with 8-bit programmable prescaler



Special Microcontroller Features:

- 10,000 erase/write cycles *Enhanced* FLASH Program memory typical
- 10,000,000 typical erase/write cycles EEPROM Data memory typical
- EEPROM Data Retention > 40 years
- In-Circuit Serial Programming™ (ICSP™) - via two pins
- Power-on Reset (POR), Power-up Timer (PWRT), Oscillator Start-up Timer (OST)
- Watchdog Timer (WDT) with its own On-Chip RC Oscillator for reliable operation
- Code protection
- Power saving SLEEP mode

CMOS Enhanced FLASH/EEPROM Technology:

- Low power, high speed technology
- Fully static design
- Wide operating voltage range:
  - Commercial: 2.0V to 5.5V
  - Industrial: 2.0V to 5.5V
- Low power consumption:
  - < 2 mA typical @ 5V, 4 MHz
  - 15 µA typical @ 2V, 32 kHz
  - < 0.5 µA typical standby current @ 2V

THE PIC16F887 BASIC FEATURES:

RISC architecture

Only 35 instructions to learn

All single-cycle instructions except branches

Operating frequency 0-20 MHz

Precision internal oscillator

Factory calibrated

Software selectable frequency range of 8MHz to 31KHz

Power supply voltage 2.0-5.5V

Consumption: 220uA (2.0V, 4MHz), 11uA (2.0 V, 32 KHz)
50nA (stand-by mode)

Power-Saving Sleep Mode

35 input/output pins

High current source/sink for direct LED drive

software and individually programmable *pull-up* resistor

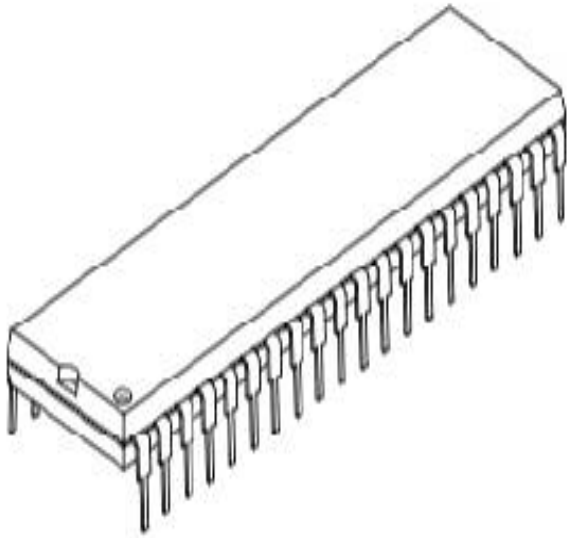
Interrupt-on-Change pin

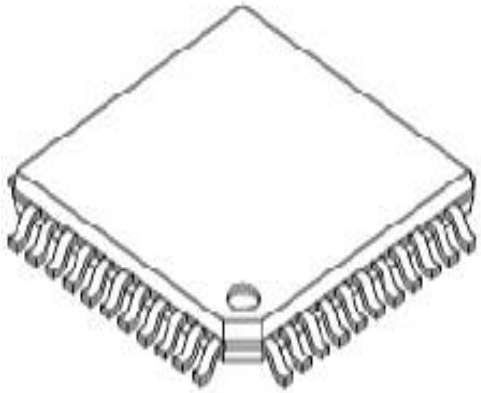
8K ROM memory in FLASH technology

Chip can be reprogrammed up to 100.000 times

***In-Circuit Serial Programming* Option**

Chip can be programmed even embedded in the target device





THE PIC16F887 BASIC FEATURES:

256 bytes EEPROM memory

Data can be written more than 1.000.000 times

368 bytes RAM memory

A/D converter:

14-channels

10-bit resolution

3 independent timers/counters

Watch-dog timer

Analogue comparator module with

Two analogue comparators

Fixed voltage reference (0.6V)

Programmable on-chip voltage reference

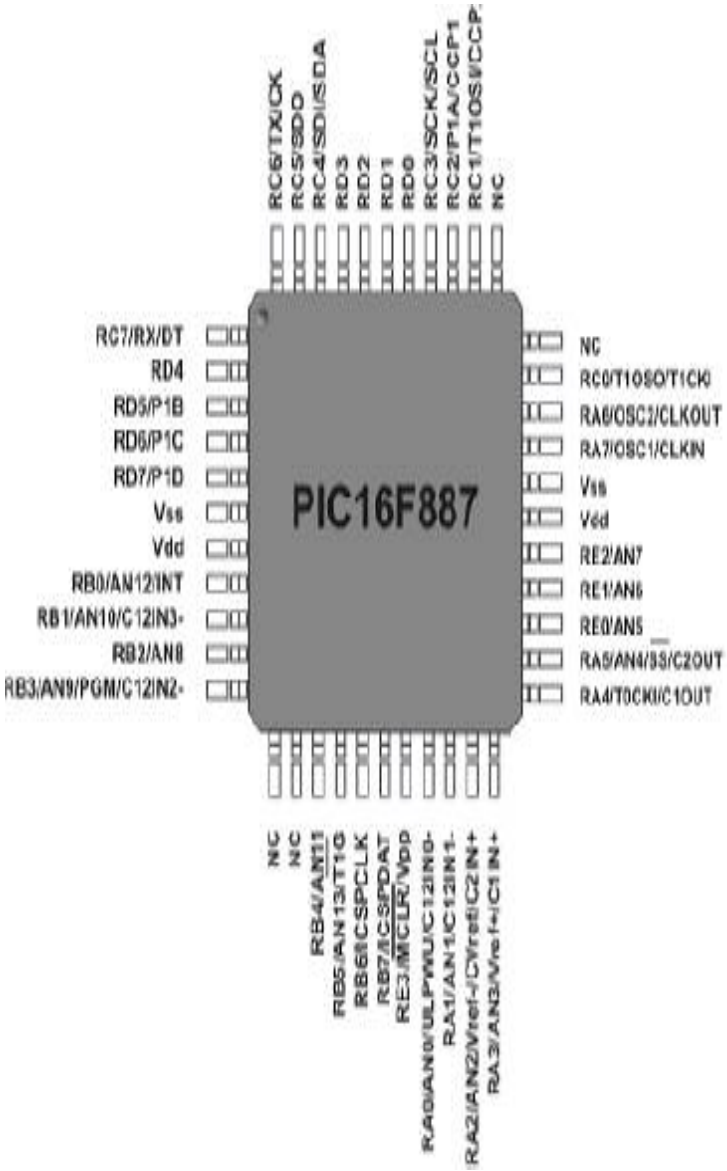
PWM output steering control

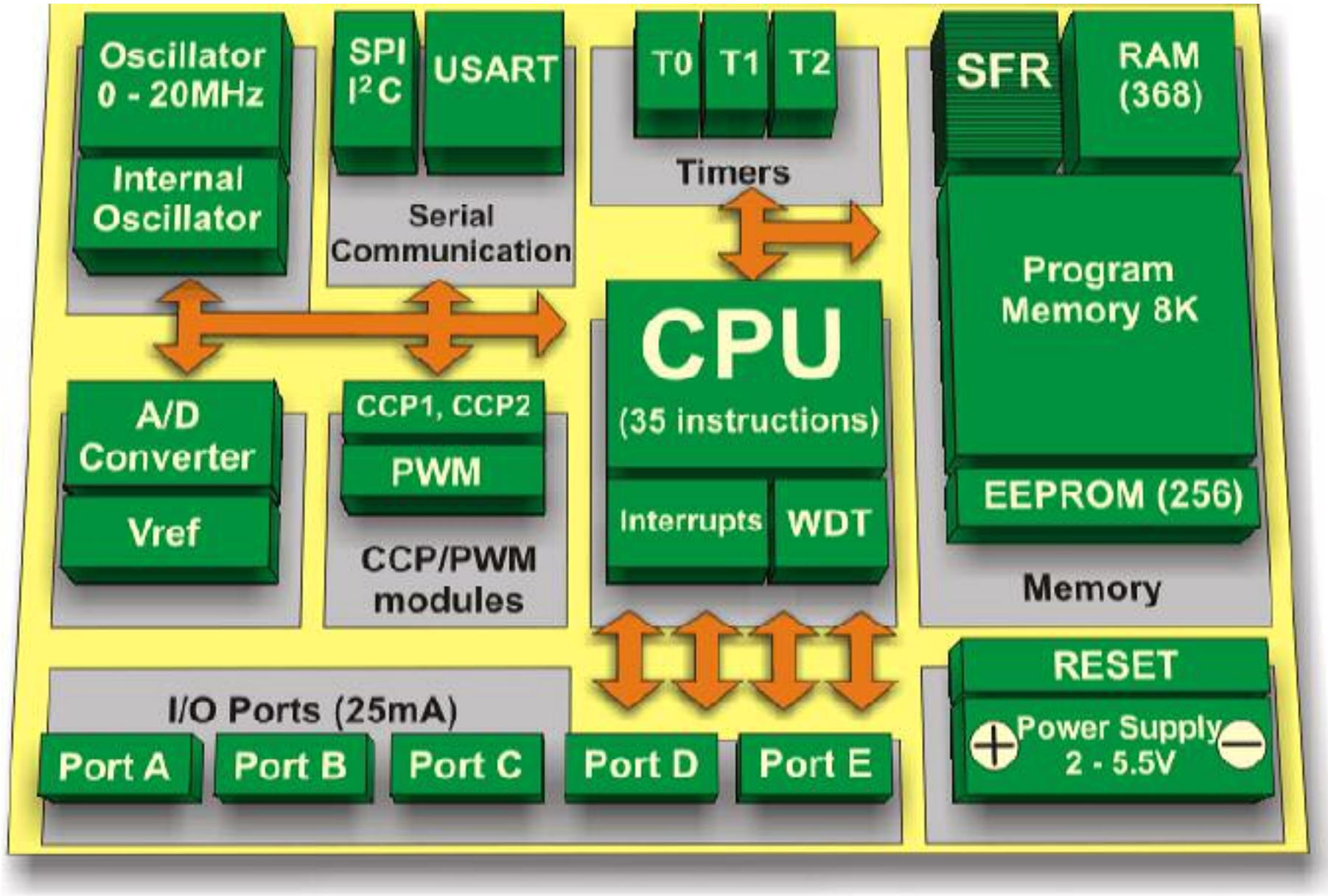
Enhanced USART module

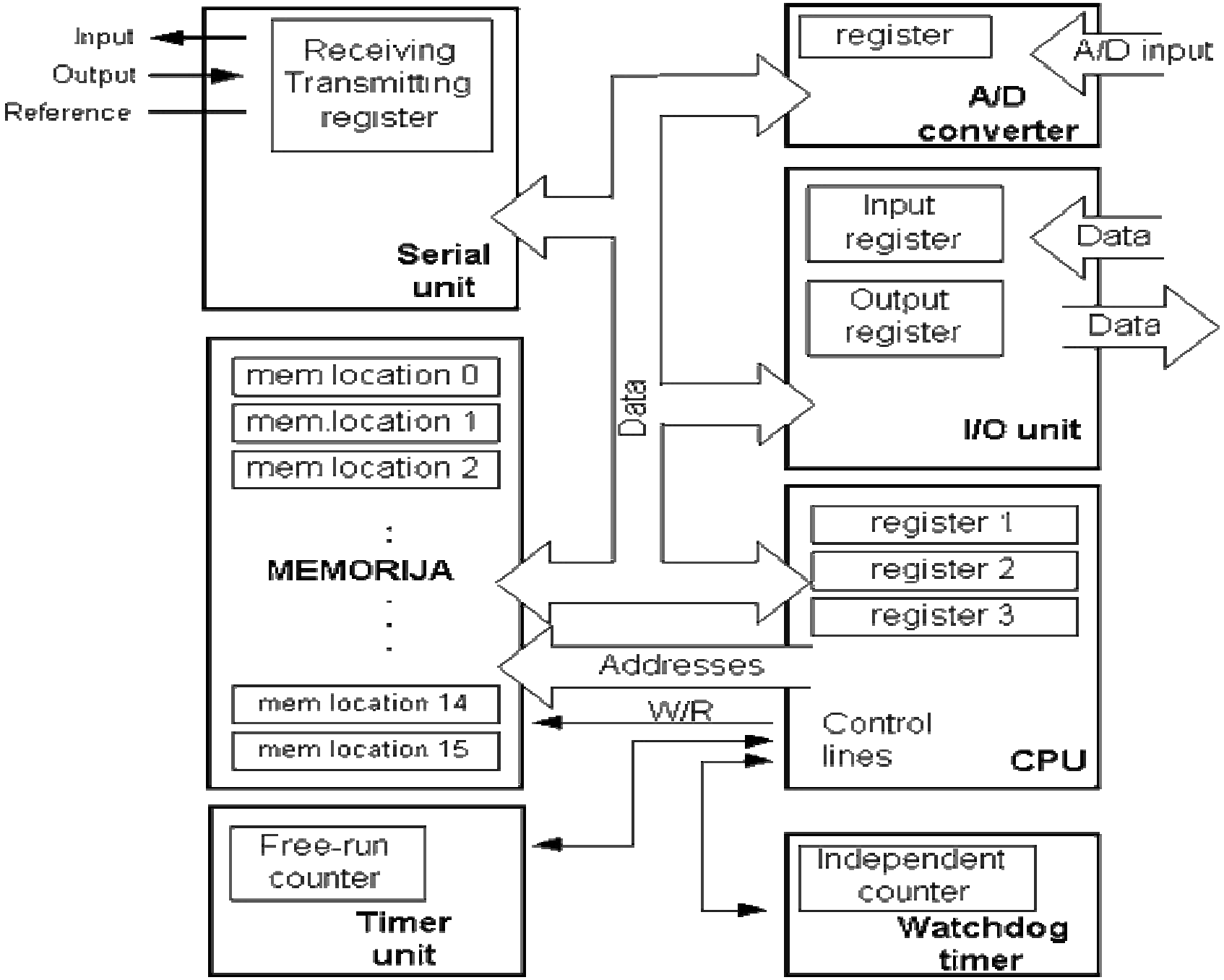
Supports RS-485, RS-232 and LIN2.0

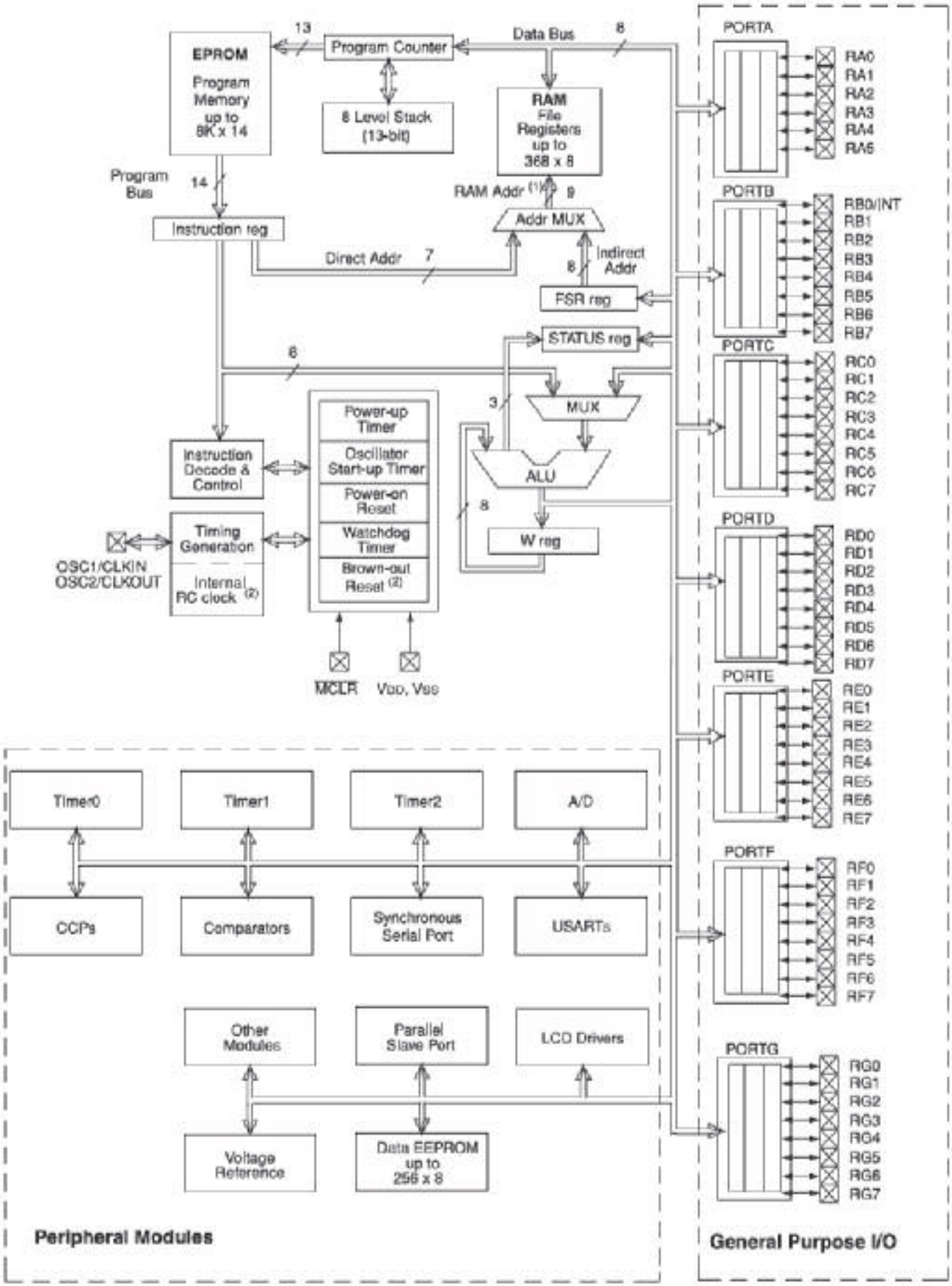
Auto-Baud Detect

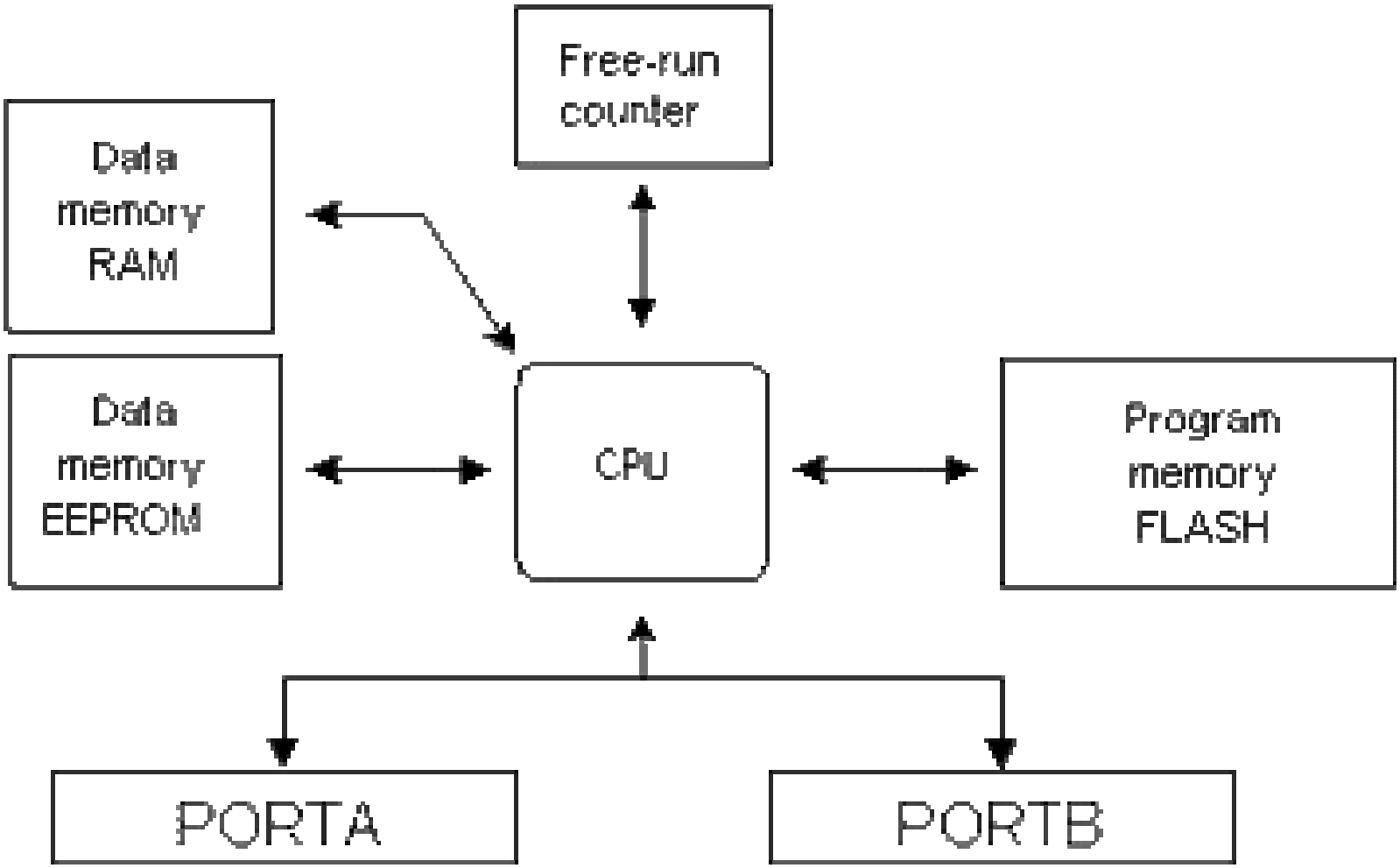
Master Synchronous Serial Port (MSSP)



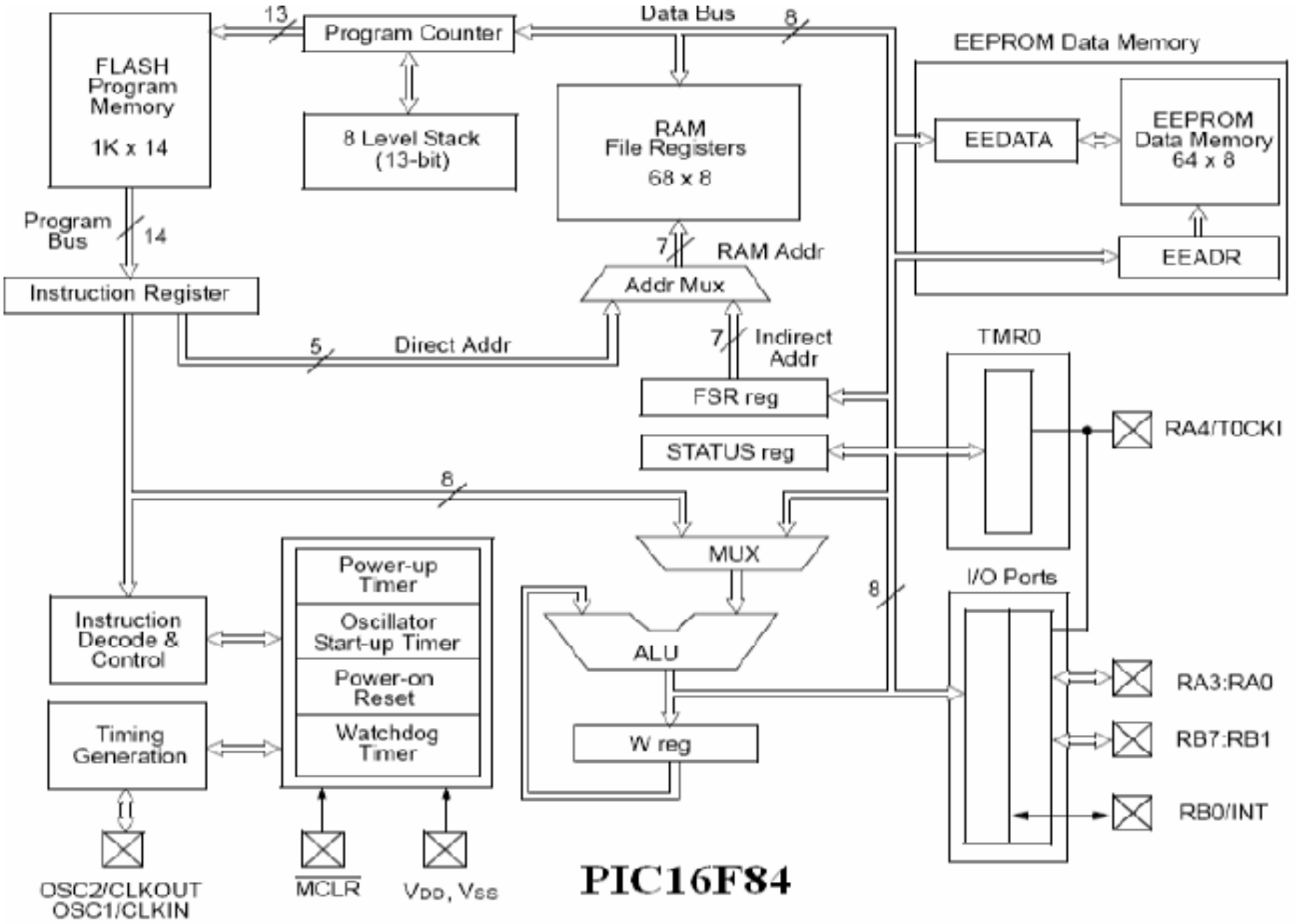

Oscillator
0 - 20MHz
Internal
Oscillator
SPI
I²C
USART
Serial
Communication
T0
T1
T2
Timers
SFR
RAM
(368)
Program
Memory 8K
CPU
(35 instructions)
EEPROM (256)
Interrupts
WDT
Memory
A/D
Converter
Vref
CCP1, CCP2
PWM
CCP/PWM
modules
I/O Ports (25mA)
Port A
Port B
Port C
Port D
Port E
RESET
Power Supply
2 - 5.5V


Input
Output
Reference
Receiving
Transmitting
register
Serial
unit
register
A/D input
A/D
converter
Input
register
Data
Output
register
Data
I/O unit
Data
mem location 0
mem.location 1
mem location 2
:
MEMORIJA
:
mem location 14
mem location 15
register 1
register 2
register 3
Addresses
W/R
Control
lines
CPU
Free-run
counter
Timer
unit
Independent
counter
Watchdog
timer

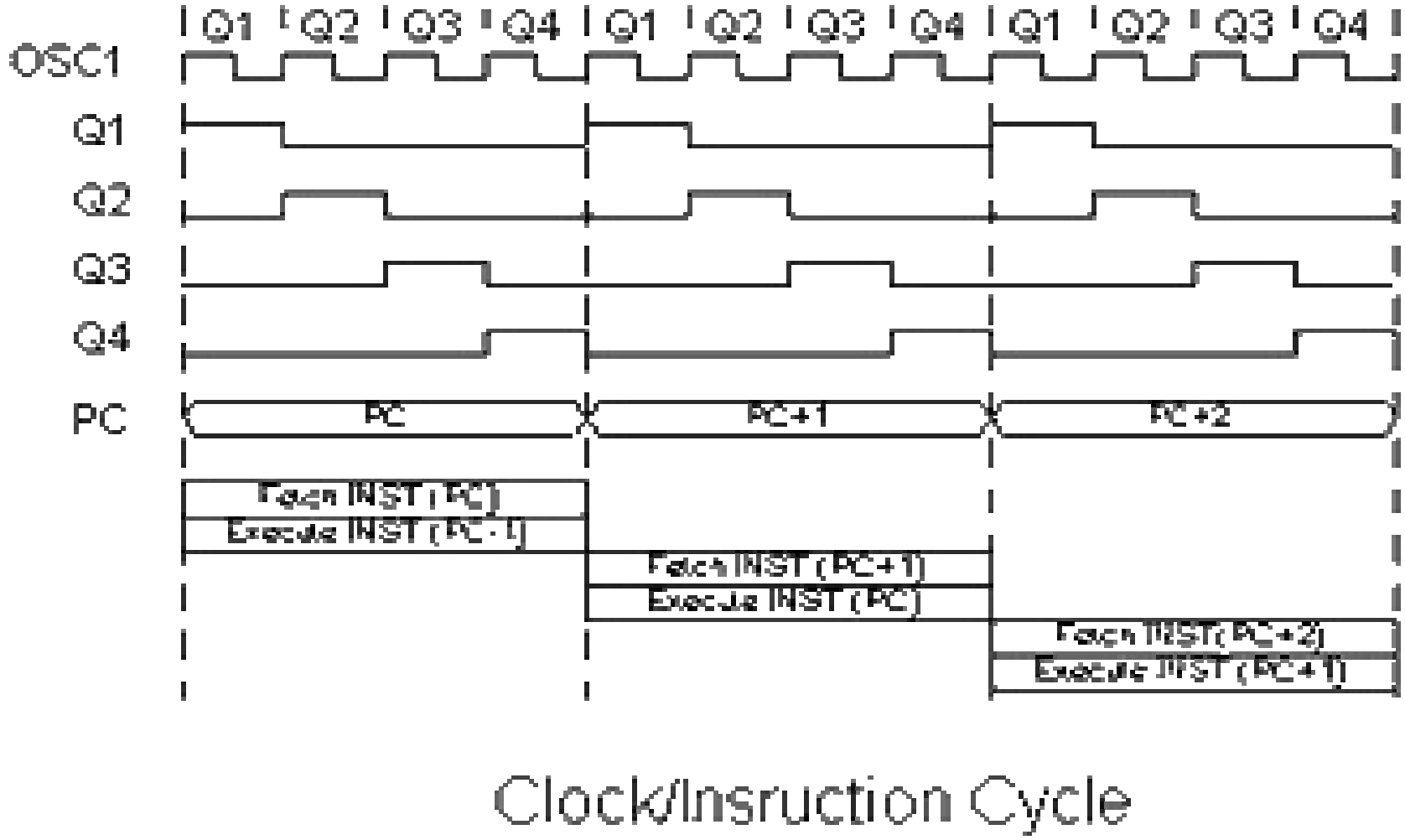

EPROM
Program Memory up to 8K x 14
13
Program Counter
Data Bus
8
8 Level Stack (13-bit)
RAM File Registers up to 368 x 8
Program Bus
14
RAM Addr (1)
9
Addr MUX
Instruction reg
Direct Addr
7
Indirect Addr
8
FSR reg
STATUS reg
6
3
MUX
Power-up Timer
Oscillator Start-up Timer
Power-on Reset
Watchdog Timer
Brown-out Reset (2)
Instruction Decode & Control
ALU
8
W reg
Timing Generation
Internal RC clock (2)
OSC1/CLKIN
OSC2/CLKOUT
MCLR
VDD, VSS
PORTA
RA0
RA1
RA2
RA3
RA4
RA5
PORTB
RB0/INT
RB1
RB2
RB3
RB4
RB5
RB6
RB7
PORTC
RC0
RC1
RC2
RC3
RC4
RC5
RC6
RC7
PORTD
RD0
RD1
RD2
RD3
RD4
RD5
RD6
RD7
PORTE
RE0
RE1
RE2
RE3
RE4
RE5
RE6
RE7
PORTF
RF0
RF1
RF2
RF3
RF4
RF5
RF6
RF7
PORTG
RG0
RG1
RG2
RG3
RG4
RG5
RG6
RG7
Timer0
Timer1
Timer2
A/D
CCPs
Comparators
Synchronous Serial Port
USARTs
Other Modules
Parallel Slave Port
LCD Drivers
Voltage Reference
Data EEPROM up to 256 x 8
Peripheral Modules
General Purpose I/O



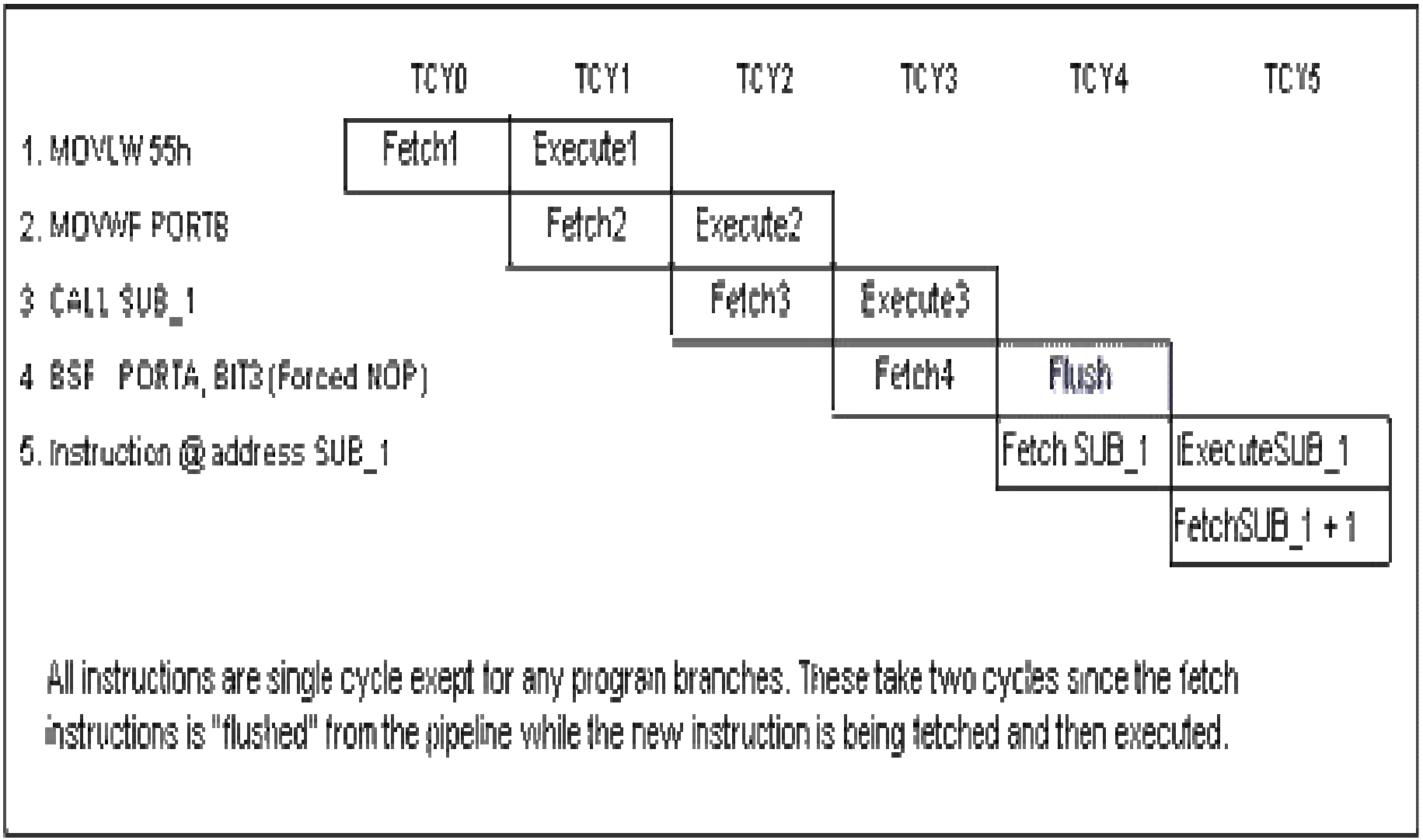
PIC16F84 microcontroller outline


FLASH
Program
Memory
1K x 14
13
Program Counter
8 Level Stack
(13-bit)
Data Bus
8
RAM
File Registers
68 x 8
EEPROM Data Memory
EEDATA
EEPROM
Data Memory
64 x 8
EEADR
Program
Bus
14
Instruction Register
7
RAM Addr
Addr Mux
5
Direct Addr
7
Indirect
Addr
FSR reg
STATUS reg
TMR0
RA4/T0CKI
8
MUX
I/O Ports
8
Instruction
Decode &
Control
Power-up
Timer
Oscillator
Start-up Timer
Power-on
Reset
Watchdog
Timer
ALU
W reg
Timing
Generation
RA3:RA0
RB7:RB1
RB0/INT
OSC2/CLKOUT
OSC1/CLKIN
MCLR
VDD, VSS
PIC16F84

Pipelining:

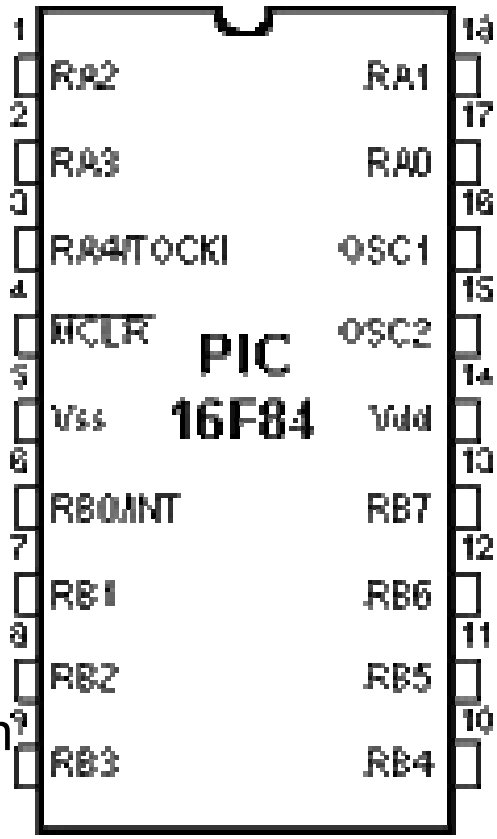


Clock/Insruction Cycle



Instruction Pipeline Flow

Pin no.1: **RA2** Second pin on port A.
Pin no.2: **RA3** Third pin on port A.
Pin no.3: **RA4** Fourth pin on port A. TOCK1 which functions as a timer is also found on this pin.
Pin no.4: **MCLR** Reset i/p and Vpp programming voltage.
Pin no.5: **Vss** Ground of power supply.
Pin no.6: **RB0** Zero pin on port B. Interrupt input.
Pin no.7: **RB1** First pin on port B.
Pin no.8: **RB2** Second pin on port B.
Pin no.9: **RB3** Third pin on port B.
Pin no.10: **RB4** Fourth pin on port B.
Pin no.11: **RB5** Fifth pin on port B.
Pin no.12: **RB6** Sixth pin on port B. 'Clock' line in program mode.
Pin no.13: **RB7** Seventh pin on port B. 'Data' line in program mode.
Pin no.14: **Vdd** Positive power supply pole.
Pin no.15: **OSC2** Pin for connecting with an oscillator.
Pin no.16: **OSC1** Pin for connecting with an oscillator.
Pin no.17: **RA2** Second pin on port A.
Pin no.18: **RA1** First pin on port A.

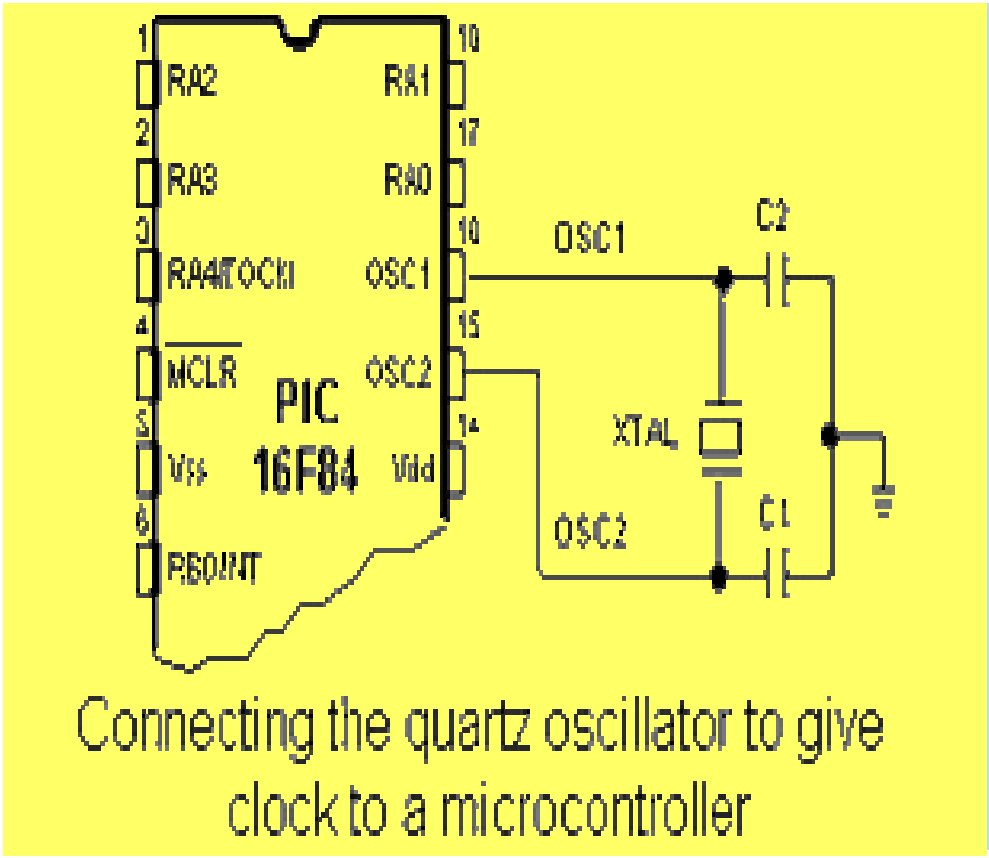


Clock generator - oscillator

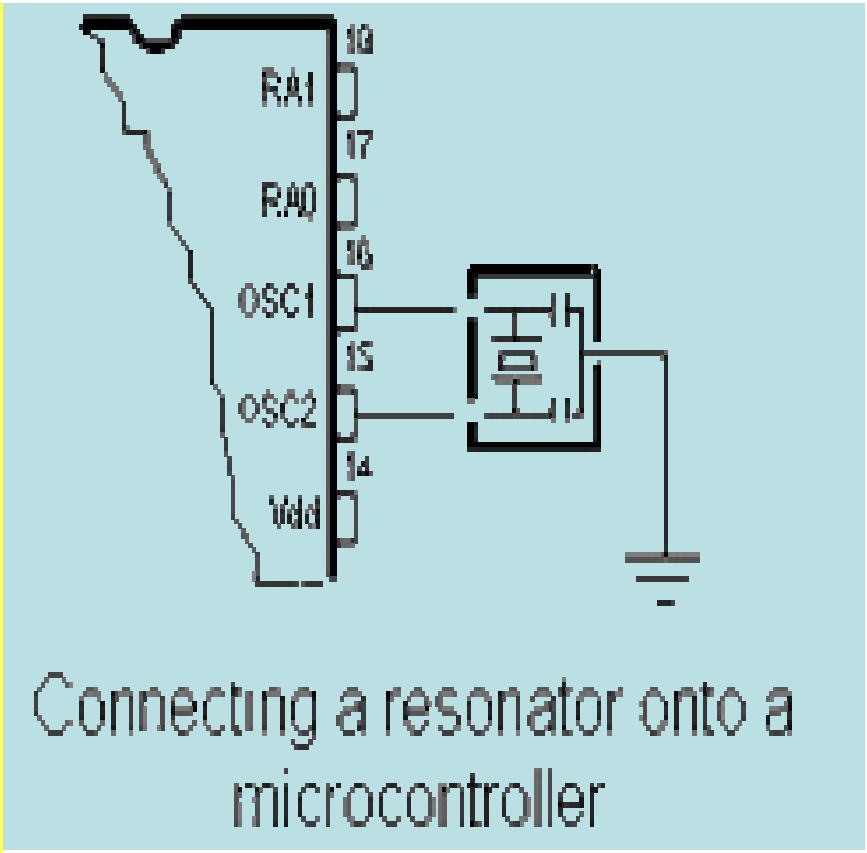
Oscillator circuit is used for providing a MC with a clock.

Types of oscillators:

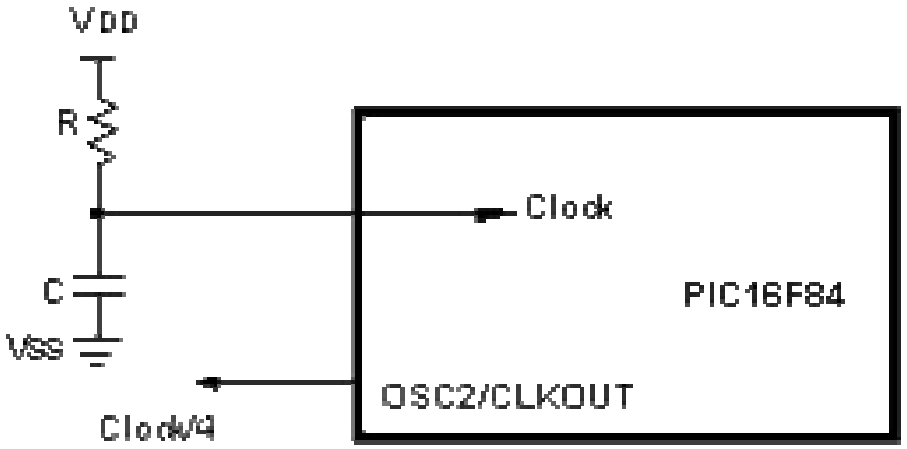
- PIC16F84 can work with four different configurations of an oscillator.



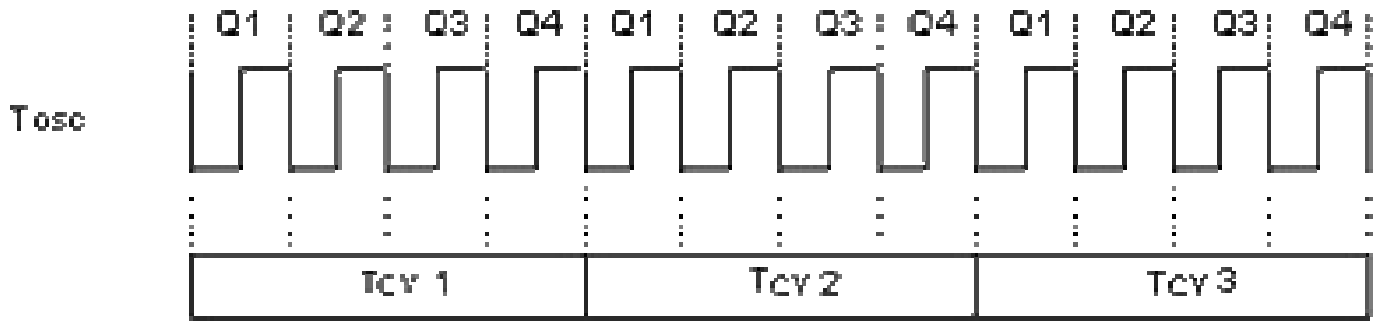
Connecting the quartz oscillator to give clock to a microcontroller



Connecting a resonator onto a microcontroller



Note: This pin can be configured as input/output pin

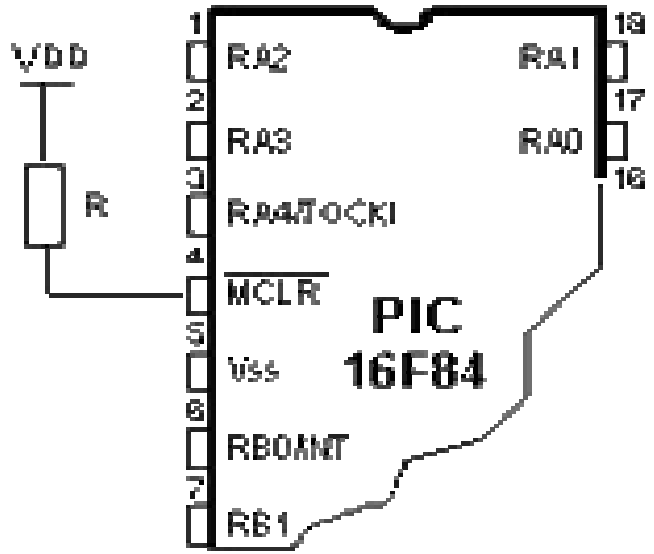


Relationship between a clock and a number of instruction cycles

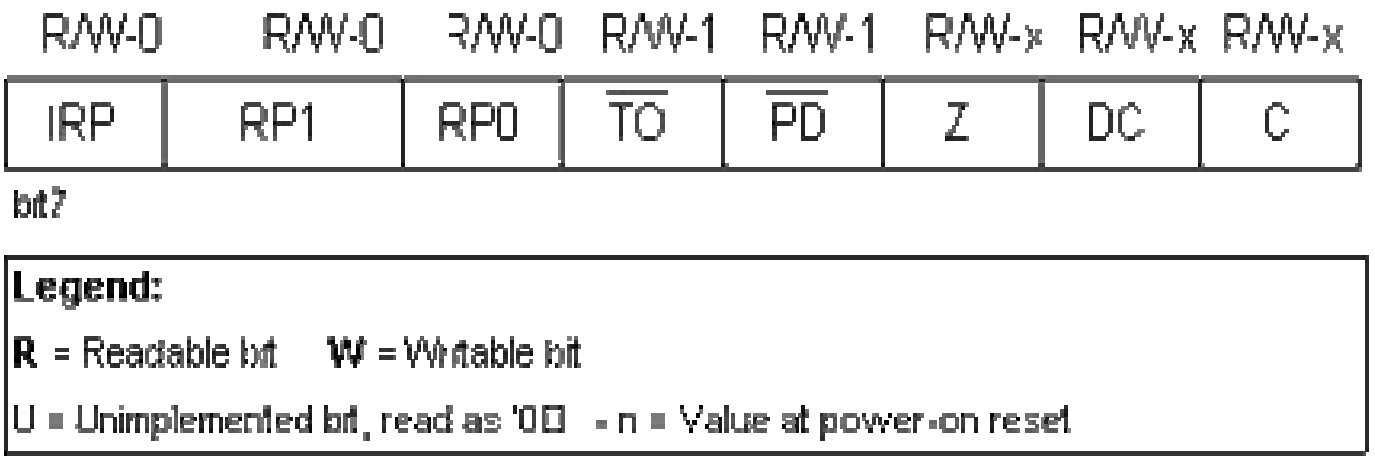
Reset MC:

Microcontroller PIC16F84 knows several sources of resets:

- Reset during power on, POR (Power-On Reset)
- Reset during regular work by bringing logical zero to MCLR microcontroller's pin.
- Reset during SLEEP regime.
- Reset at watchdog timer (WDT) overflow.
- Reset during at WDT overflow during SLEEP work regime.



Using the internal reset circuit



STATUS Register

- *bit 7* ***IRP*** *(Register Bank Select bit)*
- *bits 6:5* ***RP1:RP0*** *(Register Bank Select bits)*
- *bit 4* ***TO*** *Time-out ; Watchdog overflow*
- *bit 3* ***PD*** *(Power-down bit)*
- *bit 2* ***Z*** *(Zero bit) Indication of a zero result*
- *bit 1* ***DC*** *(Digit Carry) DC Transfer*
- *bit 0* ***C*** *(Carry) Transfer*