



# Video Encoding with Multicore Processors

**March 29, 2007**

# Video is Ubiquitous . . .

Demand for **Any Content**  
**Any Time**  
**Any Where**

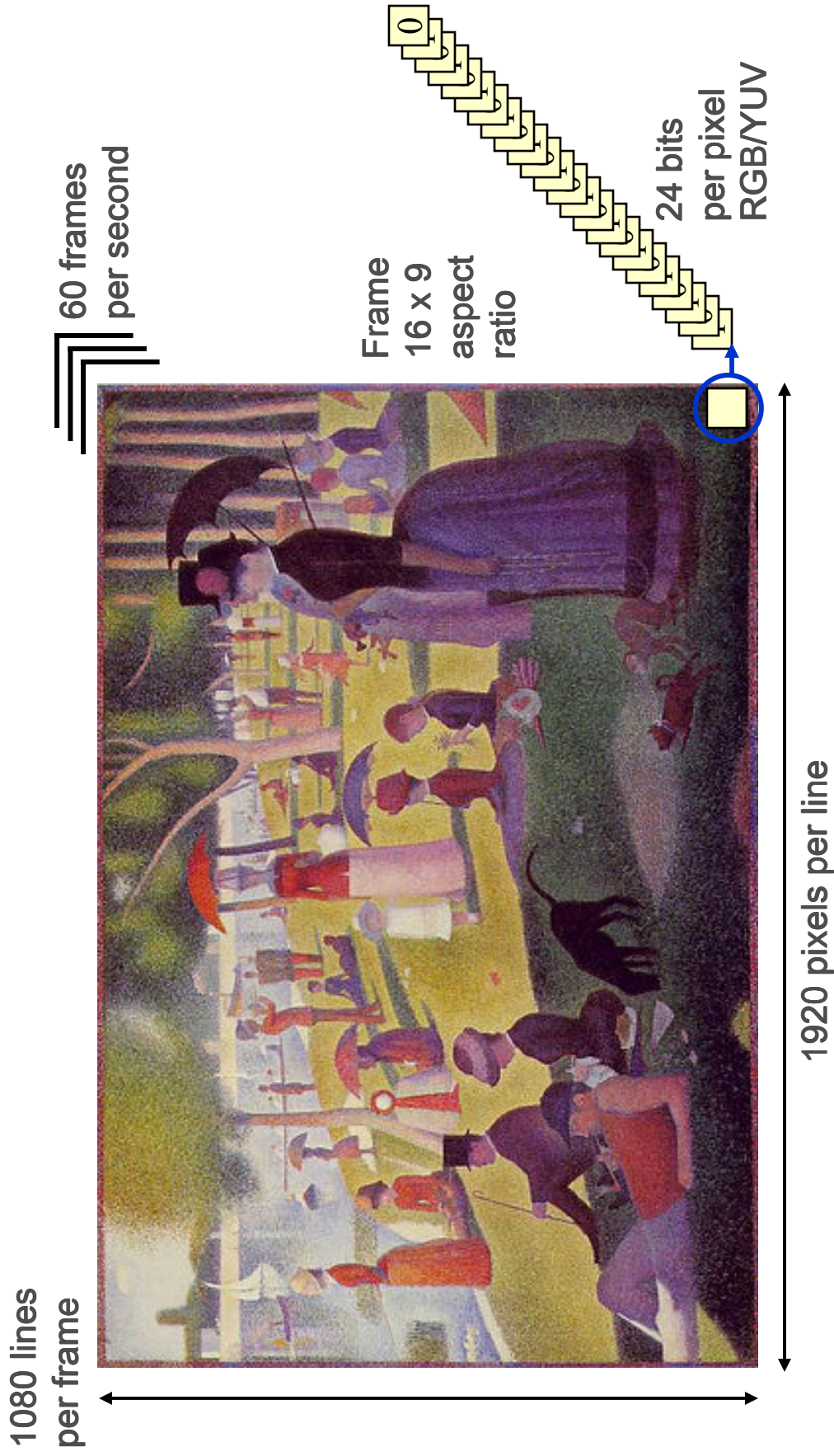
Resolution ranges from  
 128x96 pixels for mobile to  
 1920x1080 pixels for full HD  
 Frame rates range from  
 10 to 60 fps



**The only constant is that raw digital data always outstrips available capacity!**

| FORMAT   | lpf  | ppl  | bpp | Mbpf   | fps | Mbps  | 2 hr video | Channel Mbps                           | Storage GB              |
|----------|------|------|-----|--------|-----|-------|------------|----------------------------------------|-------------------------|
| Sub-QCIF | 96   | 128  | 8   | 0.0983 | 10  | 0.983 | 885 MB     | GSM .0014<br>POTS .0056<br>Brdbd .3840 |                         |
| NTSC     | 480  | 720  | 16  | 5.53   | 30  | 166   | 149 GB     | Satellite 006<br>Cable 020             | DVD 17<br>iPod 80       |
| HDTV     | 1080 | 1920 | 24  | 49.87  | 60  | 2,986 | 2.69 TB    | T3 044.7<br>OC-3 155.5                 | HD-DVD 30<br>Blu-Ray 50 |

# High Definition = High Quality

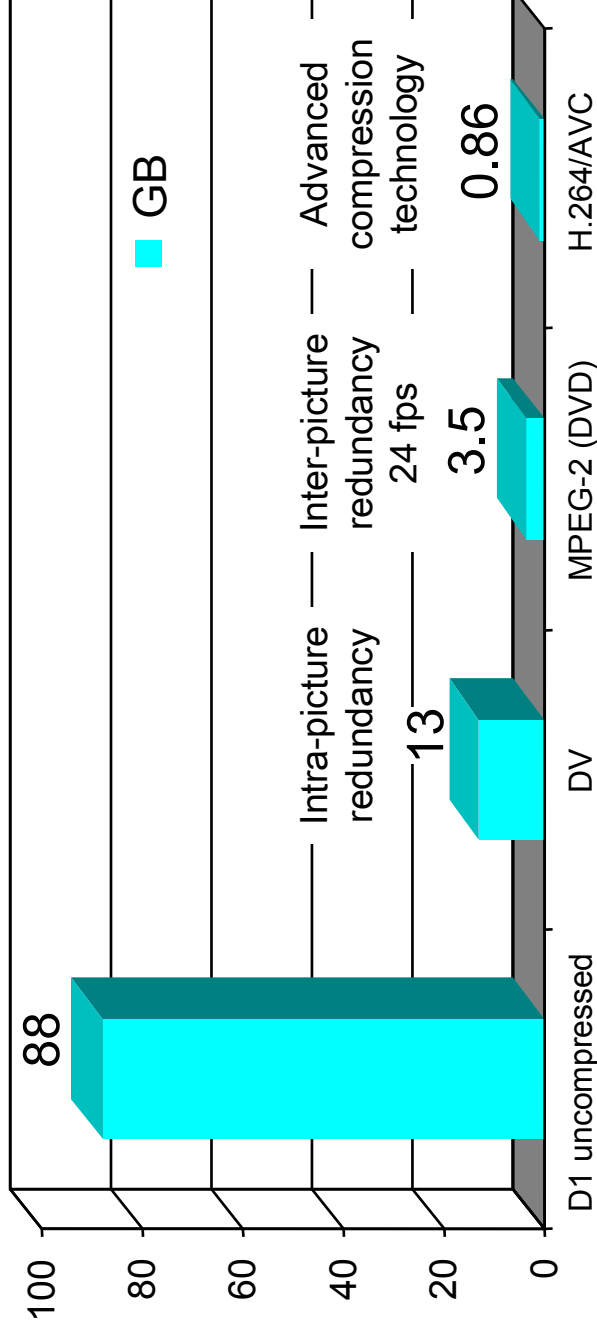


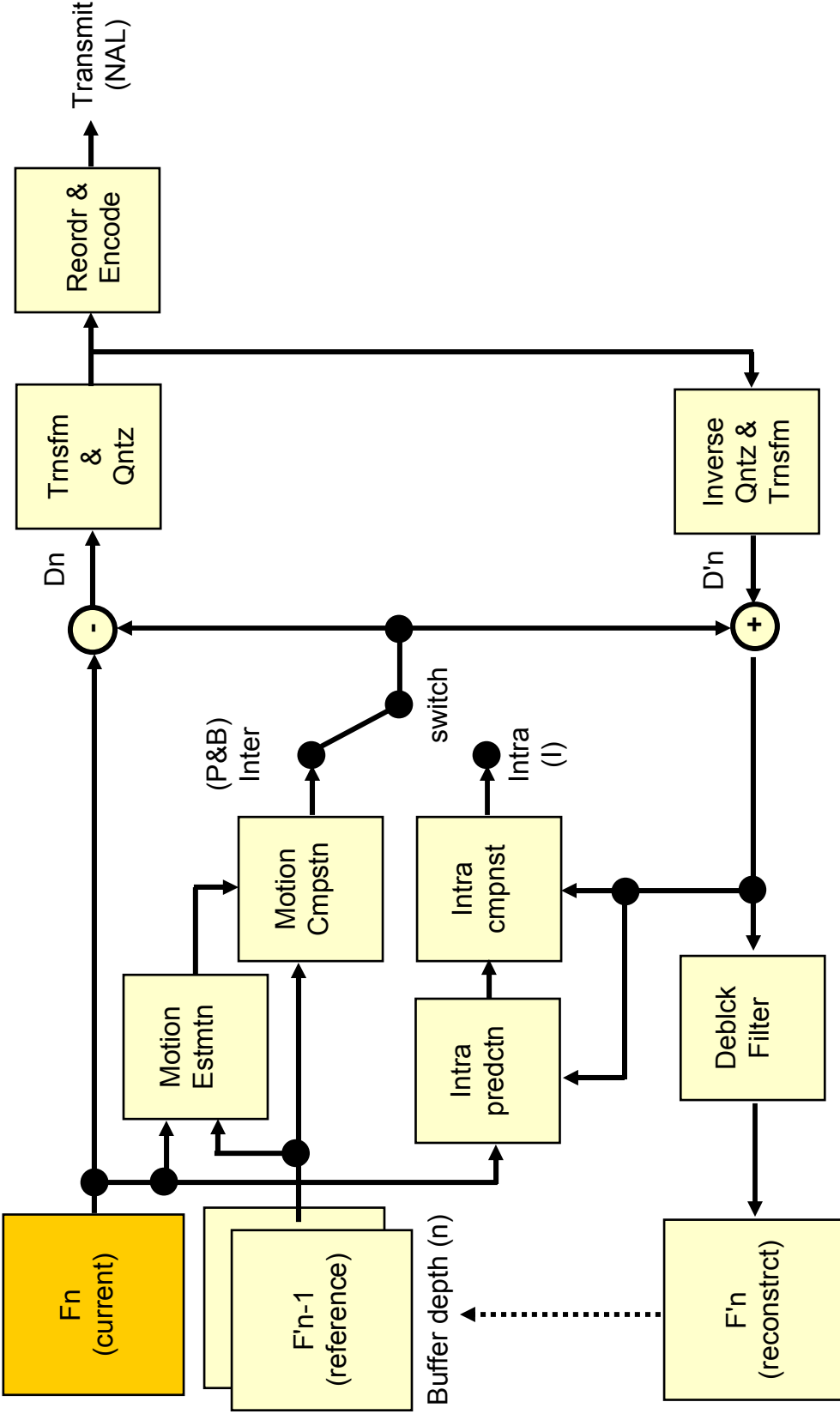
Le Grand Jatte (aka "Sunday in the Park"), 1886 – George Seurat – 120 x 81 inches  
 About 3.5 million dots = 19 dpi – view from 18-25 feet (vs. about 2.1 million pixels on HDTV screen)

# Video Encoding Standards

- Defined by the ISO/IEC – MPEG Group  
MPEG2, AVC/H.264 or MPEG4 Part 10
- Can achieve up to 100:1 reduction in HD video data

Relative file sizes 1 hour video

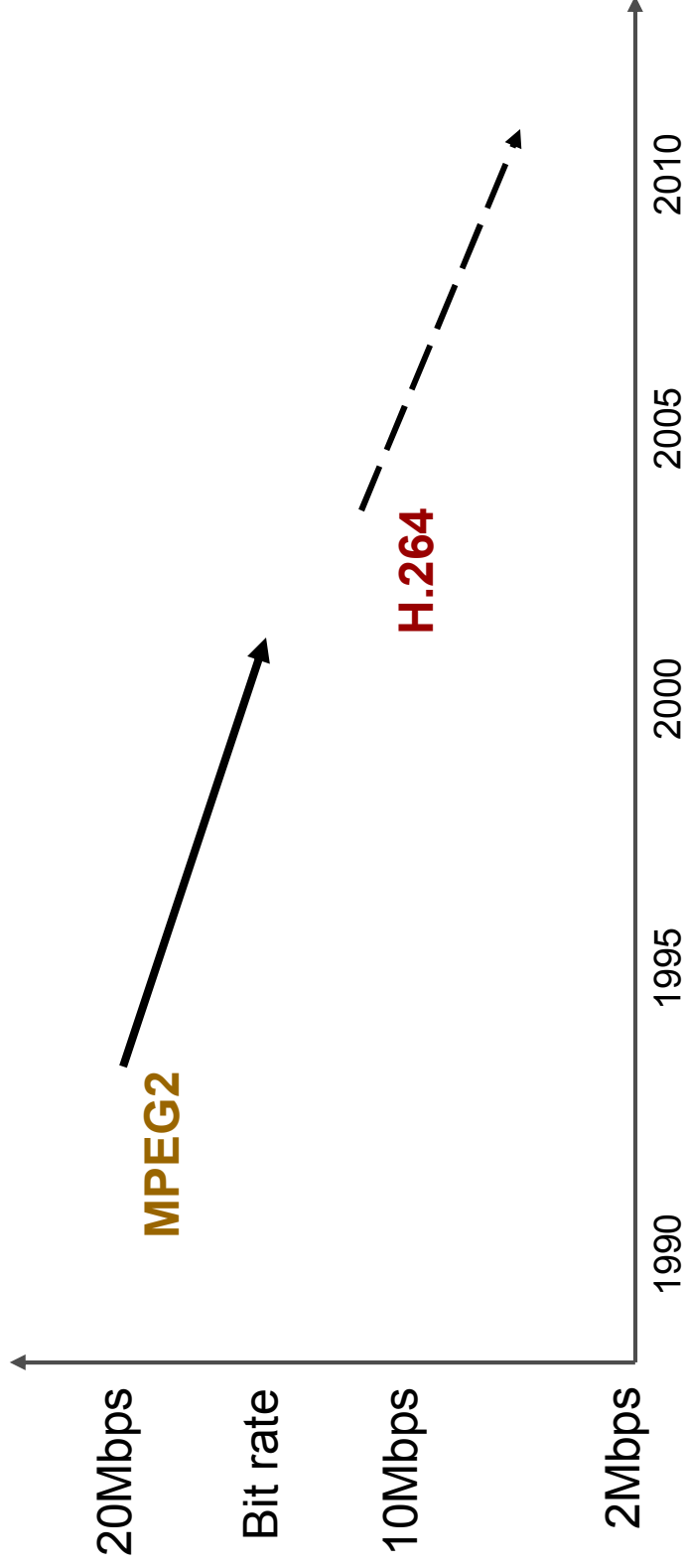




# AVC / H.264 Algorithm

| Sub Blocks             | Features                                                                               | Processing Characteristics                                      |
|------------------------|----------------------------------------------------------------------------------------|-----------------------------------------------------------------|
| Motion Estimation      | Adaptive block sizes<br>16x16, 8x8, 4x8, 8x4, 4x4                                      | Greatest processing requirement (~50%)<br>Highly parallelizable |
| Transform              | 4x4 , 8x8 (High P) Simple Integer                                                      | Highly parallelizable                                           |
| Motion Compensation    | To $\frac{1}{4}$ pel                                                                   | Highly parallelizable                                           |
| Deblocking filter      | In Loop                                                                                | Partly parallelizable                                           |
| Intra prediction Modes | 13 (4x4 – 9 modes, 16x16 – 4 modes)                                                    | Partly parallelizable                                           |
| Inter prediction modes | Numerous choices of block size, number/type of reference frames                        | Partly parallelizable                                           |
| Entropy Encoding       | Context-based Adaptive VLC (CAVLC) &<br>Context-based Binary Arithmetic Coding (CABAC) | Bit wise operations<br>Partly parallelizable                    |
| Quantization           | Finer range of parameters                                                              | Highly parallelizable                                           |
| Next Generation        | Fidelity Range extensions (FRext)<br>4:2:0 – High; 4:2:2 – 8-10 bit ; 4:4:4 – 10-12bit | Still higher processing reqrmts.                                |

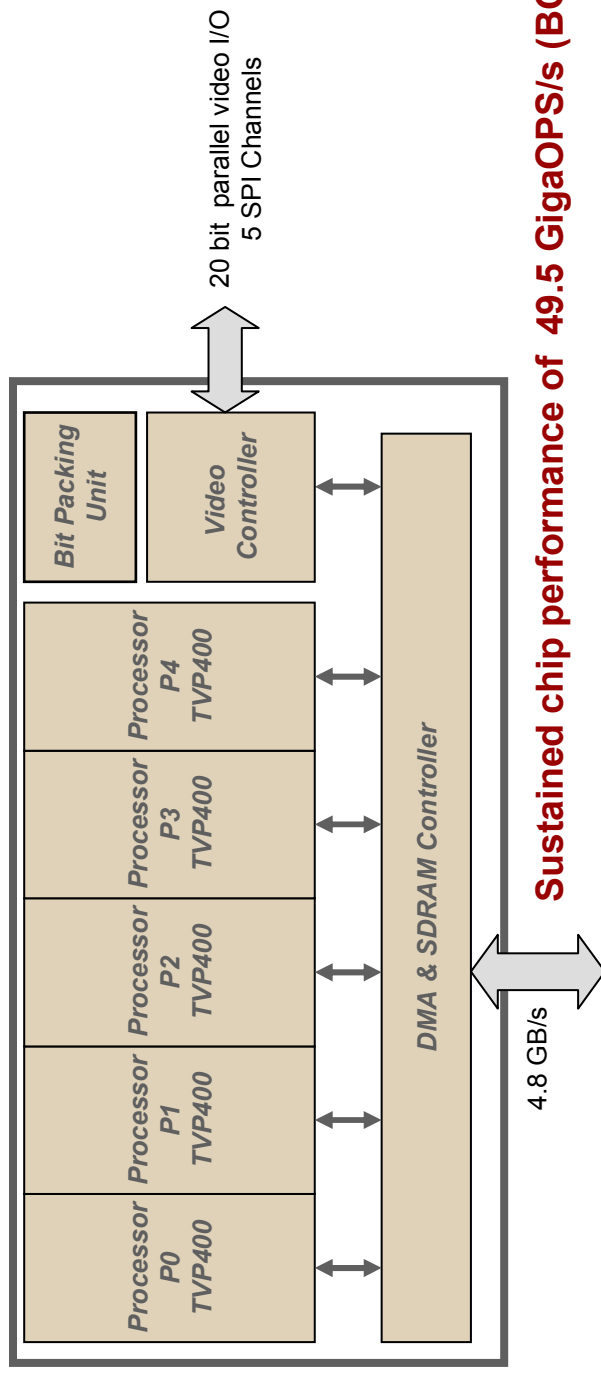
# H.264 Improves Video Quality and Bit Rate



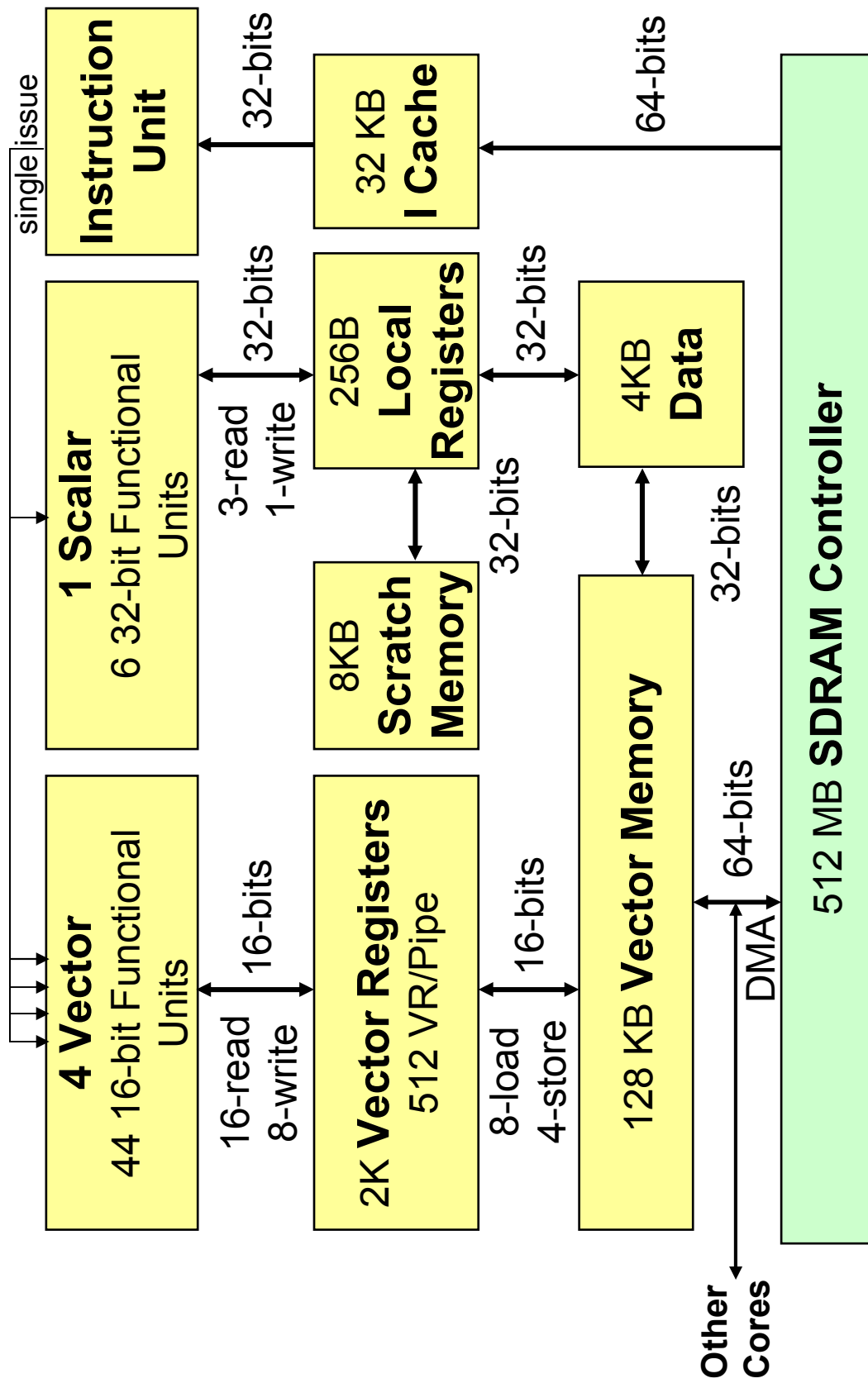
- **Ideal Application for multiprocessor, multicore solution**
  - Keeps up with performance requirements (5-6X MPEG2)
- **Requires programmability to keep pace with algorithm improvements**

# Telairity-1 Video Architecture

- Architecture designed for High Definition video
- 5 identical loosely-coupled vector/scalar processor cores in single chip
  - Integrated DRAM controller
  - Integrated Video controller
- Fully programmable
- 90nm process technology - up to 750 MHz operation (594 MHz today)



# TVP400 Core Block Diagram



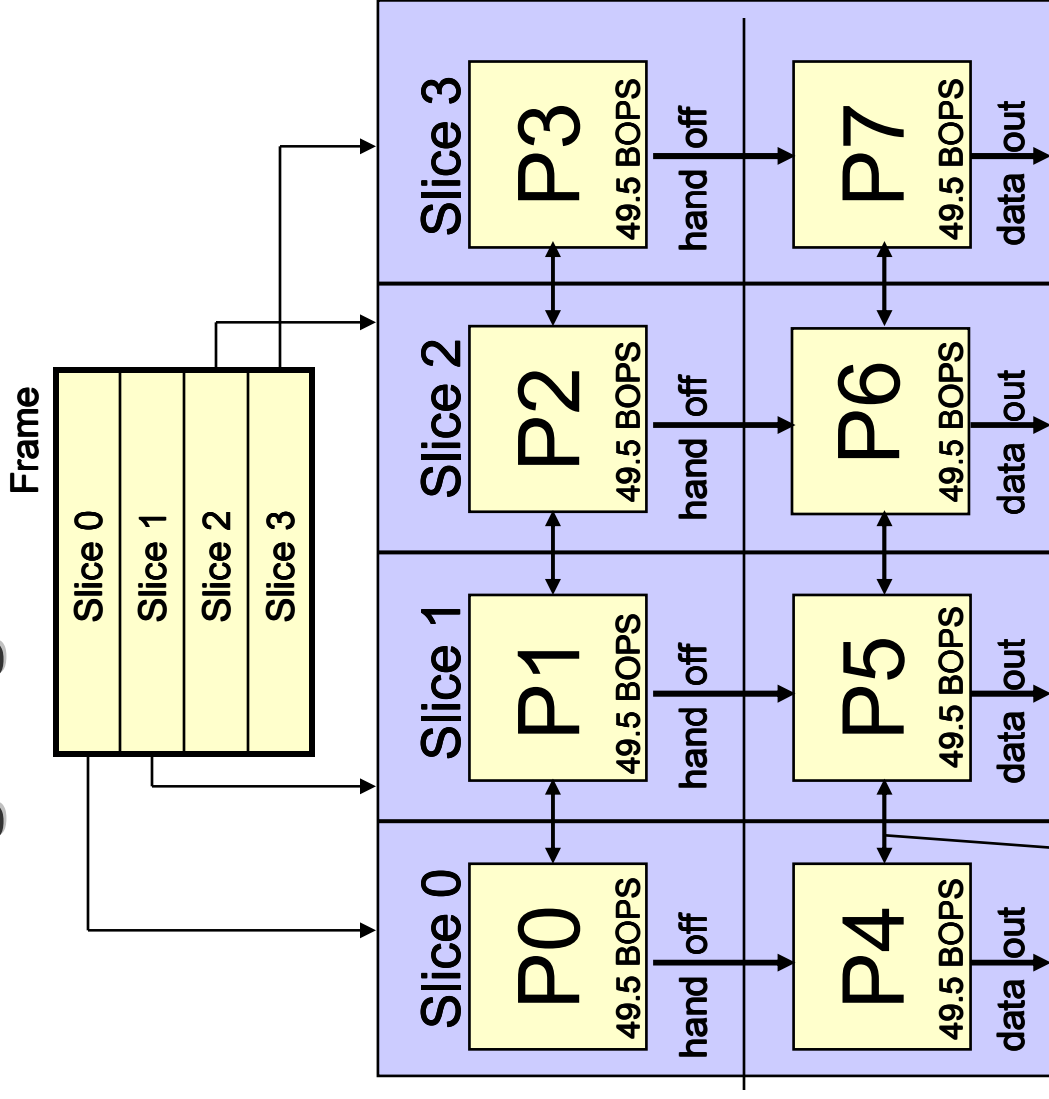
## Multi Pipe Vector Instructions

- 4 independent 16-bit vector pipes
  - 5 instructions per pipe – total of 20 in parallel
- Vector length of 32
  - From 1 to 32 vector elements processed sequentially
- Extremely efficient for several video operations
  - Motion estimation / compensation
  - 8 x 8, 4x4 transforms
- H.264/AVC 4x4 block Intra-Prediction algorithm
  - Uses multi-pipe vector core
  - Calculates eight modes simultaneously
  - Eightfold speed up in intra-prediction

# Multiprocessor Encoding Engine



- Partition video data by parallelizing each frame into multiple slices



AND

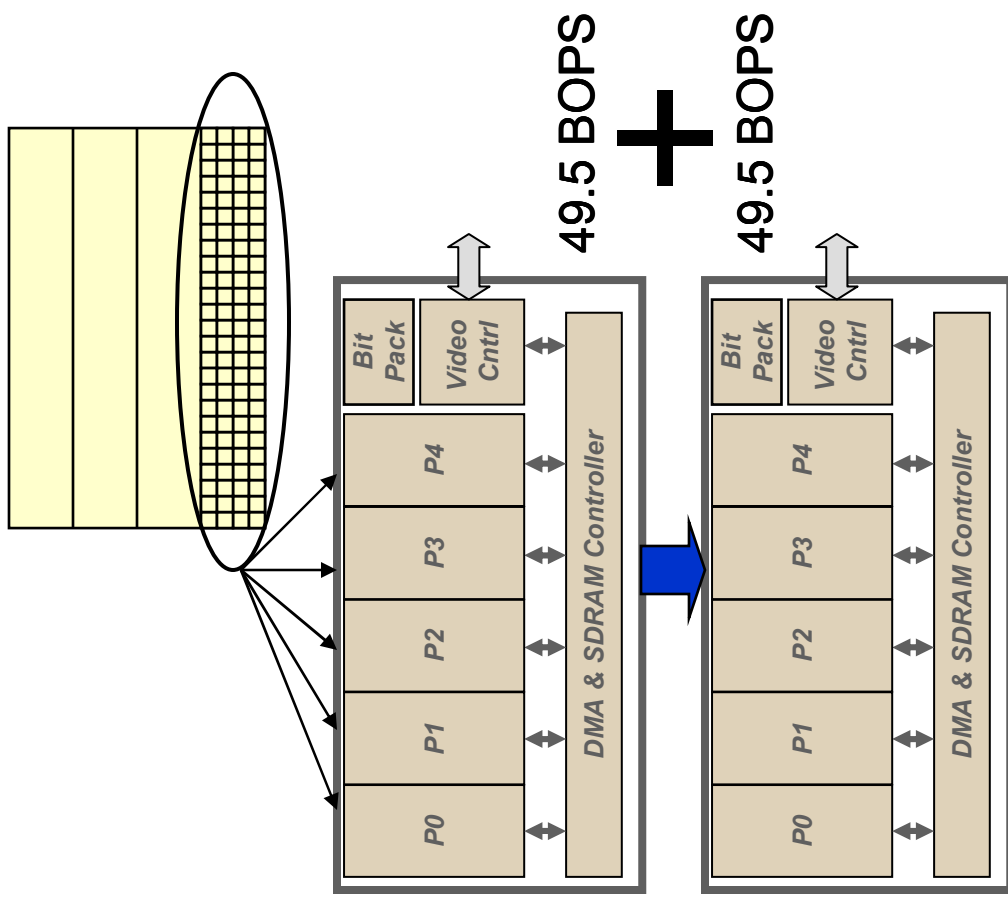
- Partition algorithm between top and bottom row of processors

High bandwidth chip-chip communication to eliminate slice artifacts

396 sustained BOPS

# Multicore Processing

- Partition video data further by parallelizing each slice into multiple macroblocks
- Processed in parallel using 5 TVP400 cores
- Tasks divided sequentially across two T1 processors
- Really, very doable:
  - 720p is  $80 \times 45 = 3,600$  macroblocks per frame x 60 fps = 216,000 mb/sec
  - Divided by 4 slices = 54,000 mb/sec x 2 50 BOPS T1 processors





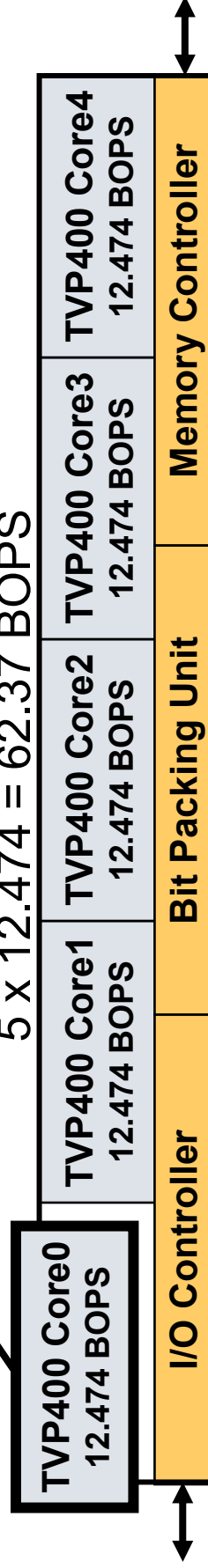
# BE8000 Peak Performance

$$5+5+5+5+1 = 21 \text{ ops/clock} \times 594 \text{ MHz} = 12.474 \text{ BOPS}$$

| VP0                                | VP1                                | VP2                                | VP3                                | SP          |
|------------------------------------|------------------------------------|------------------------------------|------------------------------------|-------------|
| 2 16-bit ops<br>2 loads<br>1 store | 2 16-bit ops<br>2 loads<br>1 store | 2 16-bit ops<br>2 loads<br>1 store | 2 16-bit ops<br>2 loads<br>1 store | 1 32-bit op |

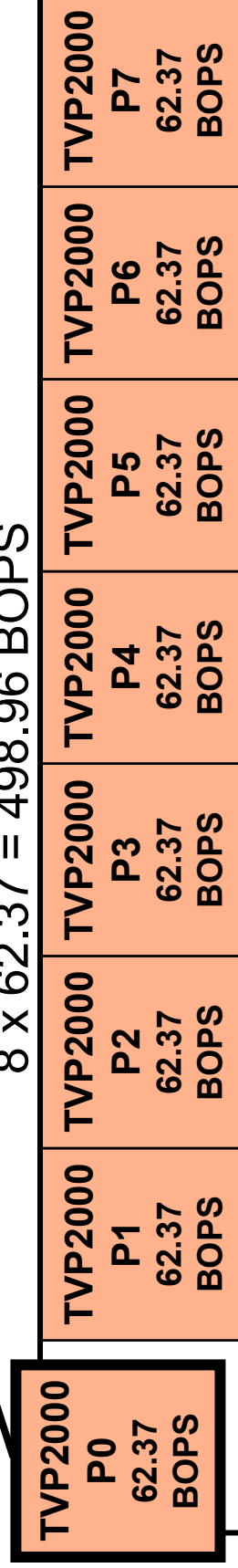
TVP400 Processor Core: 5 Pipelines

$$5 \times 12.474 = 62.37 \text{ BOPS}$$



TVP2000 Processor: 5 cores

$$8 \times 62.37 = 498.96 \text{ BOPS}$$



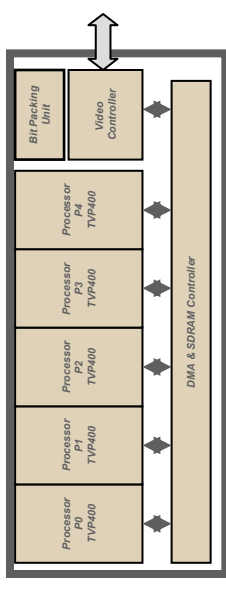
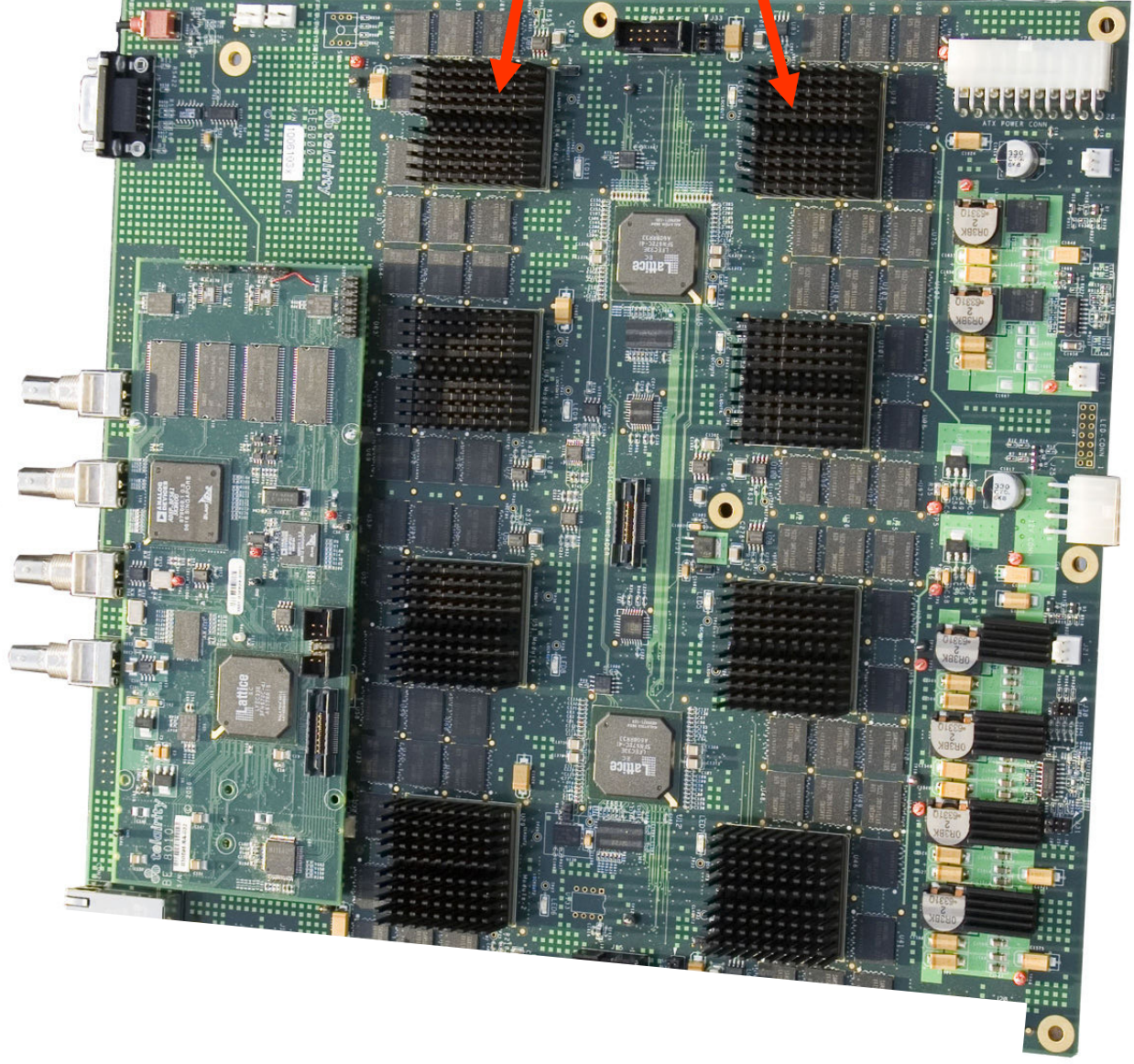
BE8000 Encoder Board: 8 processors

# AVClairity Compression Software

- Dedicated AVC software
  - All written in-house (C and intrinsics)
  - Runs directly on BE8000 hardware (no OS)
  - Flexible, scalable for different resolutions, standards
- Main Profile, High Profile of AVC standard
  - Level 4.0
  - 4:2:0, 8-bit compression
  - Video formats: 720 p 50/59.94/60 and 1080 i 25/29.97/30
  - Constant Bit Rate (CBR) or Variable Bit Rate (VBR)
  - Bit rate: 2-20 Mbps
  - Scene change detection
  - Context Adaptive Entropy Coding: CABAC or CAVLC
  - Spatial and motion compensated temporal filtering

# Software Issues and Challenges

- Load balancing between processors
  - One slice/frame may contain extremely dense data relative to other slices/frames
  - Managing idle time – waiting for processors to finish
- Synchronization of data exchange between processors
  - Minimization of latency
- Efficient and high bandwidth communication between processors and cores
  - >300 MB/sec path between processors
    - Eliminates slice boundary artifacts
  - 5 cores share Vector memory and DDR2 DRAM memory per processor
    - Minimizes inter-core communication requirements



# **BE8000 Video Encoding Platform**



## **HD AVC Video Encoding AAC Audio Encoding**

- Highest performance; multiprocessor, multicore solution
  - Runs 40 concurrent threads
  - Each thread has 5 execution units available to it
- Achieves low latency and high video quality
- Flexible and software upgradeable for video and bit-rate improvements