IPG AUTOMOTIVE

SOLUTIONS FOR TESTING CAMERA-BASED ADVANCED DRIVER ASSISTANCE SYSTEMS

SOLUTIONS FOR VIRTUAL TEST DRIVING

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Motivation

The number and variety of on-board vehicle sensors keeps increasing. On the one hand, diverse sensors support a consistently growing number of (assistance) functions. On the other hand, increasingly complex functions require more and more methods of sensor fusion and interlinking as well.
Consequently, the demands made on the required testing tools keep growing, too. It is no longer sufficient for test environments and methods to merely cover individual components. Instead, they have to increasingly take the integration of systems, preferably in the total vehicle context, into account.
Camera-based systems play a key role in this. Even at this point, they are elements of a wide range of functions. They will become even more widely used in the future due to their continuous further development, a trend that is additionally encouraged by declining unit prices.

High-Beam Assist

Parking Assist

Night Vision Assist

Lane Detection

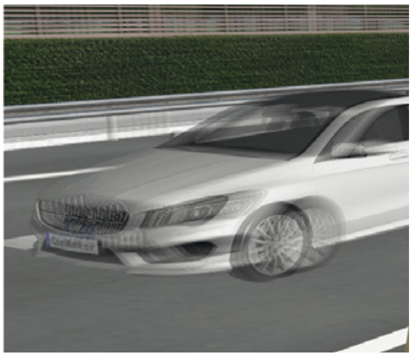
Traffic Sign Recognition

Surround View Systems

Requirements

Simulation-aided methods have long become indispensable to the management of testing requirements. The CarMaker open integration and test platform is a universally usable basic tool which makes it possible to set up, run and analyze test cases in the form of virtual test driving. For camera-based systems, the 3D visualization tool, IPGMovie, is of major importance as well. It provides realistic real-time visualization which serves as a source for various kinds of testing techniques. In addition, to satisfy the need for a camera “view,” various properties and effects which are of crucial relevance to a wide range of functions (e.g. shadows, motion blur, reflections, lens distortions, noise, light scattering) have been physically modeled.

Motion Blur



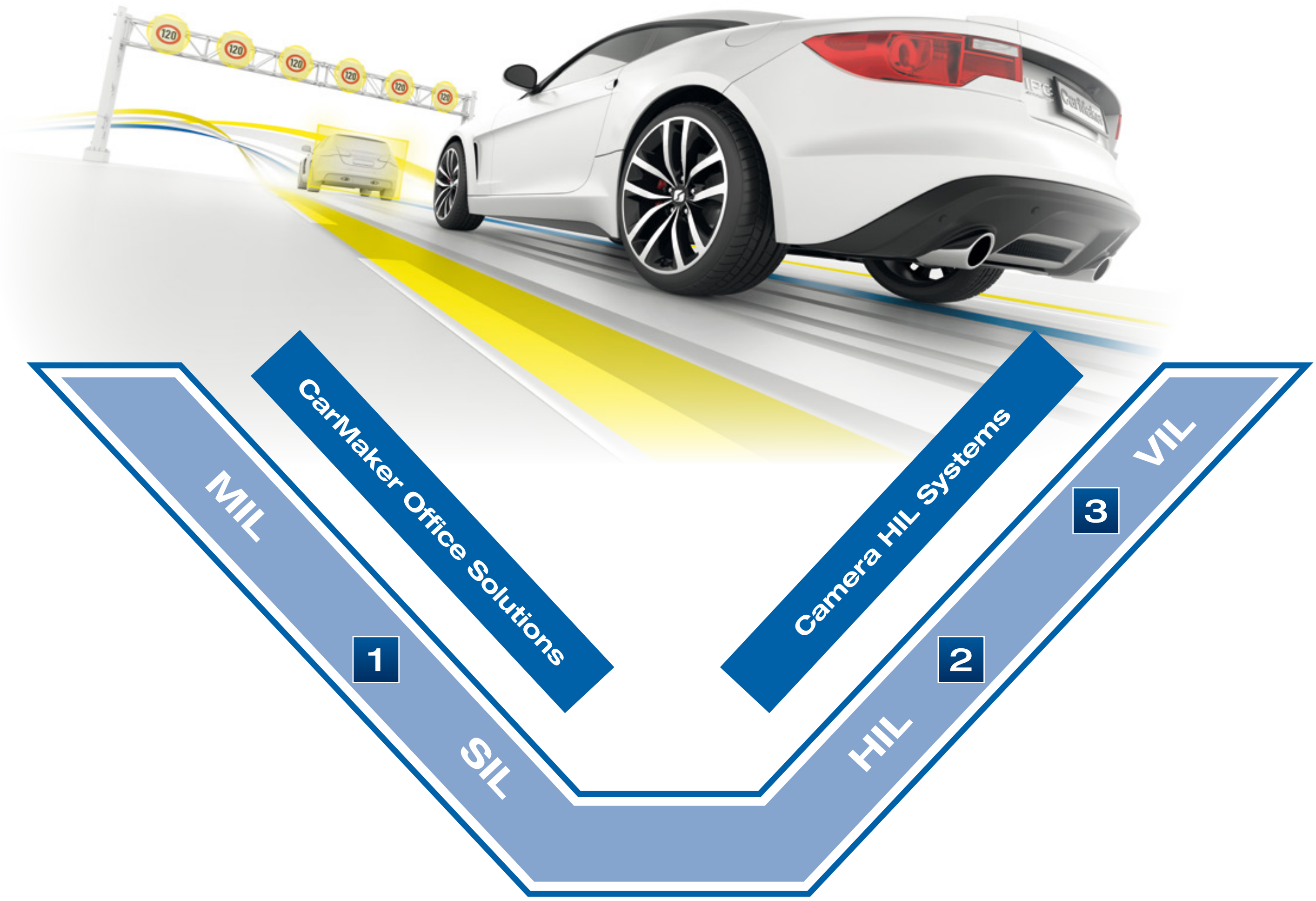
Active Lights

Reflections

Solutions at a Glance

The Sensor Model Extension Package provides a comprehensive toolbox for CarMaker to define optical properties for camera systems. Included, among other things, are various types of lenses and photographic objectives, any desired distortion as well as exposure effects. These modeling possibilities are basic prerequisites for many solutions used for testing camera-based systems, as described below.

There are various solutions available for testing camera-based systems, depending on the application and stage in the development cycle. In the MIL and SIL stage, for example, image processing algorithms can be tested fast and efficiently, using real-time animation and the Video Data Stream, without requiring the camera to be available as a hardware component.
If the camera is already available as a physical hardware prototype, camera HIL systems are used. Should the camera system be tested as a completed component, a monitor-HIL solution is used in which the real-world camera films the virtual animation from the simulation environment. However, for multi-lens systems or special functions (such as a light assistant), the utilization of a Video Interface Box, which enables image data to be injected directly into the electronic control unit, is more advantageous.



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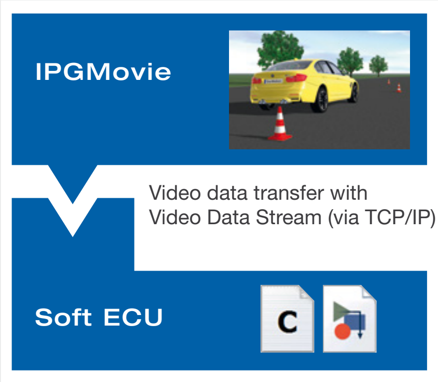
Video Data Stream



In a nutshell:

- Early testing of function algorithms
- Video data transfer directly from the simulation environment (3D visualization)
- Freely definable camera lenses and camera properties

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Monitor-HIL

In a nutshell:

- “Filming” of the animation with a real-world camera
- Closed-loop connection of the camera, also thanks to realistic vehicle dynamics
- Standard solution for testing mono camera systems

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Video Interface Box

In a nutshell:

- Injection of video data directly into the camera ECU
- Realistic emulation of lenses and image sensors
- Active feedback channel (aperture control) in real-time

Video Data Stream

General description

The complexity and diversity of situations encountered by (camera-based) assistance functions is enormous. Approaches using signal-based tests can only reflect fractions of conditions.

Therefore, it is very important to also integrate the camera-based components in the total “Closed-Loop” test and integration platform in order to enable testing of sensor data fusion technologies under realistic conditions.

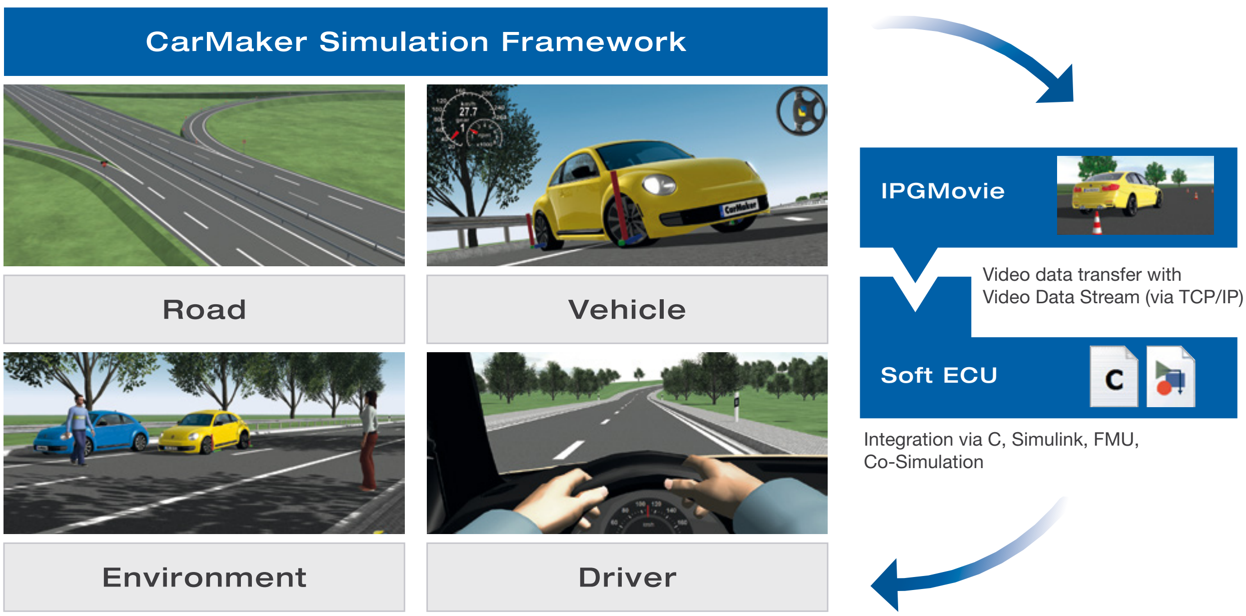
For this purpose, the real-time visualization has been extended by a sophisticated camera model to generate simultaneous video data such as gray scale, color or stereo pictures as well as depth maps (e.g. PMD) for 3D images besides the well-known environment sensors (radar, lidar, ultrasonic).

Within the sensor model extension package, it is possible to freely define the type of camera lens (e.g. fisheye) with lens settings such as opening angle and typical lens failures (e.g. distortion and vignetting). With this new technology, it is possible that camera and radar data, for instance, can be provided time synchronal for the fusion algorithm to be tested.

Furthermore, it is possible to configure the resolution, frame rate, optical sensor properties as well as the position and direction of each camera separately. The video data is transferred via the TCP/IP network interface to the controller or image processing algorithm under test (see VDS data transfer image on the lower right-hand side).

The simulation closely models the real-world traffic situation and enables repeatable and comparable test conditions. Due to a powerful simulation environment, a broad range of validation tests can be shifted into simulation because even complex test scenarios can be replicated. The simulation data can be provided time synchronously, which is imperative for fusion algorithms.

Block diagram (example configuration)



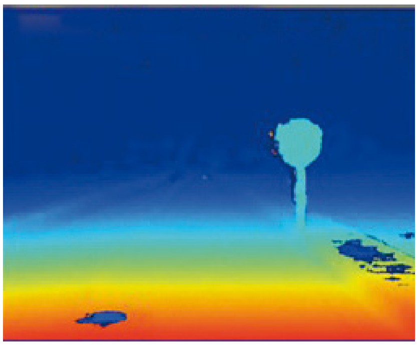
Use cases

For recognition of traffic-related objects, the utilization of camera-based sensors (e.g. gray scale, color cameras) and depth cameras (e.g. PMD 3D cameras) will increase. A wide range of image-based systems is currently being used in the field for purposes such as traffic sign recognition and lane tracking to achieve adaptive speed control systems and lane departure warning systems and automated driving.

As mentioned before, prices for camera systems are declining and future vehicles will be equipped with more than one camera system. Obviously, the evaluation of multiple cameras entails multiple costs. At an early stage of development or in cases where it is not necessary to test the existing real-world hardware, it is completely sufficient to test the software/algorithm itself. This mainly includes:

- Testing of relevant data as input for soft ECUs
- Pre-verification of data processing algorithms
- MIL and SIL Closed-Loop tests for all camera-based ADAS





Features at a glance

- Virtual camera for the virtual world
- Pre-verification of data processing algorithms
- Replication of real-world test scenarios
- Generation of simultaneous video data such as RGB, gray and depth (see images below)
- Testing of sensor data fusion technologies under realistic conditions
- Free definition of lens settings such as fisheye-lenses, including lens failures like vignetting
- Free configuration of resolution, frame rate, etc.

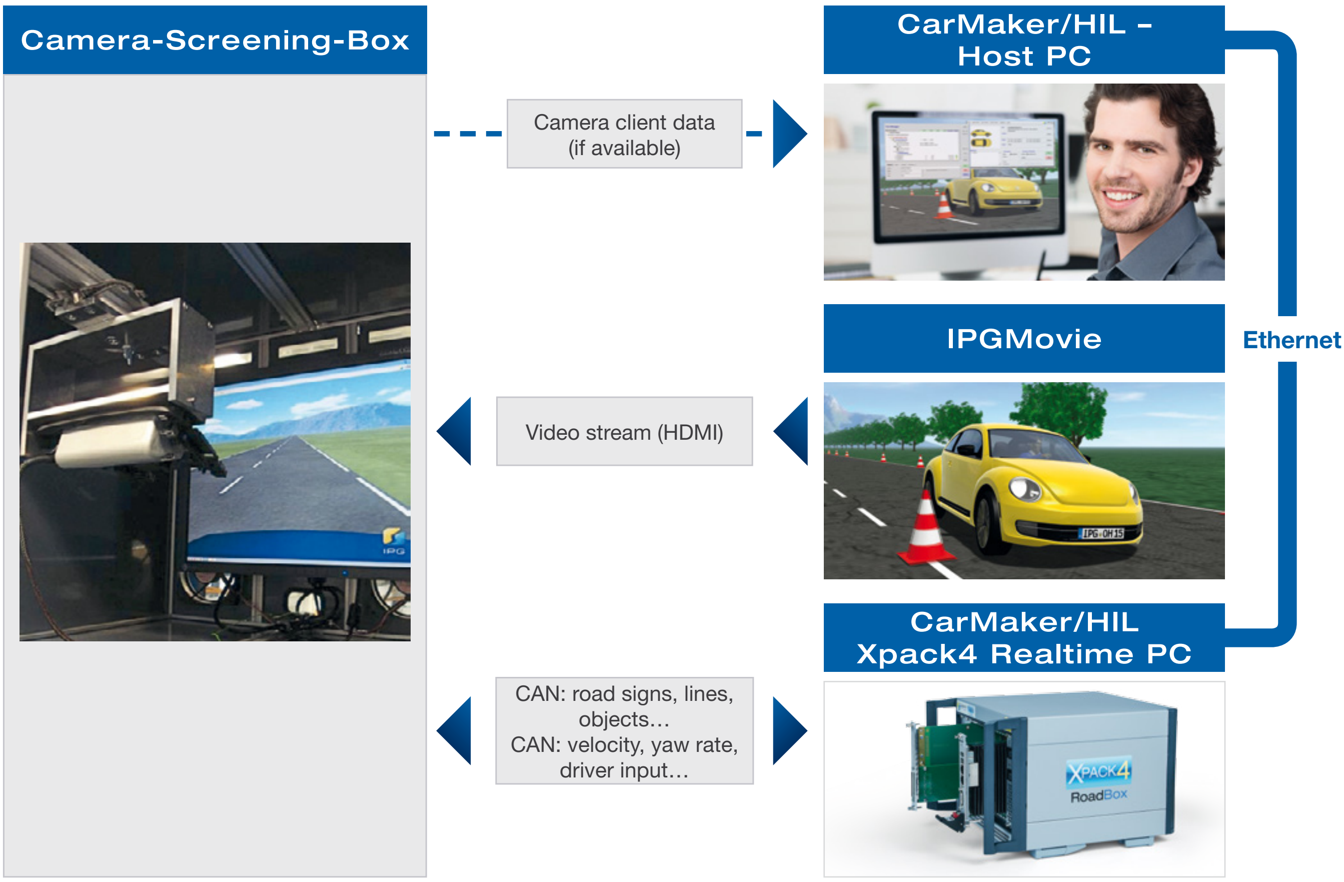


Monitor-HIL (Screen Capturing)

General description

In a monitor-HIL system, the CarMaker simulation environment is connected to the real (prototypical) camera system as a device under test. The camera is placed in front of a monitor in a shaded housing. On the monitor itself, via IPGMovie, the visualization is presented as output from the simulation environment in real-time. IPGMovie shows the effects which are relevant to the function in a freely definable format (such as lines, signs or traffic objects). The actual full-vehicle simulation is run simultaneously on an Xpack4 real-time PC (e.g. RoadBox). Here, all the additionally relevant stimuli data for the camera is generated and forwarded to the camera, for instance via CAN. Conversely, the simulation receives and processes output signals of the camera ECU in the form of messages about detected objects or other responses by advanced driver assistance systems that may have already been implemented in the camera ECU. Further potential assistance functions may be co-integrated in the form of a hard or soft ECU. This results in a Closed-Loop environment which makes it possible to test even complex scenarios. The tests are completely reproducible and can be run and analyzed in automated modes.

Block diagram (example configuration)



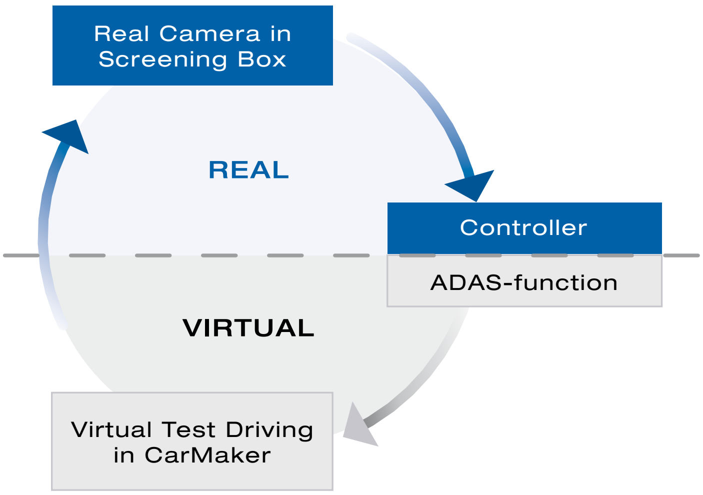
Use cases

Monitor-HIL solutions are characterized by their relatively non-complex structure. They can be implemented without detailed knowledge about the image sensor. Particularly for mono camera systems, this results in key fields of application for testing and validating the following functions:

- Line / lane detection for lane keeping assist or lane departure warning system
- Traffic sign recognition / detection
- Other ADAS functions in combination with sensor fusion

Features at a glance

- Full HIL integration of camera systems
- Closed-Loop capability thanks to short latencies and feedback of the camera response into the simulation
- Correct vehicle dynamics properties lead to valid results (e.g. sign recognition in the event of brake dive)
- Large number of applications achievable by using the IPGMovie visualization environment
- Seamless development: direct adoption of test cases from MIL or SIL
- Driving of millions of test kilometers in automated mode and under laboratory conditions

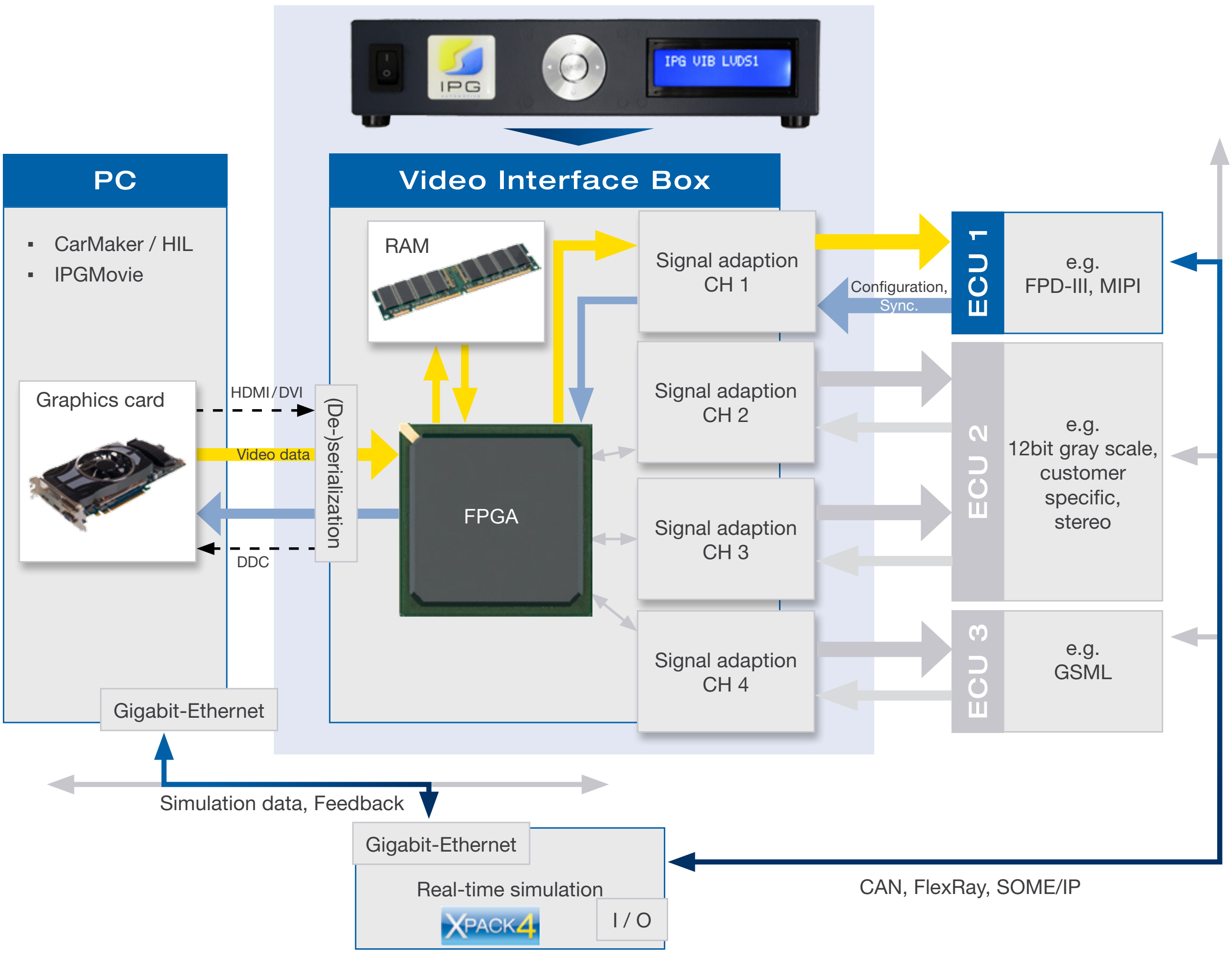


Video Interface Box (Video Injection)

General description

With the Video Interface Box, image data is injected directly into the ECU. For this purpose, the optics and the image sensor are physically separated from the rest of the camera system and a tailored hardware interface is used for the resulting interface. The optical path, consisting of the lens and the color filter attached to the sensor, is fully emulated in IPGMovie. All aspects in terms of timing and embedding of data that does not contain the actual image information are stored on the motherboard of the Video Interface Box as FPGA code and can be parameterized by the user via IPGMovie. The connection between IPGMovie and the Video Interface Box is created via the HDMI output of the graphics card. The proprietary IPG Automotive protocol in combination with HDMI transmission guarantees low-delay and efficient transmission of image data with reliable, exact timing. The HDMI connection is also used by IPGMovie to access the register structure of the emulated imager. Due to this access, for instance, IPGMovie is able to read the exposure time previously assigned by the ECU and respond accordingly. In the opposite direction, the initialization of the register structure and adjustment of the runtime values can be performed via this feedback channel.

Block diagram (example configuration)



Use cases

Due to the dynamic response to changes of exposure settings, “true” in-the-Loop testing in combination with CarMaker is made possible. In addition, the utilization of the Video Interface Box enables and simplifies testing, particularly involving:

- Camera-based systems with more than one lens (e.g. emergency brake assist, surround view systems)
- Systems with significant differences in contrast (e.g. (high-beam) headlight assist, night vision assist)
- Camera systems with extreme lens aperture angles (e.g. fisheye for surround view functions)
- Vehicle-in-the-Loop systems (due to space-saving installation in the test vehicle)

Features at a glance

- Direct feeding of video data into the camera ECU interface
- Contrast range > 8 bits per pixel
- User-definable resolution per emulation, e.g. 4096 x 2034 pixels
- Depending on contrast range and frame rate; all channels in total limited to 7.92 Gbit/s
- Support of up to four cameras (channels) per Video Interface Box module
- Feedback channels
- For synchronization, configuration und control between camera emulation und ECU
- For synchronization between video data source and camera emulation
- Various standardized interfaces available, e.g. FPD-III, MIPI, GMSL, Camera Serial Interface, FBAS (PAL, NTSC), HDMI / DVI
- FPGA-based hardware facilitates implementation of further interfaces and functional ranges
- Optimized for Xpack4 and CarMaker/HIL

SOLUTIONS FOR VIRTUAL TEST DRIVING

As a global leader in virtual test driving technology, IPG Automotive develops innovative simulation solutions for vehicle development. Designed for seamless use, the software and hardware products can be applied throughout the entire development process, from proof-of-concept to validation and release. The company's virtual prototyping technology facilitates the automotive systems engineering approach, allowing users to develop and test new systems in a virtual whole vehicle.

IPG Automotive is an expert in the field of virtual development methods for the application areas of ADAS & Automated Driving, Powertrain, and Vehicle Dynamics. The company's CarMaker product family is used around the world to address the challenges associated with developing and testing advanced driver assistance and automated driving functions by integrating a highly accurate vehicle model in a realistic environment. In order to generate realistic input data for the functions to be tested, detailed sensor models are stimulated by an environment model of any complexity, comprising elements of infrastructure and road users, while taking relevant environmental influences into account.

IPG Automotive stands for quality, holistic user orientation, efficiency, promotion of innovation und lasting partnership.

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