Embedded systems

- there are many times an IBM-PC is an overkill solution
- an IBM-PC is a general purpose computer, sometimes a more specific computer is cost effective
- a specific computer executing a specific operating system might be the solution and in a minimal case we might choose to use an embedded operating system
  - or embedded system if we include the application

Characteristics of an embedded system

- these systems can be tiny
  - could be < 1KBytes

- only use software which you need
  - for example many times it is possible to implement an embedded system using no interrupts
  - choice, it might be
    - easier to implement
    - guarentee a hard realtime performance for time critical applications

Case examples: embedded systems built using the ATMega328p

- we will look at building a basic computer running a tiny embedded system
  - flashing LED program

- many, many other examples in which the ATMega328p can be used
  - network on/off switch
  - cruise controller for an electic bicycle
  - amplifier controller
  - tiny web server and LCD panel
  - Arduino!

Why use ATMega processsors?

- support within `gcc` in mature (it has support ATMega microprocessors for about two decades)
  - the ATMega series of microprocessors have very similar instructions

- harvard risc architecture

Atmel ATMega series of microprocessors

- the number of components to make a minimal system is tiny
- they are also extremely easy to interface to peripherals
  - A->D, D->A, pwm (servo and motor control) etc
  - multiple hardware timers etc

Atmel 328p

- is an 8-bit AVR RISC-based microcontroller (some of its features include):
  - 32KB flash memory
  - 1024B EEPROM, 2KB SRAM
- 23 general purpose I/O lines
  - 32 general purpose working registers
  - three flexible timer/counters with compare modes
  - internal/external interrupts, a 6-channel 10-bit A/D converter
  - programmable watchdog timer with internal oscillator
  - 2 PWM channels (ie control two servos) in hardware
- many features omitted for sake of brevity

Simple computer flashing a LED with the ATMega328p

line from 4.331,9.398 to 4.331,9.240 line from 4.331,9.319 to 4.488,9.398 line from 4.331,9.319 to 4.488,9.240 to 4.488,9.398 line -> from 4.409,9.476 to 4.252,9.634 line -> from 4.331,9.398 to 4.173,9.555 arc at 2.165,9.713 from 1.969,9.713 to 2.362,9.713 circle at 0.407,7.364 rad 0.041 circle at 0.381,9.319 rad 0.041 circle at 0.381,6.550 rad 0.041 circle at 3.136,6.957 rad 0.041 circle at 0.394,6.957 rad 0.041 box with .sw at (1.575,3.807) width 1.181 height 5.906 box with .sw at (1.496,8.138) width 0.079 height 0.079 box with .sw at (1.496,7.744) width 0.079 height 0.079 box with .sw at (1.496,7.350) width 0.079 height 0.079 box with .sw at (1.496,6.957) width 0.079 height 0.079 box with .sw at (1.496,6.563) width 0.079 height 0.079 box with .sw at (1.496,6.169) width 0.079 height 0.079 box with .sw at (1.496,5.776) width 0.079 height 0.079 box with .sw at (1.496,5.382) width 0.079 height 0.079 box with .sw at (1.496,4.988) width 0.079 height 0.079 box with .sw at (1.496,4.594) width 0.079 height 0.079 box with .sw at (1.496,4.201) width 0.079 height 0.079 box with .sw at (2.756,9.319) width 0.079 height 0.079 box with .sw at (2.756,8.925) width 0.079 height 0.079 box with .sw at (2.756,8.531) width 0.079 height 0.079 box with .sw at (2.756,8.138) width 0.079 height 0.079 box with .sw at (2.756,7.744) width 0.079 height 0.079 box with .sw at (2.756,7.350) width 0.079 height 0.079 box with .sw at (2.756,6.957) width 0.079 height 0.079 box with .sw at (2.756,6.563) width 0.079 height 0.079 box with .sw at (2.756,6.169) width 0.079 height 0.079 box with .sw at (2.756,5.776) width 0.079 height 0.079 box with .sw at (2.756,5.382) width 0.079 height 0.079 box with .sw at (2.756,4.988) width 0.079 height 0.079 box with .sw at (2.756,4.594) width 0.079 height 0.079 box with .sw at (2.756,4.201) width 0.079 height 0.079 line from 2.835,9.319 to 3.543,9.319 box with .sw at (3.543,9.240) width 0.394 height 0.157 line from 3.937,9.319 to 4.331,9.319 line -> from 4.488,9.319 to 4.724,9.319 to 4.724,9.555 box with .sw at (1.496,9.319) width 0.079 height 0.079 box with .sw at (1.496,8.925) width 0.079 height 0.079 box with .sw at

(1.496,8.531) width 0.079 height 0.079 line from 1.575,9.319 to 0.394,9.319 to 0.394,8.335 box with .sw at (0.315,7.941) width 0.157 height 0.394 line from 1.562,6.563 to 0.381,6.563 line from 0.407,7.941 to 0.407,6.957 to 1.588,6.957 box with .sw at (0.236,6.655) width 0.315 height 0.066 box with .sw at (0.249,6.812) width 0.315 height 0.066 line from 0.420,6.944 to 0.407,6.865 line from 0.407,6.655 to 0.407,6.629 to 0.407,6.602 to 0.407,6.576 to 0.407,6.550 line from 0.394,6.563 to 0.394,6.327 line from 0.236,6.366 to 0.551,6.366 line from 0.315,6.287 to 0.472,6.287 line from 0.394,6.209 to 0.433,6.209 box with .sw at (3.937,4.988) width 0.079 height 0.079 box with .sw at (3.937,5.382) width 0.079 height 0.079 box with .sw at (3.937,4.594) width 0.079 height 0.079 box with .sw at (3.937,5.776) width 0.079 height 0.079 box with .sw at (3.937,6.169) width 0.079 height 0.079 box with .sw at (3.740,4.398) width 0.394 height 1.969 line from 2.756,5.776 to 3.937,5.776 line from 2.756,5.382 to 3.937,5.382 line from 2.756,4.988 to 3.937,4.988 line from 2.756,6.957 to 3.543,6.957 to 3.543,6.169 to 3.937,6.169 line from 3.058,6.655 to 3.215,6.655 line from 3.937,4.594 to 5.512,4.594 to 5.512,9.909 to 0.394,9.909 to 0.394,9.319 line -> from 0.394,7.350 to 0.197,7.350 to 0.197,7.744 line from 3.150,6.563 to 3.189,6.563 line from 3.150,6.957 to 3.150,6.760 line from 2.953,6.760 to 3.346,6.760 "1" at 1.772,9.352 ljust "2" at 1.772,8.959 ljust "3" at 1.772,8.565 ljust "4" at 1.772,8.171 ljust "5" at 1.772,7.777 ljust "6" at 1.772,7.384 ljust "7" at 1.772,6.990 ljust "8" at 1.772,6.596 ljust "9" at 1.772,6.203 ljust "10" at 1.772,5.809 ljust "11" at 1.772,5.415 ljust "12" at 1.772,5.022 ljust "13" at 1.772,4.628 ljust "14" at 1.772,4.234 ljust "27" at 2.520,8.959 ljust "26" at 2.520,8.565 ljust "25" at 2.520,8.171 ljust "24" at 2.520,7.777 ljust "23" at 2.520,7.384 ljust "22" at 2.520,6.990 ljust "21" at 2.520,6.596 ljust "20" at 2.520,6.203 ljust "19" at 2.520,5.809 ljust "18" at 2.520,5.415 ljust "17" at 2.520,5.022 ljust "16" at 2.520,4.628 ljust "15" at 2.520,4.234 ljust "1K" at 3.622,9.510 ljust "10K" at 0.591,8.171 ljust "10uF" at 0.787,6.793 ljust "28" at 2.520,9.352 ljust "GND" at 4.724,6.203 ljust "SCK" at 4.724,5.809 ljust "MISO" at 4.724,5.415 ljust "MOSI" at 4.724,5.022 ljust "RESET" at 4.724,4.628 ljust "+5V" at 0.591,7.581 ljust "ATMega328P" at 1.614,3.525 ljust

Code for the flashing LED

```
MODULE flashled ;

PROCEDURE Turn (on: BOOLEAN) ;
BEGIN
   IF on
   THEN
      (* turn LED on *)
      ASM VOLATILE ("cbi 8,5");
   ELSE
      (* turn LED off *)
      ASM VOLATILE ("sbi 8,5");
   END
END Turn ;

(*
   InitLed - initialize pin 0 as an output
*)

PROCEDURE InitLed ;
BEGIN
   ASM VOLATILE ("sbi 7,5")
END InitLed ;
```

Code for the flashing LED

```
CONST
   Delay = 400 ;

VAR
   i, j: CARDINAL ;
```

Code for the flashing LED

```
BEGIN
   InitLed ;
   Turn(FALSE) ;
   LOOP
      FOR i := 0 TO Delay DO
         FOR j := 0 TO Delay DO
            ASM VOLATILE ("nop")
         END
      END ;
      Turn(TRUE) ;
      FOR i := 0 TO Delay DO
         FOR j := 0 TO Delay DO
            ASM VOLATILE ("nop")
         END
      END ;
      Turn(FALSE)
   END
END flashled.
```

Cruise controller for an electric bicycle

- uses PWM device to control the power delivered to the electric motor
- uses a A to D device to take input from the throttle (potentiometer)
- uses several output pins to control status LEDs
- uses input pins for wheel movement sensing
- due to the hardware support inside the Atmega328p the software is extremely simple
  - no need for interrupt service routines
  - no need for separate processes

Amplifier control embedded system

- uses the Atmega328p to
  - turn on the +-12v power
  - turn on the +-9v power
  - connect the speakers after 2 seconds (speaker protection)
  - uses the A to D device to take input from a potentiometer to select input source

Amplifier control embedded system

- uses input lines to detect push button
  - three pulses turns it off
  - two pulses turns off the speakers
  - one pulse resets the power save timer

- software is a simple C program which controls hardware directly

Conclusion

- embedded systems come in many sizes and the examples given here are tiny applications
- embedded systems might range up to and including the Linux kernel (with various scheduling and device driver changes)