A Flexible and Reconfigurable Hardware-in-the-loop Simulator for a Vehicle Programme at Jaguar & LandRover

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Introduction

- Research Fellow in the Electrical & Simulations group in the IARC
- Peter Jones & Ross McMurran
- Evolutionary Validation of Complex Systems (EVoCS)
- VITAL (Virtual Integration and Test Automation Laboratory) at JLR (Whitley)
- Alexandros Mouzakitis & team

Seminar Outline

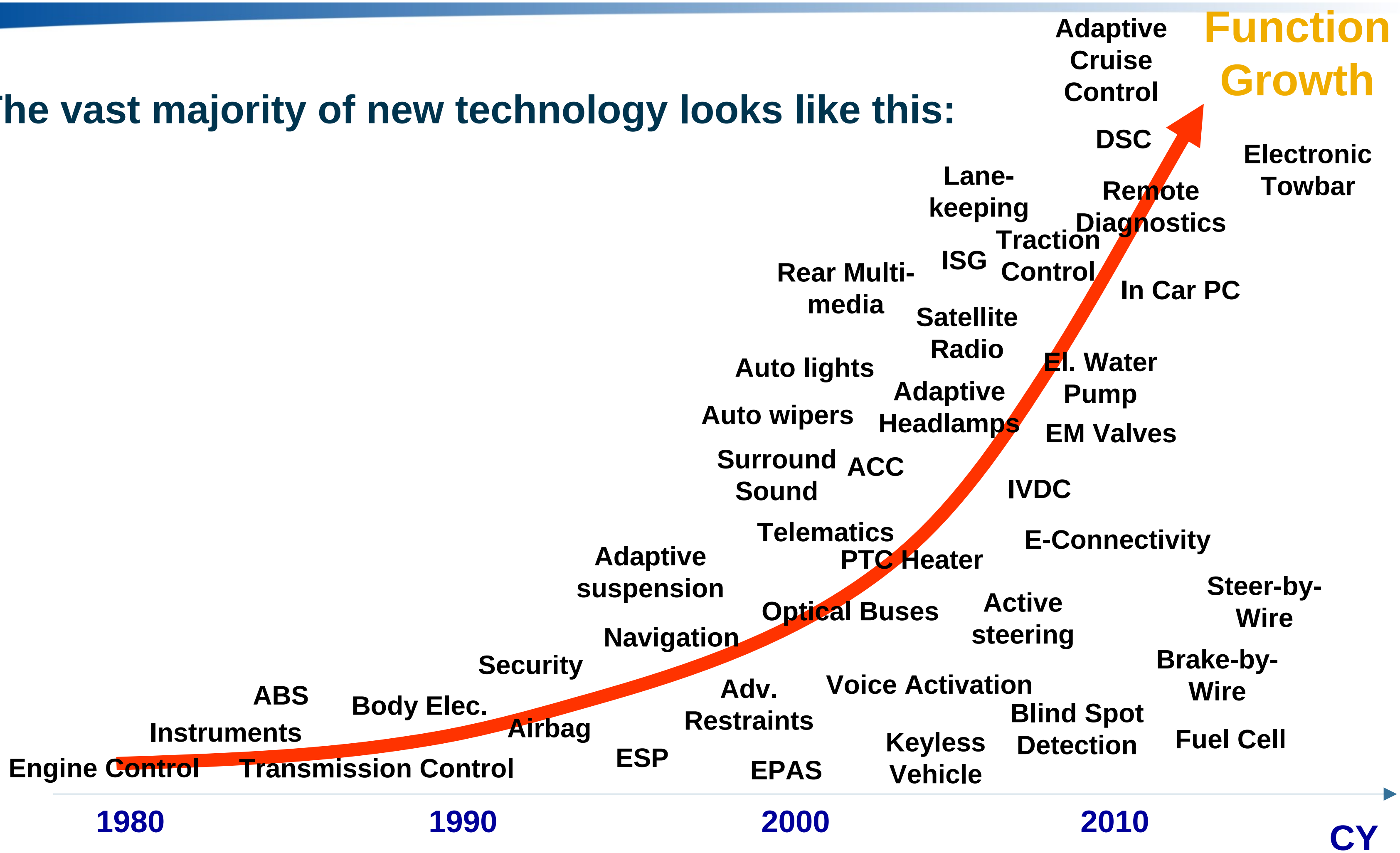
- Electronics in a vehicle
- ECU
- Hardware-in-Loop (HIL) platform
- Limitations of this platform
- Reconfigurable & Flexible HIL platform based on patented add2 Genix technology

Electronics in a Car

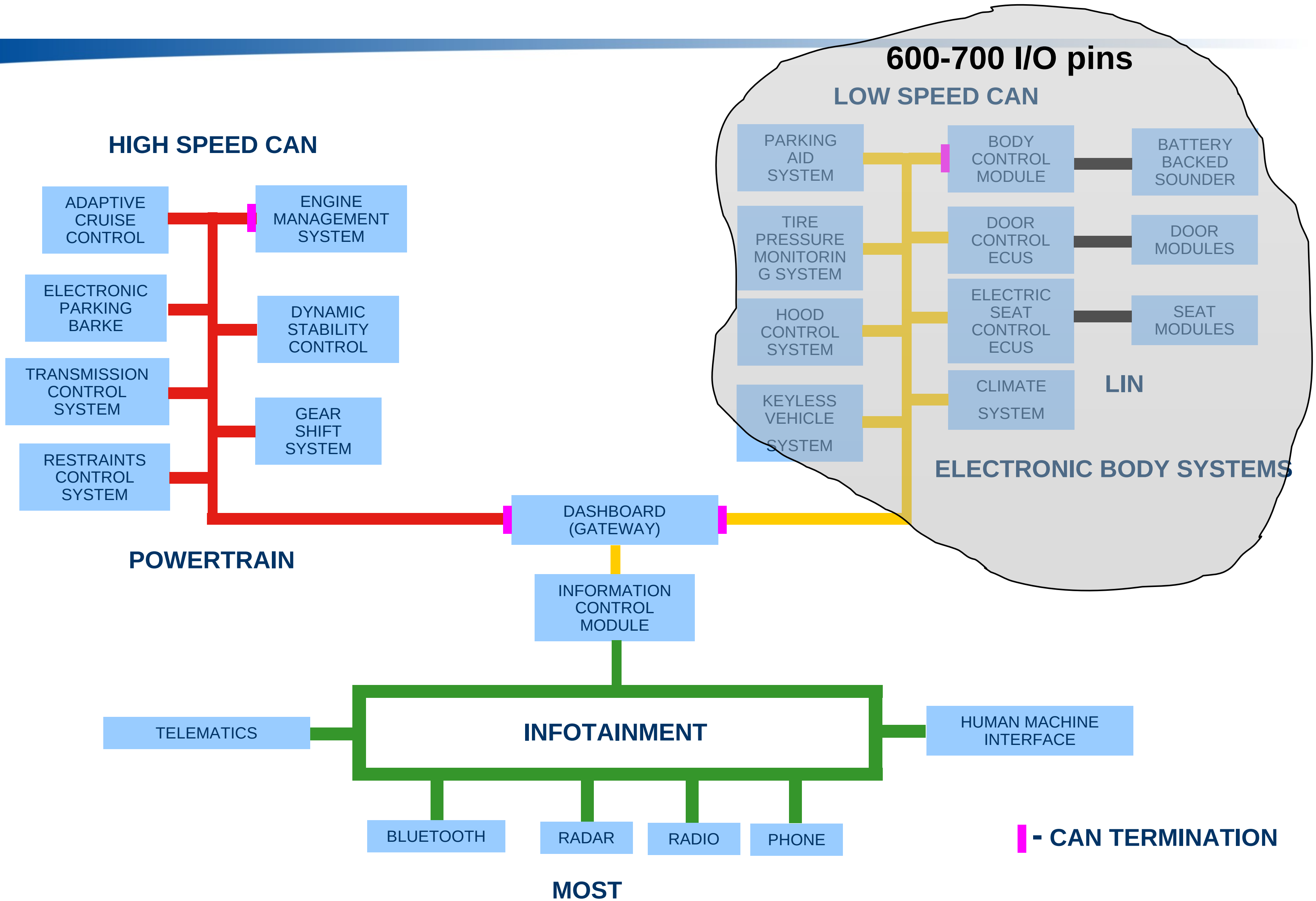
Just about everything!

Embedded control system usage

The vast majority of new technology looks like this:

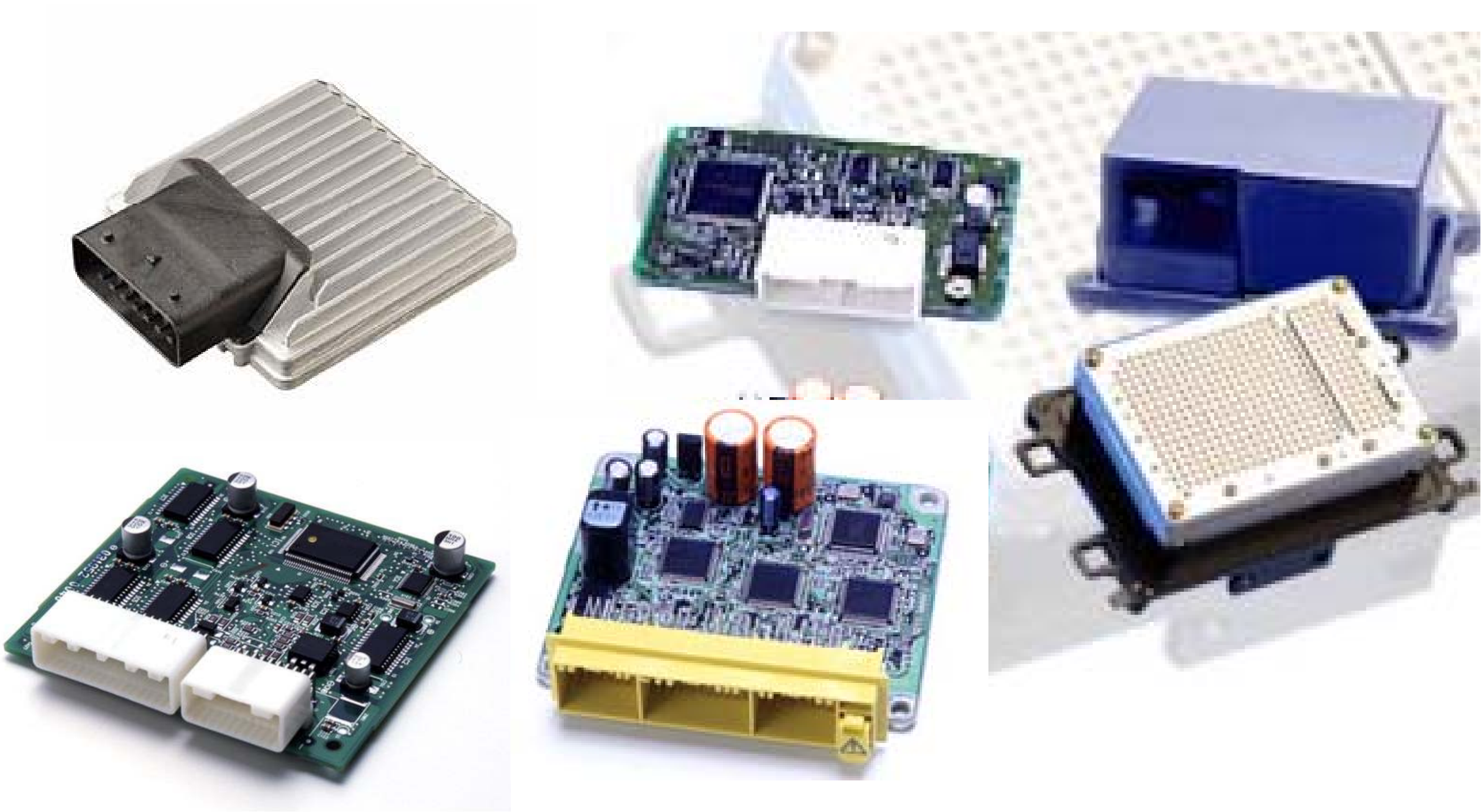


Typical automotive electrical architecture

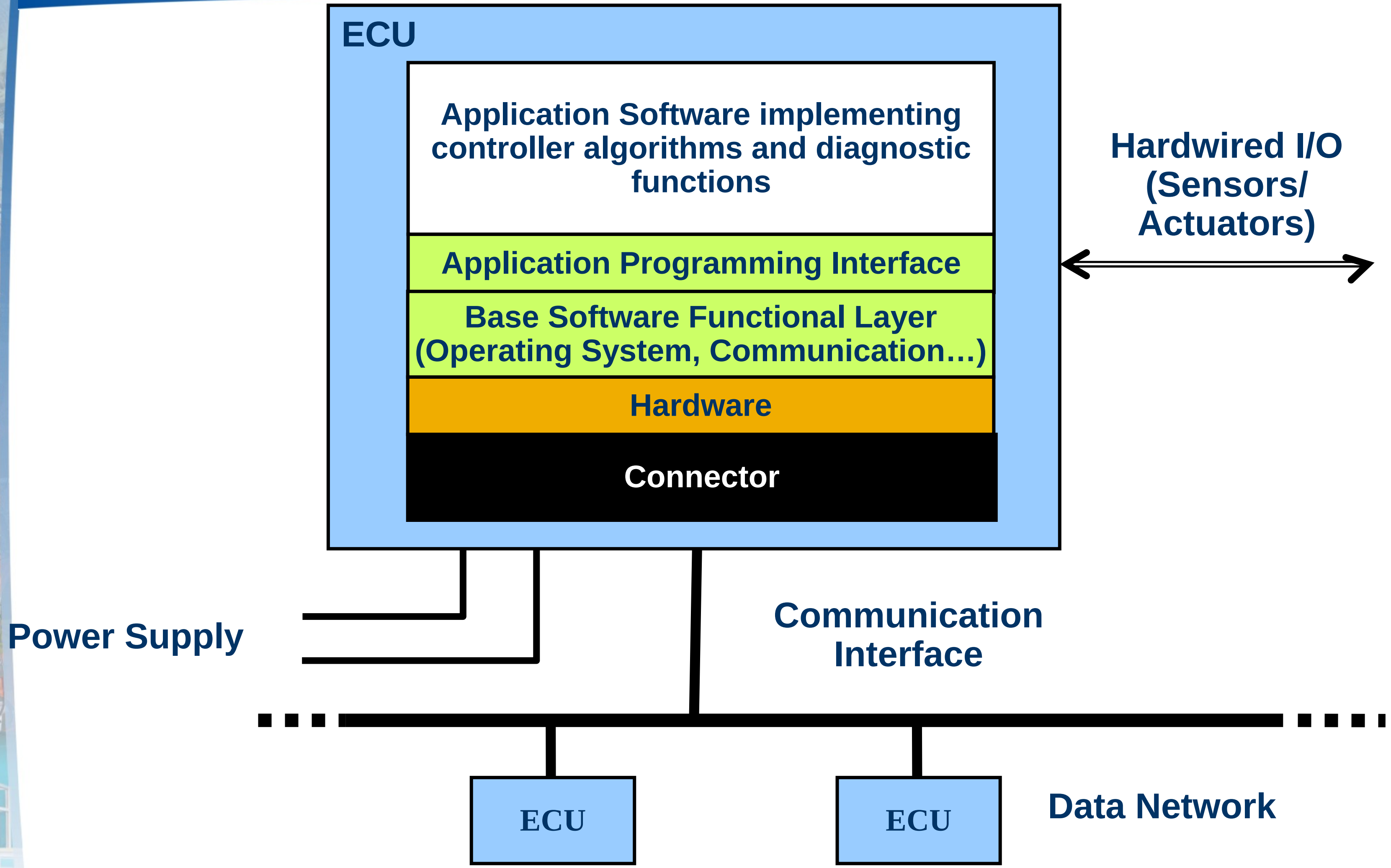


Electronic Control Unit (ECU) Overview

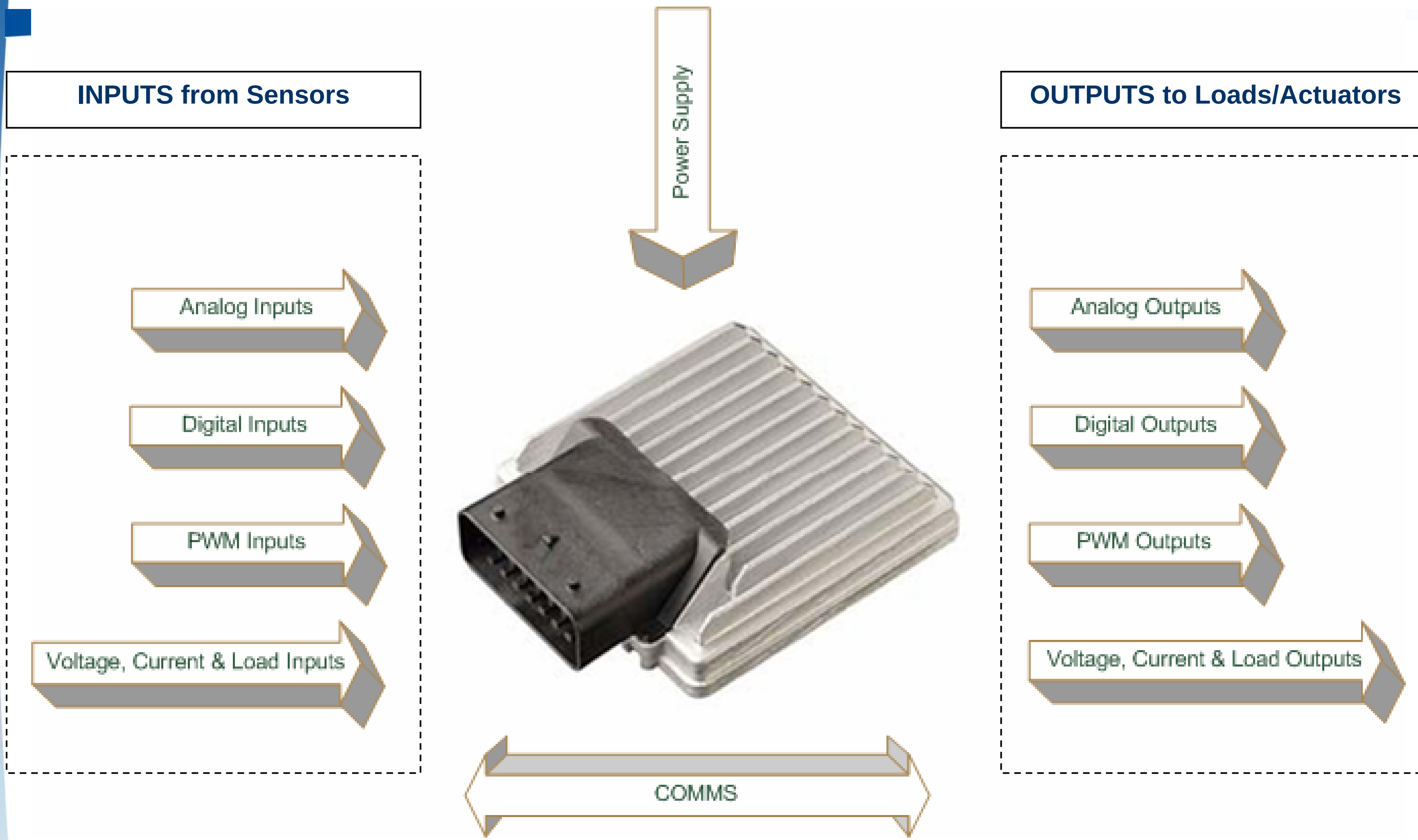
ECU is the generic term for automotive electronic control units



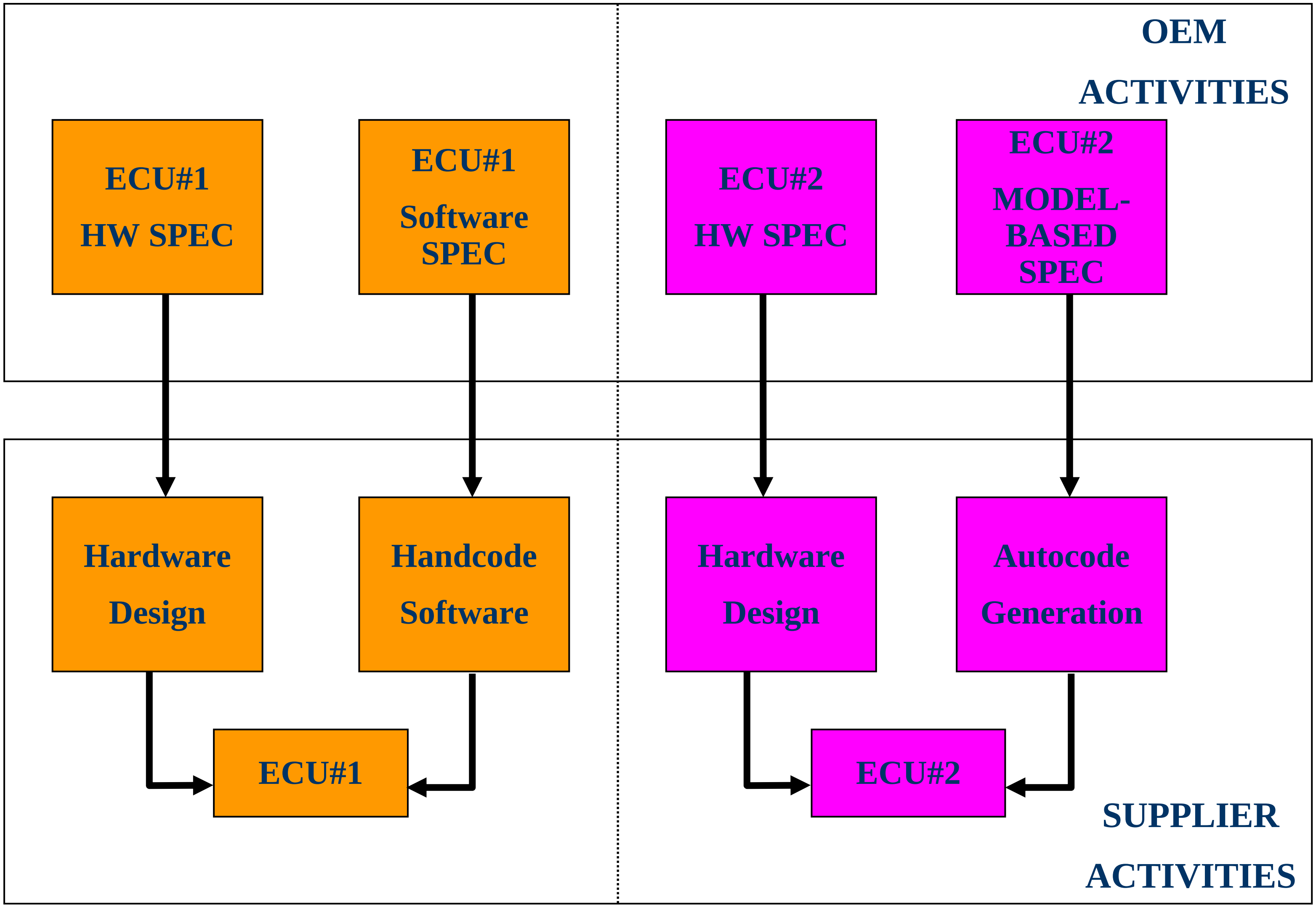
What is inside an ECU



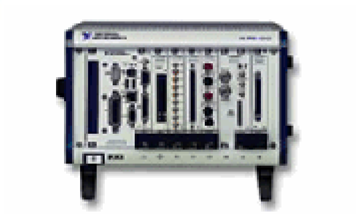
The Hardware Interface of an ECU



ECU Development Process



HIL Systems



PXI (National Instrument)

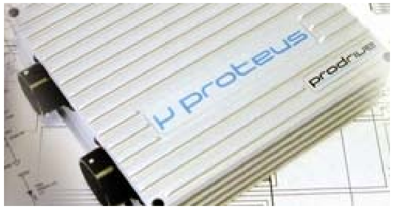
LabCar (ETAS)

RT-Lab (Opal-RT)

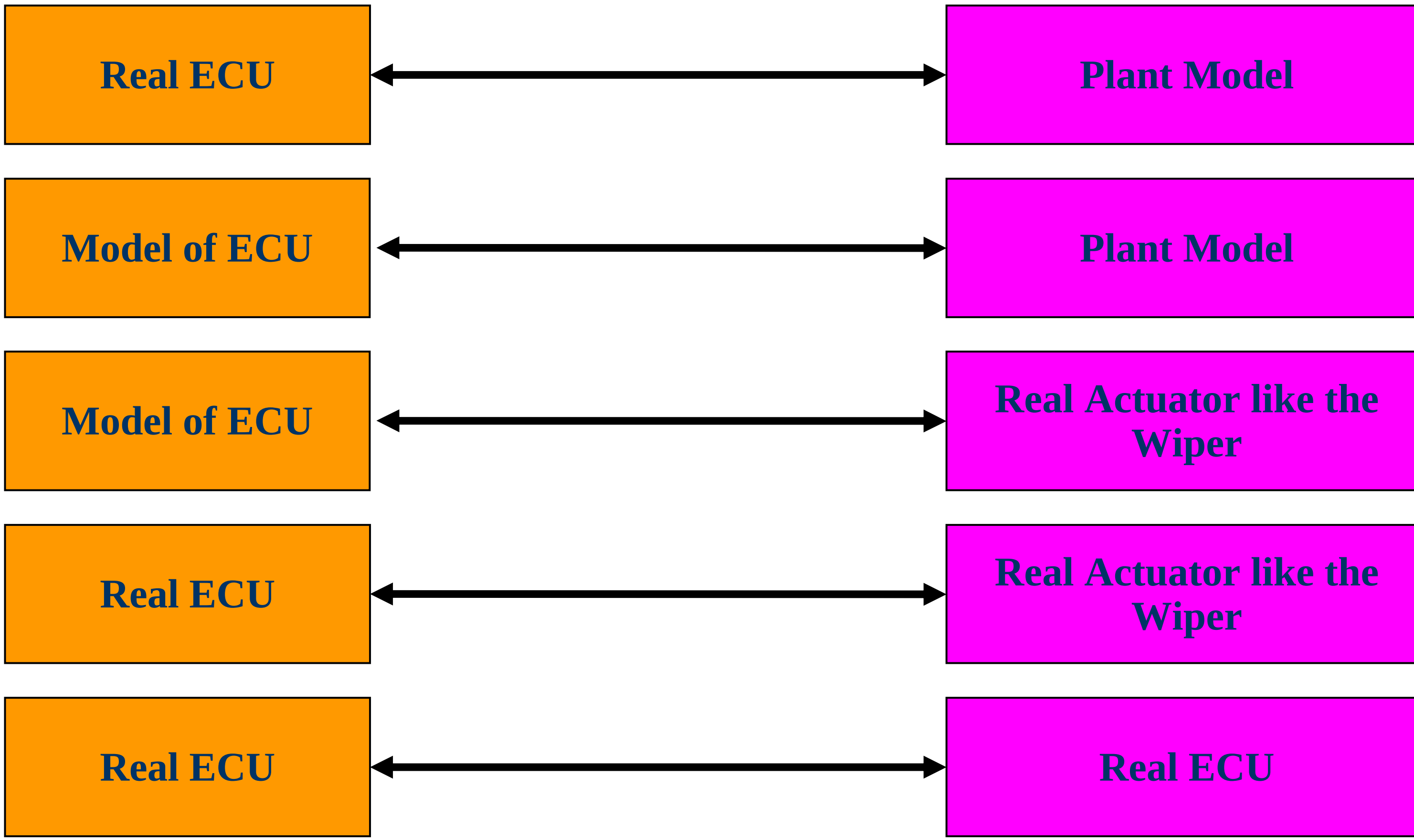
Microgen

Autobox

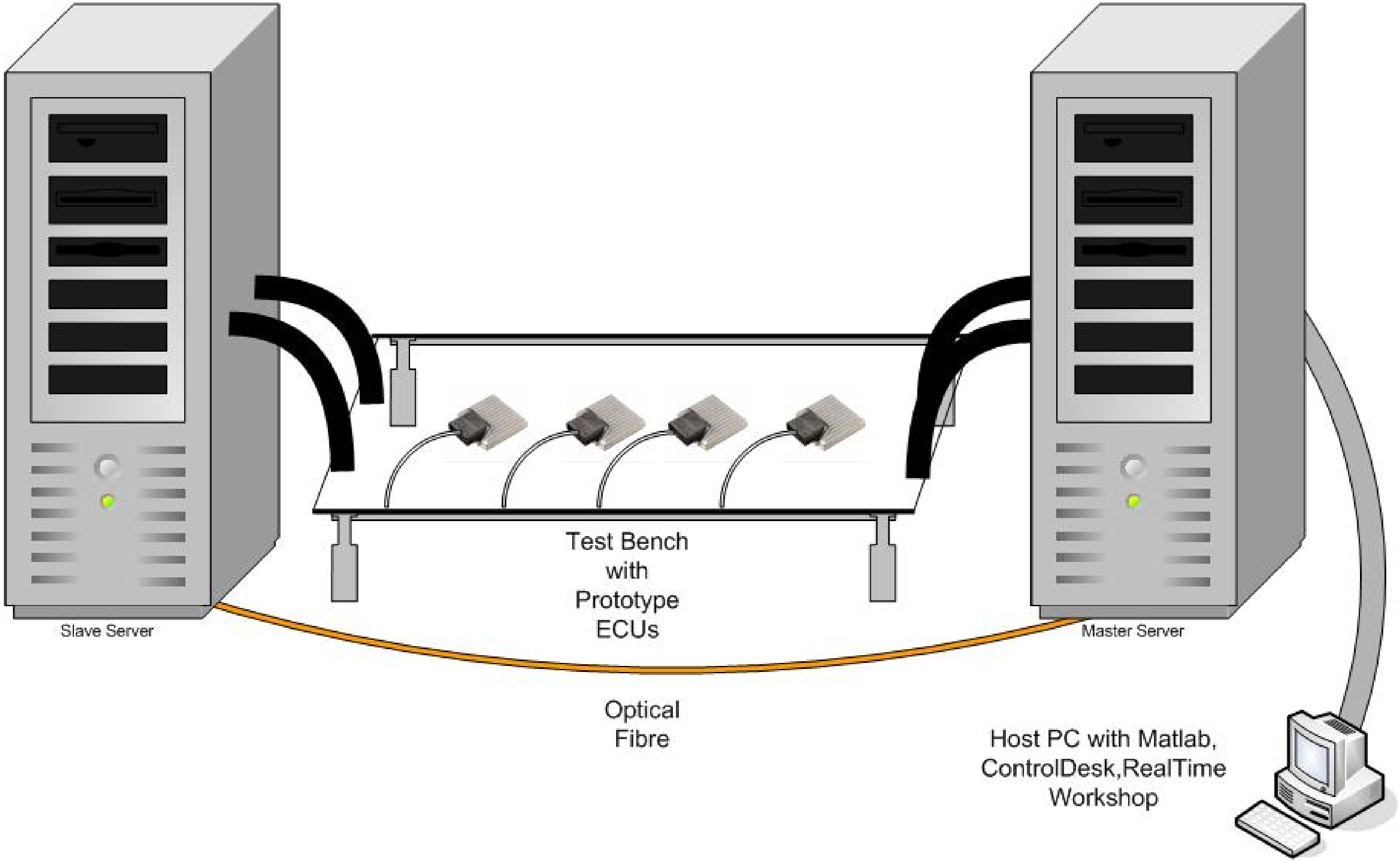
MicroAutoBox



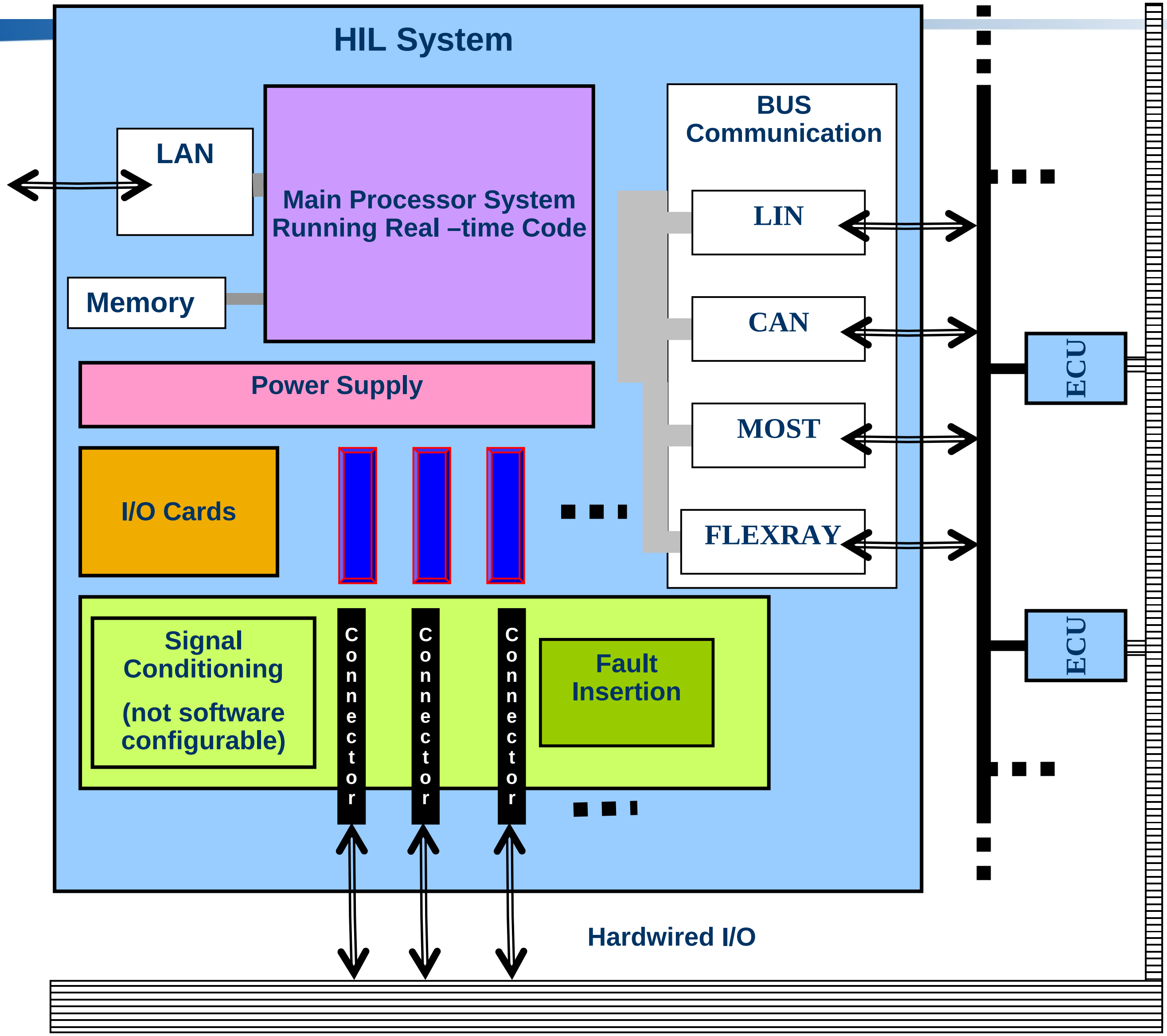
Various Interactions between ECU & HIL



A Typical HIL System



The inside of a typical HIL system



Advantages of using a HIL platform

Advantages of using a HIL platform for validation of ECU functionality

- **Reduced development costs and timescales**
- **Availability of the system for 24 hours**
- **Safer testing conditions because of the ability to simulate operating conditions like fault and damaged conditions**
- **Functionality testing can begin earlier in the design process with models of the ECUs even before the actual ECU hardware become available**

Weaknesses of existing HIL Platform

Main weaknesses are:

→Wiring harness HIL simulation platform needs to be redone each time the hardware interface of an ECU changes

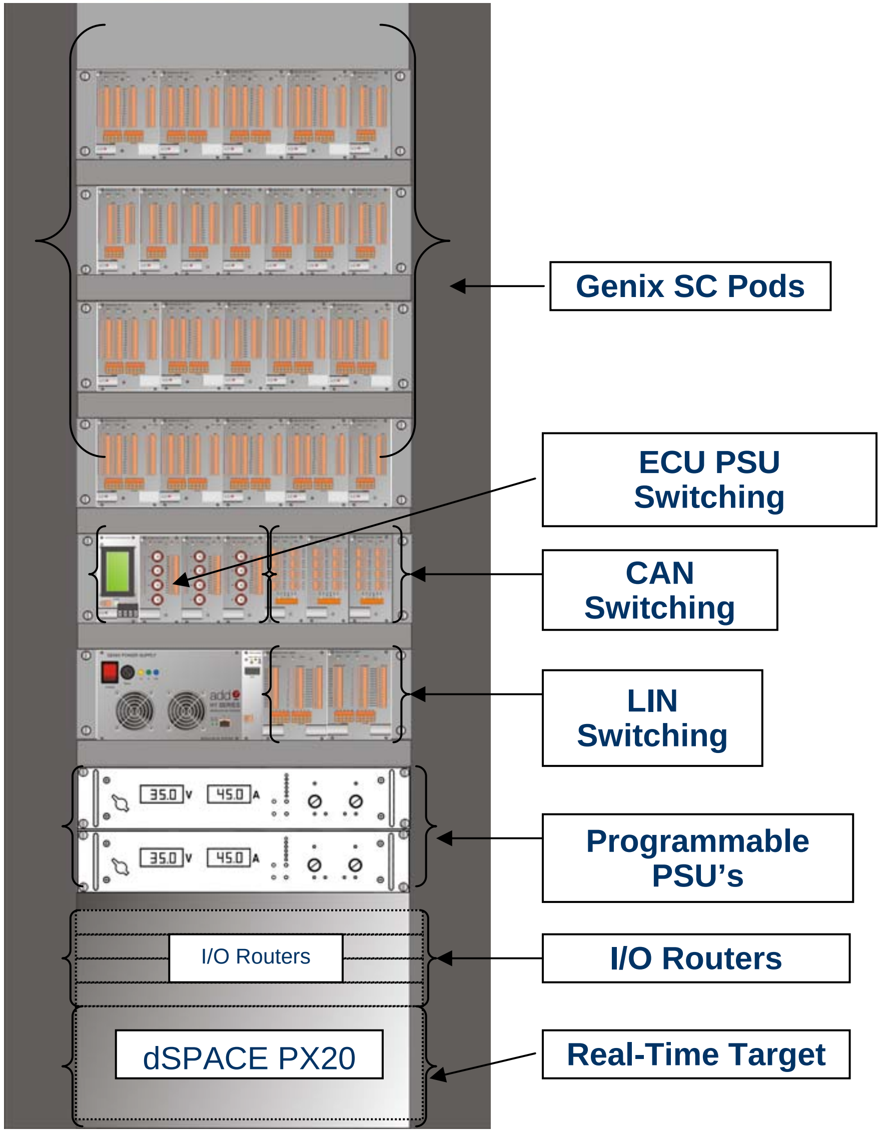
→Uncertainty in module specifications

→Number of likely model variants

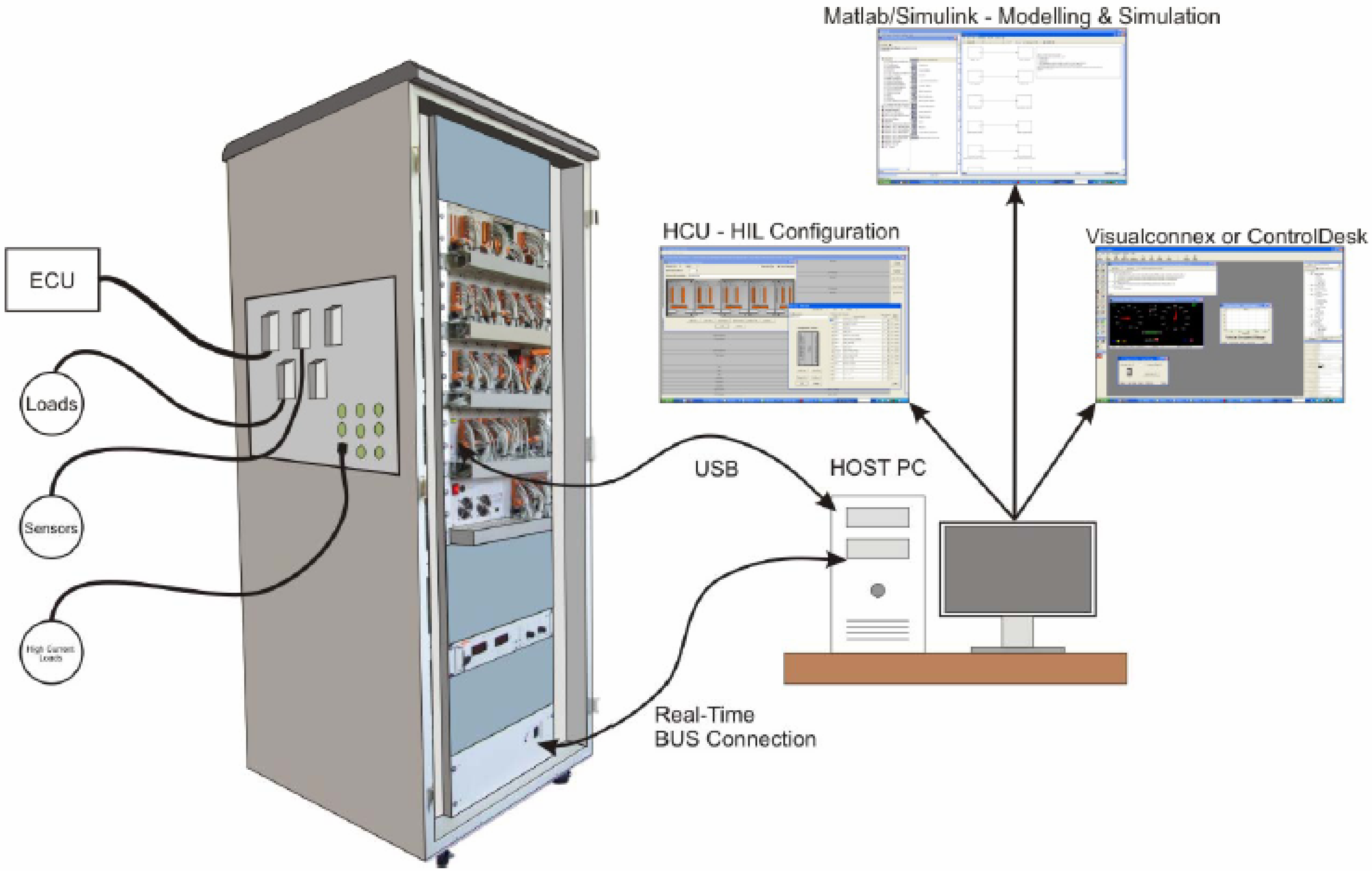
→Requirement for reusing HIL system in different applications

→Reusability of the HIL platforms from one vehicle programme to another is limited

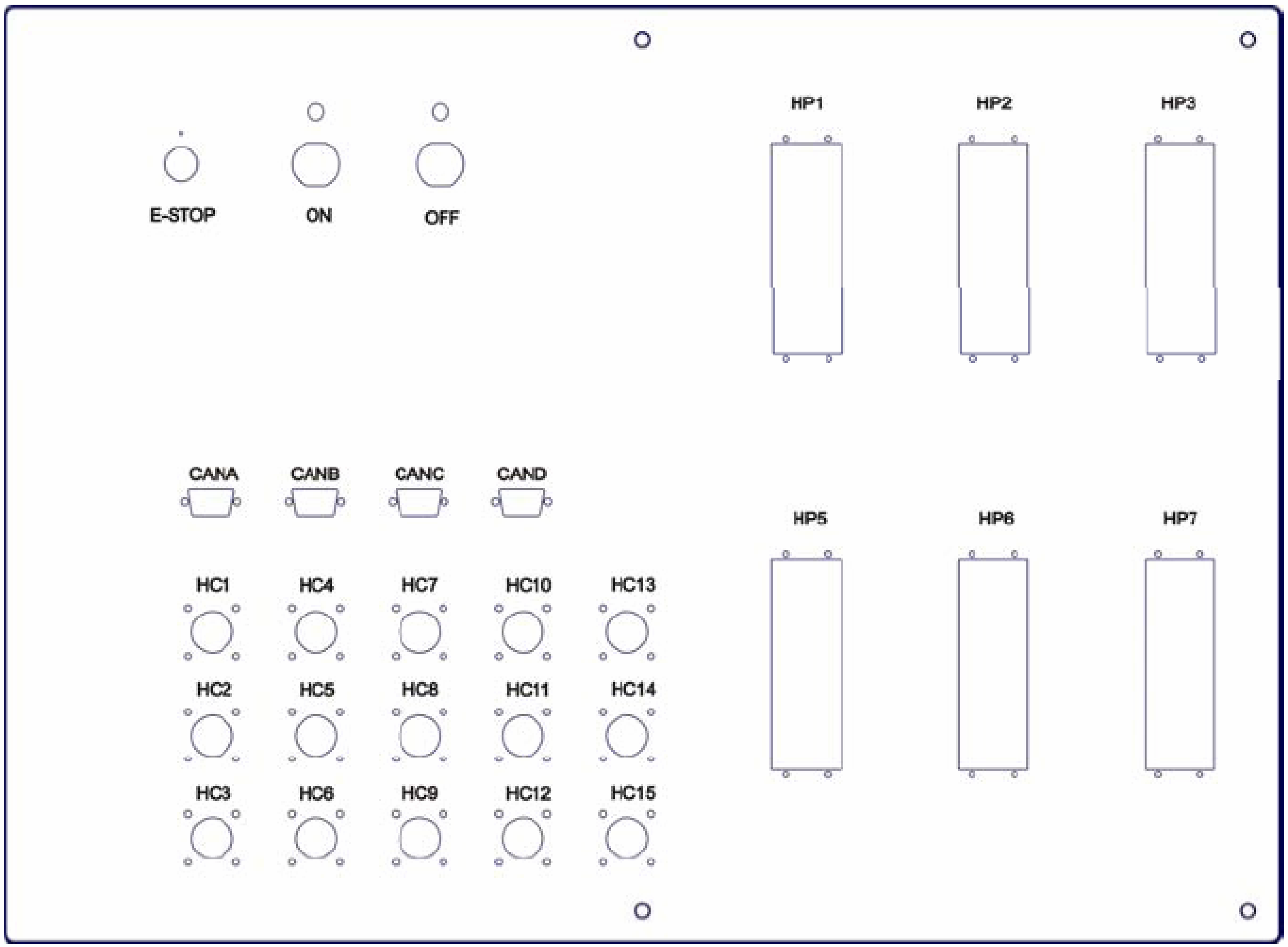
Jaguar Reconfigurable HIL Platform



Jaguar Reconfigurable HIL Platform

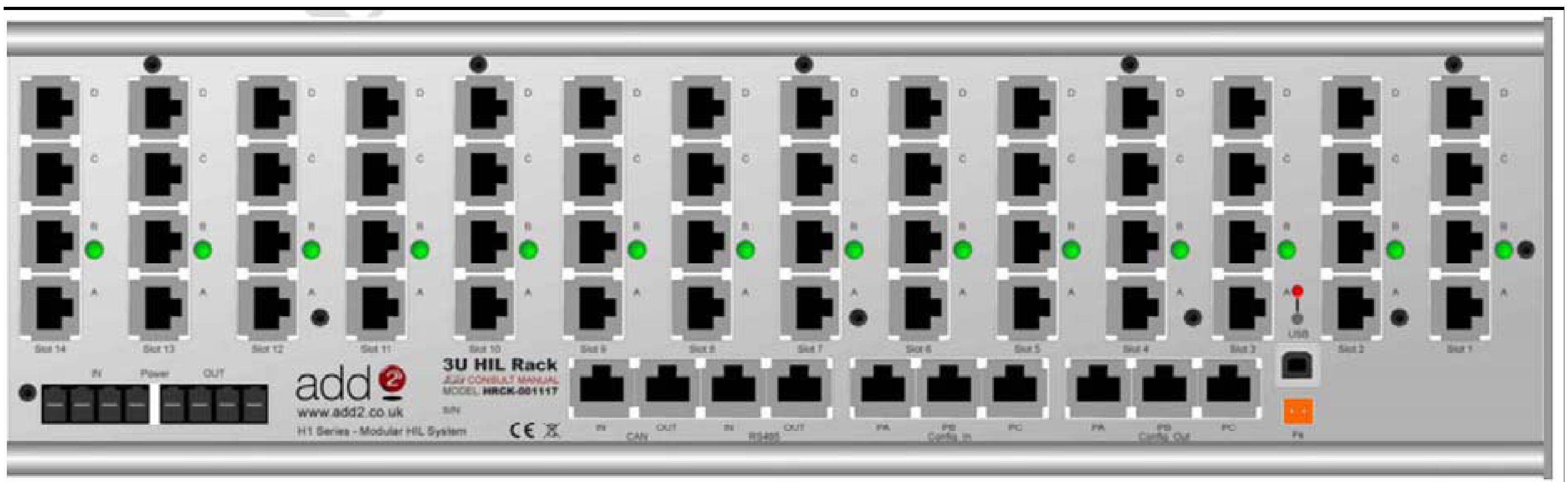


Connector Panel Arrangement for an add2 HIL simulator

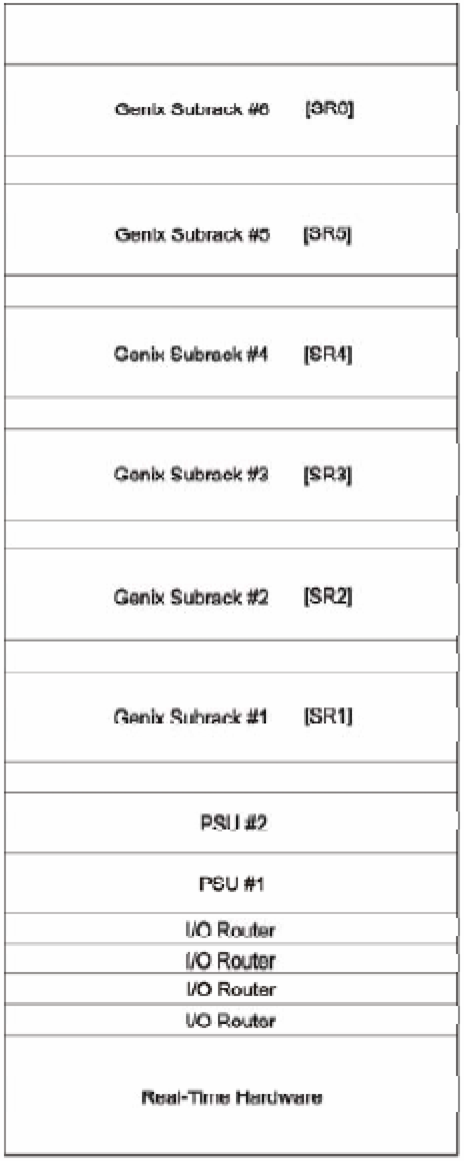


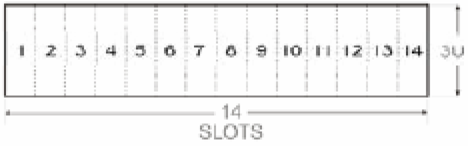
Genix Subrack

BackPlane of Genix SubRack

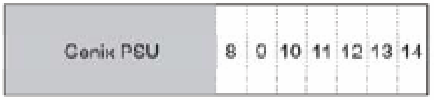


Outline illustration of add2 HIL Simulator

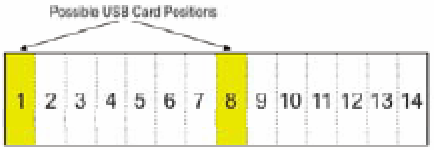




b) 14 Slot Subrack



c) 7 Slot Subrack with Genix PSU

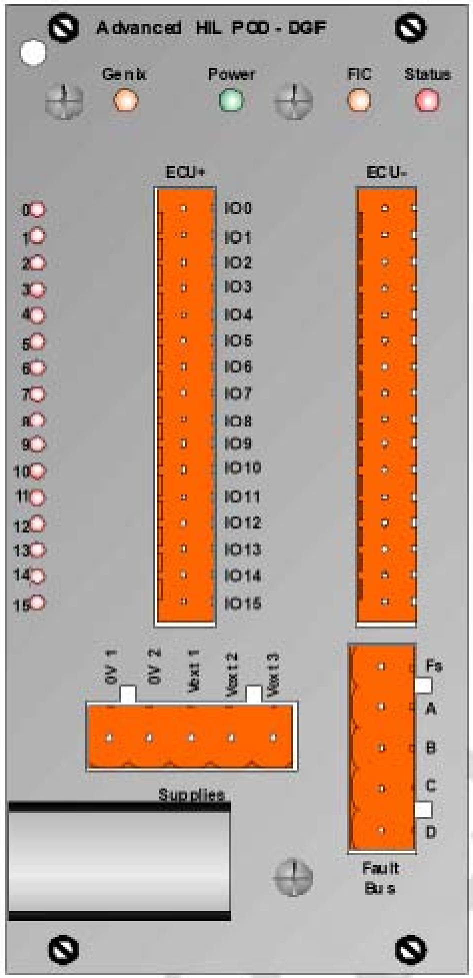


d) USB Card Positions within a Subrack

The Genix Pod

- DG – Differential Genix
- DGF – Differential Genix with Fault Insertion
- DGLF – Differential Genix with Load & Fault Insertion
- DGELF – Differential Genix with External Load and Fault Insertion

Genix Pods

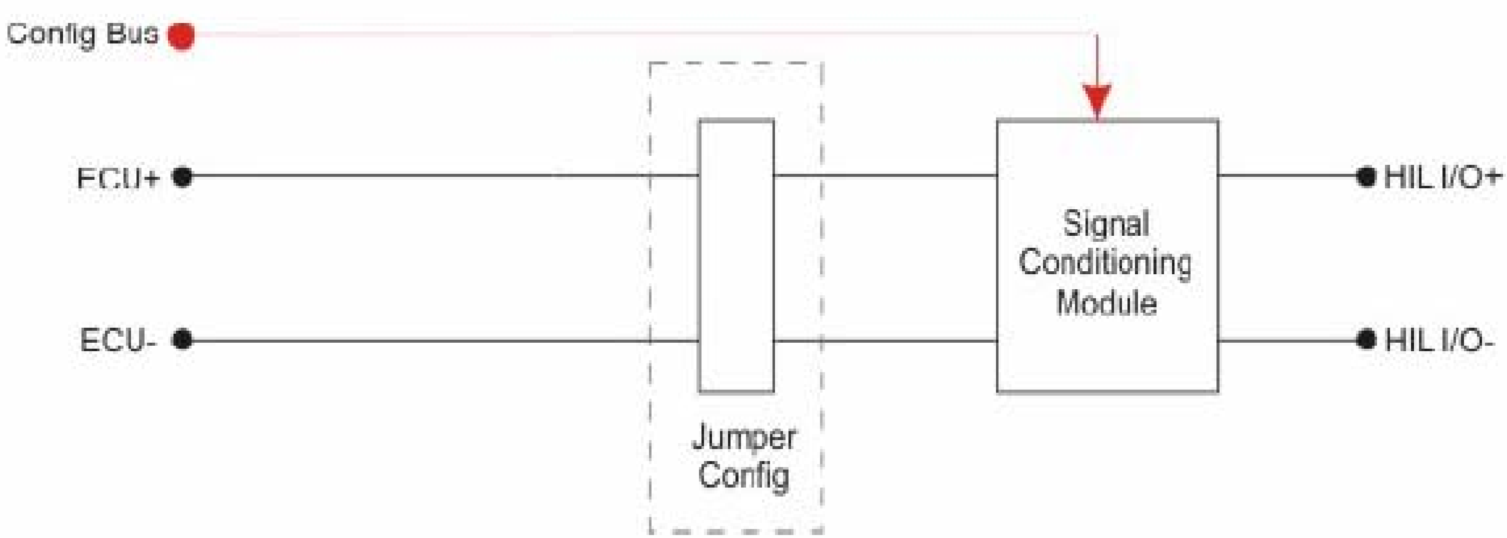


DGF Front Panel

DGELF Front Panel

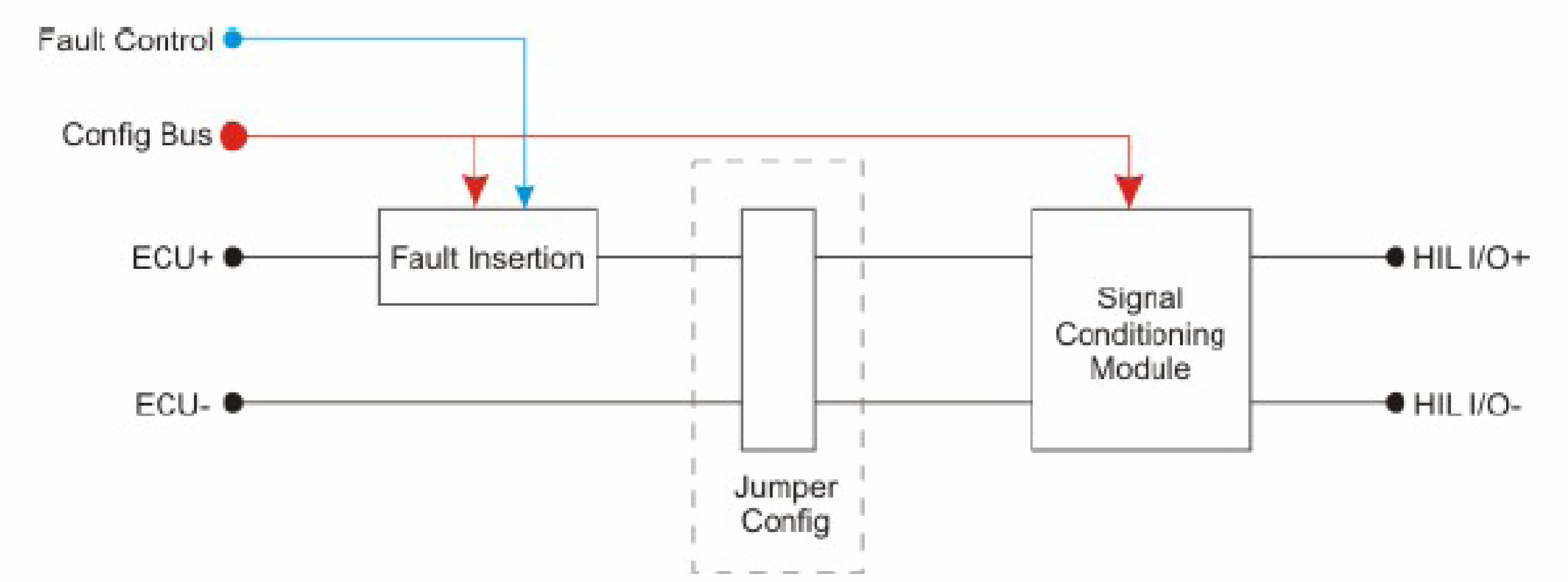
Typical Front Panel Wiring

Type DG



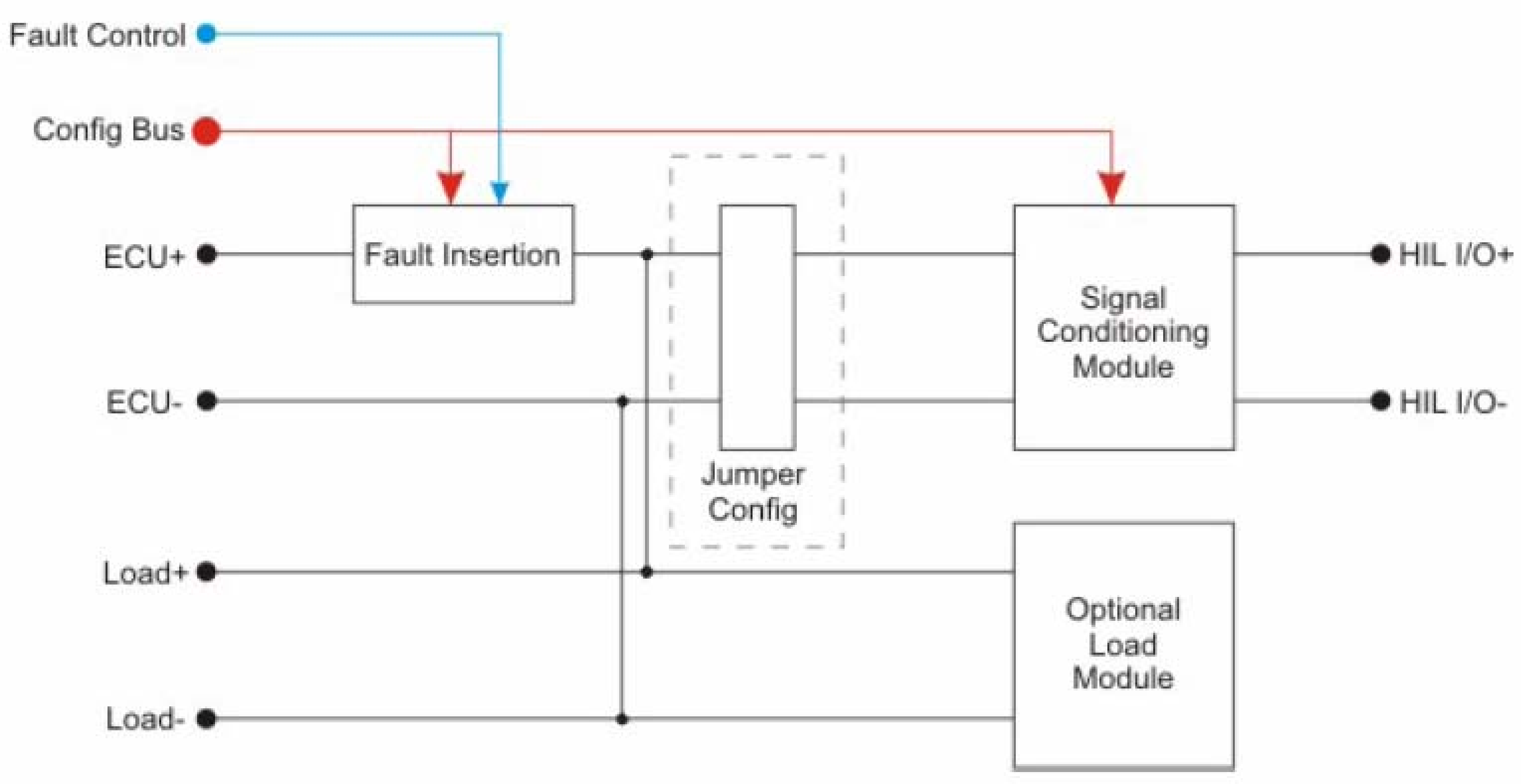
Config Bus
ECU+
ECU-
Jumper
Config
Signal
Conditioning
Module
HIL I/O+
HIL I/O-

Type DGF



Fault Control
Config Bus
ECU+
ECU-
Fault Insertion
Jumper
Config
Signal
Conditioning
Module
HIL I/O+
HIL I/O-

Type DGELF


Fault Control
Config Bus
ECU+
Fault Insertion
ECU-
Jumper
Config
Signal
Conditioning
Module
HIL I/O+
HIL I/O-
Load+
Load-
Optional
Load
Module

The HIL Power Supply System

- Each Genix Pod can be connected to three different external voltage sources (Vext1, Vext2 or Vext3) as the high power rail

- one of two different 0V references (0V1 or 0V2) as the two low power rail

- A typical Genix Pod will reference to Vext1 which is supplied by PSU1, normally used as the VBatt supply, and 0V1 which is tied to ground.

- When a programmable power supply is used as a source, the voltage can be continuously varied within the operating range of 5 to 22V

Signal conditioning which is reconfigurable by software

The unique and novel innovation in this HIL platform is the use of Genix configurable signal conditioning.

Each of the channel can be configured individually under software control

The front end can be designed and customized for different kind of sensors and has the capability to support all feasible combinations of the I/O interface of the ECUs.

Signal Conditioning which is software reconfigurable

The Genix based Pods have the capability to configure each channel according to its

- →signal type
- →Direction
- →Bandwidth
- →Gain
- →Loading requirements
- →internal loads can be pulled up to a supply rail or pulled down to ground

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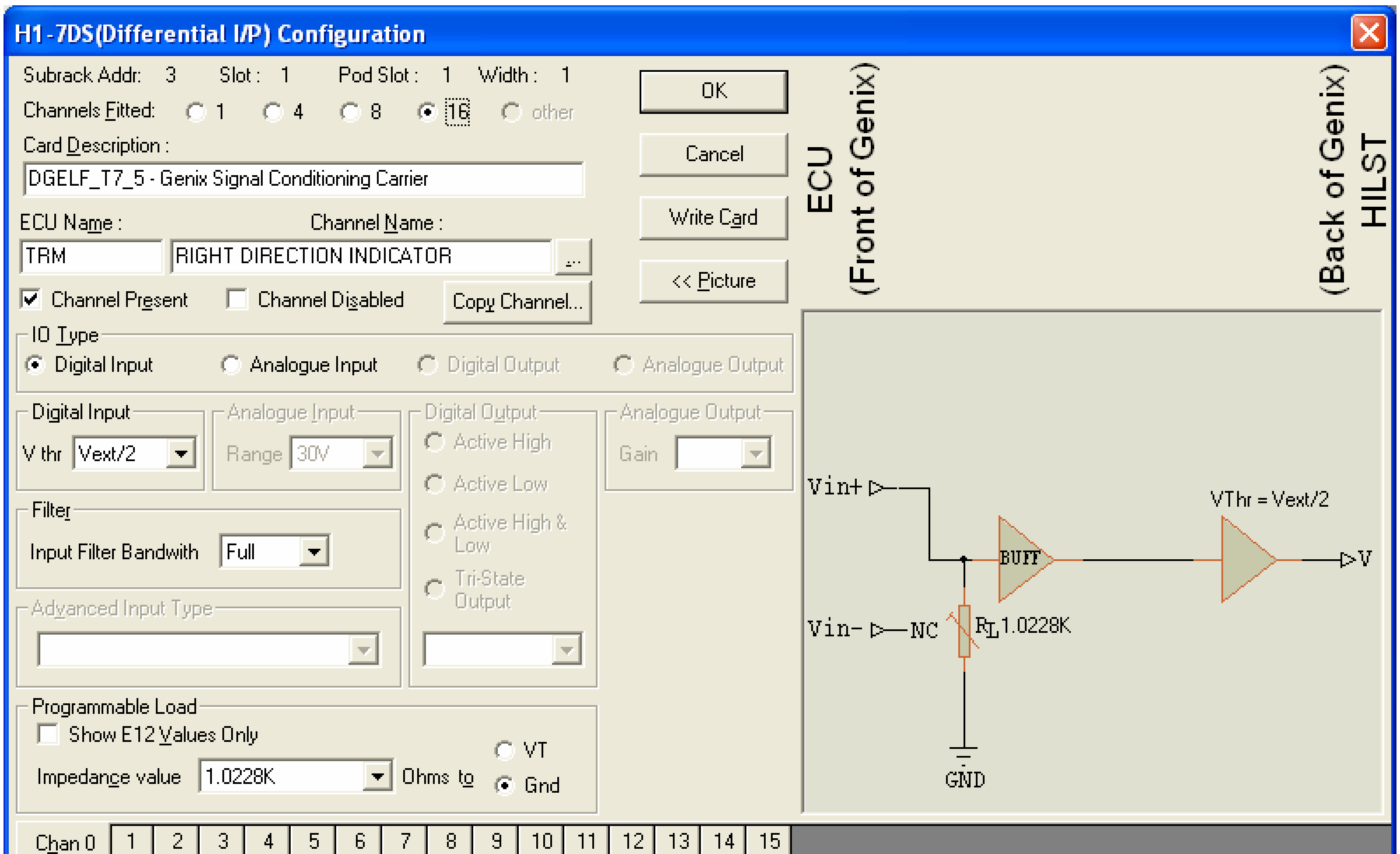
Signal Conditioning which is software reconfigurable

- has the ability to support either internal or external loads
- digital input circuit has a configurable threshold detection capability
- gain of the analogue inputs and outputs can be varied
- Analogue inputs can be conditioned using one of 3 preset filters

HIL Configuration Utility (HCU)



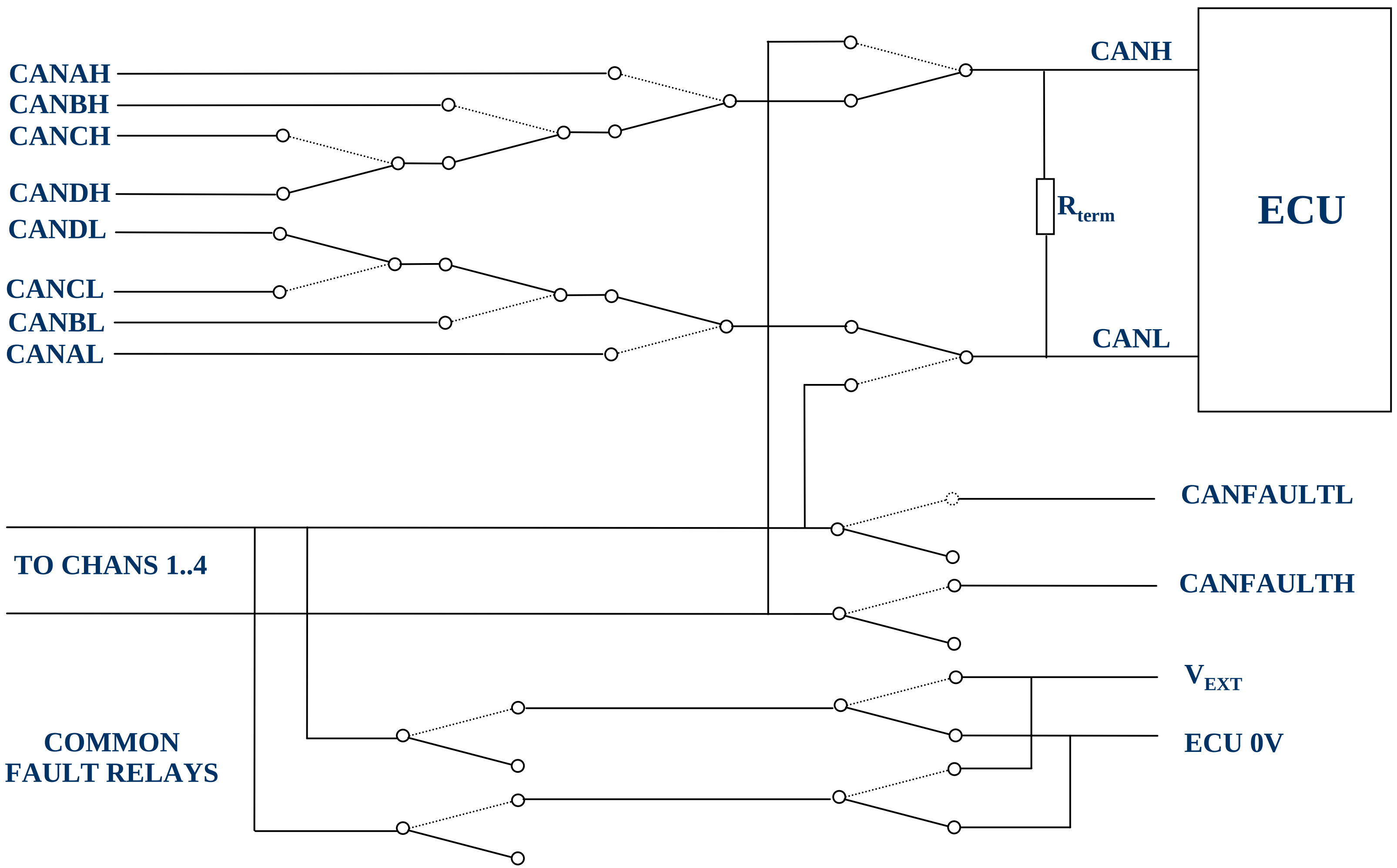
Genix Module Input/Output Capability

Genix Module Type	Function	Digital Input	Digital Output	Analogue Input	Analogue Output
H1 Type 4 - DIOA	Fully Configurable I/O	Y	Y	Y	Y
H1 Type 5 - AO	Analogue Output	N	N	N	Y
H1 Type 6 - DO	Digital Output	N	Y	N	N
H1 Type 7 - ADI(DS)	Analogue/Digital Input	Y	N	Y	N
H1 Type 7 - ADI(DD)	Analogue/Digital Input	Y	N	Y	N
H1 Type 7 - ADI(SD)	Analogue/Digital Input	Y	N	Y	N
H1 DCO	Digital Current Output	N	Y*	N	N

Genix Module Configuration Capability

Genix Module Type	Direction (In/Out)	Type (Digital/Analogue)	Load Value	Pull-Up/Down	Range/Threshold
H1 Type 4 - DIOA	Y	Y	Y	Y	Y
H1 Type 5 - AO	N	N	N	N	N
H1 Type 6 - DO	N	N	Y	Y	N
H1 Type 7 - ADI(DS)	N	Y	Y	Y	Y
H1 Type 7 - ADI(DD)	N	Y	Y	Y	Y
H1 Type 7 - ADI(SD)	N	Y	Y	Y	Y
H1 DCO	N	N	N	N	N

The CAN Switching Strategy



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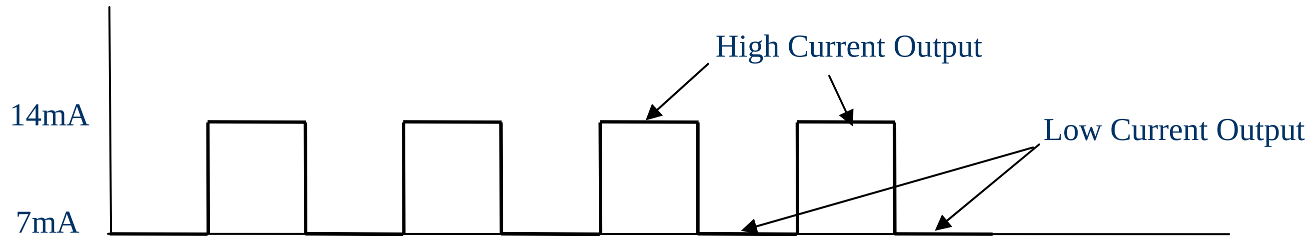
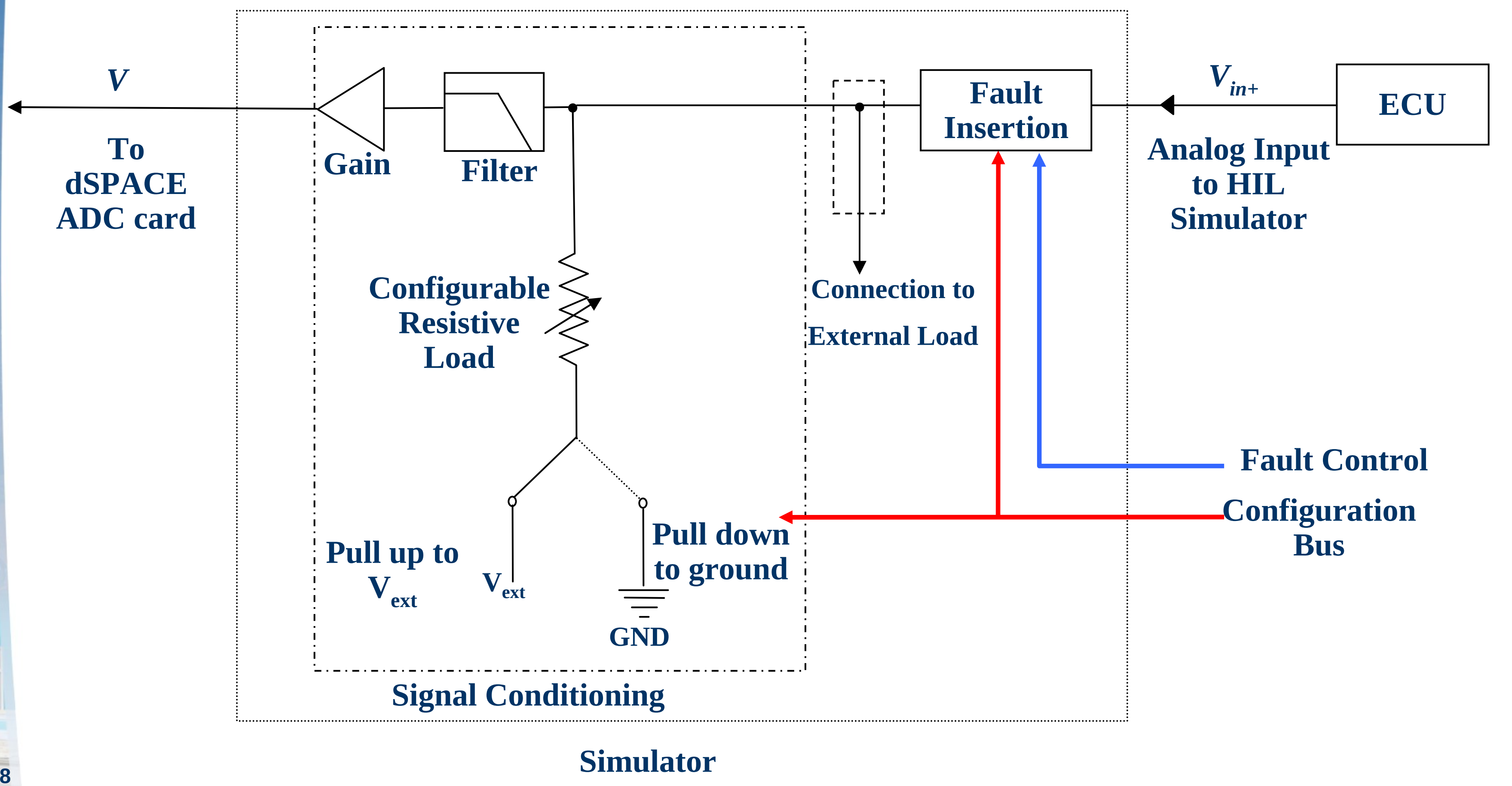
Other Key Features of the Software Reconfigurable HIL platform

- CAN, Power Supply and LIN Switching either the HCU software or using the CAN based configuration bus
- High Current Capabilities
- Fault Insertion Capabilities
- Digital Current Output Modules



Example


V
To
dSPACE
ADC card
Gain
Filter
Configurable
Resistive
Load
Pull up to
V ext
V ext
Pull down
to ground
GND
Signal Conditioning
Connection to
External Load
Fault
Insertion
V in+
ECU
Analog Input
to HIL
Simulator
Fault Control
Configuration
Bus
Simulator

Conclusion

- Software reconfigurable HIL platform described was fully implemented for a vehicle programme at JLR
- Reconfigurable platform has guaranteed high flexibility and portability in interfacing all kinds of ECUs, sensors and actuators
- Easier to suit the wiring harness of the test rig to adapt the ECU under test
- Robustness inbuilt in its design through its ability to support high current loads
- The unique feature of the Genix signal conditioning module is that it has external load capabilities, fault insertion capabilities and high current capabilities all on one Pod card.
- Genix modules have signal conditioning that is configurable by software.