DSP Chip Architecture

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What Is Signal Processing

- A branch of mathematics
- Is often considered part of electrical engineering
- Has many applications in other fields
What Is DSP?

- Digital Signal Processing
- This includes a wide variety of goals
Why Use DSP

• What can DSP do?

• What are DSP’s strengths?
Topics In DSP

• Filtering
• Spectral Analysis
• Synthesis
• Correlation
DSP Vs. Analog Electronics

- DSP systems are programmable
- Fixed performance
- Are there any advantages to analog electronics?
Economics

- As analog filters performance is enhanced the complexity increases

- One time cost for processor

- Commercial Off the Shelf (COTS)
Functionality

- Increased DSP operations
- General purpose processes
DSPs Vs Microprocessors

- Single-Cycle Multiply-accumulate capability
- Specialized addressing modes
- Memory
- Specialized execution control
- Irregular instruction sets

-Ole Wolf
Addressing Modes

- Pre- and post-modification of address pointers
- Circular addressing
- Bit-reversed addressing
Example Address Diagram

AGU Block Diagram

Program Counter (PC) Address

Memory Data Bus 1 (XDBA)  64
Memory Data Bus 2 (XDBB)  64

Address Arithmetic Unit

Bit Mask Unit (BMU)

R0  R1  R2  R3  R4  R5  R6  R7  NSP  ESP

XABA  XABB  PAB

R8/B0  R9/B1  R10/B2  R11/B3  R12/B4  R13/B5  R14/B6  R15/B7

M0  M1  M2  M3

MCTL

N0  N1  N2  N3
Example Memory Diagram
Specialized Execution Control

DSP processors provide a loop instruction for fast nesting of repetitive operations. This is usually done hardware wise to increase the speed.
Irregular Instruction Sets

Unlike general microprocessors, DSPs’ instruction allow for arithmetic operations to be carried out in parallel with data moves.

Example four instruction in an execution set

<table>
<thead>
<tr>
<th>MACR -D0, D1, D7</th>
<th>AND D4, D5</th>
<th>MOVE.L (R0) +N0, R6</th>
<th>ADDA R2, R3</th>
</tr>
</thead>
<tbody>
<tr>
<td>DALU Instr</td>
<td>DALU Instr</td>
<td>AGU Instr</td>
<td>AGU Instr</td>
</tr>
</tbody>
</table>
# General Comparison

<table>
<thead>
<tr>
<th></th>
<th>DSP</th>
<th>DSP/μc combination</th>
<th>DSP w/ μc extensions</th>
<th>μc w/DSP extensions</th>
<th>μc</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Raw DSP Bandwidth</strong></td>
<td>Excellent</td>
<td>Excellent</td>
<td>Excellent</td>
<td>good</td>
<td>poor</td>
</tr>
<tr>
<td><strong>Address space</strong></td>
<td>Small to medium</td>
<td>Small to medium/</td>
<td>Small to medium</td>
<td>medium</td>
<td>Small to medium</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>Medium to high</td>
<td>medium</td>
<td>Medium</td>
<td>Low to medium</td>
<td>Low to medium</td>
</tr>
<tr>
<td><strong>MAC</strong></td>
<td>Yes</td>
<td>High</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td><strong>Fast Shifter</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Feature</td>
<td>DSP</td>
<td>DSP/µc comb</td>
<td>DSP w/ µc ext.s</td>
<td>µc w/DSP ext.s</td>
<td>µc</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>-----------</td>
<td>-------------</td>
<td>-----------------</td>
<td>----------------</td>
<td>----</td>
</tr>
<tr>
<td>Memory busses</td>
<td>2-3</td>
<td>2-3 DSP</td>
<td>2-3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Circular addressing</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Saturation/Overflow</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>?</td>
</tr>
<tr>
<td>Zero-over-head looping</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Stack</td>
<td>Hw</td>
<td>Hw&amp;mem</td>
<td>Hw(&amp;mem)</td>
<td>Mem</td>
<td>Mem</td>
</tr>
<tr>
<td>FFT addressing</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>?</td>
<td>No</td>
</tr>
<tr>
<td>Digital I/O</td>
<td>minimal</td>
<td>Medium</td>
<td>Medium</td>
<td>Excellent</td>
<td>Excellent</td>
</tr>
</tbody>
</table>
TMS320C31 (C3x) Specs

- Introduced by TI in July of 1999
- Third-gen floating point processor
- 32-bit processor
- 40ns instruction cycle time
  - 50 million fp ops/sec (MFLOPS)
  - 25 million instructions/sec (MIPS)
- 2 1Kx32 words of internal mem (RAM)
- 24-bit address bus
  - $2^{24}$ or 16 million words (32-bit) of mem
- Only one serial port, but very fast execution speed
Applications of TMS320C31

- Targeted at digital audio, data comm, and industrial automation
- Consists of a multiplier, barrel shifter, ALU and a register file containing eight 40-bit fp registers
- No support for rounding when converting fp → integer
  - Lower 8 bits are chopped off
- Shifter can shift up to 32 bits left or right
- All operations performed in a single clock cycle; some in parallel
Why Floating Point?

- Only a little more expensive
- Much more “real estate”
- Easier to program
- FP support tools easier to use
- C compiler is more efficient
  - Has a multiplier and accumulator
Modified Harvard Arch

- Independent mem banks
- Separate busses for program, data, and direct mem access (DMA)
  - Performs concurrent program fetches, data read and write, and DMA ops
- Allows for 4 levels of pipelining
  - While 1 instruction is being executed, 3 instructions are being read, decoded, and fetched
  - Fewer gates per pipeline stage
  - Increased clock rate and performance
Addressing Mode / Instructions

- Indirect mem access
- Efficiency of mem access
- Richer more powerful set of instructions with simplistic programming
# Direct Comparison

<table>
<thead>
<tr>
<th>Processor</th>
<th>MHz</th>
<th>MIPS</th>
<th>DSP Benchmarks</th>
<th>ISR Latency</th>
<th>Power</th>
<th>Price</th>
<th>Dimensions (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pentium MMX</td>
<td>233</td>
<td>233</td>
<td>49</td>
<td>1.38 us</td>
<td>4.25 W</td>
<td>$213</td>
<td>5.5 x 2.47 x 0.647</td>
</tr>
<tr>
<td>Pentium MMX</td>
<td>266</td>
<td>266</td>
<td>56</td>
<td>1.38 us</td>
<td>4.85 W</td>
<td>$348</td>
<td>5.5 x 2.47 x 0.647</td>
</tr>
<tr>
<td>TMS320C62</td>
<td>120</td>
<td>960</td>
<td>62</td>
<td>0.09 us</td>
<td>1.14 W(est.)</td>
<td>$25</td>
<td>1.3 x 1.3 x 0.07</td>
</tr>
<tr>
<td>TMS320C62</td>
<td>200</td>
<td>1600</td>
<td>103</td>
<td>0.09 us</td>
<td>1.9 W</td>
<td>$96</td>
<td>1.3 x 1.3 x 0.07</td>
</tr>
</tbody>
</table>
References

http://www.sundance.com/index.htm

http://www.bdti.com/
