UG0952
User Guide
PolarFire JPEG IP

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1 Revision History

The revision history describes the changes that were implemented in the document. The changes are listed by revision, starting with the most current publication.

1.1 Revision 1.0

The first publication of this document.

2 Introduction

JPEG is a commonly used method for image compression. JPEG is an intraframe compression method where each video frame is compressed by using the data of the same frame. The compression does not depend on past or future frames. The video frame is divided into multiple 8x8 blocks, which are called Macroblocks. A 2-dimensional Discrete Cosine Transform (DCT) is applied to each macroblock. The output of DCT represents frequency components in the horizontal and vertical directions. The DCT output is quantized using a quantization table that makes insignificant high-frequency components to zero, thereby reducing the number of bytes required to represent an 8x8 macroblock. The number of non-zero bytes in the quantization output depends on the high-frequency components in the image as well as on the quality factor (Q factor) used to generate the quantization table. The degree of compression can be adjusted by the Q factor allowing a trade-off between size and image quality.

The output of quantization is passed through Huffman encoding, which reduces the number of bits used to represent the components of quantization output. A typical compression ratio of 20:1 can be achieved at a 50% Q factor. This user guide describes the JPEG encoder that encodes camera data given as input to JPEG IP in 4:4:4(YCbCr) format in 8-bits per pixel mode. IP can provide compressed data for the selected quality factor (Quantization tables are programmable).

JPEG IP can include JPEG Header and Tables used for compression along with compressed data based on the input signal.

2.1 Key Features

- Samples input in 4:4:4 YCbCr format
- Implements compression in 4:2:2 or 4:4:4 format
- Support 8-bits for each component (Y, Cb, and Cr)
- Includes or skips JPEG Header and Tables from the compressed data as per user selection
- Supports Programmable Quantization tables

2.2 Supported Families

- PolarFire® SoC
- PolarFire®

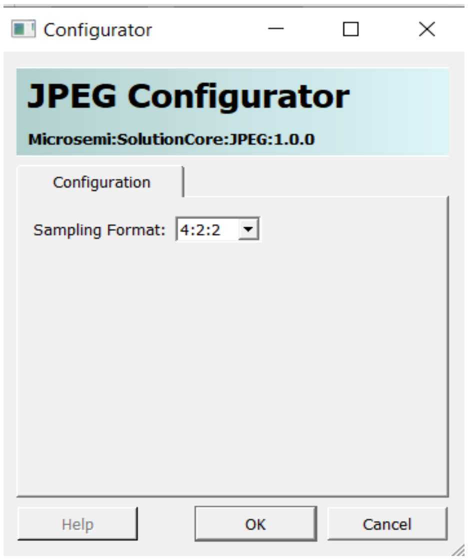
2.3 JPEG IP Configuration

JPEG IP can be configured in 4:4:4 or 4:2:2 mode. It supports an 8-bit width for each component of Y, Cb, and Cr.

2.3.1 Change of Sampling format

The JPEG Configurator is shown in the following figure.

Figure 1 • **JPEG Configurator in Compile Time Mode**

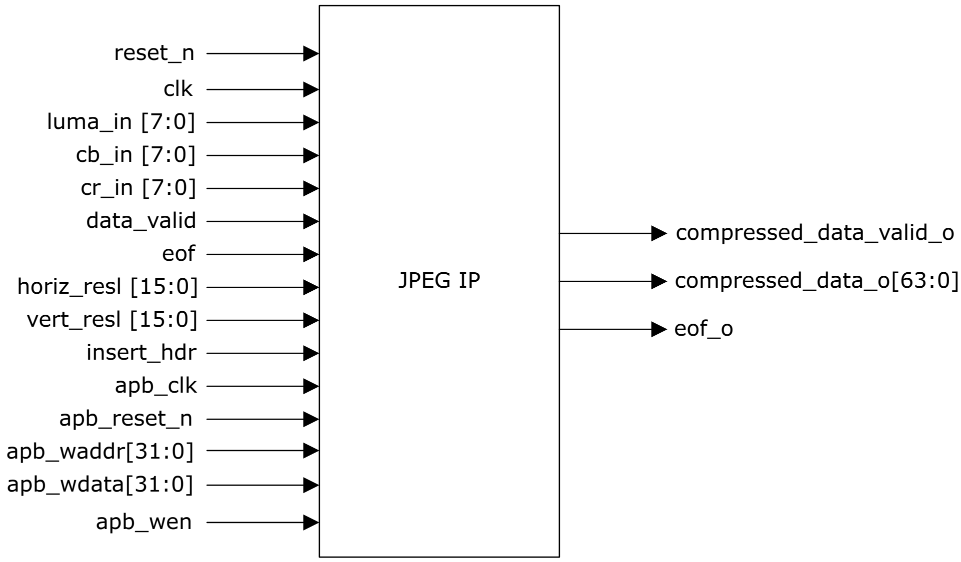


At compile time, the user can select the Sampling format.

3 Hardware Implementation

The JPEG IP block diagram is shown in the following figure.

Figure 2 • **JPEG IP Block Diagram**



3.1 Inputs and Outputs

Table 1 • **Input and Output Ports of JPEG Encoder IP**

Signal Name	Direction	Width	Port Valid under	Description
reset_n	Input	1		Active Low Asynchronous reset signal to design
clk	Input	1		Input clock with which incoming pixels are sampled
luma_in	Input	8		8-bit Luma (Y) input
cb_in	Input	8		8-bit Chroma (Cb) input
cr_in	Input	8		8-bit Chroma (Cr) input
data_valid	Input	1		Input Pixel data valid signal
eof	Input	1		End of Frame indication
horiz_resl	Input	[15:0]		Horizontal resolution of input image
vert_resl	Input	[15:0]		Vertical resolution of input image
insert_hdr	Input	1		Signal to enable adding JPEG Header and Tables in compressed data. 1 - Enable Adding JPEG Header and Tables 0 - Disable Adding JPEG Header and Tables
apb_wen	Input	1		APB Interface write enable signal
apb_waddr	Input	[31:0]		APB Interface write address signal
apb_wdata	Input	[31:0]		APB Interface write data signal
apb_clk	Input	1		APB Interface clock. All APB interface signals are synchronous to this clock
apb_reset_n	Input	1		APB Interface reset signal. This reset is synchronous to apb_clk
compressed_data_valid_o	Output	1		Signal indicating valid compressed data on the compressed_data_o bus
compressed_data_o	Output	[63:0]		Compressed data
eof_o	Output	1		End of frame indication on output side

3.2 Configuration Parameters

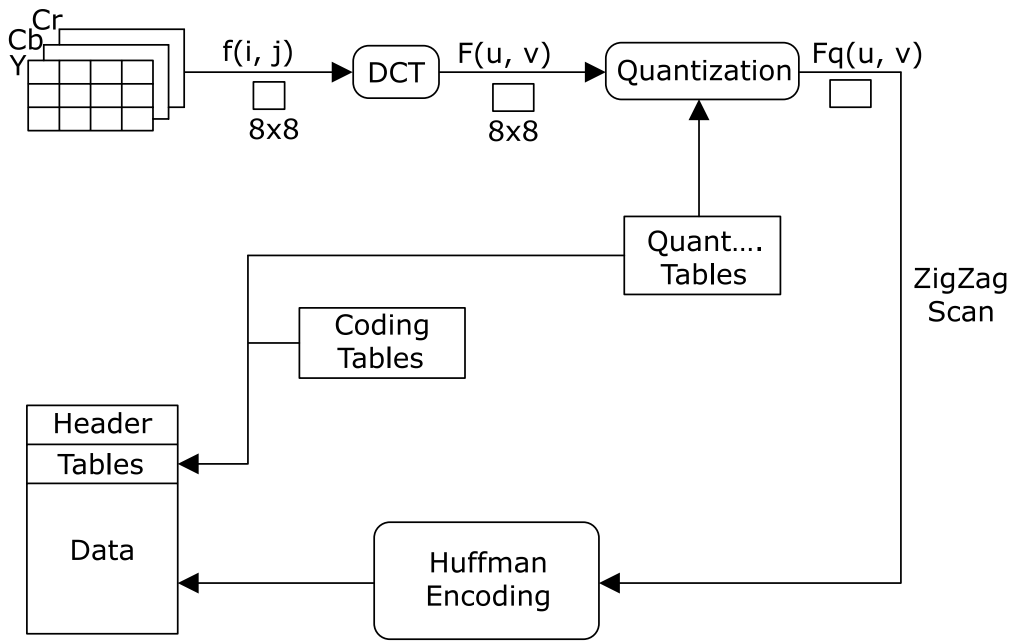
Table 2 • **Configuration Parameters**

Parameter Name	Configurator Prompt	Parameter Valid under	Description
g_SAMPLING_FORMAT	Sampling Format	Compile Time	Compressed data format for the output data. It support 4:4:4 or 4:2:2 formats on the compressed data. 0: Compressed data output in 4:4:4 format 1: Compressed data output in 4:2:2 format

3.3 Hardware Implementation of JPEG Encoder IP

The JPEG Encoder IP block diagram is shown in the following figure.

Figure 3 • **JPEG Encoder IP Block Diagram**



3.3.1 Design Description for JPEG IP

This section describes the different internal modules of the JPEG compression IP. Data input to the JPEG IP should be in the form of 8x8 blocks in YCbCr format.

3.3.1.1 DCT

This module processes the incoming data based on the selected Data format (4:4:4 or 4:2:2).

As a first step in computing the DCT of the 8×8 block, its values are shifted from a positive range to one centered on zero. For an 8-bit image, each entry in the original block falls in the range [0 255]. The midpoint of the range (in this case, value 128) is subtracted from each entry to produce a data range that is centered on zero, so that the modified range is [-128 127]. Every 8x8 block of each component (Y, Cb, Cr) is converted to a frequency domain representation, using a normalized, two-dimensional type-II DCT.

3.3.1.2 Quantization

The human eye is good at seeing small differences in brightness over a relatively large area but not so good at distinguishing the exact strength of a high-frequency brightness variation. This allows one to reduce the amount of information in the high-frequency components. This is done by dividing each component in the frequency domain by a constant for that component and then rounding to the nearest integer. This rounding operation is the only lossy operation in the whole process (other than chroma subsampling) if the DCT computation is performed with sufficiently high precision. As a result of this, it is typically the case that many of the higher frequency components are rounded to zero, and many of the rest become small positive or negative numbers, which take many fewer bits to represent.

Default Quantization table that is valid for Quality value of 50.

Luma Table

Default Luma Table[0 - 63] -

[16 11 10 16 24 40 51 61 12 12 14 19 26 58 60 55 14 13 16 24 40 57 69 56 14 17 22 29 51 87 80 62 18 24 37 56 68 109 103 77 24 35 55 64 81 104 113 92 49 64 78 87 103 121 120 101 72 92 95 98 112 100 103 99]

Chroma Table

Default Chroma Table[0 - 63] -

[17 18 23 47 99 99 99 99 18 21 26 66 99 99 99 99 24 26 56 99 99 99 99 99 47 66 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99]

Quant value for Luma and Chroma to be calculated with following equation for 0 to 63 :

If Quality value is < 50 then use the following equation:

```
quant_luma[i] = ((5000/Quality Value)*Default Luma Table[i]+50)/100

quant_chroma[i] = ((5000/Quality Value)*Default Chroma Table[i]+50)/100
```

If Quality value is >= 50 then use the following equation:

```
quant_luma[i] = 0.5+(((200 - 2*Quality Value)*Default Luma Table[i]+50)/100)

quant_chroma[i] = 0.5+(((200 - 2*Quality Value)*Default Chroma
Table[i]+50)/100)
```

IQuant value for Luma and Chroma to be calculated with following equation for 0 to 63:

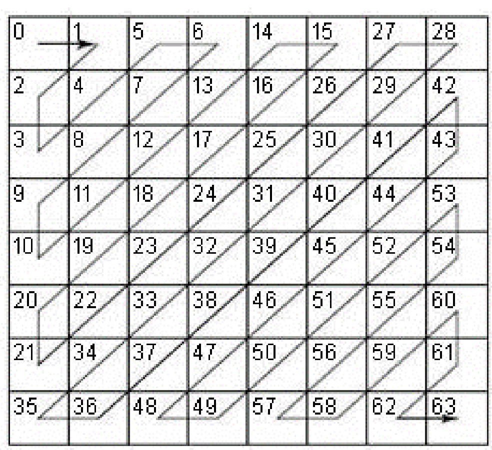
```
IQuant value for Luma :

iquant_luma[i] = 0.5+(4096/quant_luma[i]) ;

IQuant value for Chroma :

iquant_chroma[i] = 0.5+(4096/quant_chroma[i])
```

Note: Iquant = Inverse Quant

3.3.1.3 Zigzag Scan

Zigzag scanning is used to group low-frequency coefficients of the 8x8 quantized block to the top level of the vector and the high coefficient to the bottom. This is likely to result in the large number of zeros of the quantized matrix get grouped towards the end of the block. These large number of zeros at the end of the block can be encoded for better compression. Zigzag scan order is shown in the following figure.

Figure 4 • **ZigZag Scan**



3.3.1.4 Huffman Coding

Separate Huffman tables are used for DC and AC components of Luma and Chroma samples. Standard Huffman tables are used for encoding.

3.3.1.5 Data packing

This module is used to generate compressed data that is driven by the output. Based on insert_hdr input, Header and Table data will be inserted at the start of the compressed data.

4 Register Table

Table 3 • **Register Table**

Address[12:0]	Data width	Description
0x0	12	Inverse quant table value for Luma [0]
0x4	12	Inverse quant table value for Luma [1]
0x8	12	Inverse quant table value for Luma [2]
0xc	12	Inverse quant table value for Luma [3]
0x10	12	Inverse quant table value for Luma [4]
0x14	12	Inverse quant table value for Luma [5]
0x18	12	Inverse quant table value for Luma [6]
0x1c	12	Inverse quant table value for Luma [7]
0x20	12	Inverse quant table value for Luma [8]
0x24	12	Inverse quant table value for Luma [9]
0x28	12	Inverse quant table value for Luma [10]
0x2c	12	Inverse quant table value for Luma [11]
0x30	12	Inverse quant table value for Luma [12]
0x34	12	Inverse quant table value for Luma [13]
0x38	12	Inverse quant table value for Luma [14]
0x3c	12	Inverse quant table value for Luma [15]
0x40	12	Inverse quant table value for Luma [16]
0x44	12	Inverse quant table value for Luma [17]
0x48	12	Inverse quant table value for Luma [18]
0x4c	12	Inverse quant table value for Luma [19]
0x50	12	Inverse quant table value for Luma [20]
0x54	12	Inverse quant table value for Luma [21]
0x58	12	Inverse quant table value for Luma [22]
0x5c	12	Inverse quant table value for Luma [23]
0x60	12	Inverse quant table value for Luma [24]
0x64	12	Inverse quant table value for Luma [25]
0x68	12	Inverse quant table value for Luma [26]
0x6c	12	Inverse quant table value for Luma [27]
0x70	12	Inverse quant table value for Luma [28]
0x74	12	Inverse quant table value for Luma [29]
0x78	12	Inverse quant table value for Luma [30]
0x7c	12	Inverse quant table value for Luma [31]
0x80	12	Inverse quant table value for Luma [32]
0x84	12	Inverse quant table value for Luma [33]
0x88	12	Inverse quant table value for Luma [34]

Table 3 • **Register Table *(continued)***

Address[12:0]	Data width	Description
0x8c	12	Inverse quant table value for Luma [35]
0x90	12	Inverse quant table value for Luma [36]
0x94	12	Inverse quant table value for Luma [37]
0x98	12	Inverse quant table value for Luma [38]
0x9c	12	Inverse quant table value for Luma [39]
0xa0	12	Inverse quant table value for Luma [40]
0xa4	12	Inverse quant table value for Luma [41]
0xa8	12	Inverse quant table value for Luma [42]
0xac	12	Inverse quant table value for Luma [43]
0xb0	12	Inverse quant table value for Luma [44]
0xb4	12	Inverse quant table value for Luma [45]
0xb8	12	Inverse quant table value for Luma [46]
0xbc	12	Inverse quant table value for Luma [47]
0xc0	12	Inverse quant table value for Luma [48]
0xc4	12	Inverse quant table value for Luma [49]
0xc8	12	Inverse quant table value for Luma [50]
0xcc	12	Inverse quant table value for Luma [51]
0xd0	12	Inverse quant table value for Luma [52]
0xd4	12	Inverse quant table value for Luma [53]
0xd8	12	Inverse quant table value for Luma [54]
0xdc	12	Inverse quant table value for Luma [55]
0xe0	12	Inverse quant table value for Luma [56]
0xe4	12	Inverse quant table value for Luma [57]
0xe8	12	Inverse quant table value for Luma [58]
0xec	12	Inverse quant table value for Luma [59]
0xf0	12	Inverse quant table value for Luma [60]
0xf4	12	Inverse quant table value for Luma [61]
0xf8	12	Inverse quant table value for Luma [62]
0xfc	12	Inverse quant table value for Luma [63]
0x100	12	Inverse quant table value for Chroma [0]
0x104	12	Inverse quant table value for Chroma [1]
0x108	12	Inverse quant table value for Chroma [2]
0x10c	12	Inverse quant table value for Chroma [3]
0x110	12	Inverse quant table value for Chroma [4]
0x114	12	Inverse quant table value for Chroma [5]
0x118	12	Inverse quant table value for Chroma [6]
0x11c	12	Inverse quant table value for Chroma [7]
0x120	12	Inverse quant table value for Chroma [8]

Table 3 • **Register Table *(continued)***

Address[12:0]	Data width	Description
0x124	12	Inverse quant table value for Chroma [9]
0x128	12	Inverse quant table value for Chroma [10]
0x12c	12	Inverse quant table value for Chroma [11]
0x130	12	Inverse quant table value for Chroma [12]
0x134	12	Inverse quant table value for Chroma [13]
0x138	12	Inverse quant table value for Chroma [14]
0x13c	12	Inverse quant table value for Chroma [15]
0x140	12	Inverse quant table value for Chroma [16]
0x144	12	Inverse quant table value for Chroma [17]
0x148	12	Inverse quant table value for Chroma [18]
0x14c	12	Inverse quant table value for Chroma [19]
0x150	12	Inverse quant table value for Chroma [20]
0x154	12	Inverse quant table value for Chroma [21]
0x158	12	Inverse quant table value for Chroma [22]
0x15c	12	Inverse quant table value for Chroma [23]
0x160	12	Inverse quant table value for Chroma [24]
0x164	12	Inverse quant table value for Chroma [25]
0x168	12	Inverse quant table value for Chroma [26]
0x16c	12	Inverse quant table value for Chroma [27]
0x170	12	Inverse quant table value for Chroma [28]
0x174	12	Inverse quant table value for Chroma [29]
0x178	12	Inverse quant table value for Chroma [30]
0x17c	12	Inverse quant table value for Chroma [31]
0x180	12	Inverse quant table value for Chroma [32]
0x184	12	Inverse quant table value for Chroma [33]
0x188	12	Inverse quant table value for Chroma [34]
0x18c	12	Inverse quant table value for Chroma [35]
0x190	12	Inverse quant table value for Chroma [36]
0x194	12	Inverse quant table value for Chroma [37]
0x198	12	Inverse quant table value for Chroma [38]
0x19c	12	Inverse quant table value for Chroma [39]
0x1a0	12	Inverse quant table value for Chroma [40]
0x1a4	12	Inverse quant table value for Chroma [41]
0x1a8	12	Inverse quant table value for Chroma [42]
0x1ac	12	Inverse quant table value for Chroma [43]
0x1b0	12	Inverse quant table value for Chroma [44]
0x1b4	12	Inverse quant table value for Chroma [45]
0x1b8	12	Inverse quant table value for Chroma [46]

Table 3 • **Register Table *(continued)***

Address[12:0]	Data width	Description
0x1bc	12	Inverse quant table value for Chroma [47]
0x1c0	12	Inverse quant table value for Chroma [48]
0x1c4	12	Inverse quant table value for Chroma [49]
0x1c8	12	Inverse quant table value for Chroma [50]
0x1cc	12	Inverse quant table value for Chroma [51]
0x1d0	12	Inverse quant table value for Chroma [52]
0x1d4	12	Inverse quant table value for Chroma [53]
0x1d8	12	Inverse quant table value for Chroma [54]
0x1dc	12	Inverse quant table value for Chroma [55]
0x1e0	12	Inverse quant table value for Chroma [56]
0x1e4	12	Inverse quant table value for Chroma [57]
0x1e8	12	Inverse quant table value for Chroma [58]
0x1ec	12	Inverse quant table value for Chroma [59]
0x1f0	12	Inverse quant table value for Chroma [60]
0x1f4	12	Inverse quant table value for Chroma [61]
0x1f8	12	Inverse quant table value for Chroma [62]
0x1fc	12	Inverse quant table value for Chroma [63]
0x200	8	Quant value for Luma [0]
0x204	8	Quant value for Luma [1]
0x208	8	Quant value for Luma [2]
0x20c	8	Quant value for Luma [3]
0x210	8	Quant value for Luma [4]
0x214	8	Quant value for Luma [5]
0x218	8	Quant value for Luma [6]
0x21c	8	Quant value for Luma [7]
0x220	8	Quant value for Luma [8]
0x224	8	Quant value for Luma [9]
0x228	8	Quant value for Luma [10]
0x22c	8	Quant value for Luma [11]
0x230	8	Quant value for Luma [12]
0x234	8	Quant value for Luma [13]
0x238	8	Quant value for Luma [14]
0x23c	8	Quant value for Luma [15]
0x240	8	Quant value for Luma [16]
0x244	8	Quant value for Luma [17]
0x248	8	Quant value for Luma [18]
0x24c	8	Quant value for Luma [19]
0x250	8	Quant value for Luma [20]

Table 3 • **Register Table *(continued)***

Address[12:0]	Data width	Description
0x254	8	Quant value for Luma [21]
0x258	8	Quant value for Luma [22]
0x25c	8	Quant value for Luma [23]
0x260	8	Quant value for Luma [24]
0x264	8	Quant value for Luma [25]
0x268	8	Quant value for Luma [26]
0x26c	8	Quant value for Luma [27]
0x270	8	Quant value for Luma [28]
0x274	8	Quant value for Luma [29]
0x278	8	Quant value for Luma [30]
0x27c	8	Quant value for Luma [31]
0x280	8	Quant value for Luma [32]
0x284	8	Quant value for Luma [33]
0x288	8	Quant value for Luma [34]
0x28c	8	Quant value for Luma [35]
0x290	8	Quant value for Luma [36]
0x294	8	Quant value for Luma [37]
0x298	8	Quant value for Luma [38]
0x29c	8	Quant value for Luma [39]
0x2a0	8	Quant value for Luma [40]
0x2a4	8	Quant value for Luma [41]
0x2a8	8	Quant value for Luma [42]
0x2ac	8	Quant value for Luma [43]
0x2b0	8	Quant value for Luma [44]
0x2b4	8	Quant value for Luma [45]
0x2b8	8	Quant value for Luma [46]
0x2bc	8	Quant value for Luma [47]
0x2c0	8	Quant value for Luma [48]
0x2c4	8	Quant value for Luma [49]
0x2c8	8	Quant value for Luma [50]
0x2cc	8	Quant value for Luma [51]
0x2d0	8	Quant value for Luma [52]
0x2d4	8	Quant value for Luma [53]
0x2d8	8	Quant value for Luma [54]
0x2dc	8	Quant value for Luma [55]
0x2e0	8	Quant value for Luma [56]
0x2e4	8	Quant value for Luma [57]
0x2e8	8	Quant value for Luma [58]

Table 3 • **Register Table *(continued)***

Address[12:0]	Data width	Description
0x2ec	8	Quant value for Luma [59]
0x2f0	8	Quant value for Luma [60]
0x2f4	8	Quant value for Luma [61]
0x2f8	8	Quant value for Luma [62]
0x2fc	8	Quant value for Luma [63]
0x300	8	Quant value for Chroma [0]
0x304	8	Quant value for Chroma [1]
0x308	8	Quant value for Chroma [2]
0x30c	8	Quant value for Chroma [3]
0x310	8	Quant value for Chroma [4]
0x314	8	Quant value for Chroma [5]
0x318	8	Quant value for Chroma [6]
0x31c	8	Quant value for Chroma [7]
0x320	8	Quant value for Chroma [8]
0x324	8	Quant value for Chroma [9]
0x328	8	Quant value for Chroma [10]
0x32c	8	Quant value for Chroma [11]
0x330	8	Quant value for Chroma [12]
0x334	8	Quant value for Chroma [13]
0x338	8	Quant value for Chroma [14]
0x33c	8	Quant value for Chroma [15]
0x340	8	Quant value for Chroma [16]
0x344	8	Quant value for Chroma [17]
0x348	8	Quant value for Chroma [18]
0x34c	8	Quant value for Chroma [19]
0x350	8	Quant value for Chroma [20]
0x354	8	Quant value for Chroma [21]
0x358	8	Quant value for Chroma [22]
0x35c	8	Quant value for Chroma [23]
0x360	8	Quant value for Chroma [24]
0x364	8	Quant value for Chroma [25]
0x368	8	Quant value for Chroma [26]
0x36c	8	Quant value for Chroma [27]
0x370	8	Quant value for Chroma [28]
0x374	8	Quant value for Chroma [29]
0x378	8	Quant value for Chroma [30]
0x37c	8	Quant value for Chroma [31]
0x380	8	Quant value for Chroma [32]

Table 3 • **Register Table *(continued)***

Address[12:0]	Data width	Description
0x384	8	Quant value for Chroma [33]
0x388	8	Quant value for Chroma [34]
0x38c	8	Quant value for Chroma [35]
0x390	8	Quant value for Chroma [36]
0x394	8	Quant value for Chroma [37]
0x398	8	Quant value for Chroma [38]
0x39c	8	Quant value for Chroma [39]
0x3a0	8	Quant value for Chroma [40]
0x3a4	8	Quant value for Chroma [41]
0x3a8	8	Quant value for Chroma [42]
0x3ac	8	Quant value for Chroma [43]
0x3b0	8	Quant value for Chroma [44]
0x3b4	8	Quant value for Chroma [45]
0x3b8	8	Quant value for Chroma [46]
0x3bc	8	Quant value for Chroma [47]
0x3c0	8	Quant value for Chroma [48]
0x3c4	8	Quant value for Chroma [49]
0x3c8	8	Quant value for Chroma [50]
0x3cc	8	Quant value for Chroma [51]
0x3d0	8	Quant value for Chroma [52]
0x3d4	8	Quant value for Chroma [53]
0x3d8	8	Quant value for Chroma [54]
0x3dc	8	Quant value for Chroma [55]
0x3e0	8	Quant value for Chroma [56]
0x3e4	8	Quant value for Chroma [57]
0x3e8	8	Quant value for Chroma [58]
0x3ec	8	Quant value for Chroma [59]
0x3f0	8	Quant value for Chroma [60]
0x3f4	8	Quant value for Chroma [61]
0x3f8	8	Quant value for Chroma [62]
0x3fc	8	Quant value for Chroma [63]

5 License

JPEG IP is provided in encrypted form only under license.

6 Installation Instructions

The core must be installed into Libero software. It is done automatically through the Catalog update function in Libero, or the CPZ file can be manually added using the **Add Core** catalog feature. Once the CPZ file is installed in Libero, the core can be configured, generated, and instantiated within SmartDesign for inclusion in the Libero project.

For further instructions on core installation, licensing, and general use, refer to the *Libero SoC Online Help*.

7 Resource Utilization

The following table shows the resource utilization of a sample JPEG IP design made for PolarFire FPGA (MPF300TS-1FCG1152I package) and generates compressed data by using 4:2:2 sampling of input data.

Table 4 • **Resource Utilization of the JPEG IP that compresses data sampled in 4:2:2 format**

Element	Usage
DFFs	6767
4-input LUTs	9131
LSRAM	67
µSRAM	2
Math Blocks	34