198 461 Microcontrollers

1st Semester 2017

Course Webpage
http://gear.kku.ac.th/~watis/courses/198461/198461.html

Course Objective and Grading Policy

Course Objectives

- To gain knowledge in microcontroller theory
- To gain experience in designing microcontroller applications
- To familiarize students with well-accepted uCs among designers

Grading Policy

* **40%** Lab Report (in group of 2 students)

* **30%** Term Project (in group of 2 students)
    - 10% Report (group)
    - 10% Functional Correctness (group)
    - 10% Presentation (individual)

* **15%** Midterm Practical Examination (Software)

* **15%** Final Practical Examination (Hardware + Software)

Past issues in computer controlled applications

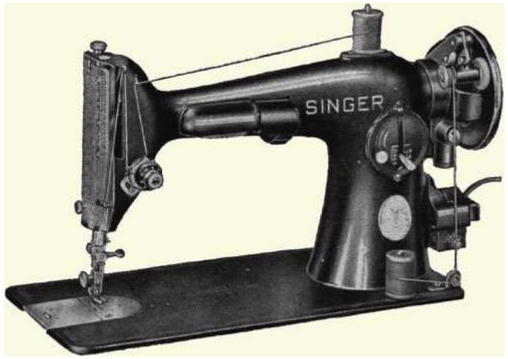
- Many real-world applications require computer to control their operations

- Computer is complex machine consisting of CPU, memory, I/O, etc.

- Computation power, cost, size, power consumption may not match requirement (usually over qualify)

Sewing Machine: A case study

- Invented since 1791
- Has been involving with everyone until now
- So, what?



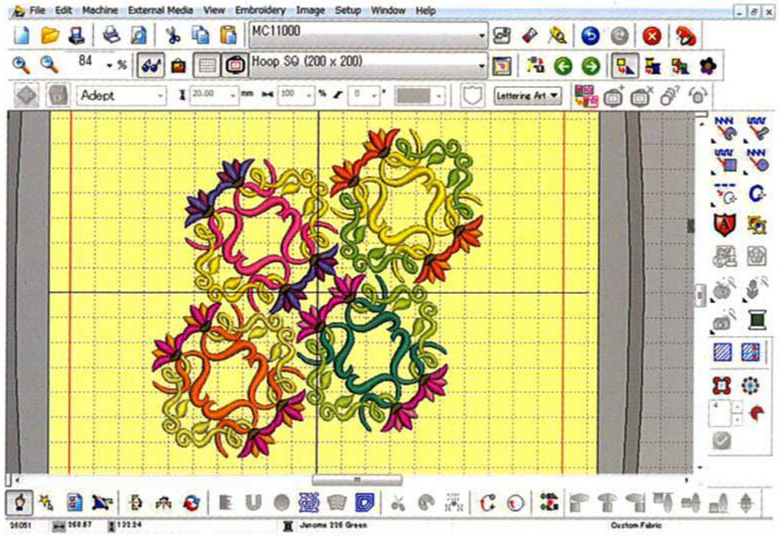
- Persons who operate it must be well-trained
- Producing high quality work requires lots of experience

Sewing Machine: A case study

Until recently, a new kind of sewing machine has emerged

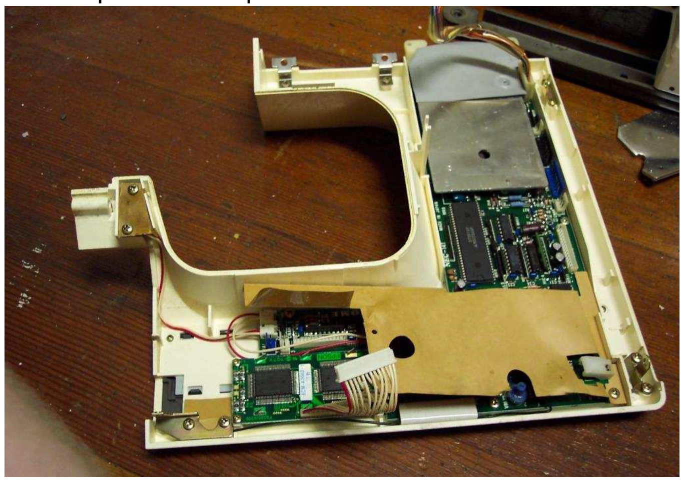
Sewing Machine: A case study

Everyone can be as good as an experienced seamstress



Sewing Machine: A case study

With help from microprocessor

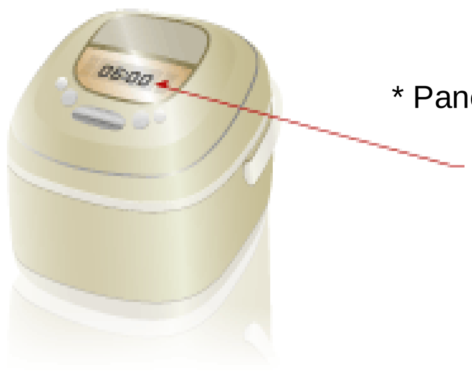


- But how can we cramp uP circuit board in a tiny space?
- We need something occupies much less space, but powerful enough to control the machine - - - > It's microcontroller that we need!

Examples of computer controlled application

Main objective is to make them intelligent appliances

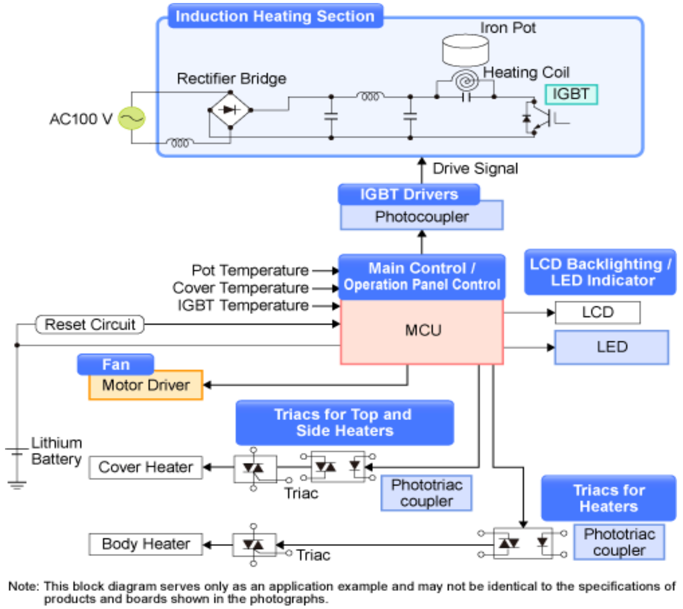
Examples of computer controlled application (1)



* Main Control
  - IGBT control

* Panel Control
  - LCD display
  - LED display
  - Key input operations
  - Buzzer output
  - RTC & calender

Examples of computer controlled application (1)

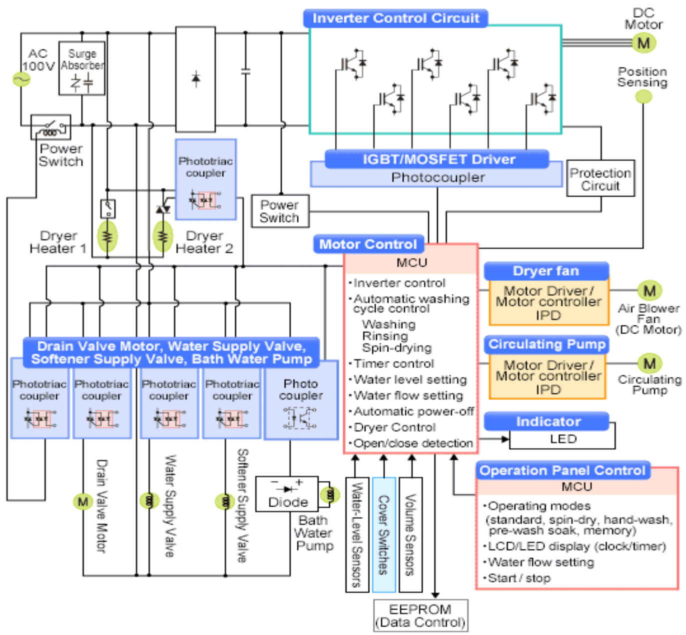


Examples of computer controlled application (2)

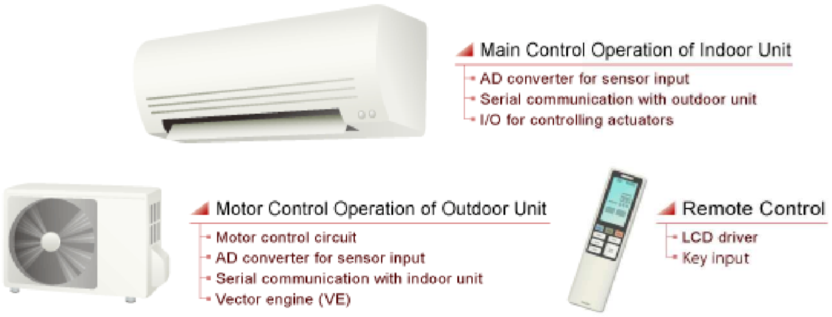
* Panel Control
  - LCD driver
  - LED driver

* Motor Control
  - Vector engine
  - PMD motor control

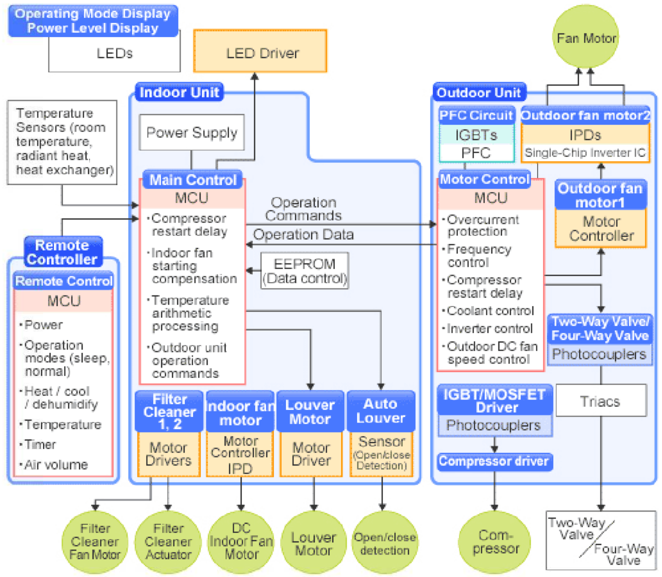
Examples of computer controlled application (2)



Examples of computer controlled application (3)

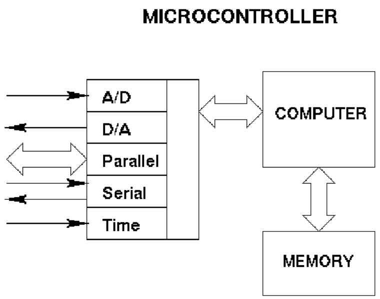


Examples of computer controlled application (3)

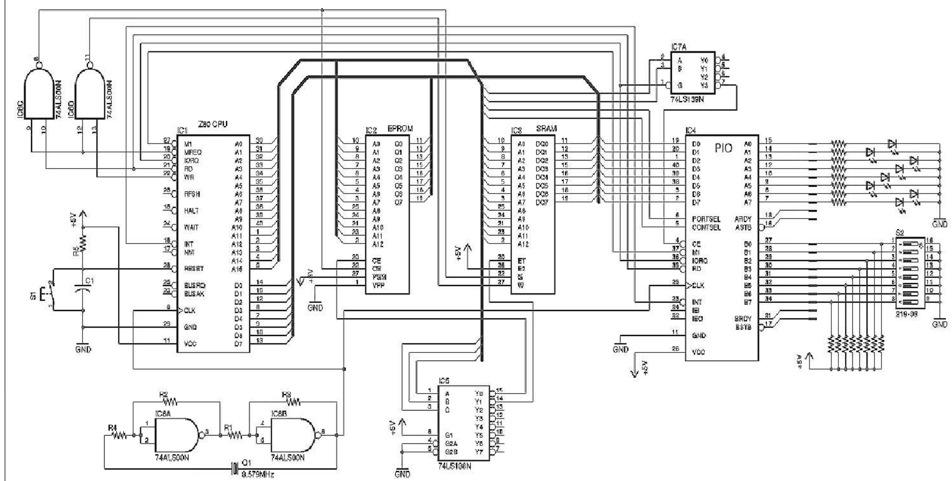


Microcontroller

- A **microcontroller** (also **MCU** or **µC**) is a computer-on-a-chip.
- It is a type of microprocessor emphasizing self-sufficiency and cost-effectiveness.
- Microcontrollers may not implement an external address or data bus
- Microcontroller integrates additional elements such as read-only and read-write memory, and input/output interfaces.

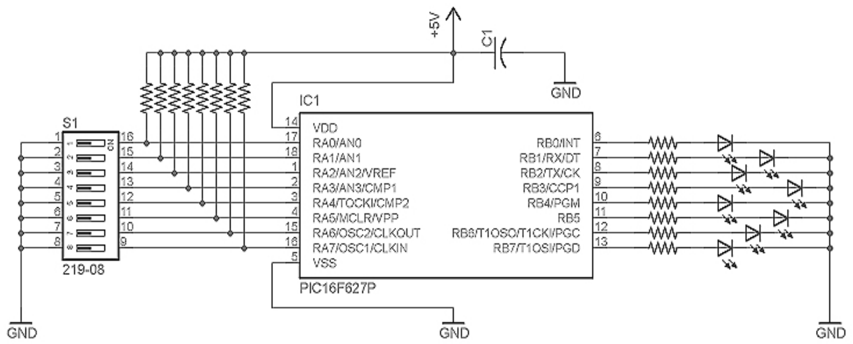


Microcontroller vs microprocessor



MPU minimal system

Microcontroller vs microprocessor



uC minimal system

Commonly integrated units are:

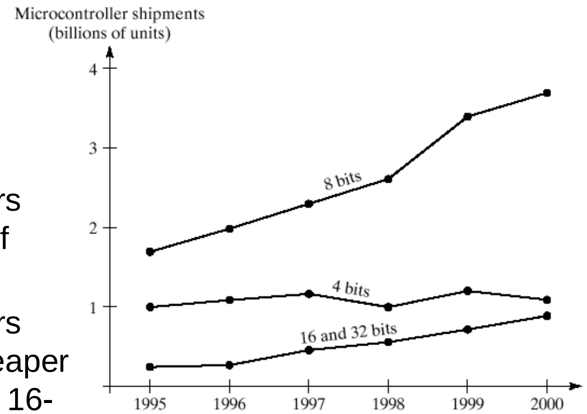
- Central processing unit
  ranging from 4-bit processors to complex 16- or 32-bit processors
- Discrete input and output bits
- Serial input/output such as serial ports (UARTs)
- Other serial communications interfaces
  like I²C, Serial Peripheral Interface and Controller Area Network
- Peripherals such as timers and watchdog
- Volatile memory (RAM) for data storage
- ROM, EPROM, [EEPROM] or Flash memory
  for program and operating parameter storage
- Clock generator
  often an oscillator for a quartz timing crystal, resonator or RC circuit
- many include analog-to-digital converters

Programming Environments

- Originally, microcontrollers were only programmed in assembly language
- Later, high-level programming languages such as C become more popular
- Recent microcontrollers integrated with on-chip debug circuitry accessed by In-circuit emulator via JTAG enables a programmer to debug the software of an embedded system with a debugger.
- Some microcontrollers have begun to include a built-in high-level programming language interpreter for greater ease of use.

Microcontroller Usage

- 8-bit microcontrollers dominate number of units shipped
- 8-bit microcontrollers are significantly cheaper than more powerful 16- and 32-bit.



Intel 8048 Families: The first microcontroller

Device	Internal Memory		RAM Standby
8050AH	4K x 8 ROM	256 x 8 RAM	yes
8049H	2K x 8 ROM	128 x 8 RAM	yes
8048H	1K x 8 ROM	64 x 8 RAM	yes
8040AHL	none	256 x 8 RAM	yes
8039HL	none	128 x 8 RAM	yes
8035HL	none	64 x 8 RAM	yes
8749H	2K x 8 EPROM	128 x 8 RAM	yes
8748H	1K x 8 EPROM	64 x 8 RAM	yes

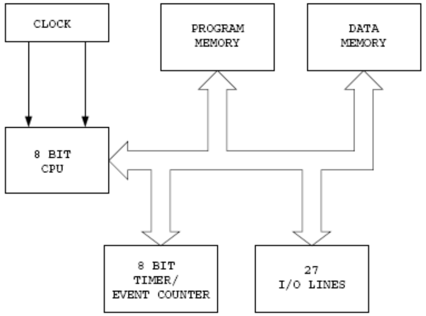


Figure 1.
Block Diagram

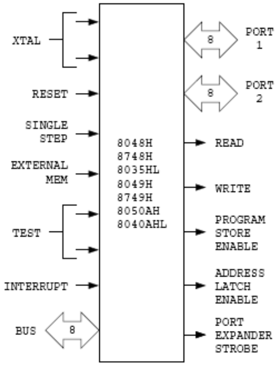


Figure 2.
Logic Symbol

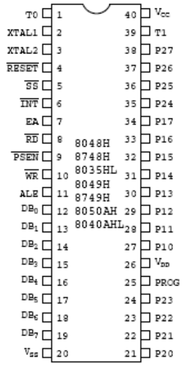
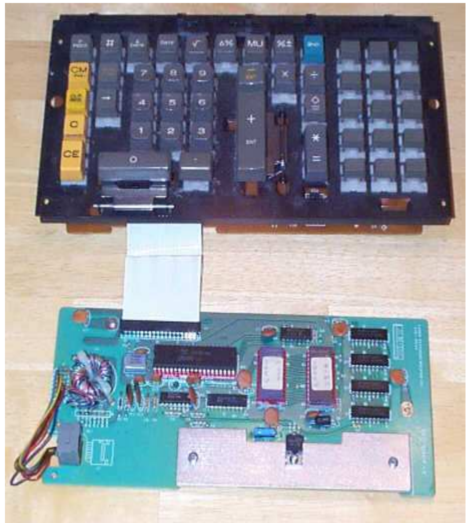


Figure 3.
Pin Configuration

Intel 8048 Families: The first microcontroller

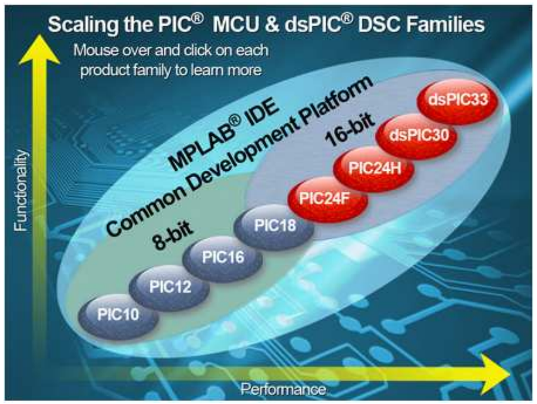


Popular microcontrollers

- MCS-51 from **Intel**
- AT89 series (Intel 8051 architecture) from **Atmel**
- 68HCxx series from **Motorola (Freescale)**
- **PIC from Microchip**
- Z8 from **Zilog**
- ST-7 from **STMicroelectronics**
- LPC series from **Phillips**
- MSP430 from **Texas Instrument**

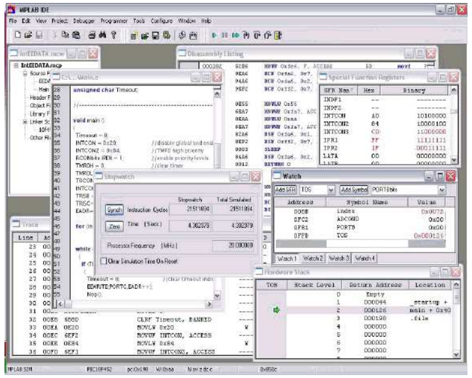
PIC microcontrollers

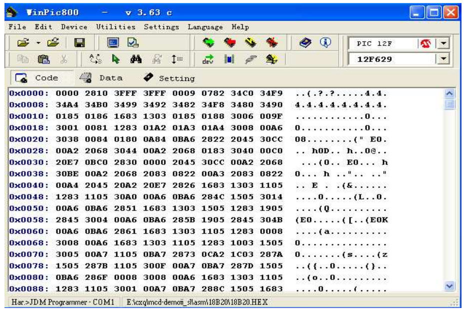
- Available in many product families (8-bit, 16-bit, RF-applications, DSP)
- Easy migration across product families
- Simple programming model (~30 instructions)
- **Made in Thailand** ***



uC for this course

- We start with low-end PIC **16F628** and then move to mid-end **16F877**
- Then, proceed to the cost-effective 12F625 (8-pin uC) for term project
- Software tools are:
  1. MPLAB-IDE from Microchip (Freeware) Editor + Assembler + Simulator
  2. WinPIC-800 (Freeware)





PIC 16F628 Overview

High-Performance RISC CPU:

- 8-bit CPU core
- Operating speeds from DC – 20 Mhz
- Interrupt capability
- 8-level deep hardware stack
- Direct, Indirect and Relative Addressing modes
- 35 single-word instructions:
  - All instructions single cycle except branches

PIC 16F628 Overview

Special Features:

- Internal and external oscillator options:
  - Precision internal 4 MHz oscillator factory calibrated to ±1%
  - Low-power internal 48 kHz oscillator
  - External Oscillator support for crystals and resonators
- Power-saving Sleep mode
- Watchdog Timer with independent oscillator for reliable operation
- Low-voltage programming
- In-Circuit Serial Programming™ (via two pins)
- Programmable code protection
- Brown-out Reset / Power-on Reset
- Power-up Timer and Oscillator Start-up Timer
- Wide operating voltage range (2.0-5.5V)
- High-Endurance Flash/EEPROM cell:
  - 100,000 write Flash endurance
  - 1,000,000 write EEPROM endurance
  - 40 year data retention

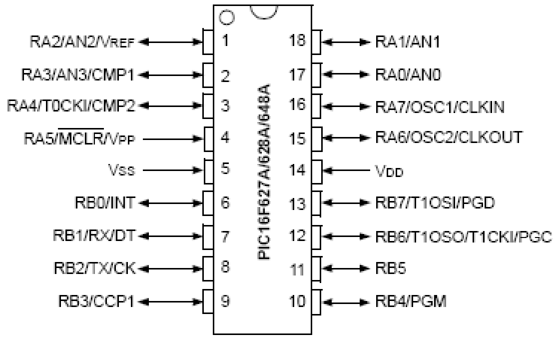
PIC 16F628 Overview

Peripheral Features:

- 16 I/O pins with individual direction control
- High current sink/source for direct LED drive
- Analog comparator module with:
  - Two analog comparators
  - Programmable on-chip voltage reference (VREF) module
  - Selectable internal or external reference
  - Comparator outputs are externally accessible
- Timer0: 8-bit timer/counter with 8-bit programmable prescaler
- Timer1: 16-bit timer/counter with external crystal/clock capability
- Timer2: 8-bit timer/counter with 8-bit period register, prescaler and postscaler
- Capture, Compare, PWM module:
  - 16-bit Capture/Compare
  - 10-bit PWM
- Addressable Universal Synchronous/Asynchronous Receiver/Transmitter USART/SCI

PIC 16F628 Overview

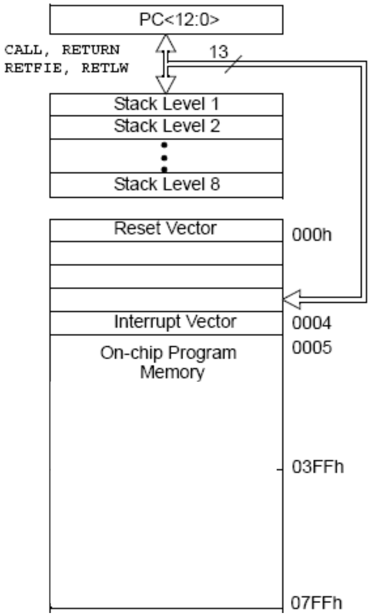
Device	Program Memory	Data Memory		I/O	CCP (PWM)	USART	Comparators	Timers 8/16-bit
	Flash (words)	SRAM (bytes)	EEPROM (bytes)					
PIC16F627A	1024	224	128	16	1	Y	2	2/1
PIC16F628A	2048	224	128	16	1	Y	2	2/1
PIC16F648A	4096	256	256	16	1	Y	2	2/1



PIC Architecture (8-bit uC)

- separate code and data spaces (Harvard architecture)
- a small number of fixed length instructions
- most instructions are single cycle execution (4 clock cycles), with single delay cycles upon branches and skips
- a single accumulator (W)
- All RAM locations function as registers as both source and/or destination of math and other functions
- a **hardware stack** for storing return addresses
- a fairly small amount of addressable data space (typically 256 bytes), extended through banking
- data space mapped CPU, port, and peripheral registers

PIC 16F628 : Program Memory Organization



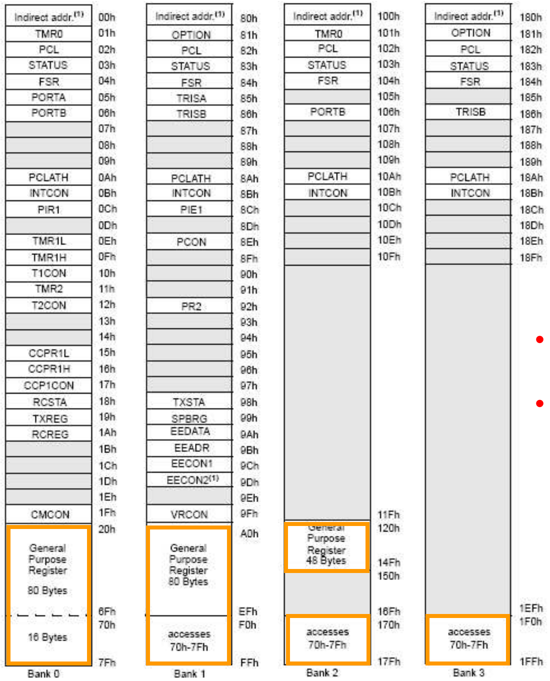
- **The PIC16F628A has a 13-bit PC capable of addressing an 8K x 14 program memory space.**
- **The first 2K x 14 (0000h-07FFh) for the PIC16F628A is physically implemented.**
- **Accessing a location above these boundaries will cause a wraparound within the first 2K x 14 space**
- **The Reset vector is at 0000h and the interrupt vector is at 0004h**

PIC 16F628 : Data Memory Organization

- The data memory is partitioned into four banks, which contain the General Purpose Registers (GPRs) and the Special Function Registers (SFRs).
- The SFRs are located in the first 32 locations of each bank.
- There are GPRs implemented as static RAM in each bank.
- GPRs are user space
- SFRs are used mostly for controlling on-chip peripherals

GPRs Addresses

	PIC16F627A/628A
Bank0	20-7Fh
Bank1	A0h-FF
Bank2	120h-14Fh, 170h-17Fh
Bank3	1F0h-1FFh



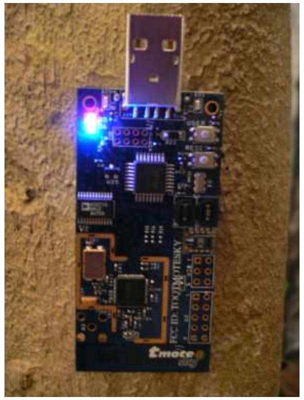
- **User can access only one memory bank at a time**
- **Choosing memory bank is called "bank switching"**

PIC Architecture (cont'd)

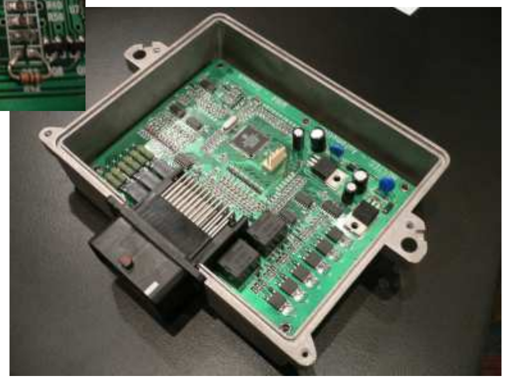
Unlike most other CPUs, there is no distinction between "*memory*" and "*register*" space because the RAM serves the job of both memory and registers, and the RAM is usually just referred to as the **register file** or simply as the registers.

Example of Applications

- Classical control applications
- Wireless sensor network
- Automobile ECU
- Agritronics (Agriculture + Electronics)



Example of Applications



Term Project: Intelligent light control switch

- In modern buildings, light controller is a mandatory equipment
- Required basic functions are:
  - Light on/off switch
  - Light dimming
- Some allows users a convenient control via remote control
- Some are automatically turned on when dark
- But none **<u>has all above functions</u>**!!!

It's time to engineer such a thing

Term Project: Intelligent light control switch

- You are going to design an intelligent light control whose features are:
- Able to turn incandescent bulb on/off by pushing a switch
- Able to turn the bulb on/off via remote control
- Able to dim the light via remote control
- Programmable in 2 modes
  - Light sensing mode

    auto turn on in low light and turn off in bright light or
  - Timer mode

    turn on/off at present time

Term Project: Intelligent light control switch