

# CS6310

## High Performance DCT



At the heart of many video compression systems is the discrete cosine transform (DCT) function. The JPEG-compliant CS6310 DCT provides a high-performance transformation of a video waveform to its constituent frequency components. Capable of processing one symbol per cycle at sustained data rates of over 210 mega-samples/sec<sup>1</sup> in an ASIC implementation and 80 mega-samples/sec in FPGA, the CS6310 forms the heart of a high-performance video compression solution. The CS6310 DCT is available in both ASIC and programmable logic versions that have been handcrafted by Amphion to deliver high performance with low-power and minimal silicon area.

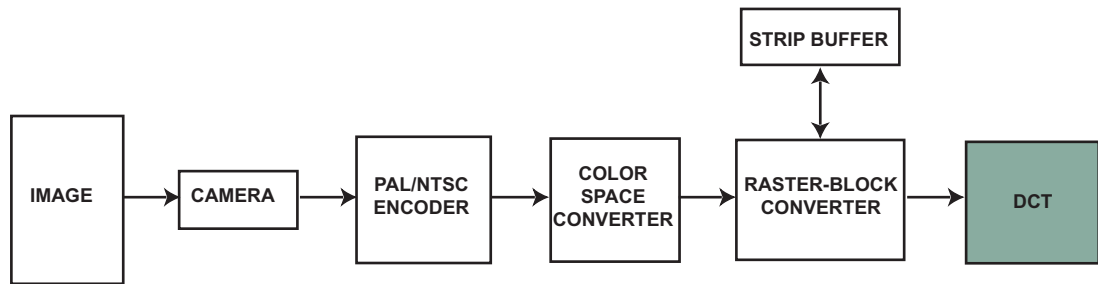


Figure 1: Typical Digital Video Processing Channel Containing the CS6310

### FEATURES

- ◆ High Performance DCT Core
- ◆ ASIC/FPGA/PLD versions available
- ◆ Continuous one symbol per cycle processing capability
- ◆ High performance (to 217 Msamples/second)<sup>1</sup>
- ◆ Highly portable firm core
- ◆ Ideal solution for JPEG
- ◆ Fully compliant with baseline JPEG Standard ISO/IEC 10918-1/2

### KEY METRICS

- ◆ Logic: 34K gates
- ◆ Memory: 1K bits RAM
- ◆ Max Frequency: 217 MHz

### APPLICATIONS

- ◆ JPEG systems
- ◆ Scanners
- ◆ Copiers
- ◆ Remote digital video

1. Actual performance is dependent on the ASIC libraries used and ASIC process targeted

## PIN/PORT DESCRIPTION

Table 1 describes the input and output ports (shown graphically in Figure 2) for the CS6310 High Performance DCT core. Unless otherwise stated, all signals are active high and bit (0) is the least significant bit.

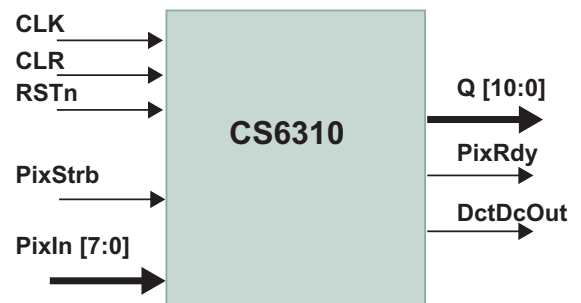


Figure 2: CS6310 Core Symbol

Table 1: I/O Signal Descriptions

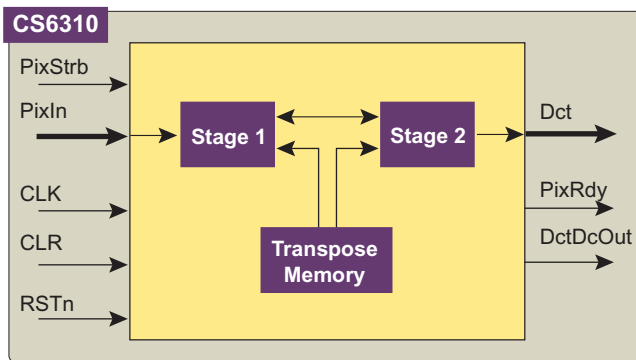
| Signal      | I/O    | Description   |
|-------------|--------|---|
| CLK         | Input  | Clock signal  |
| CLR         | Input  | Synchronous reset signal  |
| RSTn        | Input  | Active low, asynchronous reset signal   |
| PixStrb     | Input  | Signal to indicate to the core that the first sample in a 8x8 block is available for processing. Active high asserted pulse for one CLK period. PixStrb can be left high after first assertion for continuous processing of data blocks. However, in case of any gaps between successive blocks, it must be asserted along with first data sample of a block. Re-assertion of PixStrb within a 8x8 block segment has no effect on processing. |
| PixIn [7:0] | Input  | 8-bit wide pixel data input port. The data is burst in on block by block basis. The 8-bit data for DCT computation is internally level shifted. If the data sequence is corrupted for any reason, the port will continue to read 64 elements of an 8x8 block and then wait for the assertion of PixStrb to read next valid data block.  |
| Q [10:0]    | Output | 11-bit wide DCT coefficient output port. The data is burst out on block by block basis in column-major order.   |
| DctDcOut    | Output | DC flag of Q, associated with the first coefficient (DC coefficient) of an 8x8 block, can also be regarded as the start signal of the block. Active high pulse for one CLK period.  |
| PixRdy      | Output | Active high signal indicates that the core can read a new block of pixel. It goes to a low state whenever PixStrb has been asserted.  |

## FUNCTIONAL DESCRIPTION

The DCT is a transform that converts a signal into its constituent frequency components as represented by a set of coefficients. For an image, this transform is performed on a 2 dimensional array of samples, resulting in a 2 dimensional array of coefficients. The data input into the core and output from the core takes place as a block of 8x8 samples.

The transform can be performed as a one or two stage process. The two-stage process performs the transform as two separate one-dimensional transforms. This results in a set of intermediate results being produced which require storage and further processing.

The CS6310 performs its function as two 1-dimensional transforms, using row-column decomposition, with the intermediate results being stored in the transpose memory. Figure 3 is a block diagram of the core, showing the main interfaces and functional blocks.



**Figure 3: DCT Block Diagram**

The core is initialized on power-up by an asynchronous active low pulse at the RSTn port or a synchronous active high pulse at CLR port. Data is burst into the core in blocks of 64, with the first data value being accompanied by PixStrb signal. The core accepts 8-bit input signal and produces an 11-bit DCT output. The blocks shown in the schematic are detailed in the following sections.

### STAGE 1

This processing stage comprises a multiplier-accumulator unit as well as a Cosine lookup table for respective DCT computations. The input to this stage is the data PixIn from the I/O port. The output from this processing stage is rounded to 15-bits to provide the desired computational accuracy and passed onto the transpose memory.

### STAGE 2

This processing stage comprises a multiplier-accumulator unit as well as a Cosine lookup tables for respective DCT computations. The input to this stage is the data stored in the Transpose Memory by stage 1. This stage, similar to stage1, performs a 1-D DCT and provides the final 11-bit output at DCT port.

### TRANPOSE MEMORY

This 64x15 dual-port RAM stores intermediate results after first stage of processing. The data is written into the memory in a row-major order and read from it in a column-major order, which is effectively a transposition. Along with the transposition of data, it provides input to the processing stage for the second stage of DCT processing.

### ALGORITHM

The core implements the 2-D DCT as two one-dimensional operations as defined by the following equation. The results from the first stage are stored in the transpose memory.

$$S(u) = \frac{C(u)}{2} \sum_{x=0}^7 s(x) \cos \left[ \frac{(2x+1)u\pi}{16} \right]$$

where

$$C(u) = \frac{1}{\sqrt{2}} \quad \text{for } u=0$$

$$C(u) = 1 \quad \text{for } u>0$$

$s(x)$  = 1-D sample value

$S(u)$  = 1-D DCT coefficient

### ACCURACY

The Amphion implementation performs the transform in two stages with the first stage results being stored in the Transpose memory. The width of this memory, 15-bit, controls the number of fractional bits stored and hence influences the accuracy of the final result. The other factor that controls the accuracy is the number of fractional bits used when calculating the cosine coefficients which is 14-bit.

### DCT OPERATION

The processing may begin by supplying 8x8 blocks of unsigned binary samples to the PixIn port, with the first sample of the block being coincident with the PixStrb.

On entering the core, the 8-bit data is level shifted. The DCT is performed as two one dimensional DCTs, with the intermediate results being stored in the transpose memory. In this high performance DCT, two processing blocks comprising multipliers and accumulators are used for both the one

dimensional computation stages of 2D-DCT. The output from the first stage is stored in the Transpose Memory and appropriately supplied to the second stage. Once the complete 8x8 block has been processed, the PixRdy signal is asserted to indicate that the core can now read the next block of data. The start of each output block is indicated by the assertion of DctDcOut signal which coincides with the first output sample at the Dct port.

## LATENCY IN THE DESIGN

There is a latency of 75 clock cycles before which the first output sample appears at the output. Consequently, there is a similar latency of 75 clock cycles between the last input data and the last output data. The latency is depicted in the functional timing diagram in Figure 4.

The timing diagram in Figure 4 depicts the activities at various ports for DCT operation. The start of the block is marked by PixStrb pulse which remains active for one clock period. After 75 clock cycles, i.e. system latency, the DctDcOut goes high to mark the start of new output data block at Q port. The processing of two contiguous input blocks can be delayed by delaying the assertion of PixStrb signal. The PixRdy signal, which shows that the core is ready for processing, will remain asserted until the core starts to read new data block. The core will start processing the data when PixStrb is asserted. All input signals are sampled with CLK and all outputs are updated with CLK. Any gaps at the input PixIn are replicated at the output Q port after the latent period. The core is capable of performing consecutive DCT with or without gaps between successive input blocks.

## I/O FUNCTIONAL TIMING DIAGRAMS

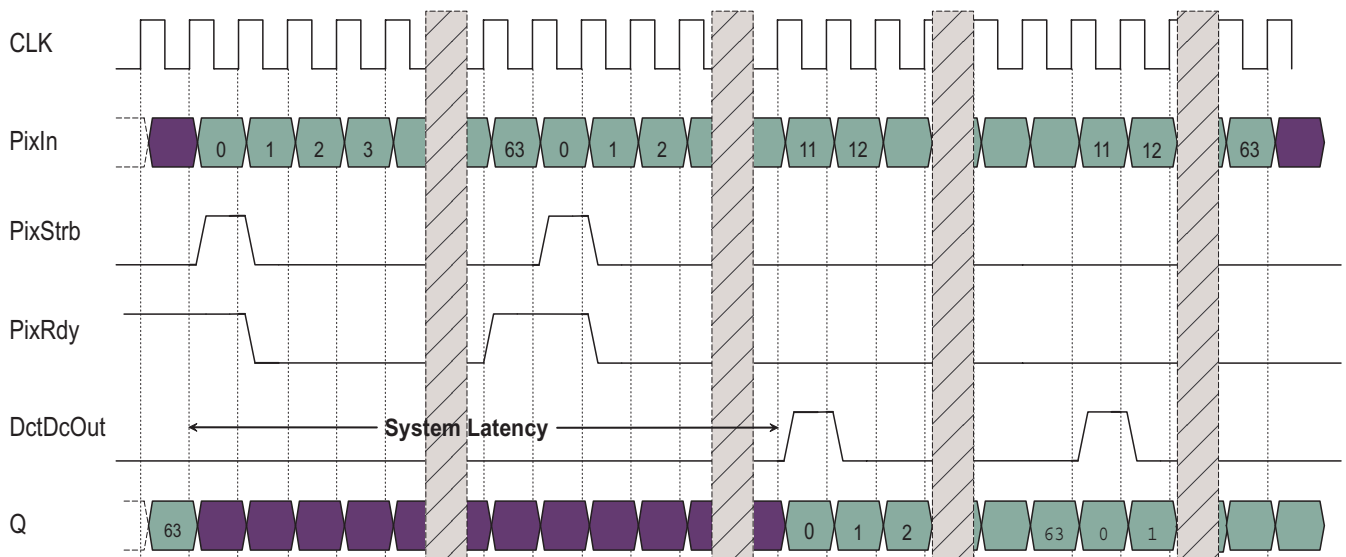


Figure 4: DCT Timing

## AVAILABILITY AND IMPLEMENTATION INFORMATION

### ASIC CORES

For applications that require the high performance, low cost and high integration of an ASIC, Amphion delivers a series of multimedia ASVCs that are pre-optimized by Amphion experts to a targeted silicon technology. Choose from off-the-shelf versions of the CS6300 family available for many popular ASIC and foundry silicon supplier technologies or Amphion can port the CS6300 to a technology of your choice.

**Table 2: CS6310 ASIC Cores**

| PRODUCT ID | SILICON VENDOR | PROCESS TECHNOLOGY                          | PERFORMANCE* | LOGIC GATES** | MEMORY AREA | AVAILABILITY |
|------------|----------------|---|--------------|---------------|-------------|--------------|
| CS6310TK   | TSMC           | 180nm using Artisan standard cell libraries | 217          | 34k           | 1k bits RAM | Now          |

\*Performance figures based on silicon vendor design kit information. ASIC design is pre-layout using vendor-provided statistical wire loading information, under the following condition: ( $T_J = 125^\circ\text{C}$ ,  $V_{CC} -10\%$ )

\*\*Logic gates do not include clock circuitry

Consult you local Amphion representative for product specific performance information, current availability of individual products, and lead times on ASIC core porting.

### PROGRAMMABLE LOGIC CORES

For ASIC prototyping or for projects requiring the fast time to market of a programmable logic solution, Amphion provides programmable logic core solutions that offer the silicon-aware performance tuning found in all Amphion products, combined with the rapid design times offered by today's leading programmable logic solutions.

**Table 3: CS6310 Programmable Logic Cores**

| PRODUCT ID | SILICON VENDOR | PROGRAMMABLE LOGIC PRODUCT | PERFORMANCE* (MSAMPLES/SEC) | DEVICE RESOURCES USED (LOGIC) | DEVICE RESOURCES USED (MEMORY) | AVAILABILITY |
|------------|----------------|----------------------------|-----------------------------|-------------------------------|--------------------------------|--------------|
| CS6310AE   | Altera         | Apex 20KE                  | 87                          | 2834 LEs                      | 1 ESB                          | Now          |
| CS6310XE   | Xilinx         | Virtex-E                   | 84                          | 1279 Slices                   | 1 block RAM                    | Now          |

\*Performance represents core only under worst case commercial condition.

Does not include timing effect of external logic and I/O circuitry.

**ABOUT AMPHION**

Amphion (formerly Integrated Silicon Systems) is the leading supplier of speech coding, video/image processing and channel coding application specific silicon cores for system-on-a-chip (SoC) solutions in the broadband, wireless, and multimedia markets

**Web:** [www.amphion.com](http://www.amphion.com)

**Email:** [info@amphion.com](mailto:info@amphion.com)

**CORPORATE HEADQUARTERS**

Amphion Semiconductor Ltd  
50 Malone Road  
Belfast BT9 5BS  
Northern Ireland, UK

Tel: +44.28.9050.4000

Fax: +44.28.9050.4001

**EUROPEAN SALES**

Amphion Semiconductor Ltd  
CBXII, West Wing  
382-390 Midsummer Boulevard  
Central Milton Keynes  
MK9 2RG England, UK

Tel: +44 1908 847109

Fax: +44 1908 847580

**WORLDWIDE SALES & MARKETING**

Amphion Semiconductor, Inc  
2001 Gateway Place, Suite 130W  
San Jose, CA 95110

Tel: (408) 441 1248

Fax: (408) 441 1239

**CANADA & EAST COAST US SALES**

Amphion Semiconductor, Inc  
Montreal  
Quebec  
Canada

Tel: (450) 455 5544

Fax: (450) 455 5543

---

**SALES AGENTS****Voyageur Technical Sales Inc**

1 Rue Holiday  
Tour Est, Suite 501  
Point Claire, Quebec  
Canada H9R 5N3

Tel: (905) 672 0361

Fax: (905) 677 4986

**Phoenix Technologies Ltd**

3 Gavish Street  
Kfar-Saba, 44424  
Israel

Tel: +972 9 7644 800

Fax: +972 9 7644 801

**SPINNAKER SYSTEMS INC**

Hatchobori SF Bldg. 5F 3-12-8  
Hatchobori, Chuo-ku  
Tokyo 104-0033 Japan

Tel: +81 3 3551 2275

Fax: +81 3 3351 2614

**JASONTECH, INC**

Hansang Building, Suite 300  
Bangyidong 181-3, Songpaku  
Seoul Korea 138-050

Tel: +82 2 420 6700

Fax: +82 2 420 8600

**SPS-DA PTE LTD**

21 Science Park Rd  
#03-19 The Aquarius  
Singapore Science Park II  
Singapore 117628

Tel: +65 774 9070

Fax: +65 774 9071