# SPECIFICATIONS
# NI DCM-2301

Embedded Direct Injector Control and Measurement (DCM) Device
with Real-Time Processor and Reconfigurable FPGA

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**Preliminary**

*The contents of this document are preliminary and are subject to change without notice.*
*This document may contain errors, omissions, or information that no longer applies.*

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This document lists the specifications for the National Instruments DCM-2301. The following
specifications are typical for the 0 °C to 55 °C operating temperature range unless otherwise
noted.

⚠️ **Caution**   Do not operate the NI DCM-2301 in a manner not specified in this
document. Product misuse can result in a hazard. You can compromise the safety
protection built into the product if the product is damaged in any way. If the product
is damaged, return it to NI for repair.
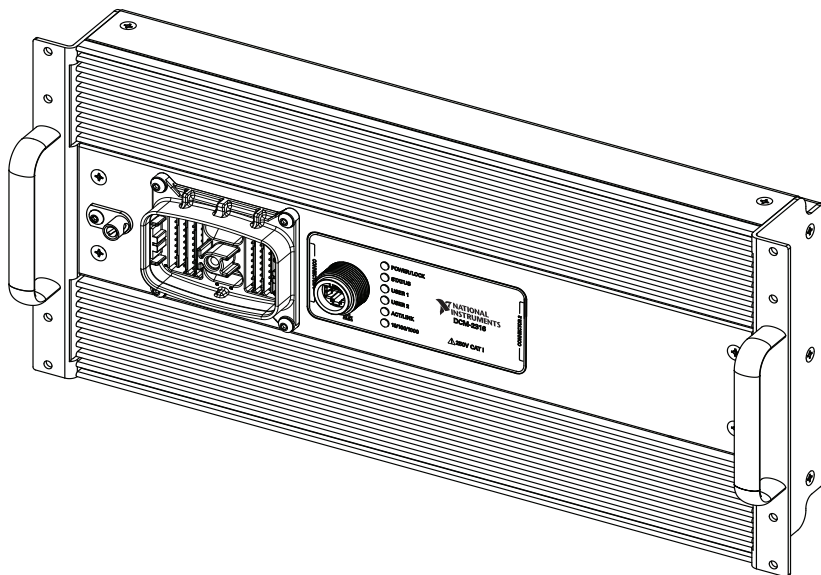
# Processor

| Type | Xilinx Zynq-7000, XC7Z020 All Programmable SoC |
| --- | --- |
| Architecture | ARM Cortex - A9 |
| Speed | 667 MHz |
| Cores | 2 |
| Operating system | NI Linux Real-Time (32-bit) |
| Nonvolatile memory | 512 MB, SLC NAND Flash |
| Volatile memory (DRAM) | 512 MB, DDR3 |
| Real-time clock accuracy | 5 ppm |
| Flash reboot endurance | 100,000 cycles |

For information about the life span of the nonvolatile memory and about best practices for using nonvolatile memory visit `ni.com/info` and enter Info Code `SSDBP`

# Reconfigurable FPGA

| Type | Xilinx Zynq-7000, XC7Z020 All Programmable SoC |
| --- | --- |
| Number of logic cells | 85,000 |
| Number of flip-flops | 106,400 |
| Number of 6-input LUTs | 53,200 |
| Number of DSP slices (18 x 25 multipliers) | 220 |
| Available block RAM | 560 KB |
| Number of DMA channels | 16 |
| Number of logical interrupts | 32 |

**Note** The DCM-2301 internally utilizes the NI sbRIO-9651 System on Module as the digital processing core.

# Network/Ethernet Port

| | |
|---|---|
| Number of ports | 1 |
| Network interface | 10Base-T, 100Base-T, and 1000Base-T Ethernet |
| Compatibility | IEEE 802.3 |
| Communication rates | 10 Mbps, 100 Mbps, 1000 Mbps, auto-negotiated |
| Maximum cabling distance | 100 m/segment |

# Connector 1

### Connector 1 Mating Plug Manufacturer Specifications

| | |
|---|---|
| Number of Pins | 86 |
| Mating Connector Plug | • Deutsch P/N: DRCP28-86SA |
| Mating Connector Contacts For Pins 1-80 (large wires) | |
|     Manufacturer Specifications | • Deutsch P/N: 0462-005-20141<br>• Contact Size #: 20<br>• Wire Size: 18 AWG - 16 AWG<br>• Continuous Current Rating: 7.5 A<br>• Color Marking: Purple band<br>• Material: Nickel<br>• Wire strip length: 0.17 in (4.32 mm) |
| Mating Connector Contacts For Pins 1-80 (small wires) | |
|     Manufacturer Specifications | • Deutsch P/N: 0462-201-20141<br>• Contact Size #: 20<br>• Wire Size: 20 AWG<br>• Continuous Current Rating: 7.5 A<br>• Color Marking: None<br>• Material: Nickel<br>• Wire strip length: 0.17 in (4.32 mm) |

## Connector 1 Mating Plug Manufacturer Specifications

Mating Connector Contact For
Pins 81-86

| | |
|---|---|
| Manufacturer Specifications | • Deutsch Part Number: 0462-203-12141<br>• Contact Size #: 12<br>• Wire Size: 14 AWG - 12 AWG<br>• Continuous Current Rating: 25 A<br>• Color Marking: None<br>• Material: Nickel<br>• Wire strip length: 0.25 in (6.35 mm) |
| Connector 1 securement tool | 4 mm hex key |
| Connector 1 securement torque | 44 in/lb to 62 in/lb (5 Nm to 7 Nm) |
| Connector 1 hand-crimper tool for solid contacts | • Deutsch Part Number: HDT-48-00<br>• Supported Contact Size #: 20, 16, 12 |

**Note**  Connector 1 mating plug, assortment of contacts, and hex key tool are included in DCM accessory part number 785113-01

**Note**  Connector 1 hand-crimper for solid contacts is included in NI DCM accessory part number 785202-01
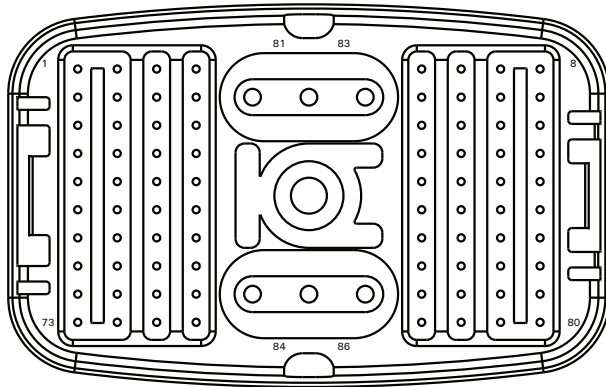
**Figure 1.** DCM Connector 1 Face



**Figure 2.** DCM Connector 1 Pinout

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HH1 | 1 | DI_S_A1 | 2 | DI_P_A1 | 3 | DI_L_A1 | 4 | | DIO1a | 5 | DIO2a | 6 | DIO3a | 7 | BATT | 8 |
| HH2 | 9 | DI_S_A2 | 10 | DI_P_A2 | 11 | DI_L_A2 | 12 | PGND | DIO1b | 13 | DIO2b | 14 | DIO3b | 15 | MPRD | 16 |
| HH3 | 17 | DI_S_A3 | 18 | NC | 19 | NC | 20 | PGND | DIO4a | 21 | DIO5a | 22 | DIO6a | 23 | KEY | 24 |
| HH4 | 25 | NC | 26 | NC | 27 | NC | 28 | 81 82 83 | DIO4b | 29 | DIO5b | 30 | DIO6b | 31 | IO_LOCK+ | 32 |
| NC | 33 | NC | 34 | HV_A | 35 | DI_L_AP | 36 | | DIO7a | 37 | DIO8a | 38 | DGND | 39 | IO_LOCK– | 40 |
| NC | 41 | NC | 42 | NC | 43 | NC | 44 | 84 85 86 | DIO7b | 45 | DIO8b | 46 | AGND | 47 | CAN_H | 48 |
| NC | 49 | NC | 50 | NC | 51 | NC | 52 | | AI4 | 53 | AI18 | 54 | AI12 | 55 | CAN_L | 56 |
| NC | 57 | NC | 58 | NC | 59 | NC | 60 | DRVP | AI3 | 61 | AI17 | 62 | AI11 | 63 | IGND | 64 |
| NC | 65 | NC | 66 | NC | 67 | NC | 68 | DRVP | AI2 | 69 | AI6 | 70 | AI10 | 71 | RS232_TX | 72 |
| NC | 73 | NC | 74 | NC | 75 | NC | 76 | DRVP | AI1 | 77 | AI5 | 78 | AI9 | 79 | RS232_RX | 80 |

**Figure 3.** DCM Connector 1 Recommended Contact and Wire Size

Contact Size #/ Wire Size (awg)

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20/16 | 1 | 20/16 | 2 | 20/16 | 3 | 20/16 | 4 | | 20/20 | 5 | 20/20 | 6 | 20/20 | 7 | 20/20 | 8 |
| 20/16 | 9 | 20/16 | 10 | 20/16 | 11 | 20/16 | 12 | 12/12 | 20/20 | 13 | 20/20 | 14 | 20/20 | 15 | 20/20 | 16 |
| 20/16 | 17 | 20/16 | 18 | NC | 19 | NC | 20 | 12/12 | 20/20 | 21 | 20/20 | 22 | 20/20 | 23 | 20/20 | 24 |
| 20/16 | 25 | NC | 26 | NC | 27 | NC | 28 | 81 82 83 | 20/20 | 29 | 20/20 | 30 | 20/20 | 31 | 20/20 | 32 |
| NC | 33 | NC | 34 | 20/16 | 35 | 20/16 | 36 | | 20/20 | 37 | 20/20 | 38 | 20/20 | 39 | 20/20 | 40 |
| NC | 41 | NC | 42 | NC | 43 | 20/16 | 44 | 84 85 86 | 20/20 | 45 | 20/20 | 46 | 20/20 | 47 | 20/20 | 48 |
| NC | 49 | NC | 50 | NC | 51 | NC | 52 | | 20/20 | 53 | 20/20 | 54 | 20/20 | 55 | 20/20 | 56 |
| NC | 57 | NC | 58 | NC | 59 | NC | 60 | 12/12 | 20/20 | 61 | 20/20 | 62 | 20/20 | 63 | 20/20 | 64 |
| NC | 65 | NC | 66 | NC | 67 | NC | 68 | 12/12 | 20/20 | 69 | 20/20 | 70 | 20/20 | 71 | 20/20 | 72 |
| NC | 73 | NC | 74 | NC | 75 | NC | 76 | 12/12 | 20/20 | 77 | 20/20 | 78 | 20/20 | 79 | 20/20 | 80 |

## Powers Requirements and Power Control

| | |
|---|---|
| Related Connector 1 Pins: | BATT<br>DRVP (3x)<br>PGND (3x)<br>MPRD<br>AGND<br>DGND<br>IGND<br>Chassis Ground |

**BATT to PGND**

| | |
|---|---|
| Absolute min/max input voltage range | 6 V to 48 V |
| Recommended input voltage range | 9V to 48 V<br><br>Note: A combination of circuitry and low-level software is implemented to prevent large inrush current to the DRVP circuit capacitance.<br><br>When voltage is applied to the BATT pin, the following occurs:<br><br>• The sbRIO-9651 controller boots<br>• Digital and analog circuits are powered<br>• The battery input circuit begins trickle-charging the DRVP circuit capacitance<br>• MPRD is disabled until DRVP voltage is greater than 9 V and within 2 V of BATT<br><br>After MPRD is switched ON, BATT voltage is continuously monitored for a low-voltage fault, triggered by dropping below 7 V.<br><br>Refer to **Figure 4** for a diagram of the BATT, DRVP and MPRD circuits. |
| Reverse polarity protection | -48 V |
| Maximum inrush current | 3 A |
| Continuous current (BATT =12 V) | 750 mA to 2000 mA typical |

## Powers Requirements and Power Control

| | |
|---|---|
| Recommended fuse in-line with BATT | 7.5 A, Fast-Acting |
| Recommended BATT wire size | 16 AWG |
| Input capacitance | 100μF |
| **DRVP to PGND** | |
| Absolute min/max input voltage range | 6V to 48 V |
| Recommended input voltage range | 9 V to 48 V |
| Reverse polarity protection | -48 V |
| Maximum continuous current (each pin) | 25 A |
| Recommended fuse in-line with DRVP (3x) | 25 A, Fast-Acting |
| Recommended DRVP wire size | 12 AWG |
| Input capacitance | 3300 μF |
| **MPRD low-side switch to PGND** | |
| Configuration | • Low-side MOSFET switch to PGND<br>• Short-circuit and over-load protection<br>• Thermal shutdown protection<br>• Suitable for resistive and inductive loads |
| Maximum withstand voltage | 60 V |
| Maximum continuous current | 2 A |
| Short-circuit / over-load shutdown current | 6 A |

## Powers Requirements and Power Control

| | |
|---|---|
| Internal flyback diode | No |
| | Note: The MPRD low-side MOSFET switch is internally protected against back-EMF of inductive load switching. However, it is recommended to use an external flyback diode in parallel with the inductive load. The PDU-2300 utilizes relays which contain internal flyback diodes. |
| Recommended external main power relay | 12 V or 24 V coil, 75 A switch (see note below) |
| PGND maximum continuous current (each pin) | 25 A |
| Recommended PGND wire size | 12 AWG |
| DGND maximum continuous current | 2 A |
| AGND maximum continuous current | 2 A |
| IGND isolation voltage (IGND to all other system grounds) | 250 VDC |
| IGND maximum continuous current | 500 mA |
| PGND, DGND & AGND configuration | Note: Pins PGND, DGND and AGND are internally connected. However, they must only be used for their explicit purpose, as follows: |
| | PGND pins (3x) may be used as a power ground return path for BATT and DRVP pins. |
| | A 12 AWG wire should be connected between battery ground and earth ground as shown in **Figure 4.** |
| | DGND pin may be used as a ground reference only for digital IO signals DIOxa and DIOxb. Do not use DGND as a power ground return path for BATT or DRVP. Otherwise, the DCM may be damaged. |
| | AGND pin may be used as a ground reference only for external analog input pins AIx and KEY. Do not use AGND as a power ground return path for BATT or DRVP. Otherwise, the DCM may be damaged. |

## Powers Requirements and Power Control

| | |
|---|---|
| IGND | Note: IGND is provided as a ground reference for isolated circuits CAN, RS-232 and IO_LOCK. IGND is isolated from all other DCM grounds. IGND may only be used as a reference for CAN, RS-232 and IO_LOCK pins.<br><br>Note: While IO_LOCK pins belong to the isolated circuitry, it is not necessary to utilize IGND with IO_LOCK+ and IO_LOCK- because they operate with an external passive ESTOP switch. |
| Chassis Ground | Note: A chassis ground lug is provided on the DCM enclosure next to Connector 1 (see **Figure 5**). A 12 AWG wire should be connected between the chassis ground lug and earth ground. |
| Maximum power input | 1000 W |
| Maximum power consumption | 200 W |

**Note** The NI PDU-2300 and DCM 23XX Starter harness accessories are designed specifically for the DCM-23XX. These accessories utilize the recommended relays, fuses and wire sizes specified in this document.

**Note** The maximum power consumption specification is based on a system running a high-stress application. Measurement Category I is for measurements performed on circuits not directly connected to the electrical distribution system referred to as MAINS voltage. MAINS is a hazardous live electrical supply system that powers equipment. This category is for measurements of voltages from specially protected secondary circuits. Such voltage measurements include signal levels, special equipment, limited-energy parts of equipment, circuits powered by regulated low-voltage sources, and electronics.

**Caution** Do not connect the DCM-2301 to signals or use for measurements within Measurement Categories II, III, or IV.

**Note** Measurement Categories CAT I and CAT O are equivalent. These test and measurement circuits are not intended for direct connection to the MAINS building installations of Measurement Categories CAT II, CAT III, or CAT IV.

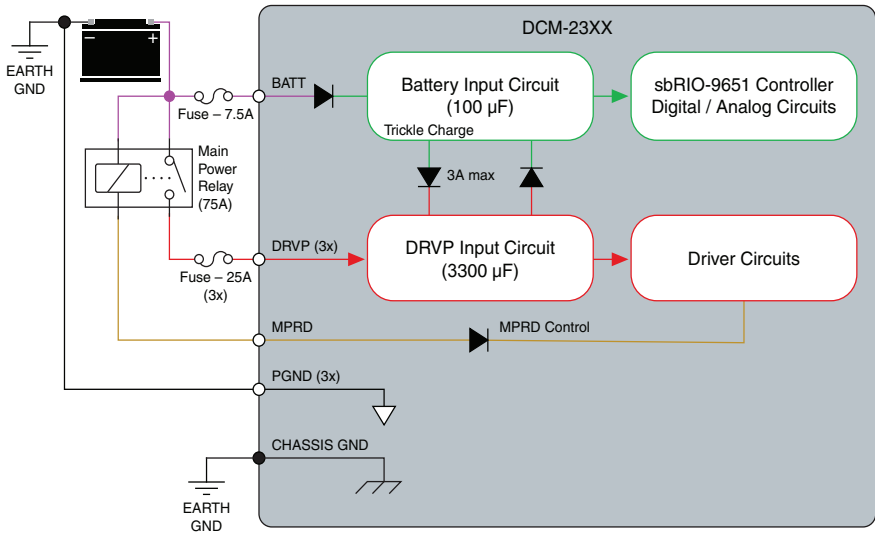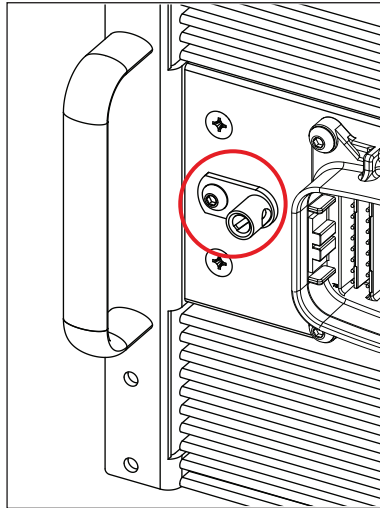**Figure 4.** Battery Input, DRVP Input and MPRD Control Diagram



**Table 1.** Recommended Fuse Part Numbers (Referenced in Figure 4)

| Manufacturer | Amps | Part Number |
|:---:|:---:|:---:|
| Littelfuse | 7.5 A | 099707.5.WXN |
| Littelfuse | 25 A | 0997025.WXN |

**Figure 5.** Chassis Ground Lug

## Direct Injector (DI) Half-H Driver Channels

| | |
|---|---|
| Related Connector 1 Pins | DI_S_xy<br>DI_P_xy<br>DI_L_xy<br>DI_L_xP<br><br>(x = bank A, y = 1- 3) |
| Topology | • Single Bank A<br>• Two independent DI Half-H driver circuits<br>• Secondary stage boost or DRVP drive source for each DI Half-H high-side pin<br>• Dedicated high-side pins for solenoid and piezo injector loads, with internal series inductance on piezo pins<br>• Dedicated fuel pump low-side driver per bank<br>• Programmable DI-Zener clamp for each DI Half-H low-side pin<br>• Additional programmable pump-Zener clamp with independent set-point<br>• Low-side current sense for each DI Half-H and pump pin<br>• Differential voltage measurements for each DI Half-H and pump pins<br>• Multiple modes of operation, supporting solenoid and piezo injectors, unipolar and bipolar drive, multiplexed channels, and engine-synchronous fuel pump<br><br>Note: Refer to **Figure 6** for a circuit topology showing two DI Half-H driver circuits |
| Maximum drive voltage from secondary boost power supply | 220 V |
| Maximum drive voltage from DRVP | 48 V |
| Maximum drive current (solenoid operation) | +/- 40 A |
| Maximum drive current (piezo operation) | +/- 10 A |

## Direct Injector (DI) Half-H Driver Channels

| | |
|---|---|
| Current control methods (solenoid and piezo injector modes) | • Closed loop: Uses hardware DAC set-point to comparator with current sense feedback<br>• Two DACs and two comparators per channel for upper and lower current dither set-points |
| Current sense range | -12 A to +50 A |
| Current control resolution | 60 mA |
| Voltage control methods (piezo injector modes) | • Closed loop: Uses hardware DAC set-point to comparator with voltage sense feedback<br>• Two DACs and two comparators per channel for upper and lower voltage range set-points |
| Voltage sense range | -250 V to +250 V |
| Piezo voltage control resolution | 500 mV |
| Internal series inductor between high-side voltage drive and DI_P_xy | 47 µH @ 100 kHz (1 V)<br>ISat = 9.5 A<br>DCR = 90 mΩ |
| Modes of operation (each bank) | • 2 unipolar solenoid injectors, 1 pump<br>• 1 unipolar piezo injectors, 1 pump<br>• 1 bipolar solenoid injectors, 1 pump<br>• 1 bipolar piezo injectors, 1 pump<br>• 4 unipolar solenoid multiplexed injectors, 1 pump<br>• 5 unipolar solenoid multiplexed injectors, no pump<br>• 2 unipolar piezo multiplexed injectors, no pump<br><br>Note: Refer to **Figure 7** for wiring connections for each mode of operation |
| High-side high-voltage-drive short circuit protection (short between DI_S_xy and PGND) | 90 A - 260 A, depending on secondary boost supply voltage, component tolerances and temperature |
| High-side low-voltage-drive short circuit protection (short between DI_S_xy and PGND) | 70 A - 100 A, depending on DRVP, component tolerances and temperature |

## Direct Injector (DI) Half-H Driver Channels

| | |
|---|---|
| Low-side over-current protection threshold (short between DI_S_xy and DI_L_xy, or short between DRVP and DI_L_xy) | 45 A |
| Programmable DI-Zener clamp | |
|     Topology | • One dedicated programmable DI-Zener set-point per bank<br>• Four DI-Zener clamp circuits per bank |
|     Voltage range | DRVP to 150 V |
|     Voltage set-point resolution | 270 mV |
|     Circuit maximum power dissipation | 6 W RMS |
| Programmable pump-Zener clamp | |
|     Topology | • One dedicated programmable pump-Zener set-point per bank<br>• One pump-Zener clamp circuit per bank |
|     Voltage range | DRVP to 150 V |
|     Voltage set-point resolution | 270 mV |
|     Circuit maximum power dissipation | 6 W |

## Direct Injector (DI) Half-H Driver Channels

Programmable secondary boost clamp

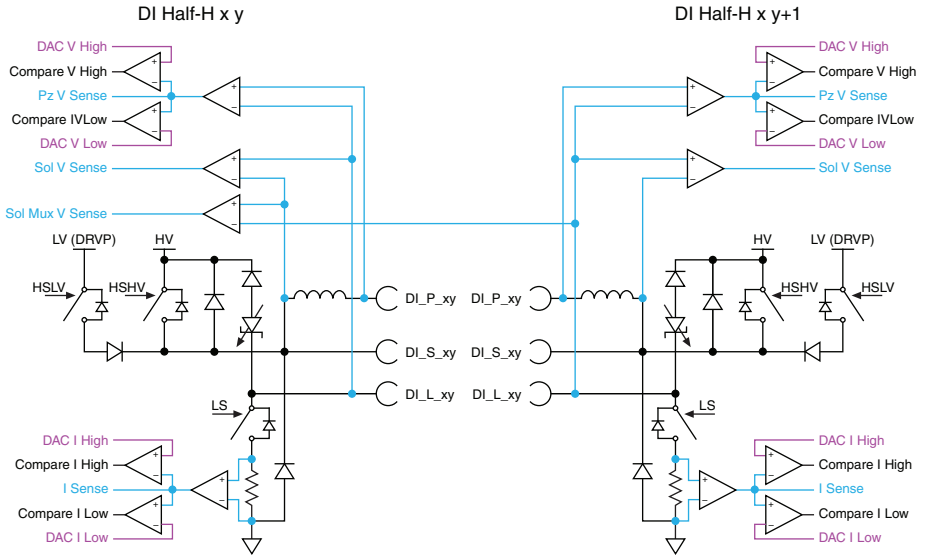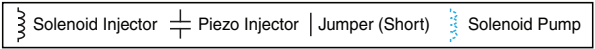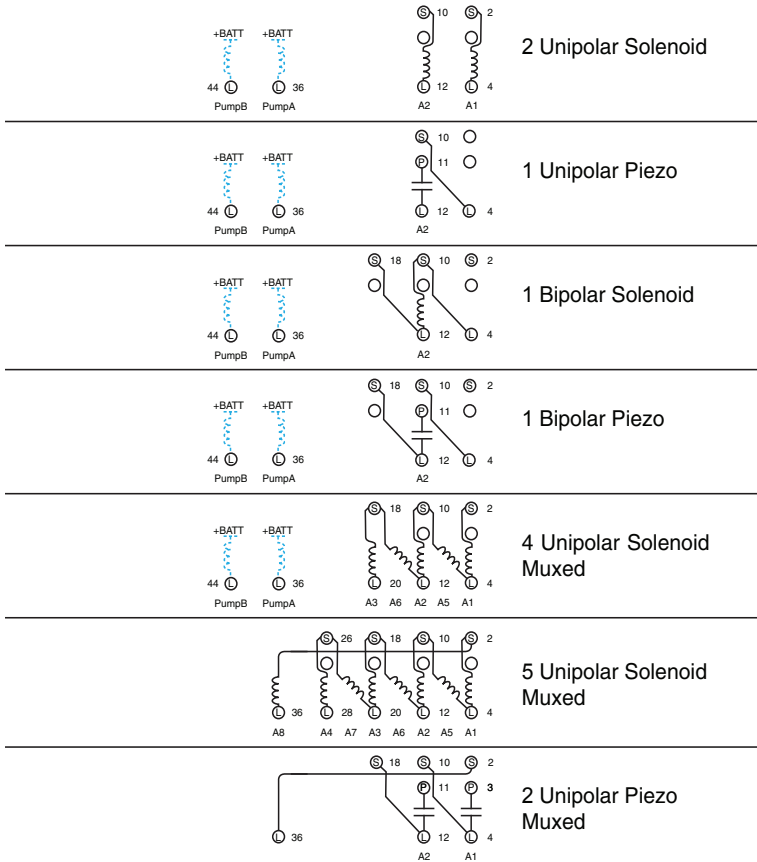| | |
|---|---|
| Topology | • One programmable secondary boost clamp bleed circuits per bank, single set-point for both circuits<br>• Secondary boost supply is clamped to voltage set-point via a bleed resistor to PGND<br><br>Note: Boost clamp is used when the inductive back-EMF power into the boost power supply exceeds the boost power consumed during injections. This prevents the secondary boost supply from being over-charged. |
| Voltage range | *Max[(DRVP + 5V),(secondary set-point + 5V), 24V]* to 220 V |
| Voltage set-point resolution | 250 mV |
| Circuit maximum power dissipation | 5 W |

**Figure 6.** DI Half-H Driver Circuit Topology

**Figure 7.** DI Half-H Driver Wiring Connections



**2 Unipolar Solenoid**

**1 Unipolar Piezo**

**1 Bipolar Solenoid**

**1 Bipolar Piezo**

**4 Unipolar Solenoid Muxed**

**5 Unipolar Solenoid Muxed**

**2 Unipolar Piezo Muxed**

Solenoid Injector | Piezo Injector | Jumper (Short) | Solenoid Pump

## Internal Boost Power Supply
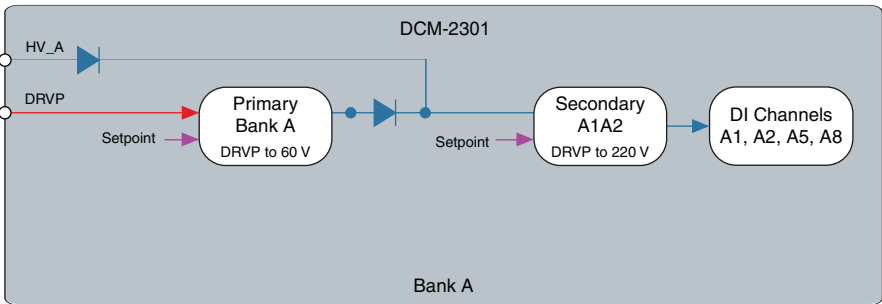
| | |
|---|---|
| Topology | • Two-stages, Two banks<br>• Dual primary stage and dual secondary stage for Bank A<br>• Dual primary stage and dual secondary stage for Bank B<br><br>Note: Effectively, the dual primary stage for each bank acts as a unified primary stage, controlled by a single set-point, with connected outputs.<br><br>Note: The dual secondary stage for each bank is controlled by a single set-point, but has independent outputs.<br><br>Note: Refer to **Figure 8** for the internal boost power supply topology diagram. |
| Primary stage voltage set-point range | DRVP – 60 V, automatically controlled based on desired secondary voltage<br><br>Note: The primary stage voltage is automatically set to approximately 10 V less than the user set-point of the secondary stage, until the secondary voltage set-point exceeds 70 V. After this, the primary stage set-point remains at 60 V. |
| Secondary stage voltage set-point range | DRVP – 220 V<br><br>Note: If the secondary stage is disabled, its voltage will adapt to the voltage of the primary stage. |
| Secondary stage voltage set-point resolution | 220 mV |
| Primary stage capacitance (each bank) | 2000 µF, V, Aluminum Electrolytic |
| Secondary stage capacitance (each supply) | 260 µF, 250 V, Aluminum Electrolytic |

## Internal Boost Power Supply

| | |
|---|---|
| Supply recharge time | |
| 55 V to 60 V (secondary disabled) | 120 μs |
| 70 V to 75 V | 130 μs |
| 115 V to 120 V | 335 μs |
| 155 V to 160 V | 650 μs |
| 215 V to 220 V | 2.32 ms |
| Time for secondary stage voltage to bleed from 220 V to 60 V after disabled, or after DCM is powered down | 130 s |

**Figure 8.** Internal Boost Power Supply Topology

## External Boost Supply Inputs

| | |
|---|---|
| Related Connector 1 Pins | HV_A |
| Topology | • HV_A is an external boost supply input to the secondary stage capacitance of Bank A<br><br>• Each HV_A input connects to the secondary stage capacitance via a series diode, preventing reverse current<br><br>Note: Refer to **Figure 8** for the internal boost power supply topology diagram. which shows how the external boost supply inputs connect to the secondaries |
| Voltage range | DRVP - 220 V |
| Maximum current | 2.5 A RMS |

## General Purpose Half H-Bridge Driver Channels

| | |
|---|---|
| Related Connector 1 Pins | HH1-HH4 |
| Topology | • Four independent half H-bridge driver circuits<br><br>• Hardware-controlled "flyback diode" FET, based on operating mode<br><br>• PFI-Zener clamp circuit for PFI operating mode<br><br>• Independent current sense, open-circuit, and short-circuit detection for each channel<br><br>Note: Refer to **Figure 9** for the general purpose half H-bridge driver topology |

## General Purpose Half H-Bridge Driver Channels

| | |
|---|---|
| Modes of Operation | • Low-side: Half-H channel operates as low-side switch to power ground (PGND), with continuous internal flyback-diode enabled |
| | • High-side: Half-H channel operates as high-side switch to driver-power (DRVP), with continuous internal flyback-diode enabled |
| | • Port Fuel Injector (PFI): Half-H channel operates as low-side switch to power ground (PGND), with flyback-diode enabled during command, and higher back-EMF clamp at end of command |
| | • Full-H Pair: Adjacent Half-H channels operate as a Full-H sinking/sourcing driver, with continuous flyback-diode enabled |
| | • Independent current measurement ADC for each Half-H channel |
| | Note: Half-H channels only use DRVP when sourcing, and use PGND when sinking. Half-H channels do not have access to the internal boost power supplies. |
| | Note: Refer to **Figure 10** for the general purpose half H-bridge driver wiring connections for each mode of operation |
| External voltage range to high-side of load (Low-side and PFI modes) | 0 V to DRVP |
| | Note: Half-H channels are not reverse-battery protected. It is recommended to use the PDU-2300 for power distribution, providing reverse-battery protection and fusing for high-side power to external loads. |
| External voltage to low-side of load (High-side mode) | PGND |
| PFI-Zener clamp voltage at end of command | -26 V, measured differentially across load, DRVP to HHx |
| | Note: PFI-Zener clamp circuit clamps with respect to DRVP, not PGND |

## General Purpose Half H-Bridge Driver Channels

| | |
|---|---|
| Maximum command frequency (Low-side, High-side and Full-H modes) | 5 kHz |
| Maximum command frequency (PFI mode) | 400 Hz<br><br>Note: This maximum frequency is lower than other modes in order to protect the PFI-Zener clamp circuit |
| Maximum continuous current | +/- 4 A |
| Maximum peak current | +/- 8 A |
| Maximum peak current time | 2 ms, not to exceed 10% duty cycle |
| Current measurement range | +/- 9.17 A |
| Current measurement resolution | 12-bit, 4.5 mA per count |
| Current measurement rate | 500 kS/s |
| Current control method (Low-side, High-side and PFI modes) | Closed-loop: Channel-independent upper and lower dither set points |
| Current control method (Full-H mode) | Open loop: min/max current level depends on command frequency and duty cycle for given load resistance and inductance |

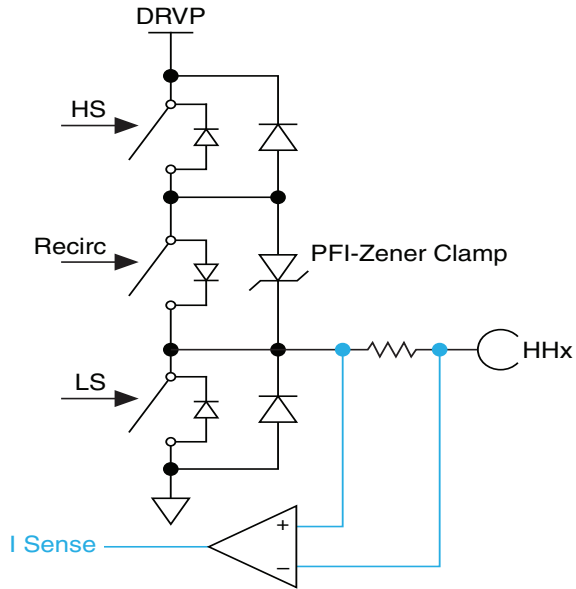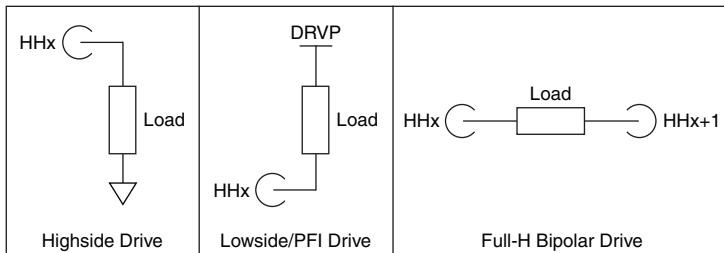**Figure 9.** General Purpose Half H-Bridge Driver Circuit Topology



DRVP

HS

Recirc

PFI-Zener Clamp

LS

HHx

I Sense

**Figure 10.** General Purpose Half H-Bridge Driver Wiring Connections



HHx

Load

Highside Drive

DRVP

Load

HHx

Lowside/PFI Drive

Load

HHx — HHx+1

Full-H Bipolar Drive

## IO Lock

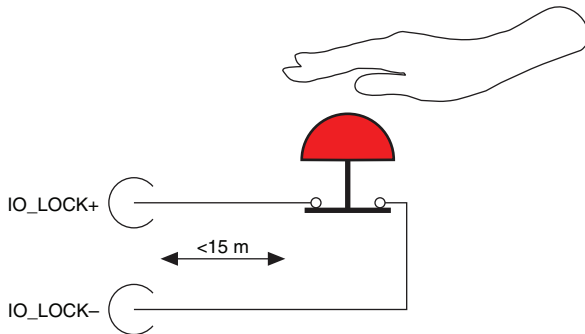| | |
|---|---|
| Related Connector 1 Pins | IO_Lock+<br>IO_Lock- |
| Configuration | • Locks and unlocks the DI Half-H and general purpose Half-H driver circuit operation at hardware level<br>• General purpose Half-H driver lockout may be overridden via software on a per-channel basis<br>• To be implemented with external contact closure, such as an emergency stop switch<br>• IO Locked (driver circuits disabled): Contact open between IO_LOCK+ and IO_LOCK-<br>• IO Unlocked (driver circuits enabled): Contact closed between IO_LOCK+ and IO_LOCK-<br><br>Note: The IO_LOCK pins utilize an isolated RS-232 transceiver channel. IO_LOCK+ (Tx) outputs a PWM signal which must be looped-back and measured by IO_LOCK- (Rx), via ESTOP contact closure, in order for driver channels to be unlocked.<br><br>Note: Refer to **Figure 11** for recommended IO_LOCK connection to an emergency stop switch. |
| IO_Lock- input<br>(IO_LOCK- to IGND) | |
|     Input voltage range | -70 V to +70 V |
| IO_Lock+ output<br>(IO_LOCK+ to IGND) | |
|     Output voltage swing | +/- 5 V minimum<br>+/- 6 V typical |
|     Output resistance | 300Ω |
|     Output over-voltage protection threshold | -70 V to +70 V |
|     Output short-circuit current | +/- 80 mA |

## IO Lock

| | |
|---|---|
| Continuous PWM output frequency | 1000 Hz |
| Continuous PWM output duty cycle | 50% |
| IO Locked detection time after contact open | 25 ms maximum |
| IO Unlocked detection time after contact closed | 25 ms maximum |
| Recommended IO Lock emergency stop switch, compatible with DCM Starter Harness | Manufacturer: ABB Jokab Safety<br>Model: Smile 11 EA<br>Part Number: 2TLA030051R0000 |

**Figure 11.** IO_LOCK Connection to Emergency Stop Switch (ESTOP)



## External Analog Inputs

| | |
|---|---|
| Related Connector 1 Pins | AI1 - AI12<br>AGND |
| Configuration | • 12 analog input channels<br>• Multiplexed sampling<br>• Dedicated A/D converter<br>• Successive Approximation Register (SAR)<br>• No channel-to-channel isolation |
| Measurement range (AI to AGND) | 0 V - 5 V |

## External Analog Inputs

| | |
|---|---|
| Over-voltage protection (AI to AGND) | -48 V to +48 V |
| Measurement resolution | 12-bit, 1.22 mV per count |
| Sample rate | 1 MS/s aggregate |
| Hardware filter | $2^{nd}$ order low-pass, $f_c$ = 100 kHz |
| Input resistance (AI to AGND) | 1 GΩ |
| AGND maximum continuous current | 2 A |
| | Note: AGND pin may be used as a ground reference only for external analog input pins AIx and KEY. Do not use AGND as a power ground return path for BATT or DRVP. Otherwise, the DCM may be damaged. |

## Internal / External System Analog Measurement

| Related Connector 1 Pins | DRVP<br>HV_A<br>BATT<br>MPRD<br>KEY |
|---|---|
| Configuration | • 21 internal analog channels<br>• Multiplexed sampling<br>• Dedicated A/D converter<br>• Successive Approximation Register (SAR) |
| Measurement resolution | 12-bit |
| Sample rate | 500 kS/s aggregate |

| Internal System Analog Signal Sources | Range |
|---|---|
| Temp HH 1-6 [°C] | -40 °C to +125 °C |
| Temp HH 7-12 [°C] | -40 °C to +125 °C |
| Temp DI A [°C] | -40 °C to +125 °C |
| Temp DI Zener A [°C] | -40 °C to +125 °C |
| Temp DI B [°C] | -40 °C to +125 °C |
| Temp DI Zener B [°C] | -40 °C to +125 °C |
| Temp Fan Intake [°C] | -40 °C to +125 °C |
| Temp Primary A [°C] | -40 °C to +125 °C |
| Temp Secondary A [°C] | -40 °C to +125 °C |
| Temp Boost B [°C] | -40 °C to +125 °C |
| Primary A1A2 [V] | 0 V - 80 V |
| Secondary A1A2 [V] | 0 V - 240 V |
| Ext HV A [V] | 0 V - 240 V |
| FET Driver [V] | 0 V - 50 V |
| Fan [V] | 0 V - 50 V |

## Internal / External System Analog Measurement

| | |
|---|---|
| Battery [V] | 0 V - 50 V |
| DRVP (Driver Power) [V] | 0 V - 50 V |
| Key [V] | 0 V - 50 V |
| DI Zener A [V] | 0 V - 240 V |
| Pump Zener A [V] | 0 V - 240 V |
| MPRD (Main Power Relay Driver) [V] | 0 V - 55 V |

## Internal DI Scope Analog Measurement

| Configuration | <ul><li>4 dedicated analog channels</li><li>Simultaneous sampling</li><li>28 user-selectable signal sources for each channel</li><li>Successive Approximation Register (SAR)</li></ul> |
|---|---|
| Measurement resolution | 15-bit |
| Sample rate | 5 MS/s per channel |

| Selectable DI Scope Signal Sources | Range |
|---|---|
| I LS A1/A5 (Low-side current of DI A1 or A5) | -12 A to +50 A |
| I LS A2/A6 (Low-side current of DI A2 or A6) | -12 A to +50 A |
| I LS A8/PumpA (Low-side current of DI A8 or Pump A) | -12 A to +50 A |
| V PZ A1 (Piezo differential voltage of DI A1) | -250 V to +250 V |
| V PZ A2 (Piezo differential voltage of DI A2) | -250 V to +250 V |
| V S A1 (Solenoid differential voltage of DI A1) | -250 V to +250 V |
| V S A2 (Solenoid differential voltage of DI A2) | -250 V to +250 V |
| V S A5 (Solenoid differential voltage of DI A5) | -250 V to +250 V |
| V S A6 (Solenoid differential voltage of DI A6) | -250 V to +250 V |
| V S A8 (Solenoid differential voltage of DI A8) | -250 V to +250 V |
| V Pump A (Voltage at DI_L_AP) | -250 V to +250 V |

## Internal DI Scope Analog Measurement

| | |
|---|---|
| V Secondary A1A2 (Voltage of Secondary A1A2) | 0 V - 240 V |
| V Ext HV A (External high-voltage input to bank A secondary) | 0 V - 240 V |
| I LS B8/PumpB (Low-side current of DI B4 or Pump B) | -12 A to +50 A |
| V Pump B (Voltage at DI_L_BP) | -250 V to +250 V |
| AI 1 (External analog input voltage at AI1) | 0 V - 5 V |
| AI 2 (External analog input voltage at AI2) | 0 V - 5 V |
| AI 3 (External analog input voltage at AI3) | 0 V - 5 V |
| AI 4 (External analog input voltage at AI4) | 0 V - 5 V |
| AI 5 (External analog input voltage at AI5) | 0 V - 5 V |
| AI 6 (External analog input voltage at AI6) | 0 V - 5 V |
| AI 7 (External analog input voltage at AI7) | 0 V - 5 V |
| AI 8 (External analog input voltage at AI8) | 0 V - 5 V |
| AI 9 (External analog input voltage at AI9) | 0 V - 5 V |
| AI 10 (External analog input voltage at AI10) | 0 V - 5 V |

## Internal DI Scope Analog Measurement

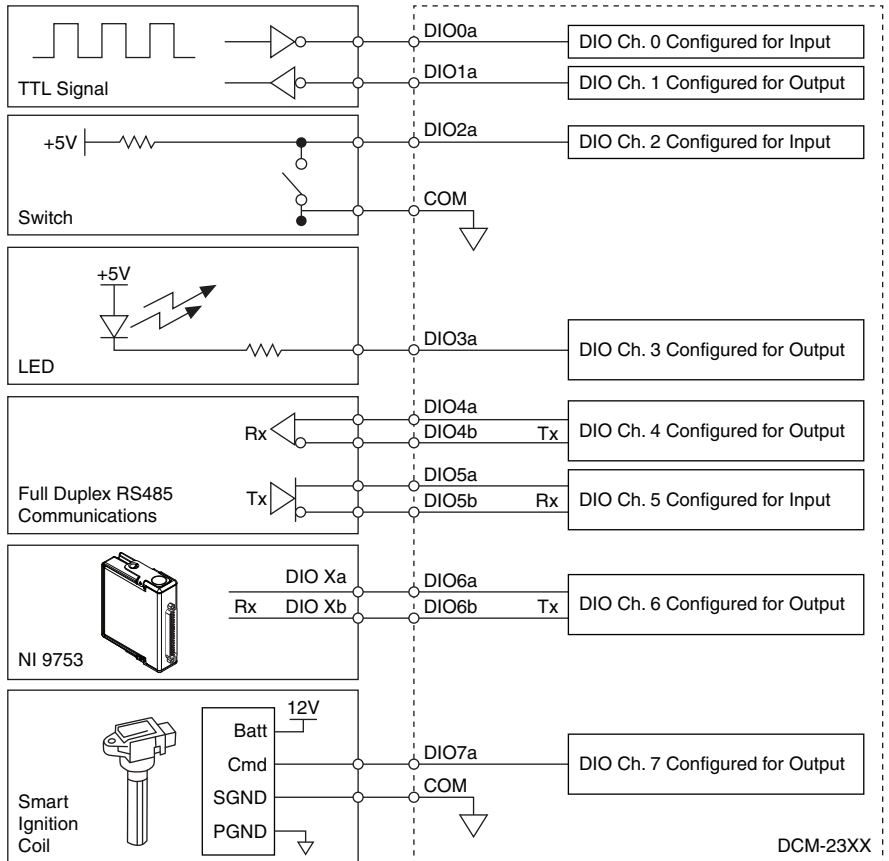| | |
|---|---|
| AI 11 (External analog input voltage at AI11) | 0 V - 5 V |
| AI 12 (External analog input voltage at AI12) | 0 V - 5 V |
| V DRVP (Voltage at Driver Power input pins) | 0 V - 50 V |

## RS485 Compatible Differential Digital I/O

| | |
|---|---|
| Related Connector 1 Pins | DIOxa<br>DIOxb<br>DGND<br><br>(x=1-8) |
| Configuration | • 8 Differential digital IO channels<br>• RS485-compatible transceivers<br>• Independently configured as input or output<br>• Can be used as differential or single-ended IO<br>• No channel-to-channel isolation<br><br>Note: Refer to **Figure 12** for example connections to a variety of external digital IO devices |
| Default power-on line direction | Input |
| Input logic levels | |
|     Differential (DIOxa to DIOxb) | |
|         Input high range | 200 mV to 48 V |
|         Input low range | -200 mV to -48 V |
|         Common mode voltage range | -15 V to +15 V |
|         Protection ranges | 15 V to 48 V, -15 V to -48 V |
|     Single-ended (DIOxa to DGND) | |
|         Input high range | 1.8 V to 48 V |

## RS485 Compatible
## Differential Digital I/O

| | |
|---|---|
| Input low range | 0 V to 1.4 V |
| Input Current (e.g sensor load) | |
| At -7 V to +7 V | +/- 250 μA maximum |
| At -15 V to +15 V | +/- 1 mA maximum |
| At -48 V to +48 V | +/- 6 mA maximum |
| Differential output voltage | |
| No load | 5 V |
| 100 Ω load | 2.4 V minimum<br>3.2 V typical |
| 54 Ω load | 1.5 V minimum<br>2.5 V typical |
| Driver short-circuit current (DIOxa or DIOxb to DGND) | 13 mA maximum continuous |
| Maximum switching frequency per channel | 10 MHz (input and output) |
| Maximum direction change frequency | 1 kHz |
| Input delay time | 200 ns maximum |
| Output delay time | 200 ns maximum |
| DGND maximum continuous current | 2 A |
| | Note: DGND pin may be used as a ground reference only for digital IO signals DIOxa and DIOxb. Do not use DGND as a power ground return path for BATT or DRVP. Otherwise, the DCM may be damaged. |

**Figure 12.** Connecting to External Digital IO Devices

## CAN

| | |
|---|---|
| Related Connector 1 Pins | CAN_H<br>CAN_L<br>IGND |
| Configuration | • 1 channel high-speed CAN transceiver<br>• Fully ISO 11898-2:2003 compliant transceiver<br>• Fault-protected<br>• Utilizes NI Embedded CAN devices drivers<br>• Circuitry Isolated from PGND to accommodate long distance communications with systems not tied to PGND |
| Baud rate | |
|     Maximum | 1 Mbps |
|     Minimum | 10 Kbps |
| Input voltage range<br>(CAN_H or CAN_L to IGND) | -58 V to +58 V |
| Differential input voltage range<br>(CAN_H to CAN_L) | -27 V to +27 V |
| Differential output voltage | |
|     Dominant: Normal Mode | |
|         60 Ω load | 1.5 V to 3 V |
|         2240 Ω load | 1.5 V to 5 V |
|     Recessive | |
|         Normal mode (no load) | +/- 50 mV |
| Differential receiver threshold voltage<br>(normal/silent modes) | 0.5 V to 0.9 V |
| Receiver recessive voltage<br>(normal/silent modes) | -3 V to +0.5 V |
| Receiver dominant voltage<br>(normal/silent modes) | 0.9 V to 8 V |
| Differential receiver hysteresis voltage<br>(normal/silent modes) | 50 mV to 200 mV |

## CAN

| | |
|---|---|
| Dominant short-circuit output current | -100 mA maximum |
| Recessive short-circuit output current | +/- 5 mA maximum |
| Differential input resistance | 30 kΩ |
| Common-mode input capacitance (CAN_H or CAN_L to IGND) | 20 pF |
| 200 mV Differential input capacitance (CAN_H to CAN_L) | 10 pF |
| IGND isolation (IGND to all other system grounds) | 250 VDC |
| IGND maximum continuous current | 500 mA |
| | Note: IGND is provided as a ground reference for isolated circuits CAN, RS-232 and IO_LOCK. IGND is isolated from all other DCM grounds. IGND may only be used as a reference for CAN, RS-232 and IO_LOCK pins. While IO_LOCK pins belong to the isolated circuitry, it is not necessary to utilize IGND with IO_LOCK+ and IO_LOCK- because they operate with an external passive ESTOP switch. |

## RS-232

| | |
|---|---|
| DCM Connector 1 Pins | RS232_TX<br>RS232_RX<br>IGND |
| Configuration | • 1 channel RS-232 transceiver<br>• Fault-protected<br>• Utilizes NI-VISA serial device drivers<br>• Circuitry Isolated from PGND to accommodate long distance communications with systems not tied to PGND |
| UART/Console Out (Serial1) | |
|    UART Specifications | |
|       Maximum baud rate | 230,400 bps |
|       Data bits | 5, 6, 7, 8 |

**RS-232**

| | | |
|---|---|---|
| Stop bits | 1, 2 | |
| Parity | Odd, Even, Mark, Space | |
| Flow control | None | |
| Console Out specifications | When Console Out is enabled, the Serial1 interface functions as a console for the operating system. You can use a serial-port terminal program to read the DCM IP address, read the sbRIO-9651 firmware version, and access the console. Ensure that the serial-port terminal program is configured with the following settings: | |
| | • 115,200 bps | |
| | • Eight data bits | |
| | • No parity | |
| | • One stop bit | |
| | • No flow control | |
| | Note: Refer to the *Safe Mode and IP Reset* (**Figure 13**) section of this document for more information about how to enable Console Out. | |

| Transceiver input (RS232_RX to IGND) | | |
|---|---|---|
| Input voltage range | -70 V to +70 V | |
| Input threshold low | 0.8 V | |
| Input threshold high | 2.4 V | |
| Input resistance | 35 k$\Omega$ to 250 k$\Omega$ | |

| Transceiver output (RS232_TX to IGND) | | |
|---|---|---|
| Output voltage swing | +/- 5 V minimum<br>+/- 6 V typical | |
| Output resistance | 300 $\Omega$ | |
| Output over-voltage protection threshold | -70 V to +70 V | |
| Output short-circuit current | +/- 80 mA | |

**RS-232**

| | |
|---|---|
| IGND isolation<br>(IGND to all other system grounds) | 250 VDC |
| IGND maximum continuous current | 500 mA |
| | Note: IGND is provided as a ground reference for isolated circuits CAN, RS-232 and IO_LOCK. IGND is isolated from all other DCM grounds. IGND may only be used as a reference for CAN, RS-232 and IO_LOCK pins. While IO_LOCK pins belong to the isolated circuitry, it is not necessary to utilize IGND with IO_LOCK+ and IO_LOCK- because they operate with an external passive ESTOP switch. |

# Safe Mode and IP Reset

The following figure shows the reset behavior of the DCM.

**Figure 13.** Reset Behavior
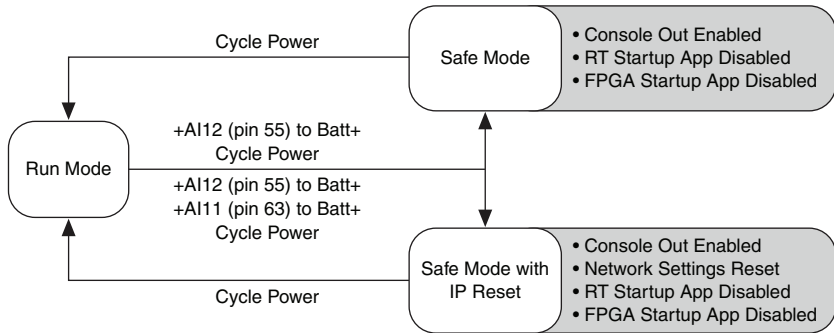
# Physical Characteristics

| | |
|---|---|
| Dimensions | 19 in X 8.7 in X 4.4 in<br>(48.3 cm X 22.1 cm X 11.2 cm) |
| Weight | 16.60 lbs (7.5 kg) |

Note: If you need to clean the controller,
wipe with a dry towel

For indoor use only

# Ventilation Clearance

| | |
|---|---|
| Minimum vent clearance | 0.75 in (19.05 mm) |

📝 **Note**   The DCM-2301 cooling inlet air vents are located on the right side of the chassis and the outlet air vents are on the left side of the chassis. For best performance the air vents must allow easy air circulation without wiring or panels blocking the vents.

**Figure 14.**  Airflow and Ventilation Clearance

Intake Vents

0.75 in. (19.05 mm)

0.75 in. (19.05 mm)
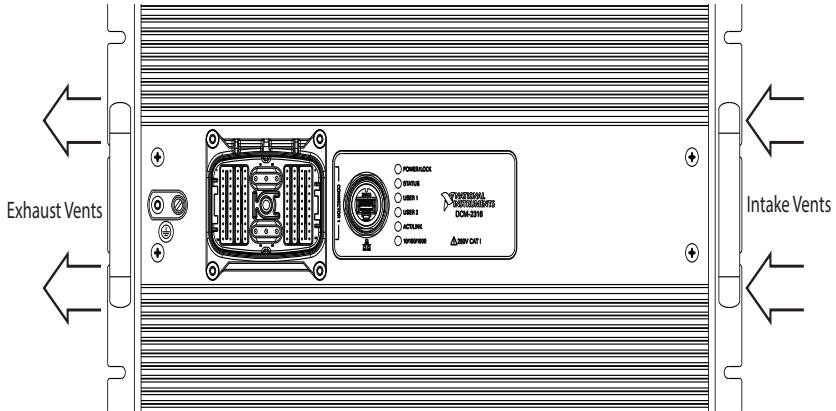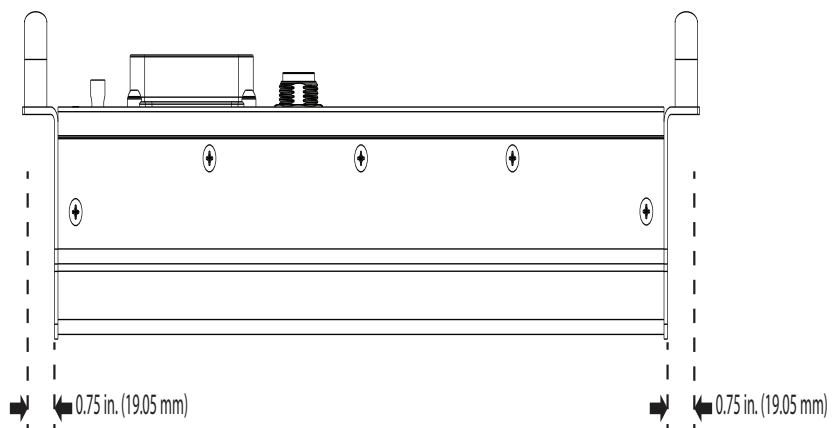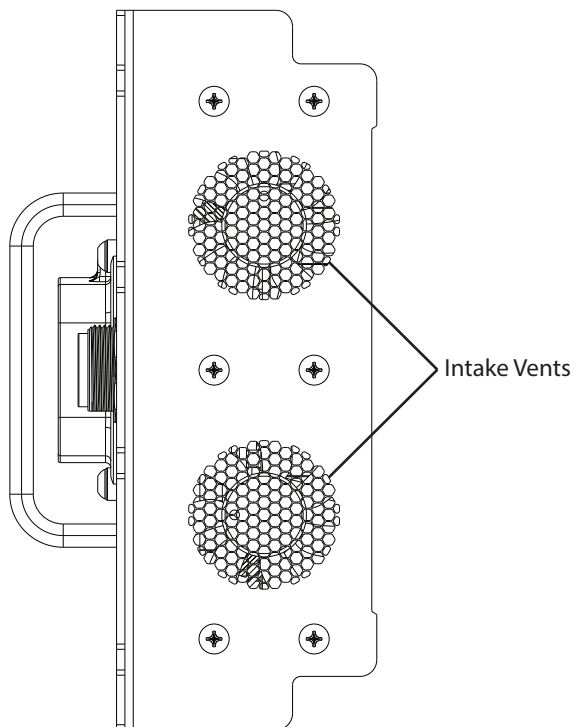
# Internal Real-Time Clock Battery

| | |
|---|---|
| Configuration | • Internal coin cell battery maintains controller's real-time clock<br>• Non-serviceable. Replaced by National Instruments. |
| Typical battery life with power applied to Connector 1 BATT pin | 10 years |
| Typical battery life in storage at 55 **°C** | 5.7 years |
| Typical battery life in storage at 85 **°C** | 5.3 years |

# Environmental

| | |
|---|---|
| Temperature<br>(IEC 60068-2-1 / IEC 60068-2-2) | |
|     Operating | 0 °C to +55 °C |
|     Storage | -40 °C to +85 °C |
| Ingress protection | IP 20 |
| Operating humidity<br>(IEC 60068-2-56) | 10% RH to 90% RH, noncondensing |
| Storage humidity<br>(IEC 60068-2-56) | 5% RH to 95% RH, noncondensing |
| Pollution Degree<br>(IEC 60664) | 2 |
| Maximum altitude | 2,000 m |

# Shock and Vibration

| | |
|---|---|
| Operating Shock | 30 g peak, half-sine, 11 ms pulse<br>(Tested in accordance with IEC-60068-2-27. Meets MIL-PRF-28800F Class 2 Limits) |
| Random vibration | |

| Operating | 5 to 500 Hz, 0.3 $g_{rms}$ |
|---|---|
| Non-operating | 5 to 500 Hz, 2.4 $g_{rms}$<br>(Tested in accordance with IEC-60068-2-64.<br>Non-operating test profile exceeds the requirements<br>of MIL-PRF-28800F, Class 3.) |

# Safety Standards

This product is designed to meet the requirements of the following electrical equipment safety standards for measurement, control, and laboratory use:

- IEC 61010-1, EN 61010-1
- UL 61010-1, CSA 61010-1

**Note** For UL and other safety certifications, refer to the product label or the *Online Product Certification* section.

# Electromagnetic Compatibility

This product meets the requirements of the following EMC standards for sensitive electrical equipment for measurement, control, and laboratory use:

- EN 61326-1 (IEC 61326): Class A emissions; Basic immunity
- EN 55011 (CISPR 11): Group 1, Class A emissions
- EN 55022 (CISPR 22): Class A emissions
- EN 55024 (CISPR 24): Immunity
- AS/NZS CISPR 11: Group 1, Class A emissions
- AS/NZS CISPR 22: Class A emissions
- FCC 47 CFR Part 15B: Class A emissions
- ICES-001: Class A emissions

These requirements and limits provide reasonable protection against harmful interference when the product is operated in the intended operational electromagnetic environment. This product is intended for use in industrial locations. However, harmful interference may occur in some installations, when the product is connected to a peripheral device or test object, or if the product is used in residential or commercial areas. To minimize interference with radio and television reception and prevent unacceptable performance degradation, install and use this product in strict accordance with the instructions in the product documentation. Furthermore, any changes or modifications to the product not expressly approved by National Instruments could void your authority to operate it under your local regulatory rules.

To ensure the specified EMC performance, you must operate this product with shielded cables and clamp-on ferrite beads as specified in Table 1 below. The clamp-on ferrite beads must be connected to the cable as close to the DCM as possible. Placing the ferrite elsewhere on the cable noticeably impairs its effectiveness.

**Table 2.** EMC Clamp-on Ferrite Bead and Cable Shielding

| Connector 1 Pins (Names) | Cable Shielding | Clamp-on Ferrite Bead |
|---|---|---|
| 84, 85, 86 (DRVP) | Not Required | NI 782803-01 |
| 2, 10, (DI_S_Ax) | Not Required | NI 782803-01 |
| 3, 11, (DI_P_Ax) | Not Required | NI 782803-01 |
| 5, 13, 6, 14, 7, 15, 21, 29 (DIO1-DIO4) | Foil shield | NI 782803-01 |
| 22, 30, 23, 31, 37, 45, 38, 46 (DIO5-DIO8) | Foil shield | NI 782803-01 |

**Note**  For the standards applied to assess the EMC of this product, refer to the *Online Product Certification* section.

# CE Compliance  $C \, \epsilon$

This product meets the essential requirements of applicable European Directives, as follows:

- 2014/35/EU: Low-Voltage Directive (safety)
- 2014/30/EU: Electromagnetic Compatibility Directive (EMC)
- 2011/65/EU: Restriction of Hazardous Substances (RoHS)

# Online Product Certification

Refer to the product Declaration of Conformity (DoC) for additional regulatory compliance information. To obtain product certifications and the DoC for this product, visit *ni.com/certification*, search by model number or product line, and click the appropriate link in the Certification column.

# Environmental Management

NI is committed to designing and manufacturing products in an environmentally responsible manner. NI recognizes that eliminating certain hazardous substances from our products is beneficial to the environment and to NI customers.

For additional environmental information, refer to the *Minimize Our Environmental Impact* web page at `ni.com/environment`. This page contains the environmental regulations and directives with which NI complies, as well as other environmental information not included in this document.

## Waste Electrical and Electronic Equipment (WEEE)

**EU Customers**  At the end of the product life cycle, all products *must* be sent to a WEEE recycling center. For more information about WEEE recycling centers, National Instruments WEEE initiatives, and compliance with WEEE Directive 2002/96/EC on Waste and Electronic Equipment, visit ni.com/environment/weee.

## Battery Replacement and Disposal

**Battery Directive**  This device contains a long-life coin cell battery. If you need to replace it, use the Return Material Authorization (RMA) process or contact an authorized National Instruments service representative. For more information about compliance with the EU Battery Directive 2006/66/EC about Batteries and Accumulators and Waste Batteries and Accumulators, visit ni.com/environment/batterydirective.

## 电子信息产品污染控制管理办法 （中国 **RoHS**）

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