# 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?

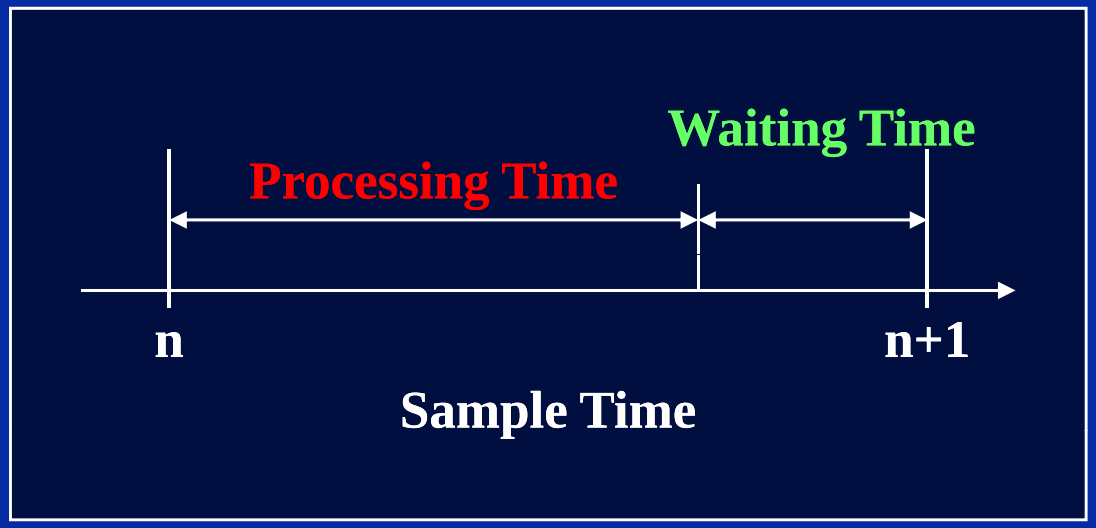
- **High frequency signals cannot be processed digitally because of two reasons:**
  - **Analog to Digital Converters, ADC cannot work fast enough.**
  - **The application can be too complex to be performed in real-time.**

# Real-time processing

- 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:

$$y(n) = \sum_{k=0}^{99} a(k)x(n-k)$$

# Real-time processing




- 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:**

| Algorithm | Equation |
|---|---|
| Finite Impulse Response Filter | $y(n)=\sum_{k=0}^{M} a_k\, x(n-k)$ |
| Infinite Impulse Response Filter | $y(n)=\sum_{k=0}^{M} a_k\, x(n-k)+\sum_{k=1}^{N} b_k\, y(n-k)$ |
| Convolution | $y(n)=\sum_{k=0}^{N} x(k)h(n-k)$ |
| Discrete Fourier Transform | $X(k)=\sum_{n=0}^{N-1} x(n)\exp[-j(2\pi/N)nk]$ |
| Discrete Cosine Transform | $F(u)=\sum_{x=0}^{N-1} c(u).f(x).\cos\left[\frac{\pi}{2N}u(2x+1)\right]$ |

# 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).

| Hardware | Microcode | |
|---|---|---|
| 1011 | 1011 | |
| x 1110 | x 1110 | |
| 10011010 | 0000 | Cycle 1 |
| | 1011. | Cycle 2 |
| | 1011.. | Cycle 3 |
| | 1011... | Cycle 4 |
| | 10011010 | Cycle 5 |

# Parameters to consider when choosing a DSP processor

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

- C6711 Datasheet: \Links\TMS320C6711.pdf
- C6211 Datasheet: \Links\TMS320C6211.pdf

# Parameters to consider when choosing a DSP processor

| Parameter | TMS320C6211 (@150MHz) | TMS320C6711 (@150MHz) |
|---|---|---|
| I/O bandwidth: Serial Ports (number/speed) | 2 x 75Mbps | 2 x 75Mbps |
| DMA channels | 16 | 16 |
| Multiprocessor support | Not inherent | Not inherent |
| Supply voltage | 3.3V I/O, 1.8V Core | 3.3V I/O, 1.8V Core |
| Power management | Yes | Yes |
| On-chip timers (number/width) | 2 x 32-bit | 2 x 32-bit |
| Cost | US$ 21.54 | US$ 21.54 |
| Package | 256 Pin BGA | 256 Pin BGA |
| External memory interface controller | Yes | Yes |
| JTAG | Yes | Yes |

# 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 higher cost.
  - 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.

# General Purpose DSP vs. DSP in ASIC

- **Application Specific Integrated Circuits (ASICs) are semiconductors designed for dedicated functions.**
- **The advantages and disadvantages of using ASICs are listed below:**

| Advantages | Disadvantages |
|---|---|
| • High throughput<br>• Lower silicon area<br>• Lower power consumption<br>• Improved reliability<br>• Reduction in system noise<br>• Low overall system cost | • High investment cost<br>• Less flexibility<br>• Long time from design to market |

# Texas Instruments' TMS320 family

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




## Lowest Cost

**Control Systems**

- Motor Control
- Storage
- Digital Ctrl Systems

## Efficiency

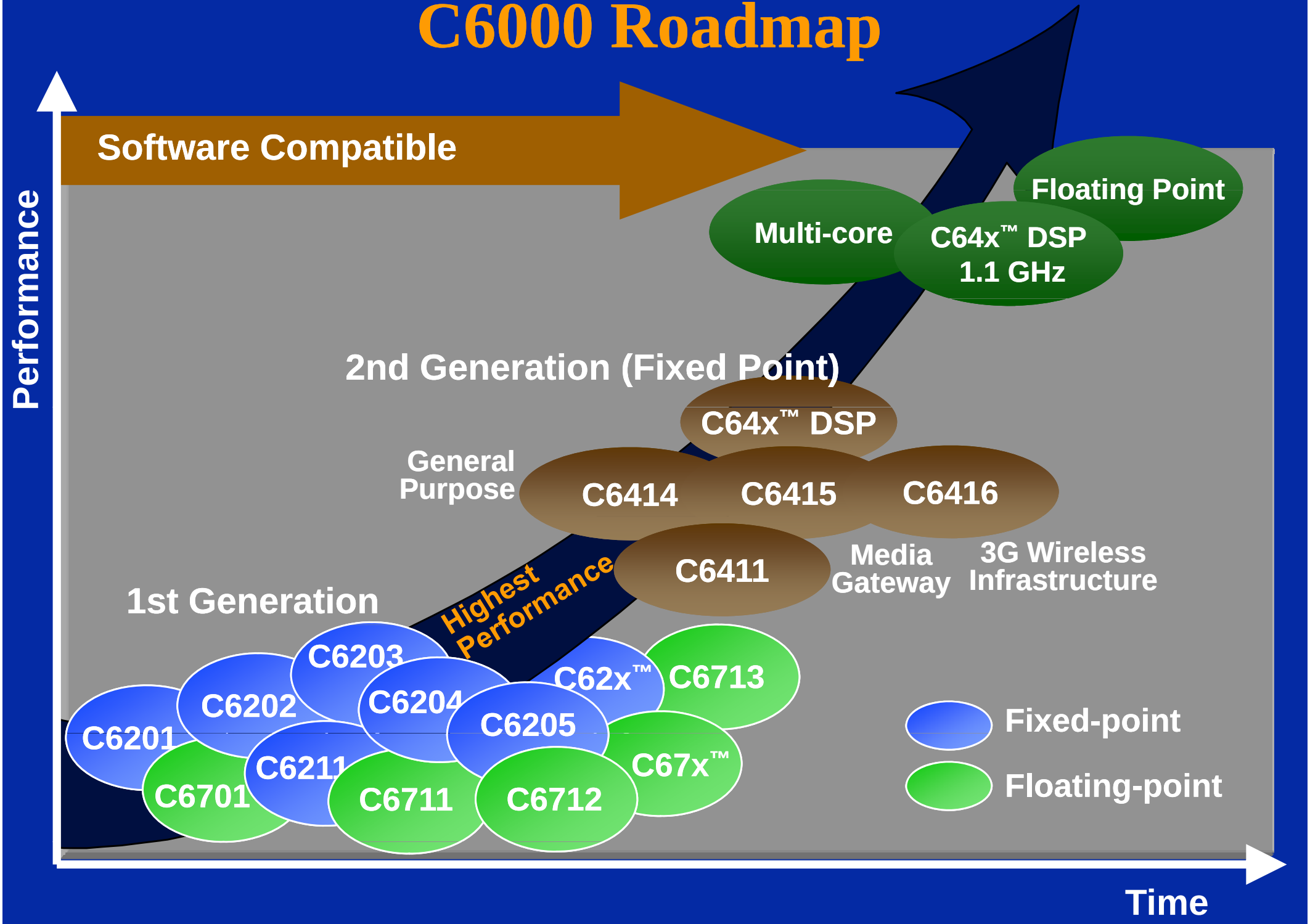
**Best MIPS per Watt / Dollar / Size**

- Wireless phones
- Internet audio players
- Digital still cameras
- Modems
- Telephony
- VoIP

## Performance & Best Ease-of-Use

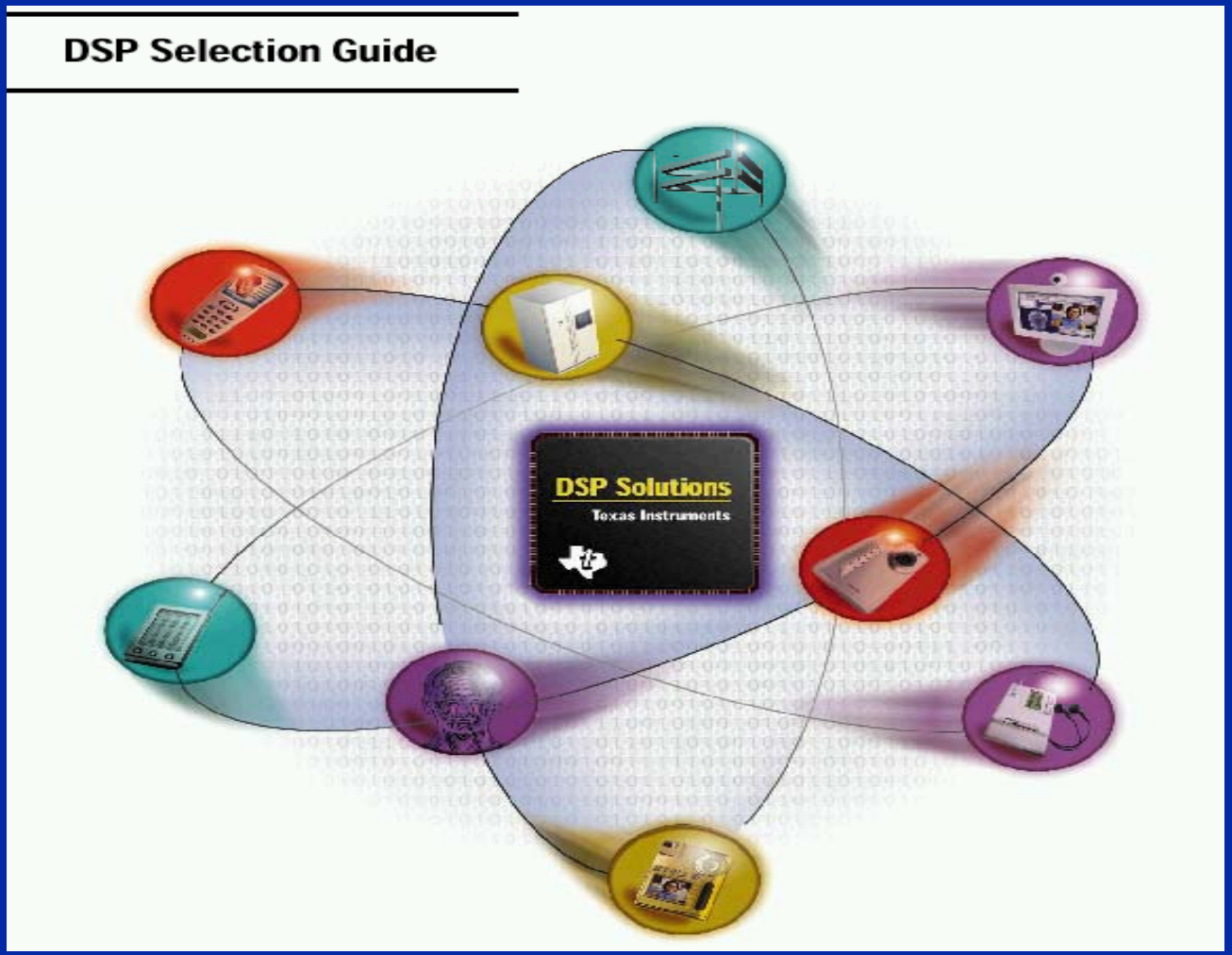
- **Multi Channel and Multi Function App's**
- Comm Infrastructure
- Wireless Base-stations
- DSL
- Imaging
- Multi-media Servers
- Video

# C6000 Roadmap



# Useful Links

- **Selection Guide:**
  - **\Links\DSP Selection Guide.pdf**



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