

Real-Time HIL Simulation Tools Optimize Automotive Chassis Control System Development

// **Software now accounts for more than one-third of** total automobile production costs...Driving the trend is embedded software's importance in vehicles to manage more electronics needed to meet new safety, fuel economy, and environmental protection requirements...Under-the-hood-and in-cab subsystems must increasingly communicate in real time with each other and the driver, calling for more complex and costly software in the electronic control units. Automotive OEMs continually seek to shorten design cycles and improve product quality/safety (by) developing and testing vehicles in a virtual prototyping environment. This relies on help from more modeling, simulation, and test automation tools. //

**Automotive embedded software development
costs outpace other apps**

Control Engineering, (January 15, 2004)

INTRODUCTION

Simulation is widely recognized as an indispensable tool in the automotive product development process. Real-time hardware-in-the-loop (HIL) simulation takes simulation further into the development process by providing advanced capabilities as both a design and verification tool.

As automotive subsystems become increasingly complex and the costs associated with their development steadily increase, HIL simulation delivers assurance and efficiency for system design and verification.

Since its founding in 1957, Applied Dynamics International (ADI) has been in the business of designing, manufacturing, and marketing computer-based equipment for real-time HIL simulation of complex, dynamic systems. No other simulation solution provider has a longer history of supporting HIL simulation for new product development and testing applications than ADI.

ADI's newest real-time HIL solution, the rtX Real-Time Expandable Simulation Computer, builds on the company's SIMsystem product line, a complete set of hardware and software tools providing a full featured environment for interactive or automated Electronic Control Unit (ECU) test activities. The rtX extends the reach and usability of the SIMsystem product line by answering the automotive industry's need for high-efficiency simulation and test automation tools that are modular, flexible, scalable, and price competitive.

For experienced simulation users as well as those who are just getting started, ADI's rtX Real-Time Expandable Simulation Computer delivers flexible, high-quality HIL with microsecond determinism at an affordable price.

PRODUCT OVERVIEW

rtX Real-Time Expandable Simulation Computer

The rtX Real-Time Expandable Simulation Computer is ADI's next-generation solution to the automotive industry's need for price competitive, PC-based simulation and test automation tools.

Extending the robust capabilities of the SIMsystem product line, the rtX provides an economical extension to the SIMsystem product line by delivering high-quality PC-based HIL, with microsecond determinism, at an affordable price.

Offering the same functionality as the SIMsystem, the rtX is a standards-based, open system that takes advantage to the greatest extent possible of today's PC technology and commodity-priced products. At the same time, the rtX delivers the functionality needed for the future as the automotive industry strives to develop better products at lower cost and with shorter time to market.

The rtX takes advantage of the same graphical user interfaces and methods as the SIMsystem. The same "open systems" architecture applies as well, providing the capability to flexibly configure the system to suit your needs, and enabling the system to grow with your programs. This philosophy extends to coding environments, too, allowing users to run models written in various computer language types together.

Requirements imposed on the development of the rtX included modularity, scalability, flexibility in system configuration, ease of use, and compatibility with the powerful suite of SIMsystem software tools.

A choice of two available configurations, the Chassis System and the Advanced Chassis System configurations, provide tools at two different price points and levels of capability for testing the various automotive chassis ECUs. Each of these configurations can be expanded to meet the needs of particular applications.

rtX Software Tools

The rtX takes full advantage of a robust set of real-time and non-real-time software tools.

The rtX takes full advantage of the SIMsystem product line's robust set of hardware and software tools. These provide a full-featured environment for interactive or automated Electronic Control Unit (ECU) test activities. These tools include co-simulation products and real-time, HIL simulators. The real-time tools allow the user to manipulate the simulation in a deterministic fashion. The non-real-time and real-time software tools have a consistent look and feel for easy assimilation into automotive engineering processes.

The ADvantage Toolset

The ADvantage toolset is common across the real-time platforms. Software compatibility exists across the non-real-time PC simulation environment, RTS-based systems, and the rTX HIL simulator.

ADvantage Development Environment

ADvantage is an open tool that greatly simplifies integration of multiple models, interconnecting them, and connecting I/O points in the models to external hardware.

ADvantage provides a GUI that allows the user to specify the simulation project including model(s) to be executed, model connections, sensors/actuators or I/O devices to be connected, and the configuration of I/O devices.

All components of a system may be modeled in the same modeling tool or with multiple modeling tools. ADvantage allows the components developed in one or more modeling paradigms to be integrated and connected to each other automatically via model connections. The models may then be co-simulated in non-real-time on a PC or in real-time on an ADI real-time simulation system.

ADvantage allows for models to be developed using modeling languages such as: C, C++, Fortran, and Ada. Models may also be developed using model development packages such as Simulink, SystemBuild, Statemate, or in domain-specific high-level modeling packages such as CarSim.

ADvantage allows model I/O points to be easily connected to actuators/sensors or to other models or controlled through the user interface. ADvantage supports a unique and elegant concept of logical devices which allows hardware interfaces to be encapsulated as a sensor or actuator emulation. These logical devices have specifically named ports that are connected automatically in ADvantage to allow complex hardware to be driven easily by model variables or through the user interface.

ADvantageVI Test Environment

ADvantage Visual Interact is the point of entry for test project execution. Its rich Windows features allow users to get up and running quickly.

ADvantageVI's features include:

- + Interactive execution control
- + Data browser with visibility into models
- + Tabular run-time data display
- + Data logging system with multiple rates, multiple streams and powerful control features
- + Debugging support
- + SIMplotter package for high-speed signal plotting
- + Altia panels for virtual instrumentation

Tests may be run in an interactive mode or alternatively, users may select from one of many automation modes. ADvantageVI provides three levels of automation:

- + Real-time event scripting
- + Command-line automation scripting
- + Visual Basic application automation

The ability to interface ADvantageVI with other Windows applications such as Matlab, Excel, LabVIEW and Access provide extendibility to the test environment. Open interfaces are available to integrate test system-specific tools such as calibration tools, analyzer tools, databases, etc.

rtX Chassis Electronic Control Unit Test Systems

ADI has developed two system configurations, specifically designed for automotive ECU testing.

The automotive industry represents a significant target market for the rtX. To this end, ADI has developed two system configurations, the Chassis System and the Advanced Chassis System, specifically designed for automotive ECU testing. The Chassis System and the Advanced Chassis System configurations are designed to be price competitive while offering the best value in terms of functionality and performance. Both configurations provide tools for controller testing and can be expanded as needed to meet specific application requirements.

Chassis System

The Chassis System provides an ideal starting point for configuring a real-time, HIL test system for testing individual ECUs for functions such as ABS (anti-skid braking), ESP (electronic stability program), etc., or for testing a distributed set of such controllers.

The standard Chassis System contains a variety of I/O and communications interfaces described in Table 1.

Signal Type	Quantity
Ratiometric Sensor Output –16-bit resolution, 12bit accuracy, ± 10 V	6
PWM output signal generation, 0 to 50 Volts	8
PWM input signal measurement, 0 to 50 Volts	8
Frequency measurement	4
Quadrature Drive Signal Decoder – (e.g., stepper motor drive)	4
Quadrature Encoder Device – (e.g., steering wheel position sensor)	4
High-voltage discrete inputs, isolated, 0 to 50 Volts	16
High-voltage discrete outputs - Form C (SPDT) electromechanical relays, 0 to 50 VDC, 0 to 0.5 Amps	16
ADC channels – 12-bit, multiplexed, ± 10 Volts	16SE / 8 Diff
DAC channels – 12-bit, ± 10 Volts	2
TTL channels, bidirectional	32
Wheel Sensors	4
CAN Interface Controllers with ISO 11898-compliant transceiver	1

Table 1: I/O and Communications Interface Functionality for the Chassis System

The standard Chassis System uses a single Industry Pack (IP) containing four independent, variable-frequency, fixed output amplitude, sine wave generators for the wheel speed sensors. An add-on Option is available for the Chassis System that replaces the four sine wave generators with an ADI product, called the VRS (Variable Reluctance Sensor) Board. This board contains four independent arbitrary function generators, one for each wheel speed sensor simulator. This board can be used to simulate both variable reluctance and Hall Effect sensors.

The boards included in the Chassis System are listed in Table 2 below. The wheel speed sensor simulator option is indicated in the right-hand column of Table 2.

Signal Type	Board	Quantity	Option
Ratiometric Sensor Output	IP-3DAC Board	2	
	IP-Carrier Board	1	
	SCR-B	1	
PWM Outputs	IP-uc336*	2	
PWM Inputs	IP-Carrier Board*	1	
Frequency Measurements	SCR-A*	1	
Quadrature Inputs			
Quadrature Outputs			
High-voltage Discrete Inputs	PCI-AD7256 Board	1	
High-voltage Discrete Outputs			
ADC Channels	PCI-MC6025 Board	1	
DAC Channels			
TTL Channels			
Wheel Sensors	IP-Sine Board*	1	-1
Wheel Sensors	PCI-VRS Board	0	1
CAN Interface Controller	IP-T816 Board*	1	

Note: 2 each IP-uc336 Boards, 1 each IP-Sine Board, and 1 each IP-T816 Board are mounted on one IP-Carrier Board and share one SCR-A Board.

Table 2: I/O Subsystem Configuration for the Chassis System

Advanced Chassis System

The Advanced Chassis System provides a powerful set of I/O and communications interface tools for performing sophisticated development and testing activities for a broad range of chassis controllers and distributed controller networks.

The Advanced Chassis System contains the I/O and communications interface functionality described in Table 3.

The Advanced Chassis System has an option that adds one PCI-565 Board and its associated Signal Conditioning / Routing Board, the SCR-565 Board. If this option is chosen, the items shown in the column labeled "Option" in Table 3 increase the functional capabilities of the Advanced Chassis System. This option provides a significant increase in both functionality and performance.

Signal Type	Quantity	Option
Ratiometric Analog Output (DAC), Simultaneous Update, 16-bit, $\pm 10V$, Option $\pm 20V$	8	
PWM output signal generation, 0 to 50 Volts	8	8
PWM input signal measurement, 0 to 50 Volts	8	8
Frequency measurement	2	2
Quadrature Drive Signal Decoder – (e.g., stepper motor)	4	
Quadrature Encoder Device – (e.g., steering wheel position sensor)	4	2
High-voltage discrete inputs, isolated, 0 to 50 Volts	32	
High-voltage discrete outputs, isolated, high-side or low-side switching (jumper selectable), 0 to 50 Volts		32
Analog Voltage Input (ADC), Simultaneous Sampling, 16-bit, $\pm 10V$	32	
Analog Voltage Output (DAC), Simultaneous Update, 14-bit, $\pm 10 V$	16	
Wheel Sensors – VRS or Hall Effect	4	
CAN Interface Controllers with a selection of 3 transceivers each	2	2
LIN Interface	2	

Table 3: I/O and Communications Interface Functionality for the Advanced Chassis System

The boards included in the Advanced Chassis System are listed in the Table 4 below.

Signal Type	Board	Quantity
Ratiometric Analog Output	PCI-DAC Board	1
PWM Outputs	IP-uc336 Board	2
PWM Inputs	IP-Carrier Board	1
Frequency Measurement	SCR-A	1
Quadrature Inputs		
Quadrature Outputs		
High-voltage Discrete Inputs	PCI-DI Board	1
High-voltage Discrete Outputs	PCI-DO Board	1
Analog Voltage Inputs (ADC)	PCI-PAS202N Board	1
Analog Voltage Outputs (DAC)	PCI-PAS 2015 Board	1
Wheel Sensors – VRS or Hall Effect	PCI-VRS Board	1
CAN Interface Controller with selectable physical layer plus LIN Interface	IP-376CAN	2
	IP-Carrier Board	1
	SCR-CAN	1

Table 4: I/O Subsystem Configuration for the Advanced Chassis System

I/O and Signal Conditioning Boards

The following boards are used in one or both of the Chassis systems.

Ratiometric Sensors

There are two methods available for generating ratiometric signals in the rtX. One method uses an IP having three multiplying DACs. The other method is an intelligent I/O board that contains eight ratiometric simulator circuits.

The IP-3DAC Board

The IP-3DAC Board is an ADI product that contains three multiplying DACs. Each DAC:

- ✦ Has 16-bit resolution, 12-bit accuracy, and has a ± 10 volt output
- ✦ Has a software-selectable analog input, either an external analog signal or an internal reference voltage
- ✦ Can be individually updated to a new digital input or the three DACs can be updated simultaneously as a group.

The Chassis System contains a third-party IP-Carrier Board holding two IP-3DAC Boards for a total of six ratiometric devices. This IP-Carrier Board has expansion space for two additional IP-3DAC Boards. An ADI Signal Conditioning / Routing Board, SCR-B, is required to provide front panel terminations for these DACs.

PCI-DAC Board

ADI's PCI-DAC Board contains a Motorola MPC565 processor operating at 48 MHz to control a multiplexed, 16-bit ADC and eight 16-bit DACs on this board. This processor performs all necessary calculations, including calibration calculations, to determine the appropriate output voltage for each DAC.

The setting for each DAC can be either ratiometric or non-ratiometric depending on the software that controls the board. For ratiometric DAC operation, the multiplexed ADC on the board is used to read the reference voltages generated in the ECU under test to drive ratiometric sensors. (A ratiometric sensor is a sensor whose output voltage is proportional to the reference voltage driving the sensor.)

The standard version of this board has ± 10 Volt outputs. A ± 20 Volt version of this board is available as an option. Each channel is protected against a short to any voltage in the range of ± 50 Volts. Each output has over-current protection for currents outside the range of ± 20 mA.

The DAC outputs can be updated individually or can be grouped together for simultaneous update of a group. Furthermore, the DACs on multiple boards can be simultaneously updated if the boards are interconnected in a master/slave arrangement for this purpose.

The Intelligent Ratiometric Simulator Board is used in the Advanced Chassis System. A separate Signal Conditioning and Routing Board is not required for use with this ratiometric board.

Specialized Discrete I/O Signals

These include PWM input and output signals, frequency measurements, and quadrature encode and decode operations.

In the Chassis System these signals are handled via an ADI product known as the IP-uc336.

The IP-uc336 Board

The IP-uc336 is an Industry Pack Board containing a Motorola model 68336 micro-controller. The 68336 has a number of facilities that are useful in generating or measuring specialized discrete I/O signals including a Timer Processor Unit or TPU as part of its architecture.

Two IP-uc336s are mounted on a third-party IP-Carrier Board in the Chassis System. This Carrier Board with its two IPs is part of a two board set; the second board is a Signal Conditioning and Routing (SCR) Board, namely, SCR-A.

Various specialized discrete I/O signals are common to both powertrain and chassis simulator testing.

The SCR-A Board contains 24 discrete output driver circuits. Each driver circuit is associated with a specialized discrete output signal from one of the 68336s. The output drivers are configurable for either high-side or low-side drive via removable jumpers. Drivers are arranged in groups of four with a common high-rail and low-rail line per group. The high-rail for each group will be user-specified. The low-rail line for each group is tied to system ground. Each driver is capable of sourcing or sinking 100 mA as appropriate for the driver configuration.

The PCI-565 Board

The PCI-565 Board can be added as an option to the Advanced Chassis System to handle specialized discrete I/O signals. The PCI-565 Board is part of a two board set; the second board is a Signal Conditioning and Routing Board, the SCR-E565 Board.

The PCI-565 Board contains a Motorola MPC565 microprocessor. The MPC565 contains a 48 MHz, 32-bit PowerPC processor core with floating point arithmetic capability and three Timer Processor Units (TPUs) as well as other I/O capabilities. The MPC565 is used to:

- ✦ Generate 8 PWM output signals and 4 quadrature encoder signal sets
- ✦ Measure 8 PWM input signals, 2 input frequency signals
- ✦ Handle the decoded outputs of 4 quadrature-encoded input signal sets.

The SCR-E565 Board

The SCR-E565 Board is used in conjunction with the MPC565 Board to provide several important functions:

- ✦ Standard (i.e., non-encoded) and encoded input signal handling for TTL and VBATT-level logic inputs where the encoded signals are quadrature encoded signals from the controller under test for operating stepper motors
- ✦ Output drivers configurable via jumpers to meet either high-side or low-side output drive requirements

All discrete input signals to the simulator are limited to TTL levels through the use of resistor-diode clamping circuits. Quadrature-encoded input signals are decoded before being passed to the MPC565. Non-encoded input signals are passed to the MPC565 without being changed.

The output drivers are configurable for either high-side or low-side drive via removable jumpers. Drivers are arranged in groups of four with a common high-rail and low-rail line per group. The high-rail for each group will be user-specified. The low-rail line for each group is tied to system ground. Each driver is capable of sourcing or sinking 100 mA as appropriate for the driver configuration.

The SCR-E565 Board

- ✦ Does not have a PCI Bus connection-it only obtains power from the PCI Bus connector
- ✦ Is connected to the Engine Board via internal cables
- ✦ Has a 100-pin, high-density, output connector.

Discrete Input and Output Signals

In automotive applications there is a need for discrete (or digital) signals that range between VBATT on the high side and ground on the low side. In anticipation of the 42-volt automotive electrical architecture, the I/O subsystem circuitry for the rtX is designed to operate at supply voltages up to 50 volts where appropriate. The high rail for all discrete switches, PWM signals, etc., must be capable of being connected to supply voltages up to +50 volts DC.

PCI-AD7256 (DI / DO) Board

The PCI-AD7256 High Voltage Discrete Input / Discrete Output (DI / DO) Board is a product of ADLINK Technology, Inc. The ADLINK model number for this product is PCI-7256. This board contains 16 optically isolated discrete inputs and 16 Form C (SPDT), latching, electromechanical relays. The inputs are rated at 0 to 50 VDC, and the contacts for each relay are rated at 0 to 50 VDC and 0 to 0.5 Ampere.

The PCI-AD7256 Board is included in the standard Chassis System configuration, but is not included in the standard Advanced Chassis System configuration. This board does not require the use of an SCR board.

The PCI-DI Board

ADI's PCI-DI Board contains 32 isolated, discrete input sensing circuits where each sensing circuit features:

- ✦ An independently adjustable threshold for determining the On/Off state of the input signal
- ✦ Microsecond-level dynamic performance.

Each of these circuits is protected against faults to any voltage in the 0 to +50 Volt range.

The PCI-DI Board is used in the Advanced Chassis System. This board does not require a separate SCR board.

The PCI-DO Board

ADI's PCI-DO Board contains 16 isolated, discrete output drive circuits. This board features output drivers that can be individually configured by the user to be either high-side or low-side switches. The switching times for these drivers are:

High-side switch:	≤140 microseconds for turn-on or turn-off
Low-side switch:	≤ 20 microseconds for turn-on or turn-off

Each high-side driver will operate with a high-rail voltage in the range of 8 to 50 Volts; each low-side driver will operate between ground and a high-rail voltage in the range of 0 to 50 Volts. Each driver is capable of sourcing or sinking 100 mA as appropriate for the driver configuration.

Internal current limiting and thermal overload protection circuitry protect both high-side and low side drivers.

A PCI-DO Board is included in the Advanced Chassis System configuration. This board does not require a separate SCR board.

Analog Inputs and Outputs

There is often a need for some general-purpose analog inputs in HIL simulation testing for data acquisition. Various third-party PCI boards are available to meet these needs. ADI has selected two boards for use in the rtX to meet this need.

The PCI-MC6025 (Multifunction) Board

The PCI-MC6025 Board is a third-party product that contains:

- ✦ 16 multiplexed ADC channels (12-bits)
- ✦ 2 DAC channels (12-bit)
- ✦ 32 bi-directional TTL channels.

The PCI-MC6025 Board is included in the standard Chassis System configuration, but is not included in the standard Advanced Chassis System configuration. This board does not require the use of an SCR board.

PCI-PAS202N Analog Input Board

Precision Analog Systems Co. model PAS 202N/AI is a standard PCI card containing 32 channels of 16-bit simultaneous sampling, parallel ADCs. Each channel contains a high-resolution, 250K samples per second Analog to Digital Converter. There are five programmable input ranges for the board, namely, ± 10V, ± 5V, ± 2.5V, 0 to +5 V, and 0 to + 10V. The number of channels to be scanned can be selected from 1 to 32 in six binary-weighted programmable steps. A RAM buffer with one word of storage per ADC channel is provided for intermediate data storage.

The board contains a 32-bit RISC processor that performs auto-calibration calculations on all ranges. Both block mode and demand mode data transfers are supported over the PCI Bus. This board does not require the use of a separate signal conditioning / routing board.

A PCI-PAS202N Board is used in the Advanced Chassis System.

Wheel Sensors

The IP-Sine Board

The IP-Sine Board is an ADI product that contains four independent, variable frequency Sine-wave generators. Each Sine-wave generator has a fixed amplitude output. The IP-Sine Board is mounted on an IP-Carrier Board. A Signal Conditioning and Routing Board, the SCR-A Board, routes the outputs of the IP-Sine Board to its front panel connector. The IP-Sine Board is used to simulate wheel speed sensors in the Chassis System.

PCI-VRS Board

When sensing a sharp edge on a tone wheel, a Variable Reluctance Sensor (VRS) produces a doublet type output signal whose amplitude increases with frequency. At higher frequencies, the VRS output signal may have an amplitude in the ± 100 Volt range or more. In general, the information of particular interest in ECU testing is the zero-crossing point of the VRS waveform and, perhaps, the slope of the VRS waveform as it goes through zero. Producing a simulated VRS output signal that goes beyond ± 10 Volts is expensive and does not provide additional benefit in most applications. ADI has built systems with high voltage VRS outputs, but has found that most users do not want this added expense.

ADI's PCI-VRS Board contains four speed sensor simulator circuits. Each speed sensor simulator circuit has a variable frequency, variable output amplitude, arbitrary function generator followed by a gain of ten, operational amplifier with output hard limiting at ± 10 Volts. This type of speed sensor simulator allows the user to define the waveform to be used. This waveform can simulate either a VRS or a Hall Effect sensor, for example. The user can control the amplitude of the output signal, at least at low frequencies. The gain of ten, output amplifier provides the proper slope of the speed sensor output signal at its zero crossing that an unlimited speed sensor signal would have at higher frequencies. The hard output limiting characteristic of the output amplifier essentially "clips" the simulated speed sensor signal at the limit points without adversely affecting the dynamics of the signal inside the limit range.

CAN and LIN Buses

Both versions of the Chassis System have a CAN Bus Interface with a high-speed (ISO 11898) transceiver. The Advanced Chassis System has two CAN Bus interfaces and two LIN Bus Interfaces.

The IP-T816 Board

A third-party IP-T816 Board is used in the Chassis System. This board is the Tews Technologies model TIP816.

The IP-376CAN Board

In the Advanced Chassis System two IP-376CAN Boards are used to provide CAN Bus and LIN interfaces. The IP-376CAN is an ADI Product that contains a Motorola 68376 micro-controller. The 68376 contains both a CAN Bus controller and a UART which forms the basis for the LIN interface.

The two IP-376CANs are mounted on an IP-Carrier Board and have an associated Signal Conditioning and Routing (SCR) Board, the SCR-CAN Board. The IP-376CAN Board does not contain a CAN transceiver. Instead, the SCR-CAN Board contains a selection of transceivers for each CAN Bus output. The transceiver selection available for each CAN interface controller consists of:

- ✦ A high-speed transceiver compliant with ISO 11898-2 / J1939 / J2284
- ✦ A fault-tolerant transceiver compliant with ISO 11519-2 and/or ISO 11898-3
- ✦ A single-wire transceiver compliant with J2411.

The UART output of each IP-376CAN is routed to the associated SCR-CAN Board which contains an appropriate LIN interface transceiver for each of the two UART outputs.

rtX Architecture

The rtX employs a host-target architecture.

Like its VME-based precursor, the SIMsystem's RTS hardware, the rtX employs a host-target architecture consisting of:

- ✦ The host computer which serves as the Human/Machine Interface to the simulator
- ✦ The target computer or real-time computing engine in the rtX
- ✦ The Input/Output processing subsystem that provides the interfaces between the real-time computing engine and the external hardware including the device(s) under test.

Figure 1 shows the basic architecture of the rtX.

The host computer is a standard PC running the Microsoft Windows 2000 Operating System. The minimum requirements for the host computer can be met by almost any present-day PC system configuration. The host computer for an rtX system can be upgraded without having any effect on the real-time compute engine or the I/O subsystem.

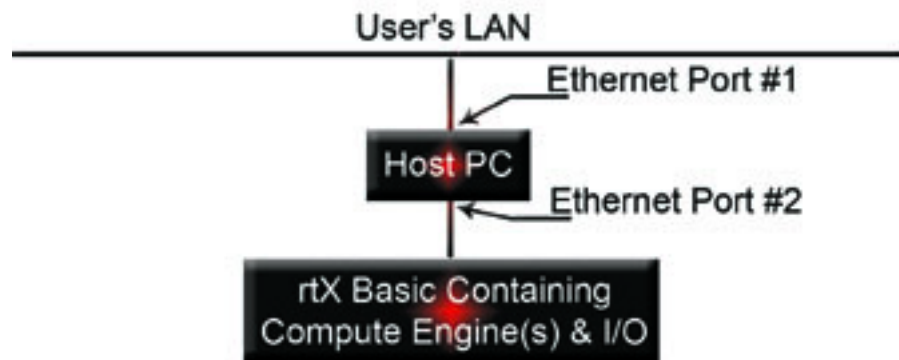


Figure 1: rtX Architecture

The rtX Basic system contains the real-time compute engine(s) consisting of one or more Intel (Pentium 4 or Xeon) or AMD (Opteron) processors mounted on a standard PC motherboard with PCI Bus on the PC motherboard. This PCI Bus connects the I/O subsystem to the real-time compute engine(s) in the rtX.

The rtX runs the POSIX-compliant, QNX Real-Time Operating System (RTOS). QNX provides a multitasking, multithreading environment to optimize the run-time usage of rtX CPU resources. The run-time software architecture is structured to ensure models run in "hard" real-time while accommodating data capture and parameter modifications. Each model runs as a separate multithreaded process that can be targeted on a single-processor or multi-processor rtX without modifying the simulation architecture. A GNU C++/C compiler is provided with the QNX RTOS.

Ethernet Communications

Ethernet is used to connect the host computer to the user's LAN. Ethernet is also used to connect the host computer to the rtX. In order to isolate the basic rtX system from the user's LAN, the host computer needs to be equipped with two separate, independent Ethernet ports as shown in Figure 1.

Port #1 is connected to the user's LAN only; Port #2 is used for intra-simulator communications only. These connections are via 10/100 Base T Ethernet.

The host Ethernet interface to the user's LAN (Port #1 in Figure 1) is used for:

- ✦ Moving models, test scripts, etc., to the simulator from a server or other devices on the user LAN
- ✦ Moving test data from the simulator to a server or other devices on the user LAN.

Once test information has been loaded into the simulator's host computer, test execution on the simulator is controlled completely from the host computer via the simulator network that connects to Host Ethernet Port #2 (see Figure 1). Test execution is completely independent of the user's LAN environment. This means that the simulator can operate normally even if the LAN is unavailable. Because the simulator has its own internal network that is used for all testing activities, the connection of the simulator to the user's LAN does not affect its operational performance.

In addition to these uses of Ethernet, the rtX can be equipped with one or more independent Ethernet ports for communication with other simulator systems or external hardware devices on a point-to-point or small network basis. The rtX supports 1 Gigabit Ethernet for such uses.

rtX Electronic Controller Test System Architecture

Figure 2 illustrates how the rtX fits into the architecture of a real-time, HIL Electronic Controller Unit (ECU) test system. Some parts of this architecture are required; others are optional. The blocks labeled "rtX Real-time Compute Engine(s)" and "rtX I/O and Communication Interfaces" denote functional entities rather than packaging configurations. As noted in the discussion of Figure 1, the rtX Basic system contains a PC motherboard having one or more PC processors that provide the real-time computing capability and a PCI Bus with a small number of PCI slots—usually 5 or 6. In a small rtX system, the I/O and communication interface devices may be contained completely within the rtX Basic system.

Optional Equipment

eXpansion Boxes

In larger systems, one or more eXpansion Boxes are used to house the I/O and communication interface devices. There are two versions of the rtX eXpansion box. One is a PCI version. The other is a version without a standard backplane where the boards connect to the rtX via a high-speed serial link such as IEEE 1394.

The rtX Basic is connected to the PCI eXpansion Box through a PCI-to-PCI bridge. The PCI eXpansion Box contains a PCI backplane with either seven or thirteen PCI board slots. This eXpansion Box will hold standard PCI I/O boards.

Other types of expansion are also possible in an rtX system. For example, a Compact PCI chassis can be connected to the rtX Basic via a PCI-to-PCI bridge. A PXI chassis can be connected to the rtX Basic through the use of a PCI-to-PXI bridge containing a MXI-3 Control link.

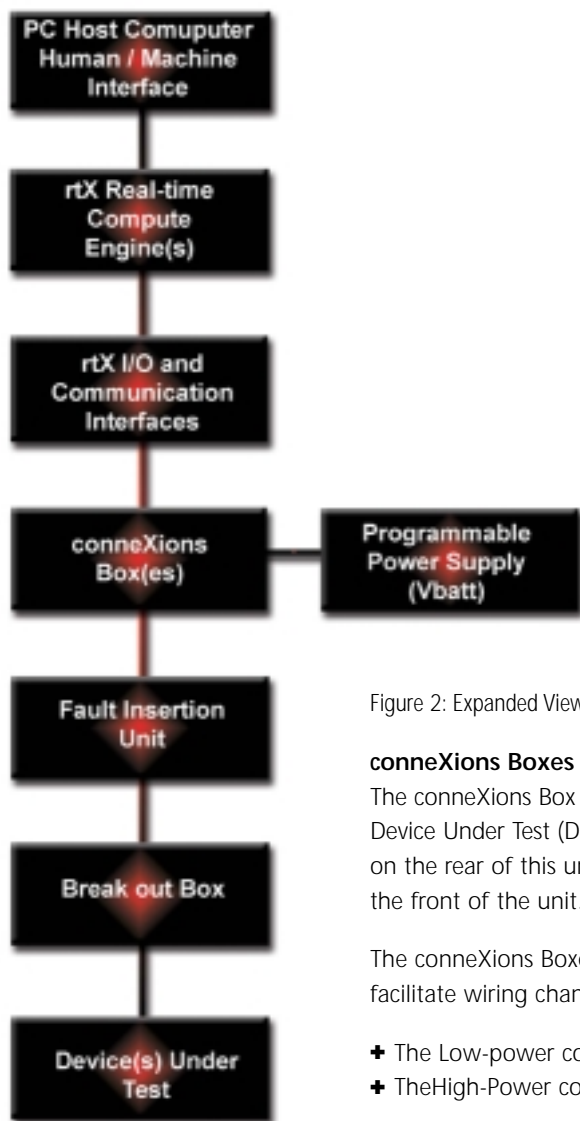


Figure 2: Expanded View of the rtX System Architecture

conneXions Boxes

The conneXions Box is an optional interface unit that simplifies connection of simulator I/O lines to the Device Under Test (DUT) and/or other external hardware. Cables from the various I/O devices terminate on the rear of this unit. Cables to the DUT and other external hardware or instruments terminate on the front of the unit. A choice of DUT connector types is provided.

The conneXions Boxes have screw terminal units inside to simplify the internal wiring tasks and to facilitate wiring changes. There are two versions of the conneXions Box:

- ✦ The Low-power conneXions Box is used for low-power signals such as analog and TTL signals
- ✦ The High-Power conneXions Box is used for all other signals.

The High-Power conneXions Box has provision for mounting low-power loads. High heat-dissipation loads and other hardware devices will be located external to the High-power conneXions Box. A connector interface is provided for cabling to external loads and hardware.

Having these two types of conneXions Boxes greatly aids in separating the signal types and shielding sensitive signals. This helps to minimize electrical noise issues in the test setup.

The conneXions Box is strongly recommended for all but the smallest rtX systems to simplify wiring issues between the rtX I/O and external hardware.

Programmable Power Supply

The programmable power supply is another optional item. ADI offers a 1200-Watt Kepco power supply unit (Kepco Model KLP 75-33-1200) as a standard product to meet Vbatt requirements. The maximum output voltage available from this supply is 75 Volts; the maximum current is 33 Amperes. (NOTE: ADI's software driver for the Vbatt supply will limit the output voltage to 50 Volts maximum to protect the simulator I/O system.) The user can select either the output voltage or the output current and the supply will automatically set the maximum value for the other parameter. For example, at 50 Volts output voltage, the maximum current is 24 Amperes. For any output voltage in the range of 0 to 36 Volts, the maximum output current is 33 Amperes. If the user specifies a Vbatt requirement that cannot be met by this Kepco power supply, ADI will recommend an alternate solution.

Programmable Vbatt Mode Switching

For applications that require ignition-type switching of Vbatt power, ADI provides eight independently controlled FET switches for Vbatt power. These switches are mounted in a conneXions Box. Each switch is capable of handling 20 Amperes of continuous current. For high-current applications, ADI provides a stand-alone mode-switching unit containing electromechanical relays, where each relay is capable of switching up to 300 Amperes. In either case, the switches are controlled from within the rtX system.

Fault Insertion Unit

Another product available as an option for use with the rtX system is a Fault Insertion Unit (FIU). The FIU handles faults consisting of open circuits, shorts to ground, shorts to an external voltage source (such as Vbatt), and shorts between I/O signals and is controllable either interactively via a user GUI or through commands from a test script.

rtX Packaging Configurations

The single-processor rtX Basic is available in either tabletop or rackmount packages. The ATX motherboard for the single-processor rtX basic has 6 PCI slots and 1 non-PCI slot. The standard Chassis configuration described in Table1 will fit the rtX Basic without the need for an eXpansion Box.

The two-processor version of the rtX Basic is also available in both tabletop and rackmount configurations. However, the ATX motherboard for the two-processor rtX Basic only has 5 PCI slots. If a standard Chassis I/O configuration is used with a two-processor rtX Basic, an eXpansion Box is required.

The use of a conneXions Box is optional, but highly recommended, for the Chassis System configuration. The use of conneXions Boxes is strongly advised with the Advanced Chassis System.

S U M M A R Y

The rtX Real-Time Expandable Simulation Computer is ADI's answer to the automotive industry's need for powerful, flexible, PC-based simulation and test automation tools that are very price competitive.

To stay at the forefront of product design, today's engineers need the best tools.

For experienced simulation users as well as those who are just getting started, the rtX offers high-quality HIL with microsecond determinism at an affordable price.

A choice of Chassis System and the Advanced Chassis System configurations provide tools at two different price points and levels of capability for automotive chassis Electronic Control Unit testing. Each of these configurations is expandable to meet the needs of particular applications.

For more information about how the rtX can enhance and optimize your product verification and design process, please contact us at:

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For over 45 years, Applied Dynamics International (ADI) has been a global supplier and developer of state-of-the-art software and hardware tools for the design and test of embedded control systems used in the automotive, aerospace, defense, and power generation industries.

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