The DCT/IDCT Solution Customer Tutorial

February 2000

Agenda

- Introduction
- DCT/IDCT Concepts
- DCT/IDCT Applications
- Spartan-II DCT/IDCT IP Solutions
- Summary

Introduction

- Spartan-II FPGAs
  - 100,000 System Gates at under $10
  - Extensive features: Block RAM, DLL, Select I/O
  - Vast IP Portfolio
  - Provide Density, Features, Performance at ASIC prices

DCT/IDCT Compression

- Compression allows increased throughput through transmission medium
  - Video and audio compression makes multimedia systems very efficient
    - Increases CPU bandwidth
    - Higher video frame rates
    - Better audio quality
    - Enables multimedia interactivity
- DCT and IDCT are widely used in video and audio compression

DCT/IDCT Overview

DCT - Discrete Cosine Transform

IDCT -Inverse Discrete Cosine Transform

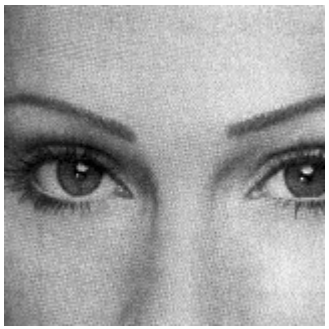
DCT/IDCT Concept

- What is DCT?
  - X= DCT(video/audio input)
    - Returns the discrete cosine transform of ‘video/audio input’
    - Can be referred to as the even part of the Fourier series
    - Converts an image or audio block into it’s equivalent frequency coefficients
- What is IDCT?
  - The IDCT function is the inverse of the DCT function
  - The IDCT reconstructs a sequence from its discrete cosine transform (DCT) coefficients

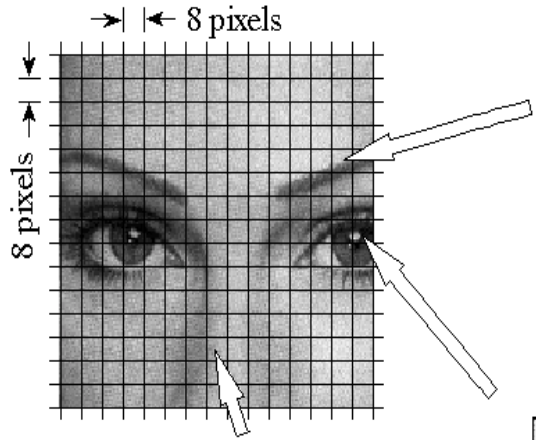
DCT/IDCT Concept

- The DCT transform of an image brings out a set of numbers called coefficients.
- A coefficient's usefulness is determined by its variance over a set of images as in video's case.
- If a coefficient has a lot of variance over a set, then it cannot be removed without affecting the picture quality.

DCT/IDCT Concept



Original Image



231	224	224	217	217	203	189	196
210	217	203	189	203	224	217	224
196	217	210	224	203	203	196	189
210	203	196	203	182	203	182	189
203	224	203	217	196	175	154	140
182	189	168	161	154	126	119	112
175	154	126	105	140	105	119	84
154	98	105	98	105	63	112	84

DCT

Frequency Coefficients Compared to Magnitude Thresholds Resulting in Compressed Data Streams

154	154	175	182	189	168	217	175
154	147	168	154	168	168	196	175
175	154	203	175	189	182	196	182
175	168	168	168	140	175	168	203
133	168	154	196	175	189	203	154
168	161	161	168	154	154	189	189
147	161	175	182	189	175	217	175
175	175	203	175	189	175	175	182

42	28	35	28	42	49	35	42
49	49	35	28	35	35	35	42
42	21	21	28	42	35	42	28
21	35	35	42	42	28	28	14
56	70	77	84	91	28	28	21
70	126	133	147	161	91	35	14
126	203	189	182	175	175	35	21
49	189	245	210	182	84	21	35

IDCT

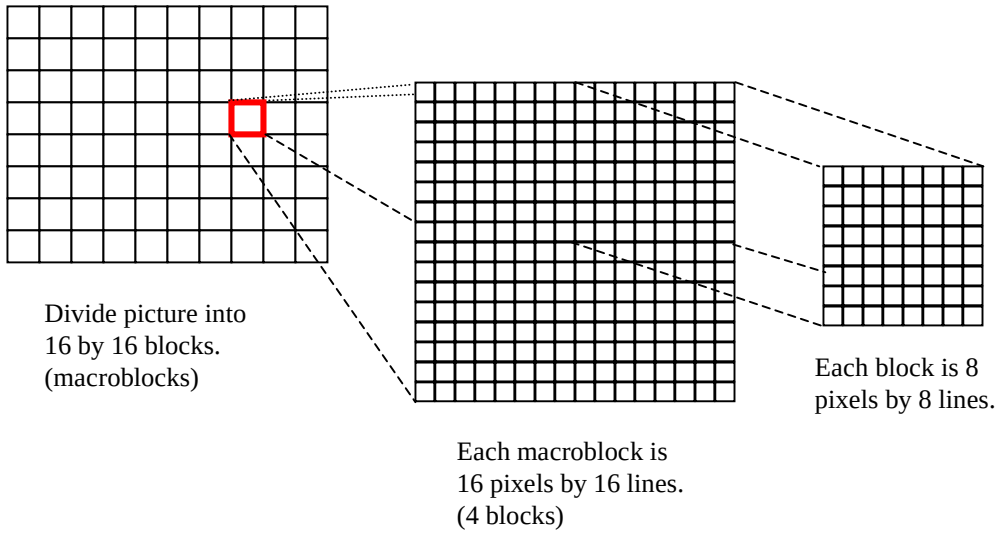
Recovered Image

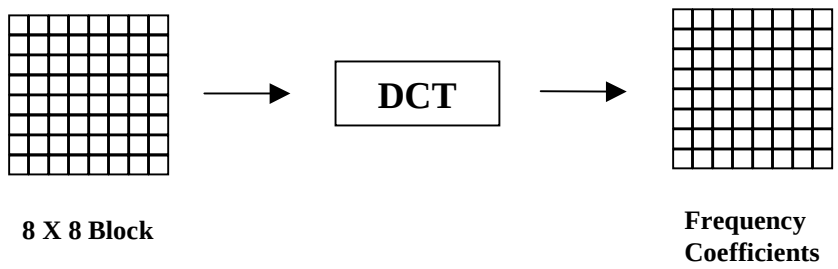
(Notice Lesser Image Quality)

The image is broken into 8x8 groups, each containing 64 pixels. Three of these 8x8 groups are enlarged in this figure, showing the values of the individual pixels, a single byte value between 0 and 255.

Courtesy: The Scientist and Engineer's Guide to Digital Signal Processing by Steven W. Smith

DCT/IDCT Concept





DCT/IDCT Usage

- Areas of Use:
  - One-Dimensional DCT/IDCT
    - Dolby AC2 & AC3
    - Biomedical signals like EEG & ECG
    - Speech information compression
  - Two-Dimensional DCT/IDCT
    - JPEG Encoders
    - MPEG-1 & MPEG-2
    - Image & Pattern Recognition

DCT/IDCT Concept

- One-Dimensional DCT Equation

$$X_c(k) = (1/N) \sum_{n=0}^{N-1} x_n \cos(k2\pi n/N),$$

where

$$k = 0, 1, 2, \ldots, N-1$$

DCT/IDCT Concept

- One-Dimensional IDCT Equation

$$x_c(k) = \sum_{n=0}^{N-1} c[u]\, X_n \cos(k2\pi n/N),$$

where

$k = 0, 1, 2, \ldots, N-1,$

X_n is the DCT result, and

$c[u] = 1$ for $u=0$, and $c[u] = 2$ for $u=1,2,3,\ldots N-1$

DCT/IDCT Concept

- Two-Dimensional DCT Equation

$$F[u, v] = 1/N^2 \sum_{m=0}^{N-1} \sum_{n=0}^{N-1} f[m, n] \cos[(2m + 1)u\pi/ 2N] \cos[(2n + 1)v\pi/2N]$$

where:

u, v = discrete frequency variables (0, 1, 2, …, N - 1),
f[m, n] = N by N image pixels(0, 1, 2, …, N - 1), and
F[u, v] = the DCT result

DCT/IDCT Concept

- Two-Dimensional IDCT Equation

$$f[m, n] = \sum_{m=0}^{N-1} \sum_{n=0}^{N-1} c[u]\, c[v]\, F[u, v] \cos[(2m + 1)u\pi / 2N] \cos[(2n + 1)v\pi / 2N]$$

where:

m, n = image result pixel indices(0, 1, 2, …, N – 1),

F[u, v] = N by N DCT result,

$c[\lambda] = 1$ for $\lambda=0$ and $c[\lambda]=2$ for $\lambda=1,2,3,\ldots N-1$

f[m, n] = N by N IDCT result

DCT/IDCT Concept

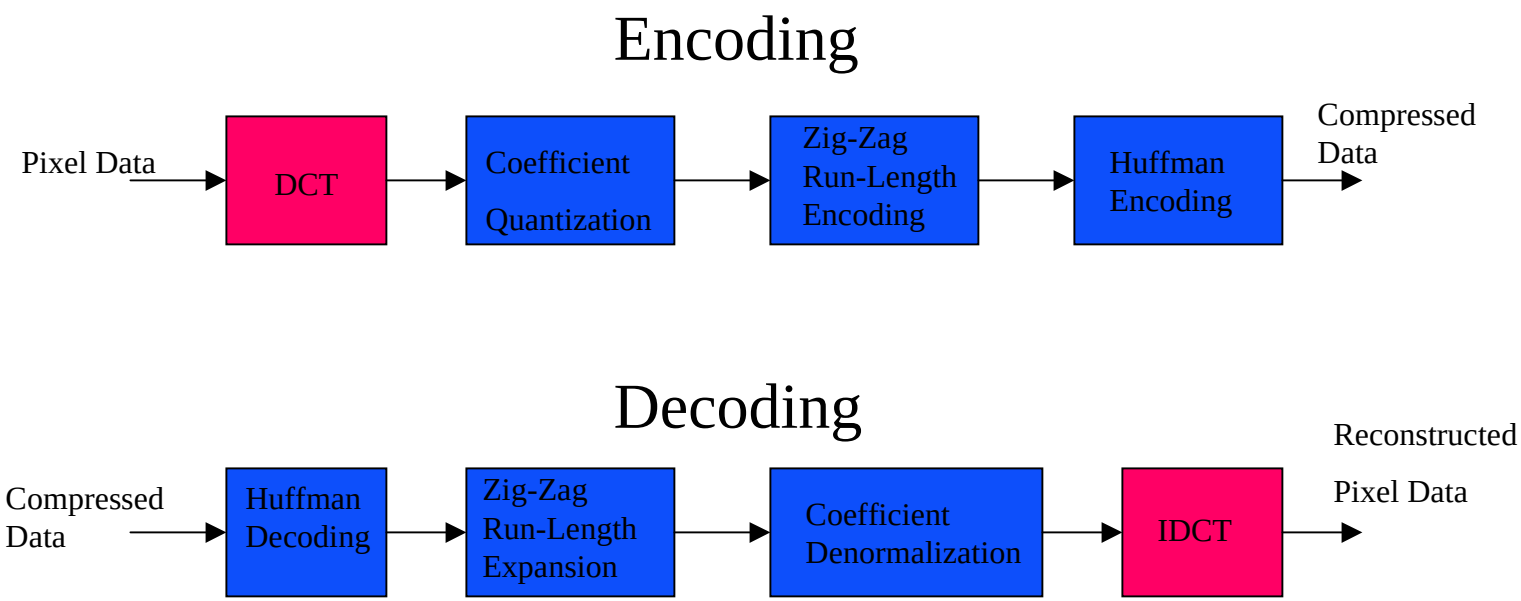
- Example of a Simplistic one-Dimensional DCT
  - Data is transformed first and the newly calculated values are threshold limited to a magnitude of 0.375
  - Assuming a data sequence to be {1, 2, 0, 5}
- Applying the one-Dimensional DCT formula,the resultant DCT sequence is {2, 0.25, -6, 0.25}
- The values that above the threshold (|values| > 0.375) are 2 and –6
- This results in a 50% reduction in data size with minimal loss in quality

DCT/IDCT Applications

DCT/IDCT Applications

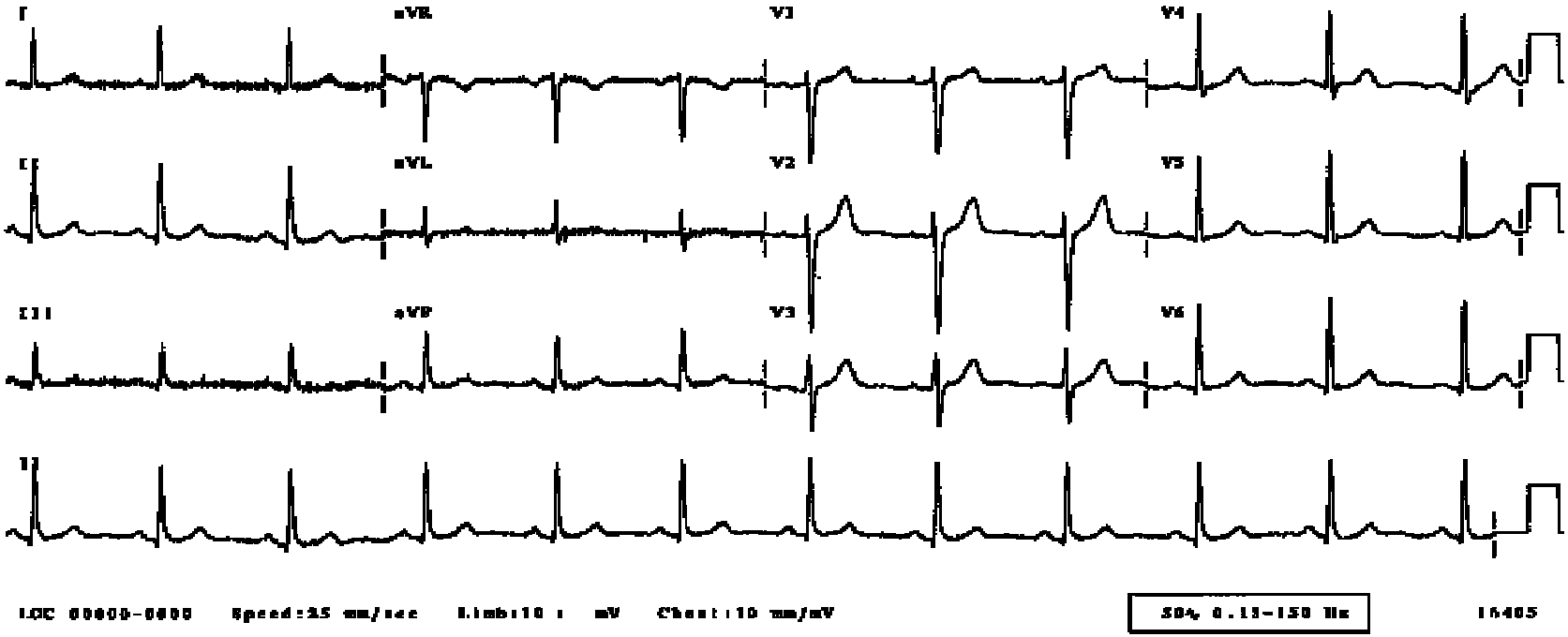
- List of Some End Applications
  - DVD/Video CD Players
  - Cable TV
  - DBS Systems
  - HDTV
  - Graphics/Image Processing Cards
  - Ultrasound/MRI Systems
  - Digital VCRs
  - Set-Top Boxes
  - Digital Camera

DCT/IDCT in JPEG



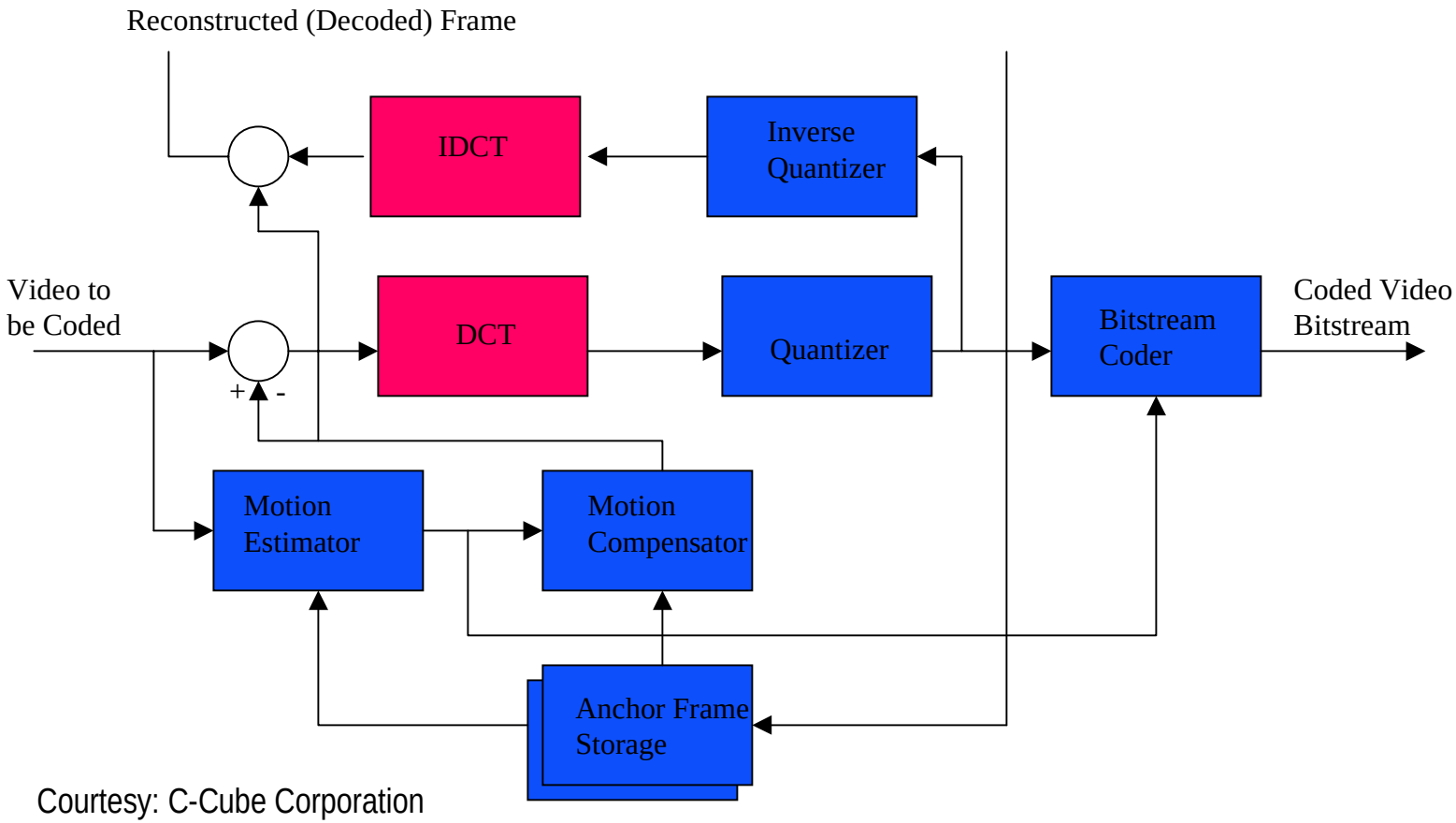
JPEG Codec Block Diagram

DCT/IDCT in Bio-Medical



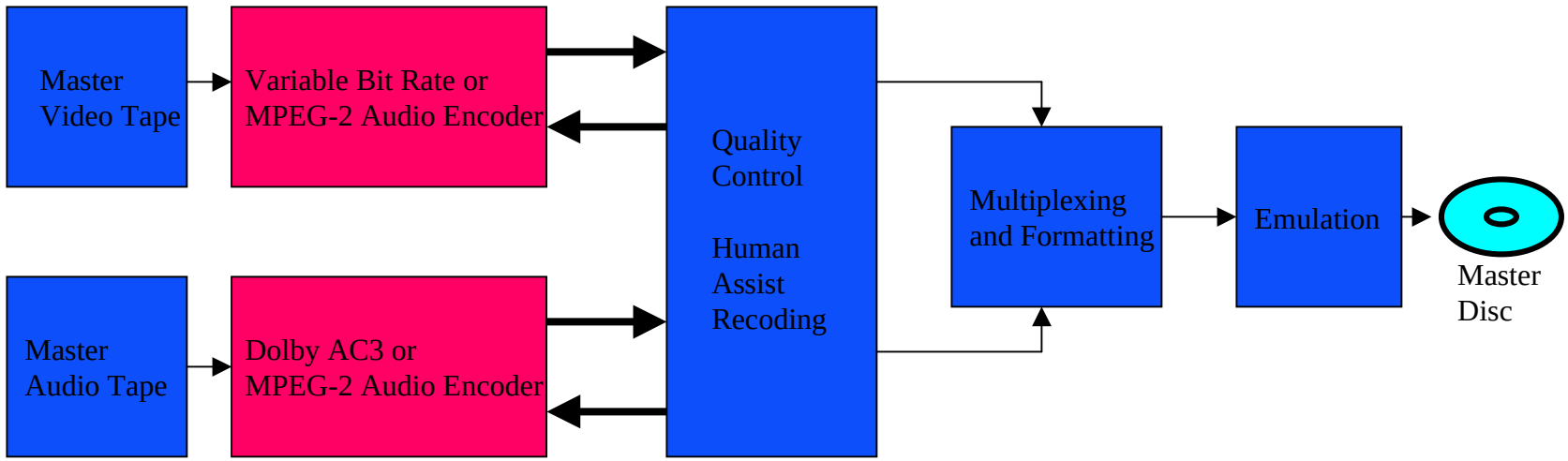
1-D DCT is commonly used on a sequence of digital information like voice or heartbeat information in an ECG

DCT/IDCT in DVD/VCD



MPEG-2 Block Diagram in a Typical DVD System

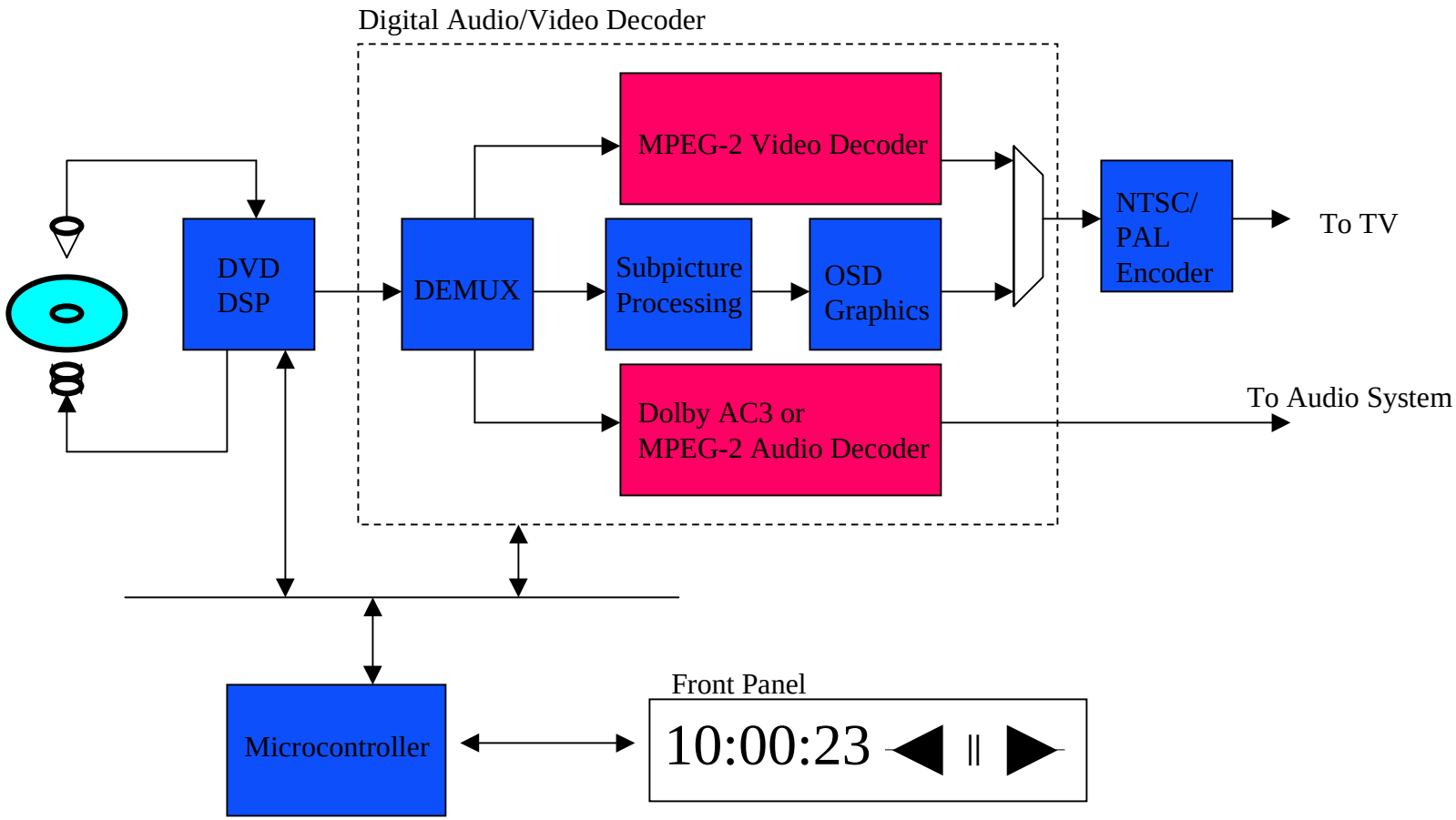
DCT/IDCT in DVD/VCD



Courtesy: C-Cube Corporation

DVD/VCD Mastering

DCT/IDCT in DVD/VCD



Courtesy: C-Cube Corporation

DVD Player

DCT/IDCT in DVD/VCD

DVD Players

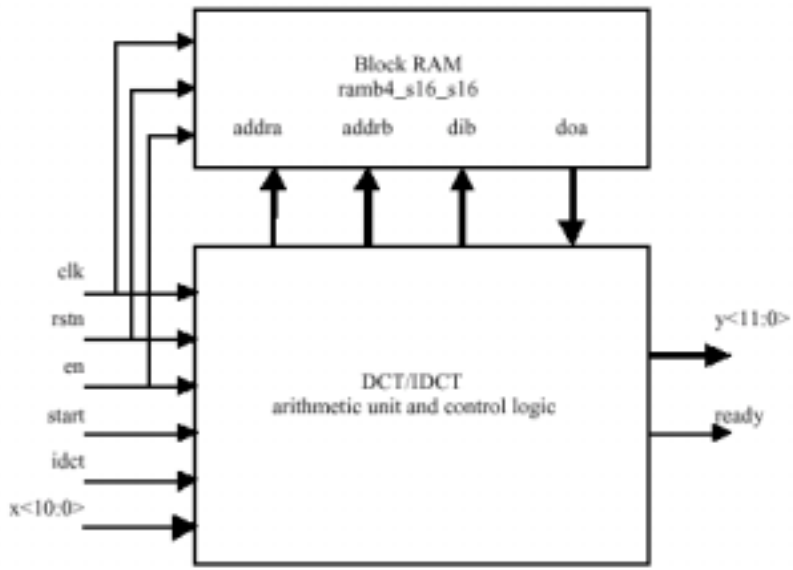
DCT/IDCT in Digital Cameras

2-D DCT/IDCT is applied generally on data sets that have a naturally two-dimensional characteristic, like a digital image

Digital Cameras

Spartan-II DCT/IDCT Solution

- DCT/IDCT Cores
  - Available Separately or Combined



AllianceCORE Xentec DCT/IDCT Core

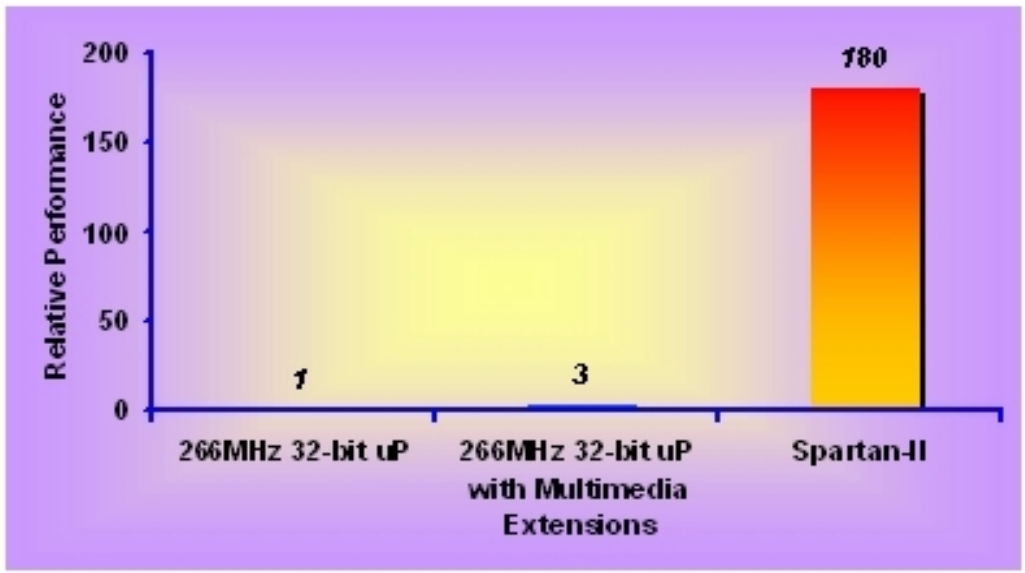
Spartan-II DCT/IDCT Solution Features

Features	Spartan-II
Device	XC2S100-6
CLBs	1026
Clock IOBs	1
IOBs	28
Performance (MHz)	33.3

AllianceCORE Xentec DCT/IDCT Core

Spartan-II DCT/IDCT Solution Performance

- Low cost Spartan-II FPGA with soft IP from Xentec has High Performance
  - 180 times faster 32-bit mainstream processor operating at 266MHz



Spartan-II DCT/IDCT Solution - Features

- The Xilinx solution is efficient and cost-effective compared to DCT/IDCT software solution being run by a high performance 32-bit processor
- The Xilinx Xentec core solution is capable of operating either as DCT or IDCT by the use of a single mode pin

Summary

- DCT/IDCT Solutions are Widely Used in Multimedia, Video, Audio, and Imaging Applications
- The Spartan-II Family has Significant Strengths in its DCT/IDCT Solution:
  - Features
  - Performance
  - Scalability and Flexibility
  - Cost effectiveness