3L Power SiC 150 kW Motor Drive

Triton150-PSiC

pn PCS-M20F30

Operation Manual

Date	Rev	Description	Author	Approved by
2/02/2018	0	First Draft	M Datta	C Cheek
3/08/2018	1	Picture update		
3/07/2019	2	Specs, pics as described on pg 2	M Datta	C Cheek
4/08/2019	3	Control power specs	C Cheek	
1/21/2020	4	Update for 150HP model	K Smith	C Cheek

Description

The Triton150 Motor Drive is a three-phase motor drive that can switch at PWM frequencies exceeding 100 kHz. It is a parallel SiC-based semiconductor drive that can operate with DC input voltages between 0 and 625 Vdc and at currents up to 220 Arms, with motor shaft position feedback either through a resolver or incremental encoder. The Triton150 has a 3L Power drive-to-drive high speed isolated communications (DHSC) port to allow multiple drives to be synchronized for multiple motor operation on a common shaft or electrically paralleled.

The Triton line of drives includes both models with higher current ratings as well as voltage ratings up to 900 Vdc. More information is available at www.3LPower.com.

Specification

Power	150 kW
Switching Frequency	40 – 120 kHz
Voltage input	100 – 625 Vdc
Inst. Max voltage withstand	800 Vdc
Vrms out max	440 Vrms
Iout max	220 Arms
Cooling	Copper plate / water cooled
Copper plate temp at max	45 °C
Control Power	24 Vdc nominal, 22-26V, 25W
Comms	Isolated CAN, isolated 3L DHSC, USB GUI
Position Feedback	Resolver, incremental encoder

Functional and Performance

The Triton150 drive takes in DC power and delivers 3-phase AC power for running a permanent magnet (PMSM) or induction motor with position feedback. Safety fusing , EMI filtering, and/or switchgear need to be applied external to the motor and drive as applicable and if necessary.

All drive functions are controlled by an integrated 3L Power Atlas board that houses all of the FPGA, CPU, and memory digital control components.

PWM

The PWM state machine for running the motor exists in FPGA firmware, and can be configured for switching frequencies between 20 kHz and 120 kHz, with variable deadtimes. Switching frequencies can be configured to follow preloaded tables as a function of output current, or remain static. The default switching frequency for the Triton150 is 100 kHz below 40A, dropping successively to 40 kHz between 120A and 220A.

Current/Torque Control

Typical motor control configurations include an inner torque / current control algorithm that relies on a current command, 3-phase feedback current, and a PI regulator that drives the actual current to match the current command. Depending on the amount of other tasks running, the control loop can run between 10 Hz up to 50 kHz, though 20 kHz is the default loop frequency. Control loop gains are not limited, and can be set by parameter adjustment. Current PI regulator gains Kp and Ki have units of Volts/Amp and Volts/Amp-second respectively, and the resulting system bandwidth is dependent on other parameters, such as input voltage and output (load) impedance.

Current feedback and voltage feedback sampling rates occur at 160 kHz per channel and are constantly evaluated for fault scenarios in firmware.

Raw current feedback signals are filtered with user-settable bandwidth, processed through a real-time RMS calculation, and processed through a DQ0 transform.

Velocity Control

Typical motor control configurations include an outer velocity control algorithm that relies on a velocity command, position feedback, and a PI regulator that drives the actual position time-derivative to match the velocity command. The output of the PI regulator is a current command that is fed into the torque / current regulator, and this output has both negative and positive limits that are user-settable. As with the current regulator, the control loop can update at rates between 10 Hz and 50 kHz. Although PI regulator gains, Kp and Ki, are settable per user requirements, the regulator can go unstable if the velocity control regulator is faster than the inner loop current regulator.

Position feedback is fed to the Atlas board FPGA pins, and can include data from discrete hall effect sensors, analog hall effect sensors, digital encoders, or resolvers. This variant of the drive is configured for resolver feedback and incremental encoder feedback. Necessary bandwidth for the position feedback varies with the maximum electrical frequency (maximum mechanical speed times the number of motor pole pairs). It is desirable that the feedback hardware slew rates are greater than the slew rate of the motor position at full speed, and that change in position is discernible over the noise background at all operating speeds. In general, resolvers yield the best results for the Atlas control platform, with the most resolution. Position feedback information can be processed through digital low-pass filters with user-settable gain. On request, advanced calibration algorithms can also be employed to adjust for position feedback non-linearities.

Speed limits (forward and backward), speed slew rates (acceleration), and speed-versus torque profiles are all settable per user requirements.

Limits and Protections

When configured as a motor controller, the Atlas firmware has several operating parameter limits and fault thresholds.

Current: The current limit is a limitation on the current demand that comes from the speed regulator. The current regulator will never try to drive a current higher than the current limit. If the actual current exceeds the current limit, then the current regulator will try to reduce the current. Above the current limit, a current fault threshold exists. If the actual current exceeds the current fault threshold, then a fault will be flagged, and the switching state machine will stop (transistors stop switching).

Speed: The speed limit is a limitation on the speed demand that comes from the user or external controller. The speed regulator will never try to drive a speed higher than the speed limit. If the actual speed exceeds the speed limit, then the speed regulator will try to reduce the motor speed. Above the speed limit, an overspeed fault threshold exists. If the actual speed exceeds the overspeed fault threshold, then a fault will be flagged, and the switching state machine will stop (transistors stop switching).

Voltage: Motor controllers typically do not regulate output or input voltages, therefore there is no voltage limit when operating the Atlas board as a motor controller. An input voltage fault threshold exists such that if the input voltage ever exceeds the threshold, a fault will be flagged, and the switching state machine will stop (transistors stop switching) to help preserve the switching devices.

All limits and fault thresholds discussed above are settable per user requirements.

Other faults: The motor controller maintains several fail safe features to detect abnormal digital controls behavior such as loss communication with the host, or a logic lockup within either the DSP or FPGA. All of the fault scenarios listed below will generate a unique fault ID and halt the motor operation.

1) Loss of communication – If the controller does not receive a communication packet within 2x period of the normal communication period, a communication fault is declared.
2) DSP Watchdog timer – If the DSP does not receive an interrupt from the FPGA within a 2x period of the normal interrupt period, a DSP watchdog fault is declared.
3) FPGA Watchdog timer – If the FPGA's control register is not written to by the DSP within a 2x period of the normal PWM period, a FPGA watchdog fault is declared.
4) DSP Internal Watchdog – If the software on the DSP freezes, a watchdog timer integrated into the DSP silicon will trigger another fault.

Heat Dissipation

The controls system and gate drivers require about 10W of control power when quiescent and up to 25W when running with 120kHz PWM. As further described in the Mechanical Interface portion of this specification, the drive is bolted to a heatsink that must stay below 45 °C under rated current output conditions. While staying below 45 °C at rated current, the heatsink needs to be able to dissipate about 2.5 kW of losses.

Field Weakening

If the motor BEMF magnitude plus voltage across the load impedance exceeds the DC link voltage, the motor can no longer be driven at unity power factor. If desired, field weakening can be used to drive the motor to higher speeds than would otherwise be achievable, at the cost of having to drive non-torque-producing current. For permanent magnet motors, the amount of speed gain per Amp of D-axis current (non-torque-producing) varies with the inductance of the stator's d-axis versus the field strength of the rotor. The speed threshold (RPM) at which field weakening starts can be set, and the amount of d-axis current driven per RPM over the threshold can be set (Amps/RPM). Care should be taken when setting these parameters so that the rotor does not get demagnetized.

Interface

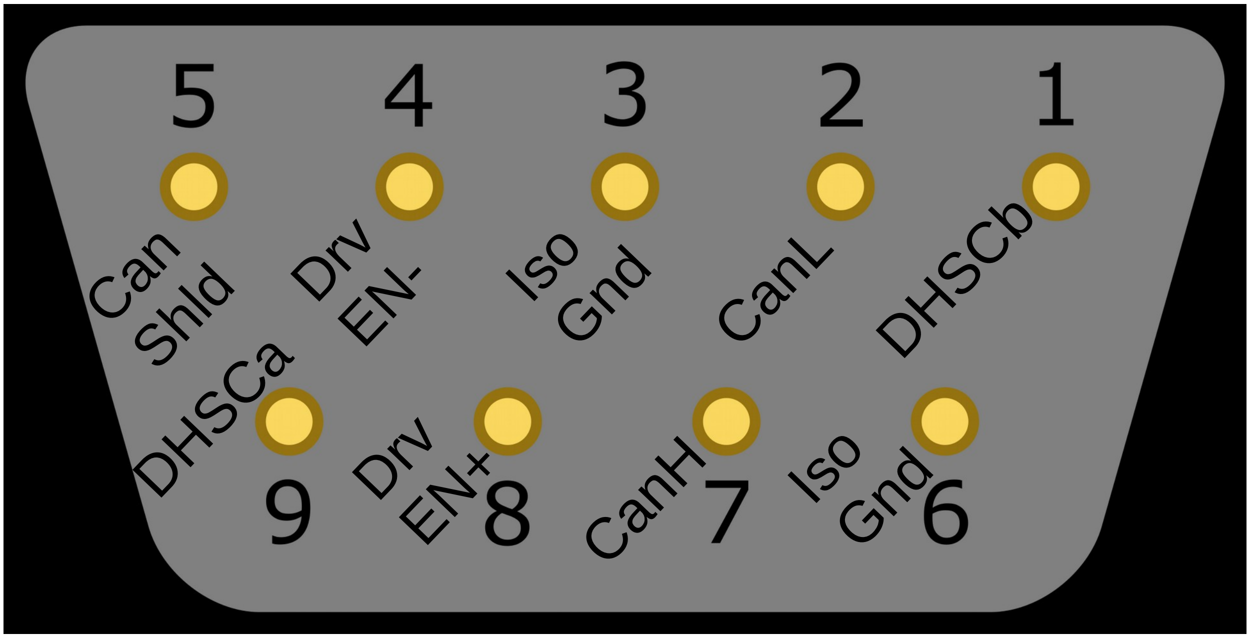
Commands and data requests are passed through the CAN communication ports or over a user interface connected to the USB port. Motor shaft position feedback signals are fed to the drive through the resolver port. All interface ports are located in the inset area on the side of the drive.

CAN Interface

The main automated communications interface is through the CAN communications port located on a 9-pin DB receptacle on the side of the drive. Refer to the Triton100/150 CAN communications specification (#Spec_Triton100CAN) for further details on message format and electrical specifications.

The pinout for the CAN communications port is shown below. The pins shown are as seen while facing the CAN port on the side of the drive. CAN high and CAN low are on pins 7 and 2, respectively. Pins labeled “Iso Gnd” are connected to the isolated ground used for the CAN transceiver. The drive enable pins, labeled “Drv EN”, provide an isolated digital input interface used to enable or disable the drive (when configured). These pins can be driven with a differential voltage between 5 and 48 Volts. DHSC “a” and “b” lines are used for drive-to-drive communications when paralleling drives (see section on drive paralleling).

The CAN interface can be used for real-time motor / drive speed control, and it can also be used to set parameters such as current regulator gains, or whether the motor is a permanent magnet motor or induction motor. Parameter descriptions and addresses are further discussed in the Triton100/150 CAN communications specification.

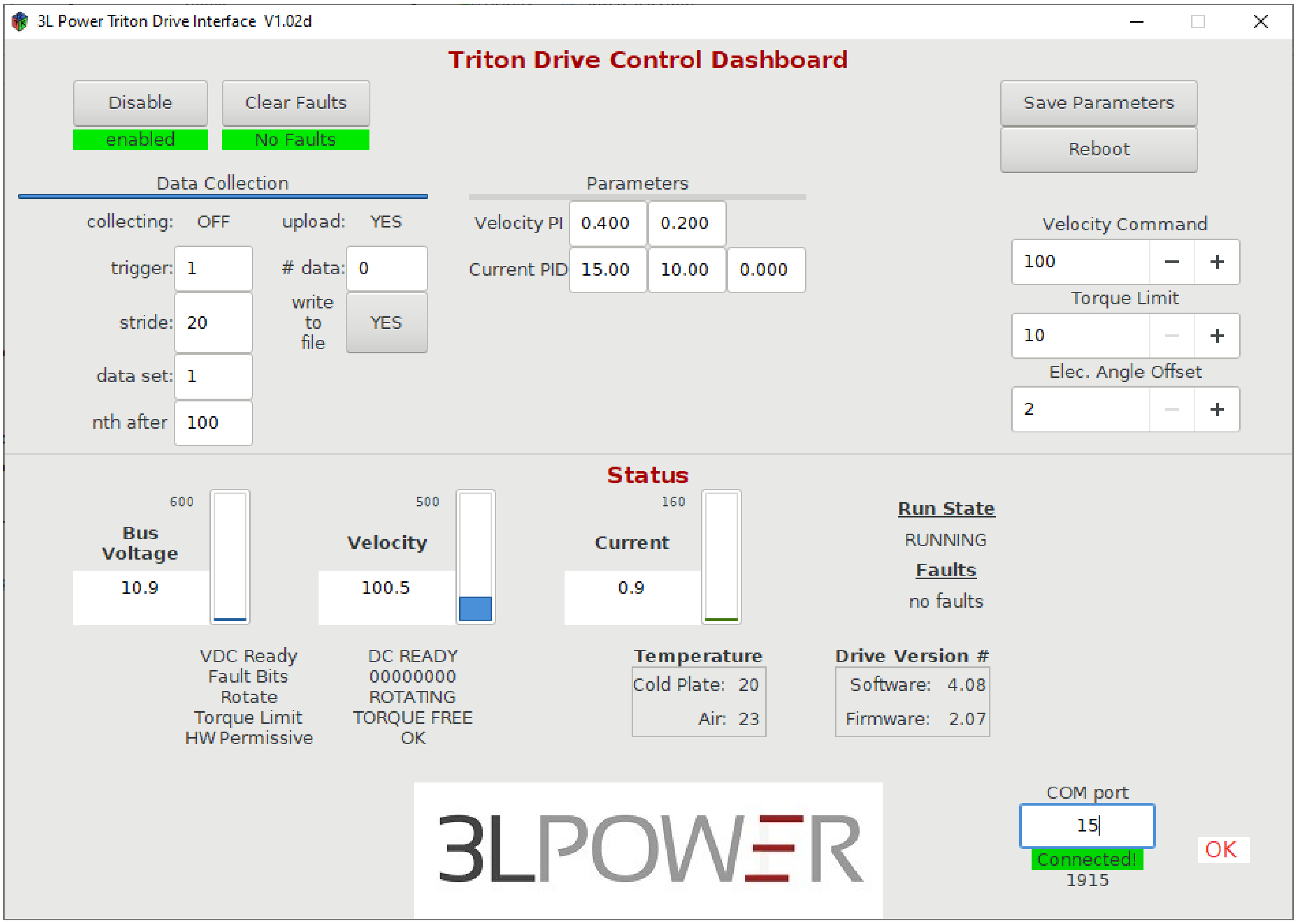


Pin Number	Signal Name	IO Type	Description
1	DHSC-b	Bidirectional	Isolated drive-to-drive comm 5V “b” line
2	CAN-L	Bidirectional	Isolated 0-3.5V CAN “Low” line
3	ISO Gnd	Passive	Isolated CAN ground
4	DRV EN-	Input	Digital IO isolated input return
5	CAN Shld	Passive	CAN shield pin, connected to isolated CAN Gnd
6	ISO Gnd	Passive	Isolated CAN ground
7	CAN-H	Bidirectional	Isolated 0-3.5V CAN “High” line
8	DRV EN+	Input	Digital IO isolated input – drive with voltage between 5Vdc and 48 Vdc
9	DHSC-a	Bidirectional	Isolated drive-to-drive comm 5V “a” line

Table 1: CAN Receptacle Pin Description

Graphical User Interface

The 3L Power motor control graphical user interface (GUI) can be used by plugging a laptop with the 3L Power GUI application into the micro-USB port on the side of the drive. This GUI interface is used for non-automated communication with the drive, such as from a person that wants to manually control the drive during testing or operation. The GUI appears as shown in the figure below, and it allows a user to enable the drive, set current and speed loop gains, and set motor speed commands and torque limits. The interface also allows data (currents, voltages, speed, temperatures, etc.) to be collected from the drive. Refer to the 3L Power Triton GUI manual (#Spec_Triton100CAN) and application for further information.

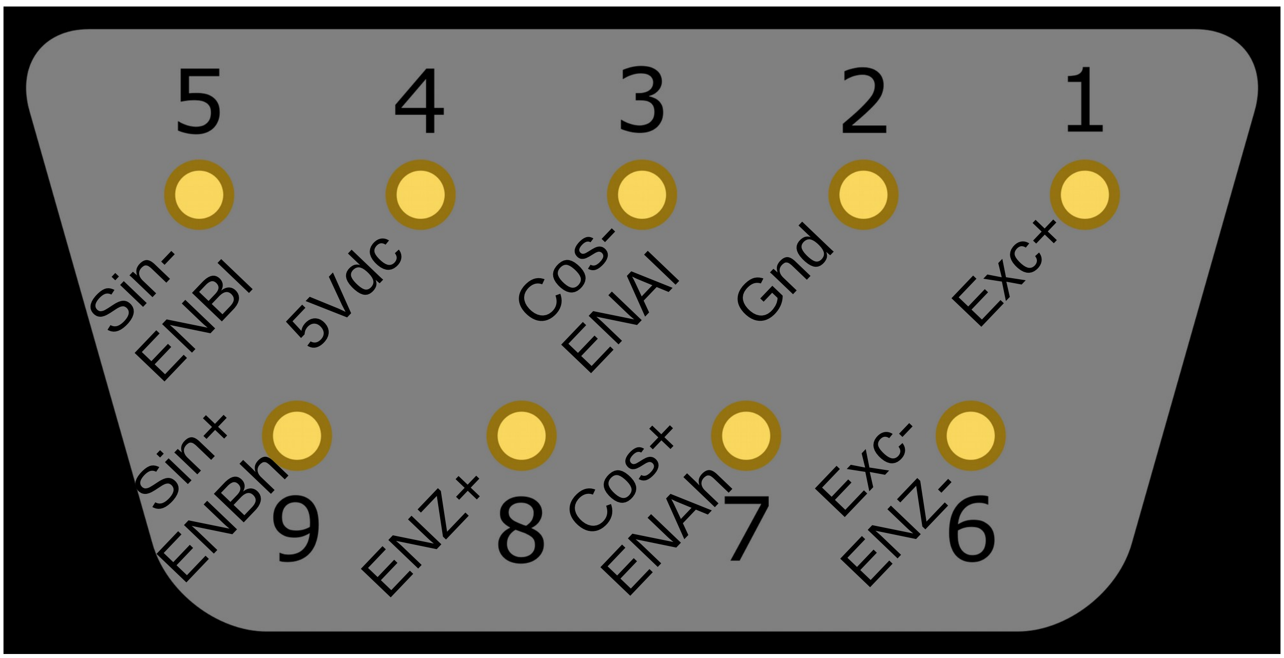

3L Power Triton Drive Interface V1.02d
Triton Drive Control Dashboard
Disable
enabled
Clear Faults
No Faults
Save Parameters
Reboot
Data Collection
collecting: OFF
upload: YES
trigger: 1
data: 0
stride: 20
write to file
YES
data set: 1
nth after 100
Parameters
Velocity PI 0.400 0.200
Current PID 15.00 10.00 0.000
Velocity Command
100
Torque Limit
10
Elec. Angle Offset
2
Status
600
Bus Voltage
10.9
500
Velocity
100.5
160
Current
0.9
Run State
RUNNING
Faults
no faults
VDC Ready
Fault Bits
Rotate
Torque Limit
HW Permissive
DC READY
00000000
ROTATING
TORQUE FREE
OK
Temperature
Cold Plate: 20
Air: 23
Drive Version #
Software: 4.08
Firmware: 2.07
3LPOWER
COM port
15
Connected!
1915
OK

Feedback Interface(s)

Motor shaft position feedback is required for operation of the motor drive. This can be provided by either a resolver or an incremental encoder. Resolution of the feedback sensor is specified by customer and programmed at the factory.

All remaining necessary feedback signals, such as 3-phase current and DC link voltage measurements, are built into the drive.

Resolver feedback and excitation for pn M20F30 occurs through the rightmost DB-9 receptacle on the drive, labeled "Resolver". The pinout for this receptacle is shown below.



The position feedback pins are dual-purpose for use with either a resolver or an encoder. The position feedback input type (resolver or encoder) is set at the factory, and can be changed through parameter adjustment using the 3L Power engineering menu. Contact 3L Power for further instructions if position feedback type needs to be changed. Since the excitation pins in resolver mode (pins 1 and 6) put out up to 10 Vrms, it is not advisable to connect an encoder to the DB-9 receptacle unless the receptacle is in encoder mode.

In resolver mode, 6 pins are used, two for resolver excitation (usually for rotor excitation), and 4 pins for the two differential cosine and sine signals that return to the drive. In encoder mode, 8 total pins are typically used: 5V and Gnd to supply the encoder with power, 2 pins for the differential A signal, 2 pins for the differential B signal, and 2 pins for the differential Z signal. If the encoder does not use differential signaling (just 3 pins for A, B, and Z), then the signals can just be connected to the A+, B+, and Z+ pins on the drive. Differential encoder signaling is recommended, however, as it has better noise immunity.

With either type of position feedback, when used with permanent magnet synchronous motors, it is important to set the position feedback angular offset as well as the number of poles. The angle offset can be set using the CAN bus register map or the 3L Power GUI.

Pin descriptions for the position feedback receptacle are given below.

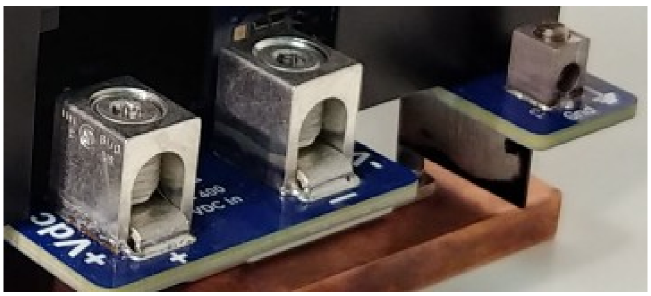
Pin Number	Mode	Signal Name	IO Type	Description
1	Resolver	EXC+	Output	Resolver excitation pin, usually for rotor excitation, up to 10Vrms
2	Either	Gnd	Power Gnd	Ground / 5V return
3	Resolver	COS-	Input	Resolver Cos- input
3	Encoder	ENC_A-L	Input	Encoder A Low input, 0-5V
4	Either	5 Vdc	Power 5V out	5Vdc power output for the encoder
5	Resolver	SIN-	Input	Resolver Sin- input
5	Encoder	ENC_B-L	Input	Encoder B Low input, 0-5V
6	Resolver	EXC-	Output	Resolver excitation return pin
6	Encoder	ENC_Z-	Input	Encoder Z Low input, 0-5V
7	Resolver	COS+	Input	Resolver Cos+ input
7	Encoder	ENC_A-H	Input	Encoder A High input, 0-5V
8	Encoder	ENC_Z+	Input	Encoder Z High input, 0-5V
9	Resolver	SIN+	Input	Resolver Sin+ input
9	Encoder	ENC_B-H	Input	Encoder B High input, 0-5V

Table 2: Resolver Receptacle Pin Description

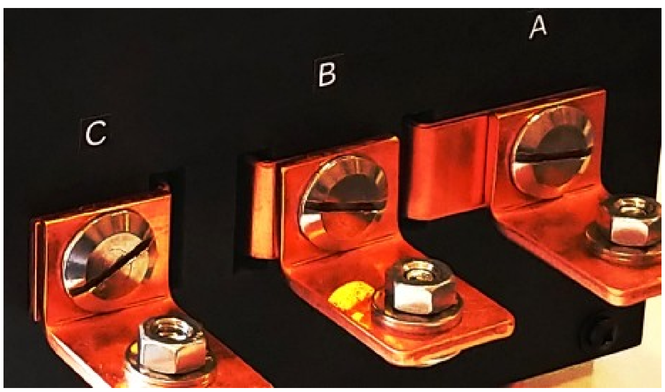
Power Interface

Control power is provided to the controller via a 2-pin connector (supplied with the drive) that plugs into the 24V receptacle on the DC end of the drive, shown below. The drive receptacle part number is Switchcraft 17282-2PG-300. The +24V pin is on the left (outboard side) when facing the inverter side with the 24V port, while the return pin is on the right.

DC plus voltage and minus voltage are supplied via cable (shielded or unshielded) to 1/0 connectors on the DC-side of the drive. A ground lug is located near the DC terminals for chassis ground connection.



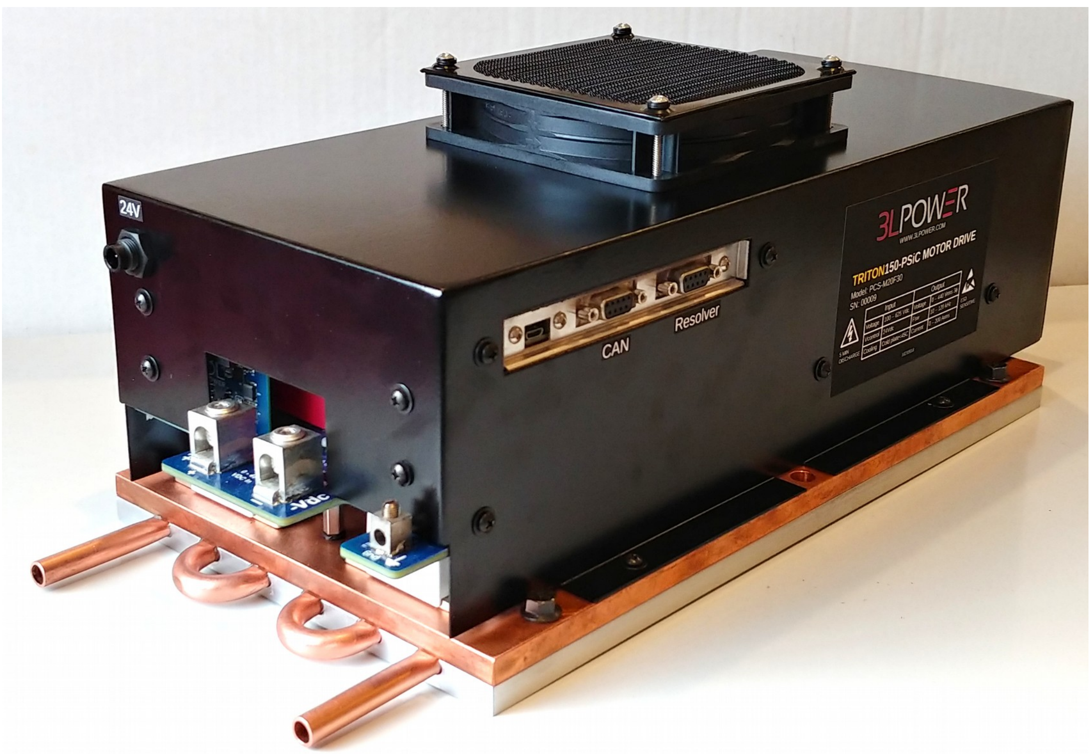
AC output voltage is connected via cable to three power lugs on the AC-output side of the drive.



Mechanical Interface

The drive is approximately 17”x7.5”x5” and is mounted to a 3/8” thick copper heat spreader. The drive is designed to bolt onto a thermally greased heatsink with four or six 1/4x20 or similar gauge threaded fasteners. Bolt hole locations can be customized.

The drive can be supplied already bolted to a water- or air-cooled heatsink per request. The Triton150 drive pictured below is bolted to a standard Triton water-cooled heatsink. Full temperature thermal tests at the 3L Power production facility utilize the Triton standard heatsink with 30C water inlet temperatures flowing at about 1 gal/min. See the heatsink data sheet (#Spec_MEC-000081) for more information.

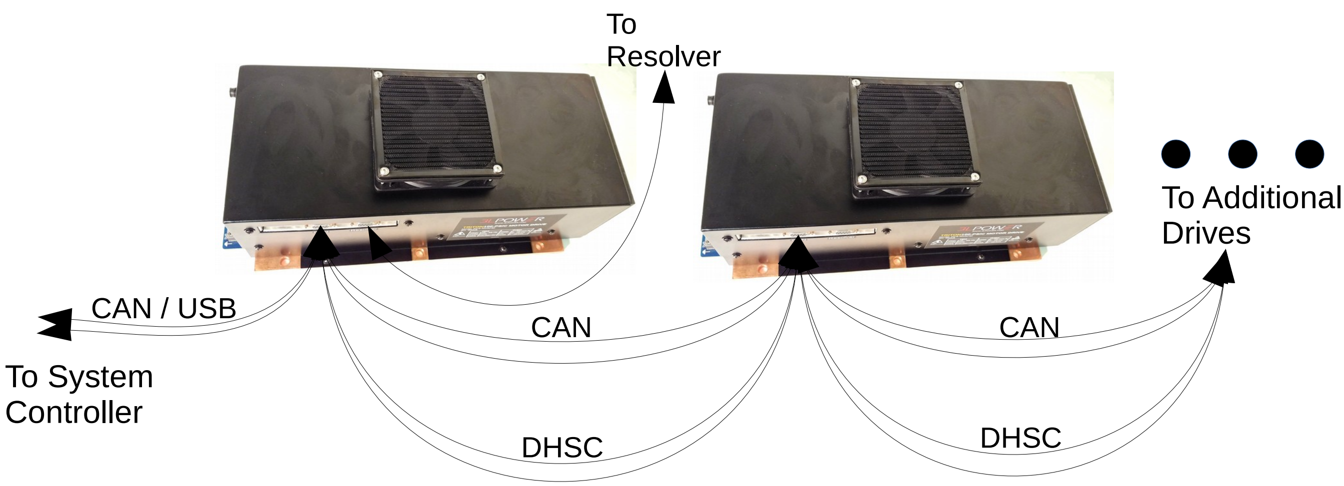


Paralleling

Two or more Triton drives can be paralleled for operation with larger motors, motors with multiple stators, or multiple motors on a single shaft or rigidly connected. The Triton150 comes with a 3L Power high-speed isolated differential communications (DHSC) port that synchronizes the drives, shares position feedback, and balances load. To enable paralleling, each drive needs to be connected together via the CAN communications interface and the DHSC communications interface (pins 1/9 and 2/7; see Interface Section for further details). The picture below shows these paralleling connections. One drive is configured as the master – this is the drive that should be sent operating commands (speed, torque limits, etc.) via one of the user interfaces. Configuration of which drives are master versus slaves are configurable by the user.

The master drive should be connected to the motor position feedback sensor (resolver or encoder) via the feedback sensor receptacle. The master shares position feedback information with the other drives over DHSC during operation.

The PWM switching period is synchronized between the drives to avoid drive beating, stator transformer effects and other issues that can arise out of non-synchronized drive operation. PWM synchronization also allows for electrically paralleling drives on a common stator. However, since each drive maintains its own current regulator for load balancing, each PWM pulse width is not guaranteed to be the same between drives (even though they are synchronized in time). For this reason, it is necessary to insert 10-50 µH of inductance at the output of each drive if they are to be used for electrical paralleling.



Environmental

Operating Environmental

Operating environmental temperature range: -40°C to 85°C (industrial) non-condensing (cold plate <45°C)

Operating shock limit: 25G