

V830R/AV : Embedded Multimedia Superscalar RISC Processor with Rambus® Interface

Tomohisa Arai, Kazumasa Suzuki, Ichiro Kuroda
NEC Corporation

Outline

- Chip Highlights
- Instruction Set Architecture (ISA)
- Micro Architecture
- Performance
- Summary

Chip Highlights (1)

❑ High Performance Embedded RISC

- Dual-issue Superscalar
- 200MHz
- Over 250 MIPS@Dhrystone 1.1
- 2,000 MOPS@16-bit Data
 - MPEG2 A/V Decoding
 - MPEG1 Video Encoding
- Under 2W Power Consumption

❑ 32KB On-chip Cache Memory

- 16KB 4-way Instruction Cache
- 16KB 4-way Non-blocking Data Cache
- Freeze Function

Chip Highlights (2)

❑ Multimedia Extension

- 64-bit SIMD Multimedia Coprocessor
- Multimedia Oriented Peripheral Integration
 - Audio/Video Output Port

❑ On-chip Rambus DRAM Interface

- High Bandwidth Rambus DRAM Memory System
- Multimedia Processing in UMA Environment
- Memory/System Separated Bus
 - Sufficient Bandwidth for Total System Operation

❑ On-Chip Debug Support

- ICE Interface

Chip Highlights (3)

❑ Technology

- 0.25µm CMOS
- 4 Layer Metal
- 2.5V with 3.3V I/O
- 3M Tr.

❑ Package

- 208-pin Plastic QFP
- 0.5mm Lead Pitch

V830 ISA

❑ RISC ISA with Improved Code Density

- Based on V810 RISC ISA
- 32 General Purpose Register Set
- Variable Length Code Format
 - 16-bit and 32-bit
- 2-operand

❑ MIX : Multimedia Instruction Extension

- Extension for Media Signal Processing
 - 32-bit Saturation Arithmetic Operation
 - 32-bit Pipelined Single-cycle MAC Operation
 - 32-bit Min/Max Operation
 - 32-bit Concatenate and Shift Operation
- 3-operand

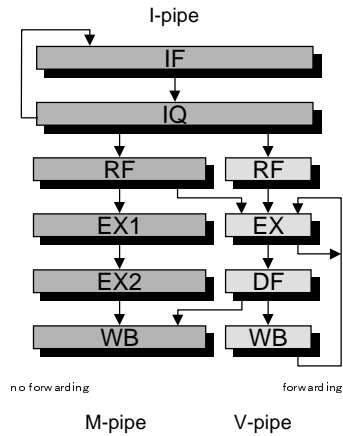
V830R ISA

- V830 Upward Compatible Integer ISA
- MIX2 : Multimedia Instruction Extension 2
 - 64-bit SIMD Media Coprocessor
 - 32 Coprocessor Register Set
 - 56 SIMD Media Instructions
 - Saturated Additions
 - Saturated Subtractions
 - Multiply-and-Accumulate (MAC)
 - ME Oriented Special Instructions
 - 3-operand
 - Cache Control Instructions
 - Invalidate
 - Write Back

MIX2 Summary

		32-bit Transfer	64-bit Transfer			
Move	Mem. -> CP Reg.	ldcp.w	ldcp.d			
	CP Reg. -> Mem.	stcp.w	stcp.d			
	Reg. -> CP Reg.	mtcp.d				
	CP Reg. -> Mem.	mfcph.w, mfcpl.w				
	CP Reg. -> CP Reg.		movcp.d			
Arithmetic	Vector Add	vsatadd.b	vadd.h, vsatadd.h	vadd.w		
	Vector Subtract	vsatsub.b	vsub.h, vsatsub.h	vsub.w		
	Vector Multiply		vmul.h, vmult.h			
	Vector MAC		vmac.h, vmacr.h	xvmach.hw, xvmacl.hw		
	Scalar Add		sadd.h			
	Scalar Subtract		ssub.h			
	Scalar Multiply		smul.h, smult.h			
	Scalar MAC		smac.h, smacr.h, smacr.h			
	Compare	Vector Max.		vmax.h		
		Vector Min.		vmin.h		
		Scalar Max.		smax.h		
		Scalar Min.		smmin.h		
	Convert	Pack	cvtpk.hb	cvtpk.wh		
Interleave		itvh.b, itvl.b	itvh.h, itvl.h	itvh.w, itvl.w		
Logical	Or				orcp.d	
	And				andcp.d	
	Xor				xorcp.d	
	Not				notcp.d	
Shift	Logical Left		vshl.h	vshl.w	vshl.d	
	Logical Right		vshr.h	vshr.w	vshr.d	
	Arithmetic Right		vsar.h	vsar.w		
	Shift and Add		vstadd.h.w, vsftadd.w			
Etc.	Partial Absolute Diff		vpad.bh			

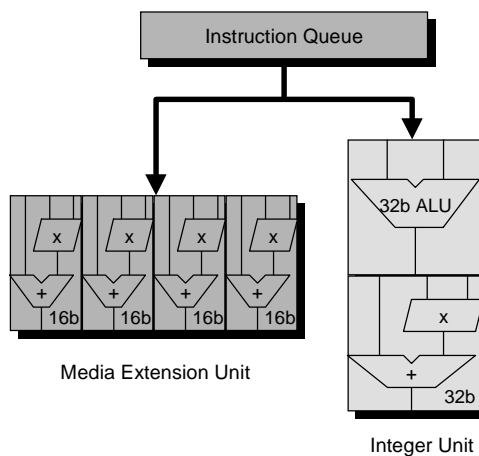
Pipeline Structure



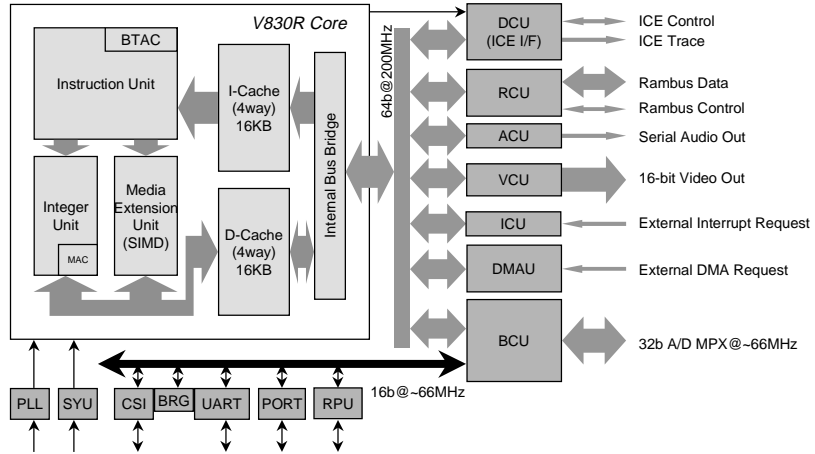
- ❑ 6-stage De-coupled Pipeline
 - Instruction Pipeline is De-coupled with Execution Pipelines
 - High Frequency Operation
- ❑ Instruction Pipeline (I-pipe)
 - Early Resolution of Branch
- ❑ Integer Pipeline (V-pipe)
 - Data Forwarding
- ❑ Media Pipeline (M-pipe)
 - Multiple Execution Stages
 - No Data Forwarding

Superscalar Operation

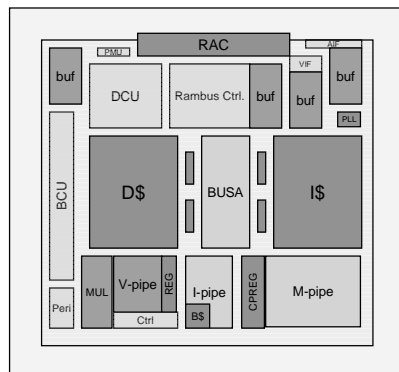
- ❑ Dual-issue Superscalar
 - Media Instruction + Integer Instruction
 - In-order Issue
 - Out-of-order Completion
- ❑ VLIW-like Instruction Issue
 - "Templated" Instruction Issue Scheme
- ❑ Dependency Control
 - Within Instruction Queue
- ❑ Simple Exception Handling
 - No Exception on M-pipe
 - No Side-effect on V-pipe Exception



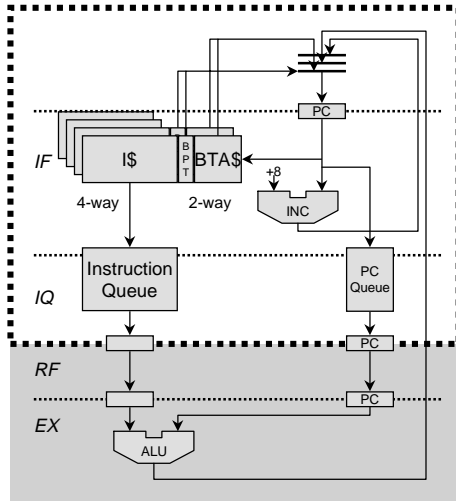
Block Diagram



Floor Plan



Instruction Unit

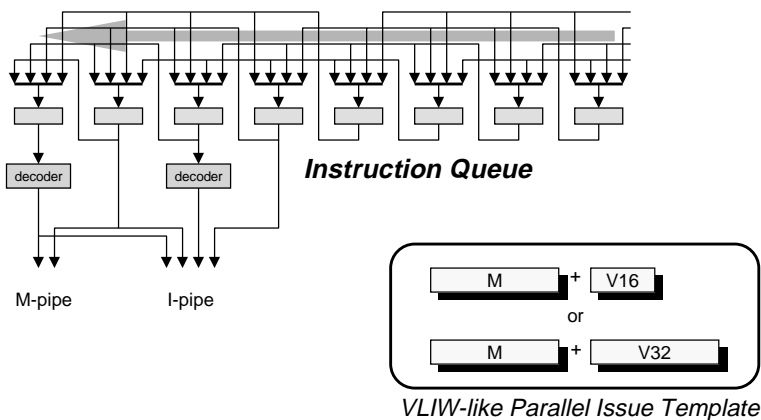


- Branch Prediction
 - 2-bit Branch Prediction Table
- Branch Target Address Cache
 - 128 Entries (64x2)
 - 2-way Set-associative
 - LRU Replacement
- Instruction Queue
 - 24-byte (Up to 12-instructions)
 - Squash Unconditional Branch
 - Zero Clock Branch
 - Conceal Overhead due to Variable Length Instruction Code
 - De-coupled Structure
 - "Templated" Instruction Issue Scheme

97/8/26

13

"Templated" Instruction Issue Scheme



97/8/26

14

Integer Unit

- ❑ 32 x 32-bit General Purpose Registers

- ❑ Conventional 4-stage Pipeline
 - RF, EX, DF, WB
 - With Data Forwarding Control
 - With Interlock Control

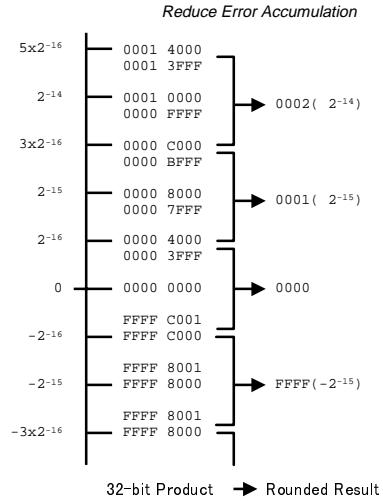
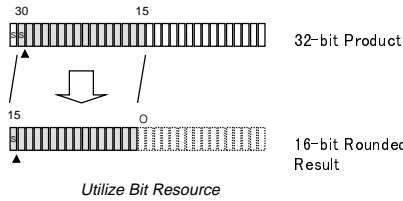
- ❑ Multimedia Oriented Function
 - 32-bit x 32-bit Multiply-adder
 - Precision required Signal Processing such as Audio Processing
 - Concatenate and Shift
 - Useful for VLC/VLD

Media Extension Unit

- ❑ 32 x 64-bit Coprocessor Registers
- ❑ 64-bit SIMD Datapath
 - Supported Data Type
 - 64-bit x 1, 32-bit x 2, 16-bit x 4 (Signed Integer, Signed Fixed Point), 8-bit x 8
 - SIMD Capability
 - 16-bit Multiply-adder with Special Rounding
 - Extended Precision MAC Operation
 - Dual 16-bit x 16-bit + 32-bit --> 32-bit MAC Operation
- ❑ Simple 4-stage Pipeline with Multiple Execution Stage
 - RF, EX1, EX2, WB
 - No Data Forwarding
 - Latency/Repeat = 4/1
 - No Exception

Special Rounding

- ❑ Maximize Precision
 - Fixed Point Style Data Handling
 - Used in vmacr.h, smacr.h Instruction
- ❑ Rounding Scheme
 - Decimal Point Adjustment
 - Symmetrical Rounding



Precision Evaluation

- ❑ IDCT Algorithm
 - Row-Column Composed 2D-DCT
 - Double Stage Composed 1D-DCT
- ❑ Evaluation Data
 - Random
 - From -384 to 383

	PEAK ERROR	MEAN SQUARE ERRORS		MEAN ERRORS	
		Worst	Overall	Worst	Overall
IEEE1180 Upper Limit	1	0.0600	0.020000	0.0150	0.0015000
Without Special Rounding	1	0.0791	0.060617	0.0061	0.0005610
With Special Rounding	1	0.0122	0.010145	0.0026	0.0000161

Cache Summary

	I-Cache	D-Cache
Associativity	4-way Set Associative	4-way Set Associative
Replacement Strategy	LRU	LRU
Write Strategy	-	Write Back/Write Allocate
Non-Blocking	-	Hits under Miss
Capacity	16KB Freezable upto 8KB on Entry Basis	16KB Freezable upto 8KB on Entry Basis
Line Size	64B	64B

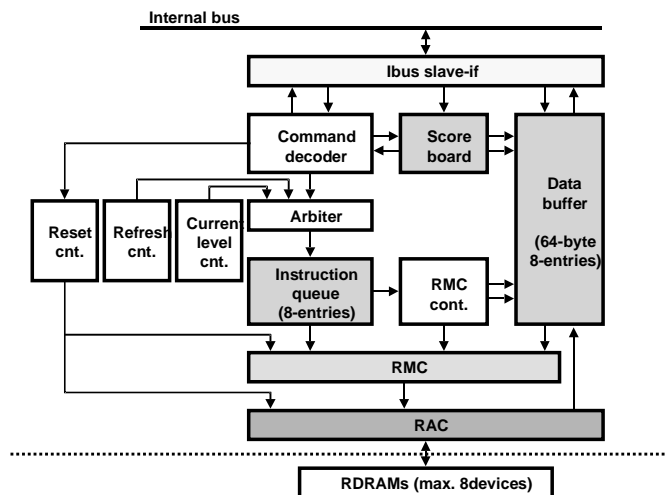
Cache Freeze Function

- ❑ Can be used as Ideal Memory
 - Never Miss
 - No Unpredictable Miss Penalty
 - Useful for Timing Assurance
- ❑ Freezing Scheme
 - Way-0 and Way-1
 - Up to 8KB can be Frozen
 - Entry by Entry Basis
 - Reduced Way Cache Operation
- ❑ On-demand Setup Capability
 - Load and Freeze at Initial Access Time
 - Don't care for explicit Loading

RCU : RDRAM™ Control Unit

- ❑ Concurrent RDRAM Protocol Support
 - Lower Latency with DRAM State Management
 - Higher Transfer Data with Interleaved Access
 - Max. 18M-byte
 - Up to 8 16M/18M RDRAM
 - Up to 2 64M/72M RDRAM
- ❑ Memory Request Queuing
 - 8-entry Instruction Queue
 - 64-byte x 8 Data Buffer
- ❑ Interleaved Access
 - 128-byte = 2 x 64-byte
 - 256-byte = 4 x 64-byte
- ❑ Pre-fetch
 - In Case of I-Cache Refill
 - Next 64-byte
- ❑ Address Re-mapping
 - Utilize Sense-amp Cache
 - Avoid Bank Conflict

RCU Structure

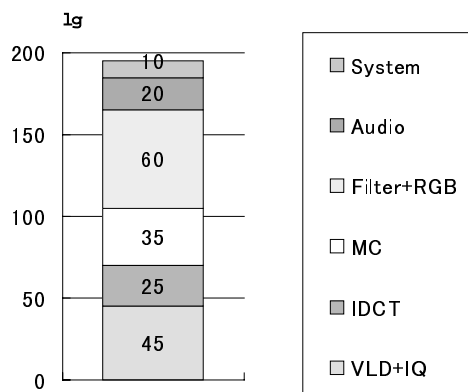


Other Peripherals

- ❑ **Multimedia Peripherals**
 - VCU : Video Control Unit
 - 16-bit Video Output
 - Double Data Buffer (256-byte X 2)
 - Y1CrY0Cb Pixel Data Format
 - ACU : Audio Control Unit
 - Serial Audio Output
 - Double Data Buffer (256-byte X 2)
 - 16b 2-channel Audio Data Format
- ❑ **“Bulk” DMA Unit**
 - Efficient “Packed” Data Transfer between
 - RDRAM and System Bus
 - RDRAM and Internal Peripherals
 - 4-ch
- ❑ **Bus Control Unit**
 - 32-bit A/D Multiplexed
 - Up to 66MHz
 - Single&Burst Bus Cycle
- ❑ **Standard Peripherals**
 - UART : 150~76800BPS
 - CSI : ~8.25MBPS
 - BRG
 - RPU : 16-bit Timer x 3
 - ICU : 17-ch
 - PORT : 1-bit I/O Port x 3
- ❑ **Debug Control Unit**
 - Serialized ICE Interface

Performance (1)

- ❑ **MPEG2 A/V Decoding Profile**
- ❑ **Video**
 - 720 x 480 x 30fps
 - 4:2:0 Format
 - 4Mbps
- ❑ **Audio**
 - MPEG Audio Layer2
- ❑ **System**
 - Program Stream Decode



Performance (2)

❑ MPEG1 Video Encoding Profile

❑ Search Range

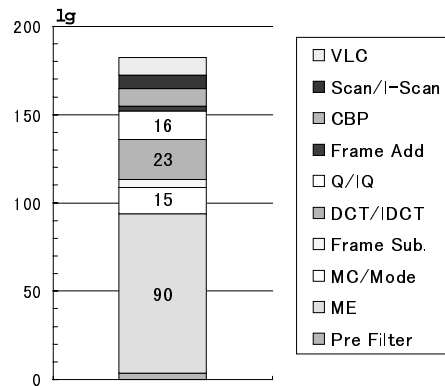
- +/- 16 Pixels

❑ 3 Step Search Algorithm

- 2 x 2 Subsampling
- Pel Precision
- Half-Pel Precision

❑ Frame Structure

- I2P8B20
- 48fps



Summary

❑ High Performance Embedded Superscalar RISC Processor

- Dual-issue Superscalar by VLIW-like "Templated" Instruction Issue Scheme
- 32K-byte On-chip Cache Memory with Freeze Capability
- 258MIPS, 2,000MOPS@16-bit at 200MHz

❑ 64-bit SIMD Multimedia Extension

- Specially Designed 16-bit MAC with Special Rounding Scheme
- 4-way Parallel IDCT Compliant to MPEG2 Standard

❑ On-chip Rambus® DRAM Interface

- UMA for Multimedia Processing with 600MB/s Rambus DRAM Memory System
- Realizes A Processor based Low Cost MPEG2 A/V Decoding System