PowerXL™

DC1 und DA1 Frequenzumrichter

AC Variable Speed Drives in Low Temperature Applications

Level 1	1 – Fundamental – No previous experience necessary 2 – Basic – Basic knowledge recommended 3 – Advanced – Reasonable knowledge required 4 – Expert – Good experience recommended

Powering Business Worldwide

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Danger! - Dangerous electrical voltage!

- Disconnect the power supply of the device.
- Ensure that devices cannot be accidentally restarted.
- Verify isolation from the supply.
- Cover or enclose any adjacent live components.
- Follow the engineering instructions (AWA/IL) for the device concerned.
- Only suitably qualified personnel in accordance with EN 50110-1/-2 (VDE 0105 Part 100) may work on this device/system.
- Before installation and before touching the device ensure that you are free of electrostatic charge.
- The functional earth (FE, PES) must be connected to the protective earth (PE) or the potential equalization. The system installer is responsible for implementing this connection.
- Connecting cables and signal lines should be installed so that inductive or capacitive interference does not impair the automatic control functions.
- Suitable safety hardware and software measures should be implemented for the I/O interface so that an open circuit on the signal side does not result in undefined states.
- Deviations of the mains voltage from the rated value must not exceed the tolerance limits given in the specification, otherwise this may cause malfunction and/or dangerous operation.
- Emergency stop devices complying with IEC/EN 60204-1 must be effective in all operating modes. Unlatching of the emergency-stop devices must not cause a restart.
- Devices that are designed for mounting in housings or control cabinets must only be operated and controlled after they have been properly installed and with the housing closed.
- Wherever faults may cause injury or material damage, external measures must be implemented to ensure a safe operating state in the event of a fault or malfunction (e.g. by means of separate limit switches, mechanical interlocks etc.).
- Frequency inverters may have hot surfaces during and immediately after operation.
- Removal of the required covers, improper installation or incorrect operation of motor or frequency inverter may destroy the device and may lead to serious injury or damage.
- The applicable national safety regulations and accident prevention recommendations must be applied to all work carried on live frequency inverters.
- The electrical installation must be carried out in accordance with the relevant electrical regulations (e. g. with regard to cable cross sections, fuses, PE).
- Transport, installation, commissioning and maintenance work must be carried out only by qualified personnel (IEC 60364, HD 384 and national occupational safety regulations).
- Installations containing frequency inverters must be provided with additional monitoring and protective devices in accordance with the applicable safety regulations. Modifications to the frequency inverters using the operating software are permitted.
- All covers and doors must be kept closed during operation.
- To reduce the hazards for people or equipment, the user must include in the machine design measures that restrict the consequences of a malfunction or failure of the frequency inverter (increased motor speed or sudden standstill of motor). These measures include: – Other independent devices for monitoring safety related variables (speed, travel, end positions etc.).
  – Electrical or non-electrical system-wide measures (electrical or mechanical interlocks).
  – Never touch live parts or cable connections of the frequency inverter after it has been disconnected from the power supply. Due to the charge in the capacitors, these parts may still be alive after disconnection. Consider appropriate warning signs.

Disclaimer

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1 General

With the widespread use of Variable Frequency Drives (VFD's) in many different regions and applications it is becoming progressively more common for the requirements to include their use in very low temperature (sub 0°C/32F) environments. For all VFD's there are limiting factors that need to be considered in such cases but Eaton's PowerXL VFD range has been demonstrated to work safely and reliably when the low temperature considerations are correctly considered as part of the overall application design process. Eaton have additional options and functions within the PowerXL product range to assist the System Designer in this area, and these are described further as part of this Application Support Note.

2 Basic Product Specifications and Operation

2.1 Storage of the VFD

For general storage (without power on or use) a VFD is typically specified for temperatures as low as -40°C (-104F), but must be keep clear of any potential for frost or ice to form on the drive internal or external surfaces.

The drive should be gradually returned to a temperature above that stated for power up and operation (see below) before it is permitted to be powered on to prevent excessive thermal cycling. Note that the drive heatsink and power components may take longer to stabilize in comparison to the ambient air temperature surrounding them.

2.2 Power On of the VFD

The minimum temperature for power on of the VFD is not necessarily the same as that specified in the instructions as the 'minimum temperature for operation' and (as in the case of the PowerXL drives range) can be lower. Eaton drives have minimum 'power on' temperature of -20°C (-4F).

When starting up with drive temperature between the minimum switch on level and the level specified for operation the drive will immediately enter into an Under-Temperature trip and operation of the motor will be prohibited.
The drive should not be powered up when temperatures are below the minimum specified for power on and should the possibility for such temperatures exist then separate interlocking measures should be taken to heat the area around the drive until minimum levels have been achieved.

2.3 VFD Operation

All VFD product should state a minimum temperature for operation in their operating instructions. This is the temperature at or above which the drive is permitted to be enabled and to start control/operation of the motor. In most cases for VFD's this limit is -10°C (14F).

Once operating the drive will typically generate enough heat to prevent low temperature becoming an issue, but should the VFD's temperature fall below this level during operation, perhaps due to low

duty cycle or long standby periods, then the drive will enter into an Under-Temperature trip and further operation of the motor will be prohibited.

When a PowerXL drive is in an under-temperature (UT) condition and temperatures increase above the -10°C (14F) threshold then the drive will automatically reset from the UT condition. If an enable/run signal is present on the drive and the start mode selection is set to 'auto-#' then the drive will automatically start operation. If the start mode selection is set to 'Edge-r' then a rising edge signal must be applied to the enable/run after the drive resets from the UT condition in order for operation to commence.

2.4 VFD switch off / Power down

When the drive is powered down it will continue to dissipate heat into the environment as it gradually cools. In very cold environments where drives are installed in electrical panels or enclosures it might be prudent to restrict any airflow into that enclosure when the drive ceases operation to decrease the levels of thermal cycling experienced by the drive or other electrical components. If cooling fans are employed in the enclosure then their operation could be governed via a 'drive running' relay on the VFD.

3 Application Design

When considering the application design the 'worst case' temperature at start up needs to be considered. This might be application specific as in refrigeration type applications or might be regional/seasonal to the local climate in a particular location.

For the following Eaton products the rating for minimum temperature at power on is -20°C (-4F), and for operation is -10°C (14F), and this value applies to the junction temperature between drive output power device (IGBT) and the drive heatsink. The temperature as measured by the drive can be read in the parameter indicated in column 3 of the table below.

Drive Model Designation	Drives Range	Ambient Temperature Parameter	Min Temp – Power up	Min Temp - Operation
DC1--#####-####	PowerXL DC1	P00-20 (Celsius)	-20°C or 4F	-10°C or 14F
DA1-#####-####	PowerXL DA1	P0-21 (Celsius)	-20°C or 4F	-10°C or 14F

Note that the accuracy of the temperature readings displayed by the drive are reduced at lower temperatures and typically should not be considered as accurate below around -17C or 1.4F (drive measurements are displayed in Celsius).

For start-up at temperatures below -20°C (-4F) it is recommended that either separate panel heaters are used that are interconnected to switch off when the drive enters into normal operation or are thermostatically controlled. It should not be permitted to switch on the drive until the temperature around the drive increases beyond -20°C (-4F).

For applications where start up temperature can be between -20°C (-4F) and -10°C (14F) then it is recommended that either a drive with the ability to self-heat via a dedicated internal function is

used, or that separate panel heaters are used as stated previous. PowerXL DA1 drives have a dedicated function for self-heating (see PowerXL Motor Pre-heat function section below).

Where panel heaters are used, the total heat output required will depend on the amount of space to be heated and the maximum time permitted before the drive enters into operation. In the case of a panel/enclosure the manufacturer will generally be able to advise or provide suitable calculation method to determine this.

Where there is exposure of the VFD to higher levels of humidity in combination with low temperatures there is a potential for moisture / condensation to form on the external surfaces of the drive. In such cases it is recommended to use an enclosed drive to negate the effect of any moisture forming on the outside of the enclosure and to limit the potential for internal moisture issues. Eaton offer enclosed drive options on the majority of model ranges for such applications.

As well as considerations for the VFD in very cold weather, some thought should also be spared for the electric motor in conjunction with the motor specifications and if necessary guidance from the motor manufacture sort. Typically motors will work down to -20^{o}C (-4F) but operation outside of the range specified by the manufacturer may cause issues with bearing lubrication or moisture / condensation getting into the motor housing. These issues can be exasperated by starting the motor directly with high speed / high load conditions, stressing the mechanical components and causing excess thermal cycling. Some VFD's have a motor pre-heat function that can pass lower levels of current through the motor windings at start up to gradually increase the motor temperature prior to entering normal operation (see PowerXL Motor Pre-heat function below).

4 PowerXL self-heat function

The self-heat function is present on Eaton's **DA1 range of products** in all frame sizes. Parameters related to the set-up of this function are listed below.

Par.	**Name**	Minimum	Maximum	Default	Units
P6-19	**Brake Resistor Resistance Value**	See Below	200	See Below	Ohms
Sets the brake resistor value in Ohms. This value is used for the brake resistor thermal protection.					
P6-20	**Brake Resistor Power Rating**	0.00	200.00	See Below	kW
Sets the brake resistor power in kW, with a resolution of 0.1kW. This value is used for the brake resistor thermal protection					
P6-21	**Brake Chopper under Temperature Duty Cycle**	0.0	20.0	2.0	%
This parameter defines the duty cycle applied to the brake chopper whilst the drive is in an under temperature trip state. A brake resistor can be mounted to the drive heat sink, and used to maintain the drive temperature above the minimum operating temperature. This parameter should be used with care, as incorrect adjustment may result in exceeding the rated power capacity of the resistor. External thermal protection for the resistor should always be used to avoid this risk.					

For best results a flat wire wound resistor is an aluminium enclosure should be used, mounted directly to the heat-sink of the drive. Typical examples are shown below.

For the PowerXL DA1 IP20 frame sizes 2 to 5, and IP55 frame sizes 4 & 5, brake resistor options are directly available that will fit into the pre-designated mounting points on the drive to heat the drive whilst in an under temperature condition.

Product Code	Description	For Drive Frame Sizes
DX-BR3-100	Brake Resistor Size 2,3 100R, 200W	2, 3
DX-BR5-033	Brake Resistor, Size 4, 33R, 500W	4, 5

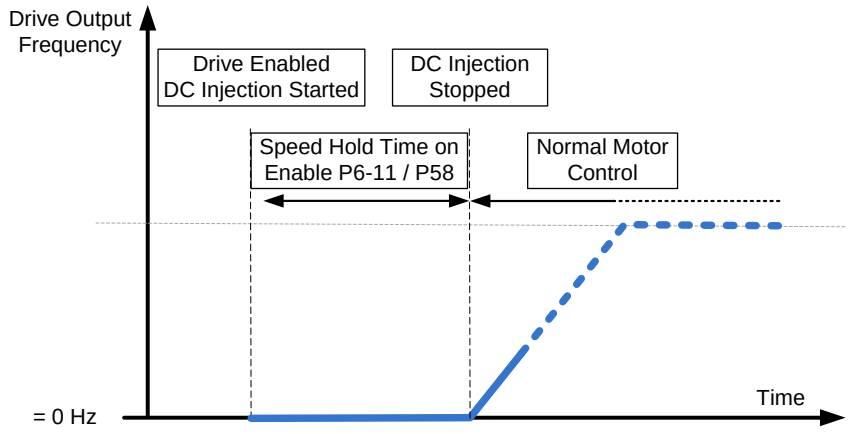
4.1 Drive Configuration (DC1)

Parameters related to the set-up of this function are listed below (DC1).

Par.	Name	Minimum	Maximum	Default	Units
P32	**DC Injection Braking**				
: Index 1	**Duration**	0.0	25.0	0.0	S
: Index 2	**DC Injection Mode**	0	2	0	%
Index 1: Defines the time for which a DC current is injected into the motor. DC Injection current level may be adjusted in P-59. Index 2: Configures the DC Injection Function. Set to value 1 for DC injection on start only.					
P-58	**DC Injection Speed**	0.0	P-01	0.0	Hz / RPM
Sets the speed reference for DC injection.					
P-59	**DC Injection Current**	0.0	100.0	20.0	%
Sets the level of DC injection braking current applied according to the conditions set in P-32 and P-58.					

- Enter advanced setup security code into parameter P-14 to access extended parameter set (default 101)
- Set the DC Injection Braking duration/time required on Start in parameter P-32, index 1.
- Set the DC Injection mode to 'on start-up' by settingP-32, index 2 to value 1
- Set DC Injection speed reference (P-58) to 0 Hz / RPM
- Set the DC Injection current level to apply at start in P-59
- Monitor current levels on the drive display and monitor motor temperature to ensure they remain within the motor manufacturers specified limits
  (The current can be monitored by changing the drive display to show Amps - cycle the display to Amps by pressing the Navigate button)

4.2 Timing Diagram



	Danger: The motor may appear to be inactive whilst DC Injection braking is applied. Care must be taken to ensure any personnel are made aware that the motor may start up unexpectedly.

5 PowerXL Maintained Motor current at 0 speed

The Maintained Motor current at 0 speed function is present on Eaton's DA1, and DC1(E1) range of products in all frame sizes.

The function uses the Boost Voltage level / setting on the drive reaching zero speed in order to create a current and maintain an appropriate temperature within the motor. Drive Standby Mode must be disabled so that the drive output is not automatically put into Standby following a period of inactivity / operation with zero speed reference.

5.1 Drive Configuration (DA1)

Parameters related to the set-up of this function are listed below (DA1).

Par.	Name	Minimum	Maximum	Default	Units
P1-11	**V/F Mode Voltage Boost**	-0.0	See User Guide	See User Guide	%
This parameter is effective only when operating in V/F Mode (P4-01 = 2). Voltage boost is used to increase the applied motor voltage at low output frequencies, in order to improve low speed and starting torque. Excessive voltage boost levels may result in increased motor current and temperature, and force ventilation of the motor may be required.					
P2-27	**Standby Mode Timer**	0 .0	250	0.0	Seconds
This parameter defines time period, whereby if the drive operates continuously at minimum frequency / speed for at least the set time period, the PowerXL drive output will be disabled, and the display will show στνδβψ. The function is disabled if P2-27 = 0.0.					

- Enter advanced setup security code into parameter P1-14 to access extended parameter set (default 201)
- Set Standby Mode Timer (P2-27) to 0 to deactivate standby mode.
- Set the V/F Mode Voltage Boost in P1-11 to maintain the required current in the motor.
- Monitor current levels on the drive display and monitor motor temperature to ensure they remain within the motor manufacturers specified limits.
  (The current can be monitored by changing the drive display to show Amps - cycle the display to Amps by pressing the Navigate button)

5.2 Drive Configuration (DC1)

Parameters related to the set-up of this function are listed below (DC1).

Par.	Name	Minimum	Maximum	Default	Units
P-11	**Low Frequency Torque Boost Current**	0.0	See User Guide	3.0	%
Low Frequency Torque Boost is used to increase the applied motor voltage and hence current at low output frequencies. This can improve low speed and starting torque. Increasing the boost level will increase motor current at low speed, which may result in the motor temperature rising - force ventilation of the motor may then be required. In general, the lower the motor power, the higher the boost setting that may be safely used.					
P-48	**Standby Mode Timer**	0.0	25/0	0.0	s
When standby mode is enabled by setting P-48 > 0.0, the drive will enter standby following a period of operating at minimum speed (P-02) for the time set in P-48. When in Standby Mode, the drive display shows στνδβψ, and the output to the motor is disabled.					

- Enter advanced setup security code into parameter P-14 to access extended parameter set (default 101)
- Set Standby Mode Timer (P-48) to 0 to deactivate standby mode.
- Set the V/F Mode Voltage Boost in P-11 to maintain the required current in the motor.
- Monitor current levels on the drive display and monitor motor temperature to ensure they remain within the motor manufacturers specified limits.
  (The current can be monitored by changing the drive display to show Amps - cycle the display to Amps by pressing the Navigate button)

6 Summary for Low Temperature Operation

- Consider the use of an enclosed drive to help mitigate moisture/condensation issues.
- Consult the motor specifications and consider using a VFD with motor pre-heat function or maintained motor current at 0 speed to reduce stress on the motor.
- At temperatures below -10^{o}C (14F) consider using a VFD with self-heating function to potentially provide a lower cost alternative to panel heaters.
- Where enclosure fans are used, consider limiting their use to times when the VFD/VFD's are in operation, switching off when they become inactive.
- Where panel heaters need to be used they should generally be thermostatically controlled or interlocked through the VFD status relay to switch off when the drive enters operation.
- Where potential is for temperatures to be sub -20^{o}C (-4F) consideration must be given to preventing drive use until effective measures have been taken to increase ambient temperature.
- The overall application should be considered in relation it any international standards that may have a bearing on product suitability at stated temperatures.

7 Typical applications where low temp operation could be a requirement.

- Pumping (particularly in oil and gas)
- Fan / extract in refrigeration applications
- Conveyor systems in refrigerated warehousing
- Rooftop condenser fan applications with outdoor/rooftop drive or enclosure installations
- Mining