ENABLING
INNOVATION

ARM9E

An ARM9TDMI with DSP extensions

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ARM

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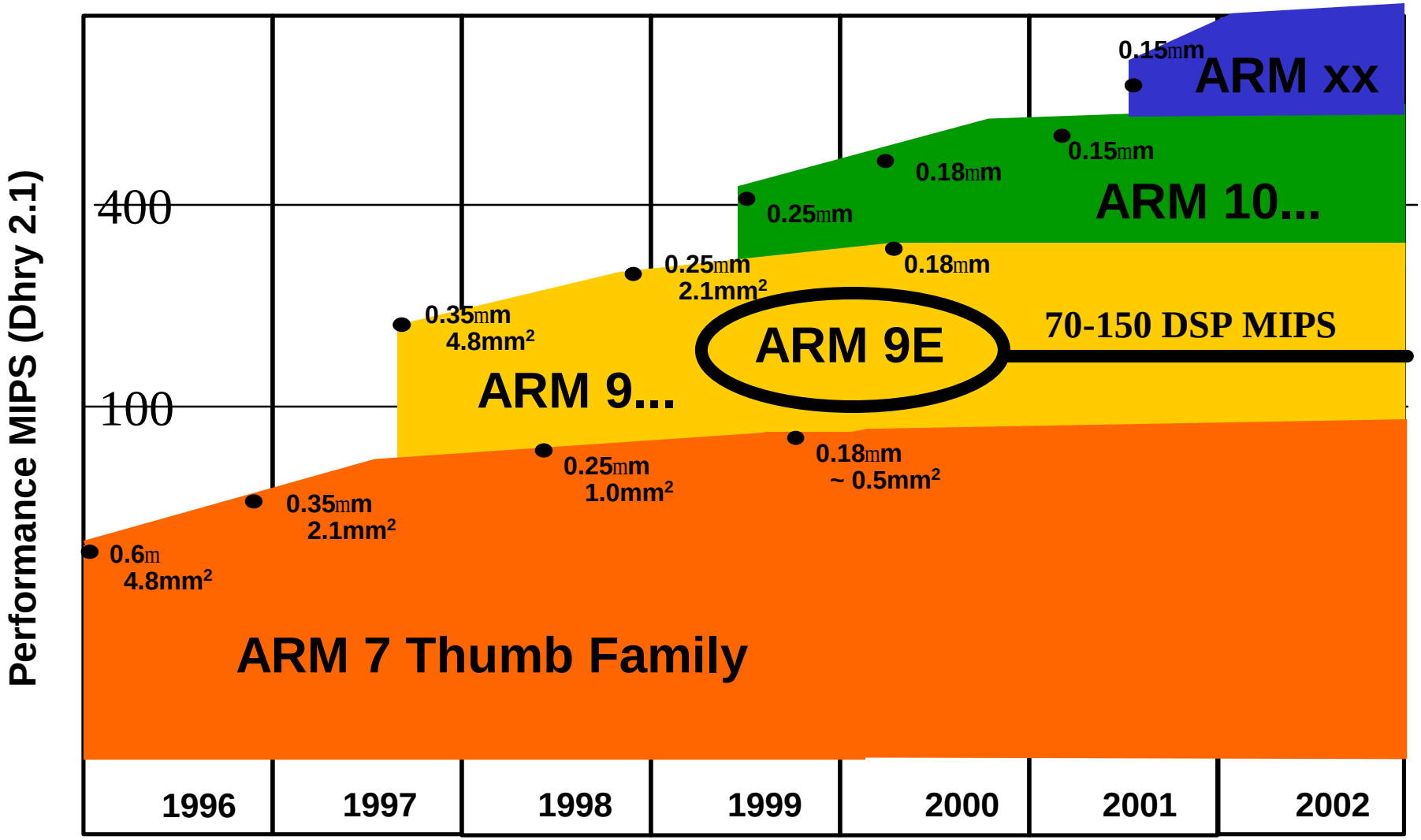
ARM POWERED

Market fit

- **The ARM9E addresses high volume applications requiring a mix of DSP and control performance**
  - Mass storage
    - servo control in HDD, DVD and other drives
  - Speech coders
    - G.723 for voice over IP
    - Multiple standards for digital cellular telephony
  - Networking applications
  - Automotive control applications
  - Modems
  - Audio decoding (Dolby Digital, MP3, etc.)

ARM9E is a DSP enhanced ARM processor

- **A 32-bit RISC single engine solution for mixed DSP and control applications**
  - Maintains full compatibility with ARM9TDMI, ARM7TDMI and all other ARM microprocessors
- **Why you want a DSP enhanced ARM processor**
  - superb array of development tools and options
  - unified development environment reduces costs
  - good HLL target - can realistically use C and C++
  - easy to learn and program the single architecture
  - reduced SOC complexity due to elimination of inter-processor communication and other overheads


Performance MIPS (Dhry 2.1)
400
100
1996
1997
1998
1999
2000
2001
2002
0.15mm
ARM xx
0.18mm
0.15mm
0.25mm
ARM 10...
0.25mm
2.1mm²
0.18mm
0.35mm
4.8mm²
ARM 9E
70-150 DSP MIPS
ARM 9...
0.25mm
1.0mm²
0.18mm
~ 0.5mm²
0.35mm
2.1mm²
0.6m
4.8mm²
ARM 7 Thumb Family

Application driven architecture decisions

- **ARM has been working with OEM's and analyzing key application code**
- **ARM processors are good at DSP already**
- **Analysis identified three bottlenecks**
  - Solutions:-
    - Single cycle multiply-accumulate
    - Zero overhead saturating fractional arithmetic
    - Efficient use of 32-bit bandwidth with packed 16-bit data

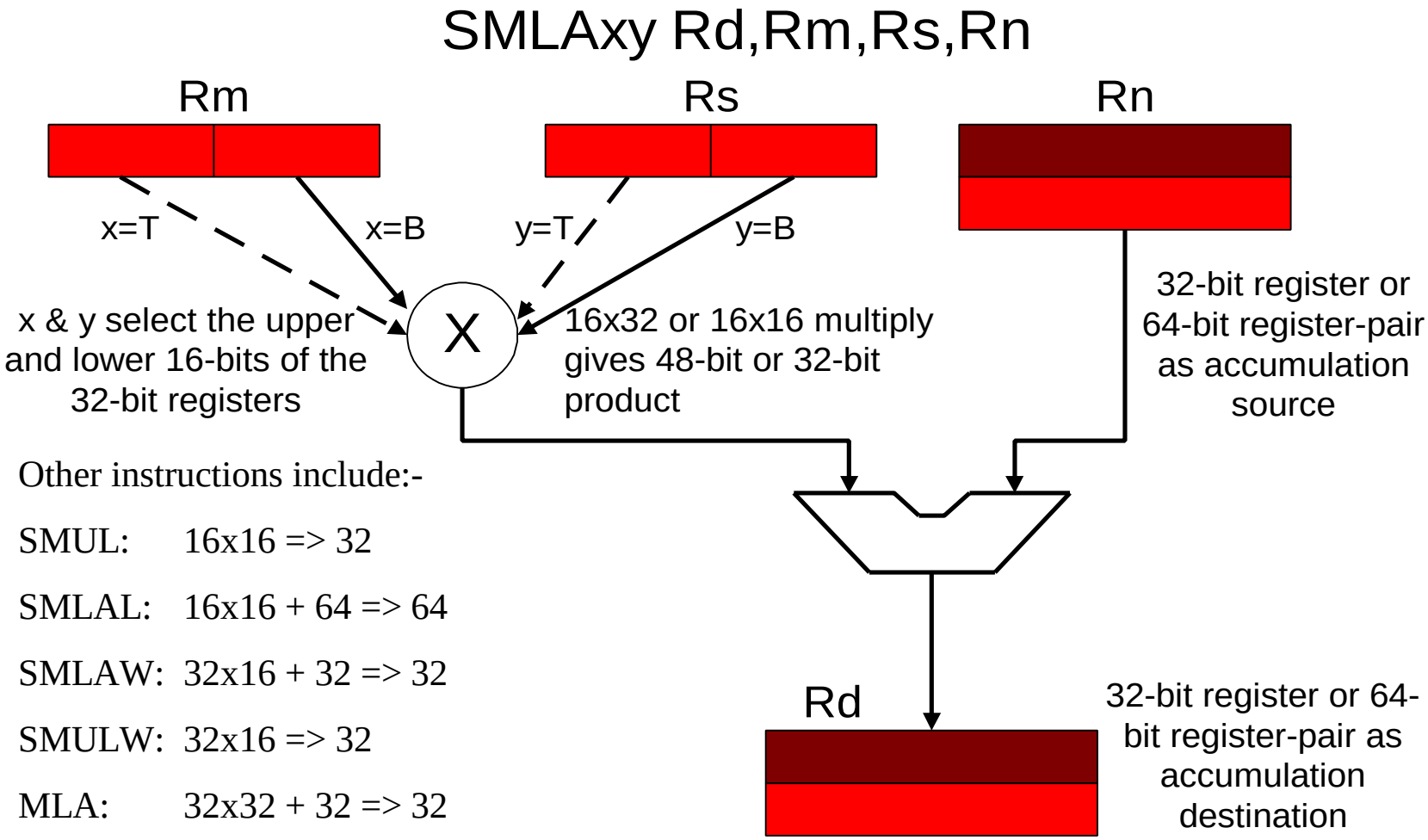
ARM cores are good at DSP already

- **High data bandwidth - 4 bytes per cycle**
  - same data bandwidth as typical 16-bit DSP
  - 600 Mbytes/sec on typical 0.25µm process
  - Harvard memory interface
  - Large register bank reduces bandwidth required by many algorithms
- **Conditional instruction execution**
  - every instruction is predicated
  - eliminates branch penalties

DSP enhancements in ARM9E

- **New instruction additions give architecture V5TE**
- **New 32x16 and 16x16 multiply instructions**
  - SMLAxy, SMLAWy, SMLALxy, SMULxy, SMULWy
  - Allows independent access to 16-bit halves of registers
    - Gives efficient use of 32-bit bandwidth for packed 16-bit operands
  - ARM ISA already has 32x32 multiply instructions
- **Zero overhead fractional saturating arithmetic**
  - QADD, QSUB, QDADD, QDSUB
- **Count leading zeros instruction**
  - CLZ for faster normalisation and division
- **Single cycle 32x16 multiplier array**
  - speeds up all ARM9E multiply instructions

Using the new multiply instructions



Other instructions include:-

SMUL: 16x16 => 32

SMLAL: 16x16 + 64 => 64

SMLAW: 32x16 + 32 => 32

SMULW: 32x16 => 32

MLA: 32x32 + 32 => 32

MLAL: 32x32 + 64 => 64

32x16 saturating multiply primitive used in international standards

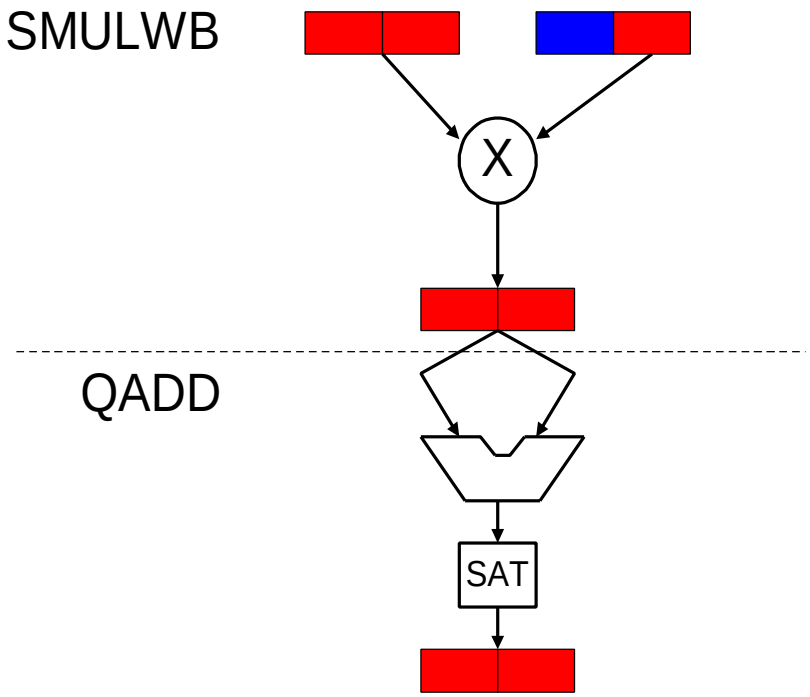
16-bit DSP implementation - 4-cycles

Result_32 = L_mult (mier_hi, mand);

temp_32 = L_mult(mier_lo,mand);

temp_32 = temp_32>>15;

Result_32 = Result_32 + temp_32;



ARM9E implementation - 2-cycles

SMULWB Prod, mier, mand

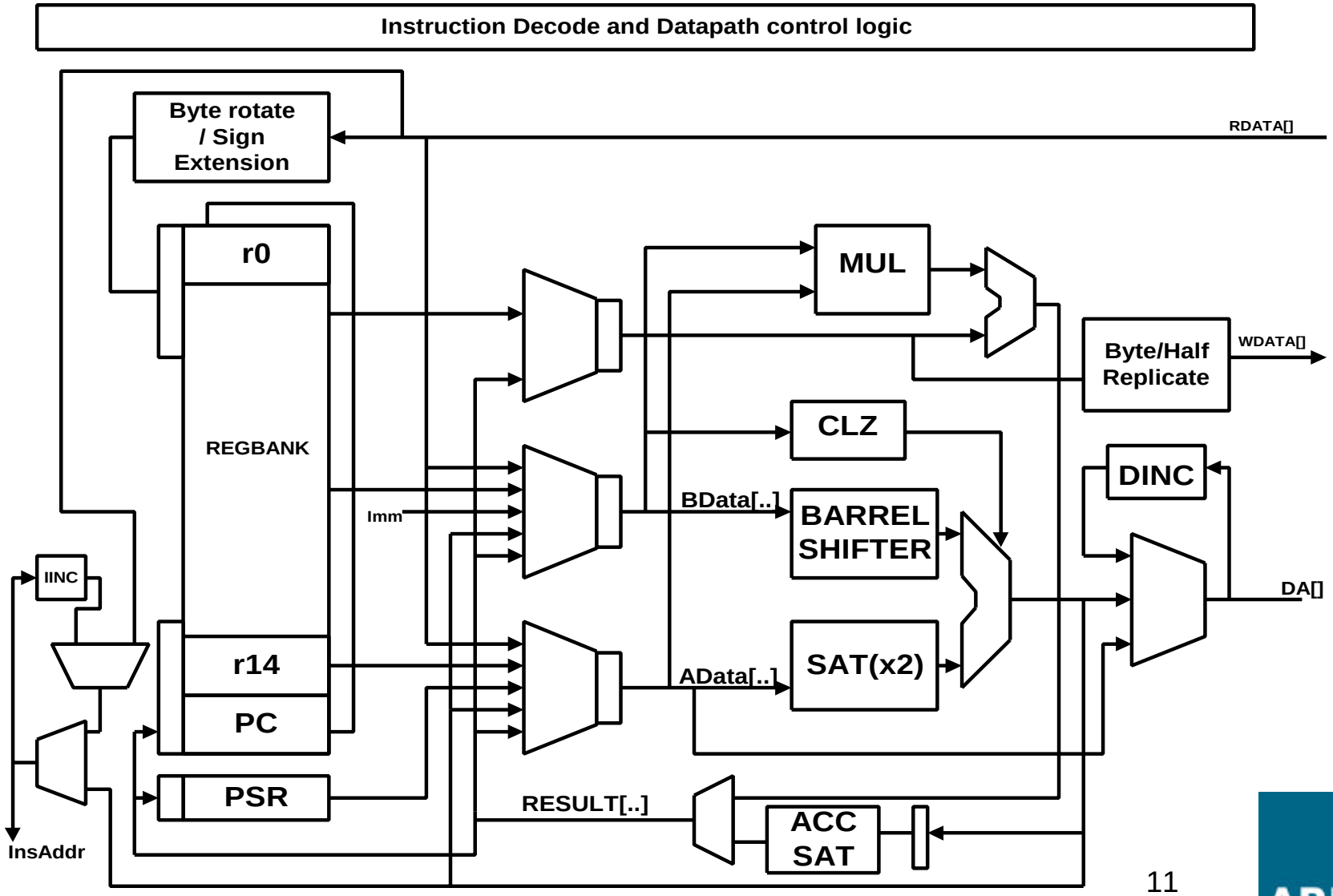
QADD Prod,Prod,Prod

Replacing QADD with QDADD achieves a 32x16+32 MAC in 2-cycles

Programmers prefer ARM9E

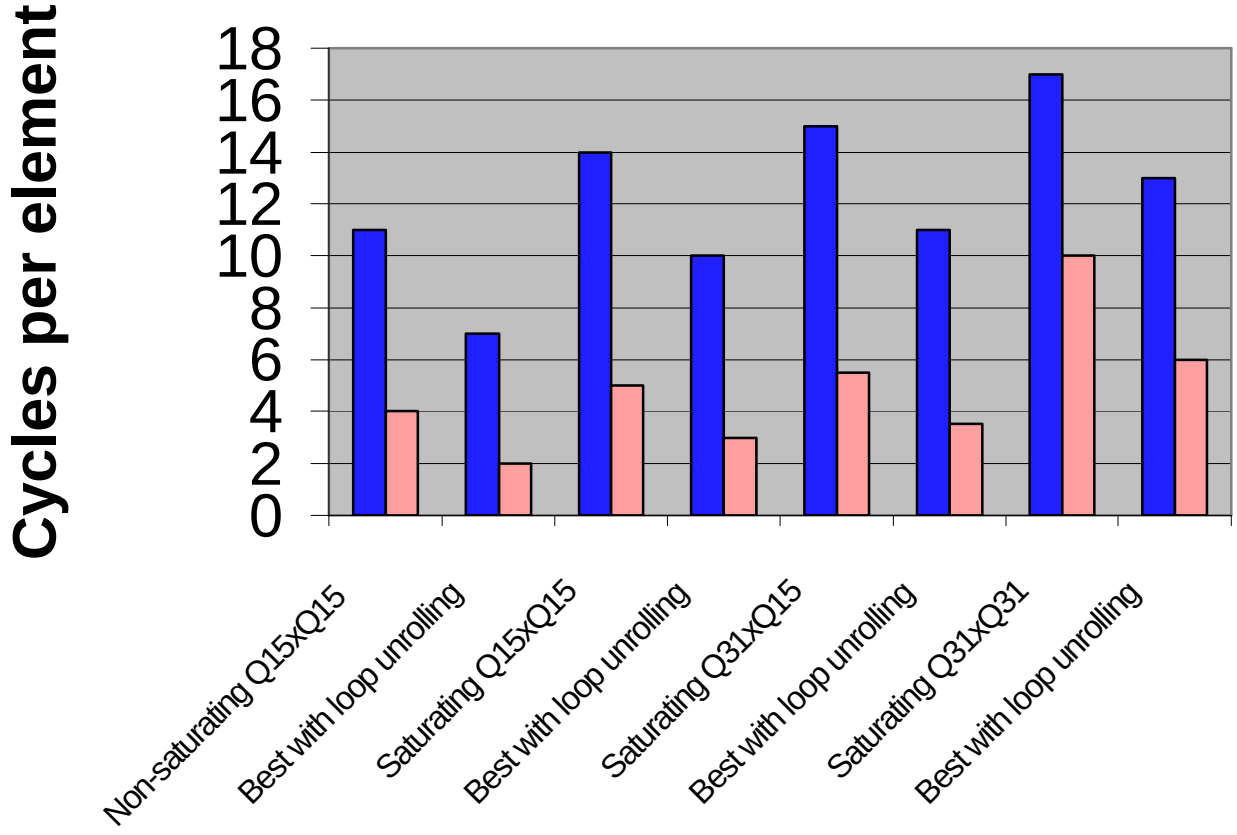
- **Clean orthogonal architecture with linear 32-bit memory space**
  - Harvard bus architecture invisible to programmer
    - no special table access instructions
  - Excellent HLL target
- **No 'extra' state to keep track of**
  - instructions select saturation mode etc.
- **32-bit stack pointer with stack located in external memory**
  - No interrupt nesting limitations imposed by architecture

ARM9E Datapath



Dot product performance

Underlying operation for state-space servo control



10 element 16x16 dot-product in 125ns on 160MHz ARM9E

Voice over IP

- **G.723.1 full-duplex**
  - Takes 25% of ARM9E at 160MHz.
  - 100% performance improvement from the ARM9E enhancements
    - similar improvements with digital cellular speech coders
  - Leaves 75% to run other applications
- **V.34bis softmodem**
  - 28% of ARM9E at 160MHz
- **Typical VoIP application - single engine internet appliance**
  - Windows CE or EPOC32, TCP/IP, Modem, Voice coder

Audio and speech processing

- **Efficient implementation of digital cellular speech coders**
  - DSP requirements of channel coding rising rapidly. Offloading the voice processing to ARM makes a more balanced system
- **MP3 decoding takes just 11% of an ARM9E at 160MHz**
  - Can run on a PDA platform with:-
    - EPOC32, WINCE, others
- **Dolby Digital (AC3) takes just 22% of ARM9E at 160MHz**

Enhanced debug capabilities

- **Real-time debug**
  - Core has been enhanced to allow a debugger to step and debug one task whilst background interrupt routines continue to run.
- **Compatible with ARM Real-time Trace solution**
  - ARM9E connects to ARM Embedded Trace Macrocell
  - allows real-time non-intrusive instruction and data tracing

Development Tools Support

- **ARM9E is fully supported by the ARM software development toolkit**
  - The ARM Debugger supports the new instructions
  - Cycle accurate simulator models are already being used
  - The C and C++ compilers support inline assembly using the new instructions
  - Assembler supports ISA enhancements
  - Real-time trace tools support the ARM9E
- **ARM is engaged with third-parties to enable other ARM9E tool chains**

Everything you need

- **EDA**
  - ARM will use its partnership with leading EDA vendors to enable ARM9E design simulation and co-simulation
- **Consulting and training**
  - ARM provides hardware and software design support services and training for all of its products
- **RTOS**
  - More than 25 RTOS are already implemented on ARM
- **Operating systems**
  - Symbian EPOC32, WindowsCE, Linux, JAVA OS

Vital statistics

- **Both soft and hard macrocell implementations of ARM9E are planned**
- **ARM9TMDI is only 2.1mm² on 0.25㎛**
  - Area increase of ARM9E is less than 30% over ARM9TDMI
- **ARM9E will run at the same clock frequency as ARM9TDMI on the same process**
  - 160MHz initial implementation on a 0.25µm process
  - 200MHz+ on a 0.18µm process
- **ARM9E will be delivered to lead partners in Q3 with first silicon in Q4**

ARM POWERED

ARM9E

A DSP enhanced ARM9TDMI core gives:

- single engine for both DSP and control code
- fully supported in ARM's development and debug tools
- system cost and complexity savings
- faster time-to-market
- an excellent compiler target
- great solution for high-volume cost sensitive applications