

# **Embedded System Design: Modeling**

**Andreas Gerstlauer**

**Center for Embedded Computer Systems**

**University of California, Irvine**

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## **Outline**

- Requirements
- Modeling
  - Introduction
  - Languages and models
  - System modeling semantics
  - Automatic model generation
- Design example
  - Tools
  - Summary and conclusions
- Verification and synthesis
- Summary, conclusions and outlook

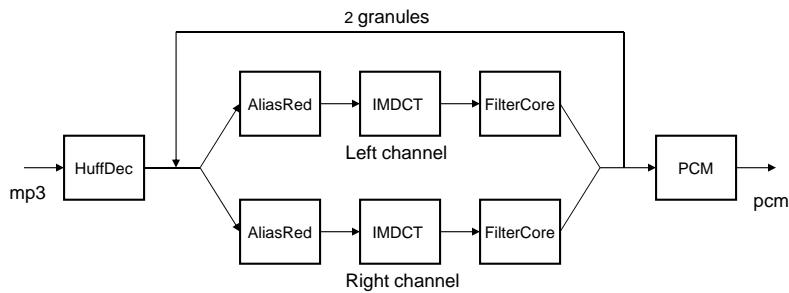
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## Example: MP3 Decoder

- Functional block diagram (major blocks only)



- Timing constraints

- 38 frames per second
- Frame delay < 26.12ms

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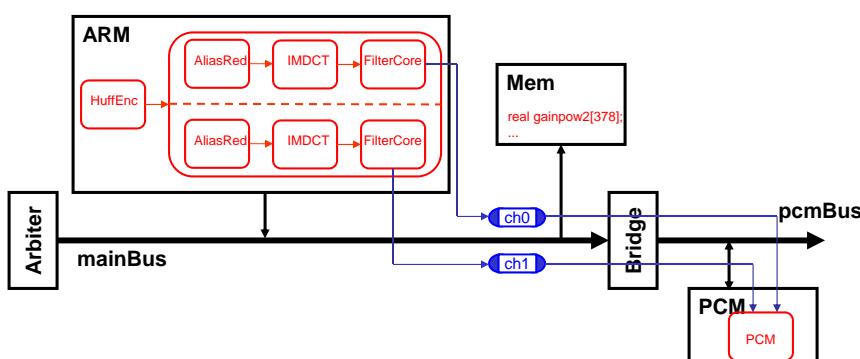
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## System Definition

- Components allocated from database
- Hierarchical processes inside PEs
  - Parallel, sequential, leaf (C code)
- Channels and variables between PEs
- Bridge used to interface two busses



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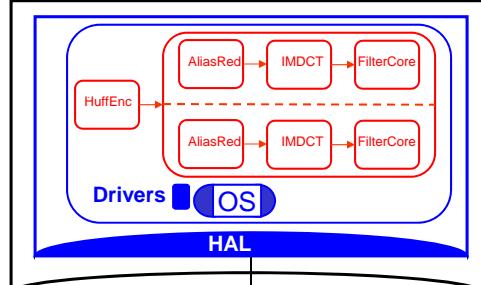
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## Output: Transaction-Level Model (TLM)

ARM



Mem

mainBus

pcmBus

Bridge

PCM

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## TLM Simulation

- **Timed-simulation**
  - Computation delays back-annotated in processes
  - Communication delays modeled in the bus channels
- **Simulation of TLM**
  - Functionally correct but frame delay far exceeds timing constraint

```
***  
*** Simulating MP3DecoderDEM01_Tlm ...  
***  
.MP3DecoderDEM01_Tlm ./testStream//spot1.mp3 MP3DecoderDEM01_Tlm.pcm ./testStream//spot1.txt  
Input MP3file: ./testStream//spot1.mp3  
Output bitstream file: MP3DecoderDEM01_Tlm.pcm  
Bitrate = 96000 bits/sec, Sampling frequency = 44100 Samples/Sec  
Initial Latency = 4.73 ms  
Missed deadline per frame at frame 2 35.98 > 26.12  
Missed deadline per frame at frame 3 35.98 > 26.12  
***  
*** Checking MP3DecoderDEM01_Tlm.pcm for correctness...  
***  
diff -s ./testStream//spot1.pcm MP3DecoderDEM01_Tlm.pcm  
Files ./testStream//spot1.pcm and MP3DecoderDEM01_Tlm.pcm are identical  
***  
*** Simulation successful!
```

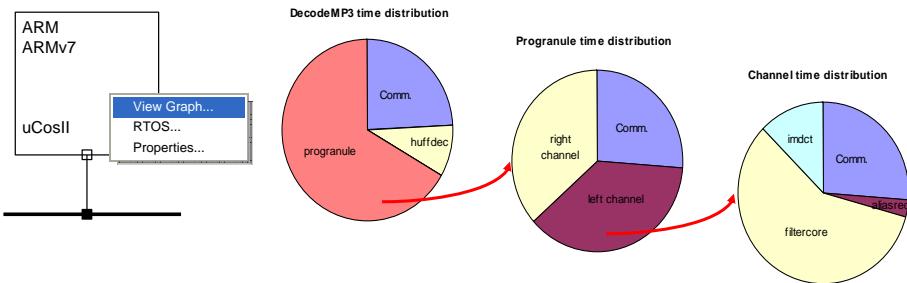
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## Computation Analysis

- View computation time of processes
  - *FilterCore* is the most computation-intensive



- Look for parallelism in process hierarchy
  - *FilterCore* processes are running in parallel  
→ Use two identical custom Hws

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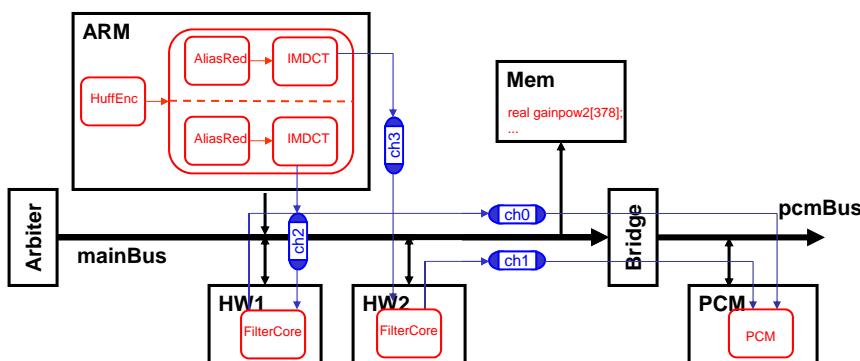
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## System Modifications

- Add two more PEs: HW1 and HW2
- Connect HW1 and HW2 to the mainBus
- Move processes from ARM to Hws
  - Channels are automatically inserted



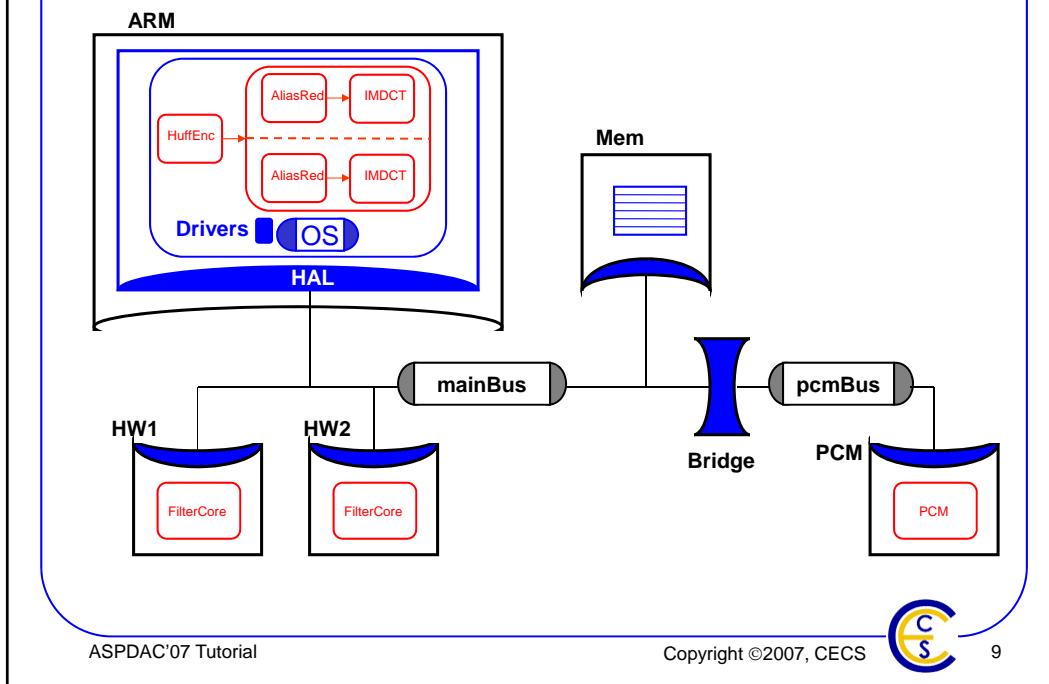
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## Modified TLM



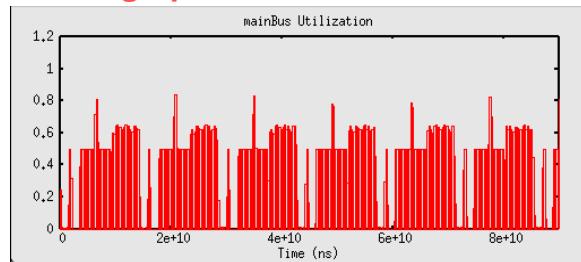
## Modified TLM Simulation

- **Simulation of TLM**
  - Functionally correct
  - Frame delay still violates timing constraint

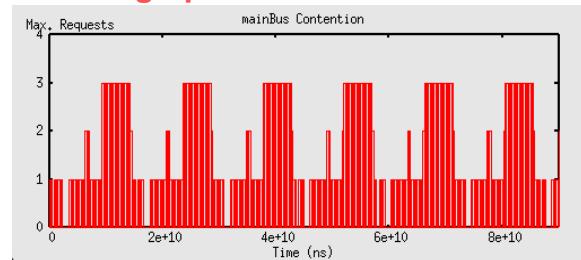
```
Terminal
File Edit View Terminal Tabs Help
*** Simulating MP3DecoderDEMO2_Tlm ...
*** ./MP3DecoderDEMO2_Tlm ./testStream//spot1.mp3 MP3DecoderDEMO2_Tlm.pcm ./testStream//spot1.txt
Input MP3file: ./testStream//spot1.mp3
Output bitstream file: MP3DecoderDEMO2_Tlm.pcm
Bitrate = 96000 bits/sec, Sampling frequency = 44100 Samples/Sec
Initial Latency = 9.39 ms
Missed deadline per frame at frame 2 28.45 > 26.12
Missed deadline per frame at frame 3 28.45 > 26.12
*** Checking MP3DecoderDEMO2_Tlm.pcm for correctness...
*** diff -s ./testStream//spot1.pcm MP3DecoderDEMO2_Tlm.pcm
Files ./testStream//spot1.pcm and MP3DecoderDEMO2_Tlm.pcm are identical
*** Simulation successful!
```

## Communication Analysis

- Bus utilization graph



- Bus contention graph



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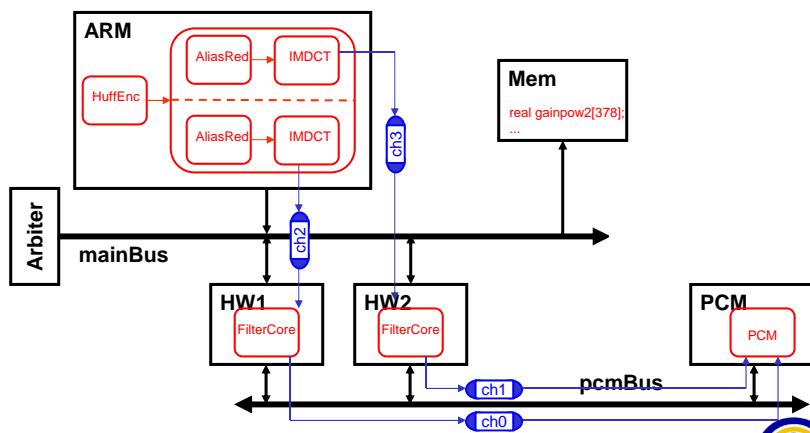
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## More System Modifications

- Make two ports in HW1, HW2
- Connect HWs directly to the DHS bus
- Remove the bridge



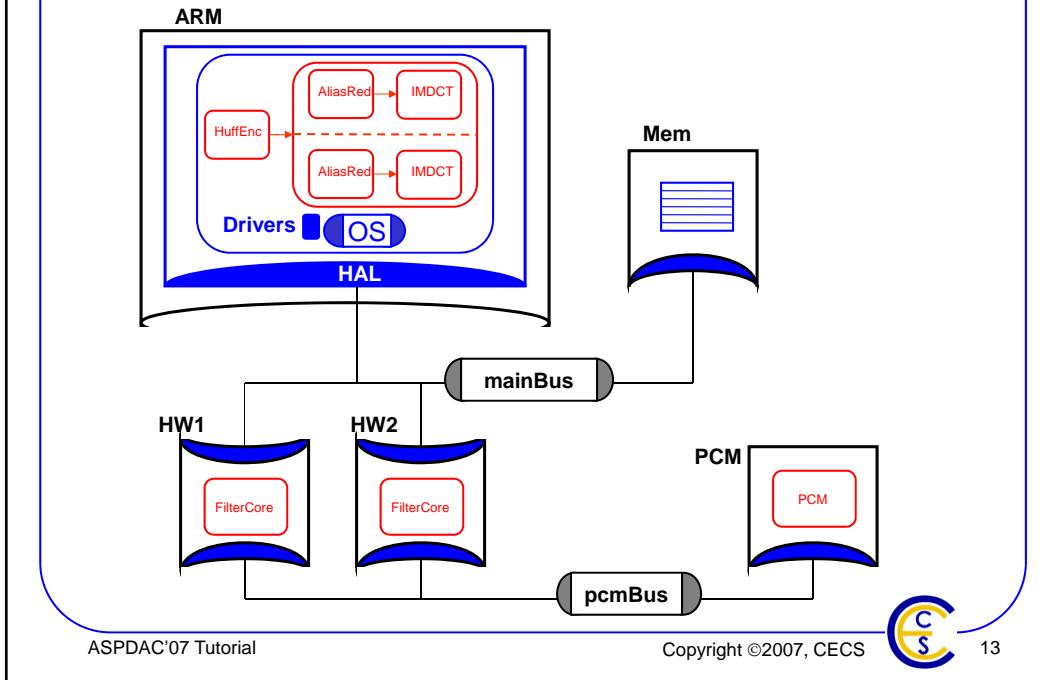
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## Modified TLM



## Modified TLM Simulation

- **Simulation of TLM**
  - Functionally correct
  - Frame delay now meets timing constraint

A screenshot of a terminal window titled "Terminal". The window displays the output of a simulation script. The text shows the command used to run the simulation, the input MP3 file, the output bitstream file, and the sampling frequency. It also provides details about the initial latency and average decode times for frames 2 and 3, comparing them against their respective deadlines. A red oval highlights the line "Average decode time per frame 2 = 25.33 ms < deadline 26.12 ms". Another red oval highlights the line "Average decode time per frame 3 = 25.33 ms < deadline 26.12 ms". The terminal concludes with a message about checking the output PCM file for correctness and a final success message.

```

*** Simulating MP3DecoderDEMO3_Tlm ...
...
./MP3DecoderDEMO3_Tlm ./testStream//spot1.mp3 MP3DecoderDEMO3_Tlm.pcm ./testStream//spot1.txt
Input MP3file: ./testStream//spot1.mp3
Output bitstream file: MP3DecoderDEMO3_Tlm.pcm
Bitrate = 96000 bits/sec, Sampling frequency = 44100 Samples/Sec
Initial Latency = 9.31 ms
Average decode time per frame 2 = 25.33 ms < deadline 26.12 ms
Average decode time per frame 3 = 25.33 ms < deadline 26.12 ms
...
*** Checking MP3DecoderDEMO3_Tlm.pcm for correctness...
...
diff -s ./testStream//spot1.pcm MP3DecoderDEMO3_Tlm.pcm
Files ./testStream//spot1.pcm and MP3DecoderDEMO3_Tlm.pcm are identical
...
*** Simulation successful!
...

```