Space Dynamics LABORATORY
Utah State University Research Foundation

JPEG 2000 Demonstration Board

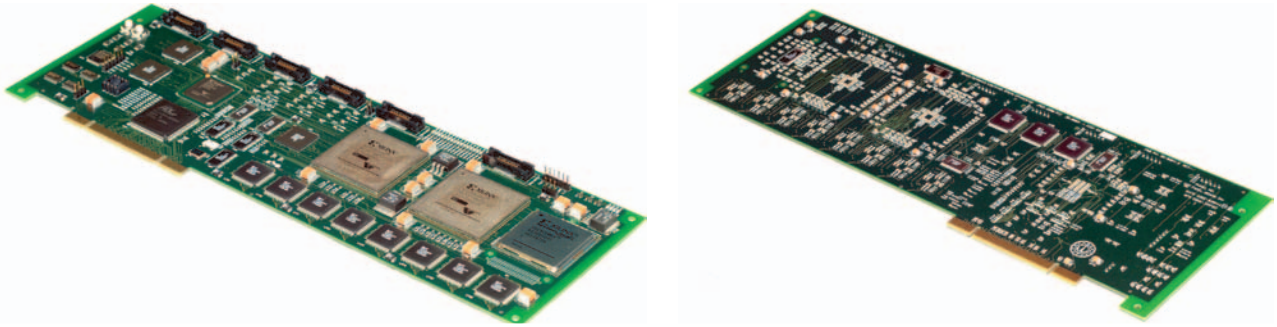
A Hardware Solution to Demonstrate JPEG 2000 Compression Technology

The Space Dynamics Laboratory (SDL), through its research and development programs, has designed and built a hardware-based JPEG 2000 image compression solution to demonstrate JPEG 2000 compression technology that could be used in air and spacecraft applications. This board implements the JPEG 2000 standard algorithm in field-programmable gate arrays (FPGAs).

The SDL JPEG 2000 demonstration board utilizes the Amphion Semiconductor Tier 1 Hardware Description Language (HDL) core as well as an SDL-developed Tier 2 HDL core to enhance the compression process. While this demonstration board is PC compatible through the implementation of a PCI interface, to allow the hardware to be usable across multiple platforms, SDL designed the HDL code for the Tier 1 and Tier 2 FPGAs to be host bus independent. This system will output a JPEG 2000 byte stream for 8-bit and 12-bit grayscale images.

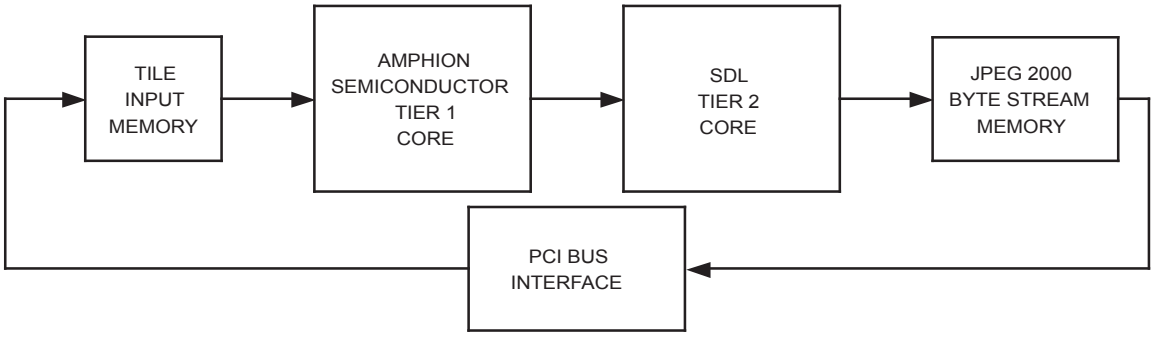
SDL can provide JPEG 2000 board level solutions as well as firmware solutions for compatible systems.

SDL Hardware JPEG 2000 Demonstration Card Front and Back Views



Compression Process

A raw image is loaded into the input memory over the PCI bus. This image is then compressed using SDL's JPEG 2000 compression process (independent of the PCI bus) and a JPEG 2000 file is read from the output memory over the PCI bus.



SDL Hardware JPEG 2000 Solution Image Compression Flow

The output byte stream contains a main header, compressed tiles in sequential order, and an end-of-codestream marker. Each compressed tile consists of a tile header and code block packets, and each code block packet has an encoded packet header.

Image compression is based on either output bit rate control (BRC) or output image quality (IQ). If BRC is selected, the Tier2 compression process compresses the image with a minimum amount of distortion for the amount of data available for the output byte stream (i.e., the amount of data generated will remain relatively constant and the image quality may fluctuate depending on the complexity of the image). If IQ compression is selected, the size of the output byte stream will be sized to achieve the desired image quality (i.e., the image quality will remain relatively constant and the amount of data generated may fluctuate depending on the complexity of the image).

Images can be compressed in the lossless mode (using the 5/3 wavelet) or compressed in a lossy mode (using the 9/7 or 5/3 wavelet). An additional feature of the compression process is the ability to increase the quality of specific areas of the image by enhancing individual tiles.

The JPEG 2000-generated byte stream can be further manipulated in software for continued compression, byte stream recode, or compressed tile usage.

Post-Hardware Compression

The output byte stream can be configured for continued compression without going through an intermediate decompression. This is useful in cases where the output byte stream was generated for a low compression ratio and more compression is desired later for archiving, transmission, or presentation.

Byte Stream Recode

The tile-by-tile byte stream output format can be recoded so packets from the compressed tiles can be placed in different parts of the file. This recoding results in a different type of transmission error resilience than the sequential tile-by-tile format.

Compressed Tile Usage

Compressed tiles from several images can be placed together in another compressed image to display information from multiple images. This new image can be formed without putting the compressed tiles from the original images through an intermediate decompression process.

Current JPEG 2000 Specifications

Property	Specification
Image Size[1]	256 pixels x 256 pixels to 1024 pixels x 2048 pixels
Bit Depth	8 and 12 grayscale
Wavelet Type	5/3 and 9/7
Compression Criteria	Bit Rate Control and Image Quality
Throughput[2]	10 Mpixels per second, 8 bit 1K x 2K image

[1] Larger images can be realized by either performing multiple passes with the same board (resulting in a reduced overall frame rate) or by implementing multiple boards, each compressing a section of the image.

[2] Throughput can be increased by paralleling the Tier 1 and/or the Tier 2 processes.

Continued development and testing will likely result in enhanced capabilities.

Continuing Efforts

JP2 Byte Stream

Effort is underway to add the JP2 header boxes to the byte stream. This will give the option of having a JP2 byte stream or an unwrapped J2K byte stream. This upgrade will include the required boxes as given in part 1 of the JPEG 2000 standard. Optional boxes can be added for systems that have this requirement.

Byte Stream Reorder

Effort is underway to create an option of outputting a tile-part byte stream from the card so all of the first tile packets are output first, followed by all of the second tile packets, and then finally the third and the fourth. This reordering results in a transmission error resilience different from that of the tile-by-tile byte stream output.

Smaller Board Design

SDL expects to reduce the size of the JPEG 2000 board to approximately 4.0 x 4.5 in. with capabilities equal to or greater than the prototype board. Depending on image size, throughput requirements and choice of FPGAs, the new design could be even smaller.

Three-Dimensional Wavelets

SDL will use the demonstration card for hardware studies of three-dimensional wavelets. This process can be used to increase compression ratios for hyperspectral imagery.

SDL's IS&R Heritage

SDL has a long history of building hardware image compression systems. SDL has developed and implemented several hardware image compression systems using standard compression algorithms, such as JPEG, as well as systems based on SDL/Utah State University (USU) proprietary algorithms. These systems have been fielded in ground stations, such as the Tactical Input Segment (TIS), and aboard both aircraft [Shared Reconnaissance Pod (SHARP) and Tactical Airborne Reconnaissance Pod System (TARPS)] and orbital spacecraft [Midcourse Space Experiment (MSX)].

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