

# OPTIDRIVE™ coolvert

AC Variable Speed Drive

1.5 - 3kW 200V Single Phase Input

5.5 - 11kW 400V Three Phase Input

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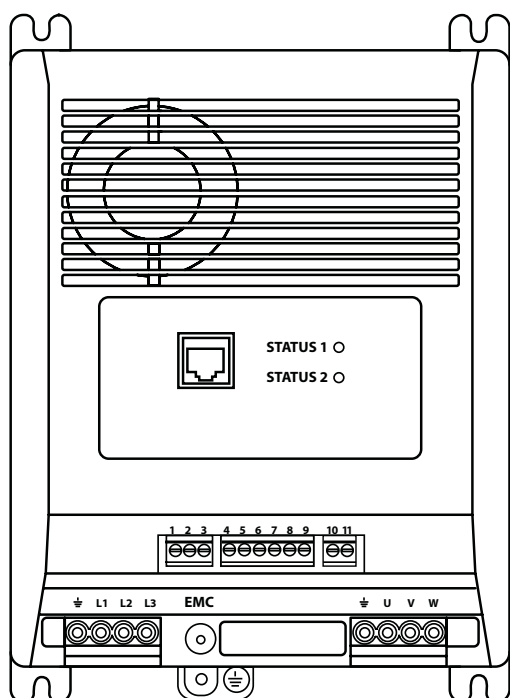
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## Declaration of Conformity

Inverterk Drives Ltd hereby states that the Optidrive Coolvert product range conforms to the relevant safety provisions of the following council directives: 2014/30/EU (EMC), 2014/35/EU (LVD) 2006/42/EC (Machinery Directive), 2011/65/EU (RoHS 2) and 2009/125/EC (Eco-design). Design and manufacture is in accordance with the following harmonised European standards:

BSEN 61800-5-1:2007 & A1:2017	Adjustable speed electrical power drive systems. Part 5-1: Safety requirements. Electrical, thermal and energy (IEC 61800-5-1:2007).
BSEN 61800-3:2018	Adjustable speed electrical power drive systems. Part 3: EMC requirements and specific test methods (IEC 61800-3:2017).
BSEN 61000-3-12:2011	Electromagnetic Compatibility (EMC). Part 3-12: Limits – Limits for harmonic currents produced by equipment connected to public low-voltage systems with input current > 16A and < 75A per phase (IEC 61000-3-12:2011). Three phase 400V Optidrive Coolvert 18A and 24A models comply with IEC 61000-3-12 with respect to the THC without the need for Line Reactors, provided that the short-circuit power $S_{SC}$ is greater than or equal to $S_{SC (min)}$ at the interface point between the user's supply and the public system. It is the responsibility of the installer or user of the equipment to ensure, by consultation with the distribution network operator if necessary, that the equipment is connected only to a supply with a short-circuit power $S_{SC}$ greater than or equal to $S_{SC (min)}$ calculated as: $S_{SC (min)} = 350 \times V_{rated} \times I_{rated}$ Where $V_{rated}$ is the drive rated voltage (phase to phase) and $I_{rated}$ is the drive rated current (per phase)
BSEN61000-3-2:2014	Electromagnetic Compatibility. Part 3-2: Limits – Limits for harmonic current emissions (equipment input current < 16 A per phase) (IEC 61000-3-2:2014). Single Phase input 230V variants only.
BSEN 61800-9-2:2017	Adjustable speed electrical power drive systems. Part 9-2: Ecodesign for power drive systems, motor starters, power electronics and their driven applications – Energy efficiency indicators for power drive systems and motor starters (IEC 61800-9-2:2017).

## Safe Torque OFF (“STO”) Function

Optidrive Coolvert incorporates a hardware STO (Safe Torque Off) Function, designed in accordance with the standards listed below.

Standard	Classification	Independent Approval
EN 61800-5-2:2016	SIL 3	TUV
EN ISO 13849-1:2015	PL "e"	
EN 61508 (Part 1 to 7):2010	SIL 3	
EN 60204-1: 2006 & A1: 2009	Uncontrolled Stop “Category 0”	
EN 62061: 2005 & A2: 2015	SIL CL 3	

## Electromagnetic Compatibility

All Optidrives are designed with high standards of EMC in mind. All versions intended for use within the European Union are fitted with an internal EMC filter. This EMC filter is designed to reduce the conducted emissions back into the supply via the power cables for compliance with harmonised European standards. It is the responsibility of the installer to ensure that the equipment or system into which the product is incorporated complies with the EMC legislation of the country of use. Within the European Union, equipment into which this product is incorporated must comply with the EMC Directive 2014/30/EU. This User Guide provides guidance to ensure that the applicable standards may be achieved.

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**2 Year Warranty:** All Inverterk Optidrive Coolvert units carry a 2 year warranty against manufacturing defects from the date of manufacture. The manufacturer accepts no liability for any damage caused during or resulting from transport, receipt of delivery, installation or commissioning. The manufacturer also accepts no liability for damage or consequences resulting from inappropriate, negligent or incorrect installation, incorrect adjustment of the operating parameters of the drive, incorrect matching of the drive to the motor, incorrect installation, unacceptable dust, moisture, corrosive substances, excessive vibration or ambient temperatures outside of the design specification.





The local distributor may offer different terms and conditions at their discretion, and in all cases concerning warranty, the local distributor should be contacted first.

**This user guide is the “original instructions” document. All non-English versions are translations of the “original instructions”.**

The contents of this User Guide are believed to be correct at the time of printing. In the interest of a commitment to a policy of continuous improvement, the manufacturer reserves the right to change the specification of the product or its performance or the contents of the User Guide without notice.

## This User Guide is for use with version 1.00 Firmware. The firmware version can be viewed in parameter P0-28. User Guide Revision 1.00

Inverterk Drives Ltd adopts a policy of continuous improvement and whilst every effort has been made to provide accurate and up to date information, the information contained in this User Guide should be used for guidance purposes only and does not form the part of any contract.

	When installing the drive on any power supply where the phase-ground voltage may exceed the phase-phase voltage (typically IT supply networks or Marine vessels) it is essential that the internal EMC filter ground is disconnected. If in doubt, refer to your Sales Partner for further information.
	This manual is intended as a guide for proper installation. Inverterk Drives Ltd cannot assume responsibility for the compliance or the non-compliance to any code, national, local or otherwise, for the proper installation of this drive or associated equipment. A hazard of personal injury and/or equipment damage exists if codes are ignored during installation.
	This Optidrive contains high voltage capacitors that take time to discharge after removal of the main supply. Before working on the drive, ensure isolation of the main supply from line inputs. Wait ten (10) minutes for the capacitors to discharge to safe voltage levels. Failure to observe this precaution could result in severe bodily injury or loss of life.
	Only qualified electrical personnel familiar with the construction and operation of this equipment and the hazards involved should install, adjust, operate, or service this equipment. Read and understand this manual and other applicable manuals in their entirety before proceeding. Failure to observe this precaution could result in severe bodily injury or loss of life.

# 1. Important Safety Information

Please read the IMPORTANT SAFETY INFORMATION below, and all Warning and Caution information elsewhere.



**Danger:** Indicates a risk of electric shock, which, if not avoided, could result in damage to the equipment and possible injury or death.

This variable speed drive product (Optidrive) is intended for professional incorporation into complete equipment or systems as part of a fixed installation. If installed incorrectly it may present a safety hazard. The Optidrive uses high voltages and currents, carries a high level of stored electrical energy, and is used to control mechanical plant that may cause injury. Close attention is required to system design and electrical installation to avoid hazards in either normal operation or in the event of equipment malfunction. Only qualified electricians are allowed to install and maintain this product.

System design, installation, commissioning and maintenance must be carried out only by personnel who have the necessary training and experience. They must carefully read this safety information and the instructions in this Guide and follow all information regarding transport, storage, installation and use of the Optidrive, including the specified environmental limitations.

Do not perform any flash test or voltage withstand test on the Optidrive. Any electrical measurements required should be carried out with the Optidrive disconnected. Internal surge arrestors are fitted, intended to protect against damage due to mains borne spikes, which will result in the product failing the flash test.

Electric shock hazard! Disconnect and ISOLATE the Optidrive before attempting any work on it. High voltages are present at the terminals and within the drive for up to 10 minutes after disconnection of the electrical supply. Always ensure by using a suitable multimeter that no voltage is present on any drive power terminals prior to commencing any work.

Where supply to the drive is through a plug and socket connector, do not disconnect until 10 minutes have elapsed after turning off the supply.

Ensure correct earthing connections and cable selection as per defined by local legislation or codes. The drive may have a leakage current of greater than 3.5mA; furthermore the earth cable must be sufficient to carry the maximum supply fault current which normally will be limited by the fuses or MCB. Suitably rated fuses or MCB should be fitted in the mains supply to the drive, according to any local legislation or codes.

Do not carry out any work on the drive control cables whilst power is applied to the drive or to the external control circuits.



**Danger:** Indicates a potentially hazardous situation other than electrical, which if not avoided, could result in damage to property.

Within the European Union, all machinery in which this product is used must comply with Directive 98/37/EC, Safety of Machinery. In particular, the machine manufacturer is responsible for providing a main switch and ensuring the electrical equipment complies with EN60204-1.

The level of integrity offered by the Optidrive control input functions – for example stop/start, forward/reverse and maximum speed, is not sufficient for use in safety-critical applications without independent channels of protection. All applications where malfunction could cause injury or loss of life must be subject to a risk assessment and further protection provided where needed.

The driven motor can start at power up if the enable input signal is present.

The STOP function does not remove potentially lethal high voltages. ISOLATE the drive and wait 10 minutes before starting any work on it. Never carry out any work on the Drive, Motor or Motor cable whilst the input power is still applied.

The Optidrive can be programmed to operate the driven motor at speeds above or below the speed achieved when connecting the motor directly to the mains supply. Obtain confirmation from the manufacturers of the motor and the driven machine about suitability for operation over the intended speed range prior to machine start up.

Do not activate the automatic fault reset function on any systems whereby this may cause a potentially dangerous situation.

Optidrives are intended for indoor use only.

When mounting the drive, ensure that sufficient cooling is provided. Do not carry out drilling operations with the drive in place, dust and swarf from drilling may lead to damage.

The entry of conductive or flammable foreign bodies should be prevented. Flammable material should not be placed close to the drive.

Relative humidity must be less than 95% (non-condensing).

Ensure that the supply voltage, frequency and no. of phases (1 or 3 phase) correspond to the rating of the Optidrive as delivered.

Never connect the mains power supply to the Output terminals U, V, W.

Do not install any type of automatic switchgear between the drive and the motor. This may cause the drive protection to activate, resulting in a trip and loss of operation.

Wherever control cabling is close to power cabling, maintain a minimum separation of 100 mm and arrange crossings at 90 degrees.

Ensure that all terminals are tightened to the appropriate torque setting.

Do not attempt to carry out any repair of the Optidrive. In the case of suspected fault or malfunction, contact your local Inverter Drives Sales Partner for further assistance.

## 2. Product Introduction

The Optidrive Coolvert is a high efficiency variable frequency drive with world-leading motor control performance when operating any of the following motor technologies:

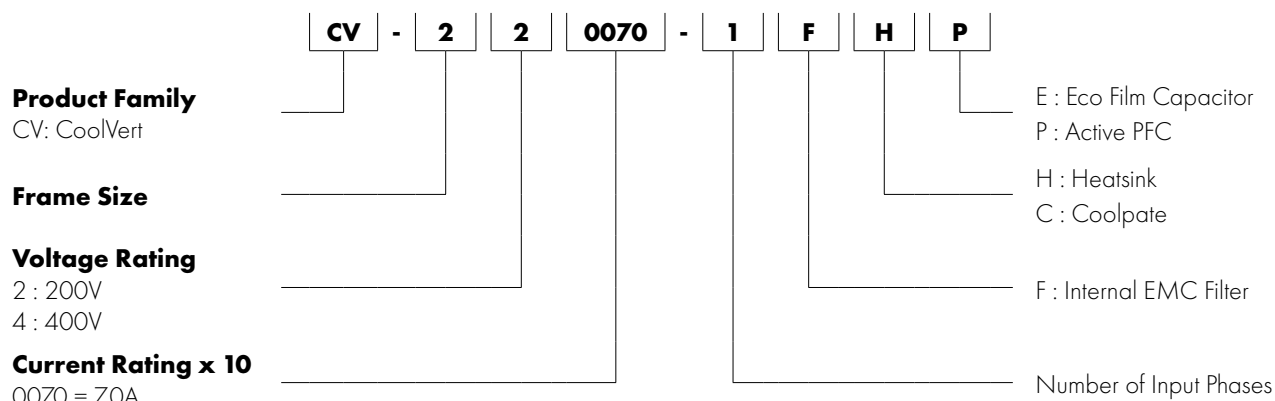
- Induction Motor
- Synchronous Permanent Magnet Motor
- Synchronous Brushless DC Motor
- Synchronous Reluctance Motor
- Line Start Permanent Magnet Motor

The product range has been specifically designed for OEM and machine-builders alike with through panel mounting and cold-plate technology options available. The drive has no direct keypad/display but shows drive status with two status indicating LEDs on the front.

The three phase input drives are low harmonic drives which do not need an input choke to comply with the THC limits provided in the relevant standard, BSEN 61000-3-12:2011. The single-phase input drives have built-in active PFC (Power Factor Correction) and in turn, are compliant with the requirements of BSEN 61000-3-2.

### 2.1. Identifying the Drive by Model Number

Each drive can be identified by its model number, shown below. The model number is on the shipping label, the drive rating label on the upper surface of the drive and on the front surface on the product identifier. The model number includes the drive and factory fitted options.



#### 2.1.1. Model Variants

200 – 240V +/-10% Single Phase Input				
Model Code	Frame	kW	HP	Amps
CV-220070-1FHP	2	1.5	2	7.0
CV-220120-1FHP	2	3	3	12.0
380 – 480V +/-10% Three Phase Input				
Model Code	Frame	kW	HP	Amps
CV-240140-3FHE	2	5.5	7.5	14
CV-240180-3FHE	2	7.5	10	18
CV-240240-3FHE	2	11	15	24

Replace 'H' with 'C' for coldplate version.

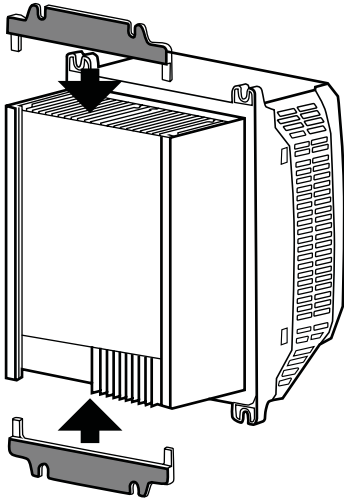
## 2.2. Accessories

### 2.2.1. Panel mounting kit

66-CVERT-FBM-1

The Coolvert (heatsink version) is designed to primarily be mounted 'through-panel' with the heatsink protruding outside of the electrical panel.

**NOTE** This mounting kit does not come with the drive and must be ordered separately.



### 2.2.2. Optional External EMC Filters

External EMC filters are available to achieve C1 conducted emission compliance with the single phase input drives. Available models are as follows:

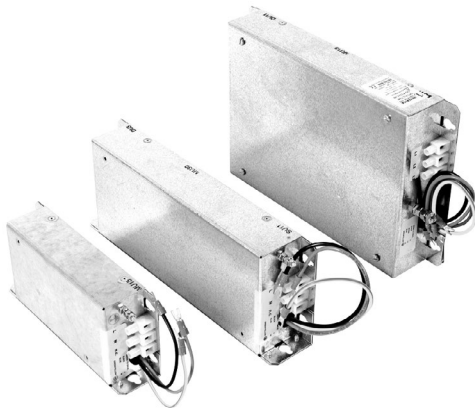
OPT-2-E1010-20 EMC Filter, 10A, 1 Ph 230V IP20

OPT-2-E1025-20 EMC Filter, 25A, 1 Ph 230V IP20

OPT-2-E3016-20 EMC Filter, 16A, 3 Ph 400V IP20

OPT-2-E3025-20 EMC Filter, 25A, 3 Ph 400V IP20

Contact your local partner for detailed information and dimensions.



### 2.2.3 Ferrite Rings

To ensure conformity to the EMC directive with the single phase 230V PFC drives, it is recommended to install a ferrite core (e.g. Fair-Rite round cable snap ferrite 0431176451), one around the supply cable and the second around the supply earth as detailed in chapter 3.3. *EMC Compliant Installation* on page 14.

**2.2.4. OptiPad – Remote TFT Text LCD Display for commissioning and diagnostics with RJ45 cable**

OPT-3-OPPAD-IN



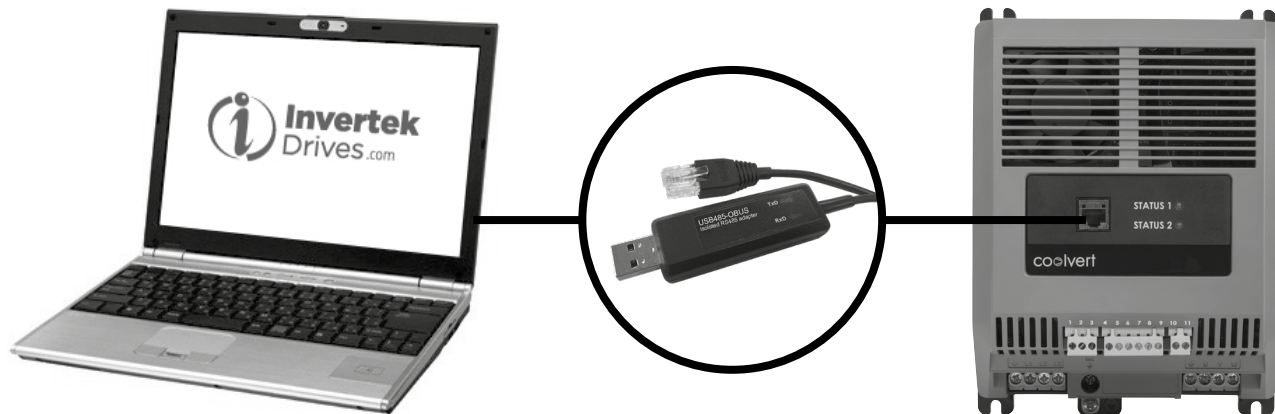
**2.2.5. Optistick Smart – Bluetooth / PC Interface with Parameter cloning function**

OPT-3-STICK-IN



**2.2.6. Isolated USB to RS485 converter - USB PC Connection Kit**

OPT-2-USB-OBUS



# 3. Installation

## 3.1. Mechanical Installation

### 3.1.1. General

- The Optidrive Coolvert should be mounted in a vertical orientation only.
- The Optidrive Coolvert has been designed to be installed in a suitable enclosure. The drive can be through panel mounted or mounted directly onto the back of a panel using the appropriate mounting kit.
- Using the drive as a template, or the dimensions shown below, mark the locations for drilling.
  - Ensure that when mounting locations are drilled, the dust from drilling does not enter the drive.
  - Mount the drive to the cabinet backplate using suitable mounting screws.
  - Position the drive, and tighten the mounting screws securely.
- The front of the drive is IP20 and must be installed in a pollution degree 1 or 2 environment only.
- In any environments where the conditions require it, the enclosure must be designed to protect the drive against ingress of airborne dust, corrosive gases or liquids, conductive contaminants (such as condensation, carbon dust, and metallic particles) and sprays or splashing water from all directions.
- Enclosures should be made from a thermally conductive material.
- Do not mount flammable material close to the Optidrive.
- Ensure that the minimum cooling air gaps, as detailed in section Ventilation and clearance.
- Ensure that the ambient temperature range does not exceed the permissible limits given in section 6.3. *Temperature and Switching Frequency De-rating Requirements for Coolvert* on page 44. Typical heat losses generated by the drives are given in section 3.1.9. *Cold-plate Capacity Calculation* and should be considered when designing the enclosure size and ventilation to ensure that the drive is not operated outside of its design conditions.

### 3.1.2. Before Installation

- Carefully Unpack the Optidrive and check for any signs of damage. Notify the shipper immediately if any exist.
- Check the drive rating label to ensure it is of the correct type and power requirements for the application.
- To prevent accidental damage always store the Optidrive in its original box until required. Storage should be clean and dry and within the temperature range  $-40^{\circ}\text{C}$  to  $+70^{\circ}\text{C}$ .

### 3.1.3. UL Compliant Installation

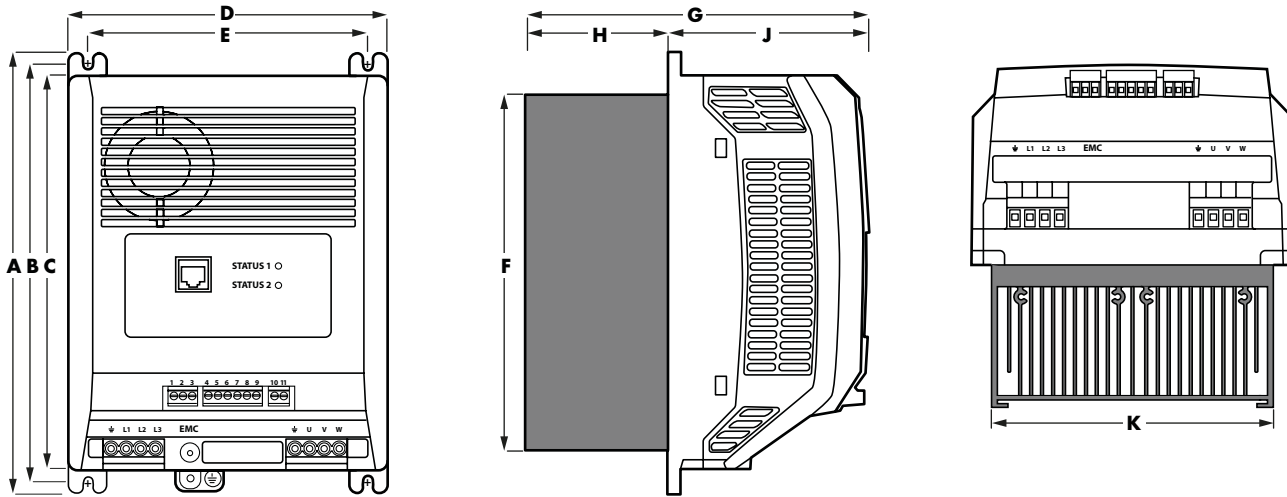
Note the following for UL-compliant installation:

- The heatsink variants of the Coolvert are cUL listed whereas the coldplate variants are cUR recognised as they require additional thermal devices to operate.
- For an up to date list of UL compliant products, please refer to UL listing NMMS.E226333 and NMMS2.E226333 for the recognised products.
- The drive can be operated within an ambient temperature range as stated in section 6.1. *General* on page 42.
- The front of the drive is IP20, installation is required in a pollution degree 1 environment.
- The rear of the drive is IP55, installation in a pollution degree 2 environment is permissible.
- If the drive is through panel mounted, ensure the correct environment is maintained for each section of the drive as indicated above
- If the drive is mounted directly onto the back plate, the whole installation is required in a pollution degree 1 environment.
- UL Listed ring terminals / lugs must be used for all bus bar and grounding connections.
- The drive is designed to be installed in a suitable enclosure.

Refer to section 6.5. *Additional Information for UL Approved Installations\**.



**3.1.4. Drive Dimensions**

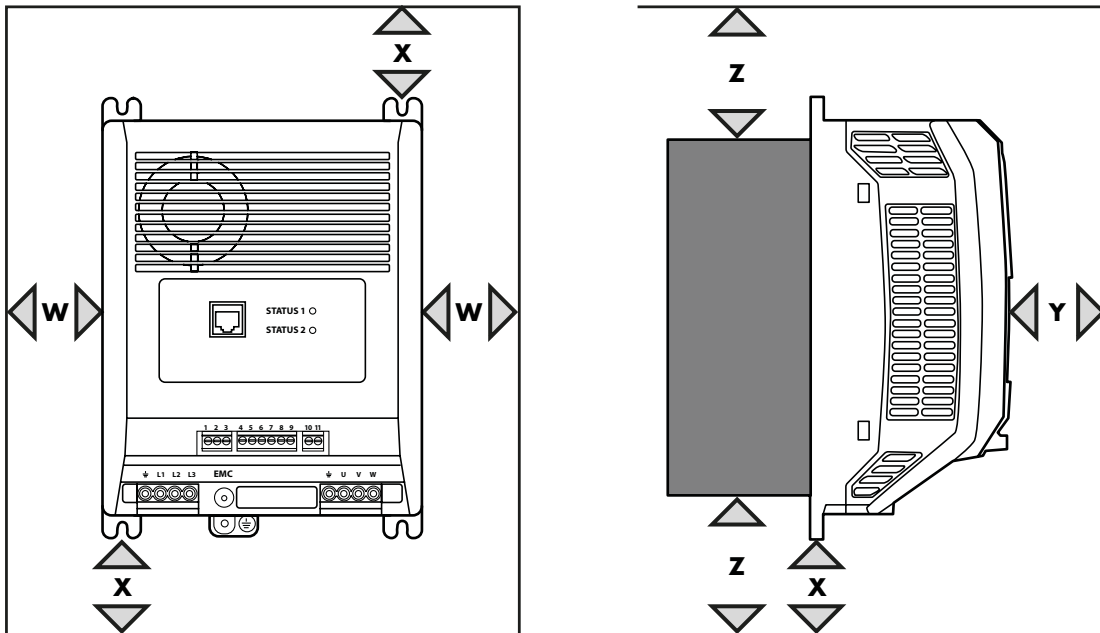


A		B		C		D		E		F		G		H		J		K	
mm	in	mm	in	mm	in	mm	in	mm	in	mm	in	mm	in	mm	in	mm	in	mm	in
226.3	8.9	215.2	8.5	201.4	7.9	165.3	6.5	144.8	5.7	182	7.2	176.2	6.9	72.7	2.9	103.5	4.1	145	5.7

Tightening Torques		
	Required Torque	
Control Terminals	0.5 Nm	4.5 lb-in
Power Terminals	1 Nm	9 lb-in

**3.1.5. Ventilation and Clearance**

In order for the drive to maintain it's temperature, a minimum clearance is required around the drive as shown in the diagram below:



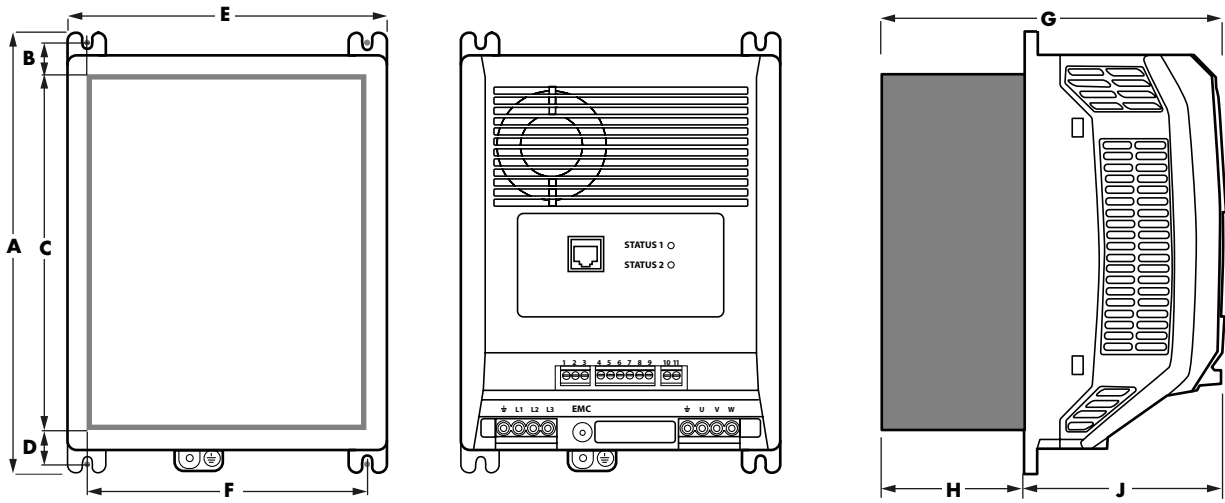
W		X		Y		Z*	
mm	in	mm	in	mm	in	mm	in
20	0.787	78	3.07	10	0.394	100	3.94

The losses generated by each drive are explained in section 3.1.9. Cold-plate Capacity Calculation.

**NOTE** Value 'Z' is not applicable to the coldplate variant. These dimensions are the absolute minimum recommended clearances to allow sufficient air flow. The enclosure itself must be significantly wider or taller than the values given above in at least one direction.

### 3.1.6. Through panel mounting

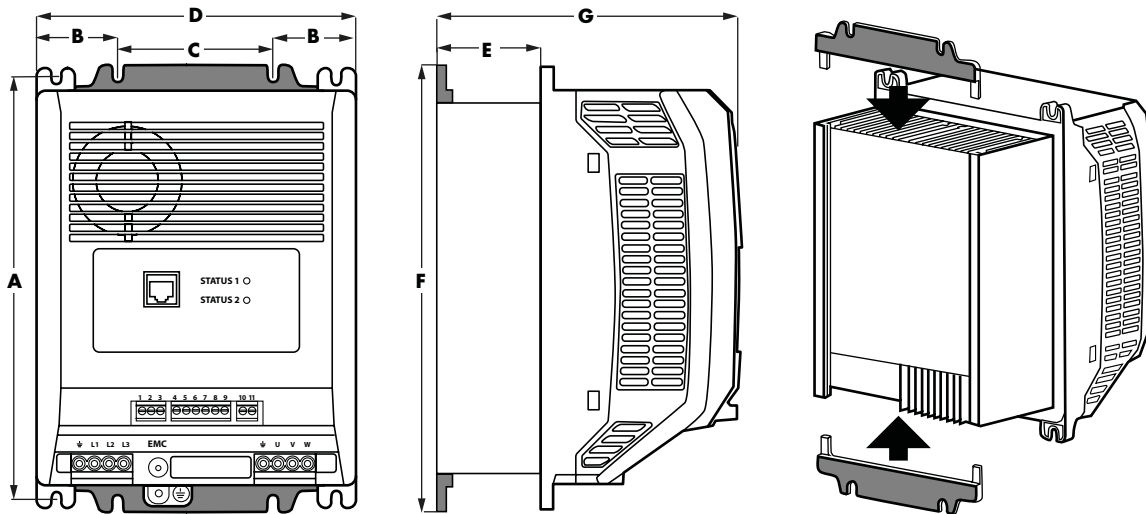
Through panel mounting is the most efficient installation in terms of both panel space and thermal management. With the heatsink protruding through the back of the electrical panel, the heat generated by the drive will be exhausted outside of the electrical panel.



A		B		C		D		E		F		G		H		J	
mm	in	mm	in	mm	in	mm	in	mm	in	mm	in	mm	in	mm	in	mm	in
226.3	8.9	16.1	0.63	183	7.2	16.1	0.63	165.3	6.5	145	5.7	176.2	6.9	72.7	2.9	103.5	4.1

### 3.1.7. Panel mounting (with the panel mounting kit)

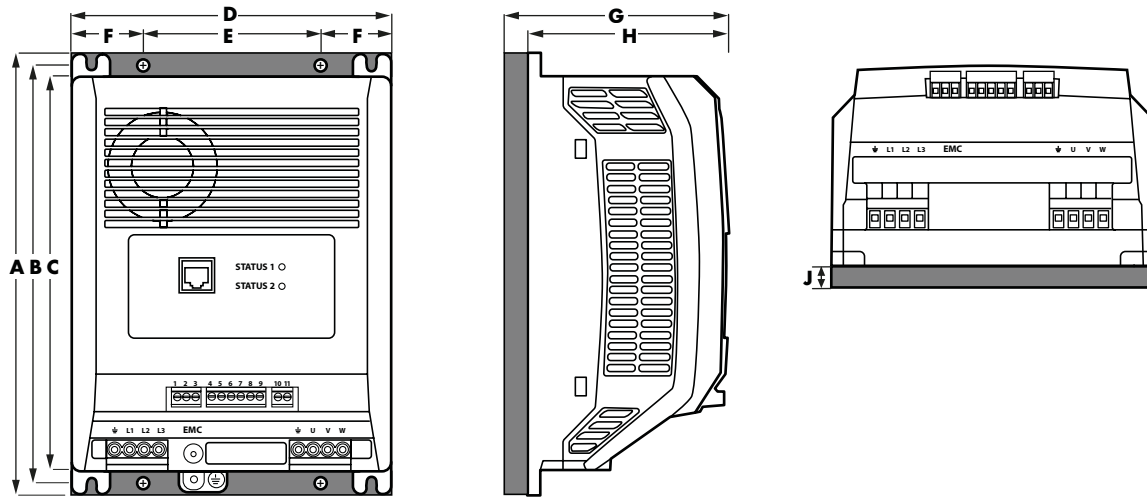
If the installation does not lend itself to through panel mounting, the drive can be mounted to a back-plate of a panel using the optional panel mounting kit.



A		B		C		D		E		F		G	
mm	in	mm	in	mm	in	mm	in	mm	in	mm	in	mm	in
216	8.5	42.6	1.67	80	3.15	165.3	6.5	73.7	2.9	228	8.98	176.2	6.9

### 3.1.8. Panel mounting the cold-plate variant

The Optidrive Coolvert is also available without a heatsink but with a coldplate that needs to be mounted onto a heat transfer surface, removing the drive losses and maintaining the coldplate temperature as shown in the table in section 3.1.9. Cold-plate Capacity Calculation on page 11.



A		B		C		D		E		F		G		H		J	
mm	in	mm	in	mm	in	mm	in	mm	in	mm	in	mm	in	mm	in	mm	in
226.3	8.9	215.2	8.5	201.4	7.9	165.3	6.5	90	3.5	37.6	1.48	115.5	4.5	103.5	4.1	9.5	0.37

Tightening Torques		
	Required Torque	
Control Terminals	0.5 Nm	4.5 lb-in
Power Terminals	1 Nm	9 lb-in

### 3.1.9. Cold-plate Capacity Calculation

The coldplate variants of the Optidrive Coolvert are designed to be mounted to a metallic, heat conducting surface, removing the heat generated as losses within the drive. Thermostat or heat transfer compound must be added to ensure optimal heat transfer and minimum thermal resistance.

In order to ensure that the drive remains within the design temperatures, the following information should be considered when designing the system:

- Select the desired PWM operating frequency from the available options in Parameter P5-06
- Determine the maximum permissible drive temperature,  $T_{MAX}$  from table X below
- Calculate the motor absorbed electrical power,  $P_{MOT}$  based on the motor rated voltage, current and efficiency  

$$P_{MOT} = \sqrt{3} * \text{Rated Voltage} * \text{Rated Current} * \text{Power Factor} * \text{Efficiency}$$
- Calculate the losses in the drive,  $P_{LOSS}$  based on the required motor power  

$$P_{LOSS} = P_{MOT} * (1 - \text{Drive Efficiency})$$

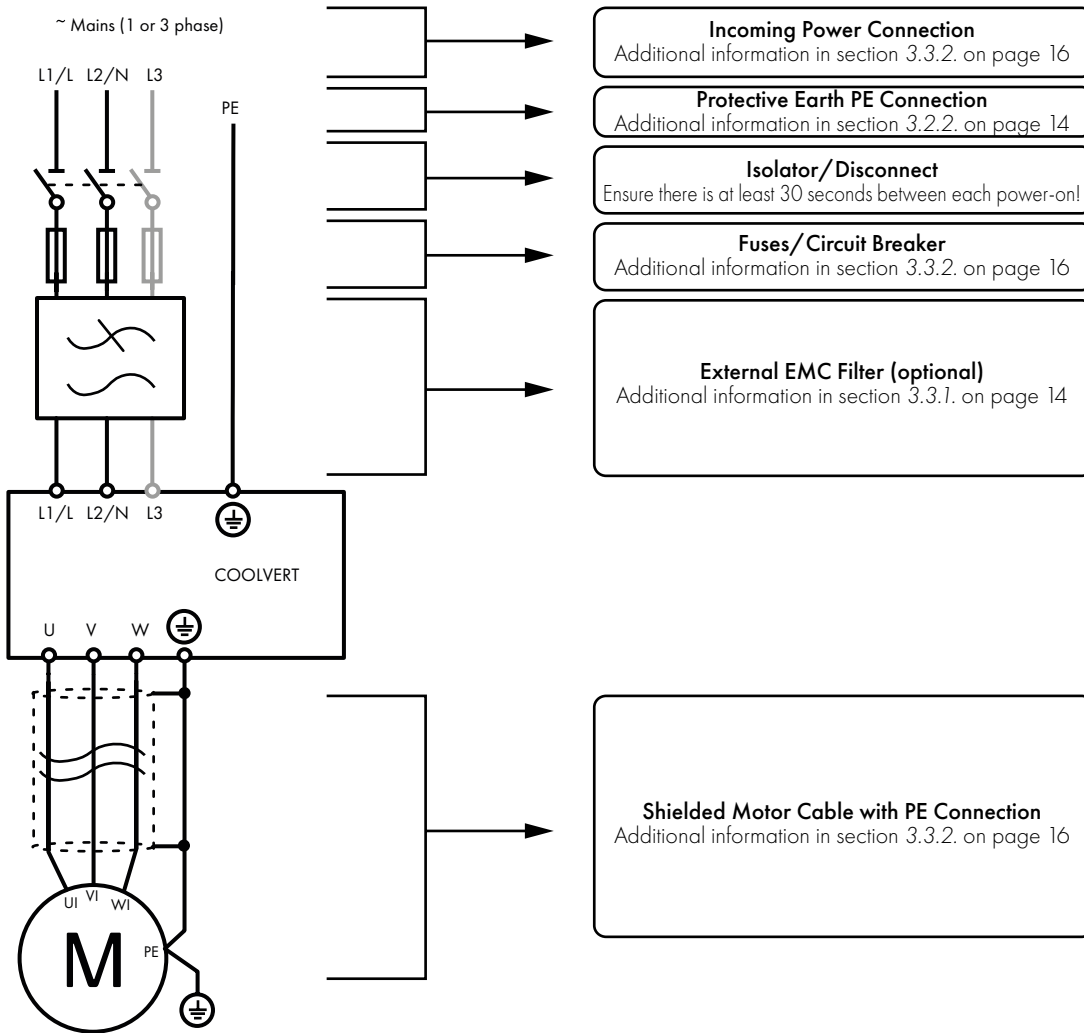
Typical drive efficiency values are shown in the table below for each available effective switching frequency:

Supply Rating		Output Rating		Product Part Number	Switching frequency	Typical Output Power	Approximate drive efficiency	Approximate losses at typical power	Maximum coldplate or Heatsink temperature
V	Ph	A	kW	Model	kHz	kW	%	W	°C
200-240V +/-10%	1	7	1.5	CV-220070-3FCP CV-220070-3FHP	4	1.5	95.0%	75.45	95
					8	1.5	94.3%	85.5	92
					12	1.5	93.7%	95.1	89
					16	1.5	93.2%	102.45	86
					24	1.5	91.9%	121.95	83
					32	1.5	90.2%	147.75	80
200-240V +/-10%	1	12	2.2	CV-220120-3FCP CV-220120-3FHP	4	3	94.5%	165.3	95
					8	3	94.0%	179.4	92
					12	3	94.0%	180.9	89
					16	3	93.3%	201.6	86
					24	3	92.3%	230.7	83
					32	3	92.3%	231.3	80
380-480V +/-10%	3	14	5.5	CV-240140-3FCE CV-240140-3FHE	10	5.5	96.7%	184	91
					12	5.5	96.4%	198	89
					14	5.5	96.2%	211	88
					16	5.5	96.1%	217	87
					18	5.5	95.7%	235	85
					20	5.5	95.5%	246	84
380-480V +/-10%	3	18	7.5	CV-240180-3FCE CV-240180-3FHE	10	7.5	97.1%	215	91
					12	7.5	97.0%	225	89
					14	7.5	96.9%	233	88
					16	7.5	96.8%	237	87
					18	7.5	96.6%	253	85
					20	7.5	96.5%	262	84
380-480V +/-10%	3	24	11	CV-240240-3FCE CV-240240-3FHE	10	11	96.8%	358	91
					12	11	96.7%	359	89
					14	11	96.7%	363	88
					16	11	96.6%	370	87
					18	11	96.5%	383	85
					20	11	96.4%	393	84

### 3.2. Connection Diagram

All power terminal locations are marked directly on the product with AC power input and motor connections located at the bottom of the unit.

#### 3.2.1. Electrical Power Connections



⚡	This manual is intended as a guide for proper installation. Invertek Drives Ltd cannot assume responsibility for the compliance or the non-compliance to any code, national, local or otherwise, for the proper installation of this drive or associated equipment. A hazard of personal injury and/or equipment damage exists if codes are ignored during installation.
⚡	This Optidrive contains high voltage capacitors that take time to discharge after removal of the main supply. Before working on the drive, ensure isolation of the main supply from line inputs. Wait ten (10) minutes for the capacitors to discharge to safe voltage levels. Failure to observe this precaution could result in severe bodily injury or loss of life.
⚡	Only qualified electrical personnel familiar with the construction and operation of this equipment and the hazards involved should install, adjust, operate, or service this equipment. Read and understand this manual and other applicable manuals in their entirety before proceeding. Failure to observe this precaution could result in severe bodily injury or loss of life.

### 3.2.2. Grounding Guidelines

The ground terminal of each Optidrive Coolvert should be individually connected DIRECTLY to the site ground bus bar (through the filter if installed). Optidrive Coolvert ground connections should not loop from one drive to another, or to, or from any other equipment. Ground loop impedance must conform to local industrial safety regulations. To meet UL regulations, UL approved ring crimp terminals should be used for all ground wiring connections. The drive Safety Ground must be connected to system ground. Ground impedance must conform to the requirements of national and local industrial safety regulations and/or electrical codes. The integrity of all ground connections should be checked periodically.

#### Protective Earth Conductor

The cross-sectional area of the PE Conductor must be at least equal to that of the incoming supply conductor.

#### Safety Ground

This is the safety ground for the drive that is required by code. One of these points must be connected to adjacent building steel (girder, joist), a floor ground rod, or bus bar. Grounding points must comply with national and local industrial safety regulations and/or electrical codes.

#### Motor Ground

The motor ground must be connected to one of the ground terminals on the drive.

#### Ground Fault Monitoring

As with all inverters, a leakage current greater than 3.5mA to earth can exist. The Optidrive Coolvert is designed to produce the minimum possible leakage current whilst complying with worldwide standards. The level of current is affected by motor cable length and type, the effective switching frequency, the earth connections used and the type of RFI filter installed. If an ELCB (Earth Leakage Circuit Breaker) is to be used, the following conditions apply:

- A Type B Device (or B+) must be used.
- The device must be suitable for protecting equipment with a DC component in the leakage current.
- Individual ELCBs should be used for each Optidrive Coolvert as opposed to one protection device serving many.

#### Shield Termination (Cable Screen)

The safety ground terminal provides a grounding point for the motor cable shield. The motor cable shield connected to this terminal (drive end) should also be connected to the motor frame (motor end). Use a shield terminating or EMI clamp to connect the shield to the safety ground terminal.

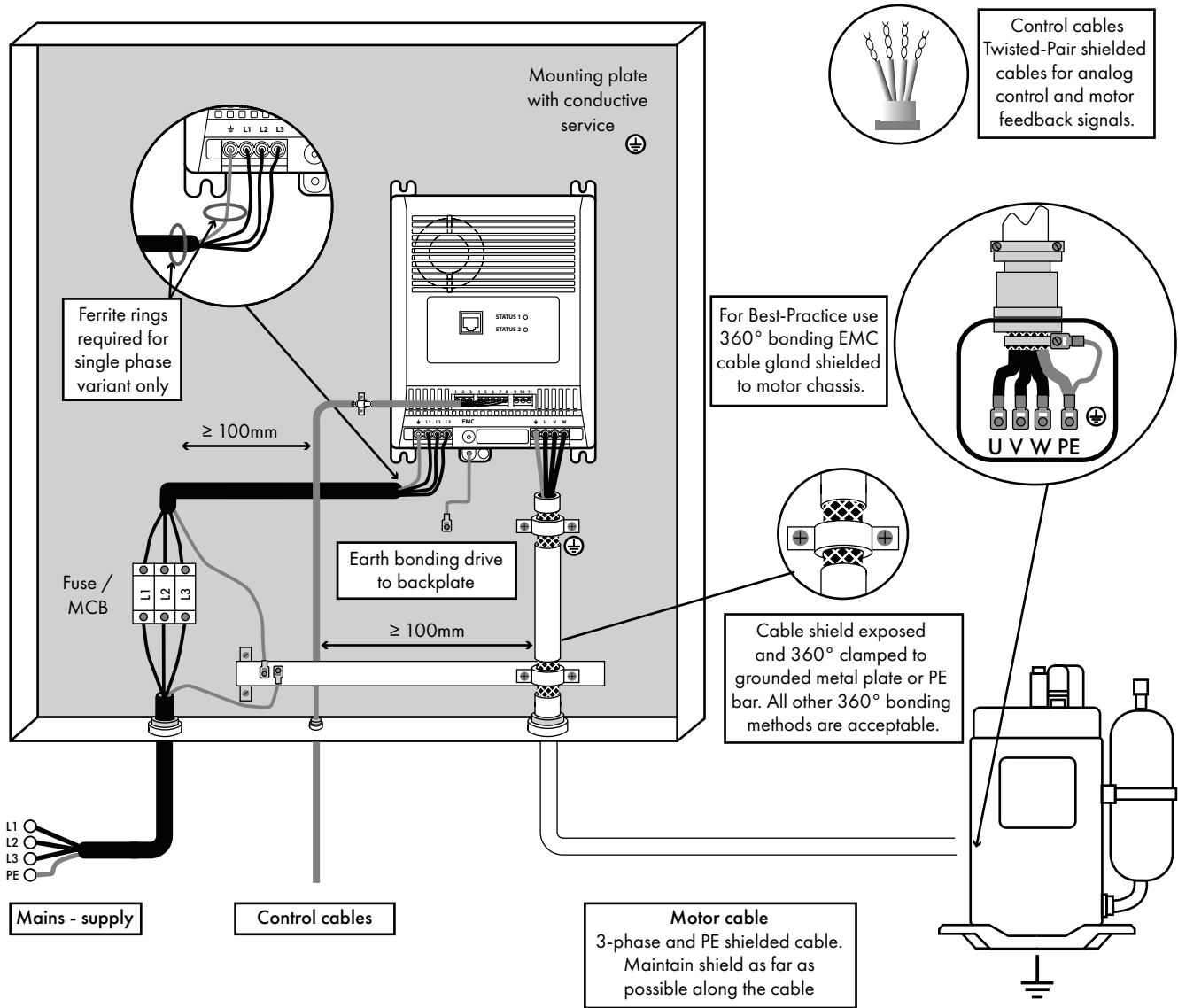
### 3.3. EMC Compliant Installation

The Optidrive Coolvert is designed in compliance with stringent EMC standards. All models are supplied with an internal EMC filter, which is specifically designed to reduce the emissions in conformity with harmonised European Standards. It is the installer's responsibility that the device or system within which the Optidrive Coolvert is incorporated, is in compliance with the Standards in force in the country of use. The relevant EMC directive in force in the European Union is the EMC 2014/30/EU.

The Optidrive Coolvert is intended to be incorporated inside fixed installation devices, only installed by skilled individuals. Conformity with the EMC Standard can only be achieved if the guidance provided in this chapter is strictly adhered to.

**NOTE** It is the responsibility of the installer to ensure that the final product containing the Optidrive Coolvert complies with any standard necessary for that final product.

### 3.3.1. Recommended Installation for EMC Compliance



Voltage Rating	Maximum permissible cable lengths	
	C1 <sub>1,2,4,5,6</sub>	C2 <sub>2,4,5,6</sub>
230V 1Phase	0 (1) <sub>3</sub>	5 (10) <sub>3</sub>
400V 3Phase	1 (5)	5 (10) <sub>4</sub>

**NOTE**

- Data in brackets shows permissible cable length with additional external EMC filter.
- Details of optional external EMC filters listed in section 2.2.2. *Optional External EMC Filters* on page 6.

## General

- Compliance with category C1 conducted emissions only is achieved. To ensure compliance with category C2 radiated emissions with the single phase 230V PFC drives, it is necessary to install a ferrite core (e.g. Fair-Rite round cable snap ferrite 0431176451), one around the supply cable and the second around the supply earth.

## Supply Cable

- A screened (shielded) cable suitable for fixed installation with the relevant mains voltage in use. Braided or twisted type screened cable where the screen covers at least 85% of the cable surface area, designed with low impedance to HF signals. Installation of a standard cable within a suitable steel or copper tube is also acceptable – in this case, ensure that metal tube is adequately grounded.
- A cable suitable for fixed installation with relevant mains voltage with a concentric protection wire. Installation of a standard cable within a suitable steel or copper tube is also acceptable.

## Motor Cable

- A screened (shielded) cable suitable for fixed installation with the relevant voltage in use. Braided or twisted type screened cable where the screen covers at least 85% of the cable surface area, designed with low impedance to HF signals. Installation of a standard cable within a suitable steel or copper tube is also acceptable – in this case, ensure that metal tube is adequately grounded.
- The cable shield should be terminated at the motor end using an EMC type gland allowing connection to the motor body through the largest possible surface area. The shield must also be terminated at the drive end, as close as practically possible to the drive output terminals. Where drives are mounted in a steel control panel enclosure, the cable screen may be terminated directly to the control panel backplate using a suitable EMC clamp or gland fitted as close to the drive as possible. The drive earth terminal must also be connected directly to this point, using a suitable cable which provides low impedance to high frequency currents.

## Control Cable

- A shielded cable with low impedance shield. Twisted pair cable is recommended for analogue signals.

### 3.3.2. Incoming Power Connection

#### Cable Selection

- For 1 phase supply, the mains power cables should be connected to L1 /L, L2/N.
- For 3 phase supplies, the mains power cables should be connected to L1, L2, and L3. Phase sequence is not important.
- For compliance with CE and C Tick EMC requirements, refer to section 3.3. *EMC Compliant Installation* on page 14.
- A fixed installation is required according to IEC61800-5-1 with a suitable disconnecting device installed between the Optidrive and the AC Power Source. The disconnecting device must conform to the local safety code / regulations (e.g. within Europe, EN60204-1, Safety of machinery).
- The cables should be dimensioned according to any local codes or regulations. Maximum dimensions are given in section 6.2. *Detailed Product Rating Tables* on page 44.

#### Fuse / Circuit Breaker Selection

- Suitable fuses to provide wiring protection of the input power cable should be installed in the incoming supply line, according to the data in section 6.2. *Detailed Product Rating Tables*. The fuses must comply with any local codes or regulations in place. In general, type gG (IEC 60269) or UL type J fuses are suitable; however in some cases type aR fuses may be required. The operating time of the fuses must be below 0.5 seconds.
- Where allowed by local regulations, suitably dimensioned type B MCB circuit breakers of equivalent rating may be utilised in place of fuses, providing that the clearing capacity is sufficient for the installation.
- The maximum permissible short circuit current at the Optidrive Power terminals as defined in IEC60439-1 is 100kA.

#### Motor Connection

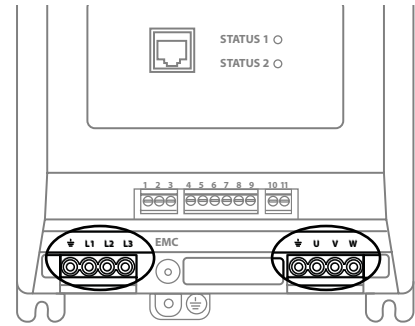
- The drive inherently produces fast switching of the output voltage (PWM) to the motor compared to the mains supply, for motors which have been wound for operation with a variable speed drive then there is no preventative measures required, however if the quality of insulation is unknown then the motor manufacturer should be consulted and preventative measures may be required.
- The motor should be connected to the Optidrive U, V, and W terminals using a suitable 3 or 4 core cable. Where a 3 core cable is utilised, with the shield operating as an earth conductor, the shield must have a cross sectional area at least equal to the phase conductors when they are made from the same material. Where a 4 core cable is utilised, the earth conductor must be of at least equal cross sectional area and manufactured from the same material as the phase conductors.
- The motor earth must be connected to one of the Optidrive earth terminals.
- Maximum permitted motor cable length for all models: 10 metres shielded, 20 metres unshielded.



## Power Connections

230V Single Phase Variants		
Power Earth / Ground	L1 (200VAC)	Neutral
<b>E</b>	<b>L</b>	<b>N</b>
Power Earth / Ground	Motor U Phase	Motor V Phase
<b>E</b>	<b>U</b>	<b>V</b>
		Motor W Phase
		<b>W</b>

400V 3-Phase Variants			
Power Earth / Ground	Supply L1	Supply L2	Supply L3
<b>E</b>	<b>L1</b>	<b>L2</b>	<b>L3</b>
Power Earth / Ground	Motor U Phase	Motor V Phase	Motor W Phase
<b>E</b>	<b>U</b>	<b>V</b>	<b>W</b>

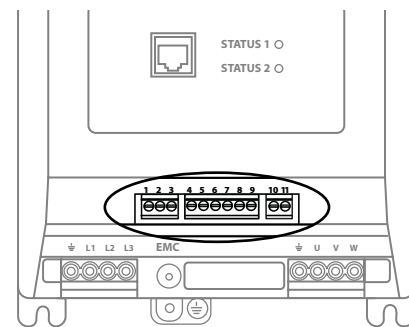


### 3.3.3. Control Wiring

The Optidrive CoolVert has pluggable control terminals to support easy installation. There are three pluggable control terminal blocks split into:

- Serial Communications (T1-T3)
- Inputs (T5 – T9)
- Output Relay (T10 – T11)

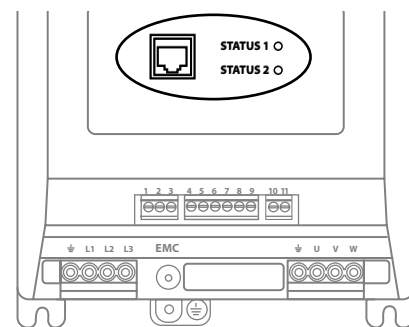
0V Common	Modbus TX/RX +	Modbus TX/RX -	+24V Output (100mA)	Digital Input 1	Analogue Input 1	0V Common	STO +	STO -	User Relay A	User Relay B
<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>7</b>	<b>8</b>	<b>9</b>	<b>10</b>	<b>11</b>
			Run / Stop	Speed Ref						



### RJ45 Port

This port is intended for use with the Optistick Smart for parameter cloning or for connection to the mobile App or to PC Tools or for Master Follower configuration of drives.

1	Not used
2	Not used
3	0 Volts
4	-RS485 (PC)
5	+RS485 (PC)
6	+24 Volt
7	RS 485- Modbus RTU
8	RS 485+ Modbus RTU
<b>Warning:</b>	
This is not an Ethernet connection. Do not connect directly to an Ethernet port.	



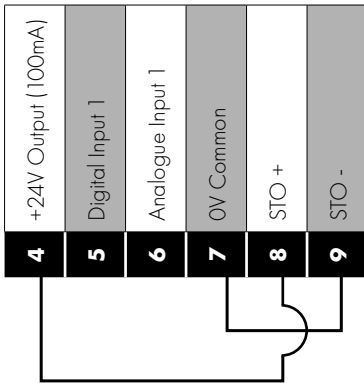
The RJ45 port has some terminals that are internally connected in parallel with the pluggable control terminals as shown below:

Pluggable Control Terminal	RJ45 Terminal	Description
1	3	0 Volt Common
2	8	Modbus RTU TX/RX + (RS485)
3	7	Modbus RTU TX/RX - (RS485)
4	6	User +24 Volt (100mA Max)
-	5	PC-Tools TX/RX + (RS485 Optibus)
-	4	PC-Tools TX/RX - (RS485 Optibus)

### 3.3.4. Safe Torque Off

Safe Torque Off will be referred to as "STO" through the remainder of this section. If the "STO" function is not required in your installation, you must link out the "STO" circuit by linking terminal 4 to terminal 8 and linking terminal 7 to terminal 9 as shown in the figure below. Please read the remainder of this chapter for further information about the functionality and limitations of the "STO" circuit.

#### Showing the links needed if the STO is not required



#### Responsibilities


The overall system designer is responsible for defining the requirements of the overall "Safety Control System" within which the drive will be incorporated; furthermore the system designer is responsible for ensuring that the complete system is risk assessed and that the "Safety control System" requirements have been entirely met and that the function is fully verified, this must include confirmation testing of the "STO" function before drive commissioning. The system designer shall determine the possible risks and hazards within the system by carrying out a thorough risk and hazard analysis, the outcome of the analysis should provide an estimate of the possible hazards, furthermore determine the risk levels and identify any needs for risk reduction. The "STO" function should be evaluated to ensure it can sufficiently meet the risk level required.

#### What STO Provides

The purpose of the "STO" function is to provide a method of preventing the drive from creating torque in the motor in the absence of the "STO" input signals (Terminal 8 with respect to Terminal 9), this allows the drive to be incorporated into a complete safety control system where "STO" requirements need to be fulfilled.<sup>1</sup> The "STO" function can typically eliminate the need for electro-mechanical contactors with cross-checking auxiliary contacts as per normally required to provide safety functions.<sup>2</sup> The drive has the "STO" function built-in as standard and complies with the definition of "Safe torque off" as defined by IEC 61800-5- 2:2016. The "STO" function also corresponds to an uncontrolled stop in accordance with category 0 (Emergency Off), of IEC 60204-1. This means that the motor will coast to a stop when the "STO" function is activated, this method of stopping should be confirmed as being acceptable to the system the motor is driving. The "STO" function is recognised as a fail-safe method even in the case where the "STO" signal is absent and a single fault within the drive has occurred, the drive has been proven in respect of this by meeting the following safety standards.

Safe Torque Off (STO)	IEC 61800-5-2:2016	SIL 3
	EN ISO 13849-1:2015	PL "e"
	EN 61508 (Part 1 to 7): 2010	SIL 3
	EN 60204-1: 2006 & A1: 2009	Cat 0
	EN 62061: 2005 & A2: 2015	SIL CL 3
	Independent Approval	TUV Rheinland

#### What STO Does Not Provide

	Disconnect and ISOLATE the drive before attempting any work on it. The "STO" function does not prevent high voltages from being present at the drive power terminals.
	<sup>1</sup> <b>NOTE</b> The "STO" function does not prevent the drive from an unexpected re-start. As soon as the "STO" inputs receive the relevant signal it is possible (subject to parameter settings) to restart automatically, Based on this, the function should not be used for carrying out short-term non-electrical machinery operations (such as cleaning or maintenance work).
	<sup>2</sup> <b>NOTE</b> In some applications additional measures may be required to fulfil the systems safety function needs: the "STO" function does not provide motor braking. In the case where motor braking is required a time delay safety relay and/or a mechanical brake arrangement or similar method should be adopted, consideration should be made over the required safety function when braking as the drive braking circuit alone cannot be relied upon as a fail safe method.
	When using permanent magnet motors and in the unlikely event of a multiple output power devices failing then the motor could effectively rotate the motor shaft by 180/p degrees (Where p denotes number of motor pole pairs).

**“STO” Operation**

When the “STO” inputs are energised, the “STO” function is in a standby state, if the drive is then given a “Start signal/command” (as per the start source method selected in P1-11) then the drive will start and operate normally.

When the “STO” inputs are de-energised then the STO Function is activated and stops the drive (Motor will coast), the drive is now in “Safe Torque Off” mode.

To get the drive out of “Safe Torque Off” mode then any “Fault messages” need to be reset and the drive “STO” input needs to be re-energised.

**“STO” Status and Monitoring**

There are a number of methods for monitoring the status of the “STO” input, these are detailed below:

▪ **Optional Remote Keypad**

In Normal drive operation (Mains AC power applied), when the drives “STO” input is de-energised (“STO” Function activated) the drive will highlight this by displaying “InHibit” on the remote keypad and bit 5 of the status word will become active.

**NOTE** If the drive is in a tripped condition then the relevant trip will be displayed on the remote keypad and not “InHibit”.

▪ **Drive Output Relay**

Drive relay 1: Setting P3-05 to a value of “5” will result in relay opening when the “STO” function is activated.

**“STO” Fault Code**


Fault Code	Code Number	Description	Corrective Action
“Sto-F”	29	A fault has been detected within either of the internal channels of the “STO” circuit.	Refer to your Invertek Sales Partner

**“STO” Function Response Time**

The total response time is the time from a safety related event occurring to the components (sum of) within the system responding and becoming safe. (Stop Category 0 in accordance with IEC 60204-1).

- The response time from the “STO” inputs being de-energised to the output of the drive being in a state that will not produce torque in the motor (“STO” active) is less than 1ms.
- The response time from the “STO” inputs being de-energised to the “STO” monitoring status changing state is less than 20ms.
- The response time from the drive sensing a fault in the STO circuit to the drive displaying the fault on the display/Digital output showing drive not healthy is less than 20ms.

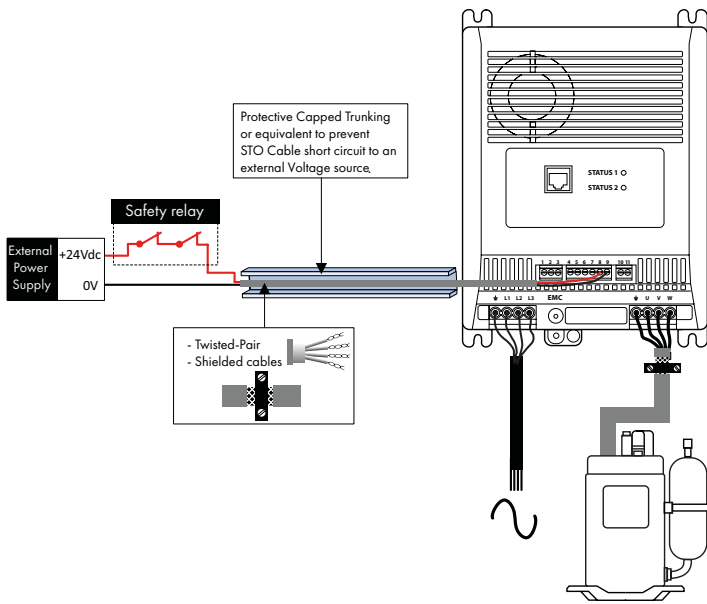
**“STO” Electrical Installation**

	The “STO” wiring shall be protected from inadvertent short circuits or tampering which could lead to failure of the “STO” input signal, further guidance is given in the diagrams below.
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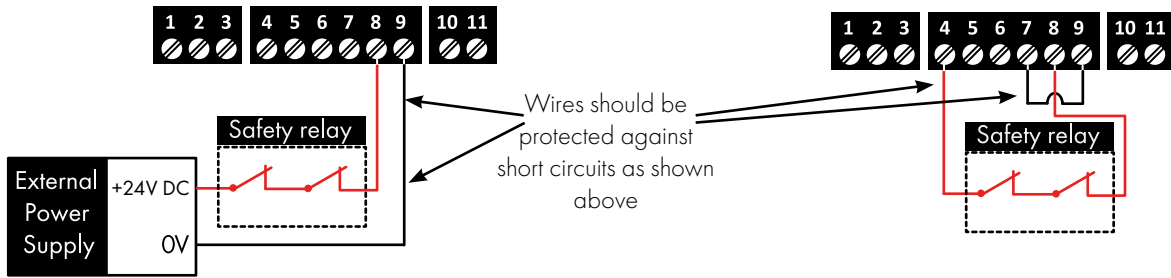
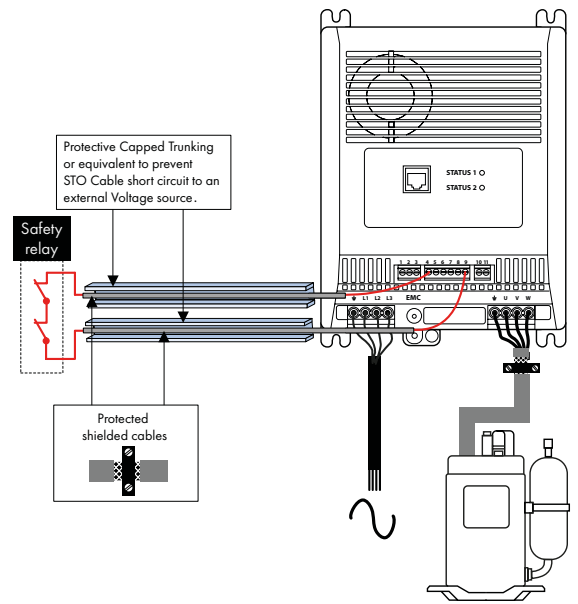
In addition to the wiring guidelines for the “STO” circuit below, section 3.3. *EMC Compliant Installation* on page 14 should also be followed. The drive should be wired as illustrated below; the 24Vdc signal source applied to the “STO” input can be either from the 24V dc on the drive or from an External 24V dc power supply.

### 3.3.5. Recommended "STO" Wiring

#### Using an External 24V DC Power Supply



#### Using the Drives On-board 24V DC Supply



**NOTE** The Maximum cable length from Voltage source to the drive terminals should not exceed 25 metres.

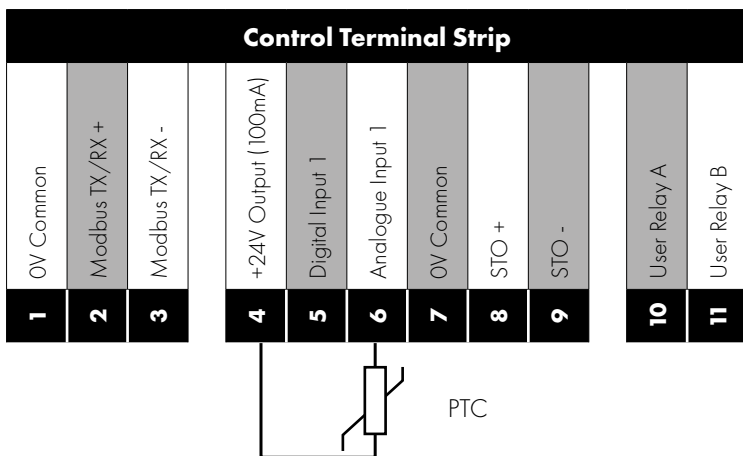
### 3.3.6. Motor Thermal Overload Protection

#### Internal Thermal Overload Protection

The drive has an in-built motor thermal overload function; this is in the form of an "I.t-trP" trip after delivering >100% of the value set in P1-08 for a sustained period of time (e.g. 130% for 10 seconds).

#### Motor Thermistor Connection

Where a motor thermistor is to be used, it should be connected as follows:



Additional Information
<ul style="list-style-type: none"> <li>Compatible Thermistor: PTC Type, 2.5kΩ trip level.</li> <li>When using a motor thermistor connected to the drive analogue input is shown in the diagram, Parameter P3-10 (Modbus register 310) must be set to a value of 8 (PTC).</li> </ul>

## 4. Set-up and Operation

### 4.1. Basic Checks Before Commissioning

It is vitally important to ensure that the Coolvert that you have purchased is suitable for the supply that you intend to connect it to, as is the importance of ensuring that this is appropriate for the motor to be connected to.

The motor nameplate data needs to be entered accurately before attempting to run the motor. The format of the information can vary depending on the technology of the motor. It is very important to ensure that the data entered is in the correct format. A common mistake is to enter an incorrect value for the back emf of a permanent magnet motor at rated speed as it can be written as a peak voltage, rms voltage and phase to phase voltage, line voltage and so on.

#### 4.1.1. Motor Type and Control Mode

Par.	Modbus Address	Description	Def	Min	Max	Unit	R/W
5-01	501	Motor Control Mode – select according to the motor connected to the drive: 0: BLDC Vector Speed Control 1: Permanent Magnet Vector Speed Control 2: Induction Motor Vector Speed Control (CT) 3: Induction Motor Vector Speed Control (VT) 4: Induction Motor V/F 5: Synchronous Reluctance Vector Speed Control 6: LSPM Speed Control	0	0	6	-	R/W

#### 4.1.2. Motor Name-plate Data

Par.	Modbus Address	Description	Def	Min	Max	Unit	R/W
1-07	107	Motor Rated Voltage (phase-to phase rms) Or Back EMF at Rated Speed for permanent magnet motor types (phase to phase rms)	-	-	-	V	R/W
1-08	108	Motor Rated Current (nominal)	-	-	-	A	R/W
1-09	109	Motor Rated Frequency at Rated Speed (nominal)	180	20	500	Hz	R/W
1-10	110	Motor Rated Speed at Rated Frequency	60	0	500	rps	R/W
5-05	505	Induction Motor Power Factor – cos phi. Only necessary for Induction Motors.	dd	0.5	0.99	-	R/W
5-02	502	Motor Parameter Autotune When enabled, the drive will inject current into the motor to identify its electrical characteristics. This test relies upon the correct setting of the motor parameters. This setting will return to 0 after completion of the auto-tune.	0	0	1	-	R/W

#### 4.1.3. Operating Limits and Ramp Rates

Par.	Modbus Address	Description	Def	Min	Max	Unit	R/W
1-01	101	Maximum Motor Speed	60	P1-02	500	Rps	R/W
1-02	102	Minimum Motor Speed	20-	0	P1-01	Rps	R/W
1-03	103	Acceleration Ramp Time from Orps to Rated Speed	30	0	6000	s	R/W
1-04	104	Deceleration Ramp Time from Rated Speed to Orps	30	0	6000	s	R/W
5-06	506	Motor Switching Frequency (24 x max frequency)	-	-	-	kHz	R/W
5-07	507	Maximum Torque / Current Limit	110	20	130	%	R/W

#### 4.1.4. Start-up Sequence

Par.	Modbus Address	Description	Def	Min	Max	Unit	R/W
2-01	201	Start Speed 1	30	P1-02		Rps	R/W
2-02	202	Start Speed 1 Time	60	0	600	s	R/W
2-03	203	Start Speed 1 Acceleration Ramp Orps to Start Speed 1	30	0	6000	s	R/W
2-04	204	Start Speed 2	30	P1-02		Rps	R/W
2-05	205	Start Speed 2 Time	60	0	600	s	R/W
2-06	206	Start Speed 2 Acceleration Ramp Orps to Start Speed 2	30	0	6000	s	R/W
2-07	207	Start Speed 3	30	P1-02		Rps	R/W
2-08	208	Start Speed 3 Time	60	0	600	s	R/W
2-09	209	Start Speed 3 Acceleration Ramp Orps to Start Speed 3	30	0	6000	s	R/W

If the start-up sequencing (or part of the start-up sequencing) is not required, set that Start Speed Time to 0s to disable that function. e.g. if you want to have one part of the start up sequence, set Start Speed 1 (P2-01) to the desired speed in rps, set the time for the motor to sit at speed 1 in P2-02 and set the desired ramp rate in P2-03 – then ensure that P2-05 and P2-08 are both set to 0s. On start-up in this example, the drive will ramp the speed set in P2-01 using the ramp rate set in P2-03 for a duration set in P2-02 before then following the chosen speed reference.

#### 4.1.5. Re-start Blocking

Par.	Modbus Address	Description	Def	Min	Max	Unit	R/W
2-10	210	Minimum Off Time	0	0	6000	s	R/W
2-11	211	Minimum On Time	0	0	6000	s	R/W
2-12	212	Re-start Delay (Start-to-start Delay)	0	0	6000	s	R/W
2-13	213	Re-start Function	Edge-r	0	Auto-5	-	R/W

**NOTE** Setting the minimum on time can mean that the drive will continue to run when the stop command is given. Removal of the STO signal will override any other command.

#### 4.1.6. Control Mode

see illustrations in section 4.2. *Modbus Connections* on page 23 for minimum control wiring required for each control mode.

Par.	Modbus Address	Description	Def	Min	Max	Unit	R/W
1-11	111	Command Source 0: Modbus Mode 1: Terminal Control 2: Terminal Control (All Start) 3: User PID Mode 4: Slave Mode	0	0	4	-	R/W
1-05	105	Stop Mode 0: Ramp to Stop 1: Coast to Stop 2: AC Flux Braking (IM Motor only) 3: Ramp to Minimum Speed then Coast to Stop	0	0	3	-	R/W

### 4.1.7. System Tuning

Par.	Modbus Address	Description	Def	Min	Max	Unit	R/W
5-03	503	Vector Speed Controller Proportional Gain	50	0.1	400	%	R/W
5-04	504	Vector Speed Controller Integral Time Constant	0.050	0.001	2.00	s	R/W
7-01	701	Minimum Switching Frequency – Thermal Management	-	-	-	kHz	R/W
7-02	702	Auto-reset Delay	20	1	60	S	R/W
7-03	703	Motor Stator Resistance (Rs) phase to phase				W	R/W
7-04	704	Motor Stator Inductance (Lsd) per phase				mH	R/W
7-05	705	Motor Stator Inductance (Lsq) per phase				mH	R/W
7-06	706	V/F Mode Magnetising Period	-	0	5000	Ms	R/W
7-07	707	Low Frequency Torque Boost Level	0.0	0.0	100	%	R/W
7-08	708	Low Frequency Torque Boost, Frequency Limit	0.0	0.0	50	%	R/W

The values for P7-03 through to P7-05 are gathered by the drive during the autotune process.

### 4.1.8. Thermal Protection

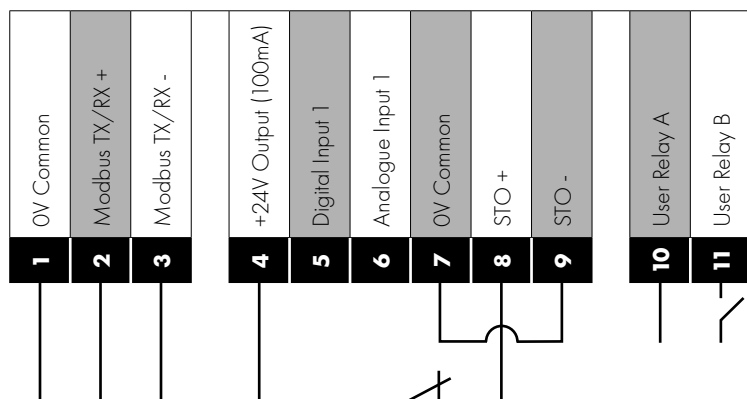
Par.	Modbus Address	Description	Def	Min	Max	Unit	R/W
5-07	507	Maximum Current Limit	110	20	150	%	R/W
5-08	508	Motor Power Limit	130	0	130	%	R/W
5-09	509	Motor Thermal Overload Management (Ixt)	0	0	1	-	R/W
5-10	510	Drive Thermal Overload Management (Drive Temperature Based)	0	0	1	-	R/W
5-11	511	Motor Thermal Overload Retention Enable	1	0	1	-	R/W
7-01	701	Minimum Switching Frequency – Thermal Management	-	-	-	kHz	R/W
7-02	702	Auto-reset Delay	20	1	60	S	R/W

## 4.2. Modbus Connections

### 4.2.1 Minimum Control Wiring Required For Each Control Mode

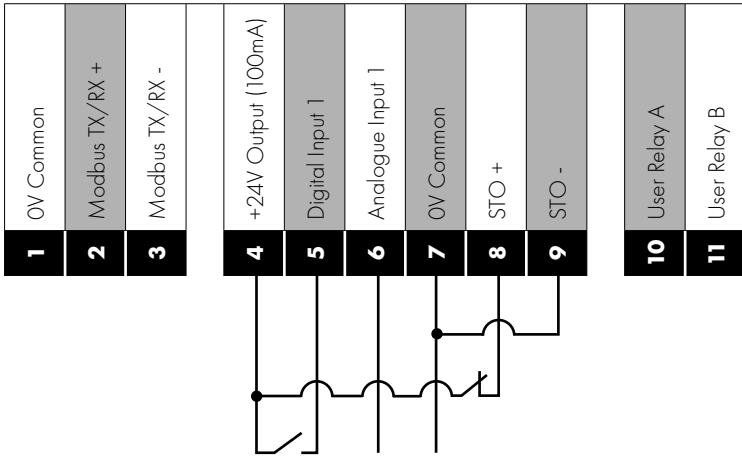
See parameter 1-11 in section 4.1.6. Control Mode on page 22.

#### P1-11 = 0 - Modbus control



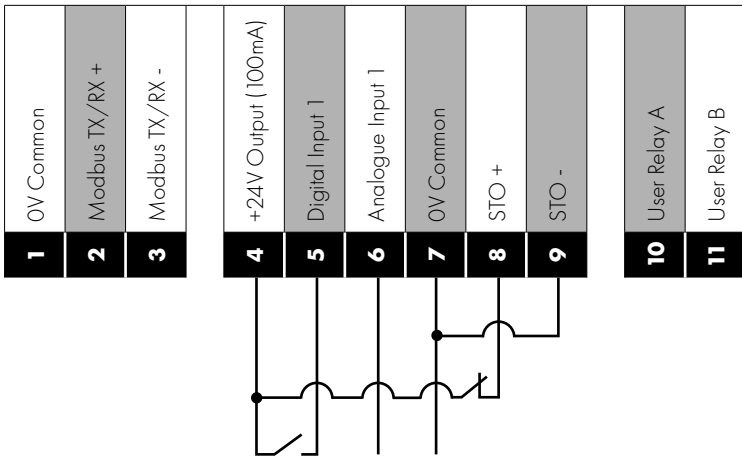
STO signal must be provided in order to permit running the motor. Start/Stop commands and speed reference are provided by serial communication. In Modbus mode, the digital input and analogue input can be used as remote I/O by the controller, the relay output can also be configured to be controlled by Modbus and used by the controller if required.

### P1-11 = 1 or 2 Terminal mode



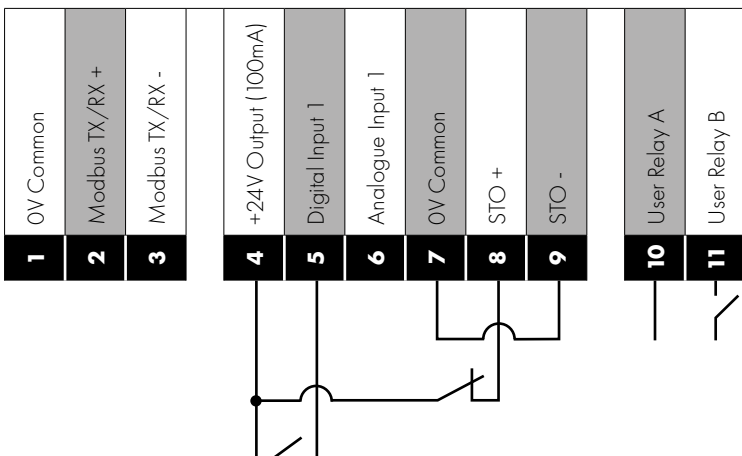
STO signal must be provided in order to permit running the motor. Start/Stop command provided by the Digital Input (P1-11 = 1) or when the analogue input level is greater than 1% (if P1-11 =2) and speed reference provided by the Analogue input.

### P1-11 = 3 Internal PI mode



STO signal must be provided in order to permit running the motor. Start/Stop command provided by the Digital Input. The speed reference is provided by the output of the PI controller and the PI feedback is provided by the analogue input.

### P1-11 = 4 Slave mode





### Master RJ45

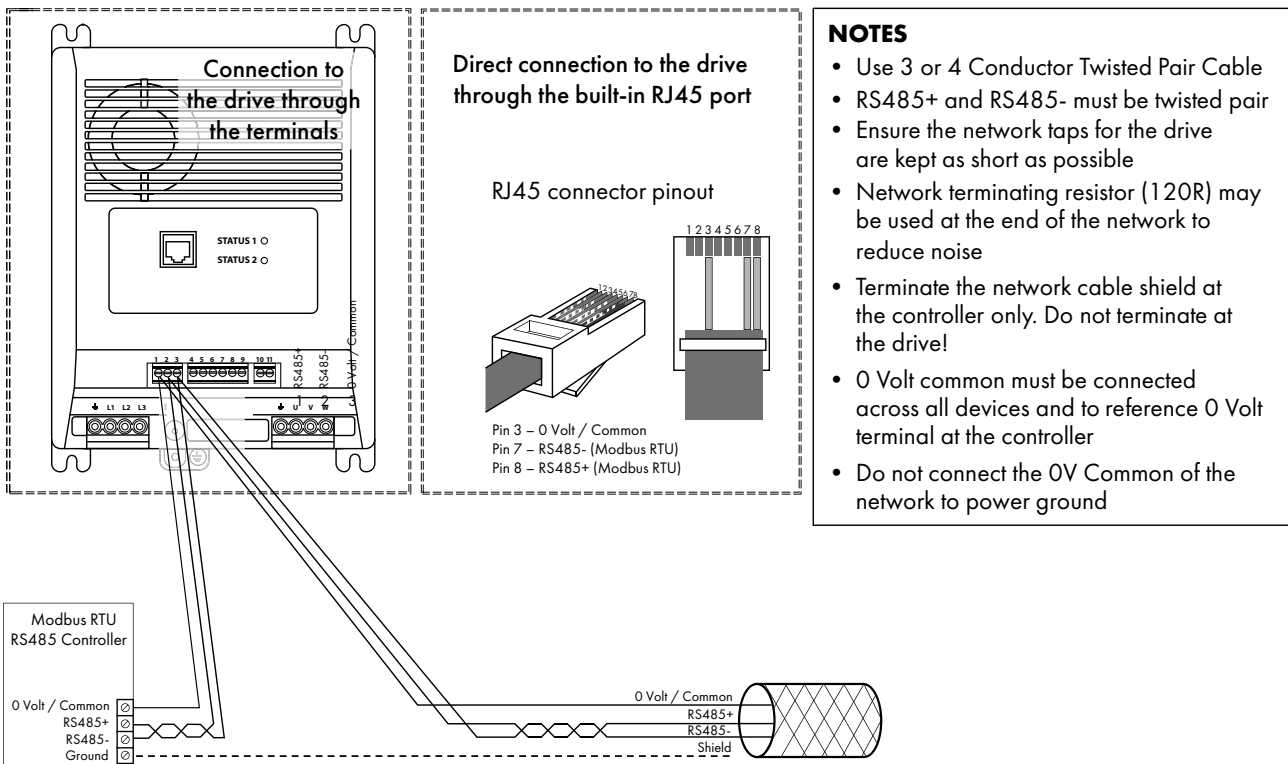
### Slave RJ45



STO signal must be provided in order to permit running the motor. Run enable is provided by the Digital Input with the Start/Stop command coming from the master drive. Speed reference also comes from the master drive. The slave drive must be connected to the master drive by a straight through (no crossover) RJ45 patch lead.

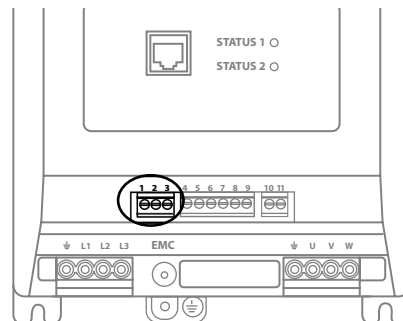
#### 4.2.2. RS-485 Communications Electrical Connections

The Optidrive Coolvert has two separate points where you can access the Modbus RTU communications. The Modbus RTU connection can be made via the RJ45 connector or control terminals 1, 2 & 3. As shown below:



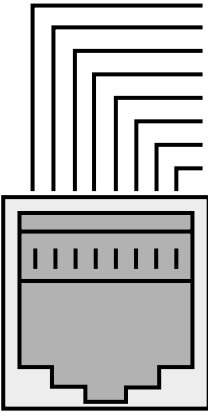
#### 4.2.3. RS-485 Communications Electrical Connections via Control Terminals

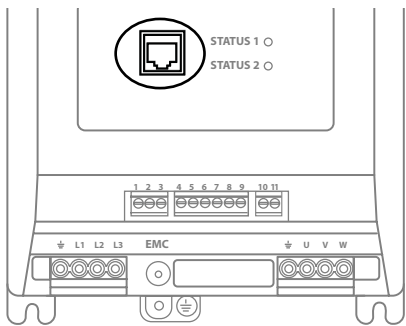
Serial Communication Connection										
1	2	3	4	5	6	7	8	9	10	11
0V Common	Modbus TX / RX +	Modbus TX / RX -	+24V Output (100mA)	Digital Input 1	Analogue Input 1	0V Common	STO +	STO -	User Relay A	User Relay B



#### 4.2.4. RS-485 Communications Electrical Connections via RJ45 Port

This port is intended for use with the Optistick Smart for parameter cloning or for connection to the mobile App or to PC Tools or for Master Follower configuration of drives.

	<b>1</b>	Not used
	<b>2</b>	Not used
	<b>3</b>	0 Volts
	<b>4</b>	-RS485 (PC)
	<b>5</b>	+RS485 (PC)
	<b>6</b>	+24 Volt
	<b>7</b>	RS 485- Modbus RTU / BACnet MSTP
	<b>8</b>	RS 485+ Modbus RTU / BACnet MSTP
<p><b>Warning:</b> This is not an Ethernet connection. Do not connect directly to an Ethernet port.</p>		



The RJ45 port has some terminals that are internally connected in parallel with the pluggable control terminals as shown below:

Pluggable Control Terminal	RJ45 Terminal	Description
1	3	0 Volt Common
2	8	Modbus RTU TX/RX + (RS485)
3	7	Modbus RTU TX/RX - (RS485)
4	6	User +24 Volt (100mA Max)
-	5	PC-Tools TX/RX + (RS485 Optibus)
-	4	PC-Tools TX/RX - (RS485 Optibus)

#### 4.2.5. Modbus Telegram Structure

The Optidrive CoolVert supports Master / Slave Modbus RTU communications, using the 03 Read Multiple Holding Registers and 06 Write Single Holding Register commands and 16 Write Multiple Holding Registers (Supported for registers 1 – 4 only). Many Master devices treat the first Register address as Register 0; therefore it may be necessary to convert the Register Numbers detail in section 4.3. *Read-only Parameter List and Modbus Registers* on page 28 and section 4.4. *Full Parameter List and Modbus Registers* on page 31 by subtracting 1 to obtain the correct Register address.

#### 4.2.6. Drive Status Word (Modbus Register 6)

The drive status has two status words where word 1 consists of two individual bytes that can be read in Modbus register 6. The Status word bit functions are defined as below:

Bit	Function	Explanation
0	Drive Running	0 : Drive stopped 1 : Drive enabled, output pulse enabled
1	Drive Tripped	0 : No trip 1 : Drive tripped
2	Minimum Off-Time Counting down	0 : Count-down at zero 1 : Minimum Off-Time counting Down
3	Minimum On-Time Counting down	0 : Count-down at zero 1 : Minimum On-Time counting Down
4	Re-start Delay Counting down	0 : Count-down at zero 1 : Re-start delay counting Down
5	Inhibit	0 : No inhibit (operation possible) 1 : STO circuit open, drive shows inhibit, operation not possible
6	Standby Mode	0 : Normal operation, not in standby 1 : Drive in Standby Mode
7	Drive Ready	0 : Drive not Ready 1 : Drive Ready, defined as <ul style="list-style-type: none"> <li>▪ Mains power applied</li> <li>▪ No Trip</li> <li>▪ No Inhibit</li> <li>▪ Enabled input present</li> </ul>
8	Current limit Active	0 : Current Limit Inactive 1 : Current Limit Active
9	Power Limit Active	0 : Power Limit Inactive 1 : Power Limit Active
10	Motor Thermal Management Active (Ixt)	0 : Motor Thermal Management Inactive 1 : Motor Thermal Management Active
11	Drive Thermal Management Active (Heatsink Temperature)	0 : Drive Thermal Management Inactive 1 : Drive Thermal Management Active
12	Start-up Sequence Active	0 : Start-up sequence not currently active 1 : Start-up sequence active and still in progress
13	Reserved	
14	Reserved	
15	Reserved	

The drive status word 2 consists of one individual byte:

Single Byte showing the last fault code when the drive has tripped.

#### 4.2.7. Drive Control Word (Modbus Register 1)

- Bit 0: Run/Stop command: Set to 1 to enable (run) the drive. Set to 0 to disable (stop) the drive.
- Bit 2: Coast stop request. Set to 1 to issue a coast stop command.
- Bit 3: Reset Fault Request. Set to 1 in order to reset the drive following a trip / fault.  
**NOTE** This bit must be reset to zero once the fault is cleared to prevent un-expected reset.
- Bit 4: User Relay Control: Set to 1 to close the onboard relay and set to 0 to open the onboard relay.  
**NOTE** This function only operates when parameter P3-05 = 6.
- Bit 5: Activate crankcase heating function.
- Bit 6: Reserved
- Bit 7: Reserved

### 4.3. Read-only Parameter List and Modbus Registers

Register	Comment	Command	Type	Scaling	Parameter
1	Drive Control Command Word	03, 06, 10	Read/Write		-
2	Speed Set Point (RPS)	03, 06, 10	Read/Write	600 = 60.0 rps	-
4	Modbus User Ramp Time	03, 06, 10	Read/Write	3000 = 300.0 Seconds	-
5	Speed Reference (IDL format)	03, 06, 10	Read/Write	3000 = 50.0Hz	-
6	Drive Status	3	Read Only		-
7	Output Frequency (Motor Speed)	3	Read Only	600 = 60.0 rps	P00-60
8	Output Current	3	Read Only	100 = 10.0 Amps	-
9	Trip Code	3	Read Only		-
10	Output Power	3	Read Only	1000 = 10.00kW	-
11	Digital Input Status	3	Read Only	Bit 0 = Digital input 1, etc	P00-03
12	Rating ID	3	Read Only		P00-29
13	Power Rating	3	Read Only		P00-29
14	Voltage Rating	3	Read Only		P00-29
15	IO Processor Software Version	3	Read Only	100 = 1.00	P00-28
16	Motor Control Processor Software Version	3	Read Only	100 = 1.00	P00-28
17	Drive Type	3	Read Only		P00-29
20	Analog Input Signal Level	3	Read Only	1000 = 100.0%	P00-01
22	Pre Ramp Speed Reference (RPS)	3	Read Only	600 = 60.0 rps	P00-04
23	DC bus Voltage	3	Read Only	600 = 600 Volts	P00-20
24	Drive Temperature	3	Read Only	40 = 40°C	P00-21
25	Drive Serial Number 4	3	Read Only		P00-30
26	Drive Serial Number 3	3	Read Only		P00-30
27	Drive Serial Number 2	3	Read Only		P00-30
28	Drive Serial Number 1	3	Read Only		P00-30
29	Relay Output Status	3	Read Only	0 = Open, 1 = Closed	-
32	kWh Meter	3	Read Only	100 = 10.0kWh	P00-26
33	MWh Meter	3	Read Only	100 = 100MWh	P00-27
34	Running Time – hour	3	Read Only		P00-31
35	Running Time – min/sec	3	Read Only		P00-31
36	Running Time since last enable – hour	3	Read Only		P00-34
37	Running Time since last enable – min/sec	3	Read Only		P00-34
39	Room (Control PCB) Temperature	3	Read Only	40 = 40°C	P00-05
40	Speed Reference value	3	Read Only	3000 = 50Hz	
42	Motor Speed (IDL Format)	3	Read Only	3000 = 50Hz	
43	Motor output voltage	3	Read Only	100 = 100V (AC)	P00-11
44	Indirect Parameter Access Index	3	Read/Write		-
45	Indirect Parameter Access Value	3	Read/Write		-

Par	Description	Display Range	Note	Comms Register
PO-01	Analog input value	-100.0 ... 100.0%	1dp, 0.0%~99.9% or 100%	20
PO-03	Digital input status	Binary: 00 ... 11 (Drive input)	Drive terminal input result (MSB = Digital input 1, LSB = AI1)	11
PO-04	Speed controller reference	- P1-02 ... P1-01	600 = 60.0rps with one decimal place	40
PO-05	Internal temperature	°C	No decimal place	39
PO-07	Speed ref via communications	- P1-02 ... P1-01	600 = 60.0rps with one decimal place	-
PO-08	User PI reference	0.0%... 100%	1 = 0.1%, 0.0% ~ 99.9% or 100%	-
PO-09	User PI feedback	0.0%... 100%	1 = 0.1%, 0.0% ~ 99.9% or 100%	-
PO-10	User PI output	0.0%... 100%	1 = 0.1%, 0.0% ~ 99.9% or 100%	-
PO-11	Applied motor voltage	V rms	No decimal place, 1 = 1V	43
PO-13	Trip log	Recent 4 trips with time tag	Four entries each with the trip code and the time stamp	-
PO-14	Magnetising current (Id)	A (rms)	Current shown with one decimal place	-
PO-15	Torque producing current (Iq)	A (rms)	Current shown with one decimal place	-
PO-16	Off time count down time	s	Displays the time remaining before the drive will be permitted to start as a consequence of the setting in P2-10	-
PO-17	On time count down time	s	Displays the time remaining before the drive will be permitted to stop as a consequence of the setting in P2-11	-
PO-18	Restart delay count down time	s	Displays the time remaining before the drive will be permitted to re-start as a consequence of the setting in P2-12	-
PO-19	Crankcase Heating Current	A	Displays the actual current injected into the motor during the crankcase heating operation	-
PO-20	DC bus voltage	V dc	No decimal place. 100 = 100V	23
PO-21	Heatsink temperature	Degrees C (calculated)	No decimal place. 10 = 10°C	24
PO-22	DC bus voltage ripple	V rms	No decimal place. 100 = 100V	-
PO-23	Time accumulated above 85°C (H/sink)	Display in hours and minutes		-
PO-24	Time accumulated above 80°C (ambient)	Display in hours and minutes		-
PO-25	Rotor speed	rps	600 = 60.0rps with one decimal place	-
PO-26	kWh meter	0.0 ... 999.9 kWh	One value only	32
PO-27	MWh meter	0.0 ... 65535 MWh	One value only	33
PO-28	Software version and checksum	Eg "IO 1.00 326B" "PS 1.00 526E"	Two entries First is IO version and checksum (no checksum over Modbus) Second is DSP version and checksum (no checksum over Modbus)	- 15 16
PO-29	Drive type	Size info, input voltage, power rating, Output phases, drive type etc	Four entries over Modbus First is frame size and input voltage level, as "F2 230" Second is power rating, as " 1.5" or "HP 10" Third is output phase number, as "3P-out" Fourth is the drive ID	- 12 13 14 17
PO-30	Drive Serial number	Unique drive identifier fixed during production	Four entries over Modbus to make up the serial number	25 26 27 28
PO-31	Hours run since date of manufacture	Display in hours and minutes	Two entries over Modbus - First is Hour Second is minute and second	34 35
PO-32	Run time since last trip (1)	Display in hours and minutes since last trip		-
PO-33	Run time since last trip (2)	Display in hours and minutes since previous trip		-

Par	Description	Display Range	Note	Comms Register
P0-34	Run time since enable	Display in hours and minutes since enable	Two entries over Modbus - First is Hour Second is minute and second	36 37
P0-35	Drive cooling fan run time	Display in hours		-
P0-36	DC bus voltage log (256ms)	Most recent 8 samples prior to trip	Eight entries	-
P0-37	DC bus voltage ripple log (20ms)	Most recent 8 samples prior to trip	Eight entries	-
P0-38	Heatsink temperature log (30s)	Most recent 8 samples prior to trip	Eight entries	-
P0-39	Ambient temperature log (30s)	Most recent 8 samples prior to trip	Eight entries	-
P0-40	Motor current log (256ms)	Most recent 8 samples prior to trip	Eight entries	-
P0-41	Critical fault counter – O-I	O-I trip counter (including h O-I)	No decimal place	-
P0-42	Critical fault counter – O-Volts	Over volts trip counter	No decimal place	-
P0-43	Critical fault counter – U-Volts	Under volts trip counter	No decimal place	-
P0-44	Critical fault counter – O-Temp (H/sink)	IGBT over temperature trip counter	No decimal place	-
P0-46	Critical fault counter – O-Temp(Amb)	Trip level is 85 degree C	No decimal place	-
P0-47	Internal I/O comms error count	0 ... 65535	No decimal place	-
P0-48	Internal DSP comms error count	0 ... 65535	No decimal place	-
P0-49	Modbus comms error count	0 ... 65535	No decimal place	-
P0-53	Current Phase U offset and ref	Internal value		-
P0-54	Current Phase V offset and ref	Internal value		-
P0-55	Current Phase W offset and ref	Internal value		-
P0-56	Drive life time	Hour/min/sec		-
P0-57	Ud/Uq	Internal value	No decimal place	-
P0-58	Output Current	A		-
P0-59	Output Power	kW		-
P0-60	Output Frequency	rps	600 = 60.0rps with one decimal place	-
P0-61	Post ramp speed reference	rps	600 = 60.0rps with one decimal place	-
P0-62	User ramp value	S2...S3 0.00 to 600s;	S2...S3 1 = 0.01s with 1 dp display as 0.01s~0.09s, 0.1s~9.9s, 10s~600s	-
P0-63	Overload level	%	% of overload level	-
P0-64	Switching frequency internal	4 ~ 32kHz		-
P0-65	Motor control lib version	1	motor control lib version	-

## 4.4. Full Parameter List and Modbus Registers

### 4.4.1. Group 1 Parameters & Modbus Registers

Par	Mod Add	Description	Def	Min	Max	Unit	R/W
1-01	101	<b>Maximum Speed Limit</b>	<b>60</b>	<b>P1-02</b>	<b>500</b>	<b>Rps</b>	<b>R/W</b>
		Sets the upper limit for the speed of the motor in rps (revolutions per second). This can be set to any value between the minimum speed limit (P1-02) and 5x the motor rated speed (as set in P1-10).					
1-02	102	<b>Minimum Speed Limit</b>	<b>20-</b>	<b>0</b>	<b>P1-01</b>	<b>Rps</b>	<b>R/W</b>
		Sets the lower limit for the speed of the motor in rps (revolutions per second). This can be set to any value between 0 and the maximum speed limit (P1-01).					
1-03	103	<b>Acceleration Ramp Time from 0 rps to Rated Speed (P1-10)</b>	<b>30</b>	<b>0</b>	<b>6000</b>	<b>s</b>	<b>R/W</b>
		Active if the start-up sequence is not configured or has been completed					
1-04	104	<b>Deceleration Ramp Time from Rated Speed (P1-10) to 0 rps</b>	<b>30</b>	<b>0</b>	<b>6000</b>	<b>s</b>	<b>R/W</b>
1-05	105	<b>Stop Mode</b>	<b>0</b>	<b>0</b>	<b>3</b>	<b>-</b>	<b>R/W</b>
		<p>Determines the action taken by the drive in the event of the drive enable signal being removed.</p> <p><b>0: Ramp to Stop.</b> When the enable signal is removed, the drive will ramp to stop, with the rate controlled by P1-04 as described above.</p> <p><b>1: Coast to Stop.</b> When the enable signal is removed, the drive output is immediately disabled, and the motor will coast (freewheel) to stop.</p> <p><b>2: AC Flux Braking (IM Motor only).</b> This mode is only valid for induction motors. AC Flux braking provides improved braking torque during stopping and deceleration.</p> <p><b>3: Ramp to minimum speed and then coast to stop.</b> When the enable signal is removed, the drive will ramp down to the minimum speed at the configured deceleration ramp. When the minimum speed is reached, the output is immediately disabled, and the motor will coast (freewheel) to stop.</p>					
1-06	106	<b>V/F Torque Boost</b>	<b>2.5</b>	<b>0.1</b>	<b>20</b>	<b>%</b>	<b>R/W</b>
		Torque Boost is used to increase the applied motor voltage and hence motor current at low output frequencies. This can improve starting torque and torque at low speeds. Increasing the boost level will increase motor current at low speed, which may result in the motor temperature rising - forced 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. This mode is only operational in V/F mode with P5-01 = 4.					
1-07	107	<b>Motor Rated Voltage (Phase to Phase)</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>V</b>	<b>R/W</b>
		Or Back EMF (phase to phase) at rated speed for permanent magnet motor types.					
1-08	108	<b>Motor Rated Current</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>A</b>	<b>R/W</b>
		By setting the motor rated current in the drive, the motor overload protection is configured to match the motor rating.					
1-09	109	<b>Motor Rated Frequency</b>	<b>180</b>	<b>20</b>	<b>500</b>	<b>Hz</b>	<b>R/W</b>
		The rated frequency of the motor. This is the frequency at which rated voltage (set in P1-07) is applied to the motor. Below this frequency, the applied motor voltage will be reduced.					
1-10	110	<b>Motor Rated Speed at Rated Frequency In Rps (Revolutions per Second)</b>	<b>60</b>	<b>0</b>	<b>500</b>	<b>Rps</b>	<b>R/W</b>
1-11	111	<b>Primary Command Source</b>	<b>0</b>	<b>0</b>	<b>4</b>	<b>-</b>	<b>R/W</b>
		<p><b>0: Modbus Mode.</b> The drive is controlled by serial communications.</p> <p><b>1: Terminal Mode.</b> The drive is start/stop is controlled by the digital input and the speed reference provided by the analogue input.</p> <p><b>2: Terminal Mode (All &gt; 10% Start).</b> The drive is enabled by the digital input and the speed reference provided by the analogue input. The start command is given when the analogue input exceeds 10%.</p> <p><b>3: User PI Mode.</b> The drive is enabled by the digital input and the speed is controlled by the internal PI controller.</p> <p><b>4: Slave Mode.</b> The drive is enabled by the digital input but the start/stop and speed reference is controlled by the connected Coolvert drive operating in Master mode.</p>					

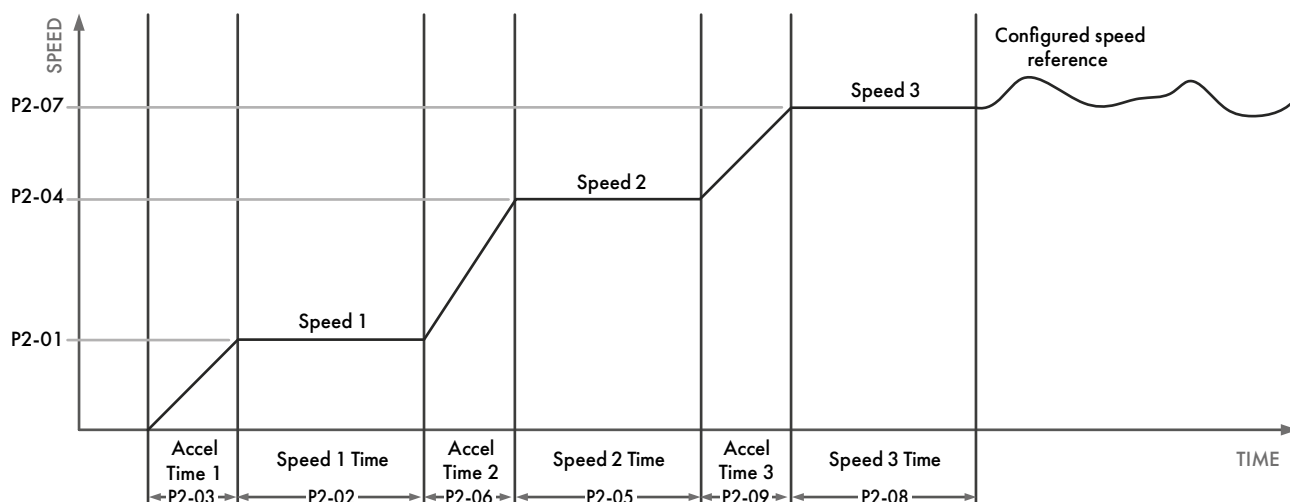
#### 4.4.2. Group 2 Parameters & Modbus Registers

Par	Mod Add	Description	Def	Min	Max	Unit	R/W
2-01	201	<b>Start Speed 1 (rps)</b>	<b>30</b>	<b>P1-02</b>		<b>Rps</b>	<b>R/W</b>
		Start-up sequence speed 1. If Start Speed 1 Time (P2-02) is greater than zero, the drive will ramp up to the speed set in this parameter for the time set in P2-02 on each start-up. If the time set in P2-02 is zero, this section of the start-up sequence is ignored.					
2-02	202	<b>Start Speed 1 Time</b>	<b>60</b>	<b>0</b>	<b>600</b>	<b>s</b>	<b>R/W</b>
		This time is the time that the drive will sit at Start Speed 1 on each start-up. This section of the start-up sequence is disabled if this time is set to zero.					
2-03	203	<b>Start Speed 1 Acceleration Ramp</b>	<b>30</b>	<b>0</b>	<b>6000</b>	<b>s</b>	<b>R/W</b>
		This is the acceleration ramp used to ramp up from 0 rps to Start Speed 1 if the function is enabled. Ramp rate is defined as time to get to rated speed from zero speed.					
2-04	204	<b>Start Speed 2 (rps)</b>	<b>30</b>	<b>P1-02</b>		<b>Rps</b>	<b>R/W</b>
		Start-up sequence speed 2. If Start Speed 2 Time (P2-05) is greater than zero, the drive will ramp up to the speed set in this parameter for the time set in P2-05 on each start-up. If the time set in P2-05 is zero, this section of the start-up sequence is ignored.					
2-05	205	<b>Start Speed 2 Time</b>	<b>60</b>	<b>0</b>	<b>600</b>	<b>s</b>	<b>R/W</b>
		This time is the time that the drive will sit at Start Speed 2 on each start-up. This section of the start-up sequence is disabled if this time is set to zero.					
2-06	206	<b>Start Speed 2 Acceleration Ramp</b>	<b>30</b>	<b>0</b>	<b>6000</b>	<b>s</b>	<b>R/W</b>
		This is the acceleration ramp used to ramp up from Start Speed 1 up to Start Speed 2 if the function is enabled. Ramp rate is defined as time to get to rated speed from zero speed.					
2-07	207	<b>Start Speed 3 (rps)</b>	<b>30</b>	<b>P1-02</b>		<b>Rps</b>	<b>R/W</b>
		Start-up sequence speed 3. If Start Speed 3 Time (P2-08) is greater than zero, the drive will ramp up to the speed set in this parameter for the time set in P2-08 on each start-up. If the time set in P2-08 is zero, this section of the start-up sequence is ignored.					
2-08	208	<b>Start Speed 3 Time</b>	<b>60</b>	<b>0</b>	<b>600</b>	<b>s</b>	<b>R/W</b>
		This time is the time that the drive will sit at Start Speed 3 on each start-up. This section of the start-up sequence is disabled if this time is set to zero.					
2-09	209	<b>Start Speed 3 Acceleration Ramp</b>	<b>30</b>	<b>0</b>	<b>6000</b>	<b>s</b>	<b>R/W</b>
		This is the acceleration ramp used to ramp up from Start Speed 2 to Start Speed 3 if the function is enabled. Ramp rate is defined as time to get to rated speed from zero speed.					
2-10	210	<b>Minimum Off Time</b>	<b>0</b>	<b>0</b>	<b>6000</b>	<b>s</b>	<b>R/W</b>
		This parameter when set greater than 0, defines the minimum time that the drive must be stopped for before allowing a re-start. The remaining time before the drive can start is available in PO-16. <b>NOTE</b> This time is valid also from first power-up.					
2-11	211	<b>Minimum On Time</b>	<b>0</b>	<b>0</b>	<b>6000</b>	<b>s</b>	<b>R/W</b>
		This parameter when set greater than 0, defines a minimum time that the drive must run for once it has started, it will delay a stop command if the time set in this parameter has not elapsed. Please note that if the drive is configured for Coast to stop (P1-05 = 1) or if the drive is below minimum speed when the stop command is issued, this function will be ignored. The STO input overrides this function. The remaining time before the drive can be stopped is available in PO-17					
2-12	212	<b>Re-start Delay</b>	<b>0</b>	<b>0</b>	<b>6000</b>	<b>s</b>	<b>R/W</b>
		This parameter configures the minimum time between each compressor starts. Any start command requests given to the drive before the time set in this parameter has elapsed will be ignored until the Re-start delay time has been observed. The remaining time before the next permitted start can be seen in PO-18.					

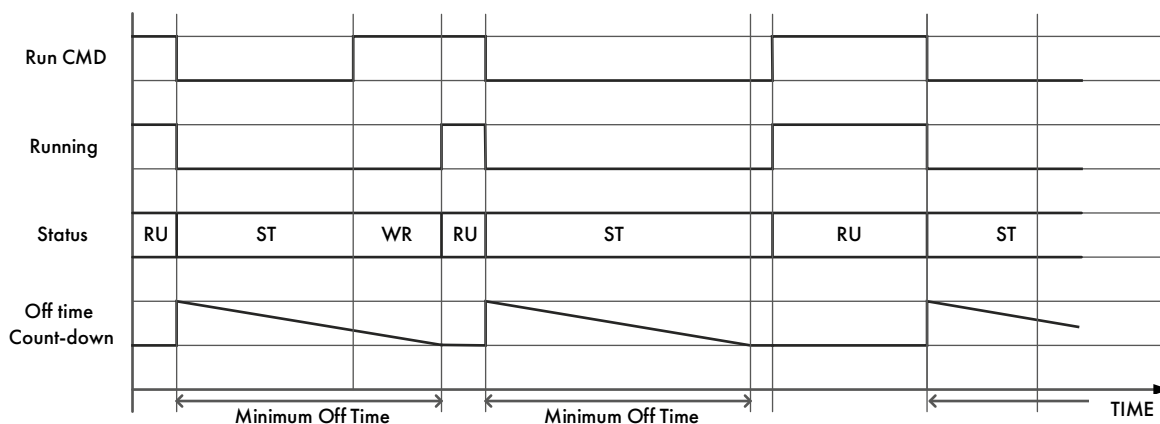


Par	Mod Add	Description	Def	Min	Max	Unit	R/W
2-13	213	<b>Drive Re-Start Function</b>	0	0	6	-	R/W
		<p>Defines the behaviour of the drive relating to the enable digital input and also configures the Automatic Restart function.</p> <p><b>Edge-r:</b> Following Power on or reset, the drive will not start if Digital Input 1 remains closed. The Input must be closed after a power on or reset to start the drive (e.g. Edge Triggered).</p> <p><b>Auto-0:</b> Following a Power On or Reset, the drive will automatically start if Digital Input 1 is closed before power on.</p> <p><b>Auto-1 to Auto-5:</b> Following a trip, the drive will make up to 5 attempts to restart at intervals defined by P6-03 (default 20 seconds).</p> <p>The drive must be powered down or reset manually to reset the counter. The numbers of restart attempts are counted, and if the drive fails to start on the final attempt, the drive will fault with, and will require the user to manually reset the fault.</p>					
2-14	214	<b>Crankcase Heating Current</b>	0	0	100%	%	R/W
		<p>When this function is activated by serial communication, it will inject this percentage of the motor rated current into the motor in pulses when the drive is not running in order to heat-up the crankcase. The STO must be active to permit this function to operate.</p> <p><b>CAUTION</b> Too high a setting of this current activated for too long could cause damage to the motor.</p>					

**Start-Up Speed Profile**



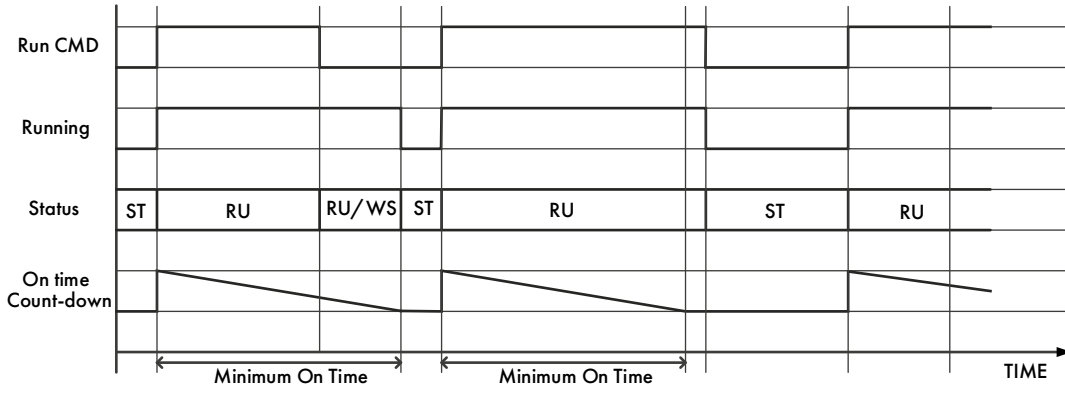
**Minimum Off Time Sequencing**



**KEY:**

**RU** Running    **ST** Stopped    **WR** Waiting to Run

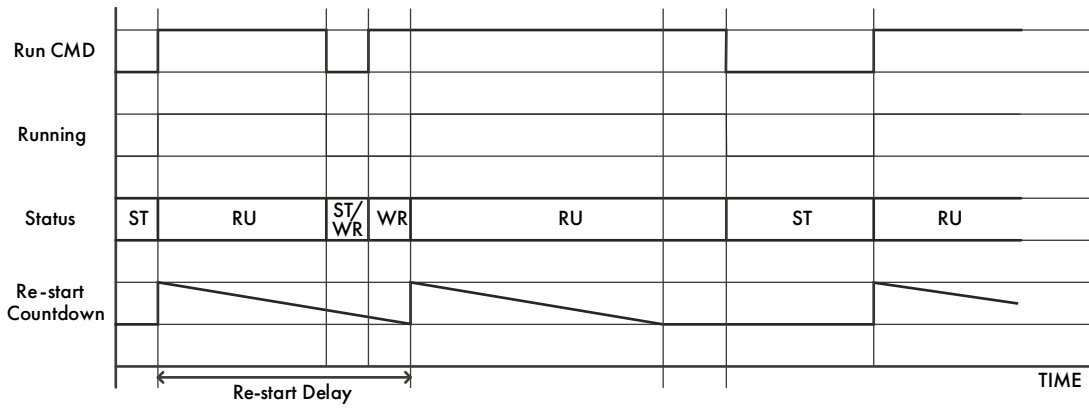
**Minimum On Time Sequencing**



**KEY:**

**RU** Running   **ST** Stopped   **WS** Waiting to Stop

**Re-Start Delay**



**KEY:**

**RU** Running   **ST** Stopped   **WS** Waiting to Stop



#### 4.4.4. Group 4 Parameters & Modbus Registers

Par	Mod Add	Description	Def	Min	Max	Unit	R/W
4-01	401	<b>PI Controller Proportional Gain</b>	1	0.1	30.0	-	R/W
		Higher values provide a greater change in the drive output frequency in response to small changes in the feedback signal. Too high a value can cause instability.					
4-02	402	<b>PI Controller Integral Time</b>	1	0.0	30.0	S	R/W
		Larger values provide a more damped response for systems where the overall process responds slowly.					
4-03	403	<b>PI Operating Mode</b>	0	0	1	-	R/W
		<b>0: Direct Operation.</b> Use this mode if a reduction in the feedback signal should result in an increase in the motor speed. <b>1: Inverse Operation.</b> Use this mode if an increase in the feedback signal should result in an increase in the motor speed.					
4-04	404	<b>PI Set-Point</b>	0.0	0.0	100	%	R/W
		This parameter sets the digital reference (setpoint) used for the PID Controller.					
4-05	405	<b>User PI Controller Output High Limit</b>	100	P4-06	100	%	R/W
		Limits the maximum value output from the PI controller.					
4-06	406	<b>User PI Controller Output Low Limit</b>	0	0	P4-05	%	R/W
		Limits the minimum output from the PI controller.					
4-07	407	<b>PI Error To Enable Ramps</b>	0.0	0.0	25.0	%	R/W
		Defines a threshold PI error level, whereby if the PI error is less than the set threshold, the internal ramps of the drive are disabled.					
4-08	408	<b>PI Error Wake-Up Level</b>	5.0	0.0	100	%	R/W
		Sets an error level (difference between the PID reference and feedback values) above which the PID controller will wake from Standby mode.					
4-09	409	<b>Standby Speed Threshold</b>	0	0	P1-01	Rps	R/W
		Specifies the speed boundary below which the drive enters Standby mode after the delay period P4-10. If the speed increases above this threshold when the drive is in Standby mode, normal operation will be resumed.					
4-10	410	<b>Standby Mode Timer</b>	0	0	6000	S	R/W
		Enables the standby mode, <b>0: Standby mode disabled.</b> <b>Non-zero: The drive will enter standby mode (output disabled) if the Standby Speed Threshold (P4-09) is maintained for the time specified in this parameter.</b> Operation automatically resumes as soon as the PI Error increases above the value set in P4-08.					
4-11	411	<b>PI Reset Control</b>	0	0	1	-	R/W
		Selects whether the internal PI controller operates continuously, or is disabled when the drive stops. With continuous operation, the PI function is always active, which can result in the PI controller reaching maximum output whilst the drive is disabled. Resetting the PI controller on drive disable means the PI output will always start from zero when the drive is enabled. <b>0: PI loop will run continuously as long as P gain (P4-01) is not zero.</b> <b>1: PI loop will only run when the drive is enabled.</b> If the drive is not running, the PI output will be reset to 0 (including the integral result).					

#### 4.4.5. Group 5 Parameters & Modbus Registers

Par	Mod Add	Description	Def	Min	Max	Unit	R/W
5-01	501	<b>Motor Control Mode</b>	<b>0</b>	<b>0</b>	<b>6</b>	-	R/W
		<b>0: BLDC vector speed control</b> <b>1: Permanent Magnet Vector Speed Control</b> <b>2: Induction Motor Vector Speed Control (CT)</b> <b>3: Induction Motor Vector Speed Control (VT)</b>	<b>4: Induction Motor V/F</b> <b>5: Synchronous Reluctance Vector Speed Control</b> <b>6: LSPM speed control</b>				
5-02	502	<b>Motor Parameter Autotune</b>	<b>0</b>	<b>0</b>	<b>1</b>	-	R/W
		When set to 1, the drive immediately carries out a non-rotating autotune to measure the motor parameters for optimum control and efficiency. Following completion of the autotune, the parameter automatically returns to 0.					
5-03	503	<b>Vector Speed Controller Proportional Gain</b>	<b>50</b>	<b>0.1</b>	<b>400</b>	%	R/W
		Sets the proportional gain value for the speed controller when operating in Vector Speed motor control mode (P5-01 < 4).					
5-04	504	<b>Vector Speed Controller Integral Time Constant</b>	<b>0.050</b>	<b>0.001</b>	<b>2.00</b>	s	R/W
		Sets the integral time for the speed controller in Vector Speed control mode (P5-01 < 4).					
5-05	505	<b>Motor Power Factor (Cos Ø)</b>	<b>dd</b>	<b>0.5</b>	<b>0.99</b>	-	R/W
		When operating with induction motors in Vector Speed or Vector Torque motor control modes, this parameter must be set to the motor nameplate power factor before autotuning.					
5-06	506	<b>Effective Power Stage Switching Frequency</b>	<b>0</b>	<b>0</b>	<b>6</b>	-	R/W
		Higher frequency reduces the audible 'ringing' noise from the motor, and improves the output current waveform, at the expense of increased heat losses within the drive.					
5-07	507	<b>Maximum Current Limit</b>	<b>110</b>	<b>20</b>	<b>130</b>	%	R/W
		This parameter defines the maximum current limit used by the drive as a percentage of motor rated current (P1-07).					
5-08	508	<b>Motor Power Limit</b>	-	-	-	-	R/W
		This parameter set's the power limit of the drive in percentage of drive rating. If this power limit is reached, the drive will fold back the output frequency to keep within the configured limit.					
5-09	509	<b>Motor Thermal Overload Management</b>	<b>0</b>	<b>0</b>	<b>1</b>	-	R/W
		When Motor Overload Management is enabled, full overload current will be available until the overload integrator approaches the I.t trip level. At this point, the current limit will be reduced automatically to the maximum level that can be sustained on a continuous basis. This will normally result in the speed of the motor automatically reducing. This feature is typically used in applications where overload trips need to be avoided and a reduction in speed can be accepted. When Thermal Overload Management is disabled, full overload current will be available until the drive trips on "I.t-trP".					
5-10	510	<b>Drive Thermal Overload Management</b>	<b>0</b>	<b>0</b>	<b>1</b>	-	R/W
		When enabled (P5-10 = 1), the drive will automatically set the current limit to 80% of the motor rated current if the heatsink temperature is greater than 90 degree C.					
5-11	511	<b>Motor Thermal Overload Retention Enable</b>	<b>1</b>	<b>0</b>	<b>1</b>	-	R/W
		When enabled, the motor thermal memory retention function will save the calculated motor thermal history on drive power down, using this saved value as the starting value on next power up. If this function is disabled, the motor thermal history is reset to zero on every power up.					
5-12	512	<b>Discontinuous Modulation Mode Select</b>	<b>0</b>	<b>0</b>	<b>7</b>	-	R/W
		<b>0: 3-Phase Modulation.</b> <b>1: 2-Phase Modulation.</b> 2-Phase modulation mode slightly improves drive efficiency of the drive but can cause more audible noise in the motor.					
5-13	513	<b>Enable Reverse Speed Selection</b>	<b>0</b>	<b>0</b>	<b>1</b>	-	R/W
		If this parameter is set to 1 (Enabled), it will allow a -ve speed reference to be written by serial communications to the drive which will cause reverse speed operation. This setting should be kept as 0 (disabled) if prevention of reverse operation is required.					



Par	Mod Add	Description	Def	Min	Max	Unit	R/W
6-06	606	<b>Fieldbus Ramp Control Enable</b>	0	0	1	-	R/W
		<p>Selects whether the acceleration and deceleration ramps are control directly via the Fieldbus, or by internal drive parameters.</p> <p><b>0: Disabled.</b> Ramps are control from internal drive parameters.</p> <p><b>1: Enabled.</b> Ramps are controlled directly by the Fieldbus.</p>					
6-07	607	<b>Modbus Response Delay</b>	0	0	16	Char	R/W
		<p>Defines the response delay time for Modbus communications. The value entered represents the delay expressed as the number of characters added to the minimum permitted Modbus response delay time.</p> <p>The actual delay time will vary depending on the Modbus communications baudrate.</p>					

#### 4.4.7. Group 7 Parameters & Modbus Registers

Par	Mod Add	Description	Def	Min	Max	Unit	R/W
7-01	701	<b>Automatic Thermal Management Minimum Switching Frequency</b>	0	0	6	-	R/W
		<p>During operation, the drive measures the power module temperature and will switch automatically to a lower switching frequency if the temperature reaches a pre-defined limit. This parameter determines the lowest frequency that can be used. In the event that the power module temperature continues to increase, the drive will trip on over temperature.</p>					
7-02	702	<b>Auto-reset Time Delay</b>	20	1	60	S	R/W
		<p>Sets the delay time which will elapse between consecutive drive reset attempts when Auto Reset is enabled in P2-13.</p>					
7-03	703	<b>Motor Stator Resistance (Rs)</b>	-	0.00	655.35	ohm	R/W
		<p>This is the motor phase to phase resistance value in ohms.</p>					
7-04	704	<b>Motor Stator Inductance (Lsd)</b>	-	0.0	6553.5	mH	R/W
		<p>For induction motors: phase stator inductance value. For permanent magnet motors: phase d-axis stator inductance in Henry (H).</p>					
7-05	705	<b>Motor Stator Inductance (Lsq)</b>	-	0.0	6553.5	mH	R/W
		<p>For permanent magnet motors : phase d-axis stator inductance in Henry (H).</p>					
7-06	706	<b>V/F Mode Magnetising Delay Time</b>	-	0	5000	Ms	R/W
		<p>This parameter is used to set up a minimum delay time for the magnetising current control in V/F mode when drive run signal is given. Too small a value may cause the drive to trip on over-current if the acceleration ramp is very short.</p>					
7-07	707	<b>Low Frequency Torque Boost Level</b>	0.0	0.0	100	%	R/W
		<p>Boost current applied at start-up, as % of motor rated current (P1-08). The drive provides a boost function that can inject some current into the motor at low speed to help ensure the rotor alignment is maintained and to allow effective operation of the motor at lower speeds. To implement low speed boost, run the drive at the lowest frequency required by the application and increase boost levels to provide both required torque and smooth operation.</p>					
7-08	708	<b>Low Frequency Torque Boost, Frequency Limit</b>	0.0	0.0	50	%	R/W
		<p>Frequency range for applied boost current (P7-07) as a %age of motor rated frequency (P1-09). This sets the frequency cut-off point above which boost current is no longer applied to the motor.</p>					

# 5. Diagnostics

## 5.1. Trips

Fault Code	No.	Description	Suggested Remedy
no-FLt	00	No Fault or No Trip	No fault in trip log – no problem with the drive
O-I	03	Instantaneous over current	High current from either – short-circuit on the drive output / acceleration ramps too short / incorrect motor data
I_t-trP	04	Motor Thermal Overload (I2t)	Drive has been delivering more than the configured motor rated current for a period of time – check the operating point of the compressor
PS-trP	05	Power stage trip	Hardware fault, contact the supplier of the drive
O-UoLt	06	Over voltage on DC bus	DC Bus Overvoltage from either - the supply voltage is too high, a spike in the supply voltage, motor instability, try setting P1-05 = 3
U-UoLt	07	Under voltage on DC bus	Usually caused by the supply voltage dropping too low – check connections and voltage at the drive terminals
O-t	08	Heatsink over temperature	Check the ambient temperature, check that the ventilation is not restricted, check the cooling system for the coldplate version
U-t	09	Under temperature	Drive heatsink temperature is too low
P-dEF	10	Factory Default parameters have been loaded	Warning to advise that the drive has been returned to factory defaults
SC-ObS	12	Optibus comms loss	Loss of communications between drive and remote keypad or PC tools
FLt-dc	13	DC bus ripple too high	Check for supply phase imbalance or phase loss
P-LOSS	14	Input phase loss trip	Input phase loss trip – similar to FLt.dc above
h O-I	15	Instantaneous over current on drive output	Hardware overcurrent on drive output – similar to O-I trip above
tH-FLt	16	Faulty thermistor on heatsink	If the drive heatsink temperature is within limits, contact the supplier of the drive
dRtA-F	17	Internal memory fault (IO)	If not coinciding with a firmware upgrade procedure, contact the supplier of the drive
4-20 F	18	4-20mA Signal Lost	Analogue input configured for 4-20mA but less than 3mA detected on drive terminals
dRtA-E	19	Internal memory fault (DSP)	If not coinciding with a firmware upgrade procedure, contact the supplier of the drive
U-dEF	20	User Default Parameters Loaded	User Default Parameters Loaded
F-Ptc	21	Motor PTC thermistor trip	Drive configured to monitor motor temperature through the PTC and resistance increases above 2.5k
FRn-F	22	Cooling Fan Fault	Drive cooling fan not running at demanded speed – check for any blockages in the cooling fan
O-hEAt	23	Environmental temperature too high	Check ambient temperature and ventilation system
OUt-F	26	Drive output fault	Check for wiring faults, loose connections or badly terminated cables between the drive and the motor
Sto-F	29	Safety input circuit error	Can happen if an external 24V supply is used and it powers-up slowly – contact the supplier of the drive in all other events
RtF-O1	40	Measured motor stator resistance varies between phases	Check the motor wiring, disconnect the drive and measure the phase to phase resistance from the motor cable
RtF-O2	41	Measured motor stator resistance is too large	Check the motor wiring, disconnect the drive and measure the phase to phase resistance from the motor cable and refer to motor datasheet
RtF-O3	42	Measured motor inductance is too low	Check the motor wiring
RtF-O4	43	Measured motor inductance is too large	Check the motor wiring
RtF-O5	44	Measured motor parameters are not convergent	Check the motor wiring
OUt-Ph	49	Motor output phase loss	Check the motor wiring
SC-FD1	50	Modbus comms loss fault	Check the Modbus wiring, ensure that the OV common is used, ensure that the communication wiring is kept away from any power wiring



## 5.2. Status LED Indication

Two LEDs are used to indicate the drive status as follows:

Drive Status	LED 1 Status		LED 2 Status
	Green	Red	Yellow
Stop / Inhibit	Slow flashing	Off	Off
Running	Constant On	Off	Slow flashing if in overload
Standby	Constant On	Off	Blink every 3s
Trip / Fault	Off	Constant On	Off
Internal Comms Loss	Off	Blink every 3s	Off
Optistick Transfer Pass	Fast Flashing 2s	Off	Off
Optistick Transfer Fail	Off	Fast Flashing 5s	Off
Optistick Fail Other	Off	Off	Fast Flashing 5s
DSP Firmware Upgrade	All three LEDs lights up in order (Green->Yellow->Red->Yellow...)		
IO Firmware Upgrade	All LEDs on with weak light		

## 6. Technical Data

### 6.1. General

Input Ratings	
Supply Voltage	200 - 240V ± 10%
	380 - 480V ± 10%
Maximum Isc	100kA when installed in a suitable enclosure
Supply Frequency	48 - 62Hz
Displacement Power Factor	>0.98
Permissible phase imbalance	3% maximum
Inrush Current	< rated current
Power Cycles	120 per hour evenly spaced

Output Ratings	
Output Power	200V: 1.5 - 3.0kW
	400V: 5.5 - 11kW
Overload Capacity	130% for 10s - see rating tables for detailed values
Output Frequency	0-500Hz
Acceleration Time	0.01 - 600s
Deceleration Time	0.01 - 600s
Maximum Motor Cable Length	10m shielded, 20m unshielded

Ambient Conditions	
Temperature	Storage: -40°C to 70°C
	Operation: -20°C to 60°C
Altitude	Up to 1000m ASL without derating
	Up to 2000m ASL UL approved
	Up to 4000m ASL maximum (non UL)
Humidity	95% Maximum, non-condensing
Vibration	Conforms to EN61800-5-1

Environmental	
Ingress Protection (IP)	Front IP20
	Rear (Through Panel Mounting) IP55
Coated PCBs	Designed for operation in 3S2/3C2 environments according to IEC 60721-3-3

Programming	
Modbus RTU (RS485)	Modbus RTU on Pluggable terminals and through RJ45 port
PC Tools	PC Tools software for Diagnostics and parameter configuration (RJ45 port only)
Keypad	Optional Remote Keypad with TFT display for diagnostic and programming

Control Specification	
Output Voltage	0 - Vin
PWM Frequency	4 – 32kHz
Stop Mode	Ramp to stop, Ramp to minimum speed then coast to stop, Coast to stop
Skip Frequency	2 skip frequencies, user adjustable
Control Modes	Modbus RTU (RS485)
	Terminal Control Digital / Analogue
	Terminal Control PI mode
	Master / Slave Mode

I/O Specification	
Power Supply	24 Volt DC, 100mA, Short Circuit Protected
Digital Inputs	1 (24V Positive Logic)
Analogue Inputs	1 (0-10V, 0-20mA, 4-20mA, PTC)
Relay Outputs	1 (AB type)
	Maximum Voltage 250VAC, 30VDC
	Switching Current Capacity: 6A AC, 5A DC
	Resistive Load
Safe Torque Off (STO)	Independently approved STO input

Safe Torque Off (STO)	
IEC 61800-5-2:2016	SIL 3
EN ISO 13849-1:2015	PL "e"
EN 61508 (Part 1 to 7): 2010	SIL 3
EN 60204-1: 2006 & A1: 2009	Cat 0
EN 62061: 2005 & A2: 2015	SIL CL 3

Application Features	
PI Control	Internal PI Controller.
3 - step start-up profile	Start-up profile configurable with up to 3-steps to reduce the risk of oil migration and support better charge distribution in the system.
Compressor start-up protection	Several configurable built-in compressor protection features including Minimum Compressor On Time, Minimum Compressor Off Time and Compressor Restart Delay.
Intelligent Drive Thermal Management	Reduced-load operation of the compressor can be configured under high drive temperatures to prevent nuisance tripping.
Intelligent Motor Thermal Management	Reduced-load operation of the compressor can be configured under continued motor overload to prevent nuisance tripping.
Serial Communications-Loss Fall-Back Speed	The ability to configure the drive to run at a 'safe' speed in the event of a loss of serial communication. Can prevent loss of cooling/heating.
Master Follower Configuration	The ability to run a cascade of compressors with one Master regulating the operating point in PI Control.

Maintenance & Diagnostics	
Fault Memory	Last 3 trips stored with time stamp
Data Logging	Logging of data prior to last trip for diagnostic purposes: <ul style="list-style-type: none"> <li>▪ Output Current</li> <li>▪ Drive Temperature</li> <li>▪ DC Bus Voltage.</li> </ul>
Monitoring	Hours Run Meter
	kWH

Conformance	
The CoolVert product range conforms to the relevant safety provisions of the following council directives: 2014/30/EU (EMC) and 2014/35/EU (LVD).	
Designed and manufacture is in accordance with the following harmonised European standards:	
EN 61800-5-1: 2007 & A1: 2017	Adjustable speed electrical power drive systems. Safety requirements. Electrical, thermal and energy.
EN 61800-3: 2004 & A1 2012	Adjustable speed electrical power drive systems. EMC requirements and specific test methods.
EN 55011: 20016 & A1: 2017	Limits and Methods of measurement of radio disturbance characteristics of industrial, scientific and medical (ISM) radiofrequency equipment (EMC).
EN60529: 1992 & A2: 2013	Specifications for degrees of protection provided by enclosures.
UL 61800-5-1	cUL Listed *
RohS	

\* Pending. Drive variants with a heatsink are cUL listed whereas the coldplate variants are cUR recognised.

## 6.2. Detailed Product Rating Tables

Part Number	Power Rating		Input Current	Fuse or MCB (Type B)		Max Input Cable Size		Continuous Output Current	Overload Output Current	Maximum Output Cable Size		Maximum Motor Cable Length	
	kW	HP	A	Non UL	UL	mm <sup>2</sup>	awg	A	A	mm <sup>2</sup>	awg	m	ft
CV-240070-1FHP	1.5	2	8.9	16	15	16	6	7	9.1	6	10	10	33
CV-240120-1FHP	3	3	15.8	25	25	16	6	12	13.2	6	10	10	33
CV-240070-1FCP	1.5	2	8.9	16	15	16	6	7	9.1	6	10	10	33
CV-240120-1FCP	3	3	15.8	25	25	16	6	12	13.2	6	10	10	33
CV-240140-3FHE	5.5	7.5	12	16	15	6	10	14	18.2	6	10	10	33
CV-240180-3FHE	7.5	10	16	25	25	6	10	18	23.4	6	10	10	33
CV-240240-3FHE	11	15	22	25	25	6	10	24	28	6	10	10	33
CV-240140-3FCE	5.5	7.5	12	16	15	6	10	14	18.2	6	10	10	33
CV-240180-3FCE	7.5	10	16	25	25	6	10	18	23.4	6	10	10	33
CV-240240-3FCE	11	15	22	25	25	6	10	24	28	6	10	10	33

**NOTE** Maximum permissible motor cable without the use of output filters is 10m with shielded cable and 20m with unshielded cable – for all ratings.

## 6.3. Temperature and Switching Frequency De-rating Requirements for Coolvert

### 6.3.1 230V Single Phase

#### CV-220070-1FHP / CV-220070-1FCP

Switching Frequency	Maximum continuous output current at ambient temperature						
	0	10	20	30	40	50	60
4 kHz	7	7	7	7	7	7	7
8 kHz	7	7	7	7	7	7	7
12 kHz	7	7	7	7	7	7	7
16 kHz	7	7	7	7	7	7	7
24 kHz	7	7	7	7	7	7	4.7
32 kHz	7	7	7	7	7	6.5	3.7

**CV-220120-1FHP / CV-220120-1FCP**

Switching Frequency	Maximum continuous output current at ambient temperature						
	0	10	20	30	40	50	60
4 kHz	12	12	12	12	12	12	11.5
8 kHz	12	12	12	12	12	12	10
12 kHz	12	12	12	12	12	11.5	9
16 kHz	12	12	12	12	12	11	8.5
24 kHz	12	12	12	12	12	10.5	8
32 kHz	12	12	12	12	12	9.5	7.5

**6.3.2 400V 3-phase Models**

**CV-240140-3FHE / CV-240140-3FCE**

Switching Frequency	Maximum continuous output current at ambient temperature						
	0	10	20	30	40	50	60
10 kHz	14	14	14	14	14	14	14
12 kHz	14	14	14	14	14	14	14
14 kHz	14	14	14	14	14	14	13.5
16 kHz	14	14	14	14	14	14	13
18 kHz	14	14	14	14	14	14	12.5
20 kHz	14	14	14	14	14	14	11.5

**CV-240180-3FHE / CV-240180-3FCE**

Switching Frequency	Maximum continuous output current at ambient temperature						
	0	10	20	30	40	50	60
10 kHz	18	18	18	18	18	18	18
12 kHz	18	18	18	18	18	18	16.5
14 kHz	18	18	18	18	18	18	15
16 kHz	18	18	18	18	18	18	13.5
18 kHz	18	18	18	18	18	17	12
20 kHz	18	18	18	18	18	16	10

**CV-240240-3FHE / CV-240240-3FCE**

Switching Frequency	Maximum continuous output current at ambient temperature						
	0	10	20	30	40	50	60
10 kHz	24	24	24	24	24	24	22
12 kHz	24	24	24	24	24	23	18
14 kHz	24	24	24	24	24	21	16.5
16 kHz	24	24	24	24	24	19	15
18 kHz	24	24	24	24	24	17.5	14
20 kHz	24	24	24	24	24	17	13

- The drive is protected against short-circuit from power output to protective earth for all rated cable lengths, cable sizes and cable types.
- The maximum cable lengths stated here are based on hardware limitations and do NOT take into consideration any requirements for compliance to any EMC standards. Please see section 3.3. *EMC Compliant Installation on page 14* for further information.
- Supply and motor cable sizes should be dimensioned according to local codes or regulations in the country or area of installation.
- For UL compliant installation, use Copper wire with a minimum insulation temperature rating of 70°C, UL Class CC or Class J Fuses.

## 6.4. Input Power Supply Requirements

Supply Voltage	200 – 240 RMS Volts for 230 Volt rated units, + / - 10% variation allowed.
	380 – 480 Volts for 400 Volt rated units, + / - 10% variation allowed.
Imbalance	Maximum 3% voltage variation between phase – phase voltages allowed.
	All Optidrive CoolVert units have phase imbalance monitoring. A phase imbalance of > 3% will result in the drive tripping.
Frequency	50 – 60Hz + / - 5% Variation.

## 6.5. Additional Information for UL Approved Installations\*

Optidrive CoolVert is designed to meet the UL requirements. In order to ensure full compliance, the following must be fully observed.

Input Power Supply Requirements				
Short Circuit Capacity	Voltage Rating	Min kW (HP)	Max kW (HP)	Maximum supply short-circuit current
	All	All	All	100kA rms (AC)
All the drives in the above table are suitable for use on a circuit capable of delivering not more than the above specified maximum short-circuit Amperes symmetrical with the specified maximum supply voltage when installed in a suitable enclosure.				
Incoming power supply connection must be according to section 3.3.2. <i>Incoming Power Connection</i> .				
All Optidrive Coolvert units are intended for indoor installation within controlled environments which meet the condition limits shown in section 6.1. <i>General</i> .				
Branch circuit protection must be installed according to the relevant national codes. Fuse ratings and types are shown in section 6.2. <i>Detailed Product Rating Tables</i> .				
Suitable Power and motor cables should be selected according to the data shown in section 3.3.2. <i>Incoming Power Connection</i> and section 6.2. <i>Detailed Product Rating Tables</i> .				
Power cable connections and tightening torques are shown in section 3.1.2. <i>Before Installation</i> and section 3.3.2. <i>Incoming Power Connection</i> and section.				
Optidrive CoolVert provides motor overload protection in accordance with the National Electrical Code (US). <ul style="list-style-type: none"> <li>▪ Where a motor thermistor is not fitted, or not utilised, Thermal Overload Memory Retention must be enabled by setting P5-11 = 1.</li> <li>▪ Where a motor thermistor is fitted and connected to the drive, connection must be carried out according to the information shown in section 3.3.6. <i>Motor Thermal Overload Protection</i>.</li> </ul>				
For Canadian Installations: transient surge suppression shall be installed on the line side of this equipment and shall be rated as shown below, suitable for over voltage category III and shall provide protection for a rated impulse withstand voltage peak of 2.5kV.				
Supply Voltage Rating of the Drive		Phase-Phase Surge Protection Voltage Rating	Phase-Ground Surge Protection Voltage Rating	
200 - 240V AC + / - 10%		230V AC	230V AC	
380 - 480V AC + / - 10%		480V AC	480V AC	

\* UL certification pending

## 7. Useful Conversions and Formulae

Table showing the electrical frequency of the power applied to the motor and the rotational speed of the motor in both rpm (revolutions per minute) and rps (revolutions per second) for motors with different number of electrical poles:

2 Poles		
Hz	rpm	rps
20	1200	20
30	1800	30
40	2400	40
50	3000	50
60	3600	60
70	4200	70
80	4800	80
90	5400	90
100	6000	100
120	7200	120
140	8400	140
160	9600	160
180	10800	180
200	12000	200
220	13200	220
240	14400	240
260	15600	260
280	16800	280
300	18000	300
320	19200	320
340	20400	340
360	21600	360
380	22800	380
400	24000	400
420	25200	420

4 Poles		
Hz	rpm	rps
20	600	10
30	900	15
40	1200	20
50	1500	25
60	1800	30
70	2100	35
80	2400	40
90	2700	45
100	3000	50
120	3600	60
140	4200	70
160	4800	80
180	5400	90
200	6000	100
220	6600	110
240	7200	120
260	7800	130
280	8400	140
300	9000	150
320	9600	160
340	10200	170
360	10800	180
380	11400	190
400	12000	200
420	12600	210

6 Poles		
Hz	rpm	rps
15	300	5
30	600	10
45	900	15
60	1200	20
75	1500	25
90	1800	30
105	2100	35
120	2400	40
135	2700	45
150	3000	50
165	3300	55
180	3600	60
195	3900	65
210	4200	70
225	4500	75
240	4800	80
255	5100	85
270	5400	90
285	5700	95
300	6000	100
315	6300	105
330	6600	110
345	6900	115
360	7200	120
375	7500	125

8 Poles		
Hz	rpm	rps
20	300	5
40	600	10
60	900	15
80	1200	20
100	1500	25
120	1800	30
140	2100	35
160	2400	40
180	2700	45
200	3000	50
220	3300	55
240	3600	60
260	3900	65
280	4200	70
300	4500	75
320	4800	80
340	5100	85
360	5400	90
380	5700	95
400	6000	100
420	6300	105
440	6600	110
460	6900	115
480	7200	120
500	7500	125



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