Chapter 1
Introduction
Learning Objectives

- Why process signals digitally?
- Definition of a real-time application.
- Why use Digital Signal Processing processors?
- What are the typical DSP algorithms?
- Parameters to consider when choosing a DSP processor.
- Programmable vs ASIC DSP.
- Texas Instruments’ TMS320 family.
Why go digital?

 Digital signal processing techniques are now so powerful that sometimes it is extremely difficult, if not impossible, for analogue signal processing to achieve similar performance.

 Examples:
   FIR filter with linear phase.
   Adaptive filters.
Why go digital?

- Analogue signal processing is achieved by using analogue components such as:
  - Resistors.
  - Capacitors.
  - Inductors.

- The inherent tolerances associated with these components, temperature, voltage changes and mechanical vibrations can dramatically affect the effectiveness of the analogue circuitry.
Why go digital?

◆ With DSP it is easy to:
  - Change applications.
  - Correct applications.
  - Update applications.

◆ Additionally DSP reduces:
  - Noise susceptibility.
  - Chip count.
  - Development time.
  - Cost.
  - Power consumption.
Why NOT go digital?

- High frequency signals cannot be processed digitally because of two reasons:
  - Analog to Digital Converters, ADC cannot work fast enough.
  - The application can be too complex to be performed in real-time.
DSP processors have to perform tasks in real-time, so how do we define real-time?

The definition of real-time depends on the application.

Example: a 100-tap FIR filter is performed in real-time if the DSP can perform and complete the following operation between two samples:

\[ y(n) = \sum_{k=0}^{99} a(k)x(n-k) \]
We can say that we have a real-time application if:

- Waiting Time ≥ 0
Why do we need DSP processors?

❖ Why not use a General Purpose Processor (GPP) such as a Pentium instead of a DSP processor?
  ❖ What is the power consumption of a Pentium and a DSP processor?
  ❖ What is the cost of a Pentium and a DSP processor?
Why do we need DSP processors?

- Use a DSP processor when the following are required:
  - Cost saving.
  - Smaller size.
  - Low power consumption.
  - Processing of many “high” frequency signals in real-time.

- Use a GPP processor when the following are required:
  - Large memory.
  - Advanced operating systems.
## What are the typical DSP algorithms?

- **The Sum of Products (SOP) is the key element in most DSP algorithms:**

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finite Impulse Response Filter</td>
<td>( y(n) = \sum_{k=0}^{M} a_k x(n - k) )</td>
</tr>
<tr>
<td>Infinite Impulse Response Filter</td>
<td>( y(n) = \sum_{k=0}^{M} a_k x(n - k) + \sum_{k=1}^{N} b_k y(n - k) )</td>
</tr>
<tr>
<td>Convolution</td>
<td>( y(n) = \sum_{k=0}^{N} x(k) h(n - k) )</td>
</tr>
<tr>
<td>Discrete Fourier Transform</td>
<td>( X(k) = \sum_{n=0}^{N-1} x(n) \exp[-j(2\pi / N)nk] )</td>
</tr>
<tr>
<td>Discrete Cosine Transform</td>
<td>( F(u) = \sum_{x=0}^{N-1} c(u) \cdot f(x) \cos \left[ \frac{\pi}{2N} u(2x + 1) \right] )</td>
</tr>
</tbody>
</table>
Hardware vs. Microcode multiplication

DSP processors are optimised to perform multiplication and addition operations.

Multiplication and addition are done in hardware and in one cycle.

Example: 4-bit multiply (unsigned).

<table>
<thead>
<tr>
<th>Hardware</th>
<th>Microcode</th>
</tr>
</thead>
<tbody>
<tr>
<td>1011 x 1110</td>
<td>1011 x 1110</td>
</tr>
<tr>
<td>10011010</td>
<td>0000 Cycle 1</td>
</tr>
<tr>
<td></td>
<td>1011 Cycle 2</td>
</tr>
<tr>
<td></td>
<td>1011 Cycle 3</td>
</tr>
<tr>
<td></td>
<td>1011... Cycle 4</td>
</tr>
<tr>
<td></td>
<td>10011010 Cycle 5</td>
</tr>
</tbody>
</table>
## Parameters to consider when choosing a DSP processor

<table>
<thead>
<tr>
<th>Parameter</th>
<th>TMS320C6211 (@150MHz)</th>
<th>TMS320C6711 (@150MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arithmetic format</td>
<td>32-bit</td>
<td>32-bit</td>
</tr>
<tr>
<td>Extended floating point</td>
<td>N/A</td>
<td>64-bit</td>
</tr>
<tr>
<td>Extended Arithmetic</td>
<td>40-bit</td>
<td>40-bit</td>
</tr>
<tr>
<td>Performance (peak)</td>
<td>1200MIPS</td>
<td>1200MFLOPS</td>
</tr>
<tr>
<td>Number of hardware multipliers</td>
<td>2 (16 x 16-bit) with 32-bit result</td>
<td>2 (32 x 32-bit) with 32 or 64-bit result</td>
</tr>
<tr>
<td>Number of registers</td>
<td>32</td>
<td>32</td>
</tr>
<tr>
<td>Internal L1 program memory cache</td>
<td>32K</td>
<td>32K</td>
</tr>
<tr>
<td>Internal L1 data memory cache</td>
<td>32K</td>
<td>32K</td>
</tr>
<tr>
<td>Internal L2 cache</td>
<td>512K</td>
<td>512K</td>
</tr>
</tbody>
</table>

- C6711 Datasheet: \Links\TMS320C6711.pdf
- C6211 Datasheet: \Links\TMS320C6211.pdf
Parameters to consider when choosing a DSP processor

<table>
<thead>
<tr>
<th>Parameter</th>
<th>TMS320C6211 (@150MHz)</th>
<th>TMS320C6711 (@150MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I/O bandwidth: Serial Ports (number/speed)</td>
<td>2 x 75Mbps</td>
<td>2 x 75Mbps</td>
</tr>
<tr>
<td>DMA channels</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>Multiprocessor support</td>
<td>Not inherent</td>
<td>Not inherent</td>
</tr>
<tr>
<td>Supply voltage</td>
<td>3.3V I/O, 1.8V Core</td>
<td>3.3V I/O, 1.8V Core</td>
</tr>
<tr>
<td>Power management</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>On-chip timers (number/width)</td>
<td>2 x 32-bit</td>
<td>2 x 32-bit</td>
</tr>
<tr>
<td>Cost</td>
<td>US$ 21.54</td>
<td>US$ 21.54</td>
</tr>
<tr>
<td>Package</td>
<td>256 Pin BGA</td>
<td>256 Pin BGA</td>
</tr>
<tr>
<td>External memory interface controller</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>JTAG</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Floating vs. Fixed point processors

Applications which require:

- High precision.
- Wide dynamic range.
- High signal-to-noise ratio.
- Ease of use.

Need a floating point processor.

Drawback of floating point processors:

- Higher power consumption.
- Can be more expensive.
- Can be slower than fixed-point counterparts and larger in size.
Floating vs. Fixed point processors

- It is the application that dictates which device and platform to use in order to achieve optimum performance at a low cost.

- For educational purposes, use the floating-point device (C6711) as it can support both fixed and floating point operations.
Application Specific Integrated Circuits (ASICs) are semiconductors designed for dedicated functions.

The advantages and disadvantages of using ASICs are listed below:

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• High throughput</td>
<td>• High investment cost</td>
</tr>
<tr>
<td>• Lower silicon area</td>
<td>• Less flexibility</td>
</tr>
<tr>
<td>• Lower power consumption</td>
<td>• Long time from design to market</td>
</tr>
<tr>
<td>• Improved reliability</td>
<td></td>
</tr>
<tr>
<td>• Reduction in system noise</td>
<td></td>
</tr>
<tr>
<td>• Low overall system cost</td>
<td></td>
</tr>
</tbody>
</table>
Texas Instruments’ TMS320 family

Different families and sub-families exist to support different markets.

- **C2000**
  - Lowest Cost
  - Control Systems
    - Motor Control
    - Storage
    - Digital Ctrl Systems

- **C5000**
  - Efficiency
    - Best MIPS per Watt / Dollar / Size
    - Wireless phones
    - Internet audio players
    - Digital still cameras
    - Modems
    - Telephony
    - VoIP

- **C6000**
  - Performance & Best Ease-of-Use
    - Multi Channel and Multi Function App's
    - Comm Infrastructure
    - Wireless Base-stations
    - DSL
    - Imaging
    - Multi-media Servers
    - Video

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**TMS320C64x:** The C64x fixed-point DSPs offer the industry's highest level of performance to address the demands of the digital age. At clock rates of up to 1 GHz, C64x DSPs can process information at rates up to 8000 MIPS with costs as low as $19.95. In addition to a high clock rate, C64x DSPs can do more work each cycle with built-in extensions. These extensions include new instructions to accelerate performance in key application areas such as digital communications infrastructure and video and image processing.

**TMS320C62x:** These first-generation fixed-point DSPs represent breakthrough technology that enables new equipments and energizes existing implementations for multi-channel, multi-function applications, such as wireless base stations, remote access servers (RAS), digital subscriber loop (xDSL) systems, personalized home security systems, advanced imaging/biometrics, industrial scanners, precision instrumentation and multi-channel telephony systems.

**TMS320C67x:** For designers of high-precision applications, C67x floating-point DSPs offer the speed, precision, power savings and dynamic range to meet a wide variety of design needs. These dynamic DSPs are the ideal solution for demanding applications like audio, medical imaging, instrumentation and automotive.
Useful Links

**Selection Guide:**

- \Links\DSP Selection Guide.pdf
- \Links\DSP Selection Guide.pdf (3Q 2004)
- \Links\DSP Selection Guide.pdf (4Q 2004)
Chapter 1
Introduction
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