



Gowin MJPEG Decoder IP

User Guide

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Revision History

Date	Version	Description
09/26/2024	1.0E	Initial version published.
09/22/2026	1.0.1E	● Modified the speed grade in Table 2-1 Gowin MJPEG Decoder IP Overview. ● Updated section 1.2 Related Documents.

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1 About This Guide

1.1 Purpose

The purpose of the Gowin MJPEG Decoder IP User Guide is to help users understand the features and operation of the Gowin MJPEG Decoder IP describing the functions, signals, GUI, and reference design.

1.2 Related Documents

The latest user guides are available on the GOWINSEMI website. You can download and view the related documents on www.gowinsemi.com:

- [DS961, GW2ANR series of FPGA Products Data Sheet](#)
- [DS102, GW2A series of FPGA Products Data Sheet](#)
- [DS226, GW2AR series of FPGA Products Data Sheet](#)
- [DS976, GW2AN-55 Data Sheet](#)
- [DS981, GW5AT series of FPGA Products Data Sheet](#)
- [DS1103, GW5A series of FPGA Products Data Sheet](#)
- [DS1239, GW5AST series of FPGA Products Data Sheet](#)
- [DS1105, GW5AS series of FPGA Products Data Sheet](#)
- [DS1108, GW5AR series of FPGA Products Data Sheet](#)
- [DS1118, GW5ART series of FPGA Products Data Sheet](#)
- [SUG100, Gowin Software User Guide](#)

1.3 Terminology and Abbreviations

The terminology and abbreviations used in this manual are as shown in Table 1-1.

Table 1-1 Terminology and Abbreviations

Terminology and Abbreviations	Meaning
ALU	Arithmetic Logical Unit
BSRAM	Block Static Random Access Memory
CSC	Color Space Conversion
IDCT	Inverse Discrete Cosine Transform
LUT	Look-up Table
MJPEG	Motion Joint Photographic Experts Group
SSRAM	Shadow Static Random Access Memory

1.4 Support and Feedback

Gowin Semiconductor provides customers with comprehensive technical support. If you have any questions, comments, or suggestions, please feel free to contact us directly using the information provided below.

Website: www.gowinsemi.com

E-mail: support@gowinsemi.com

2 Overview

Gowin MJPEG Decoder IP is a dynamic image frame-by-frame decoder that can decompress image data compressed according to the Baseline JPEG standard and convert it into RGB format. By decompressing multiple frames of JPEG-standard images, it enables dynamic video output. Due to the varying characteristics of the images and the compression ratios used, the input and output rates are not fixed. Gowin MJPEG Decoder IP is designed to perform frame-by-frame decoding of images compressed using the Baseline JPEG standard while utilizing minimal logic resources.

Table 2-1 Gowin MJPEG Decoder IP Overview

Gowin MJPEG Decoder IP	
Logic Resource	Please refer to Table 3-1
Delivered Doc.	
Design Files	Verilog
Reference Design	Verilog
TestBench	Verilog
Test and Design Flow	
Synthesis Software	GowinSynthesis
Application Software	Gowin Software

Note!

For a list of supported devices, click [here](#).

3 Features and Performance

3.1 Features

- The input image information can be determined dynamically through the JPEG header data, including:
 - Supported image height of 64-1080 pixels
 - Supported image width of 64-1920 pixels
 - Supported dynamic 444, 420, 422 subsampling
 - Supported dynamic De-Huffman Table, with up to 2 DC and 2 AC tables
 - Supported dynamic De Quantization Table
- Supported predefined size (static)
- The input compressed data bit width is 32 bits
- The output image data bit width per channel is 8 bits, i.e., 24 bits for RGB
- The output rate can reach up to 1080P at 30 FPS

3.2 Max. Frequency

The max. frequency of the Gowin MJPEG Decoder IP is mainly determined by speed grade of the selected devices. When using the GW5A-25 series of devices, a maximum decoding speed of 65 MHz can be achieved.

3.3 Latency

The latency of Gowin MJPEG Decoder IP is determined by the configuration parameters.

3.4 Resource Utilization

Gowin MJPEG Decoder IP is implemented in Verilog. Its performance and resource utilization may vary depending on the density, speed grade, and other grades of the device used.

Taking GW5A-25 FPGA as an example, the resource utilization of the Gowin MJPEG Decoder IP is shown in Table 3-1. For the applications verification on the other GOWINSEMI devices, please refer to the subsequent release.

Table 3-1 Gowin MJPEG Decoder IP Resource Utilization

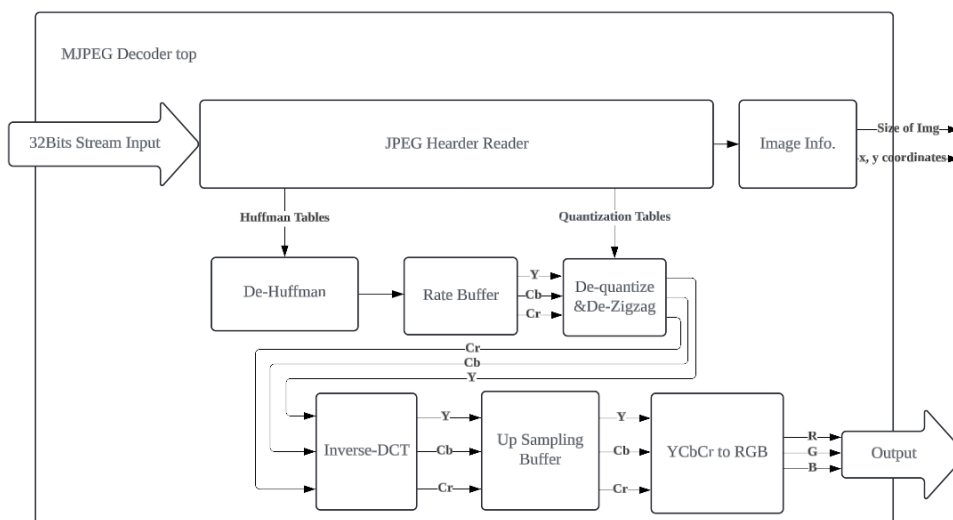
Device	Speed Grade	Resource Name	Resource Utilization
GW5A-25	C1/I/O	BSRAM	18
		SSRAM	0
		Registers	15306
		LUTs	7363
		ALUs	6207
		I/O Buf	—

4 Functional Description

4.1 Gowin MJPEG Decoder IP Structure and Function

Gowin MJPEG Decoder IP can perform continuous decompression of JPEG-standard images. It processes the received compressed image data through various modules, including De-Huffman, De-quantize, De-Zigzag, Inverse Discrete Cosine Transform (IDCT), and color space conversion (YCbCr to RGB), before outputting the image. The system block diagram is as shown in Figure 4-1.

Figure 4-1 Gowin MJPEG Decoder IP Configuration Interface



4.2 Block Diagram Description

4.2.1 Huffman Decode

Huffman decode refers to the process of restoring data that has been compressed using Huffman Encode. To decode Huffman-encoded data, the corresponding Huffman table is required, which maps characters to their respective Huffman codes. The input data and the codes in the table are then compared one by one until a match is found.

4.2.2 De-Quantization

De-quantization involves multiplying the DCT coefficients by the quantization coefficients. The quantization coefficient table is transmitted along with the JPEG header data. De-quantization involves multiplying non-zero coefficients by their respective quantization factors.

4.2.3 De-Zigzag

De-zigzag refers to the reordering of coefficients that are zigzagged during compression, according to the following index, as shown below.

Figure 4-2 De-Zigzag Table

0	1	8	16	9	2	3	10
17	24	32	25	18	11	4	5
12	19	26	33	40	48	41	34
27	20	23	6	7	14	21	28
35	42	49	56	57	50	43	36
29	22	15	23	30	37	44	51
58	59	52	45	38	31	39	46
53	60	61	54	47	55	62	63

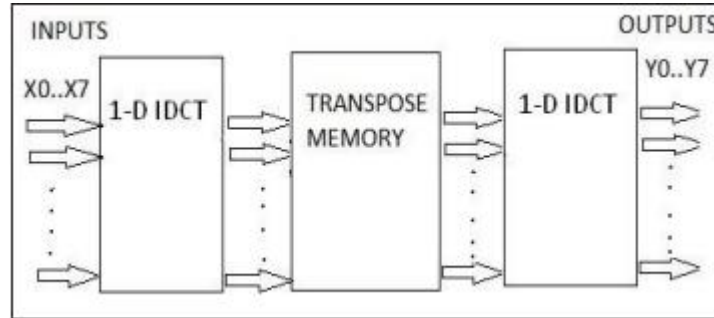
4.2.4 Inverse Discrete Cosine Transform

The IDCT uses the de-quantized DCT coefficients in the IDCT algorithm to convert them from the frequency domain back to the original time domain. The minimum computational unit of JPEG is 8x8. By inputting an 8x8 2D frequency domain IDCT coefficient matrix C, the IDCT can calculate the restored pixel value matrix P using the following formula:

The calculation formula is as follows:

$$P(x, y) = \frac{1}{64} \sum_{u=0}^7 \sum_{v=0}^7 F(u, v) \cdot C(u) \cdot C(v) \cdot \cos\left[\frac{(2x+1)u\pi}{16}\right]$$

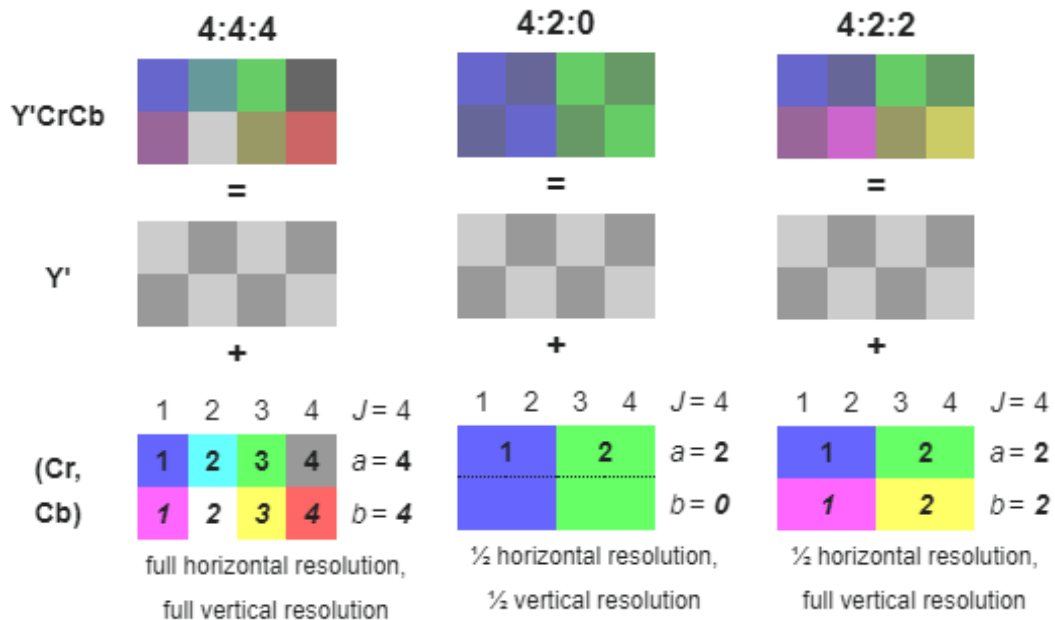
$$C(x) = \begin{cases} \sqrt{\frac{1}{2}}, & x = 0 \\ 1, & x \neq 0 \end{cases}$$

Figure 4-3 Inverse Discrete Cosine Transform Representation

This module is implemented as shown in the figure above. To reduce DSP utilization and increase speed, the IDCT module employs a butterfly transform algorithm in the FPGA to perform the conversion operations. By performing two 1D IDCT operations, the 2D matrix multiplication result is obtained, which is the output of the IDCT module. In Gowin MJPEG Decoder IP, the butterfly transform algorithm is implemented using shifters and adders in the FPGA to simulate multiplication. As a result, the actual outcome may have a slight error compared to the result obtained from the formula, with an error margin of less than 5%.

4.2.5 Sampling Restoration

The sampling standard for the frame can be obtained from the JPEG header data. During decoding, the image is restored according to the corresponding sampling standard. This IP supports three sampling standards: 4:4:4, 4:2:0, and 4:2:2, as shown in the figure below.

Figure 4-4 Sampling Restoration

4.2.6 Color Space Conversion

Color Space Conversion (CSC) involves converting Y (luminance), Cb (Chrominance), and Cr (Chroma) components into RGB image pixels. The conversion formulas are as follows:

$$R = \text{clip}(Y + 1.402 \times (Cr - 128))$$

$$G = \text{clip}(Y - 0.344 \times (Cb - 128)) - 0.714 \times (Cr - 128)$$

$$B = \text{clip}(Y - 1.772 \times (Cb - 128))$$

To reduce DSP utilization and increase speed, the CSC module in the MJPEG Decoder IP simulates multiplication using shifts and additions based on the above formulas. As a result, the actual output may differ slightly from the calculated values, with an error margin of less than 5%.

5 Port Description

The IO port descriptions of Gowin MJPEG Decoder IP are as shown in Table 5-1. The port diagram is as shown in Figure 5-1.

Figure 5-1 Port Diagram

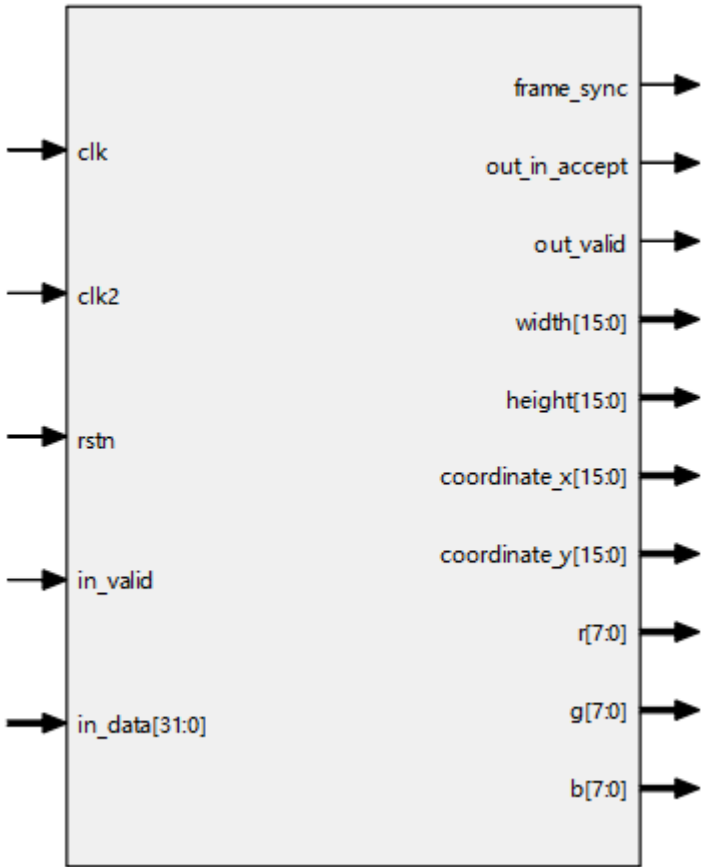


Table 5-1 I/O List of Gowin MJPEG Decoder IP

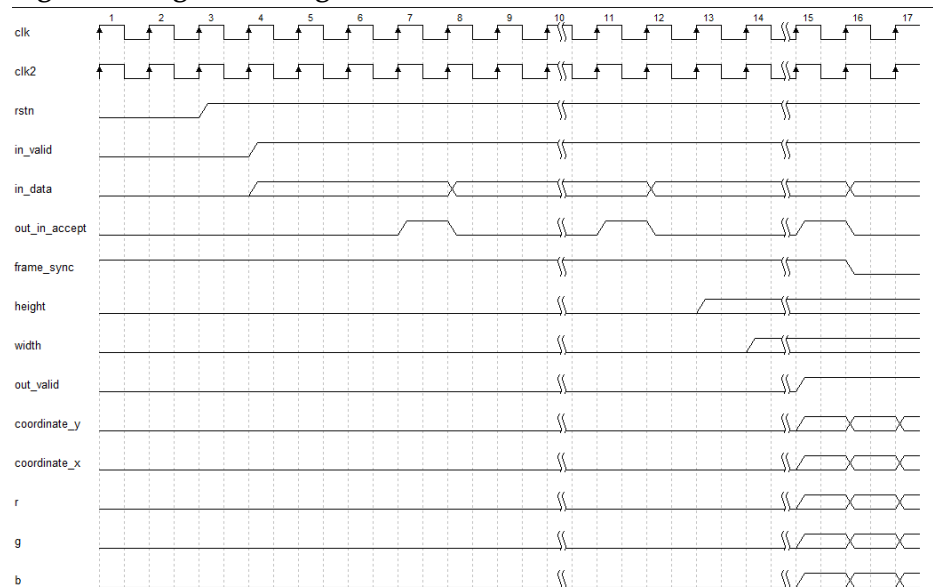
Signal	Data Width	I/O	Description
clk	1	Input	Input clock signal
clk2	1	Input	Output clock signal
rstn	1	Input	Reset signal, active-low
In_valid	1	Input	Input data valid

Signal	Data Width	I/O	Description
In_data	32	Input	Input data
In_strb	4	Input	Fixed input 4'hF
In_last	1	Input	Temporarily unused signal
Out_in_accept	1	Output	Output signal indicating acceptance of next data
Out_valid	1	Output	Output pixel valid indicator
Width	16	Output	Output image width
Height	16	Output	Output image height
Coordinate_x	16	Output	Horizontal coordinate of the valid pixel
Coordinate_y	16	Output	Vertical coordinate of the valid pixel
R	8	Output	Output 8-bit red channel
G	8	Output	Output 8-bit green channel
B	8	Output	Output 8-bit blue channel

6 Timing Description

This section describes the timing of the Gowin MJPEG Decoder IP. The timing of Gowin MJPEG Decoder IP is as shown in Figure 6-1.

Figure 6-1 Signal Timing

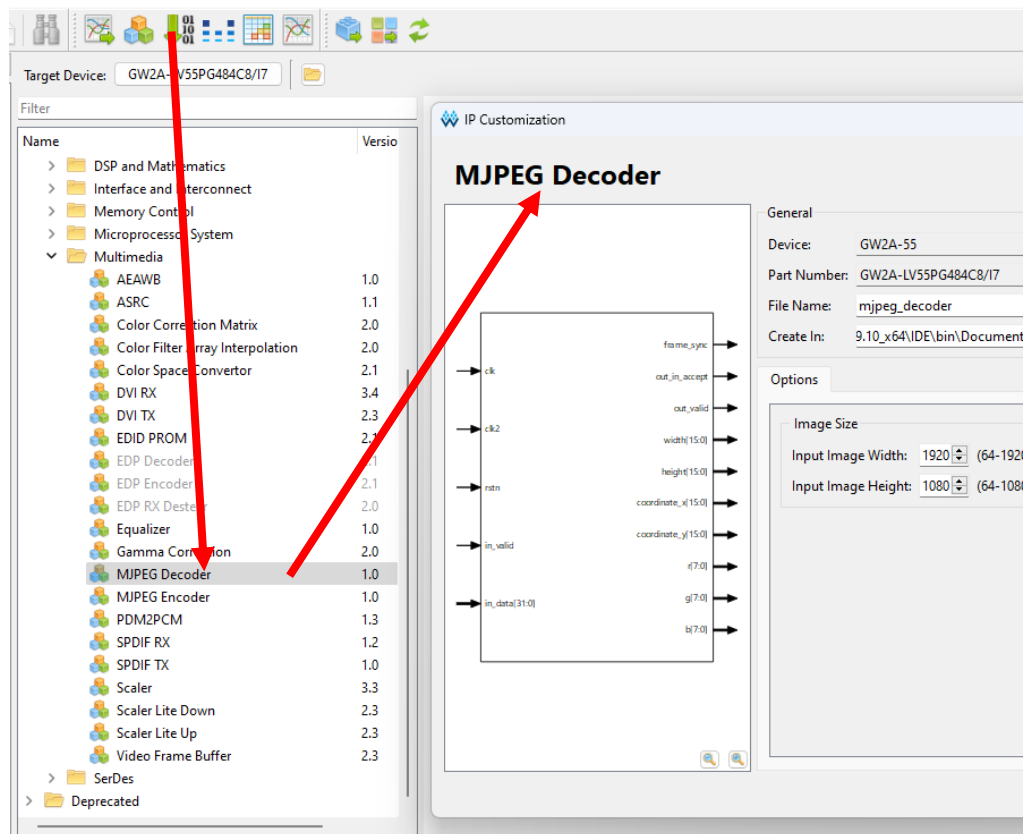


As shown in the figure above, assert `in_valid` and input the compressed image data using Baseline JPEG standard, and the `out_in_accept` signal indicates that the next data can be input. `out_valid` signal is outputted, indicating that the output data is valid.

7 Interface Configuration

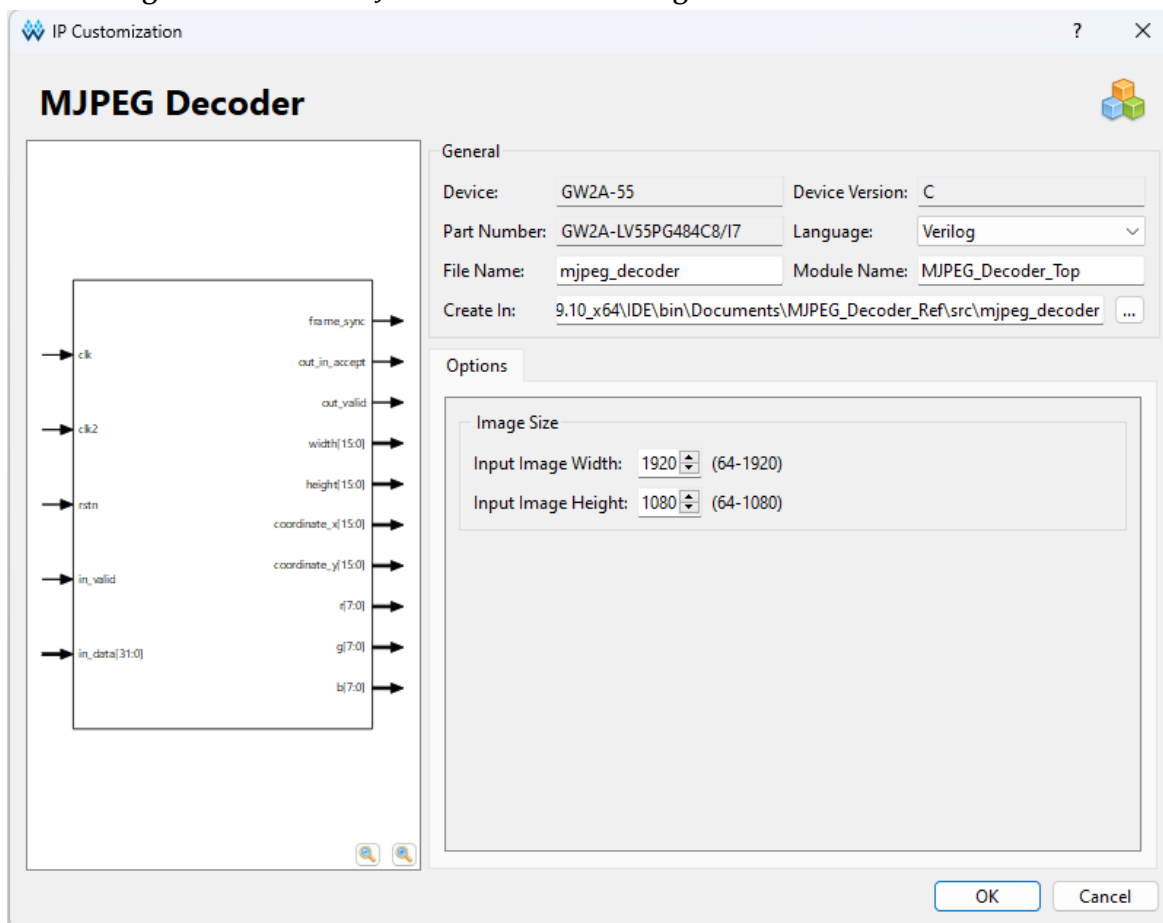
Start "IP Core Generator" from the "Tools" menu in Gowin Software, then you can call and configure MJPEG Decoder in "Multimedia" type. Toolbar icon is also available as shown in Figure 7-1.

Figure 7-1 Open the IP via Toolbar Icon



MJPEG Decoder IP configuration interface is as shown in Figure 7-2.

Figure 7-2 Gowin MJPEG Decoder IP Configuration Interface



This manual takes GW2A-55 chip and GW2A-LV55PG484C8/I7 part number as an example.

- "File Name": Specifies the file name of the generated IP files. The user can modify it as needed.
- "Module Name": Specifies the module name of the generated IP. The user can modify it as needed.
- "Create In": Specifies the directory in which the IP core files are generated. The user can modify it as needed.

8 Reference Design

Please refer to the related test cases in the Gowin MJPEG Decoder IP [RefDesign](#).

