NI Engine Control System Configuration Guide

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NI Engine Control System Overview

The NI Engine Control System (NI ECS) is a full-authority research engine controller based on the powerful multigigahertz, multicore, and expandable NI PXI platform. The NI ECS includes a downloadable NI LabVIEW software example that you can use as a baseline to get your engine up and running. The software is openly programmable to allow customization for your specific application. In NI ECS-1002 form, the NI ECS is a full-authority engine controller that contains all of the processing power and I/O you need to interface with typical engine subsystems and actuators. When combined with a combustion analysis option, the NI ECS-1002 or 1008 becomes a fully integrated off-the-shelf next-cycle control system capable of calculating pressure-based combustion parameters quickly enough to be used as closed-loop feedback in the real-time engine control algorithm. The NI ECS-1000, when combined with a combustion analysis option, is a multi-channel test cell combustion analyzer with room for adding engine control functionality once your application requires it. Combustion analysis capabilities include standard single-zone heat release modes with and without heat transfer and numerous other methods for calculating pressure-based metrics. You can choose from a range of NI and other hardware options to customize your NI ECS.

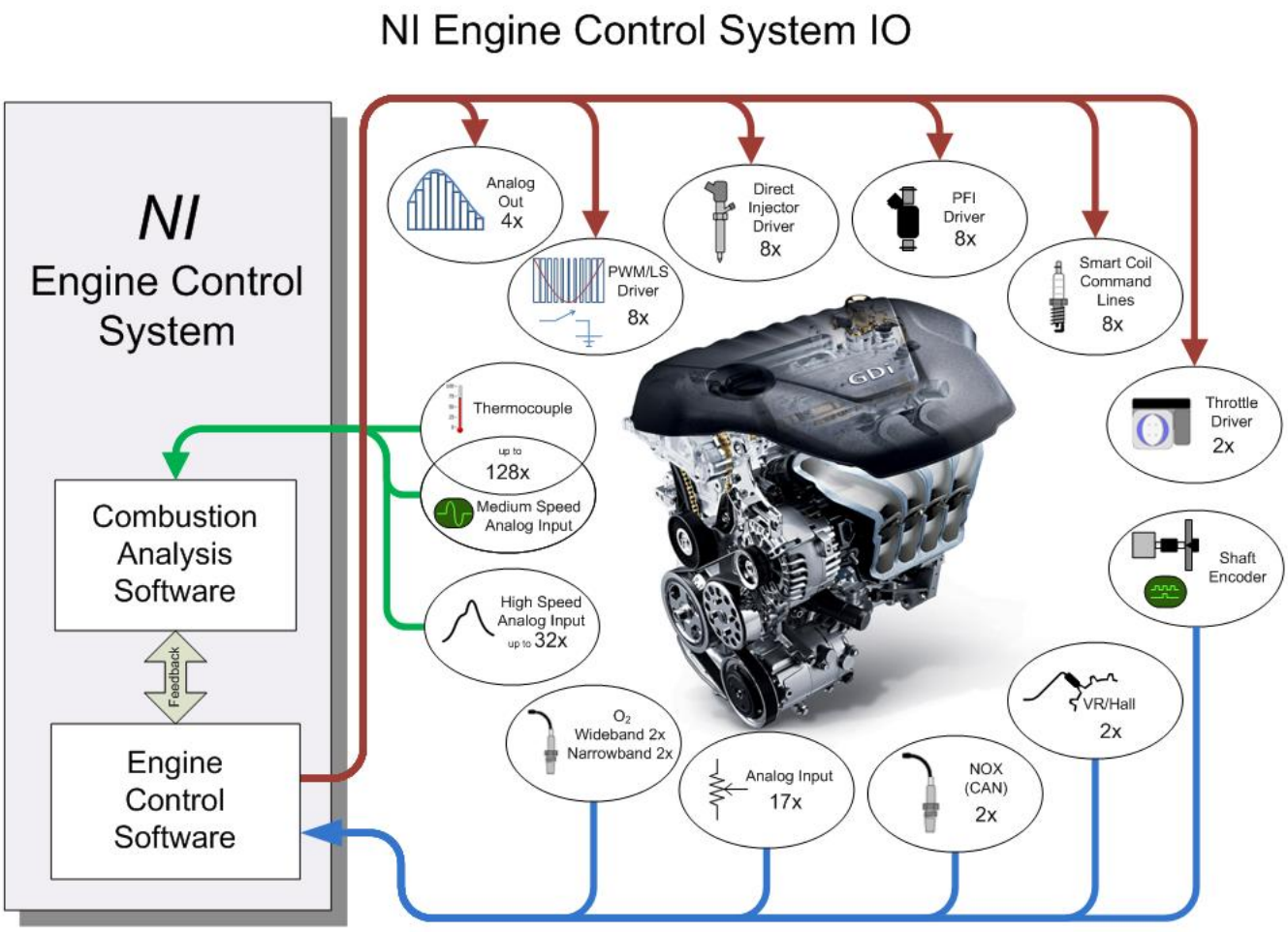


Figure 1. NI ECS I/O Diagram

NI Engine Control System Hardware

Standard NI Engine Control System

The NI ECS features a real-time processor that supervises all functions and I/O. It is delivered preloaded with LabVIEW software and drivers directly from NI, but you need to activate the ECS software the first time you use it. You can download the NI ECS open-source project from ni.com and use it as a baseline for developing your engine control algorithm. It may work out of the box for some engines. An FPGA is connected directly to the real-time OS and functions as a dedicated engine timing coprocessor. The FPGA is openly programmable to enable low-level control of timing-critical tasks such as spark or fuel timing. In base form, eight NI I/O modules are inserted in a pull-out drawer that contains integrated power supplies and cooling fans. You can use the popular 37-pin circular power connectors (CPCs) in the front of the drawer to interface directly with engine subsystems and actuators (see Table 1 for NI ECS I/O). Choose from the following standard NI ECSs:

- NI ECS-1000
- NI ECS-1002
- NI ECS-1008

I/O Type	# of Channels (ECS-1000)	# of Channels (ECS-1002)	# of Channels (ECS-1008)	Example Use Cases
Direct injector driver (piezoelectric/solenoid)*	0	2	8	Driving either piezo or solenoid direct injectors, direct voltage/current control, waveform shaping
Port fuel injector driver	0	4	8	Driving port fuel injectors
Low-side PWM	0	4	8	Driving high-pressure pumps, inlet metering valves, proportional solenoid valves, and so on
Engine-synchronous TTL output	0	8	8	Smart coil/spark plug command
Electronic throttle driver	0	2	2	Electronic throttle control with position feedback
Analog output	0	0	4	Communication to test cell
Wideband O_2	0	2	2	Calculating Lambda value
Narrowband O_2	0	2	2	Rich/lean switching
Variable reluctance	2	2	2	Cam/crank position
Hall effect	2	2	2	Cam/crank position
Encoder	1	1	1	Crankshaft position
Analog input	17	17	17	MAP, MAF, IAT, ECT, and so on
CAN	0	2	2	NOx measurement

Table 1. NI ECS I/O

*Additional solenoid DI channels may be available depending on your application. See Table 10 for details.

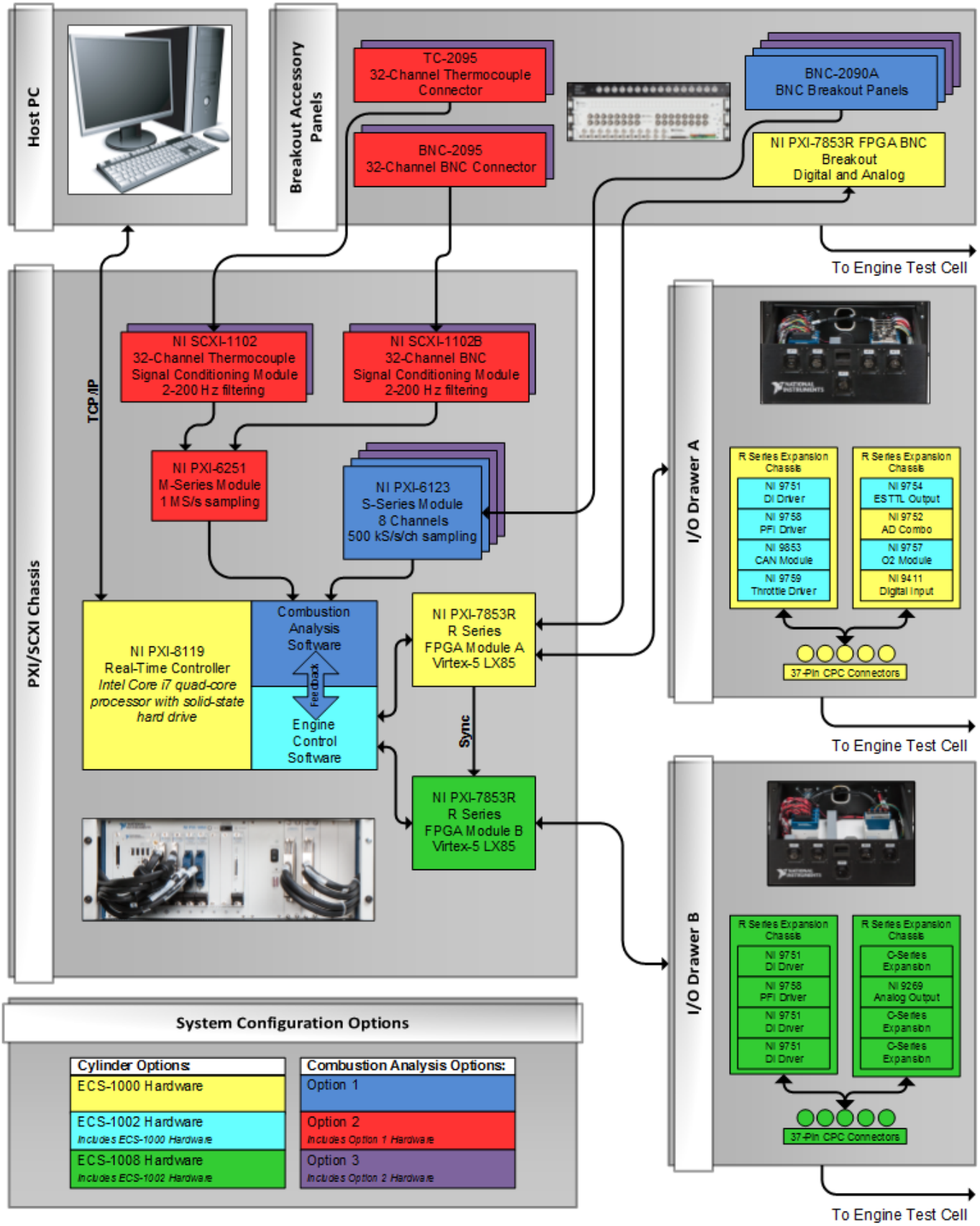


Figure 2: NI ECS Functional Block Diagram

Combustion Analysis Options

Combustion analysis options add dedicated software and hardware to your system for performing pressure-based combustion calculations. NI Combustion Analysis System (NI CAS) Software is a unique LabVIEW plug-in that provides numerous analysis functions, front panel controls, and utilities including data streaming to disk, preprocessing, heat release, pressure metrics, knock analysis, noise analysis, raw data logging, summary data reporting, and postprocessing. NI CAS Software comes with an intuitive configuration-based startup application that works out of the box (see Figure 3). The startup application is also openly programmable; take advantage of the library of functions to write custom code or incorporate other test and measurement capabilities.

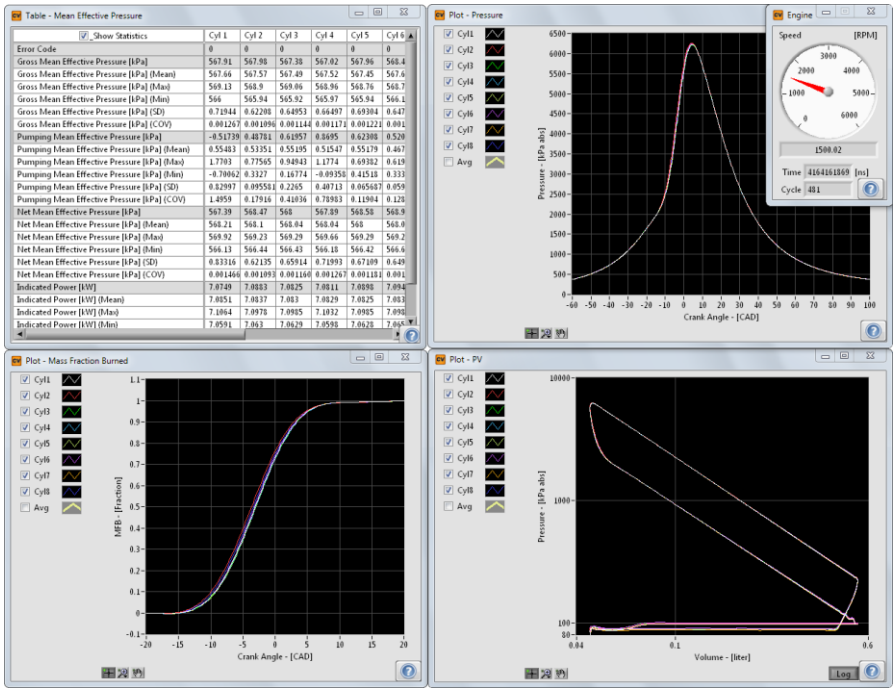


Figure 3. NI Combustion Analysis System (NI CAS) Software for LabVIEW contains hundreds of built-in functions for performing pressure-based combustion calculations.

NI CAS Software supports three timebases: high-speed engine synchronous, high-speed angular-window time domain, and medium-speed time domain. It handles synchronization between timebases for use in reports and data analysis. With NI CAS Software, you can stream raw data to file continuously or for a set number of cycles, time, or file size. Raw data files are stored in NI's open Technical Data Management Streaming (TDMS) format and include all channel configurations, engine geometry, and custom test data so you can completely reconstruct the test environment at a later date. You also can log cycle-by-cycle summaries of analysis parameters to TDMS files for later review. TDMS is an open file format that you can use to postprocess files with a variety of tools, including the NI CAS Software postprocessing tools or Microsoft Excel. You can choose from two options to add combustion analysis to your NI ECS:

1. Option 1—Includes NI CAS Software and hardware for up to 16 high-speed (500 kHz) synchronous/asynchronous channels.[1]
2. Option 2—Includes NI CAS Software and hardware for up to 16 high-speed (500 kHz) synchronous/asynchronous channels and 64 medium-speed (≤1 kHz) channels.[1]
3. Option 3—Includes NI CAS Software and hardware for up to 16 high-speed synchronous channels, 16 high-speed asynchronous channels, and 128 medium-speed channels.[1]

[1]Contact the NI Powertrain Controls Group for higher speed sampling options.

Next-Cycle Control

Next-cycle control is the process of rapidly calculating crank-angle resolved cylinder pressure data and reducing it to single-point values for use in a control loop with enough time to adjust engine control parameters and command actuators for the next combustion event (see Figure 4). Examples of single-point values used for next-cycle control include the location in crank angle degrees (CADs) of peak pressure or the location in CADs of 50 percent fuel mass fraction burned (CA50).

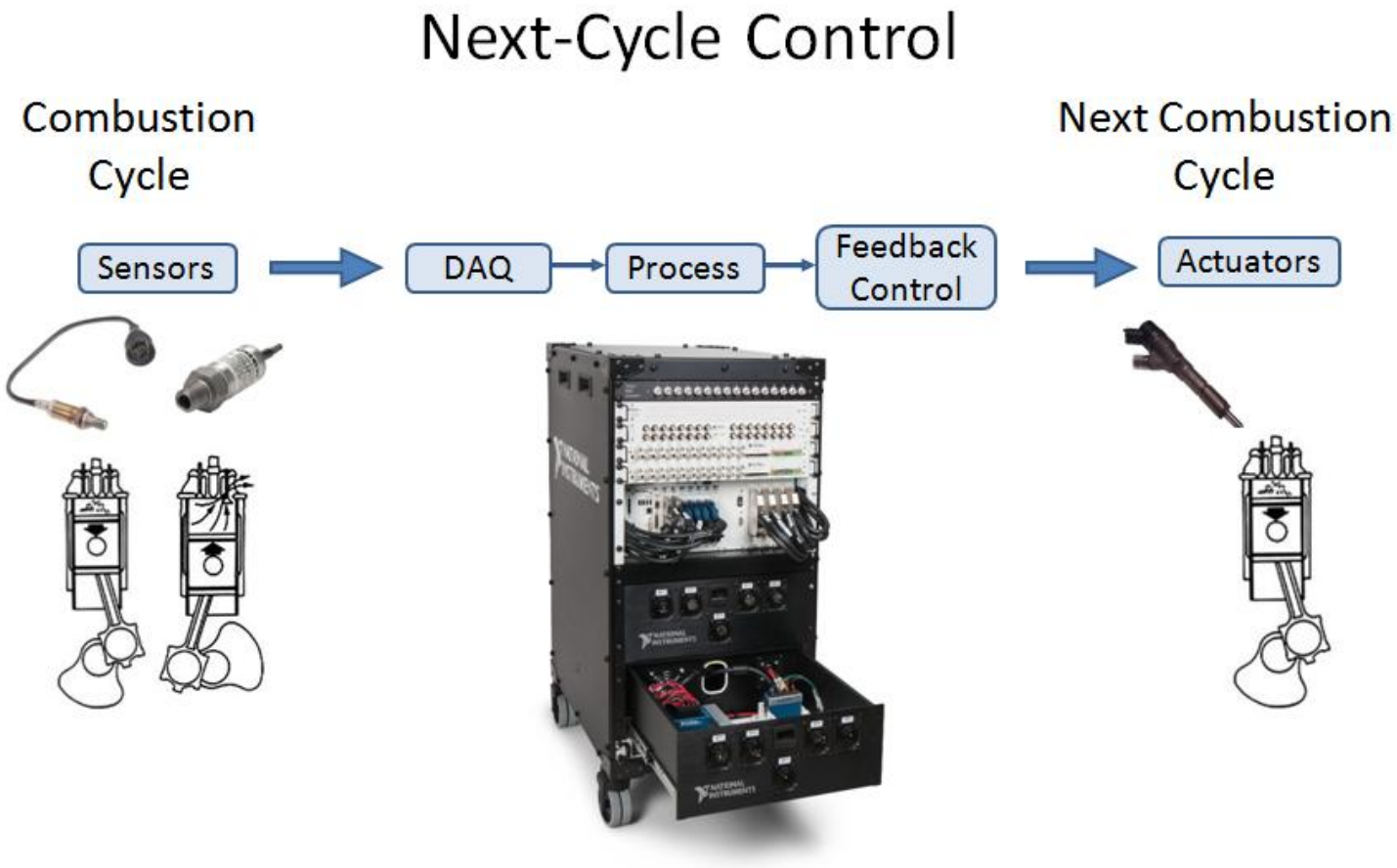


Figure 4. Next-cycle control uses pressure-based combustion analysis metrics as closed-loop feedback in the engine control algorithm.

With next-cycle control, certain combustion conditions (such as CA50) can be targeted and reliably controlled between every cycle of the engine. This is especially advantageous for research engines that use a variety of ignition strategies because combustion can vary widely between two cycles if left uncontrolled. For example, in an HCCI engine, if one cycle burns hot, the next cycle could potentially burn sooner and hotter due to the latent heat from the previous cycle. If engine inputs are not immediately adjusted, each successive cycle burns earlier and hotter than the previous, which eventually leads to engine knock and shutdown. This behavior is a common pitfall of many emerging low-temperature combustion strategies. Next-cycle control can eliminate this unwanted phenomenon by acquiring the pressure data and performing calculations quickly enough to adjust fuel injection, valve actuation, or other parameters for the next cycle based on the previous cycle's measurements. You can maintain desired combustion conditions such as CA50 on a research engine throughout its rpm range by using next-cycle control.

Because next-cycle control does not rely on a preset calibration table for fuel and spark timing decisions, you can adjust and observe certain parameters without having to worry about recalibrating a fuel map. For example, if you want to run an engine with CA50 occurring at 13.0 CAD, you have the freedom to adjust EGR and throttle position without worrying about sudden engine shutdown or knock due to calibration limits. While precisely maintaining CA50, you can sample exhaust O2 data and use that data in a proportional integral derivative (PID) loop to adjust fuel injection for optimal engine emissions without having previously created a lookup table for all possible operating conditions. This kind of flexibility is extremely valuable in research engines where the ability to finely tune and observe numerous variables without recalibration greatly increases research efficiency. Instead of spending time creating multidimensional calibration tables for all expected conditions, you can spend more time observing desirable phenomena under controlled circumstances.

You can implement next-cycle control with any NI ECS when you choose a combustion analysis option. NI CAS Software features built-in functions for next-cycle control of your engine.

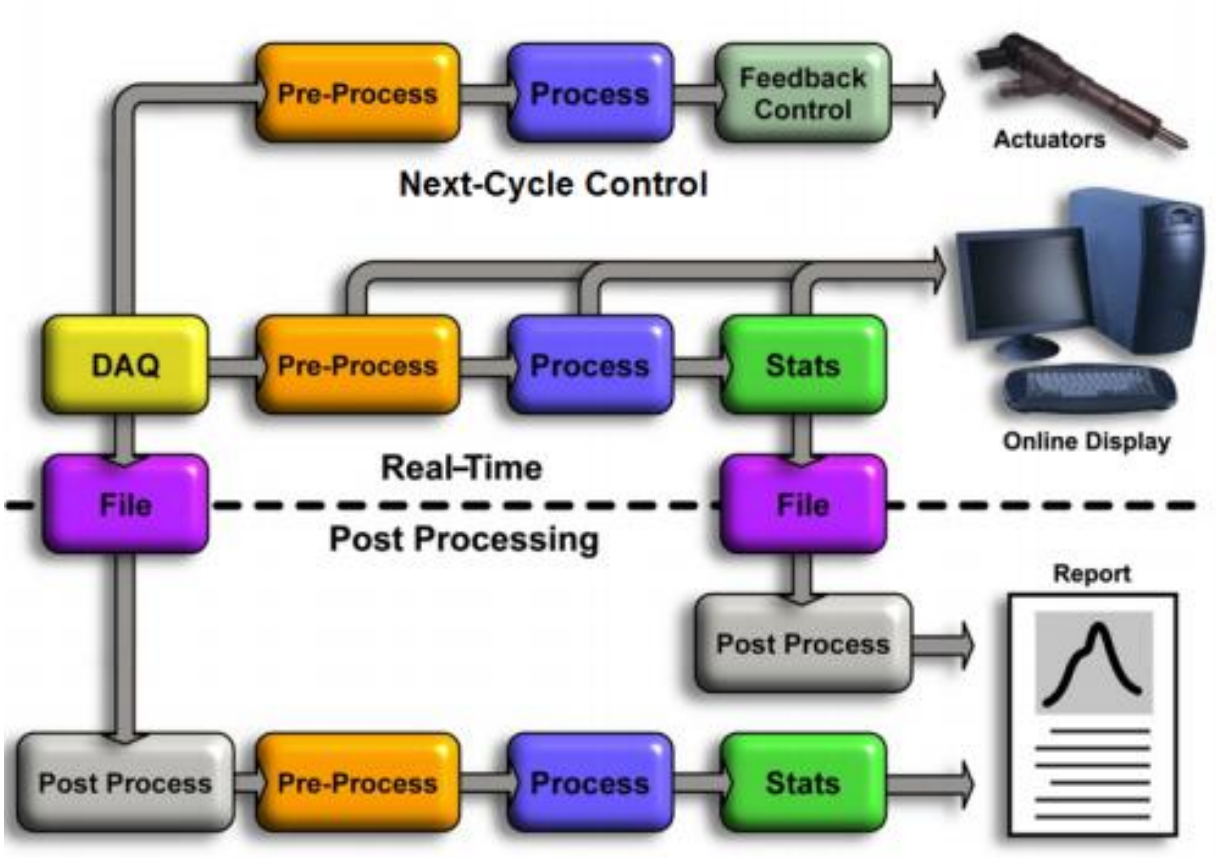


Figure 5. Next-Cycle Control Data Flow

Expansion Drawer Option for ECS-1002

Your application may require additional or different I/O from that included in the standard NI ECSs. The ECS-1002 includes a single pull-out drawer that contains all the signal conditioning C Series modules routed to the circular power connectors CPSs in the front of the drawer. There is room below Drawer A for a second drawer (Drawer B) that in the ECS-1008 comes preloaded with additional C Series I/O modules for additional channels (see Appendix E). You can add a bare second drawer to your ECS-1002 that includes:

1. Two NI 9151 four-slot R Series FPGA expansion chassis
2. One NI PXI-7853R and two SHC68-C68-S cables (provide connectivity from NI PXI-7853R to both NI 9151 chassis)
3. Screw-terminal connectivity to 5 V, 12 V, and variable power supply rails in the NI ECS
4. Cooling fan
5. Five 37-pin circular power connectors

Support Options

Advanced Support: The NI Powertrain Controls Group (PCG) directly supports the NI ECS. Each purchase of an NI ECS includes one year of unrestricted phone and email support from PCG systems engineers for an unlimited number of incidents for up to two identified contacts within your organization. You can purchase additional support from NI in yearly increments.

On-Site Application Commissioning (Five Days United States/10 Days International): The NI PCG provides on-site application commissioning and getting started assistance with a PCG systems engineer.

Custom Application and Systems Integration Engineering

Custom Software Application Development Block: Some applications require functionality that is not natively built into the NI ECS. The NI PCG offers custom software application development and remote assistance with software deployment in 40-hour blocks.

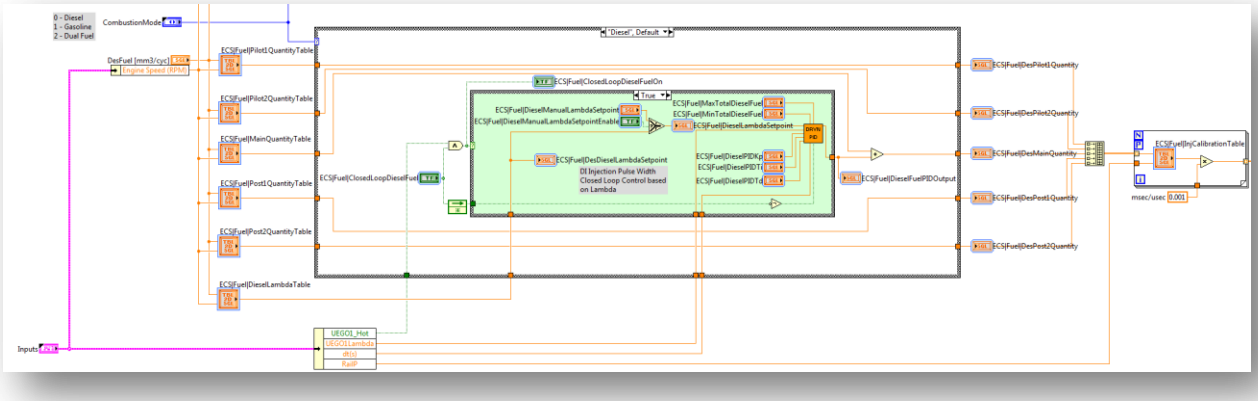


Figure 6. Example Snippet of LabVIEW Code Used for NI ECS Software

Custom ECU Adapter: The NI PCG can develop an engine control unit (ECU) adapter board to interface the NI ECS to your ECU.

Custom Wiring Harness: The NI PCG can develop a custom wiring harness up to 30 ft long that connects the NI ECS to your ECU adapter.

Figure 7. Example Custom ECU Adapter and Harness

Computer

Desktop PC With Dual Monitors: Meant for engine application development and calibration, this PC is provided with all the required development tools installed and configured to get your NI ECS up and running.

- Dual 24 in. monitors
- 8 GB memory (RAM)
- 500 GB hard drive

NI ECS Software Development Environment

All three layers of NI ECS Software are built using LabVIEW:

1. Windows Host UI—The user interface is incorporated in a LabVIEW front panel with controls and indicators that correspond to CalPoints on the real-time target. You can interact with control parameters, lookup tables, sensor values, graphs of data, and so on. The NI Software Calibration Management (SCM) toolkit, installed on the Windows host computer, is used to publish values back and forth between CalPoints on the real-time layer and the UI (see Figure 8). With the SCM toolkit, you can publish single or multiple parameters to an A2L file for ASAP3 communication to other test cell systems, save or restore different calibration files, view faults, change default values, and perform many other standard engine calibration procedures on the fly.

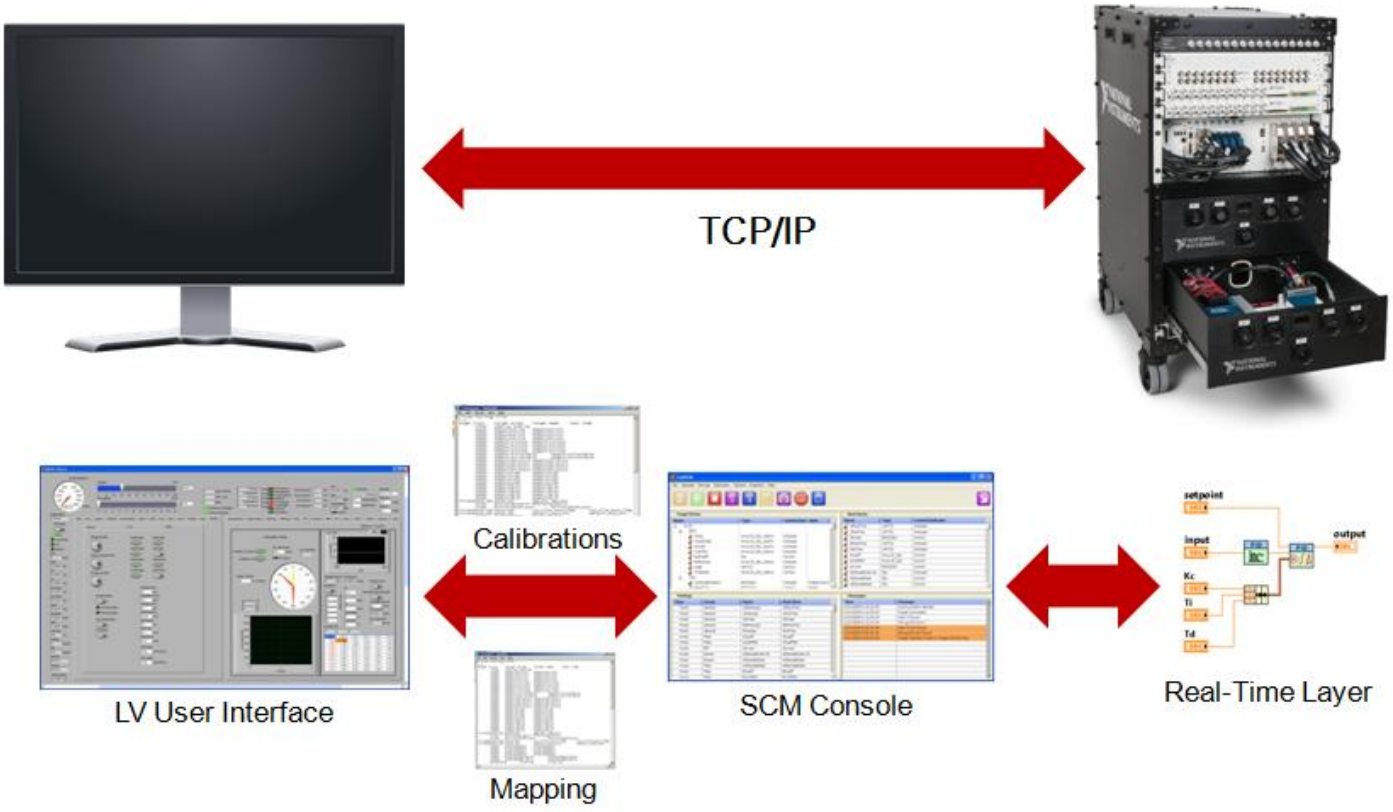


Figure 8. How the NI Software Calibration Management (SCM) Toolkit Works

2. Real-Time—The LabVIEW Real-Time Module, which is installed on the embedded real-time controller in the NI ECS, is used to schedule time-critical events such as ignition and fuel injection timing. The LabVIEW Real-Time Module features real-time OS software that runs with a high degree of determinism. Sensor feedback, high-level control strategies, and general data acquisition occur on the real-time layer. This layer also acts as the supervisor for the FPGA target and passes parameter values to and from the FPGA layer.
3. FPGA—The FPGA functions as a coprocessor to the real-time controller and features dedicated, rewritable hardware logic used in the NI ECS for functions such as real-time engine position tracking and CompactRIO module interaction. Instead of learning traditional hardware description language (HDL) code, you can use the

LabVIEW FPGA Module to program case-specific FPGA code in G, which is then compiled and deployed to the FPGA target.

NI delivers the NI ECS with a full set of device drivers and libraries. The included comprehensive example application provides a template for steady-state engine control. It contains the following features:

- Free download from ni.com
- Industry-standard automotive sensor signals (MAP, IAT, ECT, MAF, and so on)
    - Software filtering
    - 1D engineering unit conversion tables
    - Manual simulation override
- Engine position tracking
    - Support for common crank/cam patterns for engine synchronous I/O (N-M, N+1, encoder)
    - Configurable position signal channel mapping
- Generic engine control strategies for diesel, GDI, port fuel injection, and dual fueling
- Fuel systems control
    - Direct injection control (up to eight solenoid/piezoelectric channels)
        - Up to five injection pulses per cycle
        - Up to eight current-control phases within injection pulses
        - Open-loop, table-based control for injection duration, timing, and injection quantity
        - Closed-loop PID injection timing control of 50 percent mass-fraction-burn location
        - Closed-loop PID injection duration control of Lambda
        - Configurable TDC mapping to each channel
    - Port fuel injection (PFI) control (up to eight channels)
        - Independent PFI timing and duration control
        - Speed/density or MAF-based control algorithms
        - Closed-loop PID injection duration control of Lambda
    - Rail pressure control
        - High-pressure common rail using IMV and/or HPV
        - Medium-pressure common rail using a synchronous solenoid pump
- Ignition systems control
    - Up to eight channels, TTL, with up to three restrike pulses
- Air systems control
    - Throttle position control, closed loop (up to two channels, H-bridge drive)
    - Boost
        - Waste-gate actuator
        - Variable geometry turbocharger
    - EGR
        - High-pressure valve
        - Low-pressure valve
    - Variable valve actuation (cam signal-edge setpoint)
        - Intake cam
        - Exhaust cam

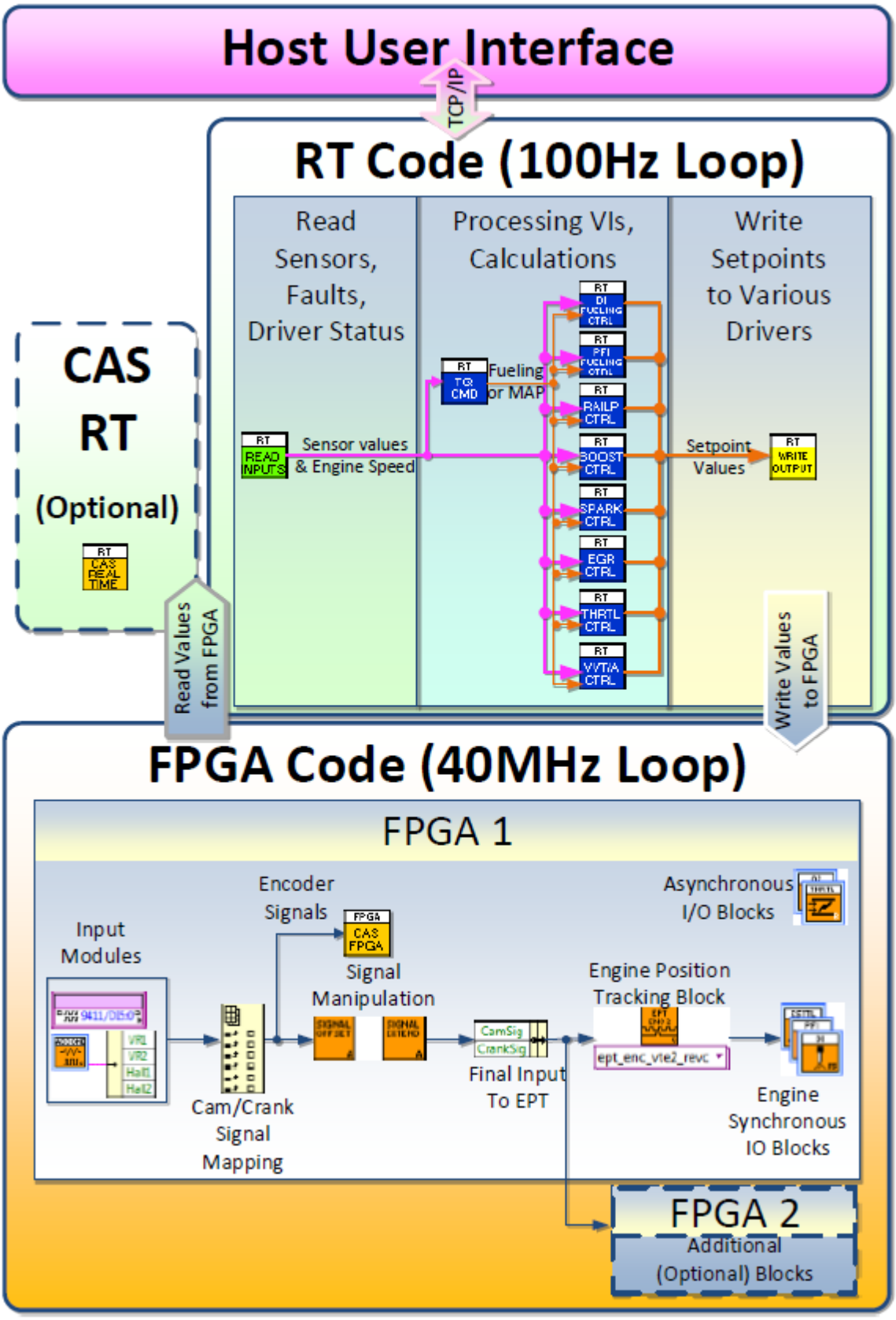


Figure 9: NI ECS Software Diagram

Frequently Asked Questions

Q. Does NI offer commissioning services (test cell integration, on-site support, and so on)?
   A. Yes, an NI PCG systems engineer provides on-site application commissioning and getting started assistance.

Q. Can the NI ECS interface with industry-standard test cell automation tools like AVL PUMA or A&D iTest?
   A. Yes. The software on the NI ECS acts as an ASAP3 slave and can interface with test cell automation systems that communicate over the ASAM MCD-3MC (ASAP3) protocol via Ethernet.

Q. Can the ECS interface with industry-standard ECU calibration tools like ETAS INCA or AVL Cameo?
   A. Not directly. The NI ECS provides an ASAM MCD-2 (A2L) file, and communication is over the ASAM MCD-3MC (ASAP3) protocol via Ethernet.

Q. Can I run a The MathWorks, Inc. Simulink® model on the ECS?
   A. Yes, using either the LabVIEW Model Interface Toolkit or NI VeriStand. You can use both of these software packages to interact with models from a variety of modeling environments and programming languages. It can run compiled models created in any supported modeling environment as well as uncompiled models (.mdl files) created using Simulink® software (Simulink® is a registered trademark of The MathWorks, Inc.)

Q. Are academic discounts available?
   A. Yes, contact either NI Powertrain Controls directly at powertraincontrolsinfo@ni.com or contact your local NI field representative.

Q. How much code do I need to write?
   A. NI delivers the NI ECS with a standard software example application based on LabVIEW that may work out of the box for certain applications. The software is openly programmable, so you can add to or modify the code to suit your specific application requirements. Additionally, if your application does not work with our standard software application and you prefer not to write code, you can purchase a block of systems engineering software time to get tailored code for your application. Contact NI PCG for more information about the standard software application.

Q. What LabVIEW package is required to use the NI ECS?
   A. You must either purchase or already own a license of the LabVIEW Professional Development System or NI Developer Suite with the LabVIEW Real-Time and LabVIEW FPGA software modules.

Q. What if I need to modify hardware or software after the purchase?
   - The combination NI PXI-1050 chassis with four slots for SCXI hardware is modular so you can add, remove, or replace any NI PXI or NI SCXI module. Additionally, you can expand your I/O with NI MXI expansion options. The second NI ECS drawer also features spare slots for additional CompactRIO modules (see page 34).
   - The NI PCG can wire up and add NI C Series modules to fit your application for a fee.
   - NI continues to support the latest versions of Windows OS through successive releases of LabVIEW. Contact NI for any questions regarding OS compatibility with LabVIEW or NI hardware.
   - The one-year Standard Service Program (SSP) covers software upgrade assistance. Contact the NI PCG for specific instructions on your system.

Simulink® is a registered trademark of The MathWorks, Inc.

Q. What ongoing support options do you provide?

A. The NI PCG offers advanced support and on-site application commissioning services. See page 10 for further information.

Q. Which combustion analysis functions do you support?

A. Combustion analysis is an option for NI ECS, which is full-featured combustion analysis software that includes traditional combustion analysis calculations such as Rassweiler and Withrow as well as single-zone heat release. Refer to page 7 for further information.

Q. How do I implement next-cycle control?

A. The NI ECS has a standard software feature built into the base application that explains how to implement next-cycle control step by step.

Q. How do I connect the NI ECS to my specific engine?

A. The NI PCG offers on-site application commissioning and startup assistance. NI can also build a custom ECU adapter board and harness to match your specific application. Refer to page 10 for further details.

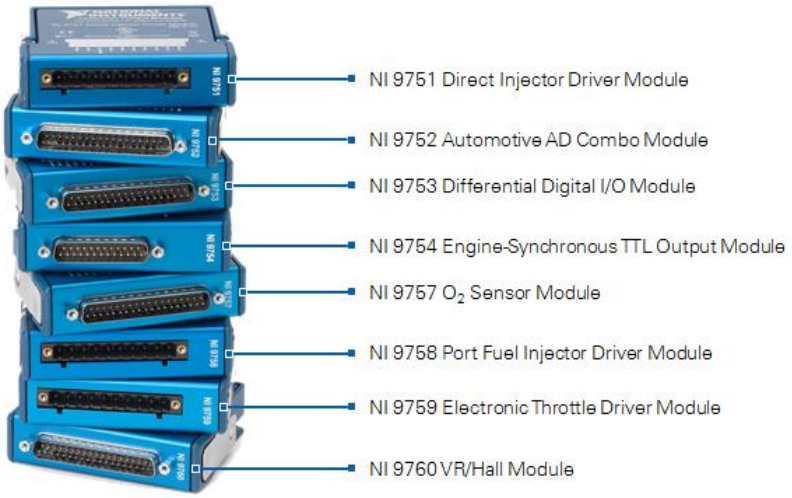
Q. What are your warranty options?

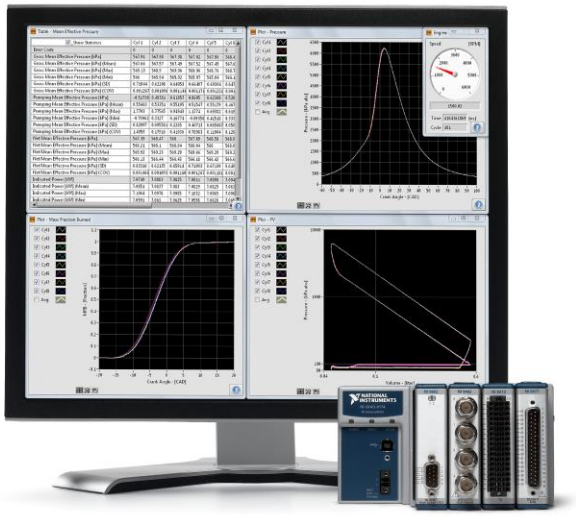
A. NI warrants its hardware products against defects in materials and workmanship for a period of one (1) year from the date it is shipped to the customer. For more information, refer to http://www.ni.com/services/warranty_repair_policies.htm.

Who Is NI Powertrain Controls?

The National Instruments Powertrain Controls Group (NI PCG) specializes in engine control and combustion analysis. Originally Drivven Inc., the San Antonio-based NI PCG provides system engineering services and standard products to the engine test, component test, and advanced research markets. NI PCG systems are the de facto standard controllers for combustion and fuels research in corporate, government, and academic research institutions throughout the world.

NI PCG products include actuator power electronics and sensor interfaces for all types of production engine I/O. You can order these components as well as some of the standard bundled systems like the NI Direct Injector Driver System from **ni.com/powertraincontrols**. NI PCG also offers a full range of consulting services from customizable hardware platforms like the NI ECS cabinets described here to completely customized systems. Though many customers simply buy the hardware and implement the application themselves, NI PCG engineers can analyze an engine, build customized software and wiring harnesses, and install turnkey research engine controllers at customer sites around the world. From lawnmowers to locomotives, NI PCG has the expertise and support you need to meet your project goals and deadlines.





Contact Us

To order your NI ECS, email powertraincontrolsinfo@ni.com.

Phone: (210) 248-9308

Web: ni.com/powertraincontrols

Appendix A: NI ECS Hardware and Options List

Though this list contains standard add-on options for the NI ECS, the NI PCG can build custom engine control systems to suit your specific application needs.

Engine Control Systems

NI ECS-1000: NI Base System
I/O for reading 2 variable reluctance and 2 hall-effect sensor channels, 1 encoder input; intended for combustion analysis only; CAS not included

NI ECS-1002: NI 2-Cylinder Engine Control System
Includes I/O for controlling 1- to 2-cylinder engines (up to two direct injectors [multiplexed]); CAS not included

NI ECS-1008: NI 8-Cylinder Engine Control System
Includes I/O for controlling 8-cylinder engines (up to eight direct injectors [four banks of two multiplexed]); CAS not included

Combustion Analysis Options

CAS Option 1
NI CAS Software and hardware for up to 16 high-speed (500 kHz) synchronous/asynchronous channels

CAS Option 2
NI CAS Software and hardware for up to 16 high-speed (500 kHz) synchronous/asynchronous channels and 64 medium-speed (≤1 kHz) channels

CAS Option 3
NI CAS Software and hardware for up to 16 high-speed synchronous channels, 16 high-speed asynchronous channels, and 128 medium-speed channels

Support Options

On-Site Application Commissioning (Five Days United States/10 Days International)
One NI Powertrain Controls Group engineer
Travel expenses included within the continental United States

Additional One-Year Advanced Support*
Annual support plan with unrestricted technical support from NI PCG engineers, unlimited number of incidents, phone or email access for up to two contacts
**First year included with initial system purchase*

Custom Application and System Integration Engineering

Custom Software Application Development Block (40 Hr)
NI Powertrain Controls Group engineer designs and develops custom application and provides remote assistance with deployment

Custom ECU Adapter – New or Existing Design
Custom engineer-developed ECU adapter board

Custom Wiring Harness – New or Existing Design
Connects NIECS to ECU adapter; up to 30 ft long

NI Developer Suite

NI Developer Suite With LabVIEW Real-Time and LabVIEW FPGA Modules
Includes one year of SSP

Computer

Desktop PC With Dual Monitors
For engine control application development and calibration; PC is provided with development tools installed and configured; minimum specifications:

- *24 in. monitors*
- *8 GB memory (RAM)*
- *500 GB hard drive*

Expansion Options and Accessories

NI Combustion Analysis System Software (Development License)
782595-01; includes one year SSP

NI PXI-6123 (16 MS) S Series Multifunction DAQ Module
779181-01; 16-bit, 500 kS/s/ch, simultaneous sampling multifunction DAQ

NI BNC-2090A Rack-Mountable Accessory for 68-Pin Multifunction DAQ
779556-01; shielded rack-mount BNC connector block

SH68-68-EP Cable
184749-01; noise rejecting, shielded cable, 1 m

NI PXI-6251 M Series DAQ Module
779631-01; 16-bit, 1 MS/s (multichannel), 1.25 MS/s (1-channel), 16 analog inputs

NI SCXI-1102 32 Ch Thermocouple Amplifier Module
776572-02; 32-channel thermocouple/RTD/thermistor input module

NI SCXI-1102B 32 Ch Amplifier, 200 Hz Bandwidth Module
776572-02B; 32-channel millivolt/volt/current input module

NI BNC-2095 Rack-Mountable Accessory for BNC Connectors
777508-01; 32-channel BNC connector configuration

NI TC-2095 Rack-Mountable Accessory for Thermocouple Connectors
777509-01; 32-channel thermocouple connector configuration

SH96-96 Cable
183228-01; shielded cable for SCXI, 1 m

Expansion Drawer for NI ECS-1002*
Supports most C Series I/O modules in eight empty slots
**Includes one NI PXI-7853R module and two SHC68-C68-S cables*

NI PXI-7853R R Series Multifunction RIO Module
780341-01; multifunction RIO module with programmable Virtex-5 LX85 FPGA

SHC68-C68-S Shielded Cable
186381-02; 68-pin VHDCI to 68-pin .050 Series D-type, 2 m

NI 9751 Direct Injector Driver Module
782076-01; 3-channel, 190 V internal boost power supply, 30 A peak

NI 9758 Port Fuel Injector Driver Module
782080-01; 8-channel PFI/low-side solenoid driver module

NI 9759 Electronic Throttle Driver Module
782081-01; 2-channel H-bridge throttle control module with analog feedback module

NI 9752 Automotive AD Combo Module
782075-01; general AI/DI module with VR/Hall effect sensor inputs

NI 9754 Engine-Synchronous TTL Output Module
782077-01; 8-channel TTL output module for engine synchronous digital output

NI 9853 2-Port High-Speed CAN Module
779429-01; up to 1 Mbit/s, 25 ns resolution, 11-bit and 29-bit arbitration ID support

NI NOx 12 V Sensor Kit
782594-01; includes 12 V sensor, connector kit, and bung

NI NOx CAN Module Interface Cable
782643-01; interface cable to connect NI 9853 to NI NOx 12 V sensor kit

NI 9269 Channel-to-Channel Isolated 10 V Analog Output Module
781098-01; 4-channel voltage output, ±10 V, channel-to-channel isolation

Wiring Tooling Kit
Wire cutter, stripper, crimpers, and extraction tools

Wiring Connector Kit
Ferrules, CPC pins, sockets, key plugs, cable clamps, and D-SUB contacts

D-SUB Connector Kits
Connector, backshell, and contacts
9-, 15-, 25-, and 37-pin versions

Appendix B: I/O Channel List

Type	Channels (ECS-1002)	Additional Channels (ECS-1008)	Connector Type	Description	Reference
Onboard FPGA digital I/O	8	n/a	BNC	NI PXI-7853R multifunction RIO	Table 4
Onboard FPGA analog output	4	n/a			
Onboard FPGA analog input	4	n/a			
Piezo or solenoid injectors	2	8	37-pin CPC	1 to 4 NI 9751 DI driver modules	Table 10
High- or low-impedance PFI driver	4	8	37-pin CPC	1 to 2 NI 9758 PFI/LS driver modules	Table 9
General-purpose low-side solenoid driver	4	8			
Throttle body drivers	2	n/a	37-pin CPC	1 NI 9759 throttle driver module	Table 8
Shaft encoder	1	n/a	37-pin CPC	1 NI 9411 differential digital input module	Table 5
Dual-purpose differential/ single-ended digital inputs	3	n/a			
Engine synchronous TTL outputs	8	n/a	37-pin CPC	1 NI 9754 engine synchronous TTL output	Table 7
A/D 0 V to 33 V	1	n/a	37-pin CPC	1 NI 9752 analog/digital input module with VR and Hall effect sensor inputs	Table 6
A/D 0 V to 5 V pull-down configuration	11	n/a			
A/D 0 V to 5 V pull-up configuration	5	n/a			
Variable reluctance channels	2	n/a			
Hall effect sensor/ general-purpose digital	2	n/a			
Bosch LSU 4.2 wideband	2	n/a	37-pin CPC	1 NI 9757 O_2 sensor input module	Table 11
Narrowband sensor input (differential)	2	n/a			
CAN protocol	2 ports	n/a	37-pin CPC	1 NI 9853 CAN interface module	Table 12
5 VDC output	10	16	37 pin CPC	5 V, 5 ADC power supply	Table 15
12 VDC output	4 (2)	6 (2)	37-pin CPC	12 V, 15 ADC power supply	Table 14, Table 20
Variable DC 0 V to 30 V output	12 (2,3)	20 (2,3)	37-pin CPC	0 V to 30 V, 50 ADC power supply	Table 13, Table 20
Fast differential analog inputs	0	32	BNC	1 to 4 PXI-6123 simultaneous sampling multifunction DAQ	Table 17
Thermocouple inputs	0	128	Mini thermocouple	1 to 4 SCXI-1102 32-channel thermocouple/voltage input module	Table 18
Low-frequency analog inputs	0	128	BNC	1 to 4 SCXI-1102B 32-channel amplifier module; 200 Hz bandwidth	Table 19

Appendix C: Specifications by Device

Table 2. NI PXI-8119 Real-Time Controller

CPU	Intel Core i7-3610QE, 2.3 GHz (base), 3.3 GHz (single-core Turbo Boost mode), 3.2 GHz (dual-core Turbo Boost mode), 3.1 GHz (quad-core Turbo Boost mode)
L3 cache	6 MB shared Intel smart cache
1600 MHz DDR3 RAM, standard	4 GB (1 x 4 GB)
1600 MHz DDR3 RAM, maximum	4 GB (1 x 4 GB)
Hard drive (extended temperature and 24/7 option), minimum	80 GB SATA (5400 rpm)
10/100/1000BASE-TX (Gigabit) Ethernet ports	2
SuperSpeed USB ports	2
Hi-Speed USB ports	4
GPIB (IEEE 488) controller	✓
Serial port (RS232)	✓
Parallel port	✓
Watchdog/trigger SMB	✓

Table 3. NI PXI-1050 PXI/SCXI Chassis

PXI slots	8
SCXI slots	4
Total power available	500 W
Maximum system bandwidth	132 MB/s

Table 4. NI PXI-7853R Multifunction RIO

FPGA	Virtex-5 LX85
Analog inputs	8 channels, single-ended or differential 16-bit resolution, 750 kS/s ±10 V range Voltage range accuracy 3.97 mV Voltage range sensitivity 0.305 mV Simultaneous sampling 384 kB onboard memory
Analog outputs	8 channels 16-bit resolution, 1 MS/s ±10 V range Voltage range accuracy 5.88 mV Voltage range sensitivity 0.305 mV 2.5 mA current drive per channel, 20 mA maximum for all channels
Digital I/O	96 channels, bidirectional 40 MHz clock rate TTL, 3.3 V, 5 V, LVTTL logic levels Maximum input range 0 V to 5 V Maximum output range 0 V to 3.3 V Maximum current drive 4 mA single, 384 mA total Programmable input filters Supports programmable power-up states
Counter/timers	96 counters 3 DMA channels Debouncing/glitch removal 0 V to 5 V 40 MHz maximum source frequency Minimum input pulse width 12.5 ns 64-bit resolution Timebase stability 100 ppm

Table 5. NI 9411 Differential Digital Input

Channels	6
Type	Single-ended or differential
Single-ended input range, high	2 V to 24 V
Single-ended input range, low	0 V to 0.8 V
Differential input range, high	300 mV to 24 V
Differential input range, low	-300 mV to -24 V
Input delay time (maximum)	500 ns
Input voltage range (Vsup)	5 VDC to 30 VDC (externally provided)
Channel-to-channel isolation	none

Table 6. NI 9752 General Automotive AI/DI Module With VR/Hall Effect Sensor Inputs

A/D channels	21
Variable reluctance channels	2
Hell effect sensor/general-purpose digital	2
Resolution	12-bit
Sampling rate	2 kS/s
Maximum input range, A/D Ch 1–3	0 V to 33 V, voltage divider
Maximum input range, A/D Ch 4– 16	0 V to 5 V, pull-down
Maximum input range, A/D Ch 17 –21	0 V to 5 V, pull-up
Maximum input range, VR Ch 1–2	-60 V to 60 V
Maximum input range, Hall Ch 1–2	-30 V to 30 V, pull-up to 5 V

Table 7. NI 9754 Engine Synchronous TTL Output

Channels	8
Resolution	200 ns

Table 8. NI 9759 Throttle Driver

H-bridge driver channels	2
Analog input channels	2
Analog input range	0 V to 5 V
Resolution	12-bit
Sampling rate	2.23 kHz
H-bridge current maximum (per channel)	3 A continuous, 6 A peak
Input voltage range (BATT)	6 VDC to 32 VDC (externally provided)

Table 9. NI 9758 PFI Driver/LS Switch

High- or low-impedance PFI driver channels	4
General-purpose low-side solenoid driver channels	4
PFI control type	Peak/hold current control
PFI current profile (maximum)	4 A peak, 1 A hold
Low-side driver current (maximum)	1.2 A continuous duty
Low-side PWM duty cycle	0% to 100%
Low-side frequency of operation	2 Hz to 10 kHz
Low-side resolution	500 ns
Input voltage range (BATT)	6 VDC to 32 VDC (externally provided)

Table 10. NI 9751 DI Driver

Number of injectors, solenoid or piezo[1]	2
Internal boost supply voltage	190 V
Current (maximum)	30 A peak, 15 A hold
Maximum recommended injection command duration[2]	5 ms
Maximum injection events per engine cycle[3]	16
Minimum time between injection events[4]	0 ms
Low-side frequency of operation	2 Hz to 10 kHz
Low-side resolution	500 ns
Optional external supply voltage range	7 VDC to 190 VDC

1. It is possible to operate three solenoid injectors with a single NI 9751 Direct Injector Driver Module if the power dissipation limit is not exceeded (low rpm or light loads) .
2. Longer injection durations are possible, but the duty cycle of the driver should be considered. For example, a single one-shot pulse on an injector test stand could safely be 200 ms. Therefore, injection duty cycle, current levels, and module temperature should be considered.
3. This is a software limit. However, overall injection duty cycle, current levels, and module temperature should be considered. Sixteen injection events per engine cycle may overload the module depending on engine speed and current levels.
4. The software can be configured to have multiple injection commands that merge. However, the injector needs a certain amount of time to close the valve at the end of an injection command. This is a property of the injector.

Table 11. NI 9757 O2 Sensor Input Module

Bosch LSU 4.2 wideband channels	2
Narrowband sensor input (differential) channels	4
Channel reading update rate	1 kHz
Resolution	12-bit
Heater control circuits	2
Input voltage range (BATT)	6 VDC to 17 VDC (externally provided)

Table 12. NI 9853 CAN Interface

Number of ports	2
API support	NI CAN Channel API (limited), NI CAN Frame API (full)
Voltage	5 V
Maximum baud rate	1 Mbit/s
Minimum baud rate	40 kbits/s
Termination	External
Synchronization frequency	20 MHz
Hardware timestamping	1 µs resolution

Table 13. TDK-Lambda GEN 30-50 Variable Power Supply

Rated power	1500 W
Output voltage	0 V to 30 V
Output current	0 A to 50 A
AC input	85 VAC to 265 VAC continuous single phase, 47 Hz to 63 Hz
AC line current (100 V/200 V)[1]	21 A/11 A
Ripple mV rms (5 Hz to 1 MHz)	8
Protection	Adjustable overvoltage, undervoltage, current foldback, overtemperature, safe/auto start

1. You must have a 20 A outlet at 120 VAC to get the full 1500 W capability.

Table 14. Pulse Power QS10.121 12 VDC Power Supply

Rated power	180 W
Output voltage	12 V to 15 V
Output current	15 A to 13.5 A
AC input	100 VAC to 240 VAC continuous single phase, 50 Hz to 60 Hz
AC line current (120 V/230 V)	1.65 A/0.93 A
Load regulation	100 mV at 15 A
Protection	Overload, temperature

Table 15. Pulse Power ML30.101 5 VDC Power Supply

Rated power	25 W
Output voltage	5 V to 5.5 V
Output current	5 A
AC input	100 VAC to 240 VAC continuous single phase, 50 Hz to 60Hz
AC line current (100 V/196 V)	0.6 A/0.25 A
Load regulation	Dynamic ±5% Vout
Protection	Overload, temperature

Table 16. Geist BRFC100-10 Power Distribution Strip

Rated power	1400 W
Rated voltage	120 V
Rated current	15 A
AC input	100 VAC to 240 VAC continuous single phase, 50 Hz to 60 Hz
Display	Amps, volts, watts, and power factor
Protection	Thermal breaker

Table 17. NI PXI-6123 Simultaneous Sampling Multifunction DAQ

Analog in channels	8 differential
Sampling speed (per channel)	500 kS/s
Resolution	16-bit
Input range (4 ranges)	±1.25 V to ±10 V
Onboard memory	16 MS or 32 MS
Trigger	Analog, digital

Table 18. NI SCXI-1102 32-Channel Thermocouple/Voltage Input Module

Thermocouple channels	32
Sampling speed	333 kS/s
Resolution	16-bit
Maximum voltage range	-10 V to 10 V
Available filters	2 Hz
Signal conditioning	Cold-junction compensation , open thermocouple, lowpass filtering , 0 mA to 20 mA current input

Note: Thermocouple and low-frequency input channels total cannot exceed 128 and each must come in multiples of 32.

Table 19. NI SCXI-1102B 32-Channel Amplifier Module; 200 Hz Bandwidth

Thermocouple channels	32
Sampling speed	333 kS/s
Resolution	16-bit
Maximum voltage range	-10 V to 10 V
Available filters	200 Hz
Signal conditioning	Cold-junction compensation, open thermocouple, lowpass filtering , 0 mA to 20 mA current input

Note: Thermocouple and low-frequency input channels total cannot exceed 128 and each must come in multiples of 32.

Table 20. System-Level Specifications

AC mains connections, rack	120 V, 15 A
AC mains connections, variable DC power supply	120 V, 20 A
CPC 37-pin current limit	13 A
I/O drawer current limit (total)	20 A, fuse protected
Maximum operating temperature	45 °C

Appendix D: Additional Photos

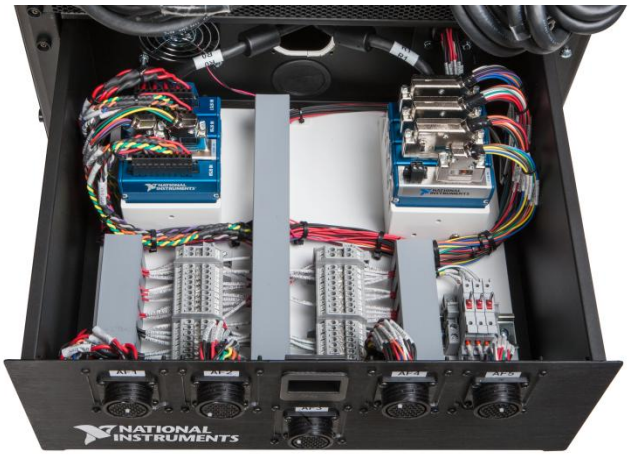


Figure 10. NI ECS-1002 and 1008 Standard Drawer A

Figure 11. Custom ECU Adapter

Figure 12. Rear View of an NI ECS-1002

Figure 13. Rear View of an NI ECS-1008 with Combustion Analysis Option 3

Figure 14: Wiring Tooling Kit

Figure 15: Expansion Drawer for NI ECS-1002

Figure 16: D-SUB Connector Kit

Figure 17: Wiring Connector Kit

Figure 18: NI ECS-1008 with CAS Option 3

Appendix E: Additional NI ECS Hardware Diagrams

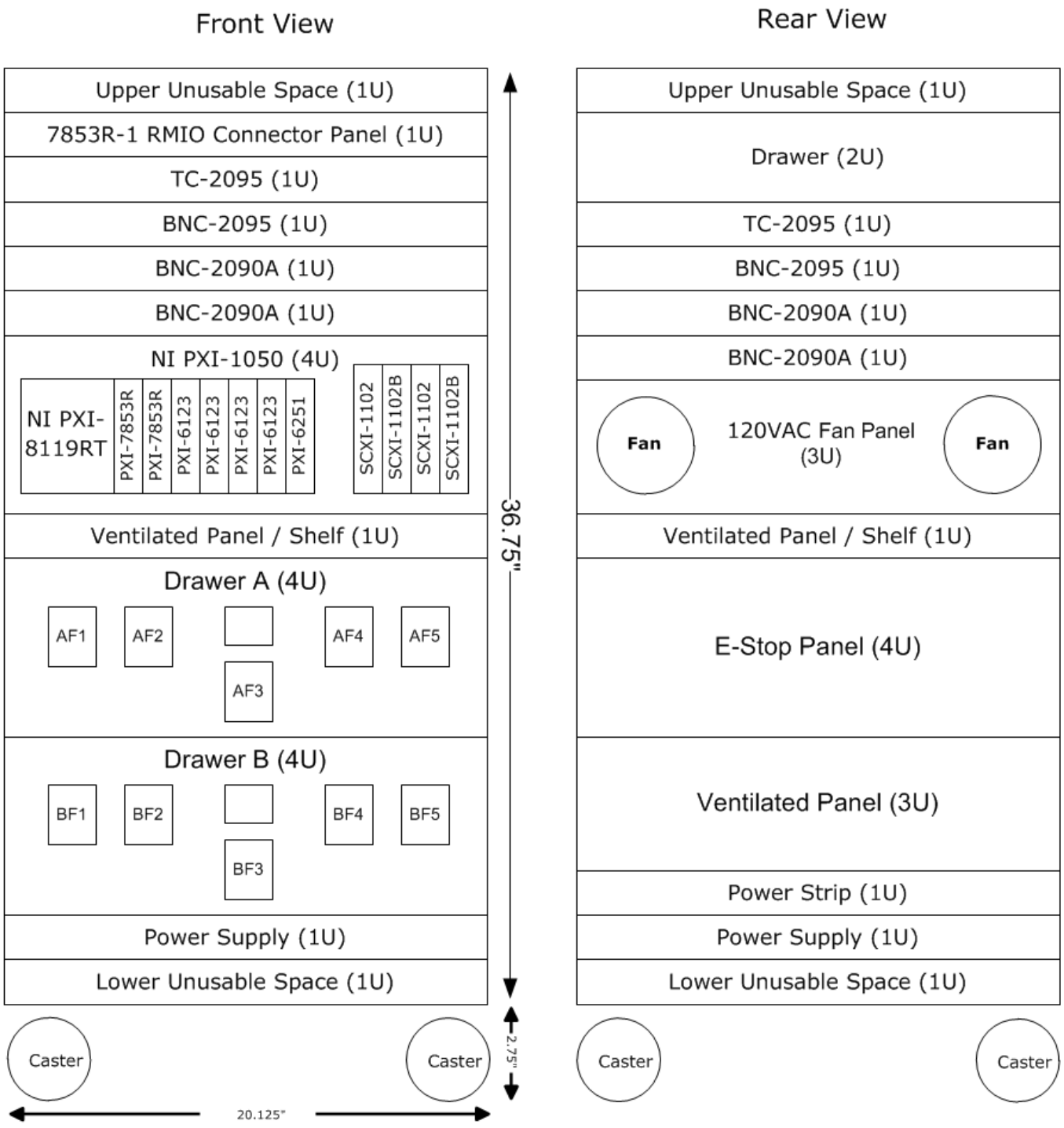


Figure 19. Rack Diagram of an NI ECS.

Refer to Figure 2: NI ECS Functional Block Diagram for Configuration Options.

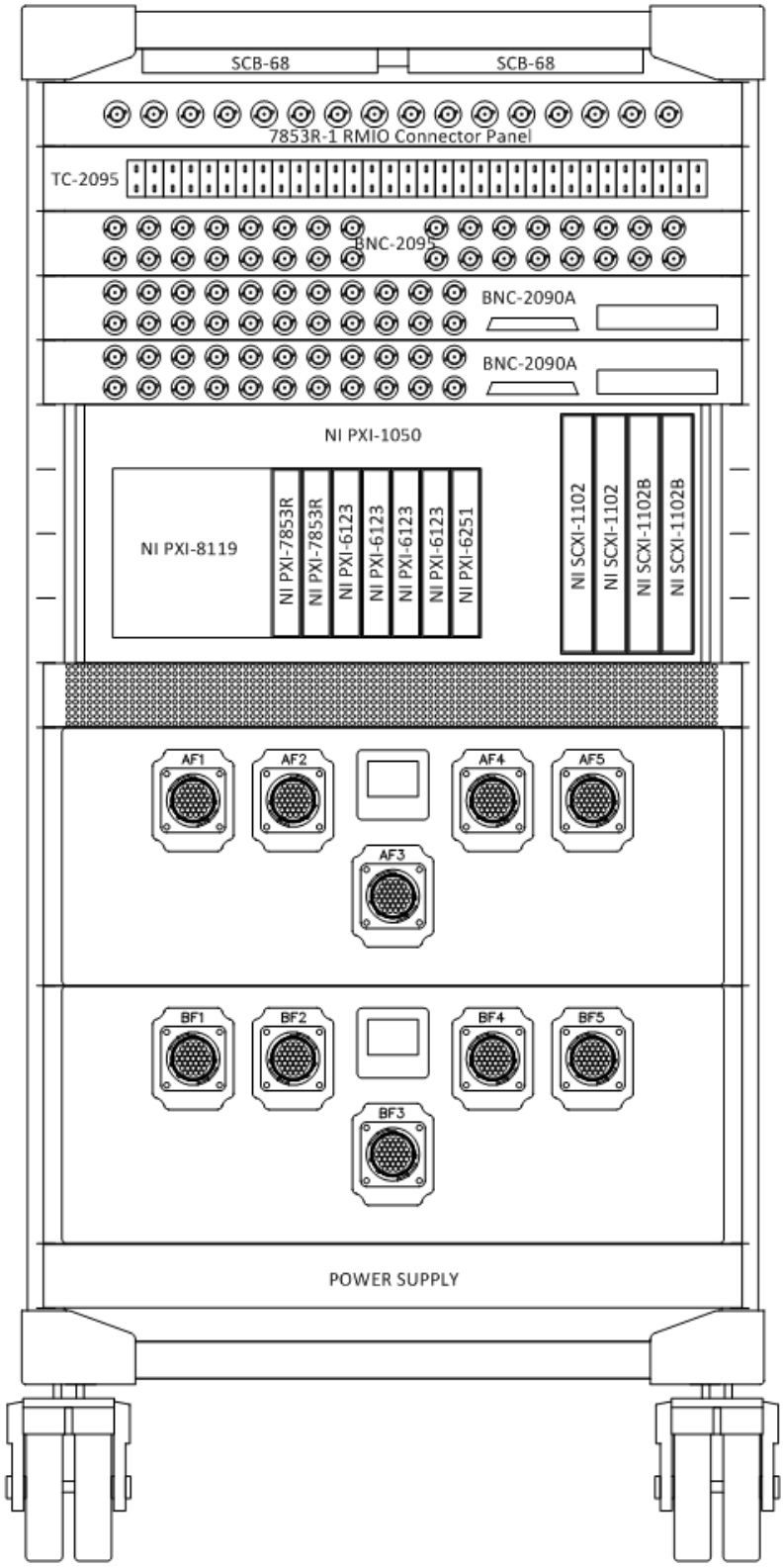


Figure 20. Mechanical Drawing of an NI ECS (Front View).

Refer to Figure 2: NI ECS Functional Block Diagram for Configuration Options.

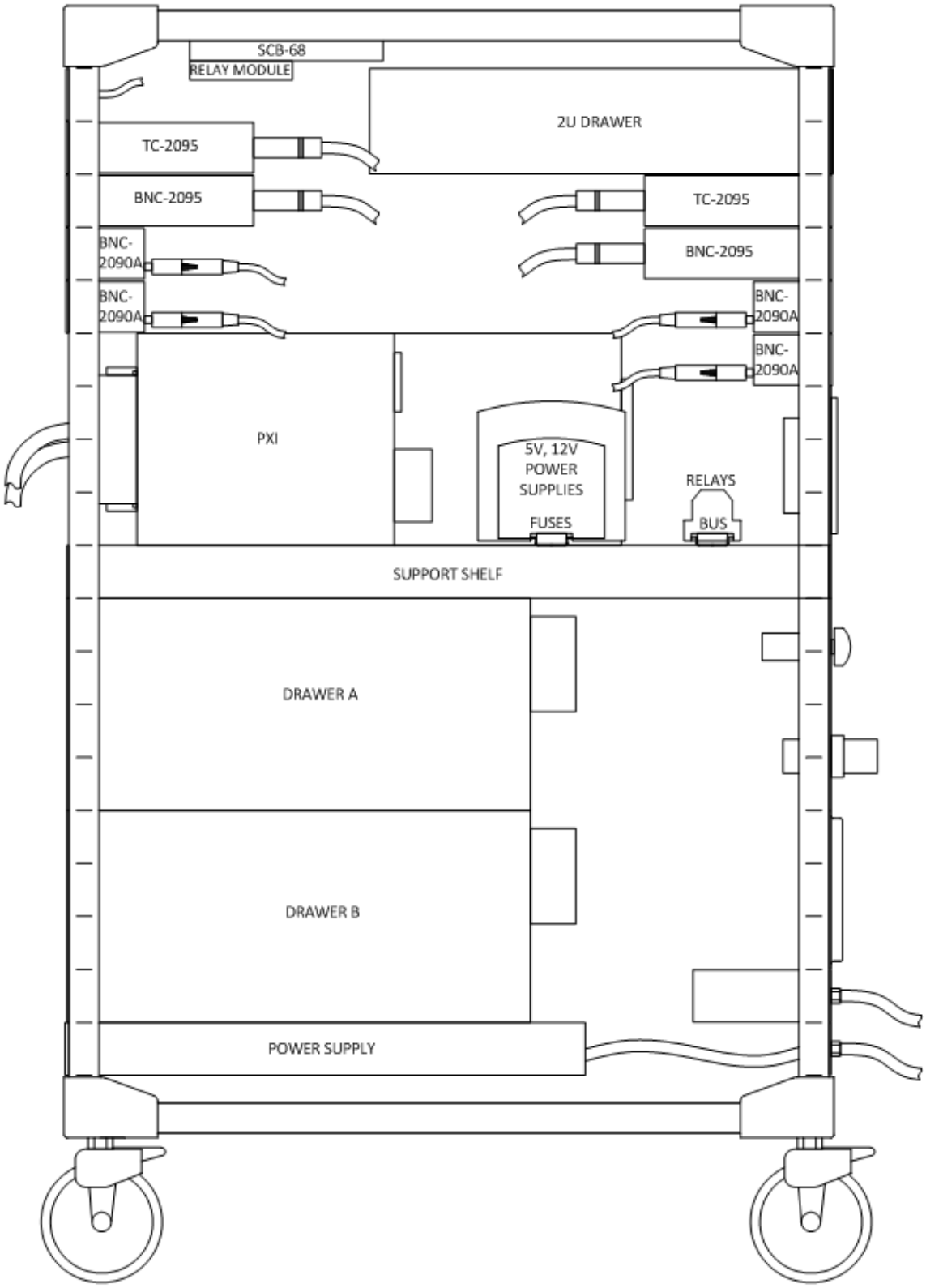


Figure 21. Mechanical Drawing of an NI ECS (Side View).

Refer to Figure 2: NI ECS Functional Block Diagram for Configuration Options.

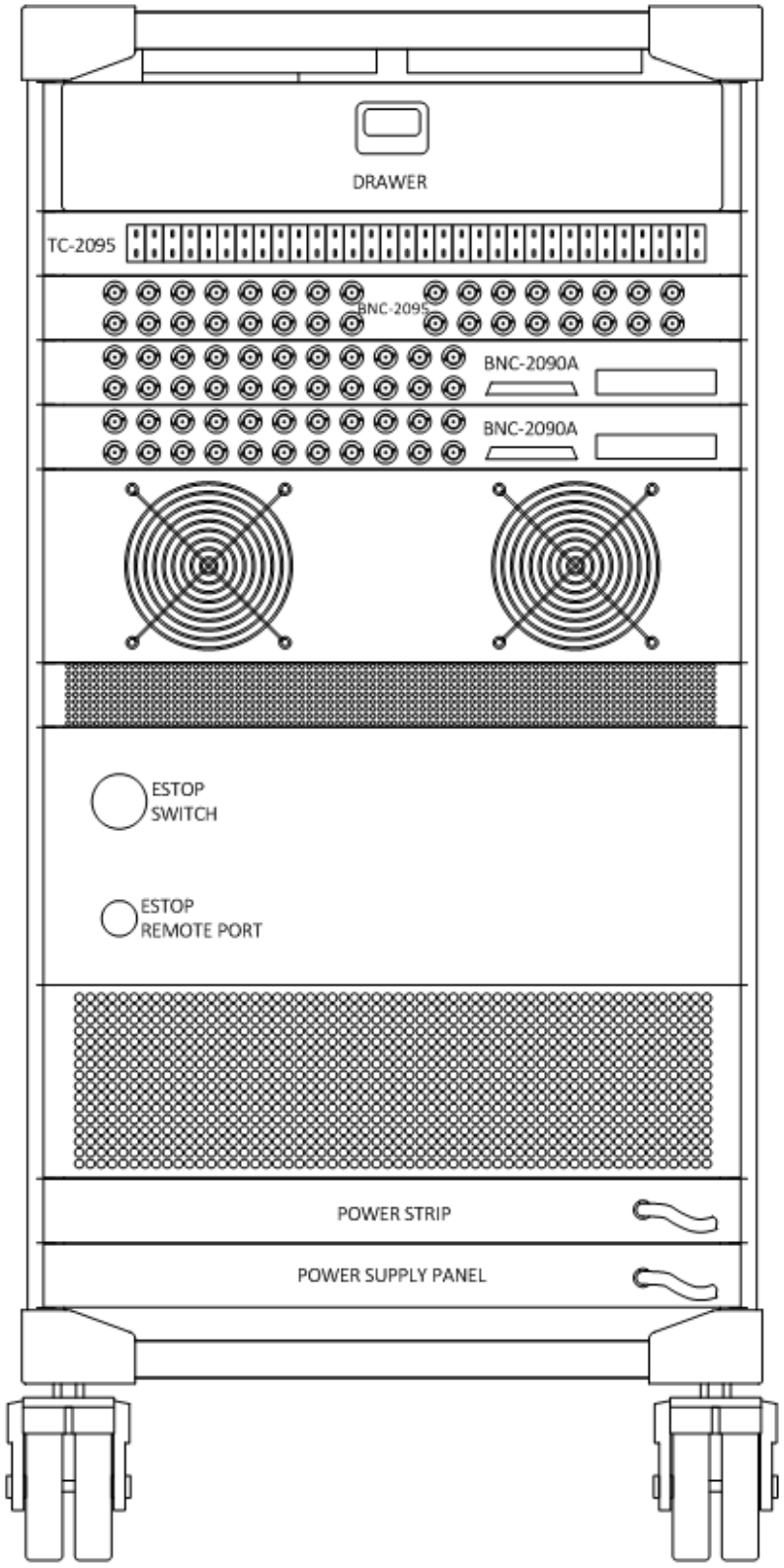


Figure 22. Mechanical Drawing of an NI ECS (Rear View).

Refer to Figure 2: NI ECS Functional Block Diagram for Configuration Options.

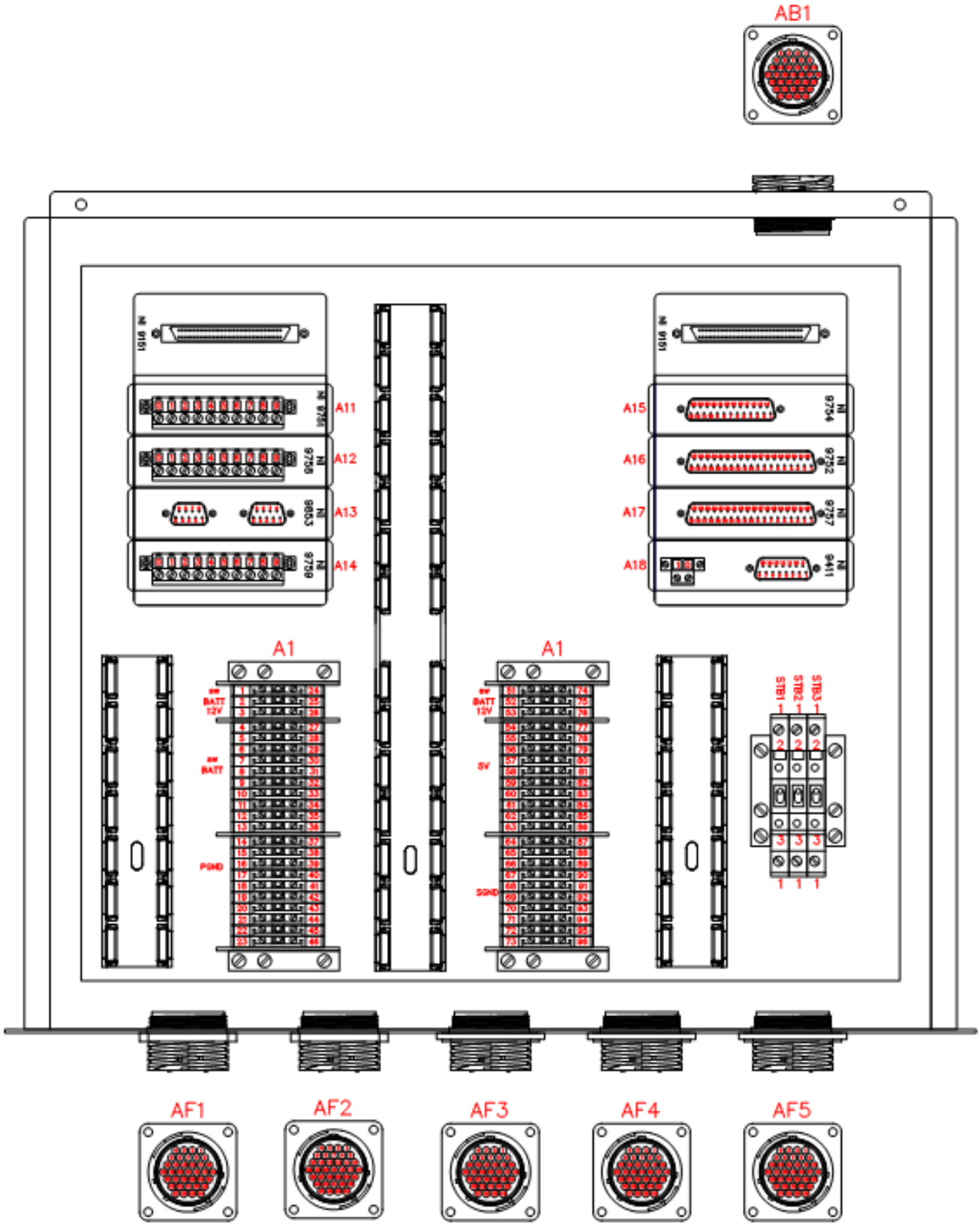


Figure 23: Mechanical Drawing of Drawer A.

Refer to Figure 2: NI ECS Functional Block Diagram for Configuration Options.

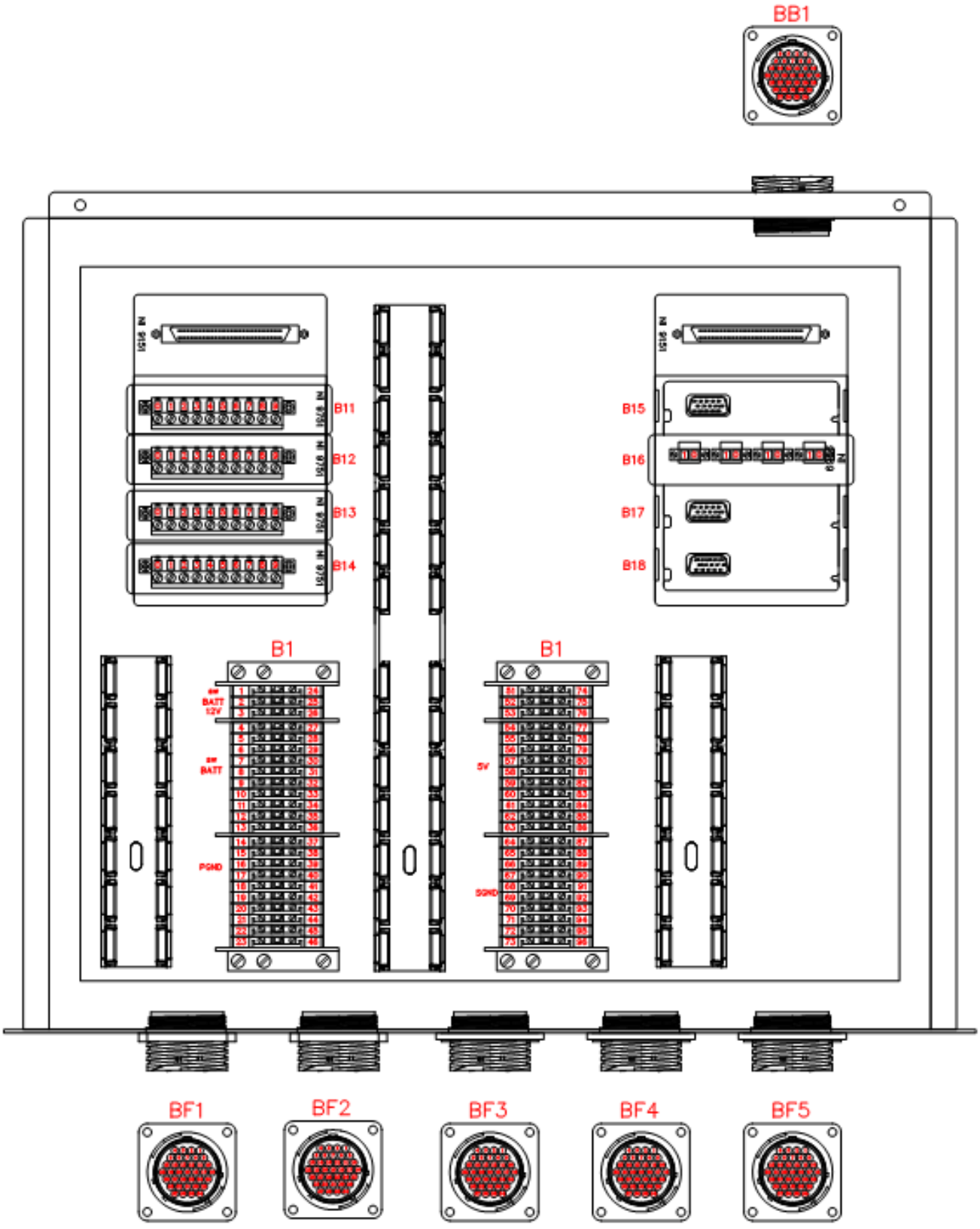


Figure 24. Mechanical Drawing of Drawer B.

Refer to Figure 2: NI ECS Functional Block Diagram for Configuration Options.

Contact NI Powertrain Controls Group

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