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KT-CAMULATOR

Automotive Camera Direct Injection Solution

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Camera Direct Injection

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1. Introduction

KT-CAMULATOR serves as a data bridge from COTS or custom automotive camera simulation environments to an AD/ADAS Electronic Control Unit (ECU) while emulating the authentic behavior of a camera. Using the **KT-CAM**ULATOR, test engineers can effectively validate a wide range of camera-based ADAS/AD systems.
KT-CAMULATOR supports three types of input sources:

•HDMI (version 2.0b)
•File – TDMS
•File – FFMPEG

The table on the right provides an overview of various features based on the input source.

Features	HDMI	File - TDMS	File - FFMPEG
Multiple Inputs	✓	✓	✓
SerDes Interface	✓	✓	✓
Format Conversion	✓	–	✓
I2C Emulation & Translation	✓	✓	✓
Imager Emulation	✓	✓	✓
Custom Resolution	✓	–	–
Custom Frame Rate	✓	✓	✓
Camera TAP	✓	✓	✓
Fault Injection	✓	✓	✓
GPIO Frame Synchronization	✓	✓	✓
Output Video Display Visualization	✓	✓	✓

2. General Specifications and Features

2.1 SerDes - Interface

KT-CAMULATOR supports two SerDes (serializer/deserializer) interfaces, GMSL (Gigabit Multimedia Serial Link) and FPD-Link (Flat Panel Display Link). The table below provides supported hardware chipsets and technical details.

Hardware	GMSL2	FPD-Link III/IV
Serializer	MAX 9295A / 96717 / 96717F	DS90UB953
Deserializer	MAX 9296A / 96716	DS90UB954
Bandwidth	6 Gbps	4.2Gbps
Number of Lanes	1/2/4	1/2
Module Types	4-Input 4-Output / 8-Input / 8-Output	
Power over Coax	None / Internal / Auxiliary	

2.2 I2C Emulation & Translation

KT-CAMULATOR performs I2C emulation and translation by using a register map for the camera. The register map is provided as a CSV file. With this information **KT-CAM**ULATOR continuously emulates the camera and interacts with the ECU with user-controlled register values.

2.3 Imager Emulation

KT-CAMULATOR can emulate imager functionalities and generates embedded lines of data to the next frame being streamed out. It continuously interacts with the ECU and processes the embedded data with new register values updated by the ECU.

2.4 Camera TAP

The camera TAP functionality has two modes:

2.4.1. I2C TAP: Tapping I2C line of real camera to ECU through **KT-CAM**ULATOR.
2.4.2. Video TAP: Tapping the image data of a real camera to ECU through **KT-CAM**ULATOR.

2.5 Frame Synchronization

KT-CAMULATOR synchronizes the streaming image data with ECU through GPIO triggers.

2.6 Fault Injection

KT-CAMULATOR supports dropping a frame from the output stream. This happens on the FPGA in real time.

2.7 Output Video Data Visualization

KT-CAMULATOR GUI displays the video data which is being transmitted to serializer output channel.

3.HDMI Input Specifications and Features

3.1 Multiple Inputs

KT-CAMULATOR accepts multiple HDMI inputs with different video properties such as resolution, fps, formats, or bit-depths.

3.2 Format Conversion

KT-CAMULATOR supports HDMI input sources based one of the three input formats. The table below provides the list of supported input/output formats.

Input	Output
YUV420/422 8-bit	YUV422 8-bit, RAW8/10/12/14 (with Bayer Filters), RGB888
YUV420/422 10-bit	YUV422 8-bit, YUV422 10-bit
RGB 10-bit	RAW8/10/12/14 (with Bayer Filters), RGB888

3.3 Custom Resolution

KT-CAMULATOR with HDMI input accepts vast range of resolution input (listed in the table on the right)which can be directly streamed to ECU. However, certain ECUs need non-standard video resolution input. In that case, the user can choose the cropping/padding feature to customize the resolution.

Input – Video Mode Types	Custom Output
640x480	**Default:** Same as input resolution **Cropping:** Smaller than input resolution **Padding:** Bigger than input resolution
720p	
1440x900	
1440x1080	
1080p	
1600x1200	
1920x1200	
1920x1440	
2560x1440	
2560x1600	
2160p	
4Kp	

3.4 Custom Frame Rate

KT-CAMULATOR allows the user to control the fps of the video output stream to ECU. The input source can be a maximum of 60 fps and the output source can be set to the same or less than the input fps. The table below provides detailed information on supported output fps based on resolution and SerDes interface.

Resolutions	Input Frame Rate	GMSL2 Output Frame Rate					FPD-Link III/IV Output Frame Rate				
		8-bit	10-bit	12-bit	14-bit	24-bit	8-bit	10-bit	12-bit	14-bit	24-bit
640x480 720p 1440x900 1440x1080 1600x1200 1920x1200 1920x1440 2560x1440 1560x1600	50-60	up to 60 fps					up to 60 fps				

Resolutions	Input Frame Rate	GMSL2 Output Frame Rate					FPD-Link III/IV Output Frame Rate				
		8-bit	10-bit	12-bit	14-bit	24-bit	8-bit	10-bit	12-bit	14-bit	24-bit
1080P	23.98-60	up to 60 fps					up to 60 fps				
2160p	23.98-60	up to 60 fps			50	31	up to 60 fps		44	34	22
4Kp	23.98-60	up to 60 fps			48	30	60	48	40	30	20

4. TDMS File Input Specifications and Features

4.1 Multiple Inputs

KT-CAMULATOR accepts multiple TDMS file inputs with different video properties such as resolution, fps, formats, or bit-depths.

4.2 Supported Formats

The table below provides the list of video input formats and respective output formats supported when using TDMS file as source.

Input	Output
YUV422 8-bit	YUV422 8-bit
YUV422 10-bit	YUV422 8-bit, YUV422 10-bit
YUV422 10-bit	RAW 8/10/12/14 (with/without Bayer Filter)

4.3 Custom Frame Rate

With this feature the user can choose the appropriate frame rate required by the ECU. The output fps should be equal or less than the recorded fps of TDMS file.

5. FFMPEG File Input Specifications and Features

5.1 Multiple Inputs

KT-CAMULATOR accepts multiple FFMPEG file inputs with different video properties such as resolution, fps, formats, or bit-depths.

5.2 Format Conversion

The user can select a video file as an input source and based on that can choose the appropriate output required by the ECU. The table below lists all the supported output formats.

Input	Output
H264/H265	YUV422 8-bit RGB888 8-bit RAW 8/10/12/14 (with Bayer Filter)

5.3 Custom Frame Rate

With this feature the user can choose the appropriate frame rate required by the ECU. The output fps should be equal or less than the recorded fps of FFMPEG video file.

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