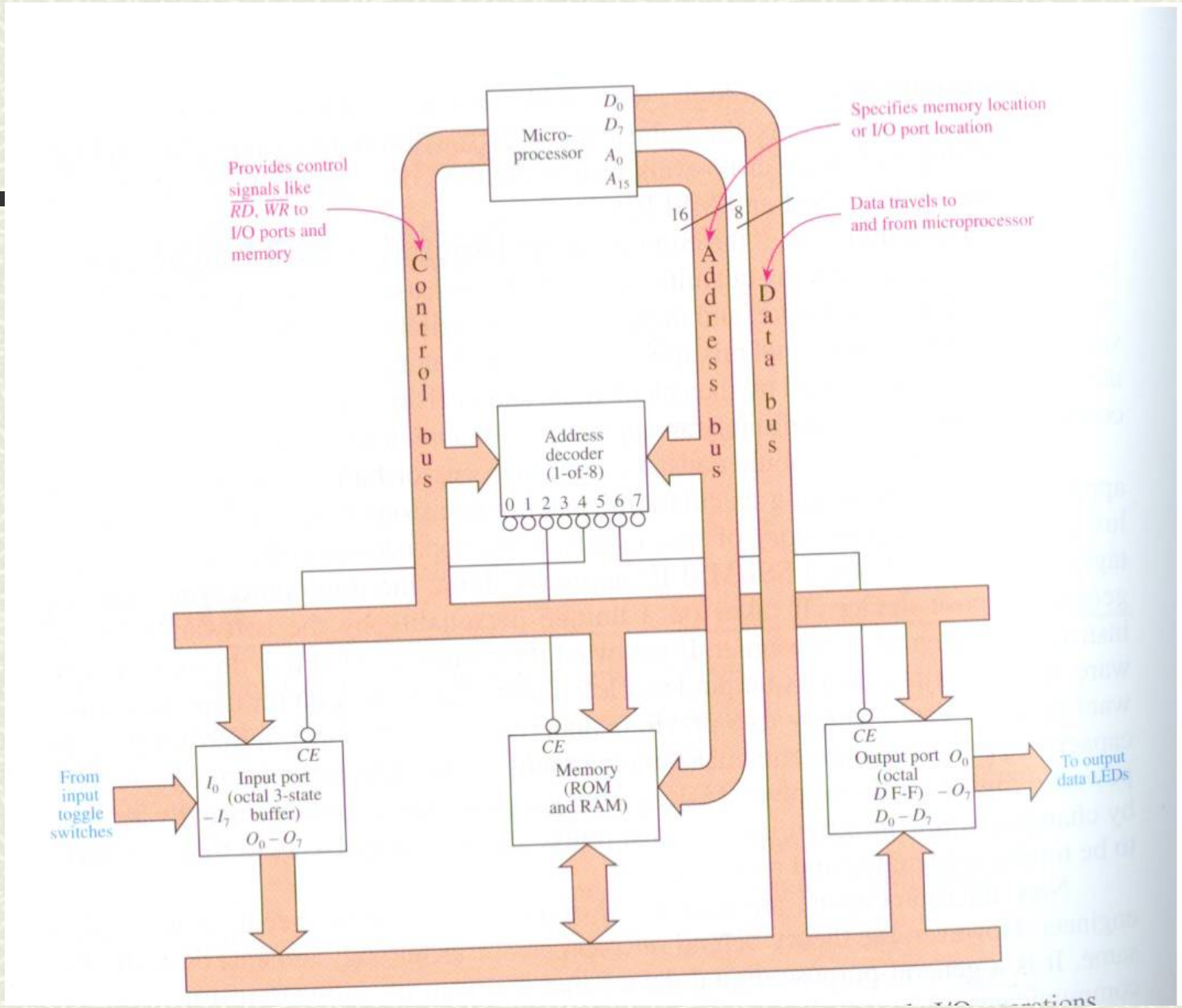
E246: Electronics & Instrumentation

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.


Micro-processor
D_0
D_7
A_0
A_{15}
16
8
Provides control signals like $\overline{RD}$, $\overline{WR}$ to I/O ports and memory
Specifies memory location or I/O port location
Data travels to and from microprocessor
Control bus
Address bus
Data bus
Address decoder (1-of-8)
0 1 2 3 4 5 6 7
CE
I_0 – I_7 Input port (octal 3-state buffer)
$O_0 - O_7$
From input toggle switches
CE
Memory (ROM and RAM)
CE
Output port (octal D F-F) O_0 – O_7
$D_0 - D_7$
To output data LEDs

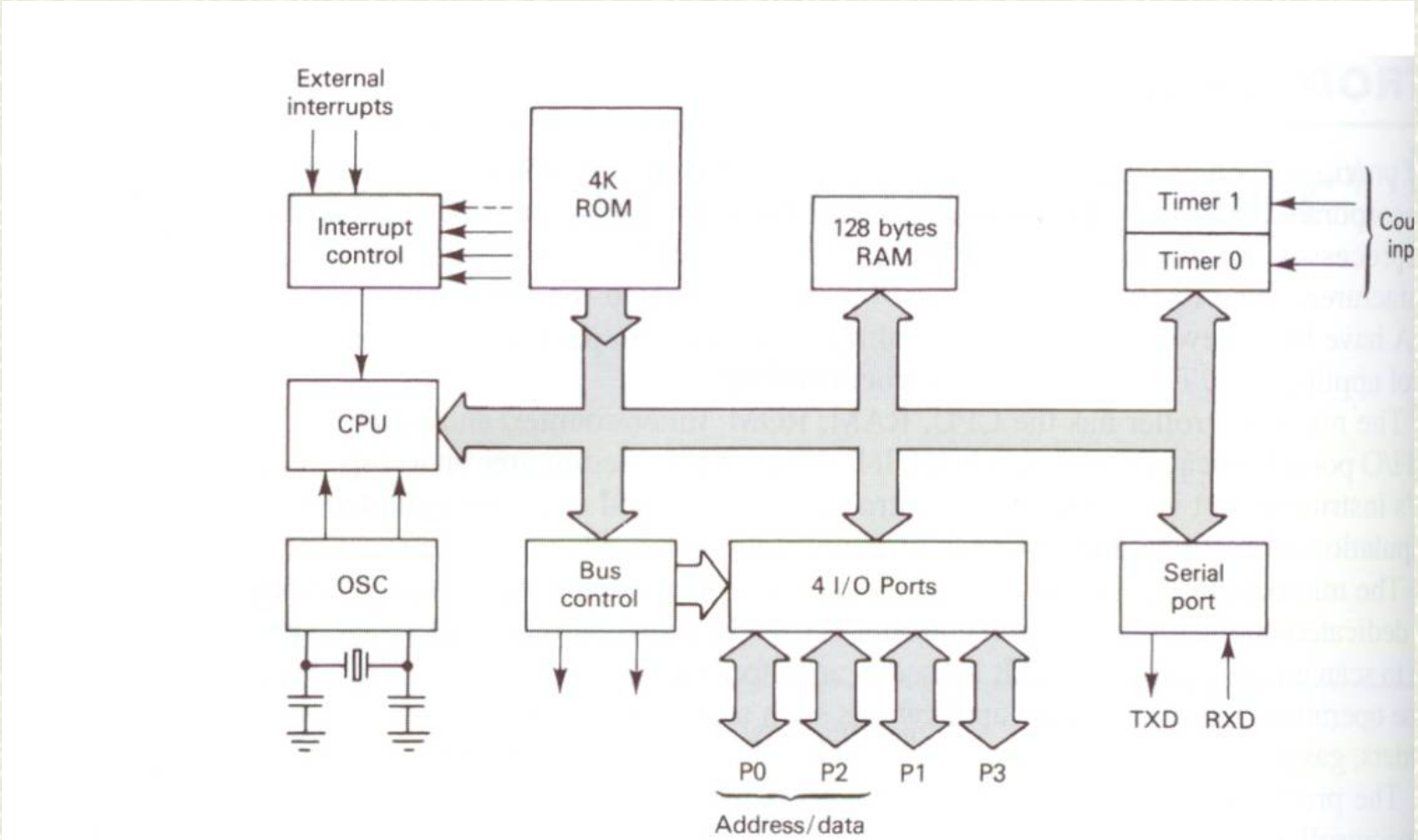
- The heart is an 8-bit *microprocessor*, it reads program instructions from memory and execute those instructions that drive the three external buses with the proper levels and timing to make the connected devices perform specific operations
- Popular 8-bit microprocessors include Intel 8085, Motorola 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 if 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.

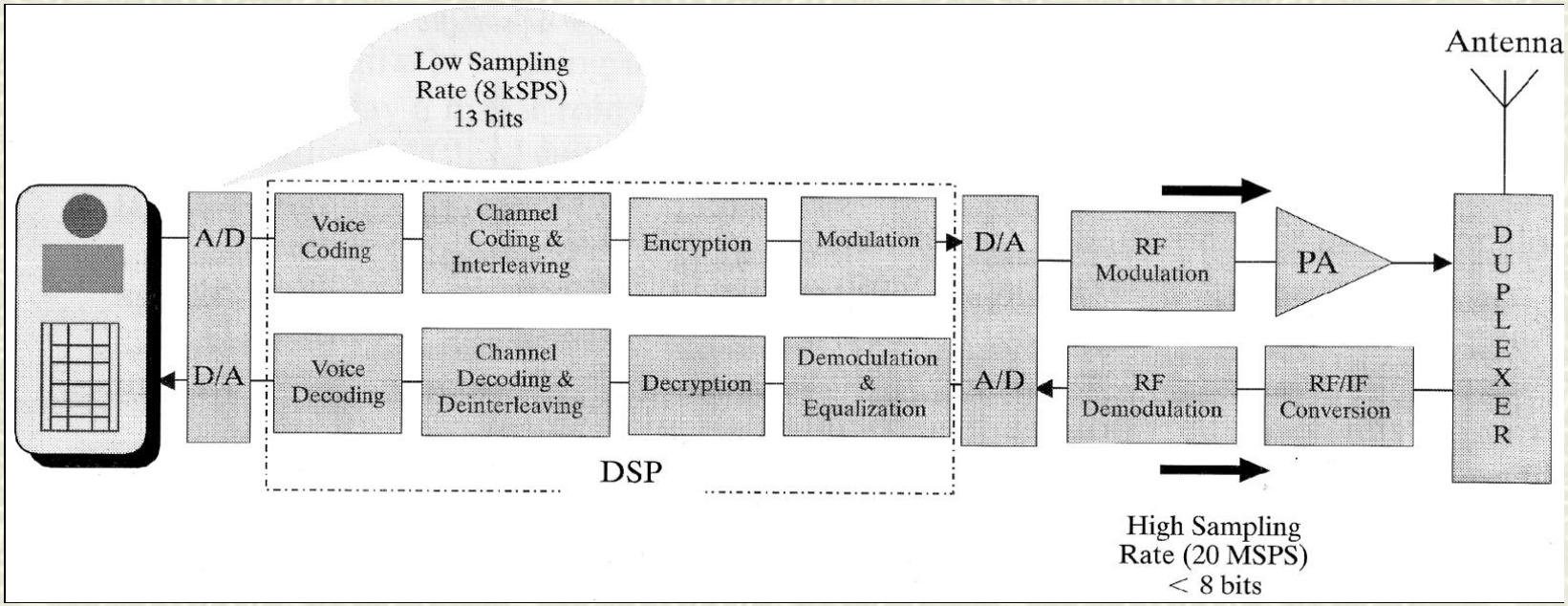
Algorithm Formula

FIR/Convolution

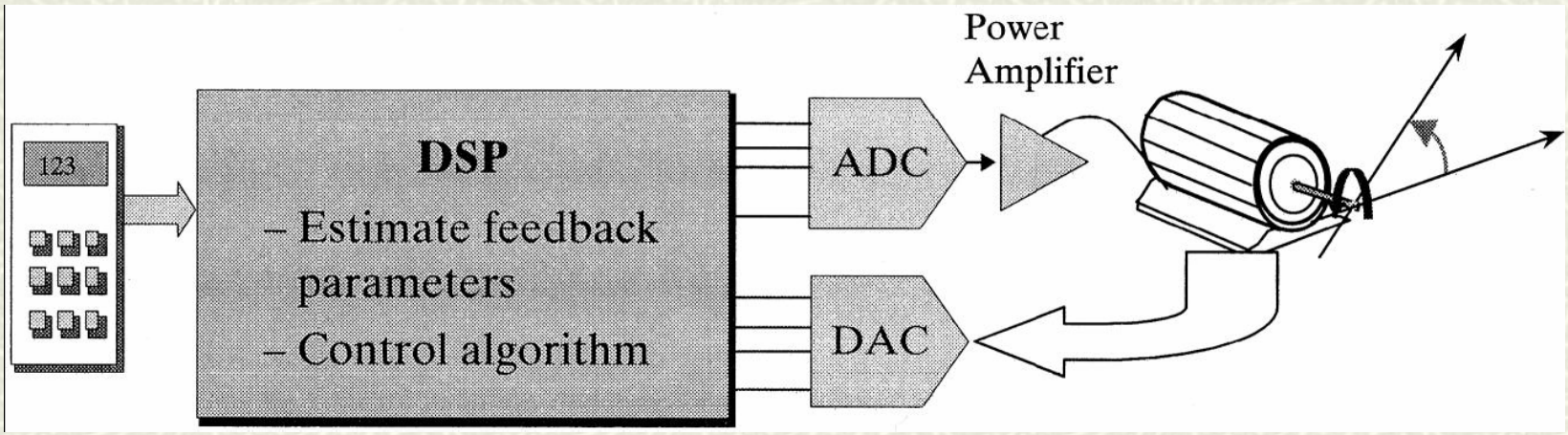
IIR/Difference equation

Discrete Cosine Transform

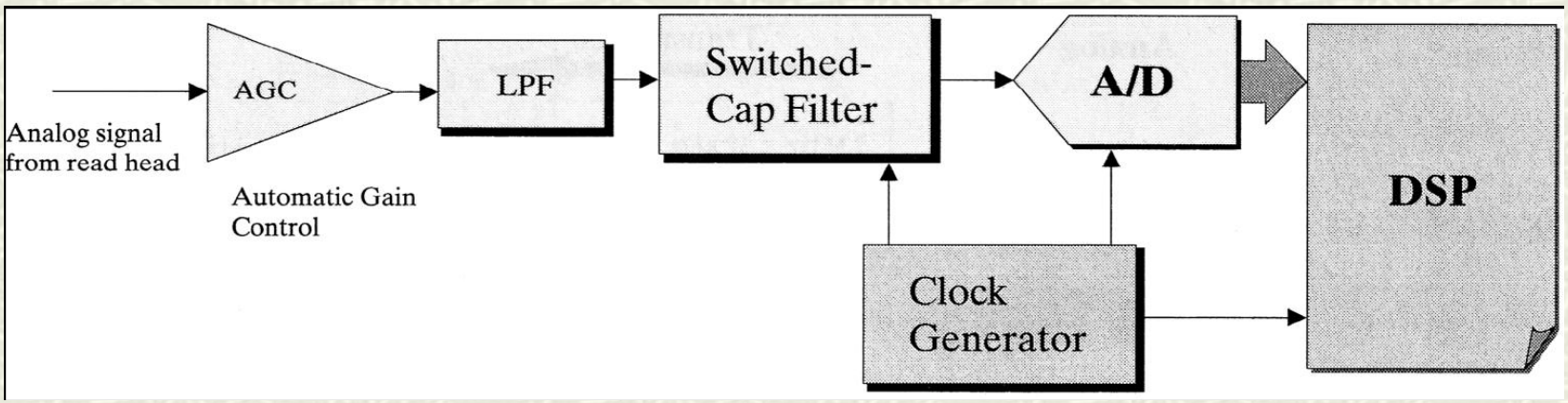
Example DSP Applications: Mobile Phones



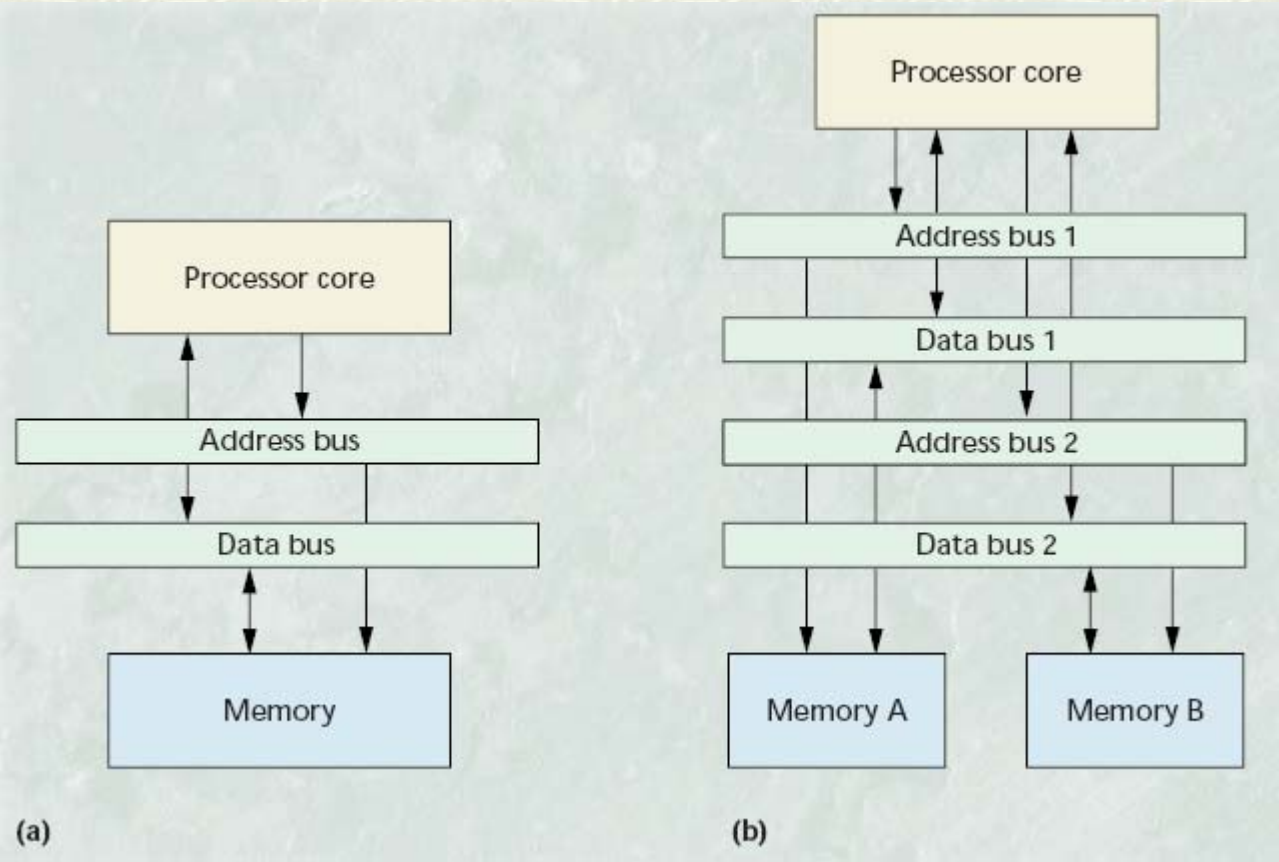
Motor Control



Disk Drives


Analog signal
from read head
AGC
Automatic Gain
Control
LPF
Switched-
Cap Filter
A/D
DSP
Clock
Generator

Architecture of a DSP



(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.

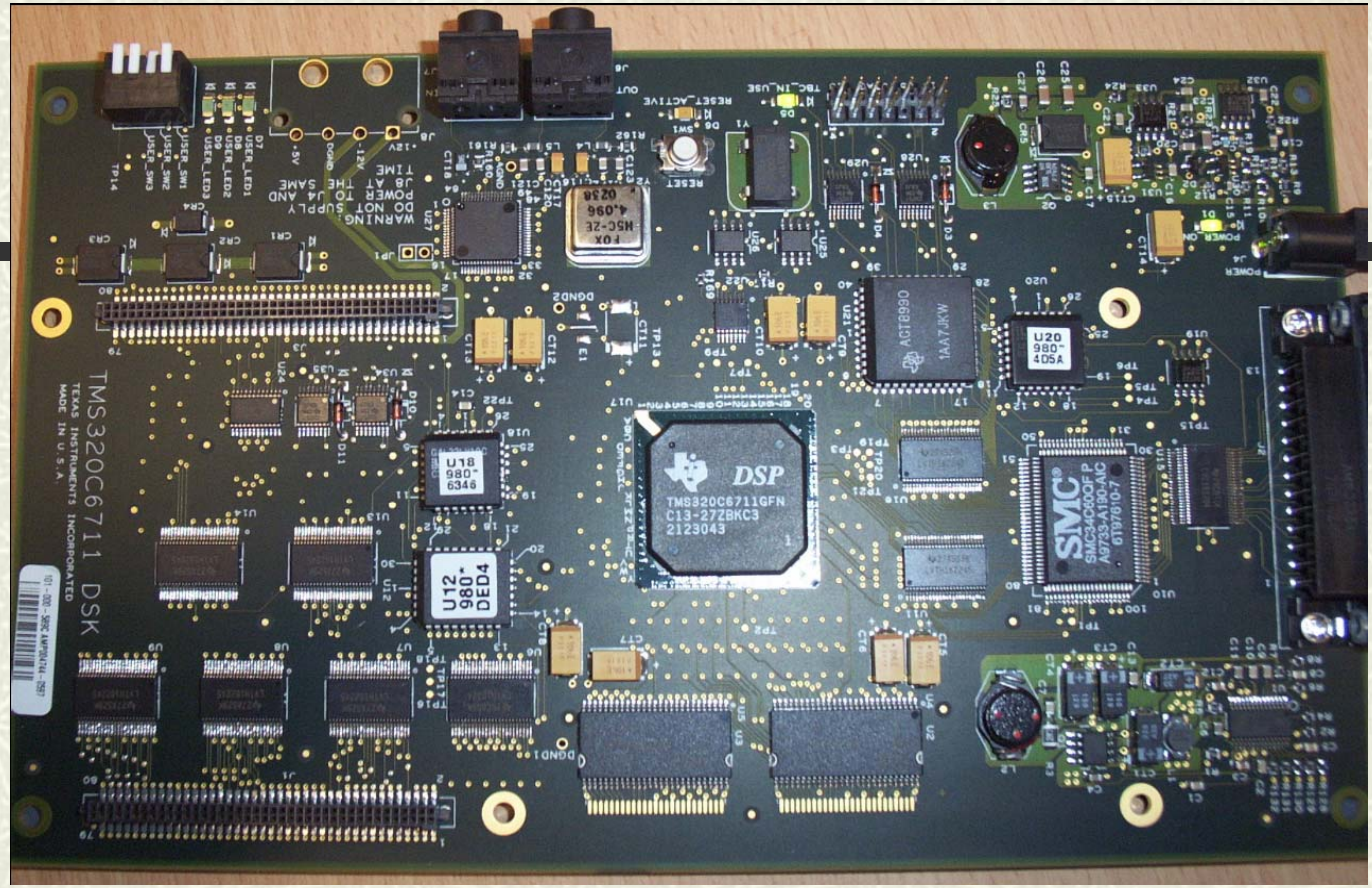
– Cost: $8–$35.

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

— Target market is broadband infrastructure, performance audio and imaging.

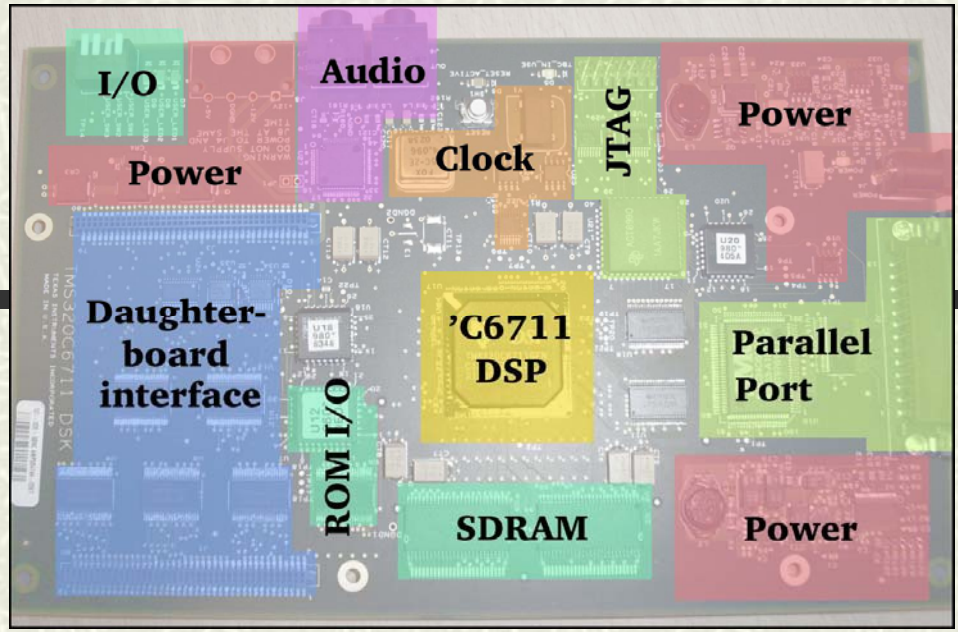
– Fixed- and floating-point processors available.

– 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 expandsion with access to the major DSP buses.