HPx Series
Installation Manual

Revision 1.1

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XP Power
Gary Bocock
Simon Wheeler

Series Covered

HPA1K5
HPF3K0
HPT5K0
HPT5K0-L
HPL5K0

Contents

1 INTRODUCTION AND ASSOCIATED DOCUMENTS

The purpose of this user manual is to provide detailed information, which supplements the contents of the appropriate product datasheet, the Communications Specification and the XP Insight user manual. The Communications Specification provides detailed information for users and system integrators, on common installation requirements associated with digitally controlled power supplies.

The term ‘HPx’ is used widely in this document, where ‘x’ is a place holder for the range of model names in the product family. The HPx product family is based upon a digital signal processing control system. Many system parameters are organised and accessible as memory registers, or commands, formatted in compliance to the PMBus Command Language. Frequent references are made to Part II of the PMBus Protocol Specification which can be accessed by sending a request through the PMBus.org web site: https://pmbus.org/current-specifications/

Cross references to Part II of the PMBus Specification will be abbreviated to: ‘PMBus Spec Section n.nn’. Refences to other parts of the specification will be clearly identified.

For all technical questions, service enquiries and product returns, we ask customers to contact us by submitting a form at this address:

https://www.xppower.com/contact/technical-support/

2 ESSENTIAL SAFETY INSTRUCTIONS

2.1 Life and Safety Critical Application Policy

These products are not authorised for use as a critical component in life support systems, nuclear control systems or equipment for use in hazardous environments.

2.2 Servicing

These products are not customer serviceable. Only XP Power and their authorised agents are permitted to perform servicing and repairs. Please see the Fault Finding/De-Bugging guide to access the Return Material Authorisation (RMA) procedure. Unauthorised repair invalidates any warranty.

2.3 Safety Design Criteria

These products are safety agency approved and intended for applications where the power supply is a component part of host equipment which entirely encloses the product and restricts access to authorised personnel. Installation must only be performed by suitably qualified and experienced persons. The power supply chassis must not be user accessible.

All products in the HPx family have been designed to the following criteria:

Safety Design Criteria	Specification
Material Group	IIIb
Pollution Degree	2
Overvoltage Category	II
Class of Protection	Class 1 – Earthed
IP Protection Class	IPX0

3 WARNINGS

3.1 Before Using the power supply

Please read the installation manual thoroughly before installing and using the product. Pay attention to all cautions and warnings. Incorrect use may result in electric shock, damage to the unit or a fire hazard.

- Never use the product in locations where flammable gas or ignitable substances are present.
- Do not make unauthorised modifications to the product.
- Do not touch the product and the input and output terminals while in use or shortly after shut down. Surfaces may be hot and stored energy in the product and the connected load may lead to residual high voltage at the output terminals for some time.
- Test to ensure that the outputs are fully discharged before commencing maintenance of the installation.
- Do not use the product in abnormal conditions, such as emission of smoke, smell or noise. Shut down the product immediately.
- Do not drop or insert anything into the product. This may result in failure, fire or risk to life.
- Do not operate the product in conditions of condensing humidity.

3.2 Electric Shock Risk

Dangerous voltages are present at the input and output terminals of the product. The professional installer must protect service personnel from inadvertent contact with these voltages in the installation.
All HPx products are Class 1 and must be professionally installed and provided with a reliable and compatible connection to Earth, before any connection to AC mains is made.
The output may be left floating or referenced to Earth by connecting one of the output terminals to the Earth.

3.3 Energy Source (ES) Ratings (IEC/EN/UL/CSA 62368-1) and outputs connected in series

The classification of a secondary circuit as SELV (Safety Extra Low Voltage) has been replaced in IEC62368-1 by three Energy Source Ratings. HPx outputs have received the following classifications during formal safety evaluation:

Product	Output	ES Rating	Outputs in series
HPA1K5	All outputs inc 5V housekeeping	ES1	Combining two or more HPx main outputs in a series configuration results in a circuit rated ES3. HPT5K0TS400 & 800 must not be connected in series.
HPF3K0	24, 36, 48 inc 5V housekeeping	ES1	
	60 inc 5V housekeeping	ES2	
HPT5K0	48, 5V housekeeping	ES1	
	60, 100, 200, 400, 800	ES3	
HPT5K0-L	48, 5V housekeeping	ES1	
	60, 100, 200	ES3	
HPL5K0	5V housekeeping	ES1	
	48, 60, 100, 200	ES3	

Note that the ES rating for the communications connector is ES1 for all units.

4 INSTALLATION

4.1 Environmental Precautions

The product must be installed in such a way as to avoid exposure to:

1. Excessive humidity and heat.
2. Ambient environments containing corrosive elements such as chlorine, hydrogen sulphide, ammonia, sulphur dioxide, nitrogen dioxide, etc.
3. Liquids (water, solvents, oil, etc). The Ingress Protection (IP) rating for this product is: IPX0
4. Dust accumulation. Dust drawn into the product by the cooling fan may accumulate on thermal dissipation surfaces, reducing their efficiency over time. Carbon loaded dust is particularly hazardous, as it may accumulate and form current leakage paths. Consider adding an air filter with a protective maintenance regime, for high dust environments.
5. Other hazardous environments. This product is not intended for use in explosive atmospheres.

4.2 Orientation

No restrictions apply to the orientation of HPx products in a customer's application; however the inlet and exhaust air flow must not be obstructed. See the section 'Installation Considerations for Airflow'.

4.3 Mounting holes - Securing the unit correctly

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HPx products are provided with either M3 or M4 threaded mounting points on two or three faces. See the datasheet mechanical drawings for detailed information. A maximum penetration depth is specified for these mounting points, which is referenced to the outer face of the chassis. This maximum depth must be carefully observed, as additional penetration may damage the product.
The maximum torque that may be applied to the mounting points during installation is defined below:

Screw Size	Max. Torque (Nm)
M3	0.7
M4	1.6

It is recommended that all appropriate available mounting points are used to secure the power supply in place. If side face mounting holes are used, then it is recommended that mounting screws on both sides are used. Not following these recommendations may introduce installation risks.

Units may be installed upside down however it is recommended that extra mounting precautions are put in place to ensure that the unit and any associated wiring are secure.

4.4 Wiring

For all models the AC input barrier terminal is not acceptable for use as a field wiring terminal.
The AC distribution branch circuit and protective device must be appropriately rated for the product or products connected to it. The connection to Earth must be compatible with the trip rating of the branch circuit protective device.

4.4.1 Input Connections

Model	Input Barrier Terminal Screw Size	Max Torque	Terminal Access Width	Maximum Input Current
HPT5K0	M4	1.5Nm	10.0	11A
HPT5K0-L	M4	1.5Nm	10.0	11A
HPL5K0	M4	1.5Nm	10.0	18A
HPF3K0	M4	1.1Nm	10.0	19A
HPA1K5	M3.5	1.0Nm	8.0	16A

4.4.2 Output Connections

Model	Output Terminal Screw Size	Max Torque	Maximum Output Current	Notes
HPT5K0TS48-200	M5	3.2Nm	114A	Two connections per terminal
HPT5K0TS400 & HPT5K0TS800	High voltage plug & socket. Part numbers listed in datasheet	0.7Nm for locking screws	13.75A	
HPT5K0-L	M5	3.2Nm	114A	Two connections per terminal

HPL5K0	M5	3.2Nm	114A	Two connections per terminal
HPF3K0	M5	3.2Nm	137.5A	Two connections per terminal
HPA1K5	M4	1.5Nm	68.75A	One connection per terminal

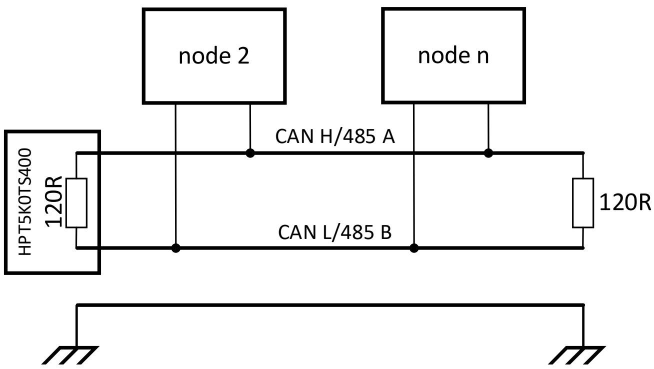
Note: A washer - recommended washer size: 5.3 (ID) x 10 (OD) x 1 (0.9-1.1) mm – may need to be added to output terminal screws to minimize any risk of screw loosening over time.

Goo4.4.3 Communications Connections

Model	Connector Reference	User connector		Notes
		Housing	Crimp contact	
HPT5K0TS48-200	J1	JST Part No: PHDR-30VS	SPHD-002T-P0.5	
HPT5K0TS400 & HPT5K0TS800	J1	Generic FCC68/RJ45 8-way plug	None	Isolated RS232/RS485 communications
	J2	Phoenix Contact Part No: 1844675. 24 way	None. Spring loaded terminations	Isolated signals and communications
		Phoenix Contact Part No: 1027614. 24 way	1013425 (26-20awg) 1013418 (22-18awg)	Alternative connector with crimp terminals
	J3	Generic USB-C plug	None	No power delivery in either direction
	J4	Phoenix Contact Part No: 1844604. 10 way	None. Spring loaded terminations	Non-isolated signals. Circuit rated Energy Source: ES3
		Phoenix Contact Part No: 1027607. 10 way	1013425 (26-20awg) 1013418 (22-18awg)	
HPT5K0-L	J1	JST Part No: PHDR-30VS	SPHD-002T-P0.5	
HPL5K0	J1	JST Part No: PHDR-30VS	SPHD-002T-P0.5	
HPF3K0	J1	JST Part No: PUDP-30V-S	SPUD-001T-P0.5 (26-22awg) SPUD-002T-P0.5 (28-24awg)	
HPA1K5	J1	JST Part No: PHDR-30VS	SPHD-002T-P0.5	

4.4.4 Termination of CANBUS and RS485 transmission lines

This section is intended to provide only a fundamental explanation of the correct termination of CAN bus and RS485 transmission lines. More detailed explanations of the detailed requirements are widely available. Both protocols specify twisted pair cable for the balanced transmission systems, with a recommended characteristic impedance of 120R (120Ω). The balanced circuit makes the cable an inefficient transmitter of radiated EMI as noise radiated from one wire is radiated in anti-phase from its adjacent wire. Equally, a balanced circuit using a twisted pair has good rejection of common mode noise: The noise coupled into one wire of the pair, will be coupled into the adjacent wire in anti-phase, thereby cancelling



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out the noise signal. Including a braided or lapped screen in the cable further enhances noise rejection and provides a common ground reference to the transmitter and receiver.

In a transmission line carrying signals with fast switching edges, points on the line where the impedance changes can cause reflections of energy significant enough to corrupt the data signal. The inclusion of termination resistors that match the characteristic impedance of the cable reduces the problem of reflections. Termination resistors should be fitted at each end of the line but not fitted to nodes on stubs that branch off from the line. Stubs should be kept as short as possible and not more than 300mm in length.
The HPT5K0TS400 and 800 models feature built-in 120Ω termination resistors for CAN bus and RS485 half and full duplex lines. These are activated by DIP switches (Pins 4 to 1 from right to left) located on the connection plane of the power supply chassis with an additional switch provided to configure either half or full duplex operation. Where other HPx models are installed at the end of a transmission line, we recommend inclusion of a termination resistor as close as possible to the power supply's thirty pin signal connector.

HPT5K0TS400 800 Models – DIP Switches		
Switch ID	Function	Description
1	CANbus 120Ω termination resistor	Switch up to apply 120R between CAN H and CAN L
2	Half-Duplex 120Ω termination resistor	Switch up to apply 120R between RS485 A & B
3	Full-Duplex 120Ω termination resistor	Switch up to apply 120R between RS485 Y & Z
4	RS485 Half or Full Duplex select	Switch up to select Full Duplex

4.5 Safe Start-Up Procedure

1. Ensure that the AC distribution branch circuit and circuit protection are appropriately rated for the connected product or products.
2. Ensure a reliable Earth connection capable of carrying a fault current that will clear the branch circuit protective device.
3. Ensure that the input and output power terminals are securely fastened, with all appropriate guards and covers fitted. Check for the correct polarity of the output power wiring.
4. Ensure that the inlet and exhaust ports for cooling air have a free flow of air around them and that no obstructions will block the rotation of the fan(s).
5. If multiple units are connected in parallel, check that the Sync and Current Share signals have been correctly connected to all units and that Remote Sense lines all connect to a single point of load with twisted wire pairs.
6. For units with a safety interlock, note that no output will be activated without a 5~24Vdc input present on the interlock input pins.
7. Ensure that all aspects of the connected load are safe and ready to be powered.

4.6 Thermal management

For Fan Fail/Over Temperature Alarm, see section 5 Product Protection.

4.6.1 Environmental Specifications

Characteristic	Minimum	Typical	Maximum	Units	Notes & Conditions
Operating Temperature	-20		+70	°C	Derate output power linearly from 100% at 50°C to 50% at +70°C
Storage Temperature	-40		+85	°C	
Cooling	Force cooled with intelligent fan speed control				

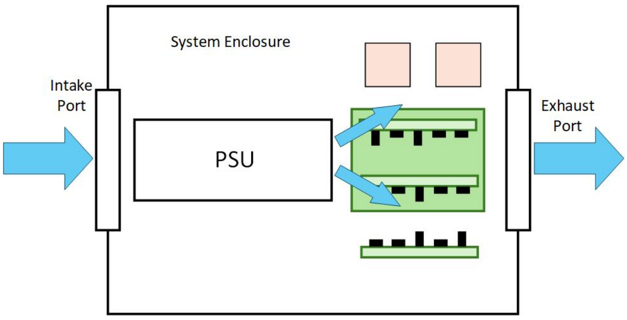
Humidity	5		95	%RH	Non-condensing

4.6.2 Fan Management

Fan management and monitoring PMBus commands may be accessed through XP Insight or one of the serial data protocols provided in the communication specification.

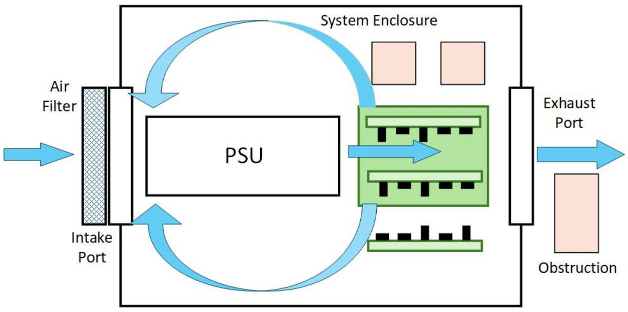
4.6.3 Minimum Fan Speed and Use of Exhaust Air.

HPx products are provided with the facility to program a minimum fan speed. In suitable applications this provides an opportunity to use the PSU exhaust air to cool other equipment within the enclosure, thereby reducing both audible noise and the running cost of additional fans. Take care to ensure that the combination of max ambient temperature + max PSU load + specified min fan speed, results in acceptable operating temperatures for all parts of the combined cooling solution.



4.6.4 Installation Considerations for Airflow

All HPx models are cooled by forced air, driven by the integral fan or fans. The inlet and exhaust air must not be obstructed. Ensure a minimum of 50mm spacing between obstructions and the air inlet and outlet of the power supply.

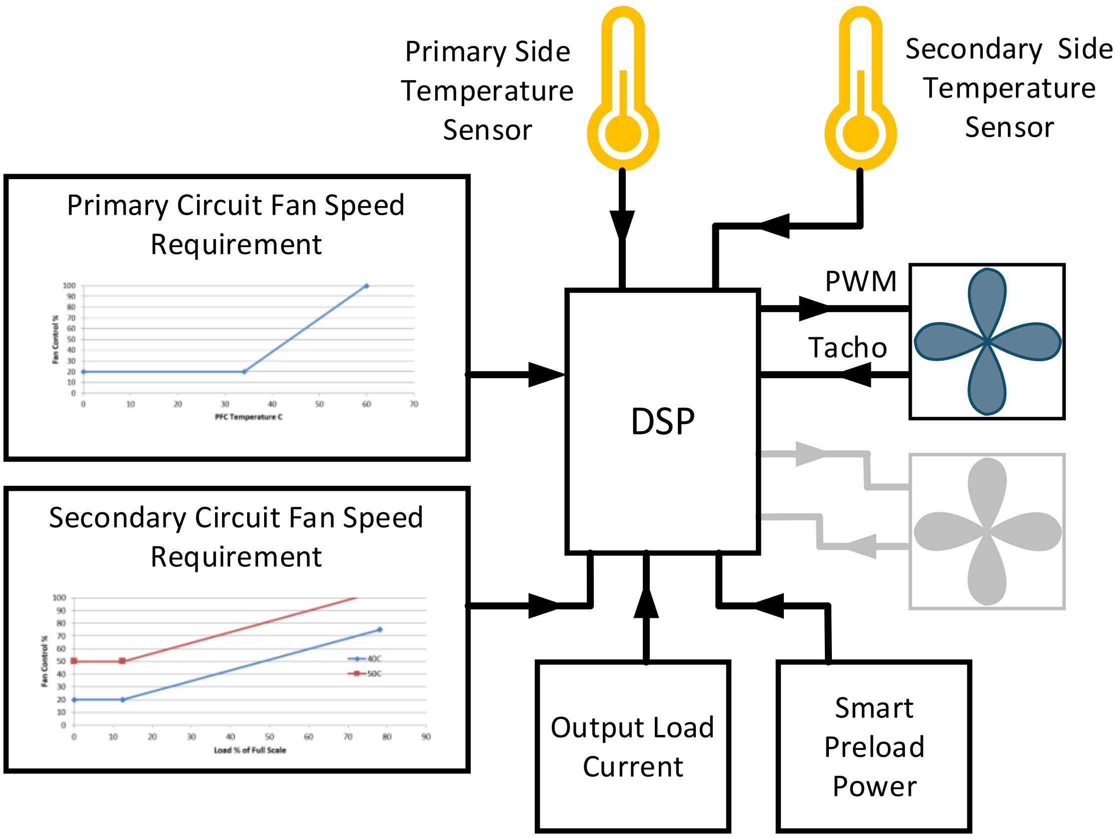


With this guidance applied, Installation can be as simple as ensuring that the maximum specified temperature is not exceeded for a given load rating and that the enclosure intake and exhaust ports are of an appropriate size.
Consider also the close coupling of the PSU air intake to the enclosure intake port. Where an intake filter is fitted or other obstructions are present, both internal and external, the PSU exhaust air may return to the intake and result in a progressive temperature rise in the enclosure. Design validation of the overall cooling system is essential.
Dust filters may be important for contaminated environments, as accumulations of dust will reduce the efficiency of internal heatsinks and lead to overheating. Carbon dust is conductive and may contribute to the growth of conductive pathways (dendrites), in high voltage areas of the product. Solvent vapours and some dusty atmospheres are also potentially explosive. Where a dust filter is included, a cleaning or replacement routine should be included in the end-equipment documentation.

4.6.5 Fan Speed Control Algorithm

Four wire, PWM controlled fans, are used in all HPx models. The fan speed control algorithm includes inputs from temperature sensors mounted within the circuits on the primary and secondary side of the isolating transformers. Corresponding fan speeds for each sensor are referenced from performance curves included in the product firmware. Product output current and the power dissipated in the Smart Preload also contribute cooling demands. The DSP will set the highest fan speed required by any of the algorithm inputs.

If fan speed falls below 320RPM for more than five seconds, the Fan Fail/Temperature hardware warning signal will change state, and the STATUS_FAN_n_n commands will be updated.
If fan speed falls below 320RPM for more than fifteen seconds, the product output will be disabled and the speed of any other normally operating fan increased to maximum. The drive to a stalled fan is removed and re-tried periodically. If the blockage is removed, the fan will re-start at the next attempt, normal speed will be restored to all fans, and the output will re-start.



4.6.6 Disable Fan(s) When Output Off

To save energy and reduce quiescent noise, the option is provided to completely shut down the fans when the output is off and no cooling demand is asserted. This is achieved using the control provided in the Insight application, or by writing a command as detailed in the communication specification. The fans will only shut down if the product has sufficiently cooled down, the Smart Preload is not actively discharging the output, and the product is not passively passing current through the rectifiers from another unit connected in series.

4.6.7 Maximum Fan Speed At Start-Up and Shutdown

The fan(s) will run with short bursts at full speed at start up and shutdown. The input circuit starts up with a temporary resistance in-circuit, for the purpose of limiting the inrush current that initially charges the input reservoir capacitors. The increased fan activity at startup is to cool and reset this resistor.
When the output is turned off or the AC input removed, the Smart Preload circuit discharges the output capacitance and any connected load, converting this energy into heat. The increased fan activity at shutdown is to cool the internal load components.

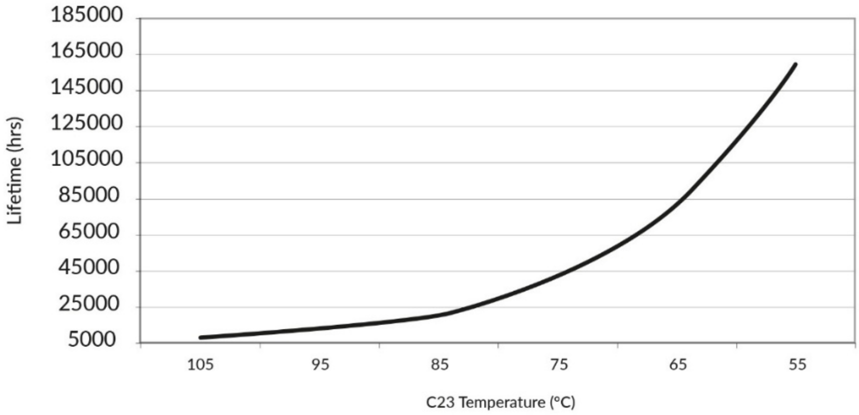
4.6.8 Temperature and Service Life

A number of factors contribute to the service life of HPx models. The factors are discussed in more depth in the Thermal Management and Reliability sections of the publication 'Essential Guide To Power Supplies', available from the XP Power website:
https://www.xppower.com/portals/0/brochures/Essential_Guide_to_Power_Supplies.pdf

For a force cooled product with a built-in fan, these factors are largely mitigated through the programming of the digital control system. The lifetime of the electrolytic capacitors is the prime consideration and two wear-out mechanisms, influenced by the installation environment, deserve a mention here.
Ambient temperature significantly contributes to the rate at which capacitor electrolyte leaks and vaporises. Lifetime calculations published by capacitor manufacturers are based upon the Arrhenius Equation, reproduced below. It can be seen that for an increase of 10 °C, the lifetime is roughly halved.

$$L = L_0 \times 2^{\left(\frac{T_{max} - T_a}{10}\right)}$$

L : Estimated life (hr)
L_0 : Life at rated temperature (hr)
T_{max} : Rated Temperature (°C)
T_a : Ambient Temperature (°C)



In addition to the ambient temperature and heating effects within the power supply, ripple current at the capacitor terminals will further heat this component internally. The PSU output regulation circuit includes a number of electrolytic capacitors, which absorb variations in load demand to provide a stable output voltage. In applications with a pulsed load, much of the instantaneous demand is fulfilled by these capacitors, which will result in capacitor self-heating. HPx products include a function to protect these capacitors from the extreme situation in which a pulsed load repeatedly exceeds the fixed, maximum output current limit. See the section 'Pulsed Loads' for more information.

4.7 Electro-Magnetic Compliance Guidance

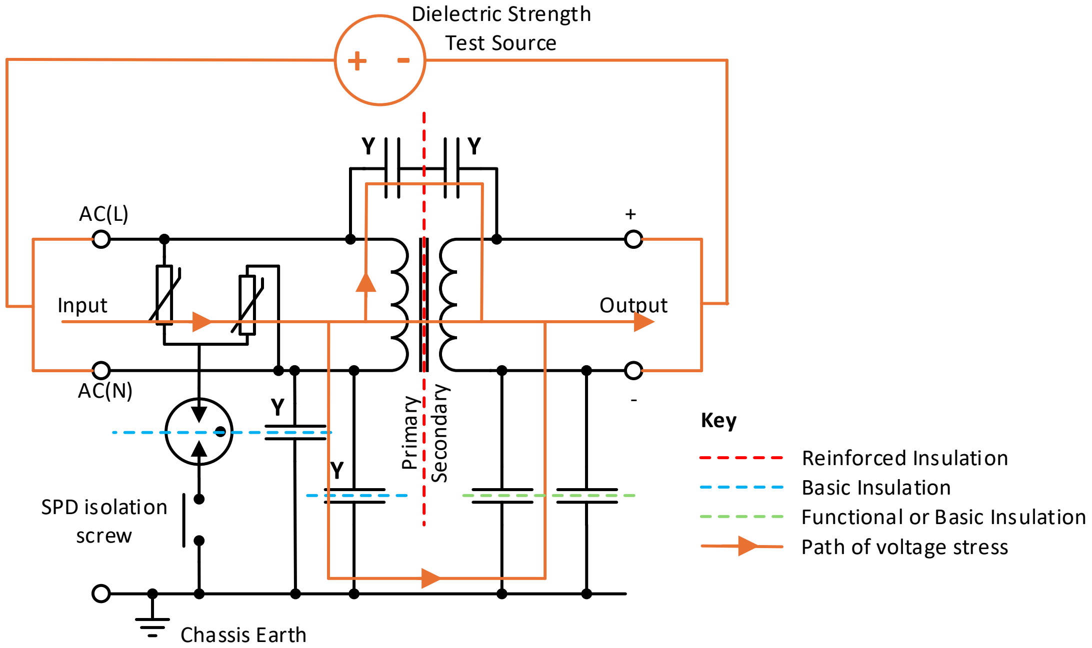
All HPx models are classified as component power supplies, intended for installation within other equipment. For this reason they do not fall within the scope of the European Union EMC Directive 2014/30/EU. Compliance with the Directive must be considered in the final installation.
All HPx models include an AC input filter to ensure compliance to the Conducted Emission standard listed in the product datasheet. A supplementary input filter may be advantageous where the installation environment is particularly noise sensitive; where noise from the load is coupled into AC distribution via the power supply; or where the cumulative emissions from several power modules within one piece of equipment exceed the limit of the applicable EMC standard.

Within the installation, consider the separation of cable runs for AC power and Secondary circuits. Where these are bundled together, high frequency noise from the Secondary side can couple into the AC input, bypassing the PSU input filter and potentially compromising the conducted emissions compliance of the installation.
Radiated emission testing of the power supply is performed with a compact resistive load and will not accurately represent the results that will be obtained in a customer's installation. This is due to each unique combination of noise sources in the installation; shielding; Earth bonding; transmission line impedance matching and many other factors. There are many resources available to aid good PCB design for minimal radiated noise, but use of good practise in the AC and DC power distribution may also save time in EMC de-bugging. Listed below are a number of best practices that can reduce EMI problems:

1. Reduce the enclosed area of radiating loops in the power distribution, by running the supply and return lines as a pair, twisted together if possible.
   The area of radiating loops , and their high frequency impedance, can be further reduced through the use of de-coupling capacitors. These are typically fitted at the point of connecting the DC power distribution to each PCB.
2. Where the installation chassis is metal, this can be used as a ground plane, by clipping cable runs tightly to it. In this way, the ground plane will intersect the magnetic field around cables that carry noise currents.
3. Consider a metal enclosure as a Faraday cage. Electrically bond the panels together, avoiding large holes and long slots. Where signal cables penetrate the enclosure, RF filtered connectors may be used to provide a low-impedance noise path to the enclosure. Cable screening and impedance matching of the send and receive ends of the signal line will further reduce noise radiation from unenclosed cables.
4. AC Input Surge and Fast Transient Immunity. Respect the specified Over Voltage Category. This relates to a classification of the AC distribution at the point where the product is connected. Anticipated peak transient voltages decrease as the impedance of the AC distribution network increases, due to reduced cable size and protection devices in building installations. HPx models are intended for OVC II environments, meaning that the power supply is connected to the fixed AC distribution network within a building. Some industrial applications, in which the power supply is installed within equipment permanently connected to the AC distribution, may be subjected to the impulse voltages of OVC III and require the protection of a supplementary surge protection device to clamp transients to the levels defined for OVC II.
5. Do not use the DC power output return for any small signal return path. One or more 0V return pins are provided on the auxiliary signal connectors for this purpose.
6. When using the Remote Sense function to compensate for losses in the DC output cables, twist the pair of sense wires together where possible and route them away from strong noise sources. See the Remote Sense section for more information.

4.8 Dielectric Strength Testing

This section is intended to provide guidance and instruction to users intending to prove the dielectric strength of insulation barriers in systems that include the installation of an HPx power supply. The main Primary to Secondary insulation barrier of the power supply will typically provide the essential galvanic isolation of the customer's system from the AC power distribution. However, the power supply will typically include three levels of insulation and care must be exercised, as units may be permanently damaged through over-stressing of insulation barrier components.
Consider the following simplified block diagram of the power supply insulation components:



4.8.1 Testing of Reinforced Insulation barriers

The typical construction of a class 1 AC-DC power supply results in circuits separated by Reinforced insulation, arranged in parallel with circuits separated by Basic and Functional insulation. In the diagram above, when a test voltage is applied between the Primary and the Secondary PSU terminals, that voltage is also applied across the pathways indicated by the orange line. The voltage induced across the input to Earth and output to Earth 'Y' capacitors will be divided, but the voltage division is not predictable and if the full Reinforced 'type test' voltage is applied, there is a risk that these components may be permanently damaged, by either the overvoltage stress, or by transients induced by arcing across the Basic and Functional insulation spacings.

Until the introduction of IEC62368-1, Reinforced insulation could not be tested in a complete PSU assembly, without over-stressing the other insulation classes present in the unit. Safety agencies allowed manufacturers to test sub-assemblies containing Reinforced barriers at the higher voltage, before they were built into the final assembly. In the 'Routine Testing' performed on every unit after manufacture, the Primary to Secondary and Primary to Earth barriers would then be screened at the voltage defined for Basic Insulation.

With the implementation of IEC62368-1, routine factory testing has become more closely aligned with the rigours of the 'type' test, performed during product evaluation for safety approvals. Applied voltages may be reduced by only 10% and the stress duration reduced from 60 to 4 seconds. However, for single phase products the new safety standard has increased the Primary to Earth voltage from 2121 to 2500Vdc and reduced the Primary to Secondary voltage from typically 4200 to 4000Vdc. XP Power has up-rated input Y capacitors to withstand the Primary to Secondary routine test, so it is now possible for customers to test the dielectric strength of a complete system with the power supply installed. Please apply the procedures and limitations below with care, to avoid damage to the product.

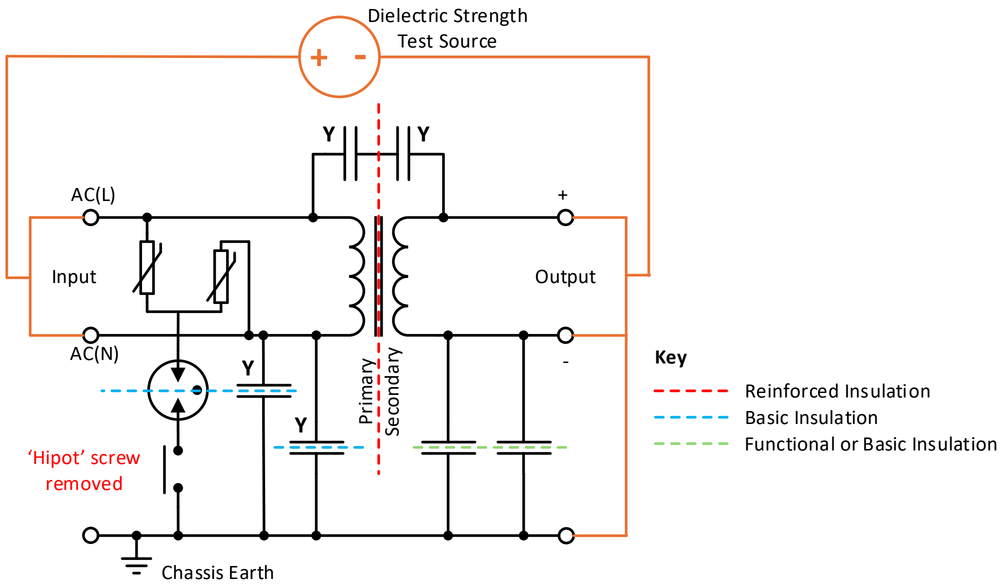
4.8.2 Surge Protection Devices

As part of the product Electro-Magnetic Interference counter measures, the following products are fitted with a surge protection device (SPD) consisting of a network of gas discharge tubes and metal oxide varistors:

HPT5K0	HPT5K0-L
HPL5K0	HPF3K0

The SPD functions by conducting at transient voltages well above the normal AC input range. Some of the transient energy is converted to heat in the device and the rest is diverted to Earth. In this way the device works with the impedance of the AC power distribution to clamp the voltage to a level acceptable to the power supply. In exceptionally difficult installations with a high frequency of voltage surges, the XP Applications Engineering team may recommend the installation of additional surge protection to the AC branch circuit.
The SPD will turn on when subjected to the dielectric strength test voltage, indicating a failure of the insulation. For this reason, a removable link is provided in the form of an M3 screw, identified by the legend "HIPOT SCREW", stamped into the chassis. The screw must be removed during the dielectric strength test and then re-fitted, with a maximum torque of 0.62Nm.

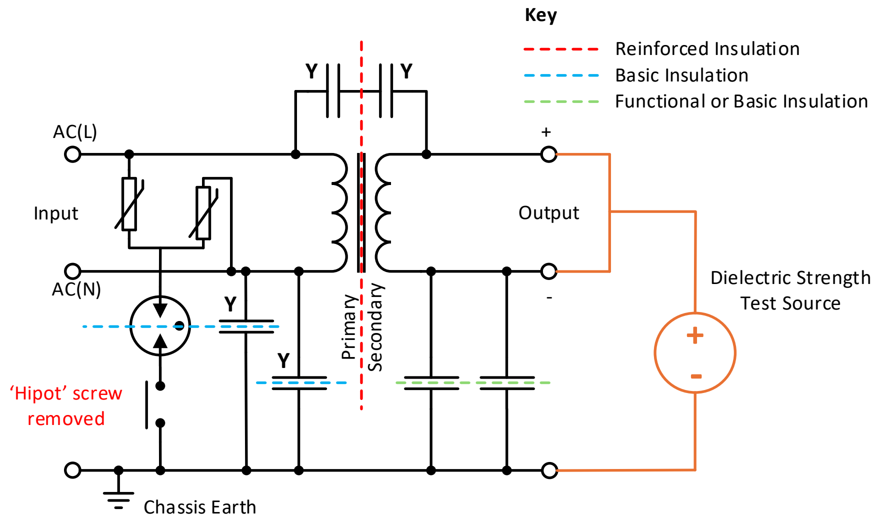
4.8.3 Primary to Earth and Secondary Insulation – Customer Test



Testing Instructions

1. Wherever possible avoid repetitions of this test, as the high applied voltage will shorten the lifetime of the insulation components.
2. Where a 'Hipot' screw is fitted to HPT5K0; HPT5K0-L; HPL5K0; HPF3K0, this must be temporarily removed and saved, or the applied test voltage reduced to 2100Vdc.
3. Fit shorting links between Phase and Neutral or link the three Phases together.
4. Fit shorting links between the output terminals and between the output and Earth. If the customer system has the 0V output return connected to Earth, fit the output to Earth link anyway, as an additional measure to protect the customer system.
5. Connect the dielectric strength test equipment and if using a DC source, slowly ramp up the applied voltage during 3-4 seconds, while continuously monitoring for leakage current or flashover.
6. Dwell at the maximum specified test voltage for a maximum of 4 seconds, with continuous monitoring, then, if using a DC source, slowly ramp down the voltage during 3-4 seconds and disable the voltage source.
7. Protect personnel by completely discharging the energy stored in the power supply and system during the test.
8. Remove the test equipment and all shorting links that have been fitted.
9. Re-fit the 'Hipot' screw, with a maximum torque of 0.62Nm.

4.8.4 Secondary to Earth – Customer Test



Testing Instructions

1. If testing the power supply while installed in the customer system, this test is only applicable where all secondary circuits served by the PSU are galvanically isolated from the system chassis and Earth.
2. Wherever possible avoid repetitions of this test, as the high applied voltage will shorten the lifetime of the insulation components.
3. Fit a shorting link between the output terminals.
4. Connect the dielectric strength test equipment as shown in the figure and apply the test voltage for 3-4 seconds, while continuously monitoring for leakage current.
5. Disable the voltage source. Use any discharge function provided by the test equipment.
6. Protect personnel by completely discharging the energy stored in the power supply and system during the test.
7. Remove the test equipment and all shorting links that have been fitted.

4.8.5 Applied Test Voltage

The following table specifies the test voltage for 'Routine Testing', defined by the product safety evaluation to IEC62368-1. These are provided as the maximum values to be used for customer testing in the product installation. This is the 'Type Test' voltage, less 10%, and either AC or DC may be used. Where products also carry approval to IEC60601-1, the IEC62368-1 figure is used.

Product series	Voltage applied from combined L-N or three phases, to combined	Voltage applied from combined Output ± to Earth

	Earth - Output ±. 'Hipot' screw must be removed		
	Vac rms	Vdc	Vdc
HPT5K0 (48 – 200)	3800	5400	500
HPT5K0 (400 & 800)	3800	5400	4000
HPT5K0-L	3800	5400	500
HPL5K0	2500	3600	500
HPF3K0	3100	4400	500
HPA1K5	2500	3600	500

5 PRODUCT PROTECTION

5.1 Internal Fuses

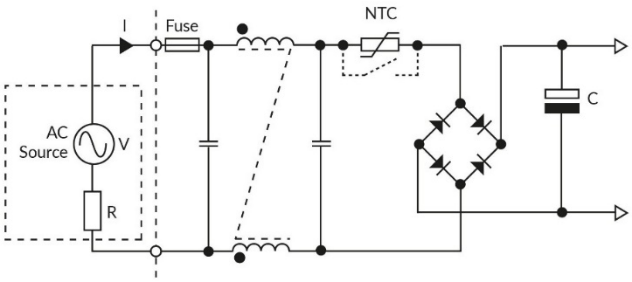
Internal fuses are not replaceable. A cleared fuse indicates the significant failure of other components within the product and must therefore not be replaced in the field. The input fuses will not clear as a result excess load connected to the output, as the overcurrent protection and other safety functions will shut down or limit the output power in this event. Please see the Fault Finding/De-Bugging section, which includes instructions for the return of units for service.

The power supply fuses are safety critical parts which have been proven during safety approval evaluation to ensure that the product cannot pose a fire risk under a fault condition. The fitted fuses are rated only for operation from AC distribution and DC input operation is not included within the scope of the safety approvals.

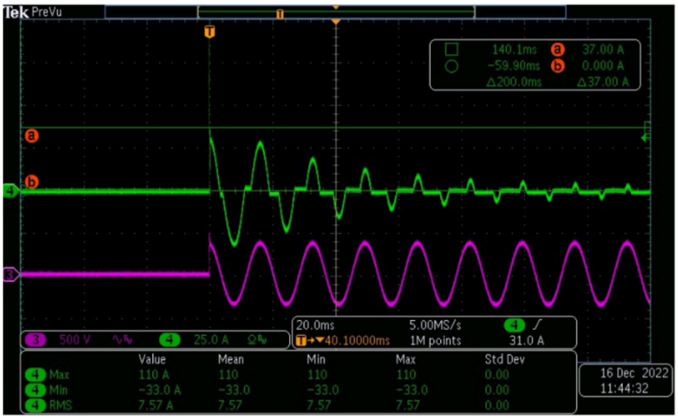
5.2 Inrush Current

An AC mains system is a low impedance power source that can supply a large amount of current. HPx products include large reservoir capacitors that start in a discharged at switch-on, giving the appearance of a short circuit. Without additional precautions the input current will therefore be very large for a short period, until the input capacitance is charged. This would result in nuisance tripping of fuses and circuit breakers, along with potential damage to relay contacts and other components in the path of the current.

The most common mitigation is to insert a Negative Temperature Coefficient (NTC) thermistor into the path of the input current. These devices have a high resistance at room temperature, which falls to a low value when hot. In HPx products we bypass the thermistor with a relay, typically four seconds after power-on. This improves the overall product efficiency and allows the device to cool down before it is re-connected for the next start-up cycle. The product datasheet provides a figure for maximum inrush current, which has a duration of typically one or two AC half-cycles and is unlikely to be detected by fuses and circuit breakers.



An example inrush current measurement from HPF3K0 is provided for reference:



264Vac Inrush current at 20ms Scale

CH3: Vin (Pink) 500V/div *CH4: Vin (Green) 25A/div*

5.3 AC Input Under and Overvoltage protection

Input voltage, current and the balance between phases are all actively monitored by the control system. The Input voltage is compared with hard-coded warning and fault limit levels for under and overvoltage. The user may define optional product responses to the fault limits, which are defined in the Communications Manual and may be accessed through XP Insight or one of the serial data protocols provided.

5.4 AC Input Current Sharing (Three Phase Models)

The architecture of HPx three phase products maintains three power conversion channels until the output rectification stage. However, in order to balance the input power between the input phases, the digital control system adjusts the output of each power factor correction stage, so that the energy switched across the three isolating transformers is balanced.

Above 500W input power, the sharing hysteresis is ±1.25%

Below 500W input power, the sharing hysteresis is ±2%.

5.5 Output Abnormal Voltage Protection

Output Over Voltage Protection has three limit thresholds:

- An upper, essential safety limit that will always shutdown and latch off the product output immediately, at 115% of the model nominal voltage. This is a hardware function (apart from the HPA series products that use a firmware function only), but also sets bit 8, HW_OVP_FAULT, of the shutdown event registers. See the Communications Manual for more information. A reset is obtained by re-cycling the AC input.
- A user programmable overvoltage fault limit, VOUT_OV_FAULT_LIMIT, up to 115%, with optional response behaviours. The behaviours are: Continue Operation; Delay Response & Retry; Disable & Retry; Disable & Resume when OK. The Retry count and Delay time are also user programmable. This value and other control parameters for output voltage can be saved to non-volatile memory, through XP Insight or one of the communication protocols.
- A user programmable overvoltage warning limit, VOUT_OV_WARN_LIMIT, which must be less than the fault limit. Reaching either a fault or warning limit will latch an associated status bit in the STATUS_VOUT register/command. Regular polling of the array of available status registers, provides opportunities for health and status monitoring, not just for the power supply, but also for 'downstream' connected loads. The relevant PMBus commands may be accessed through XP Insight or one of the serial data protocols provided.

5.6 Output Over Current Protection

HPx products have three OCP thresholds:

- An upper, fixed, essential safety limit at 110% ±3%, of the nominal current rating of the product. This is a hardware function, which also sets the OUT_OC_FAULT flag of the STATUS_IOUT register. When this limit is exceeded, the control system switches operation to constant current mode and varies the output voltage in response to the load impedance.
- A maximum current threshold (OUT_OC_FAULT) which may be user programmed between 0 ~ 110%.
- An overcurrent warning limit which may be user programmed.

The OCP threshold may be user programmed. This value and other control parameters for output current can be saved to non-volatile memory, through XP Insight or one of the communication protocols.

5.7 Short Circuit Protection

HPx series power supplies employ a constant current overload characteristic enabling operation in constant current mode for suitable applications at the programmed level. This constant current characteristic is maintained to a short circuit enabling start up of very low impedance or high inrush current loads.

For applications where this potential fault current is undesirable the minimum operating voltage can be defined using the overcurrent low voltage (OCLV) function. OCLV is a user programmed fault condition, whereby the power supply will respond as defined by the user configured retry settings defined in the fault responses for output current fault conditions list in section 6.4.8 below.

5.8 Pulsed Loads

In applications with a pulsed load, much of the instantaneous demand is fulfilled by the output capacitors of the power supply, while the intentionally slow response of the control loop increases energy transfer to re-charge the capacitors, which will result in capacitor self-heating. HPx products include a function to protect these capacitors from the extreme situation in which a pulsed load repeatedly exceeds the fixed, maximum output current limit. Exceeding this limit more than ten times during one second will cause a shutdown event to protect the output capacitors. The output will be turned off and latched in this condition, requiring a re-cycle of the AC input to clear the fault condition. The following flags will be set:
Shutdown_event.bits.pwm_fault_ocp = 1
Shutdown_event.bits.latched_fault = 1
Status_iout.bits.st_iout_oc = 1.
Pulsed-load applications which trigger this shutdown event may be unsuitable for HPx products. It is recommended that a technical request is submitted to the XP Power Applications Engineering team, for consideration of the dynamic load conditions.

5.9 Fan Fail/Overtemp

HPx power supplies provide a signal warning for fail or over temperature conditions via the fanfail/overtemp warning signal. HPx power supplies will shut down 10 seconds after this signal is asserted. Recovery is automatic once the unit has sufficiently cooled. Details are provided in the product data sheet.

5.10 Safety Interlock

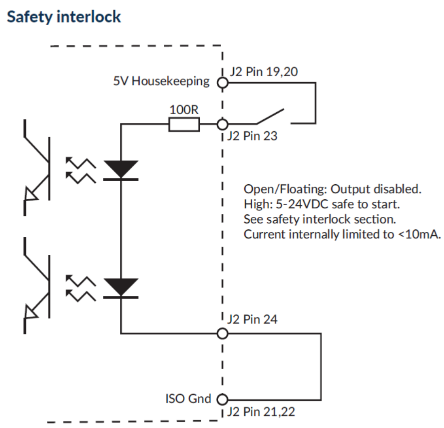
400V and 800V models of HPT5K0 include a safety interlock. This provides a fail-safe means for a safety control system to disable the output, without the need for contactors and a bulky ‘Emergency Machine Off’ (EMO) arrangement to disconnect the AC input power. Details are provided in the product data sheet.

Key Features

- Designed to meet the requirements of ISO13849-1, performance level 'd' and ISO13849-2.
- No firmware involvement in the power disablement signal path.
- Wide range opto-isolated 5 – 24Vdc input for maximum compatibility.
- Configurable ancillary functions provide prevention of unexpected start-up, through an active reset sequence.
- Adaptable to a range of safety management protocols.
- Internal active load applied to discharge output capacitance

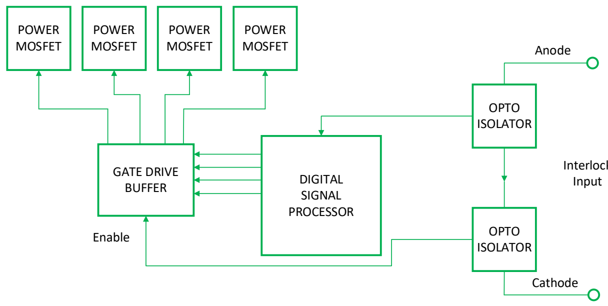
5.10.1 Safety Interlock Input Requirements

No DC output can be activated for these two models, without an active input of 5 ~ 24Vdc at the interlock input (J2 pins 23-24). Disconnection of the J2 input connector, a signal line break or failure of the user's drive circuit, will immediately stop the power supply output. A visual warning of the loss of interlock input is provided by a double blink pattern from the DC OK status LED.
For users that do not require the interlock function, a continuous input may be simply configured through the use of the 5Vdc Housekeeping supply, as shown in the adjacent application circuit diagram:



5.10.2 Safety Interlock Architecture

The adjacent block diagram describes the fundamental operating principle of the 'safety related part'. Two opto-isolator photodiodes in series provide two signal pathways. One pathway informs the primary digital signal processor of the signal input. The DSP updates the status monitor and activates the 'Smart Preload' function to discharge the output capacitance as rapidly as possible.



The second pathway bypasses all complex electronics, to control the Enable function of a buffer in the path of the gate drive signal for the main energy switching MOSFETs. Interruption of the gate drive signal stops energy transfer to the secondary side of the product and stops the product output. All parts of the signal path are designed to 'fail-safe' and no other signal, logic, or internal function is able to override this signal pathway.

5.10.3 Interlock Status Monitor

The status of the interlock may be monitored by reading a PMBus status register (or 'command' in PMBus terminology), over any of the serial data protocols provided. Full details of how to use the serial data communications are provided in the HPT5K0/HPL5K0 Communications Manual.

5.10.4 Interlock Inhibit Link Function

The interlock and Remote ON/OFF inputs may be configured to activate a reset function, such that after an AC input failure, or activation of the interlock input, a state change of the internal Remote ON/OFF logic from OFF to ON must be applied. This reset function provides the prevention of unexpected start-up required by the safety standard. The function may be used with Remote ON/OFF configured as either Active = Inhibit or Active = Enable and the input is filtered to wait for the transition that activates the output. For further information, see the truth tables below.

The control is identified as IL_INH_LINK and is accessible as one bit of the PMBus command 0xD6 USER_CONFIGURATION. As with all configurable functions, the interlock may be configured via any of the serial data protocols or via the XP Insight application.

5.10.5 OPERATION command (0x01)

The PMBus command set, which provides the core of the serial data control functions, includes the command 0x01 OPERATION, to turn the output on and off. By default, the value of this command register is 0x80, meaning that the output is on. Clearing the register to 0x00 turns the output off. By default, the logic of the Remote ON/OFF input is configured as 'Active = Inhibit' and IL_INH_LINK is off. Factory-fresh HPT5K0 models with an interlock therefore require only an AC input and a 5 ~ 24Vdc drive to the interlock input to start but note that there are three control functions that must be in the ON state to activate the output.

5.10.6 Interlock Operating Sequence Truth Tables

The user may select one of four possible configurations of the interlock functionality, via two bits of the command 0xD6 USER_CONFIGURATION: IL_INH_LINK and CFG_REMOTE_INHIBIT_LOGIC. These bits are also directly accessible through the XP Insight application. The second table below summarises the outcome of the four possible user configurations. The following tables describe the response of the product to four control inputs and are provided as a stepped sequence with comments.

Logic Co-ordination		
	Interlock-Inhibit Link	Remote ON/OFF
Command/Register:	0xD6 USER_CONFIGURATION bit 6: IL_INH_LINK	0xD6 USER_CONFIGURATION bit 9: CFG_REMOTE_INHIBIT_LOGIC
Logic meaning:	1: Requires sequence of IL and Rem ON/OFF inputs 0: No co-dependency between signals	1: Active = Inhibit the output 0: Active = Enable the output
Displayed in 'Insight' interface:	1 = a tick or green flag in the user interface	1 = a tick or green flag in the interface

Sequence Summary			
Configuration Identifier	Interlock-Inhibit-Link	Remote ON/OFF	Functional Summary
Sequence 1	1	1	Not recommended. Rem ON/OFF: Active = Inhibit. Co-dependency is active so PSU must be inhibited, then released from Inhibit to start.
Sequence 2	1	0	Full configuration for safety critical systems. PSU will fail-safe. Rem ON/OFF: Active=Enable + prevention of unexpected start-up.
Sequence 3	0	1	Default configuration. Rem ON/OFF: Active=Inhibit. No co-dependency.
Sequence 4	0	0	Rem ON/OFF: Active = Enable. No co-dependency

Sequence 1		IL_INH_LINK:	1		REM ON/OFF:	Active = INHIBIT	
Step	Comment	AC Input	IL Input	Remote ON/OFF input	OPERATION command	DC output	IL_STATUS bit
1	Inactive PSU	0	0	0	-	0	-
2	AC applied	1	0	0	1	0	1
3	IL cct closed	1	1	0	1	0	0
4	Reset IL	1	1	1	1	0	0
5	Output starts	1	1	0	1	1	0
6	IL cct broken	1	0	0	1	0	1
7	IL cct closed	1	1	0	1	0	0
8	Reset IL	1	1	1	1	0	0
9	Output starts	1	1	0	1	1	0
10	AC Fail	0	1	0	-	0	-
11	AC Restored	1	1	0	1	0	0
12	Reset IL	1	1	1	1	0	0
13	Output starts	1	1	0	1	1	0
14	Clear OPERATION command (0x00)	1	1	0	0	0	0
15	Set OPERATION command (0x80)	1	1	0	1	1	0

Sequence 2		IL_INH_LINK:	1		REM ON/OFF:	Active = ENABLE	
Step	Comment	AC Input	IL Input	Remote ON/OFF input	OPERATION command	DC output	IL_STATUS bit
1	Inactive PSU	0	0	0	-	0	-
2	AC applied	1	0	0	1	0	1
3	IL cct closed	1	1	0	1	0	0
4	OFF>ON transition. O/P starts	1	1	1	1	1	0
5	IL cct broken	1	0	1	1	0	1
6	IL cct closed	1	1	1	1	0	0
7	Reset IL	1	1	0	1	0	0
8	Restart	1	1	1	1	1	0
9	AC Fail	0	1	1	-	0	-
10	AC Restored	1	1	1	1	0	0
11	Reset IL	1	1	0	1	0	0
12	Restart	1	1	1	1	1	0

13	Clear OPERATION command (0x00)	1	1	1	0	0	0
14	Set OPERATION command (0x80)	1	1	1	1	1	0

Sequence 3		IL_INH_LINK:	0		REM ON/OFF:	Active = INHIBIT	
Step	Comment	AC Input	IL Input	Remote ON/OFF input	OPERATION command	DC output	IL_STATUS bit
1	Inactive PSU	0	0	0	-	0	-
2	AC Applied	1	0	0	1	0	1
3	O/P starts when IL cct closed	1	1	0	1	1	0
4	IL cct broken	1	0	0	1	0	1
5	IL cct closed	1	1	0	1	1	0
6	O/P inhibited	1	1	1	1	0	0
7	Inhibit removed	1	1	0	1	1	0
8	AC Fail	0	1	0	-	0	-
9	AC Restored	1	1	0	1	1	0
10	Clear OPERATION command	1	1	0	0	0	0
11	Set OPERATION command	1	1	0	1	1	0

Sequence 4		IL_INH_LINK:	0		REM ON/OFF:	Active = ENABLE	
Step	Comment	AC Input	IL Input	Remote ON/OFF input	OPERATION command	DC output	IL_STATUS bit
1	Inactive PSU	0	0	0	-	0	-
2	AC Applied	1	0	0	1	0	1
3	IL cct closed	1	1	0	1	0	0
4	O/P starts with Rem On/OFF ENABLE	1	1	1	1	1	0
5	IL cct broken	1	0	1	1	0	1
6	IL cct closed	1	1	1	1	1	0
7	O/P disabled	1	1	0	1	0	0
8	O/P enabled	1	1	1	1	1	0
9	AC Fail	0	1	1	-	0	-

10	AC Restored	1	1	1	1	1	0
11	Clear OPERATION command	1	1	1	0	0	0
12	Set OPERATION command	1	1	1	1	1	0

6 User Programmable Options

6.1 Constant Current (CC) Mode Operation

CC operation is triggered by crossing the OCP fault limit defined for the product, or by the user programmed limit. The operating mode continues until the load impedance increases to the point where output current falls below the OCP threshold when the power supply will revert to constant voltage operation. In CC mode the output current is constant, while the output voltage varies in proportion to the load impedance.

For constant current applications it is recommended to enable the "current soft start" option configured via any of the serial data protocols or via the XP Insight application to ensure that there is no current overshoot during start up.

6.2 Over Current Low Voltage (OCLV)

OCLV is a user programmed fault condition, whereby the power supply will respond as defined by the user configured retry settings defined in the fault responses for output current fault conditions list in section 6.4.8 below.

XP Power

6.3 Analogue Control and Alarm Features & LED indicators

The table below provides correlation between LED indicator activities and the appropriate hardware signal pin. See also the sections for specific signals. This table applies to all HPx products. Signals specific to the HPT5K0TS400 & HPT5K0TS800 safety interlock, are identified at the end of the table.

Conditions	LED State		Default Hardware Signals			
	AC OK	DC OK	AC OK	DC OK	FAN FAIL/TEMP	Remote On/Off (Inhibit[3])
AC input OK. Normal operating conditions	ON	ON[2]	Active	Active	Active Low	Inactive
AC input below control system startup voltage	OFF	OFF	Inactive	Inactive	Inactive	Don't Care
AC present but out of range, or PFC failure, or missing phase or internal communications fault	Blink 0.2s on, 0.2s off	OFF	Inactive	Inactive	Active Low	Don't care
Output Over Voltage Protection	ON	OFF	Active	Inactive	Active Low	Inactive
Output Over Current Protection (Constant Current Mode)	ON	Blink 0.2s on, 0.2s off	Active	Active or Inactive[2]	Active Low	Inactive
Fan Failure/Thermal Shutdown	ON	OFF	Active	Inactive	Active High[1]	Inactive
Remote ON/OFF unit disabled	ON	Blink 1.0s on, 1.0s off.	Active	Inactive	Active Low	Active
Digital communications ON/OFF unit disabled	ON	Blink 1.0s on, 1.0s off.	Active	Inactive	Active Low	Inactive
Safety Interlock input is open circuit[4]	ON	Double blink 0.2s on, 1.0s off	Active	Inactive	Active Low	Inactive

Notes:

1. In case of fan failure and/or over-temperature, FAN FAIL/TEMP warning signal will be set 10s before output shutdown.
2. DC OK LED is on if output voltage ≥ VOUT_UV_FAULT_LIMIT parameter.
3. Remote ON/OFF factory setting is: Active = Inhibit operation. User configurable.

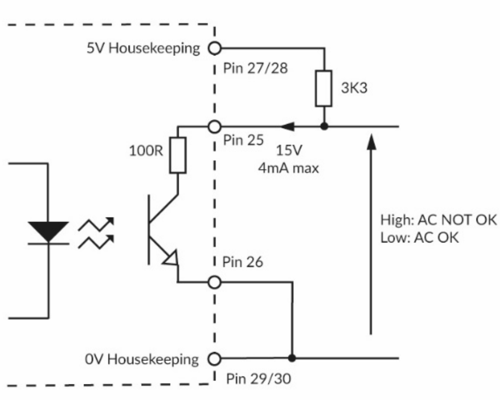
4. Indication of Safety Interlock status takes precedence over status of ON/OFF controls.

6.3.1 AC-OK Signal

The AC OK hardware signal is provided via an uncommitted opto-transistor output, for ease of customer integration. The maximum Collector-Emitter voltage is 15V and maximum Collector current is 4mA.
The default signal logic is: Not conducting = AC is out of range, or a phase is lost. Conducting = AC within range and all phases present. The logic may be inverted and saved to the firmware non-volatile memory, via the XP Insight application or by modifying the 0xD6 USER_CONFIGURATION command via one of the communication protocols. The AC input Over and Under voltage fault and warning limits are not user configurable. The values for single and three phase products are defined in the following table:

Product Series	AC Input Undervoltage		AC Input Overvoltage	
	Warning Limit	Fault Limit	Warning Limit	Fault Limit
Single phase HPA/HPF	87Vrms	85Vrms	268Vrms	270Vrms
Three phase HPT/HPT-L	175Vrms	170Vrms	536Vrms	540Vrms
Three phase lo-line HPL	166Vrms	161Vrms	278Vrms	282Vrms

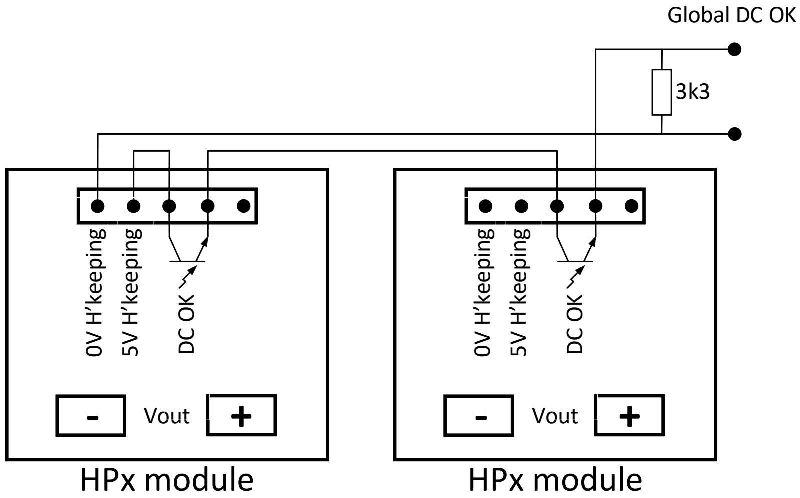
The 5V Housekeeping supply may be used as a pull-up for this output signal, as shown in this suggested application circuit. Please refer to the datasheet for the HPT5K0 400V & 800V pin numbers, as the connector layout is different:



6.3.2 DC-OK Signal

The DC OK hardware signal is provided via an uncommitted opto-transistor output, for ease of customer integration. The maximum Collector-Emitter voltage is 15V and maximum Collector current is 4mA.
The default signal logic is: Conducting = Vout is within the range determined by the user configurable alarms. The logic may be inverted and saved to the firmware non-volatile memory, via the XP Insight application or by modifying the 0xD6 USER_CONFIGURATION command via one of the communication protocols.

The default, circuit conducting, means that in multi-unit configurations, uncommitted opto-isolator outputs may be daisy-chained together to derive a single, global signal, as shown in this suggested application circuit below.



6.3.3 Fan Fail & Over-Temperature Alarm Signal

The Fan fail/Temp warning hardware signal is provided via a 3.3V TTL compatible signal, referenced to Iso Gnd/SGND. The default signal logic is High = Fan failure or Over Temperature, Low = Fan(s) and temperature OK. HPx power supplies will shut down 10 seconds after this signal is asserted. Recovery is automatic once the unit has sufficiently cooled. The logic may be inverted and saved to the firmware non-volatile memory, via the XP Insight application or by modifying the 0xD6 USER_CONFIGURATION command via one of the communication protocols.

6.3.4 Remote On/Off

The Remote on/off hardware input is provided via an uncommitted opto-diode, for ease of customer integration. It is identified in the XP Communications Manuals as 'Remote Inhibit'.
The default logic is as Active = Inhibit or Off. The input can be reconfigured to active = Enable or On via the and saved to the firmware non-volatile memory, via the XP Insight application or by modifying the 0xD6 USER_CONFIGURATION command via one of the communication protocols.

For safety critical applications we recommend configuration as an ENABLE function. In this way, a broken input control wire, loose connection or other loss of the input control will cause the power supply to 'Fail-Safe' in a non-operational state.
Configuration is via any of the serial data protocols or via the XP Insight application.

The PMBus OPERATION command provides a method to turn the output on and off using only serial data commands. Both the OPERATION command and the Remote ON/OFF hardware input must be in the output ON mode to activate the output.

6.4.5 User Configurable Fault Responses & Hardware Signal Logic Configuration

In addition to the configuration of the hardware input and output signals and alarms to suit the application via any of the serial data protocols or via the XP Insight application, the user is also able to configure the response of the device to any faults detected.

A number of commands related to input voltage, output voltage, secondary circuit temperature and output current, have user programmable, one byte memory locations, which are used to determine the response to an abnormal condition. These are available via any of the serial data protocols or via the XP Insight application and are described in the tables below.

6.4.6 Fault Responses for Output Voltage and Secondary Circuit Temperature

The list below describes the possible responses to warnings or faults that may be configured.

- The device continues operation without interruption.
- The device continues operation for the Shutdown Delay time specified. If the fault condition is still present at the end of this period, the unit responds as programmed in the Retry Setting.
- The device shuts down (disables the output) and responds according to the Retry Setting.
- The device output is disabled while the fault is present. Operation resumes and the output is enabled when the fault condition has been cleared.
- The output remains disabled until the fault is cleared. This is achieved by setting a zero value for Retry Setting value.
- The number of restarts can be configured from 1 to 20 times. If the device fails to start within the defined number of retries, the output is disabled and remains off until the fault is cleared. Starting is defined as: the fault condition is no longer present, the device is delivering power to the output and functioning as programmed. The period between start attempts is the Retry Delay.
- The delay time is a user programmable time period that delays a retry attempt or defines the time that a unit operates prior to shutting down.

6.4.7 Voltage and Temperature Commands with configurable fault responses

This table describes the responses that may be configured.

Command Name	Retry Setting	Shutdown Delay	Retry Delay
VOUT_OV_FAULT_RESPONSE (Read only value: 0x80. SD, No retry, latch O/P off)	000 No retry	0ms SD immediately	000 No restart Delay
VOUT_UV_FAULT_RESPONSE (Default: 0x00, continue, do nothing)	000~111	20ms x Delay Time (0 ~ 140ms)	10ms x Delay Time (0 ~ 70ms)
OT_FAULT_RESPONSE (Default:0xC0, SD and resume when fault is gone. Applies also to a fan fault)	000~111	10s	10s
VIN_OV_FAULT_RESPONSE (Default: 0xC0, SD and resume when fault is cleared)	000~111	6s	6s
VIN_UV_FAULT_RESPONSE (Default: 0x77, SD delay retry up to 6 times)	000~111	0.6s	6s

6.4.8 Fault Responses for Output Current Fault Conditions

The list below describes the possible responses to warnings or faults that may be configured.

- The unit continues operation indefinitely, while maintaining the output current at the value set by IOUT_OC_FAULT_LIMIT, without regard to the output voltage (Constant Current mode operation).
- The unit continues operation indefinitely, while maintaining the output current at the value set by IOUT_OC_FAULT_LIMIT, while the output voltage remains above the minimum value specified by

IOUT_OC_LV_FAULT_LIMIT. If the output voltage is pulled below this value, then the output will stop and the unit will respond according to the Retry Setting configuration.

- The unit continues to operate, maintaining the output current at the value set by IOUT_OC_FAULT_LIMIT, without regard to the output voltage, for the configured delay time. If the unit is still operating in constant current mode at the end of the delay time, the unit will respond as programmed by the Retry Setting value.
- The unit shuts down the output and responds as programmed by the Retry Setting.
- The output remains disabled until the fault is cleared. This is achieved by setting a zero value for Retry Setting value.
- The number of restarts can be configured from 1 to 20 times. If the device fails to start within the defined number of retries, the output is disabled and remains off until the fault is cleared. Starting is defined as: the fault condition is no longer present, the device is delivering power to the output and functioning as programmed. The period between start attempts is the Retry Delay.
- The delay time is a user programmable time period that delays a retry attempt or defines the time that a unit operates prior to shutting down.

6.4.9 Smart Preload

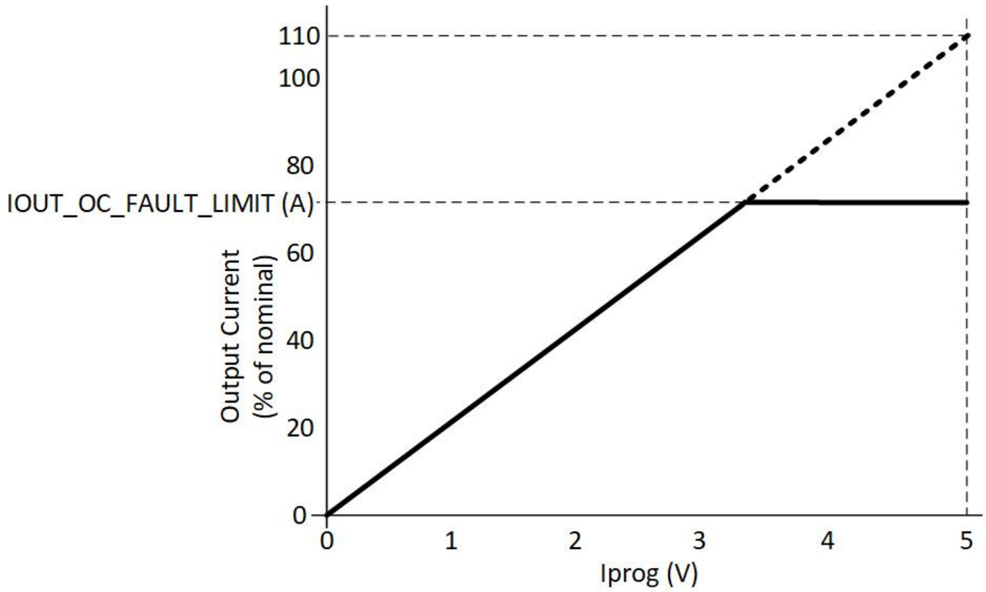
HPx series power supplies employ a smart preload which both discharges the output to a safe level on power down and supports industry leading slew rates to user programmed output voltage changes regardless of applied load. If desired the output discharge on power down can be user via any of the serial data protocols or via the XP Insight application.

6.4.10 Analogue programming

All HPx models provide the option of user programming of output voltage and output current limit via a 0-5V input applied at the Vprog & Iprog interface connections specified in the product data sheet for the relevant voltage models. At the programmed current limit threshold, constant current mode as activated and will vary the output voltage in proportion to the connected impedance. This mode continues until the power demand falls back to the current limit threshold, where constant voltage mode is restored.

It should be noted that if the voltage level set by the analogue programming is below the configured undervoltage alarm, then the DCOK LED will change state to indicate a fault.

Analogue programming is activated by linking the PMBUS_EN signal input pin to the SGND or Iso Gnd pin, as determined by the specific datasheet for the model.
If IPROG is used, any legitimate user value set via any of the serial data protocols or via the XP Insight application will be the active current limit threshold. The programming ratio is not modified by this parameter. The ratio remains linked to the maximum current rating. See the chart below:



NOTE

When analogue programming is active, a linear input between 0-5Vdc MUST be provided to both the VPROG and IPROG inputs. No output will result if either pin is left open circuit.

6.4.11 Potentiometer Options

All HPx products include an accessible potentiometer, for the purpose of adjusting the output voltage. The default mode is that the output voltage may be adjusted by ±10% of the nominal set voltage.

The user may configure one of the following operating modes for the potentiometer:

1. The output voltage may be adjusted between 0% and 105% of the nominal set voltage.
2. The potentiometer may be completely disabled.

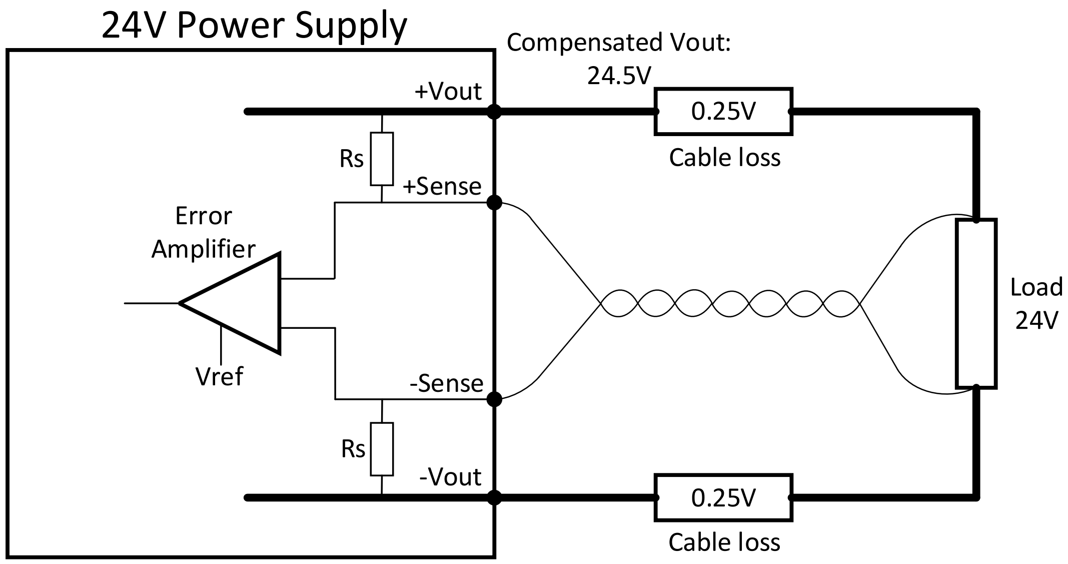
Configuration is performed via any of the serial data protocols or via the XP Insight application

7 Synchronisation Signal

This function is provided to support units with outputs connected in parallel. By linking the Sync pins of all units in the configuration to simultaneous start-up. Use of the Sync signal will prevent the situation in which the first unit to start has insufficient power to support the total connected load and triggers its programmed over-current protection response. This function is generally used in combination with the Current Share function. Both signals require a common 0V reference, through linking of the SGND signal return. Note that for the 400V & 800V models of HPT5K0, Sync and Current Share are non-isolated extensions of the DC power output circuit, classed as Energy Source 3 for IEC62368-1. The Sync function may be disabled via the XP Insight application or by modifying the 0xD6 USER_CONFIGURATION command via one of the communication protocols.

8 Remote Sense Function

If DC power output cables of significant length are used, the product of the output current and the cable resistance (I x R) will result in a voltage loss at the point of load. This may be compensated by increasing the output voltage of the power supply, or by connecting the PSU error amplifier inputs directly to the point of load, so that the voltage loss may be dynamically compensated. This is the Remote Sense function. In the example below, the error amplifier compensates for the total cable losses by increasing the voltage at the output terminals to 24.5V. HPx series products will compensate for up to 1% of the nominal output voltage per lead, or a total 2% voltage drop. Remote Sense is not fitted to the 200V; 400V and 800V models of HPT5K0.



For installations in which the Remote Sense function is not required, it is not necessary to fit wire links between the DC output and the RS terminals. This connection is already provided by low-resistance 'tie-resistors' within the product, identified as 'Rs' in the diagram. These resistors are vulnerable to damage through negligent use, when a remote sense connection has been made to the load. In the event that one of the output power cables is disconnected while the unit is running, current will flow in the corresponding remote sense line and rapidly destroy the tie resistor.

The error amplifier has high impedance inputs, meaning that the Remote Sense is susceptible to noise coupling into the circuit. To improve common-mode noise rejection, twist the wires together as a pair and do not include lines from any other circuit in the twisted loom. A further improvement to noise rejection can be achieved by using shielded twisted pair cable, with the screen connected only at the PSU end, to the product chassis.

9 Capacitive Loads

The maximum capacitive load that can be supported varies by the specific HPx model. The complex impedance of load connections and dynamic load characteristics will result in dramatically different instability thresholds. Where the application load is significantly capacitive, contact XP Power for support and additional guidance.

10 Parallel Operation, Current Sharing and Redundancy

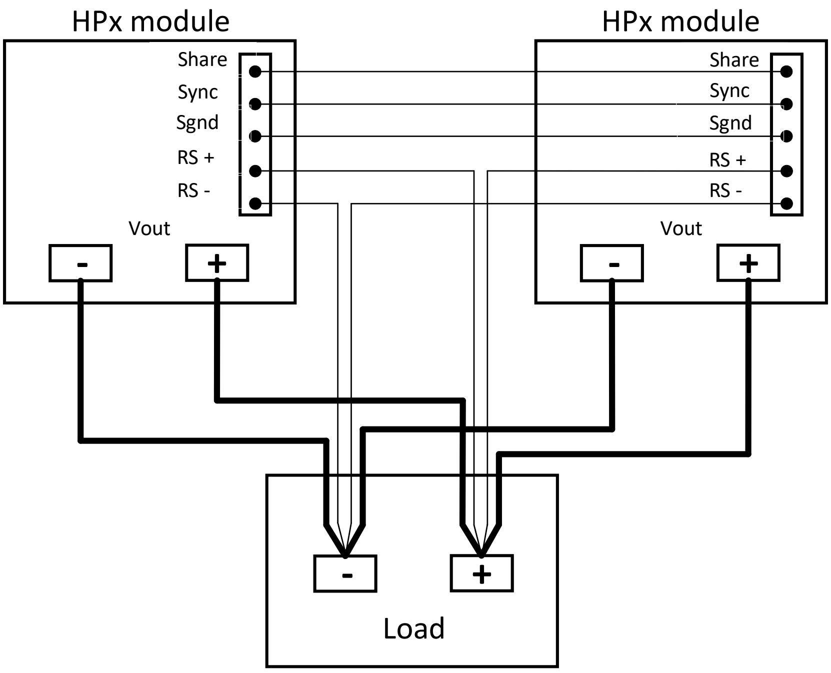
10.1 Current Sharing

All HPx models include active current sharing control to balance the load evenly across units connected in parallel. It is recommended that a maximum of five identical HPx modules are connected in parallel (contact XP Power if more than five HPx modules in parallel are required). The limiting factor is the accuracy of the active share control circuit, at ±3%. As more units are connected the error accumulates, to the point where the total power de-rating limits the return on investment.

With five units connected, the total current reliably available would be 100% - (5-1 x 3%) = 88% of the total module current rating. Product calibration during final manufacturing test, results in our specified voltage setting accuracy of ±0.1%, but it may be possible to achieve improved results by carefully synchronising the output voltage of the units in the configuration, by using the potentiometer.

The diagram below, depicting two units in parallel, provides the connection scheme, with the following recommendations:

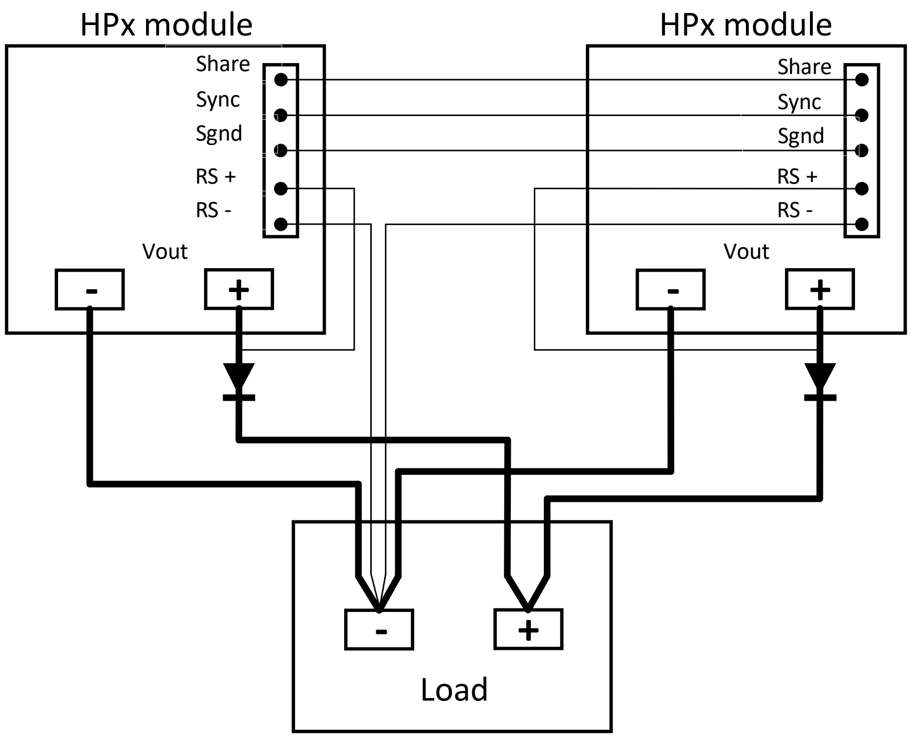
- The Current Share pins of all units in the configuration should be linked together to use the active sharing control circuit.
- The Sync pins of all units in the configuration should be linked together. This function synchronises the start-up of all outputs in the configuration, following application of the AC input. This will reduce the possibility of the first unit to start hitting the current limit threshold as it tries to provide the total current demanded by the load.
- The Sgnd (Signal Ground) pins of all units in the configuration should be linked together.
  CAUTION: On the 400V & 800V models of HPT5K0, the Current Share, Sync and SGND functions are not isolated from the DC power output circuit. This circuit is classed as energy source 3 (ES3) for IEC62368-1. Appropriate safeguards must be employed in the end-equipment.
- The Remote Sense circuit is high impedance and noise sensitive. Guidance on appropriate wiring for noise immunity is provided in the section 'Remote Sense Function'.
- Wherever possible, busbars or cables from each power supply should run independently to a single point of load, with the remote sense termination made at the same point. Matching the length and gauge of the power cables or bus bars will further assist a successful current sharing setup.



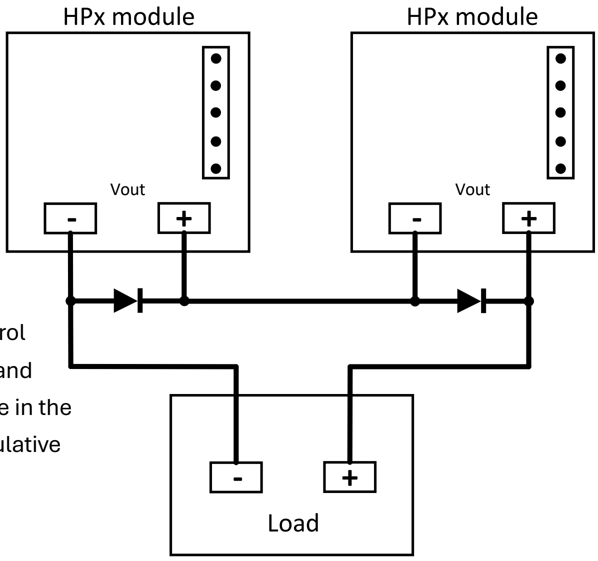
10.2 Configuration for redundant operation.

Power supply redundancy is implemented when continuous operation of the system is required in mission critical applications. One or more power modules, in excess of the system power requirement, are included, so that, in the event of module failure, sufficient capacity remains available to sustain uninterrupted system operation. Various redundancy schemes may be created, but the fundamental requirements are defined in the notes and drawing below:

- The failure of one module must not compromise the power bus. A module failing to a short circuit would overload the bus, so a reverse blocking diode (OR-ing diode) or MOSFET must be included in the feed from each module.
- A failure of one or more components in the internal remote sense circuit is low risk and could not provide a current path sufficient to pull down the DC bus. However, for true redundancy, the +ve Remote Sense connection must not bypass the diode. In this case the +ve sense line may be connected to the Anode of the blocking diode, to compensate for voltage drop in the initial length of cable. The connection of other signal lines between the modules will also be based upon a risk assessment
- Blocking diodes must be voltage and current rated in excess of the power module ratings.



11 Modules Connected in Series



With the exception of HPT5K0 400V and 800V, in which the safety approval report precludes series connection, all HPx models may be used in configurations with outputs in series. Some care is required to ensure that one module does not affect the other and the use of control and monitoring signals may require isolation modules, as discussed in the following points. Consideration must be given to one module in a chain being non-operational, due to AC failure, external ON/OFF control or failure. Bypass diodes rated in excess of the module voltage and maximum configuration current should be fitted to each module in the chain. This protects the non-operational module from the cumulative reverse voltage of the other modules.

- The maximum cumulative voltage of the series chain must not exceed the Output to Earth isolation voltage listed in the module datasheet, for any module in the chain. This is typically 500Vdc.
- Non opto-isolated signals and serial data lines are referenced to the SGND pin and DC output 0V terminal. In series configurations, isolation modules rated for the cumulative chain voltage must therefore be included in the installation. Opto-isolated signal outputs may be readily combined into a logical AND function by daisy-chaining them together, as suggested in the section ‘DC OK Signal’.
- The Sync and Current Share functions must not be connected in a series module configuration.