Outline - PICMicro

- General Concepts
  - Microcontrollers
- PIC Microcontrollers
  - History
  - Execution Speed
  - 8-bit μC Market
  - PICmicro Family
    - Properties
- PIC 18F4520
  - Basic Circuity
  - Programming
  - Boot-loader

Microcontroller

- A computer implemented on a single chip:
  - Called “Computer-on-Chip” or “System-on-Chip”

PIC Microcontroller

- The Peripheral Interface Controller (PIC) line of microcontrollers was originally developed by General Instruments Inc.
  - PIC1650
    - Original acronym was “Programmable Intelligent Computer”
- General Instruments sold its semiconductor division to a capitalist group that formed Microchip Technology.

About Microchip

- Arizona based company officially founded in 1989.
- Designs, manufactures, and markets a variety of high-performance semiconductor circuit components.
- Leader in 8-bit microcontrollers:
  - Since 1990, more than three billion PIC microcontrollers have been shipped to customers worldwide.
  - More than 212 microcontrollers in the product portfolio
- Other products are
  - Digital signal controllers (dsPICs),
  - 16-bit / 32-bit microcontrollers
  - Mixed signal products and more...
PIC Family

- PICs come with 1 of 3 CPU “cores:”
  - 12-bit cores with 33 instructions: 12F50x
  - 14-bit cores with 35 instructions: 16Fxxx
  - Enhanced 16-bit cores with 77 instructions: 18Fxxx

- PICs come in a huge variety of packages:
  - 8-pin DIPs, SOICs
  - 18-pin DIPs, SOICs
  - 28-pin DIPs, SOICs
  - 40-pin DIPs, SOICs
  - 44-, 68-, 80-pin PLCCs

PIC Family - Speed

- PICMicro requires a clock:
  - Crystals, clock oscillators, or even an RC circuit.
  - Some PICs have a built in 4 MHz RC clock
    - Not very accurate, but requires no external components!
    - Instruction execution speed is 1/4 clock speed ($T_{cyc} = 4 \times T_{clk}$)
- All PICs can be run from DC (~0 Hz) to their maximum specified frequency:
  - 12C50x up to 4MHz
  - 12C67x up to 10MHz
  - 16Fxxx up to 20MHz
  - 18Fxxx up to 40MHz
  - 24Fxxx (Newest: 16-bit family > 40 MIPS)
PIC Family – Execution Cycles

The PIC Family – Memory

Program space is different for each PICmicro:
- 12F508A: 512 12-bit instructions
- 16F84A: 1024 (1K) 14-bit instructions
- 16F877A: 8192 (8K) 14-bit instructions
- 18F4520: 16384 (16K) 16-bit instructions

PIC Family – Program Memory

Two different types of program memory:
- EPROM
  - Needs high voltage from a programmer to program (~13V)
  - UV light is used to erase windowed chips.
  - Note: One Time Programmable (OTP) chips are EPROM chips, but with no window.
  - PIC Examples: Any “C” part: 12C50x, 16C55x, etc.
- FLASH Memory
  - Re-writable (even by chip itself)
  - Much faster to develop on!
  - Finite number of writes (~100k writes)
  - PIC Examples: Any “F” part: 16F84, 16F87x, 18Fxxx

PIC Family – Data Memory

PICs use general purpose “file registers” in RAM:
- Each register is 8-bit for all PICMicros.
- Some examples are:
  - 12F508: 25 Bytes RAM
  - 16F84A: 68 Bytes RAM
  - 16F877A: 368 Bytes RAM
    - 256 Bytes of nonvolatile E2PROM
  - 18F4520: 1536 Bytes RAM
    - 256 Bytes of non-volatile E2PROM
PIC Peripherals

- PICmicros have different on-board peripherals:
  - Digital I/O pins
  - Analog to digital converters (ADC)
    - 8, 10, and 12-bit (@ 50k samples/s)
  - Capture/Compare/PWM (CCP) Modules
    - PWM (8- or 10-bit)
  - Timers and counters
    - 8-bit and 16-bit
  - Serial communications:
    - UART (RS-232C)
    - SPI, I2C, CAN, USB
  - Miscellaneous
    - Watchdog timers, Brown out detect, LCD drivers

Digital I/O Ports

- All PICs have digital I/O pins, called “Ports”
  - 8-pin 12F508 has 1 Port with 6 digital I/O pins
  - 80-pin 18F8720 has 9 Ports with 68 digital I/O pins
- Digital ports are titled A, B, C, ...
- Digital I/O pins are pins that can either
  - Write (output) ‘1’ (5V) or ‘0’ (0V) value OR
  - Read (input) the voltage level at the pin as ‘1’ (5V) or ‘0’ (0V).
- Ports have 2 control registers
  - TRISX sets whether each pin is an input or output
  - PORTX sets their output bit levels (X = A, B, ...)
- Most pins have 25mA source/sink (directly drives LEDs)
- Most peripherals share pins with digital I/O!

Analog-to-Digital Converters

- Only available in 14-bit and 16-bit cores
  - \(f_s\) (sample rate) < 54kHz
  - Most 8-bits, newer PICs have 10 or 12-bit
  - Theoretically, higher accuracy when PIC is in sleep mode
    - Less digital noise.
  - Can generate an interrupt when ADC conversion is over.

CCP Modules

- Capture counts external pin changes.
- Compare will generate an interrupt when the timer equals the value in a compare register.
- 10-bit PWM width within 8-bit PWM period (frequency)
  - Enhanced 16-bit cores have better bit widths
  - Frequency/duty cycle resolution is a trade-off:
    - 19.5 kHz has 10-bit resolution
    - 40 kHz has 8-bit resolution
    - 1 MHz has 1-bit resolution (makes a good 1MHz clock!)
  - Can use PWM as D/A Converter
**Timers**

- Timers are used to create accurate timing signals:
  - Available in all PICs.
- 14/16-bit cores may generate interrupts on timer overflow.
- Some 8-bit, some 16-bit timers have frequency dividers.
- Can use external pins as clock in/clock out: (i.e., for counting events or using a different \( f_{osc} \)).
- **Warning:** Some peripherals share timer resources.

**USART and UART**

- Serial Communications Peripheral:
  - Universal Synchronous/Asynchronous Receiver/Transmitter
- Only available in 14-bit and 16-bit cores
- Interrupt on TX buffer empty and RX buffer full
- Asynchronous communication: UART (RS-232C serial)
  - 300 bps – 115 kbps
  - 8 or 9 bits, parity, start and stop bits, etc.
  - Outputs 5V so you need a RS-232 level converter (e.g., MAX-232)

**USRT**

- Synchronous communication with a clock signal
- SPI: Serial Peripheral Interface
  - 3 wire: Data in, Data out, Clock
  - Master/Slave type (can have multiple masters)
  - Very high speed (1.6Mbps)
  - Full speed simultaneous send and receive (full duplex)
- \( \text{I}^2\text{C} = \text{Inter IC} \)
  - 2 wire: Data and Clock
  - Master/Slave type (but multiple masters are clumsy!)
  - Lots of cheap \( \text{I}^2\text{C} \) chips available:
    - Typically < 100kbps
    - For example, 8-pin E\( \text{E} \)PROM chips, ADC, DACs, etc.

**Misc. PIC Peripherals**

- **Sleep Mode:** PIC shuts down until external interrupt (or internal timer) wakes it up.
- **Interrupt on pin change:** Generate an interrupt when a digital input pin changes state (for example, interrupt on keypress).
- **Watchdog timer:** Resets chip if not cleared before overflow
- **Brown out detect:** Resets chip at a known voltage level
- **LCD drivers:** Drives simple LCD displays
- USB, CAN bus, 12-bit ADC, better analog functions.
**PIC 18F4520 (8-bit)**

- 40-pin package (PDIP, SOIC)
- 16-bit core: 75+8 instructions
- Clock frequency: DC to 40MHz
- 8×8 bit single-cycle multiplier
- 16K of 16-bit FLASH program memory
- 1536 8-bit data memory or registers ("File registers")
- 256 8-bit EEPROM (non-volatile) data registers
- Priority-level (selected) interrupts
- 33 general purpose I/O (25mA source / sink)
- **Peripherals:**
  - 13-channel 10-bit ADC
  - USART / I2C / SPI
  - 1, 2 or 4 PWM outputs
  - 16-bit & 8-bit timers / counters
- Features: Brown out detect, *In-Circuit Debugger* (ICD)

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**Programming Options**

- Assembler
  - You know exactly what your program does
  - Time consuming
  - Great for small- and time insensitive projects
- PIC-C
  - High-level
  - Lots of standard function
  - Excellent for more complex firmware

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**How to Program PICmicro**

- Program is written and "cross"compiled on a PC.
  - Machine code is then uploaded to the flash memory.
- PC must have a compiler to generate the machine code ("hex file") for the microcontroller.
- For PICmicros, the programming is usually done using the Microchip’s MPLAB® IDE (freeware):
  - Program can be developed using assembler language
  - Needs experience to program
- Fortunately, high-level programming tools are available.
  - Can be programmed using C language (CCS-C, C-18, Mikro-C, HiTech-C, etc.) and compilers are built in to produce machine codes.
  - We will use evaluation version of CCS C compiler (for now!): Customer Computer Services Inc., [www.ccsinfo.com](http://www.ccsinfo.com).
Program Downloading

- **PICSTART® Plus** is Microchip's low-cost / development programmer.
  - Connects via RS-232 port to your PC
  - Interfaces with MPLAB.
  - Almost any PICMicro with PDIP packaging (up to 40 pins) can be programmed.
- Needs to place the PIC micro on the target socket for program uploading.
- The PIC micro has to be removed from the PCB whenever there is a revision on the program.
  - A major inconvenience during the development phase!