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SCALEXIO®

New technologies for HIL simulation

Embedded Success dSPACE

SCALEXIO®

New technologies for HIL simulation

Highlights

- Versatility for different test tasks
- High channel and system flexibility
- Completely software-configurable
- Connectable to existing systems
- Multicore support

SCALEXIO fulfills all the new requirements that our hardware-in-the-loop customers have encountered over the last few years. Its completely new hardware and software architectures are the perfect answer to the changes and new challenges in today's HIL projects. SCALEXIO systems are very versatile – they provide highly flexible channels, can be extended precisely to any required size, and are completely software-configurable.

- **New Workflows**
  SCALEXIO fully supports the increasing subdivision of tasks that is taking place in HIL test teams. I/O configuration and modeling are performed separately, and code generation can also be done separately to save a lot of time.

- **Higher Flexibility**
  SCALEXIO systems can be planned, configured, and modified quickly and easily. The system is very flexible, so you can test different variants and types of electronic control units with minimum effort on one and the same system – for engine or transmission, singly or combined, and so on. If specifications are defined later or changed, it is easy to implement them. You can also test new components for vehicle platforms that are already running.

- **Versatility**
  SCALEXIO can be sized precisely to fit specific test tasks. Component test systems and network systems are both built with the same hardware components. So if errors are found during network testing, ECU code subsystems can be separated out from the network system and used to run component tests before the entire network test is repeated.

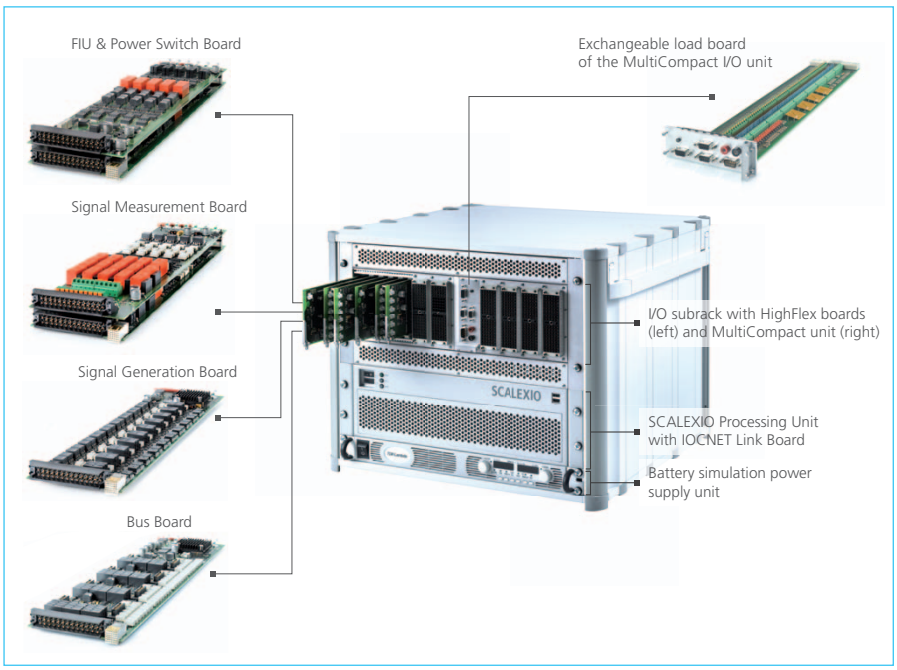
- **Less Time, Lower Costs**
  SCALEXIO has a standardized component design and standardized connections, so you can choose whatever slots you want, and the system can be set up easily. All the channels are configured in a graphical software tool that also automatically produces complete system documentation. So you can not only implement the initial system, but also make later modifications and redesigns, with enormous efficiency. A SCALEXIO system requires less internal wiring than others, and the work involved in configuring, setting up, modifying, testing and documenting a simulator is reduced.

System

The Benefits

The SCALEXIO system comprises a new hardware architecture. All the hardware is standardized and can be reused in all variations of SCALEXIO systems.

- The configuration is completely software-based, making system setup or redesign very efficient.
- The core of a SCALEXIO system, the SCALEXIO Processing Unit, is based on off-the-shelf components. You benefit from up-to-date processor technology.
- Different types of I/O hardware, HighFlex and MultiCompact, are available, tailored for your project-specific needs regarding functionality and cost.
- The new scalable serial I/O network IOCNET is system-independent. It provides the internal communication between the real-time processor and the I/O boards.



Example setup of a 9-HU SCALEXIO system with MultiCompact unit, supplemented by HighFlex boards.

HighFlex and MultiCompact

The SCALEXIO I/O hardware types HighFlex and MultiCompact are specially designed for typical ECU signals. They have the following in common:

- Local signal preprocessing on I/O boards to relieve the load on the real-time processor
- Connection to the processing unit via an IOCNET interface
- Integrated signal conditioning, as well as converters and parts of the electrical failure simulation
- Completely software configurability
- Similar installation and configuration processes, so very little time is spent learning

The HighFlex and MultiCompact I/O hardware can be combined and extended to produce whatever system configuration you want.

HighFlex	MultiCompact
■ Universal input/output/bus channels with freely assignable channel types and software configurability ■ Very versatile and finely scalable with 10 channels per I/O board, 4 channels per bus board ■ Each channel is individually galvanically isolated.	■ Large number of I/O channels for specific applications ■ Each channel has a fixed channel type, so the costs per channel are very low. ■ Galvanically separated as unit

■ Standardized connector concept for all boards
■ Boards are slot-independent and easy to assemble.
	■ DS2680 I/O Unit
	  ■ Compact design for installation in a unit carrier
	■ DS2690 Digital I/O Board
	  ■ Standardized connector for slot-independence and easy assembly

■ Four HighFlex boards, each with specific I/O functions
  ■ DS2601 for signal measurement (p. 14)
  ■ DS2621 for signal generation (p. 16)
  ■ DS2642 for failure simulation and power switch (p. 20)
  ■ DS2671 for bus communication (p. 18)
	■ DS2680 I/O Unit offers various channels with dedicated I/O functions (p. 22)
	■ DS2690 Digital I/O Board offers digital channels with dedicated I/O functions (p. 25)

Overview of Channel Types

The HighFlex I/O boards and the MultiCompact I/O Unit offer different channel types. In some cases you can use different channel types for the same function. The list below shows the channel types, the boards they are available with and the alternative channels. All the channels are configured in ConfigurationDesk. The software displays short channel names, which are stated in brackets in the Channel Type column.

	Channel Type	Alternative Channel Type	Board with No. of Channels
Input channel types	Multifunctional input channel 1 (Flexible In 1)		DS2601 (10)
	Multifunctional input channel 2 (Flexible In 2)		DS2680 (18)
		Flexible In 1	DS2601 (10)
	Analog voltage input channel 1 (Analog In 1)		DS2680 (20)
		Flexible In 1	DS2601 (10)
	Analog voltage input channel 2 (Analog In 2)		DS2680 (2)
	Digital input channel (Digital In 1)		DS2680 (30)
		Flexible In 1	DS2601 (10)
	Digital input channel (Digital In 2)		DS2690 (10)
		Flexible In 1	DS2601 (10)
		Digital In 1	DS2680 (30)
	Digital input channel (Digital In/Out 1, used as input)		DS2690 (10)
		Flexible In 1	DS2601 (10)
		Digital In 1	DS2680 (30)
		Digital In 2	DS2690 (10)

	Channel Type	Alternative Channel Type	Board with No. of Channels
Output channel types	Multifunctional output channel (Flexible Out 1)		DS2621 (10)
	Analog voltage output channel 1 (Analog Out 1)		DS2680 (15)
		Flexible Out 1	DS2621 (10)
		Analog Out 4	DS2680 (8)
	Analog output channel (Analog Out 2)		DS2680 (2)
	Analog output channel alternating voltage (Analog Out 3)		DS2680 (7)
		Flexible Out 1	DS2621 (10)
	Analog output channel (Analog Out 4)		DS2680 (8)
		Flexible Out 1	DS2621 (10)
	Digital output channel (Digital Out 1)		DS2680 (28)
		Flexible Out 1	DS2621 (10)
	Resistance simulation channel (Resistance Out 1)		DS2680 (12)
		Flexible Out 1	DS2621 (10)
	Digital output channel (Digital Out 2)		DS2690 (10)
		Flexible Out 1	DS2621 (10)
		Digital Out 1	DS2680 (28)
		Digital In/Out 1	DS2690 (10)
	Digital output channel (Digital In/Out 1, used as output)		DS2690 (10)
		Flexible Out 1	DS2621 (10)
		Digital Out 1	DS2680 (28)
		Digital Out 2	DS2690 (10)
Bus channel types	Bus (Bus 1), configurable for CAN, LIN, FlexRay, etc.		DS2671 (4)
	CAN (CAN 1)		DS2680_2672 (2)
		Bus 1	DS2671 (4)
	LIN/K-line (LIN 1)		DS2680_2672 (2)
		Bus 1	DS2671 (4)
	FlexRay (FlexRay 1)		DS2680_2672 (2)
		Bus 1	DS2671 (4)
Power channel types	Power switch with current measurement (Power Switch 1)		DS2642 (10)
	Power switch without current measurement (Power Switch 2)		DS2680 (6)
		Power Switch 1	DS2642 (10)
	Power unit control (Power Control 1)		DS2907 (2)
			DS2680 (1)

dSPACE Engineering Services

You can make use of dSPACE Engineering Services in any project phase. Whether you need engineering support for an entire project, or just for system installation or first use, you can rely on our years of experience and comprehensive know-how. These will help you get the maximum benefit from the system's flexibility for your projects. For example, all the I/O units contain FPGAs whose microcode machines we can program for project-specific I/O functions.

IOCNET (I/O Carrier Network)

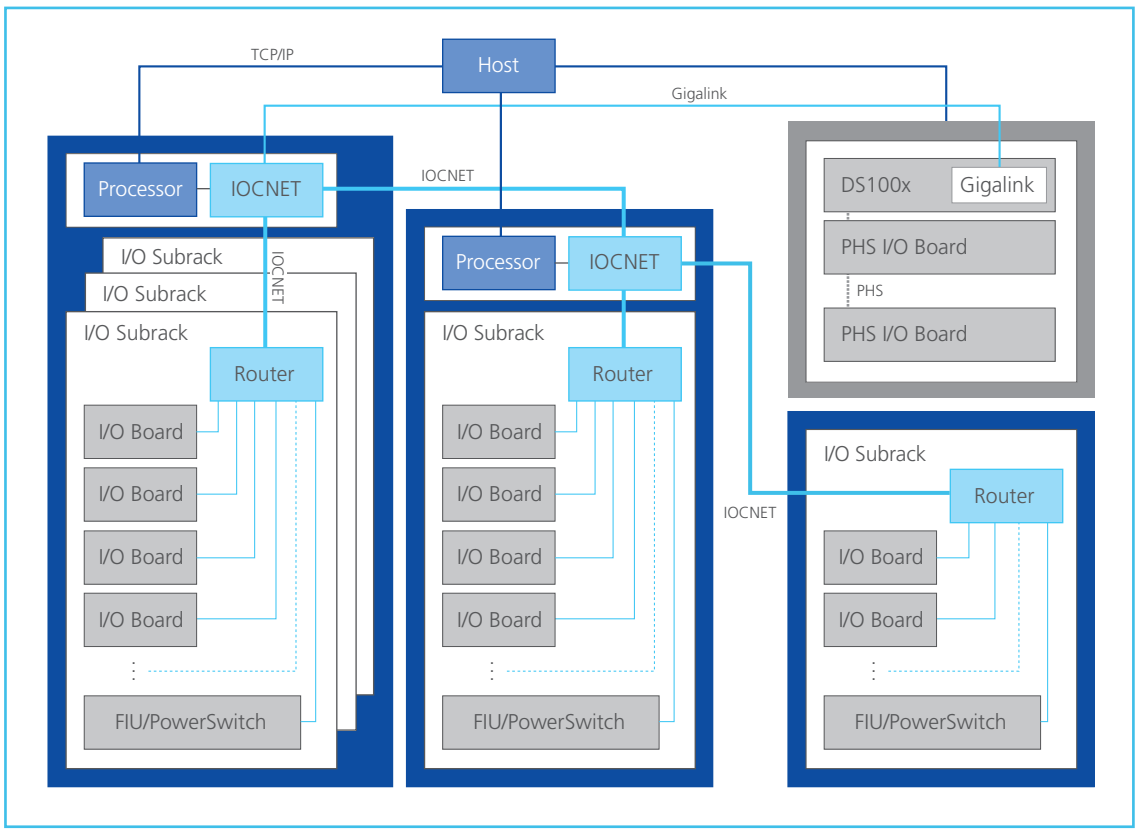
IOCNET is a network technology developed by dSPACE for internal simulator communication based on the Gigabit Ethernet physical layer. A SCALEXIO system with IOCNET comprises more than 100 device nodes, which can be located up to 100 meters apart. The transmission rate is about 10 times higher than with the previous technology. Input signals can be read synchronously, and I/O data can be bundled for transmission to the SCALEXIO Processing Unit. The model data generated by the Processing Unit can be passed to the I/O components in signal-flow-driven transmission. You can also use decentralized I/O, in other words, I/O units without their own processing units.

Coupling Several Processors

IOCNET also couples processors, and no additional hardware is necessary[1)].

Coupling SCALEXIO with Existing Systems

The SCALEXIO system can interact with all existing dSPACE HIL systems, such as dSPACE Simulator Mid-Size and dSPACE Simulator Full-Size. The existing systems are based on the peripheral high-speed (PHS) bus technology, which is used for communication between the processor and the I/O units. A SCALEXIO system is connected to a PHS system by processor-to-processor coupling with IOCNET Gigalink.



Coupling SCALEXIO with existing systems

1) *Multiprocessor functionality will be available at a later date. Unsynchronized coupling of several SCALEXIO systems is possible now.*

Configuration Variants

Flexible System Design for Optimum Scalability

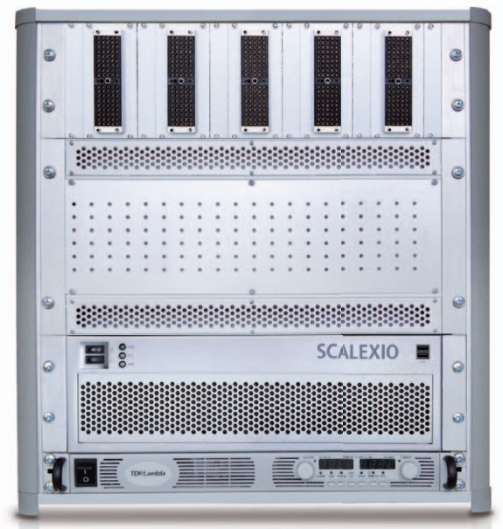
Each SCALEXIO system is highly resizable to fit its test tasks. Additional boards can be retrofitted if required. Hypertac connectors at the front can be wired according to individual project needs. This configuration is usually used for power-train and vehicle dynamics projects.

- Unit carrier SCALEXIO slot unit for 6 HighFlex I/O boards and DS2680 MultiCompact I/O unit
- SCALEXIO Processing Unit (p. 12)
- Battery simulation power supply unit (p. 10)

Software Configuration for Project Flexibility

In this example, only HighFlex I/O boards are used. With universal channels and integrated signal conditioning, a failure routing unit and converters, they make the system so versatile that it can be used in numerous different projects. The Hypertac connectors at the front can be wired generically or individually.

- Standard SCALEXIO connection unit with ECU and load connectors
- SCALEXIO slot unit for 20 HighFlex boards
- SCALEXIO Processing Unit (p. 12)
- Battery simulation power supply unit (p. 10)



Variant with External Processing Unit

The SCALEXIO system contains:

- Unit carrier with SCALEXIO slot unit for HighFlex boards (p. 14) and DS2680 I/O Unit (p. 22)
- Battery simulation power supply unit (p. 10)

Failure Simulation

License Concept

All SCALEXIO I/O boards and the DS2680 I/O Unit include a failure simulation function. To activate the Failure insertion Unit (FIU), you need an additional FIU license. You will be sent a dongle with the FIU license for the host PC. Each license can be used for one SCALEXIO system.

The licenses are scaled for using failure simulation with different numbers of channels. The failure simulation is configured with ConfigurationDesk (p. 32).

You need the appropriate SCALEXIO Failure Simulation license for the number of I/O channels you use in ConfigurationDesk. The FIU license is needed only for running the simulation, not for configuring the I/O channels with ConfigurationDesk.

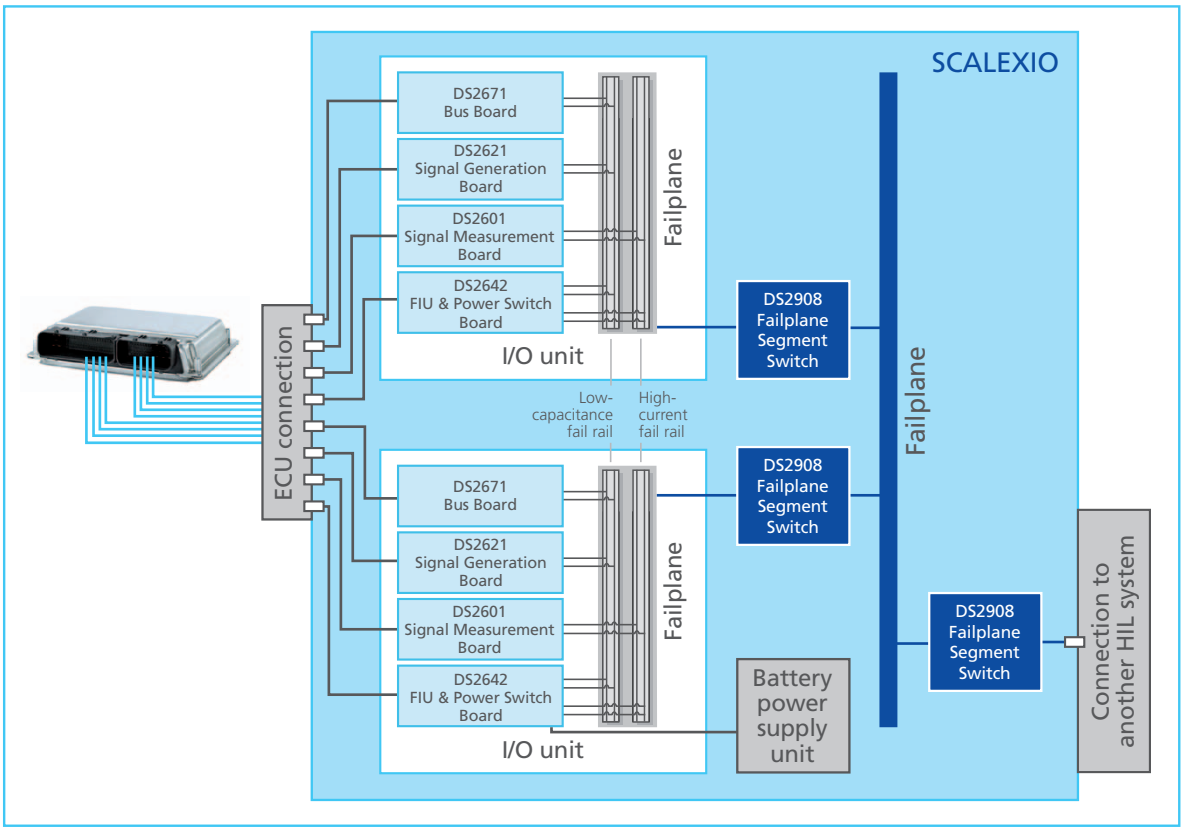
Hardware Components

The SCALEXIO Failure Insertion Unit (FIU) consists of several components:

- An onboard **failure routing unit (FRU)** on the I/O channels prepares failure simulation by switching the I/O channels to fail rails. The unit is available for each channel on each board and is implemented by relays.
- Depending on their properties, the channels are connected to the failure simulation system by the **high-current** (up to 80 A) or the **low-capacitance** (up to 1 A) **fail rail**. The low-capacitance fail rail connects signal generation channels and bus channels to the central FIU. The high-current fail rail connects signal measurement channels to the central FIU.
- The **central FIU** is located on either the DS2642 FIU & Power Switch Board (p. 20) or the DS2680 I/O Unit (p. 22). The central FIU consists of semiconductor switches and performs actual failure insertion.
- The **fail plane segment switch** is used to switch selected segments into the fail rail for failure simulation. This is a way to minimize performance capacities and avoid signal corruption with large systems that have a high number of I/O channels, contain several I/O units, or are distributed across several cabinets.

The following types of failure can be switched in via the central FIU:

- Short circuit to GND or U_{Bat}
- Broken wire
- Crossed wire between two channels
- Bouncing for all failures



The SCALEXIO FIU concept with an example selection of I/O boards.

Order Information

Product	Order Number
SCALEXIO Failure Simulation	■ SCLX_FS_100 (for 100 functions)
	■ SCLX_FS_200 (for 200 functions)
	■ SCLX_FS_300 (for 300 functions)
	■ SCLX_FS_1000 (for 1000 functions)
	■ SCLX_FS_UNLTD (for an unlimited number of functions)

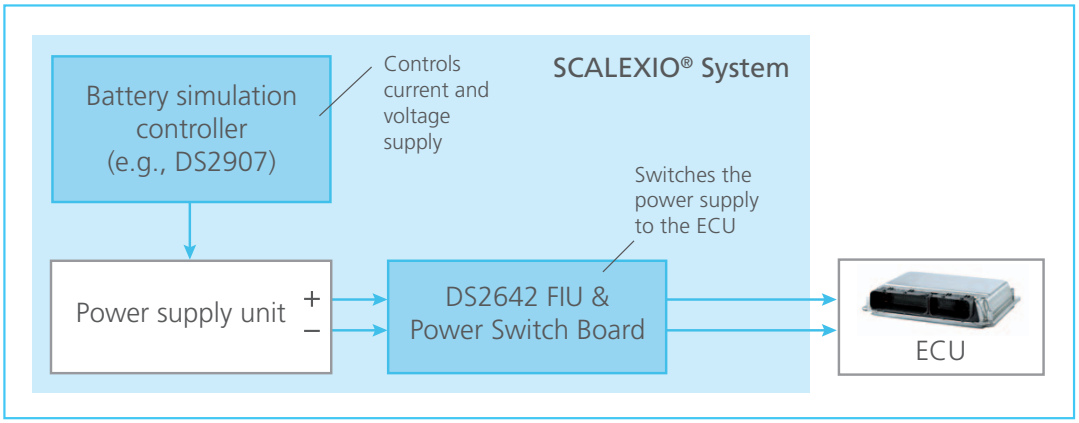
Battery Simulation

With the SCALEXIO system, the battery simulation can be addressed from directly within the simulation model. No additional I/O is needed. The battery simulation consists of three components:

- **DS2907 Battery Simulation Controller** (p. 27) to control the power supply unit by current and voltage values
- **Power supply unit** to generate current and voltage
- **DS2642 FIU & Power Switch Board** (p. 20) to switch the power supply to the ECU

The DS2680 I/O Unit (p. 22) has the control for the power supply and the power switch integrated.

You can read out and check the latest current and voltage values at any time during simulation. The voltage behavior is specified in the model.



Configuration Software

ConfigurationDesk

The SCALEXIO system's immense flexibility is fully supported and intensified by the new ConfigurationDesk® configuration software.

The configuration process involves three main tasks:

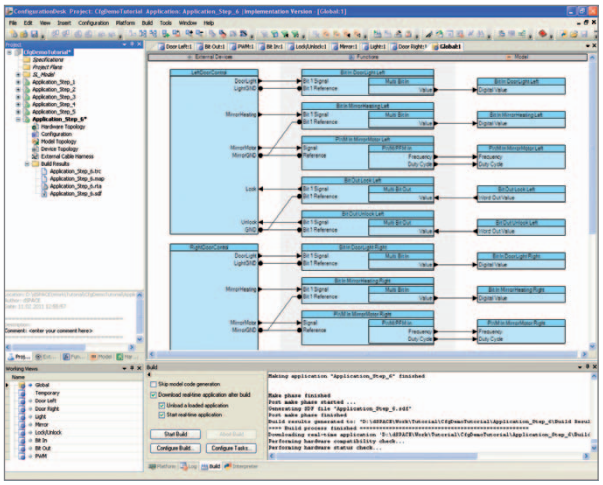
- Describing the connected devices
- Assigning I/O functions and hardware
- Connecting to the model

You can perform these tasks in any order and in a single tool, in an easy-to-read 3-column window.

ConfigurationDesk helps you select the I/O functions, assign hardware channels and generate code for the model. For an overview of all channel types available for the I/O functions, please see p. 4. You can create different views of each system to display only task-specific elements such as I/O functions.

ConfigurationDesk also produces complete documentation of the system, especially the signal path between the ECU pins and the I/O model.

For more information on dSPACE ConfigurationDesk, please see page 32.



ConfigurationDesk, the configuration and implementation software for SCALEXIO hardware.

Other Software

You can also make use of the entire familiar dSPACE software world:

- ControlDesk® Next Generation for instrumentation
- AutomationDesk® for test creation and automation
- MotionDesk for visualization
- Automotive Simulation Models for real-time simulation models
- ModelDesk for graphical model parameterization
- RTI CAN MultiMessage Blockset for connecting to CAN communication networks
- RTI CAN MultiMessage Blockset for connecting to LIN communication networks
- dSPACE FlexRay Configuration Package for configuring the system in FlexRay communication networks

SCALEXIO Processing Unit

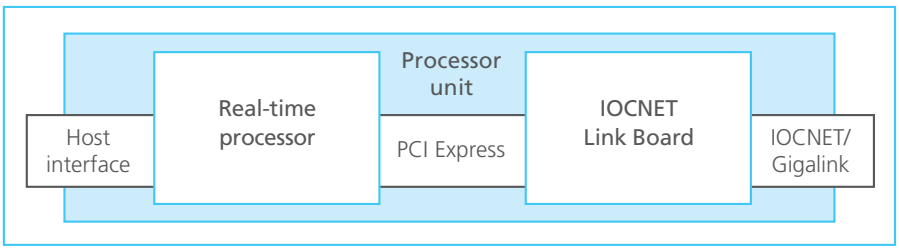
The newest processor technology

Highlights

- The latest x86 processor technology (Intel® Core™ i7)
- Communication with the SCALEXIO I/O boards via IOCNET
- SCALEXIO connectable to DS100x-based HIL systems (via Gigalink)
- Multicore support

The SCALEXIO processor core is based on an industry PC with an Intel Core i7 quad-core processor, a real-time operating system (RTOS), and a PCIe plug-on card developed by dSPACE for communication with the I/O and with other real-time processors. Because standard components are used for the motherboards and processors, they can be updated regularly to benefit from performance improvements in processor technology.

The SCALEXIO Real-Time Library builds on the QNX real-time operating system QNX and provides the I/O drivers, etc.



The real-time PC of the Processing Unit is extended by an IOCNET Link Board to connect it to the SCALEXIO system.

Multicore Support for Large Models

Large, complex simulation models can be distributed across three processor cores to ensure that they are computed in real time. The fourth core is reserved for internal system services. ConfigurationDesk (p. 32) is used to distribute model parts to the cores and to configure the communication behavior, the simulation hardware and the model connections.

IOCNET

SCALEXIO's communication network IOCNET (I/O Carrier Network) uses a proprietary dSPACE protocol to guarantee the simulator's real-time capability. It is the interface to the I/O boards, providing a flexible network topology and high bandwidth to connect a large number of I/O boards, even when they are far apart (p. 6).

IOCNET Link Board

The DS2502 IOCNET Link Board has four IOCNET connectors, which can connect I/O units or couple the SCALEXIO with other real-time processors like PHS systems.
The DS2502 also has angular processing unit (APU) functionality for highly precise angle-based simulation, for example, to generate injection and ignition signals. Up to six independent APUs can be used.

Host PC Interface

Communication with the host PC runs via Gigabit Ethernet. This means the SCALEXIO host PC system can be used in any company network. The IP address for the connection can be assigned via a DHCP server or stored on the SCALEXIO system itself.

Technical Details

Parameter		Specification
Processor		■ Intel Core i7-860 with 2.8 GHz
Memory		■ L1 cache: 32 + 32 kB (data + instructions) ■ L2 cache: 256 kB ■ L3 cache: 8 MB ■ 2 GB RAM memory (DDR3)
Angular processing unit (APU)		■ 6 APUs on the DS2502 IOCNET Link Board
Interfaces for I/O boards		■ 4 IOCNET connectors on the DS2502 IOCNET Link Board (optionally usable as Gigalink connectors)
Host interface		■ Gigabit Ethernet
Physical data	Physical size	■ 19-inch subrack ■ 3 HU ■ 483 x 133 x 400 mm (19.0 x 5.2 x 15.7 in)
	Cooling	■ Active cooling ■ Operating temperature 0 °C ... 40 °C (32 °F ... 104 °F)
	Voltage supply	■ 100 ... 240 V AC, 50/60 Hz

Order Information

Software	Order Number
SCALEXIO Real-Time Library	■ SCLX_RTLib
SCALEXIO Real-Time Library for Multicore Systems	■ SCLX_RTLib_MC

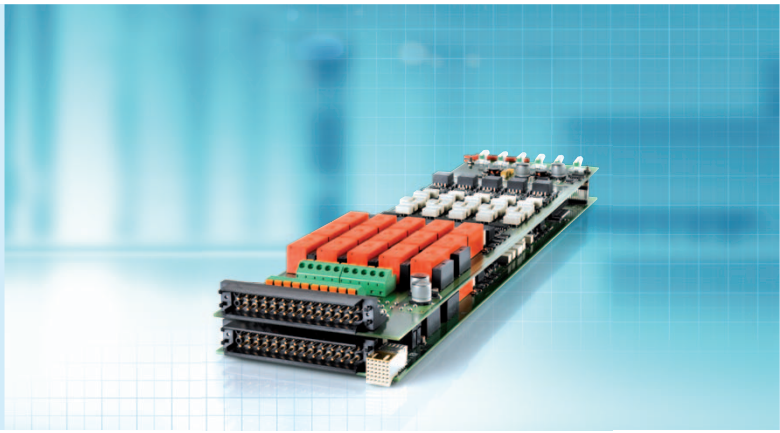
Hardware	Order Number
SCALEXIO Real-Time PC (Rack-Mount Version)	■ SCLX_RTPC_RACK_3HU/I7_860
DS2502 IOCNET Link Board	■ DS2502_4P

DS2601 Signal Measurement Board

HighFlex board for measuring ECU output signals

Highlights

- Current and voltage measurement
- Channel bundling to increase current carrying capacity
- Configurable fuses
- Onboard failure routing unit
- Onboard loads or external loads via 2nd connector
- Galvanically isolated channels



Application

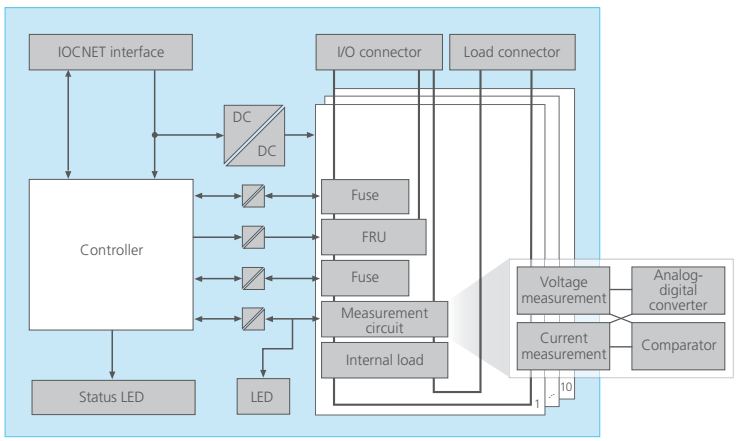
The DS2601 Signal Measurement Board measures ECU output signals and passes the measurement values to the real-time processor. Signal measurement can be time-triggered or event-triggered, and the execution of signal measurement can be voltage- or current-triggered.

For information on the failure simulation function, see Failure Simulation on p. 8.

I/O Functionality

The DS2601 has 10 flexibly configurable input channels, which can connect analog (analog-digital converter) and also digital (comparator) measurement units to measure the current and voltage. For example, the measurement units can be combined to trigger analog current measurement if a specified voltage is exceeded. The channels are defined and configured in the ConfigurationDesk® software.

The 10 channels on the DS2601 can be connected in parallel. This channel bundling increases the current-carrying capacity up to 80 A (RMS). ConfigurationDesk displays the bundled channels as one single I/O function. The DS2601 supports the use of loads for the ECU. You can either plug substitute loads onto the board itself or connect real loads via a cable harness to the externally accessible load connector.



Technical Details

Parameter		Specification
General		■ 10 galvanically isolated channels for signal measurement ■ Load connections for plugging loads of up to 2 W on the board ■ External load connection (for real loads or substitute loads > 2 W) ■ Up to 10 channels connected in parallel to increase the continuous current to max. 80 A ■ Status LED for overall board status ■ 10 channel-specific LEDs to indicate channel voltage
Electrical capacity		■ Voltage ±60 V per channel ■ Continuous current ±10 A per channel ■ Maximum continuous current of 80 A when all 10 channels bundled
Signal measurement (Flexible In 1)		■ Adjustable digital filtering for analog measurements ■ Current/voltage measurement: Sampling rate up to 250 kHz
	Voltage measurement	■ Voltage measurement ±60 V per channel ■ Voltage, analog and digital (settable trigger value) ■ ADC resolution 16 bit
	Current measurement	■ Current measurement ±30 A per channel ■ Current measurement, analog and digital (settable trigger value) ■ ADC resolution 16 bit
	Trigger	■ Time-, angle- and event-driven signal measurement ■ Voltage-driven current measurement ■ Control from within the model
Failure simulation (p. 8)		■ Onboard failure routing unit (FRU) ■ Signal forwarding to central FIU ■ Relay-based ■ Available for each channel
Electronic fuses		■ Software-configurable and software-resettable ■ Fuse trip settable 0.5 ... 10 A_{eff}
Internal communication interface		■ IOCNET
Physical data	Physical size	■ 410 x 100 x 41 mm (16.1 x 4.2 x 1.6 in) ■ Requires 2 slots
	Voltage supply	■ 24 V

Order Information

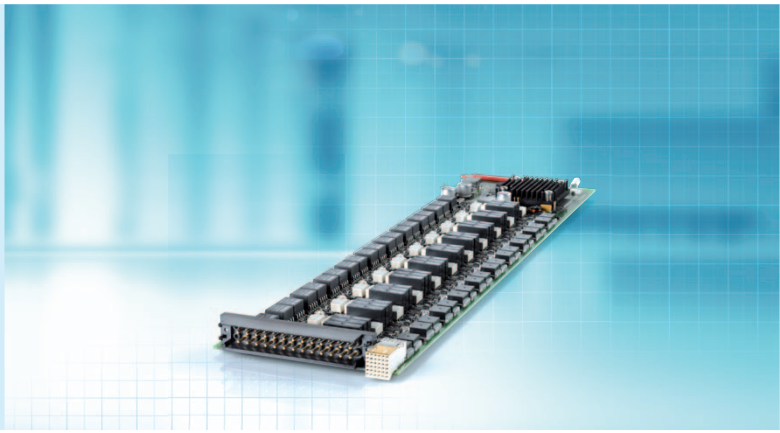
Product	Order Number
DS2601 Signal Measurement Board	■ DS2601

DS2621 Signal Generation Board

HighFlex I/O board for simulating ECU input signals

Highlights

- Signal generation for simulating voltage, current, resistance and switches
- Channel bundling to increase output voltage
- Onboard failure routing unit
- Galvanically isolated channels



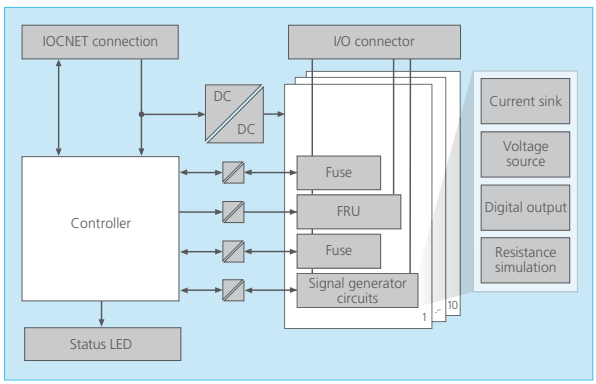
Application

The DS2621 Signal Generation Board stimulates ECU inputs. It mimics sensors or switches such as door contact switches, Hall sensors, and sensors for wheel speed and oil temperature. Each of the DS2621's 10 channels can be software-configured as a voltage source, a current sink, a digital output simulation or a resistance simulation.

For information on the failure simulation function, please refer to Failure Simulation on p. 8.

I/O Functionality

The DS2621 has 10 flexibly configurable output channels to make analog and digital signal generators available. To increase the current or voltage range, up to 10 channels can be bundled in parallel or in series. For example, two voltage sources can be switched in sequence, or two current sinks in parallel, to increase the output voltage or current. The digital output can be used as a switch and can generate time- and frequency-dependent signals (such as PWM). For example, the resistance simulation can be used to pass the specified temperature changes to an ECU via the environment model. Channel bundling is supported by the software. ConfigurationDesk displays the bundled channels as one single I/O function.



Technical Details

Parameter		Specification
General		■ 10 galvanically isolated channels ■ Up to 10 channels can be connected in sequence or in parallel to increase the current range to max. ±320 mA and the voltage range to max. ±60 V ■ Status LED for overall board status
Signal generation (Flexible Out 1)	Voltage source	■ Output voltage ±20 V ■ Output current ±40 mA ■ DAC resolution 16 bit ■ Signal frequency 0 … 140 kHz (sine)
	Current sink	■ Voltage range ±60 V ■ Current range ±40 mA ■ DAC resolution 15 bit ■ Signal frequency 0 … 140 kHz (sine)
	Resistance simulation	■ Resistance range 17.5 Ω ... 1 kΩ ■ Voltage range ±20 V ■ Current range ±40 mA
	Digital output	■ Voltage range ±60 V ■ Current range ±40 mA ■ Signal frequency 0 … 1 MHz
Failure simulation (p. 8)		■ Onboard failure routing unit (FRU) ■ Signal forwarding to central FIU ■ Relay-based ■ Available for each channel
Electronic fuses		■ 100 mA RMS ECU (effective value) ■ On ECU side tripping at I = 100 mA ■ On sensor side with configurable trip range I = 5 ... 40 mA
Internal communication interface		■ IOCNET
Physical data	Physical size	■ 410 x 100 x 15 mm (16.1 x 3.9 x 0.6 in) ■ Requires 1 slot
	Voltage supply	■ 24 V

Order Information

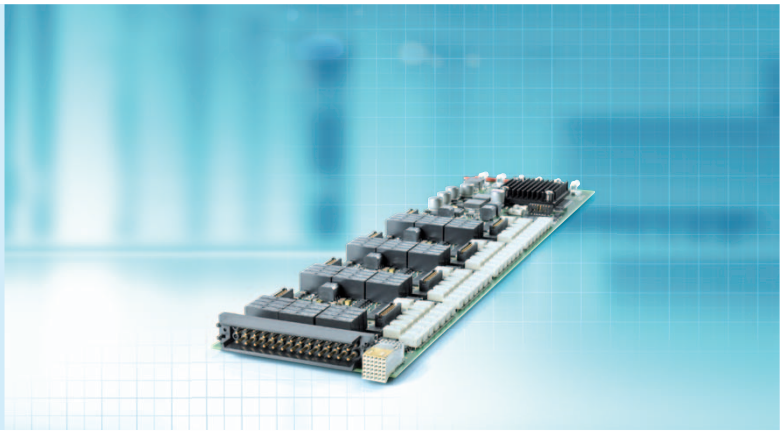
Product	Order Number
DS2621 Signal Generation Board	■ DS2621

DS2671 Bus Board

HighFlex board for interfacing to different bus systems

Highlights

- Supports CAN, LIN, and FlexRay bus systems
- 4 flexibly configurable channels
- Onboard failure routing unit



Application

The DS2671 Bus Board is the interface between the dSPACE Simulator and various bus systems. It has 4 multifunctional channels, each of which can support a bus system that is assigned to it by software.

The following buses and protocols are supported:

- FlexRay
- CAN (high-speed & fault-tolerant)
- LIN/K-line
- RS232, RS422, RS485
- TLL–based protocols

With its freely configurable channels, the DS2671 can serve different bus systems for one ECU. The selected bus system can easily be changed from project to project because the channels can be completely configured by software.

Other bus systems and protocols can be added on request.

I/O Functionality

Each channel on the DS2671 has a bus FPGA, all the standardly supported transceivers for bus systems and protocols, and a piggyback slot for customer-specific transceivers. The bus system controllers, which include certified IP cores such as the Bosch E-Ray controller for FlexRay, are implemented on the bus FPGA.

To use a bus system or protocol that is not yet standardly supported, you can install the necessary transceiver in the channel's piggyback slot.

A different bus system can be used on each of the 4 channels on the DS2671.

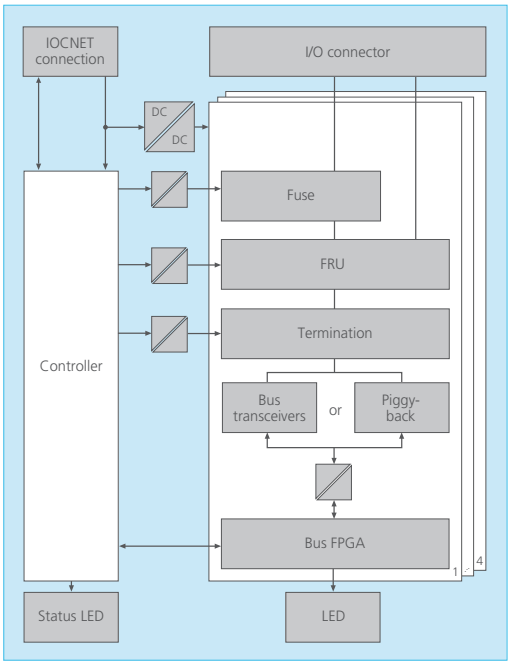
For information on the failure simulation function, please refer to Failure Simulation on p. 8.

Technical Details

Parameter		Specification
General		■ 4 independent bus channels ■ Onboard failure routing unit (FRU) (p. 8) ■ Overvoltage and undervoltage protection for transceivers ■ Parallel termination resistors with overcurrent protection ■ Status LED for overall board status ■ Channel-specific LEDs for individual bus channels (inactive, ready for data transfer, data transfer running, error message) ■ One piggyback module slot per channel for a customer-specific transceiver
Supported protocols/bus systems		■ FlexRay 2.1 (based on Bosch E-Ray) ■ High-speed CAN (ISO 11898-2) ■ Fault-tolerant CAN (ISO 11898-3) ■ LIN 2.0/K-line (ISO 9141) ■ RS232, RS422 and RS485 ■ TTL driver
Internal communication interface		■ IOCNET
Physical data	Physical size	■ 410 x 100 x 15 mm (16.1 x 3.9 x 0.6 in) ■ Requires 1 slot
	Voltage supply	■ 24 V

Order Information

Product	Order Number
DS2671 Bus Board	■ DS2671



DS2642 FIU & Power Switch Board

HighFlex board for power-switching with Failure Insertion Unit

Highlights

- Central FIU
- Switched battery voltage
- Failure feedforward
- High-precision current measurement on each channel

Application

The DS2642 FIU & Power Switch Board combines two components:

- **Central Failure Insertion Unit** (FIU) for simulating failures for the I/O channels of the SCALEXIO HighFlex boards and MultiCompact units
- **Power switches** for simulating up to 10 switched potentials, for example, on terminal K15

Central FIU

The central FIU on the DS2642 is connected to the failure routing units of the I/O boards via the fail rails. It switches the failures for the channels on the boards.
The following options are available:

- Broken wires on each individual channel, with or without bouncing as selected
- Crossed wire between two channels, with or without bouncing
- Short circuit to a fixed potential such as the supply voltage, with or without bouncing

The failures are prepared on the I/O boards by relays, and failure insertion is performed by semiconductor switches on the central FIU. The result is a fast switching frequency that enables loose contacts to be simulated.
For information on the failure simulation function, please refer to Failure Simulation on p. 8.

Power Switch

The power switch provides 10 switchable channels, which supply current to the external devices such as ECUs and loads. The current can be measured simultaneously. The central FIU can also use the power switch channels to simulate short circuits to the supply to the ECU. The channels can be bundled to increase the current, and are selected in ConfigurationDesk®. Several DS2642s can be used in one SCALEXIO system.

Current Measurement

The power consumption of the connected components can be measured precisely on each power switch channel.

Technical Details

Parameter		Specification
Power switches (Power Switch 1)	General	■ 10 channels for the ECU's current supply ■ Voltage 60 V ■ Continuous current 10 A per channel ■ Channel parallelization to increase the measurement range to max. 80 A (RMS) ■ Status LED for overall board status ■ 10 channel-specific LEDs for channel status (power switch open/closed)

	Current Measurement	■ Current measurement on each channel
		■ Precision mode
		  ■ Resolution 6.25 µA
		  ■ Sampling time 0.135 s
		  ■ Measurement range 0 ... 1.6 A
		■ Dynamic mode
		  ■ Resolution 150 µA
		  ■ Sampling time 262 s
		  ■ Measurement range 0 A ... 39 A

	Electronic fuses	■ 10 A RMS ECU (effective value) ■ Software-configurable and software-resettable
Failure Insertion Unit	General	■ Voltage ±60 V ■ Failure switch for up to 80 A ■ Continuous current for LC fail rail 80 A ■ Continuous current fail rail with low capacitance 1 A ■ Status LED for the FIU component
	Failure types	■ Broken wire ■ Short circuit to GND or U_{Bat} ■ Crossed wire between two channels ■ All failures with optional bouncing
Internal communication interface		■ IOCNET
Physical data	Physical size	■ 410 x 100 x 41 mm (16.1 x 3.9 x 1.6 in) ■ Requires 2 slots
	Voltage supply	■ 24 V

Order Information

Product	Order Number
DS2642 FIU & Power Switch Board	■ DS2642

DS2680 I/O Unit

MultiCompact unit for powertrain and vehicle dynamics scenarios

Highlights

- 140 channels for extensive I/O functions
- Galvanically isolated as a unit
- Compact half 19" unit
- Attractive price

The DS2680 I/O Unit is a MultiCompact unit for the SCALEXIO system that provides all the I/O channels required for the hardware-in-the-loop simulation of transmission or vehicle dynamics ECUs. Most of the I/O channels have a fixed function, i.e., they are dedicated analog or digital channels. With its predefined channels, the DS2680 has an attractive price, and is ideal for specific application scenarios.

I/O Functionality

The DS2680 has numerous I/O channels, each with a mostly predefined function. You can choose between analog and digital inputs and outputs, resistance simulation channels, and special I/O channels (for details, see p. 4). Signal measurement and generation can be time-triggered or angle-triggered.

Testing Electrical Failures

The DS2680 includes a Failure Insertion Unit (FIU) for testing ECU behavior in the event of a failure. It can be used as a central FIU for the SCALEXIO system. Each channel has a failure routing unit (FRU) for switching the connection to the FIU via the fail rails. For further information, please refer to Failure Simulation on p. 8.

Real Loads

Substitute loads can be plugged onto the DS2680 internally if required. An exchangeable load board is available for you to mount different plug-on loads. Real loads or large substitute loads can be connected externally via the load connector provided for them.

Component Variants

The DS2680 is available with and without an integrated bus board. The integrated bus board provides two channels for each of the bus protocols LIN, CAN and FlexRay. If you need more or different bus channels, for example, four CAN channels, you can use a HighFlex bus board in addition or as an alternative.

Technical Details

Parameters		Specification
General		■ Galvanically isolated as a unit
Signal measurement		■ Max. 6 A per channel ■ Substitute loads pluggable, up to 2 W per measurement channel ■ Connector for real loads ■ Channel bundling to increase current carrying capacity ■ Multifuse for electrical safety
	■ 20 analog inputs (Analog In 1)	■ Only voltage measurement ■ Measurement range 0 ... 60 V ■ Resolution 16 bit
	■ 30 digital inputs (Digital In 1)	■ Voltage measurement ■ Trigger value 0 ... 24 V ■ Voltage range 0 ... 60 V

	■ 18 variable inputs (Flexible In 2)	■ Voltage measurement digital
		  ■ Voltage range 0 ... 60 V
		  ■ Trigger value 0 ... 24 V
		■ Current measurement analog and digital
		  ■ Measurement range ±18 A
		  ■ Resolution 16 bit (analog)

Signal generation	■ 15 analog outputs (DC) (Analog Out 1)	■ Only voltage generation ■ Output voltage 0...10 V ■ Output current -5 ... +5 mA ■ Resolution 14 bit
	■ 8 analog outputs (DC) (Analog Out 4)	■ Output voltage 0...10 V ■ Output current -5 ... +5 mA ■ Resolution 14 bit ■ Current sink: Current range -30 .. +30 mA
	■ 7 analog outputs (DC) (Analog Out 3)	■ Only voltage generation ■ Output voltage -20...+20 V ■ Resolution 14 bit ■ Effective inner resistance 250 Ω
	■ 12 resistance simulation channels (Resistance Out 1)	■ Resistance range 16 Ω ... 1 MΩ ■ Voltage range -3 ... +18 V to GND ■ Current range -80 .. +80 mA ■ Power max. 250 mW
	■ 28 digital outputs (Digital Out 1)	■ Configurable as low-side/high-side switch or push/pull ■ Low-side = GND ■ High-Side V_{Bat} or Dig-Out-Ref ■ High-side voltage range: 5 ... 60 V ■ Current range -80 .. +80 mA
Special I/O channels	■ 2 analog input and output groups, e.g., for lambda (Analog In 2, Analog Out 2, Load 1)	■ 1 ADC ■ 1 DAC ■ 1 load (component channel) ■ Voltage range -10 ... +10 V ■ Current range -5 .. +5 mA
Voltage supply	■ 1 channel to control the power unit (Power Control 1)	■ Control of Lambda Genesys current supply
	■ 6 power switches without current measurement (Power Switch 2)	■ Voltage 60 V ■ Continuous current 4 x 6 A per channel (total current max. 50 A)

Parameters		Specification
Buses[1)]	■ 2 CAN (CAN 1)	■ Configurable as high-speed or low-speed CAN ■ Conventional CAN V_{Bat}
	■ 2 LIN (LIN 1)	■ Configurable as K-line ■ Conventional LIN V_{Bat}
	■ 2x FlexRay (FlexRay 1)	■ Only 4 bus lines, i.e., 1 fault-tolerant FlexRay bus (channels A + B) or 2 FlexRay buses (channel A) ■ Conventional FlexRay V_{Bat}
Failure Insertion Unit	General	■ Voltage ±60 V ■ Failure switch for up to 48 A ■ Continuous current for high-current fail rail 48 A ■ Continuous current fail rail with low capacitance 1 A
	Failure types	■ Broken wire ■ Short circuit to GND or U_{Bat} ■ Crossed wire between two channels ■ All failures with optional bouncing
Internal communication interface		■ IOCNET
Physical data	Physical size	■ 475 x 132 x 215 mm (18.7 x 5.2 x 8.5 in)
	Voltage supply	■ 24 V

1) *Only for DS2680 with bus support*

Order Information

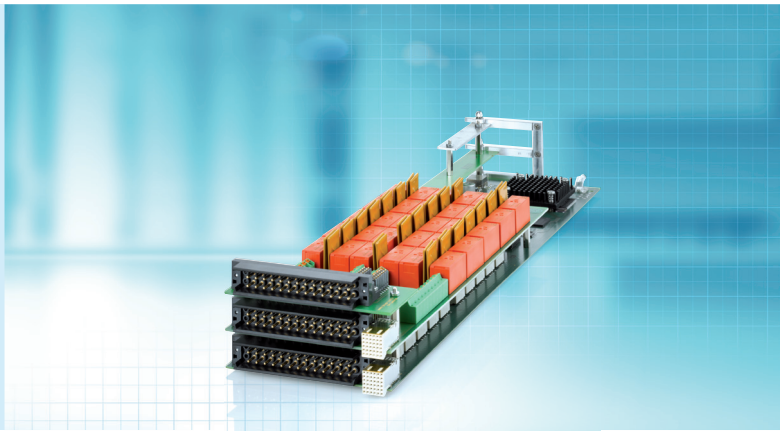
Product	Order Number
DS2680 I/O Unit (without bus support)	■ DS2680_ONLY
DS2680 I/O Unit (with bus support)	■ DS2680_2672
DS2680-IL Load Board (exchangeable load board)	■ DS2680_IL

DS2690 Digital I/O Board

MultiCompact board for vehicle body scenarios

Highlights

- Large number of digital I/O channels
- Signal measurement or generation
- Connection of real loads
- Seamless integration into SCALEXIO FIU concept
- Attractive price



Application Area

The DS2690 Digital I/O Board is the tailored SCALEXIO solution for hardware-in-the-loop (HIL) simulation of body electronics ECUs. Vehicle body applications such as electric window lift and windscreen wipers require many high-current digital I/O channels, as well as the ability to simulate failures.

Key Benefits

The DS2690 offers a large number of dedicated digital I/O channels for signal generation and measurement. Their supported I/O functionalities cover exactly the ones needed for body electronic ECUs. Real loads can be connected to each channel individually.

An on-board failure routing unit (FRU) enables failure simulation on all channels. For further information on the failure simulation function, please refer to Failure Simulation on p. 8.

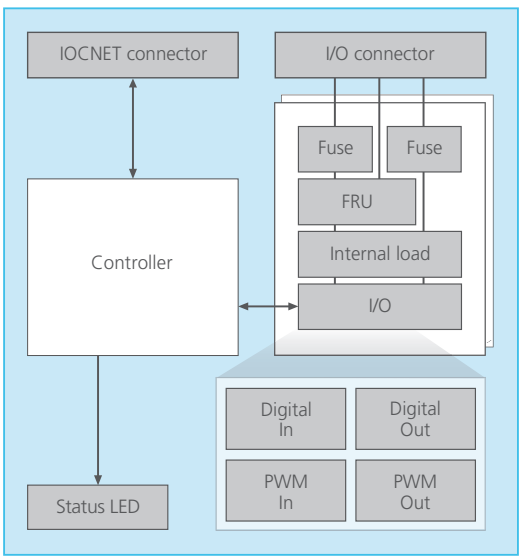
I/O Functionality

The DS2690 offers digital channels that are either predefined for signal measurement or signal generation, or can be individually configured for either. Channels for signal measurement and generation are usable as Digital In, PWM In or Digital Out, PWM Out.

The signal types and channel bundling are configured with ConfigurationDesk (p. 32).

Real Loads for Real Currents

Testing ECUs under realistic circumstances sometimes requires real currents, so real loads can be connected externally. Substitute loads are available internally as well.



Technical Details

Parameters		Specification
General		■ Galvanically isolated together with the system ■ Multifuse for electrical safety

Signal measurement
(Digital In 2)
		■ 10 channels
		■ Supported I/O functions
		  ■ Multi Bit In
		  ■ PWM/PFM In
		■ Measurement range 0 … 60 V
		■ Max. 6 A per channel
		■ Substitute loads pluggable, up to 2 W per measurement channel
		■ Real loads can be wired externally
		■ FIU via high-current failplane (p. 8)

Signal generation
(Digital Out 2)
		■ 10 channels
		■ Supported I/O functions
		  ■ Multi Bit Out
		  ■ PWM/PFM Out
		■ Configurable as low-side/high-side switch or push/pull
		■ Low-side = GND
		■ High-side = external reference for each channel
		■ Voltage range high-side: 5 … 60 V
		■ Current range -80 … +80 mA
		■ FIU via low-capacitance failplane (p. 8)

Signal measurement or generation
(Digital In/Out 1)
		■ 10 channels
		■ Supported I/O functions
		  ■ Multi Bit In
		  ■ PWM/PFM In
		  ■ Multi Bit Out
		  ■ PWM/PFM Out
		■ FIU via low-capacitance failplane (p. 8)

	Digital In	■ Measurement range 0 … 60 V ■ Max. 100 mA per channel ■ Substitute loads pluggable, up to 2 W per measurement channel ■ Real loads can be wired externally
	Digital Out	■ Configurable as low-side/high-side switch or push/pull ■ Low-side = GND ■ High-side = external reference for each channel ■ Voltage range high-side: 5 … 60 V ■ Current range -80 … +80 mA
Failure simulation		■ On-board failure routing unit (FRU) ■ Signal forwarding to central FIU ■ Based on relays ■ Available for each channel
Internal communication interface		■ IOCNET
Physical data	Physical size	■ 402 x 100 x 58 mm (15.8 x 3.9 x 2.3 in) ■ Requires 3 slots
	Voltage supply	■ 24 V

Order Information

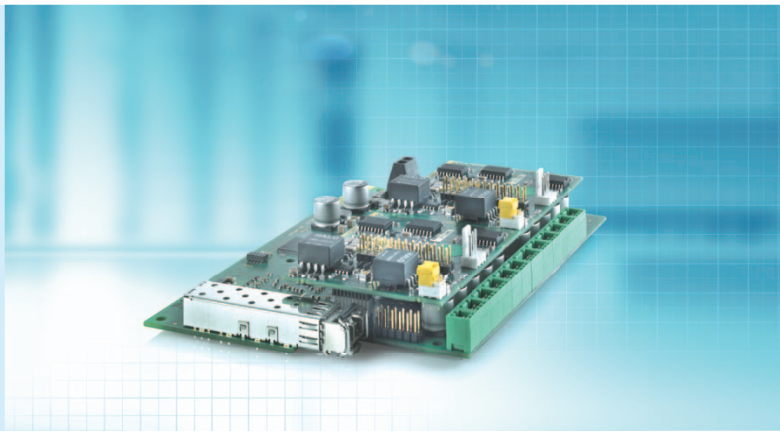
Product	Order Number
DS2690 Digital I/O Board	■ DS2690

DS2907 Battery Simulation Controller

Power supply unit for battery simulation

Highlights

- Supports different power supply units for battery simulation
- Wiring simplified by adapter



Application

The DS2907 Battery Simulation Controller is used to control the current and voltage values of battery simulation in a SCALEXIO system. Control is performed by software.

Two battery simulation modules can be plugged onto the DS2907 to support up to two power supply units from different manufacturers like TDK-Lambda and Delta. Other power supply units can also be used.

Supported Power Supply Units

Two adapter modules are available for easier connection and wiring of different power supply units.

No slot is needed for mounting it in SCALEXIO. An optical IOCNET connection acts as an internal interface.

Battery Simulation Adapter Module	Supported Power Supply Units
DS2907M1 Adapter Module	■ TDK-Lambda Genesys 20V76A
	■ TDK-Lambda Genesys 40V38A
	■ TDK-Lambda Genesys 60V25A
DS2907M2 Adapter Module	■ Delta SM35/45 (with RS232 option – P183)[1)]
	■ Delta SM15/100 (with RS232 option – P183)[1)]

[1)] *Example of custom-specific solution. Further power supplies can be supported on request.*

Order Information

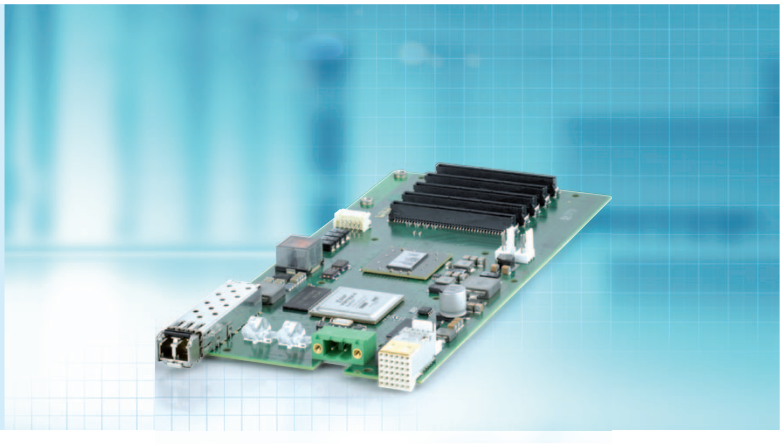
Product	Order Number
DS2907 Battery Simulation Controller (Base Board)	■ DS2907
DS2907M1 Adapter Module for TDK-Lambda power supply units	■ DS2907_M1
DS2907M2 Adapter Module for Delta power supply units	■ DS2907_M2

DS2655 FPGA Base Module

HighFlex board with user-programmable FPGA

Highlights

- User-progammable FPGA
- Flexible board for special I/O solutions
- Up to 5 piggyback modules for I/O can be added



Application Area

The DS2655 FPGA Base Module has been designed for applications that require very fast, high-resolution signal processing, for example:

- Hybrid vehicle applications
- Electric drive applications
- Wind energy converters
- Processor-based motor simulation
- FPGA-based motor simulation

Key Benefits

The DS2655 includes a powerful, freely programmable field-programmable gate array (FPGA), the Xilinx KintexTM-7 160T. To include I/O channels, you connect up to five I/O modules to the board.

Failure simulation can be added for each I/O module by using an additional FIU module. For further information on the failure simulation function, please refer to Failure Simulation on p. 8.

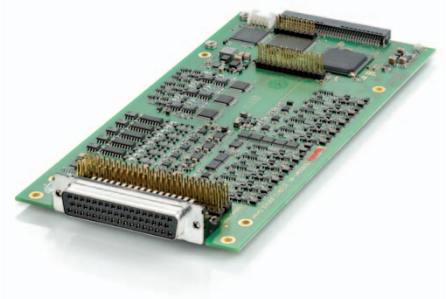
Programming the FPGA

Programs for the DS2655 FPGA Base Module's FPGA are programmed with the RTI FPGA Programming Blockset. These programs are downloaded to the FPGA via dSPACE ConfigurationDesk (p. 32).

You can test the program in offline simulation before implementing it on the real-time hardware. This enables you to react flexibly to new requirements, such as new interfaces or having to accelerate the execution of submodels.

DS2655M1 I/O Module

The DS2655M1 is a piggyback module for the DS2655 FPGA Base Module. It contains the digital and analog I/O channels needed for electric drives applications. Each module can be upgraded with one failure simulation module for accessing the central failure simulation unit (FIU) of the SCALEXIO system.



Technical Details DS2655

Parameter		Specification
General		■ User-programmable FPGA
FPGA		■ Xilinx KintexTM-7 160T ■ Logic cells: 162240 (DSP slices: 600) ■ Distributed RAM: 480 kBits ■ Block RAM: 11700 kBits
Connector for I/O Modules		■ 5
Device timing		■ 125 MHz
Internal communication interface		■ IOCNET
Physical characteristics	Physical size	■ 205 x 100 x 20 mm (8.1 x 3.9 x 0.8 in)
	Power supply	■ 24 V

Technical Details DS2655 M1

Parameter		Specification
Digital I/O		■ 10 channels, usable as input or output
	Input	■ Maximum input voltage: 15 V ■ Threshold for each channel adjustable from 1 V to 7.5 V
	Output	■ Push-pull drivers ■ One output voltage can be selected for all channels: 3.3 V or 5 V
Analog I/O	Input	■ 5 channels ■ Resolution 14 bit ■ Sampling rate 4.2 MSPS SAR ■ Input voltage range selectable for each channel: ±5 V or ±30 V
	Output	■ 5 channels ■ Resolution 14 bit ■ Update rate 10 MSPS ■ Output voltage range: ±10 V
Sensor supply		■ Adjustable ■ Output voltage range: 2 V to 20 V
Physical characteristics	Physical size	■ 208 x 100 x 18 mm (8.2 x 3.9 x 0.7 in)
	Power supply	■ 24 V

Order Information

Product	Order Number
DS2655 FPGA Base Module	Please inquire
DS2655M1 I/O Module	Please inquire

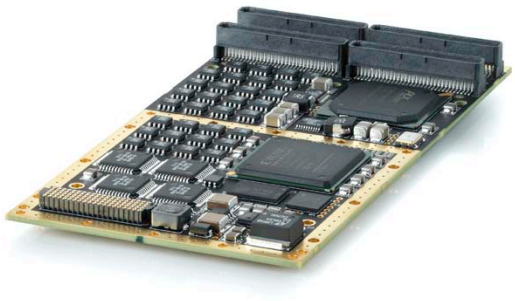
Solutions for Aerospace

For aerospace applications, dSPACE offers I/O solutions that provide access to aerospace-specific networks. The solutions are based on PMC modules from AIT, full-featured and aerospace industry-proven hardware. The PMC modules are plugged into the SCALEXIO processing unit (p. 12), providing the optimal bandwidth to the real-time model. dSPACE specifically developed QNX device drivers to ensure real-time simulation capability.

The solutions for aerospace are seamlessly integrated into the SCALEXIO system and the configuration process via dSPACE ConfigurationDesk (p. 32).

Interface to ARINC 429

- 4, 8, 16, or 32 software-programmable Tx/Rx channels per PMC module
- Programmable high-/low-speed operation
- All Tx/Rx channels can operate concurrently at high speed.
- Label selective trigger for capture and filtering



Interface to MIL-STD-1553

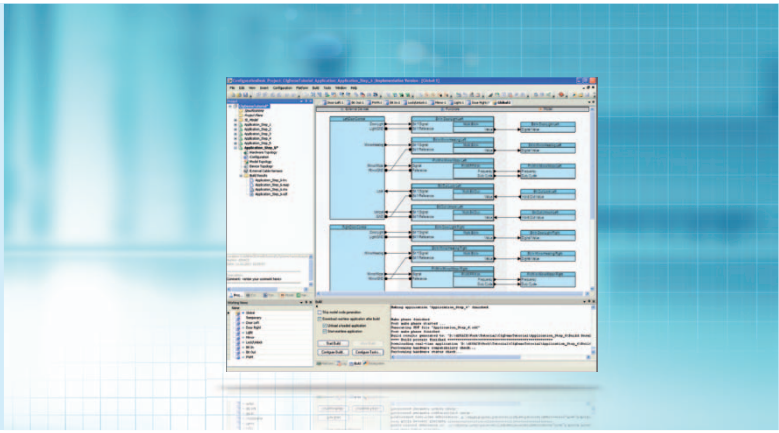
- One, two or four dual redundant MIL-STD-1553A/B databus streams
- Concurrent bus controller, 31 remote terminals, and bus monitor operation
- Multi-level trigger for capture and filtering
- IRIG-B time code encoder/decoder
- FPGA-based hardware architecture
- Transformer or direct coupling for connection to the MIL-STD-1553A/B bus stub

ConfigurationDesk®

Configuration and implementation software for dSPACE SCALEXIO® Hardware

Highlights

- Configure real-time applications graphically
- Manage signal paths between external devices (like ECUs or loads) and behavior model interfaces
- Implement behavior model code and I/O function code on dSPACE hardware
- Change the hardware configuration independently of the MATLAB®/Simulink® behavior model
- NEW: Manage multicore applications



Application Fields

ConfigurationDesk is an intuitive, graphical configuration and implementation tool. It is ideal for handling HIL real-time applications based on dSPACE SCALEXIO hardware, and for implementing behavior models and I/O function code on dSPACE SCALEXIO hardware. You can define and document external devices such as ECUs and loads, including their signal properties (descriptions, electrical properties, failure simulation settings, load settings). ConfigurationDesk displays user-defined views of the signal path between the ECU pins/load pins and the behavior model interfaces.

The Benefits

With ConfigurationDesk, it is easy to implement the behavior model code (from MATLAB/Simulink/Simulink Coder™) and the I/O function code (from ConfigurationDesk) on the dSPACE SCALEXIO hardware. The entire build process for a real-time application is handled by ConfigurationDesk. Comprehensive documentation options and graphical displays give you great project transparency – a great advantage with large-scale HIL project especially. You can assemble and configure the project-specific hardware offline as a "virtual system", in other words, as a purely software-based configuration. A real-time application can be executed for test runs even if parts of the necessary (and configured) I/O hardware are not physically available. In addition, you can generate a Microsoft® Excel® file with information on the wiring harness and on external devices.

Technical Details

Functionality	Description
I/O configuration and documentation	■ I/O configuration for connecting a MATLAB/Simulink behavior model to dSPACE SCALEXIO hardware: ■ External device topologies (properties of ECU pins and load pins) ■ Device port mapping (connections between the ECU/load pins and the signal ports of an I/O function) ■ I/O functions (describe the functionality between a set of external device ports and a set of model ports independently of the hardware topology) ■ Model port mapping (connections between function ports and model ports) ■ Model topology (model ports used for the ConfigurationDesk application) ■ Hardware resource assignment (mapping I/O functions to hardware resources) ■ Hardware topology (hardware resources used by I/O functions) ■ Documentation: ■ External device topologies (properties of ECU pins/load pins) ■ Model topology (describes the interface to the MATLAB/Simulink model) ■ Hardware topology (describes the simulator hardware: boards, internal wiring, internal loads, board locations, …) ■ Microsoft® Excel® file with pin information for external wiring harnesses ■ CAN and LIN signals are configured with the RTI CAN MultiMessage Blockset and the RTI LIN MultiMessage Blockset. FlexRay nodes are configured with the dSPACE FlexRay Configuration Package.
Real-time code generation	■ Complete build process for I/O functions (ConfigurationDesk) and the behavior model (MATLAB/Simulink/Simulink Coder)

Order Information

Products	Order Number
ConfigurationDesk – Loader Version (SCALEXIO) For use without license, limited function range (downloading real-time applications possible, but no changes or builds allowed.)	■ Free of charge ■ License for SCALEXIO Real-Time Library is needed (p. 12)
ConfigurationDesk – Implementation Version (SCALEXIO)	■ CFD_I_100 (implementation version for 100 functions) ■ CFD_I_200 (implementation version for 200 functions) ■ CFD_I_300 (implementation version for 300 functions) ■ CFD_I_1000 (implementation version for 1000 functions) ■ SCLX_I_UNLTD (for an unlimited number of functions) ■ License for SCALEXIO Real-Time Library is needed (p. 12)
SCALEXIO Failure Simulation (p. 8)	■ SCLX_FS_100 (for 100 functions) ■ SCLX_FS_200 (for 200 functions) ■ SCLX_FS_300 (for 300 functions) ■ SCLX_FS_1000 (for 1000 functions) ■ SCLX_FS_UNLTD (for an unlimited number of functions)

Relevant Software

Software		Order Number
Required	■ MathWorks MATLAB®/Simulink®/Simulink Coder™	–
	■ Operating system	www.dspace.com/goto?os_compatibility
Optional	■ RTI CAN MultiMessage Blockset	■ RTICANMM_BS
	■ RTI LIN MultiMessage Blockset	■ RTILINMM_BS
	■ dSPACE FlexRay Configuration Package	■ FCP
	■ Microsoft® Excel®	–

Application (Example)

Creating and Executing a New Real-Time Application with ConfigurationDesk

You can quickly create new real-time applications with ConfigurationDesk. The typical procedure is shown below, though the steps can be performed in a different order.

Step	Description
1. Create project and application	■ Whole real-time applications can be managed in ConfigurationDesk. This includes not only the associated ConfigurationDesk application data, but also general files such as project plans and specifications.
2. Define external devices	■ It takes just a few clicks to define the interfaces and signal properties of external devices such as ECUs and loads in ConfigurationDesk.
3. Select and configure I/O functions	■ I/O ports can be connected to the external devices graphically. You can define different views to focus on specific data sets. I/O functions automatically fetch failure simulation settings and load settings from the definitions of external devices.
4. Create model ports	■ The behavior model and ConfigurationDesk applications are connected via model port blocks.
5. Design the Simulink model	■ The model port blocks generated by ConfigurationDesk can be integrated into the MATLAB®/Simulink® model to implement the inputs and outputs between the model and the hardware. You can also use Simulink inputs and outputs in the model instead (only at the topmost model level, not inside subsystems).
6. Assign hardware resources	■ With ConfigurationDesk, the hardware resources (such as channels on the DS2601 Signal Measurement Board or the DS2621 Signal Generation Board) can be quickly assigned to the I/O functions.
7. Run the build process for the application and create the application for the dSPACE hardware	■ You can run the entire build process with ConfigurationDesk, both for the I/O functions and for the behavior model.
8. Download the application to the dSPACE hardware	■ The real-time application can be transferred to the dSPACE hardware quickly.

Failure Simulation License

To use failure simulation with SCALEXIO, you have to activate it with an additional FIU license. This must match the number of I/O channels you want to use. For example, if you work with a ConfigurationDesk license for 300 I/O functions, you require a SCALEXIO Failure Simulation License for 300 functions.

For further information on failure simulation with SCALEXIO, please see p. 8.

NEW: Configuration for Multicore Use

Large, complex models are distributed across multiple processor cores to ensure the simulation runs in real time. Two different workflows are possible for this. The first is to split the overall behavior model into separate Simulink models that can be imported into ConfigurationDesk. One processor core is able to execute one model. The core-to-model assignment is done automatically by ConfigurationDesk, and the inter-model communication is configured in ConfigurationDesk. In the second workflow, there is one overall Simulink model, and a special Simulink block is used to specify which subsystems should be computed together on one processor core. The inter-model communication is transferred from Simulink to ConfigurationDesk.

One processor core is always reserved for the communication to the host PC. The other cores can be used for behavior model calculation.

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