Application Report

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OMAP5910 Video Encoding and Decoding

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ABSTRACT

In general, video encoding and decoding on the OMAP5910 consist of three phases. The first phase is video pre-processing where the data captured needs to be converted to the encoder input format, second phase is doing the actual video encoding and decoding, and third stage is video post-processing where the decoded data is converted to the LCD input format. This document demonstrates the video encoding and decoding capabilities of the OMAP5910 and provides some video benchmarks running on the C55x DSP.

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1 Introduction

This application note is intended to show an implementation example of the wireless video codec (encoder and decoder) that includes pre-processing of the captured data to interface with the encoder and post-processing of the data to interface with the LCD panel. The video codec is compliant with the low bit rate codec for multimedia telephony defined by the Third Generation Partnership Project (3GPP) in the specifications, 3G TS 26.110, 3G TS26.111 and Recommendation 3G TR 26.911.

The baseline CODEC defined by 3GPP is H.263 and MPEG-4 Simple Visual Profile is defined as an optional. The video codec implemented supports the following video formats.

- SQCIF or 128 x 96 resolution
- QCIF or 176 x 144 resolution at Simple Profile Level 1
- CIF or 352 x 288 resolution at Simple Profile Level 2
- 64 kbits/s for Simple Profile Level 1
- 128 kbits/s for Simple Profile Level 2

2 Video CODEC Description

The video encoder implemented requires a YUV 4:2:0 non-interface video input and, therefore, pre-processing of the video input may be required depending on the application. For the video decoder, post-processing is needed to convert the decoded YUV 4:2:0 data to RGB for displaying.

2.1 Features

- Pre-processing:
  - YUV 4:2:2 interlaced (from camera for example) to YUV 4:2:0 non-interlaced, only decimation and no filtering of the UV components.
- Post-processing:
  - YUV 4:2:0 to RGB conversion
  - Display formats of 16 bits or 12 bits RGB
  - 0 to 90 degrees rotation for landscape and portrait displays
- MPEG-4 Simple Profile Level 0, Level 1 and Level 2 support
- H.263 and MPEG-4 decoder and encoder compliant
- MPEG-4 video decoder options are:
  - AC/DC prediction
  - Reversible Variable Length Coding (RVLC)
  - Resynchronization Marker (RM)
  - Data Partitioning (DP)
  - Error concealment, proprietary techniques

  - 4 Motion Vectors per Macroblock (4MV)
  - Unrestricted Motion Compensation
  - Decode VOS layers
- MPEG-4 video encoder options are:
  - Reversible Variable Length Coding (RVLC)
  - Resynchronization Marker (RM)
  - Data Partitioning (DP)
  - 4 Motion Vectors per Macroblock (4MV)
  - Header Extension Codes
  - Bit rate target change during encoding
  - Coding frame rate change during encoding
  - Insertion or not of Visual Object Sequence start code
- Insertion of I-frame during the encoding of a sequence support
- Encoder Adaptive Intra Refresh (AIR) support
- Multi-codec support, multiple codecs running from the same code

2.2 Video Architecture

2.2.1 Pixel Representation

Red, Green and Blue or RGB are the primary colors for the computer display and the color depth supported by the OMAP5910 is programmable up to 16 bits per pixel, RGB565 (5 bits for Red, 6 bits for Green and 5 bits for Blue).

In the consumer video such as DVD, camera, digital TV and others, the common color coding scheme is YCbCr where Y is the luminance, Cb is the blue chrominance and Cr is the red chrominance. Human eyes are much more sensitive to the Y component of the video and this enables video sub-sampling to reduce the chrominance component without being detected by the human eyes. This method is referred to as YCbCr 4:2:0, YCbCr 4:2:2 or YCbCr 4:4:4. Figure 1 shows the sub-sampling techniques applied to the video.

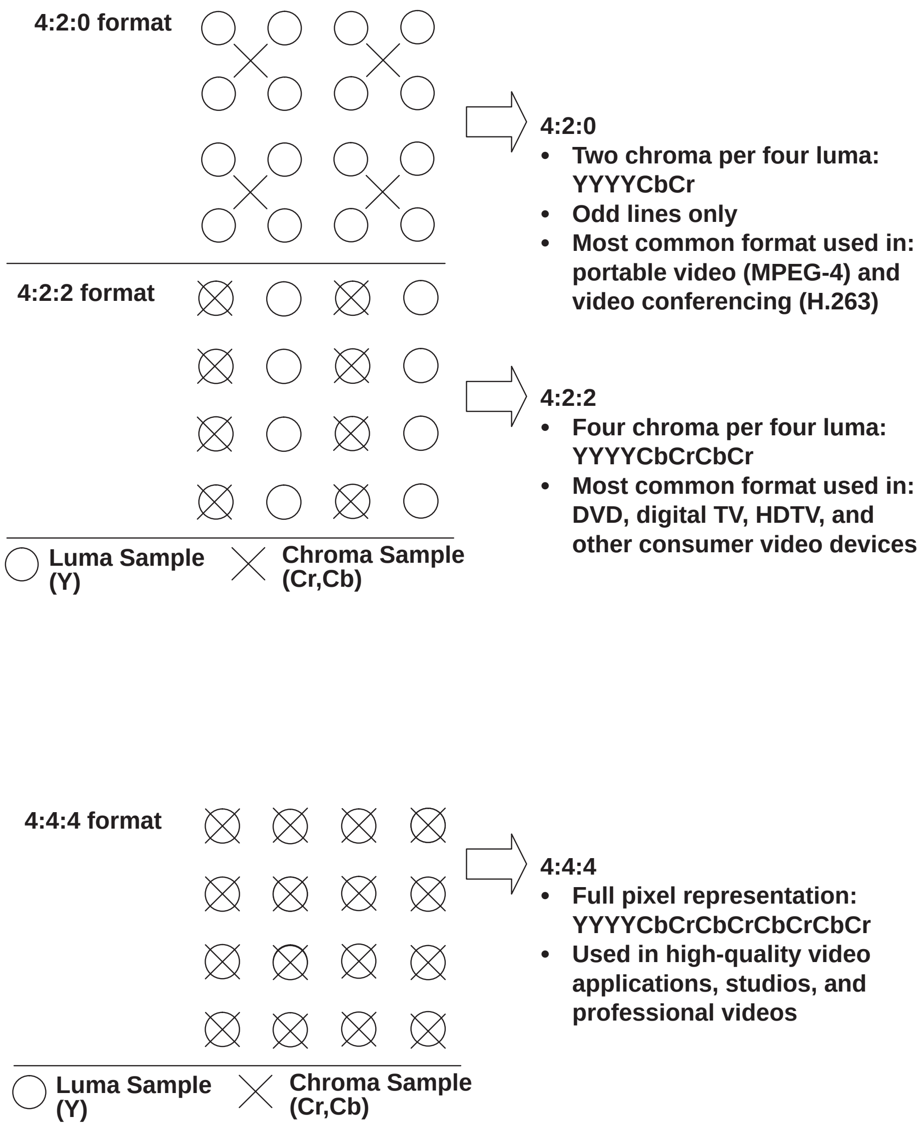

Figure 1. Chroma Sub-Sampling

In the OMAP5910 design, for the decoded video to be displayed, post-processing is needed to calculate the RGB values equivalent of the YCbCr data. The post-processing engine computes the following equations to obtain the gamma-corrected RGB information.

- $R = Y + 1.371(Cr - 128)$
- $G = Y - 0.698(Cr - 128) - 0.336(Cb - 128)$
- $B = Y + 1.732(Cb - 128)$

Refer to the NDA only specification of the test code implemented to demonstrate the pre-processing and post-processing for MPEG-4 encoder and decoder.

2.2.2 Video Encoder

Figure 2 shows a simplified block diagram of the video encoder ported to the OMAP5910. See Table 1 for a brief description of the individual block.

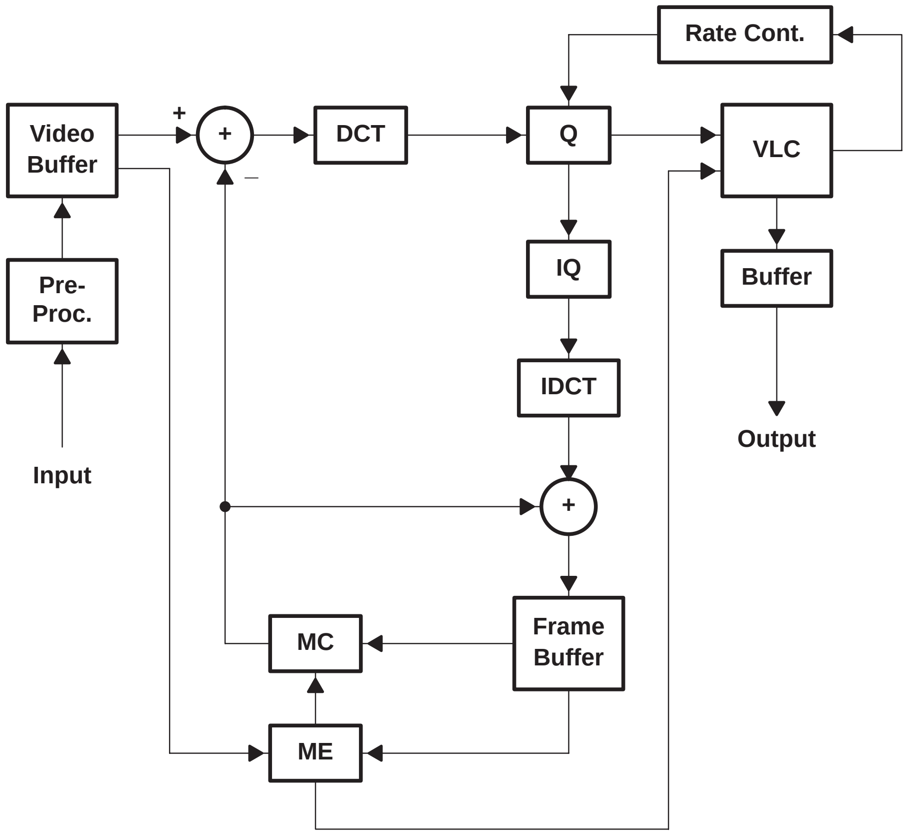

Figure 2. MPEG-4 Video Encoder

Table 1. Video Encoder Description

Block Name	Block Description	Block Function
Pre-Proc.	Pre-Processing	If necessary, the Pre-Proc. Block converts the input video format to YUV 4:2:0.
Video Buffer	Video Buffer	Encoder stores the compressed data for processing.
DCT	Discrete Cosine Transform	DCT transformation decomposes each input block into a series of waveforms with a specific spatial frequency. Outputs an 8x8 block of horizontal and vertical frequency coefficients.
Q	Quantization	Quantization block uses the psychovisual characteristics to eliminate the unimportant DCT coefficients, high frequency coefficients.
IQ	Inverse Quantization	IQ computes the inverse quantization matrix by multiplying the quantized DCT with the quantization table.
IDCT	Inverse Discrete Cosine Transform	IDCT computes the original input block. Errors are expected due to quantization.
Frame Buffer	Frame Buffer	Memory required for video processing, typically 3 frames stored.
ME	Motion Estimation	ME uses a scheme with fewer search locations and fewer pixels to generate motion vectors indicating the directions of the moving images.
MC	Motion Compensation	MC block increases the compression ratio by removing the redundancies between frames.
VLC	Variable Length Coding	Lossless VLC coding reduces the bit rate by sending shorter codes for common pairs (number of zeros and number of non-zeros) and longer codes for less common pairs.
Rate Cont.	Rate Control	Control the bit rate by changing the quantization rules, for example using fewer bits per DCT coefficient.
Buffer	Buffer	Output data buffer

Refer to the NDA only specification of the MPEG-4/H.263 encoder code example implemented by TI to demonstrate the video capabilities of the OMAP5910.

2.2.3 Video Decoder

The video decoder shown in Figure 3 is MPEG-4 and H.263 compliant. The decoder is capable of decoding both H.263 and MPEG-4 bitstreams and is automatically detecting the header to determine which decoding method (H.263 or MPEG-4) to use. The shaded blocks are common for both decoders. See Table 2 for a brief description of the individual block.

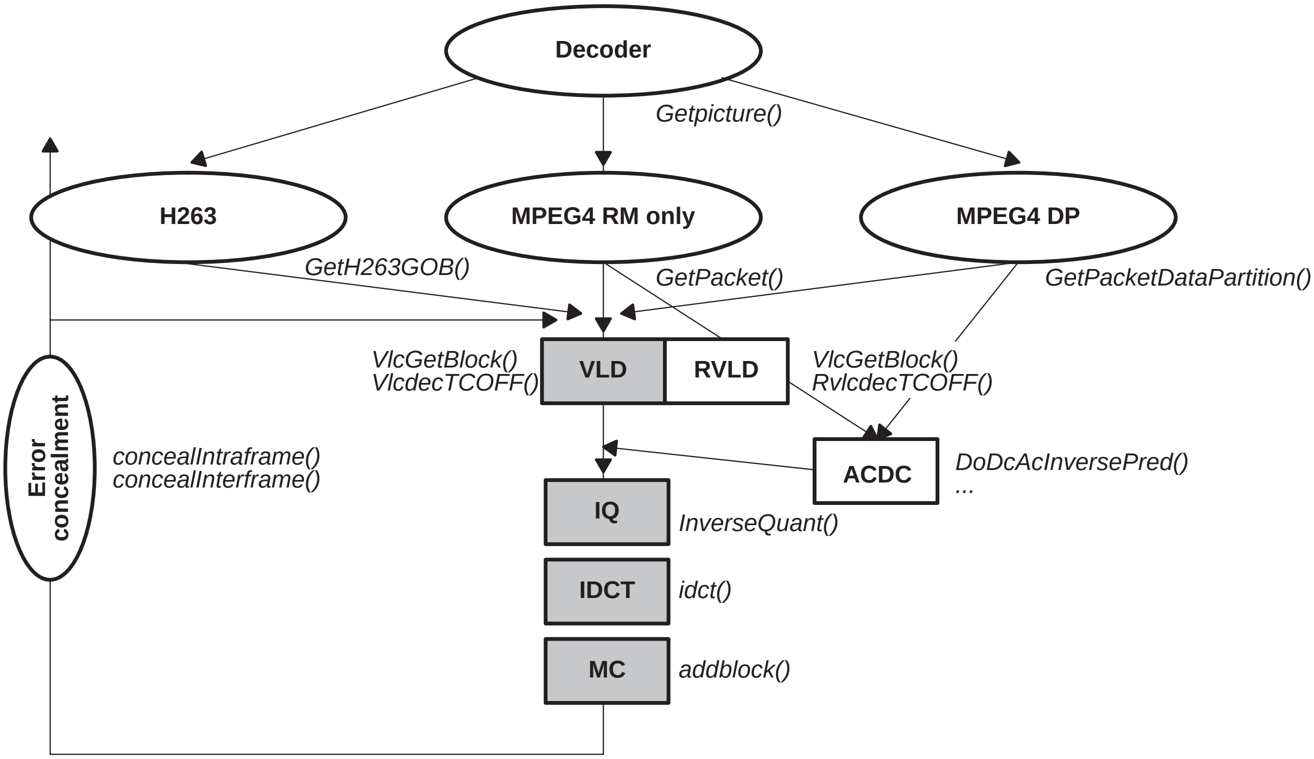

Figure 3. MPEG-4 and H.263 Decoder Architecture

Table 2. Video Decoder Description

Block Name	Block Description	Block Function
Decoder	Decoder	Determines the bitstream (MPEG-4 or H.263)
H263	H.263	Gets the H.263 stream and inputs it to the appropriate module.
MPEG4 RM Only	MPEG-4 Resynchronization Marker Only	Video stream with synchronization marker embedded.
MPEG4 DP	MPEG-4 Data Partitioning	Video stream with data partitioned
ACDC	AC and DC Coefficients of the DCT table	For MPEG-4 decoder only, predicts the AC coefficients.
RVLD	Reversible Variable Length Decoding	For MPEG-4 decoder only, allows for RVLD when the bitstream is coded using Reversible Variable Length techniques.
VLD	Variable Length Decode	For both H.263 and MPEG-4 decoders,
IQ	Inverse Quantization	IQ computes the inverse quantization matrix by multiplying the quantized DCT with the quantization table.
IDCT	Inverse Discrete Cosine Transform	IDCT computes the original input block. Errors are expected due to quantization.
MC	Motion Compensation	MC block increases the compression ratio by removing the redundancies between frames.
Error Concealment	Error Concealment	Proprietary error concealment techniques developed by TI.

Refer to the NDA only specification of the MPEG-4/H.263 decoder code example implemented by TI to demonstrate the video capabilities of the OMAP5910.

3 Video Encoder and Decoder Test Results

The decoder tests were conducted using the following sequences.

- Akiyo
- Claire
- Foreman
- Mother and Daughter
- Carphone

The performance was measured on the OMAP5910 using Code Composer Studio 2.1 profiling tools. The performance data does not include the latency associated with memory-to-memory transfer.

The encoder tests were conducted using the following sequences.

- Akiyo
- Foreman
- Coastguard

The performance was measured on the C5510 using Code Composer Studio 2.0 profiling tools. The results do include the memory-to-memory transfer in the encoder test case.

Table 3. Video Encoder and Decoder Benchmarks

Video Format	Video Encoder	Video Decoder
H.263 / QCIF @ 15 fps @ 64 kbps	23 Mcycles/s (test on C5510)	9.6 Mcycles/s (test on OMAP5910)
H.263 / QCIF @ 15 fps @ 64 kbps (includes DMA overhead)		12.9 Mcycles/s (test on OMAP5910)
QCIF @ 30 fps (MPEG-4 SP @ Level 1)	46 Mcycles/s (test on C5510)	24 Mcycles/s (test on C5510)
CIF @ 30 fps (MPEG-4 SP @ Level 3)		96 Mcycles/s (test on C5510)

4 Conclusions

This application note demonstrates the video encoding and decoding capabilities of the OMAP5910. The codec code examples used to profile the system and detailed CODEC specifications are proprietary information to TI and are only available to OMAP customers under non-disclosure agreement (NDA). Since OMAP5910 consists of ARM925 general-purpose processor and the C55x DSP, some of the benchmarks tested on the C5510 DSP should be similar when running the same tests on the OMAP5910 platform.

5 References

1. *OMAP5910 Dual-Core Processor Data Manual* (SPRS197)
2. *OMAP5910 Dual-Core Processor Functional and Peripheral Overview Reference Guide* (SPRU602)
3. *OMAP Algorithm: Wireless Video CODEC Implementation on C55xx,* TI internal proprietary document, Version 7.3, October 2003.
4. *Image Pre-Processing & Post-Processing Libraries*, TI internal proprietary document OMAP3A019, Version 0.1, December 2001.

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