E246: Electronics & Instrumentation

Lecture: Microprocessors and DSPs
Microprocessor

- It is an integrated circuit that is the fundamental building block of a digital computer, controlled by software programs that allow it to do all digital arithmetic, logic, and I/O operations.
The heart is an 8-bit *microprocessor*, it reads program instructions from memory and execute those instructions that drive the three external buses with the proper levels and timing to make the connected devices perform specific operations.

Popular 8-bit microprocessors include Intel 8085, Motorola 6800, Zilog Z80.

The *address bus* is 16 bits wide and is generated by the microprocessor to select a particular location or IC to be active.

Once the address bus is set up with the particular address that the microprocessor wants to access, the microprocessor then sends or receives 8 bits of data to or from that address via the bidirectional *data bus*. 
Two types of memory ICs: ROM and RAM.

ROM contains the initialization instructions, telling the microprocessor what to do when power is first on.

RAM is used for temporary data storage, it loses its contents when power is turned off.
Microcontroller

- Microcontroller has the CPU, RAM, ROM, timer/counter, and parallel and serial I/O ports fabricated into a single IC ("a computer on a chip")
- Its CPU instruction set is improved for control applications and offers bit-oriented data manipulation, branching, and I/O, as well as multiply and divide instructions
- It is most efficiently used in systems that have a fixed program for a dedicate application
Block Diagram of an 8051 Microcontroller
Example microcontroller systems:
- Keyboard for a personal computers
- Sensing and controlling engine operation of automobile
- Microwave ovens
- Videocassette recorders
- Gas pumps
- Automated teller machines
What is a DSP?

A digital signal processor (DSP) is a microprocessor for digital signal processing (confusingly, also generally abbreviated as DSP).

• How do DSPs differ from other microprocessors?
  They are optimized towards signal processing:
   e.g., they might have special instructions to assist digital filtering.
  Generally, they are embedded microprocessors.
   – They live in disk drives and mobile phones and car engines.
   – They are often designed to be frugal with power.
  They generally have a small number of different tasks to do:
   e.g., in a particular application, a DSP might only perform a filtering task.
   – However, it has to do it on time, every time!
   – That is, DSPs have to perform in real time.
   – Therefore, they must have predictable execution times.
When to choose a DSP?

For a specific signal processing application, there are many options for implementation, of which DSPs are only one.

**Analogue Signal Processing:**
- In analogue signal processing, a circuit is constructed from analogue components such as amplifiers, resistors, inductors and capacitors.
- Advantages: much higher bandwidths are possible than for DSP.
- Disadvantages: only limited complexity is possible, limited reconfigurability, variability in component values, difficult design.

**Application-Specific Integrated Circuits (ASICs)**
- ASICs are custom made chips that are produced in mass in a factory.
- Advantages: higher bandwidths, lower power consumption, lower cost (in a big production run).
- Disadvantages: high investment cost, limited reconfigurability, difficult design.
Field-Programmable Gate Arrays (FPGAs):
- FPGAs are ‘digital breadboards on a chip’ that can be reconfigured in firmware, e.g., Xilinx & Altera FPGAs.
- Advantages: somewhat higher bandwidths.
- Disadvantages: somewhat difficult design, somewhat higher cost.

Microcontrollers:
- Microcontrollers are microprocessors that are designed for general embedded applications, e.g., MicroChip PIC.
- Advantages: easy, flexible design, low cost, low power.
- Disadvantages: generally lower bandwidth.

General-Purpose Microprocessors (GPPs):
- By general-purpose microprocessors, we mean the mainstream microprocessors that often form the CPU of desktop computers, e.g., Intel Pentium IV, Motorola PowerPC.
- Advantages: extensive software tools, slightly higher bandwidth.
- Disadvantages: higher power, higher cost, more difficult PCB design, execution times difficult to predict.
What does a DSP do?

Common DSP Algorithms
Although the total amount of code for a particular application maybe thousands of lines, it often turns out that, for most of its time, a DSP executes fairly simple, but time-consuming, algorithms.

Algorithm Formula
FIR/Convolution
IIR/Difference equation
Discrete Cosine Transform
Example DSP Applications: Mobile Phones

Low Sampling Rate (8 kSPS) 13 bits

High Sampling Rate (20 MSPS) < 8 bits
Motor Control

- Estimate feedback parameters
- Control algorithm
Disk Drives
(a) The von Neumann memory architecture permits only one access to memory at a time.

(b) DSPs typically use a Harvard memory architecture (at least partially), which permits multiple simultaneous memory accesses. More complicated, but higher performance.
Texas Instruments DSPs

In 1982, Texas Instruments (TI) offered its first DSP, the 32010, running at 5 MHz.

- Since then, the range of DSPs offered by TI has expanded and evolved significantly.
- DSPs are used in a broad range of applications, and TI has adapted families of DSPs to suit.

- C2x. The C2x-series DSPs are aimed at control applications where throughput requirements are not extremely demanding.
  - On-chip peripherals and interfaces are important—FLASH, CAN bus.
  - Competing with microcontrollers.
  - Cost: $3–$35.

- C5x. The C5x-series DSPs are optimised for higher throughput applications where power consumption is critical.
Target market is consumer portable electronics like music players, GPS receivers, mobile phones, etc.

- The hybrid OMAP processor incorporates an ARM microprocessor also aimed at multimedia-enabled palmtops.
  - Cost: $8–$35.

**C6x.** The C6x-series DSPs are TI’s highest performance offerings.

- Target market is broadband infrastructure, performance audio and imaging.
  - Fixed- and floating-point processors available.
  - Cost: $20–$250.
The C6711 DSK (DSP Starter Kit) is a development tool from TI which incorporates their TMS320C6711 floating-point DSP.

- It provides a flexible and high-performance platform for familiarisation with the C6x DSP family.
- Capable of 900 Mflops.
- 150MHz TMS320C6711 DSP.
- Parallel port controller interface to standard PC parallel port.
- 16MB of 100MHz SDRAM.
- 128 kB of FLASH ROM.
- JTAG port for embedded control, debugging, programme and data transfer (an alternative to the parallel port interface).
- AD535 16-bit audio codec with mini stereo jacks for line-in/lineout.
- Three LEDs and three DIP switches are directly accessible to the programmer.
- A daughterboard interface allows expansion with access to the major DSP buses.