CONTROL TECHNIQUES

User Guide

MultiAx

SLM technology

Compact high-performance, 3-axis servo amplifier for brushless AC servo motors

Part Number: 0437-0005
Issue Number: 3

General Information

The manufacturer accepts no liability for any consequences resulting from inappropriate , negligent or incorrect installation or adjustment of the optional operating parameters of the equipment or from mismatching the drive with the motor.

The contents of this User Guide are believed to be correct at the time of printing. In the interests of a commitment to a policy of continuous development and 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.

Important...

Servo-amplifier software version

This product is supplied with the latest version of user-interface and machine-control software. If this product is to be used with other Control Techniques servo amplifiers in an existing system, there may be some differences between their software and the software in this product. These differences may cause a difference in functions. This may also apply to servo amplifiers returned from a Control Techniques Service Centre.

If there is any doubt, contact a Control Techniques Drive Centre.

Issue Code: 3

Software: V07.02.00 onwards

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Declaration of Conformity

Control Techniques Ltd
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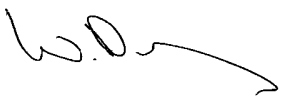
MultiAx SAC
MultiAx HAC
MultiAx SDC
MultiAx HDC

The servo drive products listed above have been designed and manufactured in accordance with the following European harmonised, national and international standards:

EN60249	Base materials for printed circuits
IEC326-1	Printed boards: general information for the specification writer
IEC326-5	Printed boards: specification for single- and double-sided printed boards with plated-through holes
IEC326-6	Printed boards: specification for multilayer printed boards
IEC664-1	Insulation co-ordination for equipment within low-voltage systems: principles, requirements and tests
EN60529	Degrees of protection provided by enclosures (IP code)
UL94	Flammability rating of plastic materials
UL508C	Standard for power conversion equipment

These products comply with the Low Voltage Directive 73/23/EEC and the CE Marking Directive 93/68/EEC.



W. Drury
Executive VP Technology
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Date: 30 March 2001.

These electronic drive products are intended to be used with appropriate motors, controllers, electrical protection components and other equipment to form complete end products or systems. Compliance with safety and EMC regulations depends upon installing and configuring drives correctly, including using the specified input filters. The drives must be installed only by professional assemblers who are familiar with requirements for safety and EMC. The assembler is responsible for ensuring that the end product or system complies with all the relevant laws in the country where it is to be used.
Refer to the this User Guide for guidelines on installation. A *MultiAx EMC Data Sheet* is also available giving detailed EMC information.

1 Safety Information

1.1 Warnings, Cautions and notes

A **Warning** contains information which is essential for avoiding a safety hazard.

A **Caution** contains information which is necessary for avoiding a risk of damage to the product or other equipment.

NOTE A **Note** contains information which helps to ensure correct operation of the product.

1.2 Electrical safety - general warning

The voltages used in the MultiAx can cause severe electrical shock and/ or burns, and could be lethal. Extreme care is necessary at all times when working with or adjacent to the MultiAx.

Specific warnings are given at the relevant places in this User Guide.

1.3 System design and safety of personnel

The MultiAx is intended as a component for professional incorporation into complete equipment or a system. If installed incorrectly, the MultiAx may present a safety hazard. The MultiAx uses high voltage and currents, carries a high level of stored electrical energy, and is used to control equipment which can cause injury.

Close attention is required to the electrical installation and the system design to avoid hazards, either in normal operation or in the event of equipment malfunction. System design, installation, commissioning and maintenance must be carried out by personnel who have the necessary training and experience. They must read this safety information and this User Guide carefully.

The STOP function of the MultiAx does not remove dangerous voltages from the output of the MultiAx or from any external option unit.

Careful consideration must be given to the functions of the MultiAx which might result in a hazard, either through their intended functions or through incorrect operation due to a fault.

In any application where a malfunction of the MultiAx could lead to damage, loss or injury, a risk analysis must be carried out, and where necessary, further measures taken to reduce the risk.

The STOP and START controls or electrical inputs of the MultiAx must not be relied upon to ensure safety of personnel. If a safety hazard could exist from unexpected starting of the MultiAx, an interlock that electrically isolates the MultiAx from the AC supply must be installed to prevent the motor being inadvertently started.

To ensure mechanical safety, additional safety devices such as electro-mechanical interlocks and overspeed protection devices may be required. The MultiAx must not be used in a safety critical application without additional high integrity protection against hazards arising from a malfunction.

Under certain conditions, the MultiAx can suddenly discontinue control of the motor. If the load on the motor could cause the motor speed to be increased (e.g. in hoists and cranes), a separate method of braking and stopping must be used (e.g. a mechanical brake).

1.4 Environmental limits

Instructions in this User Guide regarding transport, storage, installation and use of the MultiAx must be complied with, including the specified environmental limits. The MultiAx must not be subjected to excessive physical force.

1.5 Compliance with regulations

The installer is responsible for complying with all relevant regulations, such as national wiring regulations, accident prevention regulations and electromagnetic compatibility (EMC) regulations. Particular attention must be given to the cross-sectional areas of conductors, the selection of fuses or other protection, and protective earth (ground) connections. This User Guide contains instruction for achieving compliance with specific EMC standards.

Within the European Union, all machinery in which this product is used must comply with the following directives:

- 97/37/EC: Safety of machinery.
- 89/336/EEC: Electromagnetic Compatibility.

1.6 Risk analysis

In any application where a malfunction of the drive could lead to damage, loss or injury, a risk analysis must be carried out, and where necessary, further measures taken to reduce the risk. This would normally be an appropriate form of independent safety back-up system using simple electro-mechanical components.

1.7 Motor

Ensure the motor is installed in accordance with the manufacturer's recommendations. Ensure the motor shaft is not exposed.

The motor will be supplied with the flux alignment pre-entered into each speed loop module (SLM). For instructions on how to set the flux alignment, refer to the documentation for the motion controller. Damage can be caused if incorrect values are entered.

The MultiAx does not have a motor thermistor input. This function is not required due to the I^2t thermal modelling performed in the SLM (see section 2.6 *Thermal protection of the motor* on page 3).

Servo motors are designed to operate at elevated temperatures which may reach 100^oC. Ensure that no temperature-sensitive devices touch the motor casing. Where necessary, precautions to prevent human contact should be taken.

2 Introduction

2.1 Important information about this User Guide

WARNING

Variable speed drives may be hazardous if misused. Carefully follow the instructions in this User Guide, especially those in Chapter 1 *Safety Information* on page 1.

Read this User Guide before starting the installation or setting-up processes.

This User Guide is arranged as a series of topics, where each topic contains all the information and/or instructions on a specific subject. Consequently the information and instructions are not necessarily presented in the order of use.

Refer to this User Guide in conjunction with the instruction manual(s) for the motion controller for the following:

- Setting up the MultiAx and servo system
- Ensuring the user is made aware of all the related safety issues
- Making signal and data connections

2.2 Models and versions of the drive

The MultiAx is a high-performance three-axis servo amplifier for controlling permanent-magnet brushless motors that are fitted with a Control Techniques Speed Loop Module (SLM).

The MultiAx is available in several versions. In this User Guide, the term MultiAx is used for referring to all versions.

Table 2-1 Power and current ratings of all versions (total of all the axes).

	Continuous operation	Overload for 2 secs max.
Maximum AC supply current	15.6A	31.2A
Maximum total output current	18.75A	37.5A
Maximum total output power	9.75kW	19.5kW

All models in the MultiAx range can be supplied in a number of versions, each possessing a variation in the functionality specific to a particular type of application. The version code is a suffix to the model number. See the following tables:

Table 2-2 Current rating

Model		Output current					
		Maximum continuous			Maximum peak (2s max.)		
		Axis			Axis		
		A	B	C	A	B	C
 MultiAx SAC / SDC	Default current mode	2.5			5.0		
	Full current scaling selected. Pin 6 & 7 on each axis connector linked	9.375			18.75		
MultiAx HAC / HDC	Default current mode	2.5			5.0		
	Full current scaling selected. Pin 6 & 7 on each axis connector linked	15.0	9.375		30	18.75	

NOTE

Table 2-2 Current rating refers to the individual axis current limits. The sum of all three axes can NOT exceed 18.75A continuous or 37A peak without the drive tripping.

Table 2-3 MultiAx versions

Suffix	Functionality
SAC	**S**tandard drive. For use with **AC** mains supply only.
HAC	**H**igh current drive. This only applies to axis A when configured to full current scaling (see *Current-scaling modes*). For use with **AC** mains supply only.
SDC	**S**tandard drive but with the AC mains loss detection disabled for use with AC or **DC** supplies.
HDC	**H**igh current drive (as per HAC above)but with the AC mains loss detection disabled for use with AC or **DC** supplies.

Current-scaling modes

The MultiAx is supplied with all three axes operating in the default current mode. By connecting a wire link in the related D-type signal connector, one or more axes can be operated in the full current-scaling mode. This can assist with matching the MultiAx to the current-ratings of the motor.

NOTE

The link is only checked on power-up. Do NOT change without re-commissioning.

2.3 Automatic setting up of the drive for the motor

When the motor is fitted with an SLM*, the motion controller automatically reads the characteristics of the SLM and the motor each time the power is applied to the SLM and motion controller. This unique facility substantially reduces the time that is normally spent setting up a servo amplifier.

*This only applies for SLM versions 02.08.00 or higher

A servo system consists of the following:

- Motion controller having an SLM *technology* communications interface.
- One or more MultiAx servo amplifiers.
- Up to three SL-class servo motors driven by each MultiAx.
- A Control Techniques SLM fitted to each motor. The SLM samples the speed and position of the motor shaft every 125µs to a resolution of one eight-millionth of a revolution.

The MultiAx contains the following main elements:

- For each axis, a PWM inverter
- SLM *technology* data interface for each axis
- Input power stage supplying the three inverters
- Braking transistor common to the three inverters

2.4 SLM *technology*

High system-performance is achieved by the use of SLM *technology* which is an EIA485 two-wire high-speed data communications network specially designed by Control Techniques for linking the elements of servo systems with minimal connections. By this means digital control and synchronisation are maintained between all the elements. Data, which consists of unit addresses, parameter numbers and values, is transferred at 125µs intervals and at a rate of 2.5Mbits/second.

The SLM *technology* network carries the following data communications for servo control:

- The motion controller sends position and speed demands to each SLM
- Each SLM sends position and speed feedback to the motion controller
- The SLM sends a current/torque demand to each axis of the MultiAx in order to correct any position error

2.5 External braking resistor

The braking-resistor circuit allows up to 20kW to be dissipated into an external resistor of 30Ω, which is the minimum permissible value. The braklng resistor must be protected from thermal overload (recommendations are given in Chapter 3 *Installing the MultiAx*).

2.6 Thermal protection of the motor

The SLM protects the motor from thermal overload without the need for an external thermistor. At power-up the SLM transmits to the motion controller the thermal characteristics of the motor as well as the value obtained from a thermistor embedded in the SLM

When the motor is running, every 125µs a thermal-modelling function in the SLM updates an accumulator whose value represents the temperature of the motor windings. If the value of the accumulator reaches a level that indicates the motor windings are at the specified maximum safe working temperature, the output current is limited to a specified level and a motor thermal-overload alarm is produced. This alarm can be applied to, or read by, the system or motion controller to initiate reduction of demand, otherwise continued demand at this level will cause the drive to trip and cease controlling the motor.

Initial conditions are read by the drive, as follows:

- The thermal characteristics of the motor are obtained by the MC during setting-up (described in Automatic setting up of the drive for the motor).
- Each time the SLM is powered-up, the value of the initial motor temperature is obtained from a thermistor embedded in the SLM .

Adjustments can be made to the motor-protection function, such that the drive provides an early warning to the host before it starts current limiting. Preventative action can then be made.

2.7 Motion-controller requirements

The motion controller must be able to perform the following functions:

- Writing, reading and verifying parameter values
- Setting motor flux angle for each axis
- Fault monitoring of the system
- Fail-safe operation

3 Installing the MultiAx

3.1 Installation considerations

WARNING

Adhere to the instructions
The mechanical and electrical installation instructions must be adhered to. Any questions or doubt should be referred to the supplier of the equipment. It is the responsibility of the owner or user to ensure that the installation of the MultiAx and any external option unit, and the way in which they are operated and maintained, comply with the requirements of the Health and Safety at Work Act in the United Kingdom or applicable legislation and regulations and codes of practice in the country in which the equipment is used.

WARNING

Competence of the installer
The MultiAx must be installed only by professional assemblers who are familiar with the requirements for safety and EMC. The assembler is responsible for ensuring that the end-product or system complies with all the relevant laws in the country where it is to be used.

CAUTION

Motor voltage
The motor must be suitable for use with a MultiAx drive and its required supply voltage

CAUTION

Flash / insulation testing
The MultiAx and RFI filter have internal electrical components connected between the AC-supply phases and ground. In order to avoid damaging these components when flash or insulation testing the AC-supply circuit and/or motor circuit, first disconnect the MultiAx completely from the circuit to be tested.

Authorized access
Only authorized, trained service personnel should be allowed access to the drive.

Installation in an enclosure
The MultiAx must be protected against water, condensation and electrically conductive contamination.

The MultiAx has ingress protection rated at IP20 (in accordance with IEC60529).

UL listing is valid when the MultiAx is installed in a type 1 enclosure as defined in UL50.

Fire enclosure
The MultiAx case is not classified as a fire enclosure.

When this protection is required, the MultiAx should be installed in a fire enclosure.

Hazardous areas
The MultiAx must not be located in a classified hazardous area unless it is installed in an approved enclosure and the installation is certified.

Environmental
See Appendix A *UL Listing Information* on page 26.

See Appendix B *Data* on page 27 for environmental requirements.

If condensation is likely to occur when the MultiAx is not in use, an anti-condensation heater must be installed. This heater must be switched off when the MultiAx is in use; automatic switching is recommended.

If the MultiAx is to be mounted directly above any heat-generating equipment (such as another MultiAx), the maximum temperature of the air immediately below the MultiAx should be taken as the ambient temperature for the MultiAx.

Electromagnetic compatibility
The MultiAx contains powerful electronic circuits which can cause electromagnetic interference. The information and instructions in this chapter include routine EMC precautions that will minimize the risk of disturbance to typical industrial control equipment. These include installing the MultiAx in an enclosure as well as careful attention to the layout of the connecting cables.

Additional precautions must be taken if any of the following apply:

- Strict compliance with emission standards is required
- It is known that electromagnetically sensitive equipment, such as radio receivers, is located nearby
- The MultiAx is to be operated in a residential environment

The information and instructions relating to these additional precautions are contained in the EMC emission standards sections later in this chapter.

These precautions include installing an RFI filter in the AC supply to each MultiAx and additional attention paid to cables and grounding.

NOTE

Dimensions

All dimension measurements are in metric, all imperial measurements are in brackets and are calculated from the metric values.

3.2 AC supply protection

WARNING

The AC supply to the MultiAx must be fitted with suitable protection against overload and short-circuits. Failure to observe this recommendation will cause a risk of fire.

Include a fuse in each phase of the AC supply. Use of the following types of fuse are recommended:

- Europe: Type gG HRC to IEC 60269 (BS88)
- USA: CC 600Vac

An MCB or MCCB having the correct thermal and magnetic trip ratings may be used in place of fuses, on condition the fault-current clearing capacity is sufficient for the installation.

NOTE

UL listing is dependent on the use of the correct type of UL-listed fuse, and applies when the symmetrical short-circuit current does not exceed 5kA. Refer to Appendix A UL Listing Information UL Listing Information.

Table 3-1 Fuse ratings

Model	Fuse Rating
MultiAx (all versions)	30A

3.3 AC supply disturbances - use of line reactors

When a MultiAx is connected to an AC supply which is subject to severe disturbances – for example, if any of the following conditions apply...

- Capacity exceeds 200kVA
- Fault current exceeds 5kA
- Power-factor correction equipment is connected close to the MultiAx
- Large DC drives having no or ineffective line reactors are connected to the supply
- Direct-on-line started motor(s) are connected to the supply and, when any of these motors are started, a dip is produced in excess of 20% of the actual supply voltage

...excessive peak current may flow in the input power circuit of the MultiAx. This may cause nuisance tripping or, in extreme cases, failure of the MultiAx.

A 2% (0.9mH) line reactor should then be connected in each phase of the supply to each MultiAx. Line reactor(s) add the required impedance to the AC supply in order to reduce current transients to a level that can be tolerated by the MultiAx.

Three individual reactors, or a single three-phase reactor should be used. Each MultiAx must have its own reactor(s).

CAUTION

RFI filters (for EMC purposes) do not give adequate protection against these conditions.

Table 3-2 Typical line-reactor values

Model	Value
MultiAx (all versions)	1mH

Current ratings

Continuous RMS current: Not less than the continuous input current rating of the MultiAx.

Repetitive peak: Not less than 4 times the continuous input current rating of the MultiAx. (This is to prevent magnetic saturation.)

3.4 Output current, Ambient temperature, Heat dissipation, De-rating

NOTE

The ambient temperature should be taken as the temperature of the air immediately under the drive. This is especially important when the drive is to be installed above heat-generating equipment.

The drive can supply the rated maximum continuous output current (FLC) as follows...

- All models: Up to an ambient temperature of 50°C (122°F)

If the drive is to be used at an altitude in excess of 2000m (6600ft), de-rating for altitude must be applied to the output current; see Altitude in Appendix B Data.

Make a note of the following values for the model to be used; you will need to know these later:

- Maximum intended ambient temperature ($T_{AMB\ max}$) (required for calculating the enclosure size later in this chapter)
- Maximum continuous output current (if this needs to be a de-rated value)
- Maximum heat dissipated into the enclosure

CAUTION

Current de-rating
When de-rating must be applied (for ambient temperature), it is essential that the appropriate value is entered in to the motion controller (see the motion controller user guide).
If this precaution is not taken, the current of the MultiAx can exceed the maximum permissible value. This may result in loss of motor control due to excessive heatsink temperature causing the drive to trip.

Thermal protection

The power output stage (IGBT bridge) of the drive is protected as follows:

- If the heatsink temperature exceeds 85°C (185°F), the MultiAx trips; the status LED D5 will extinguish and LED D4 will light.

Table 3-3 Maximum current and heat dissipated into the enclosure (these do not need to be de-rated for altitude)

Model	Output current			Heat dissipation	
	$T_{AMB\ max}$	Max. continuous	Max. overload (2 secs. max)	Surface Mounting	Through-panel Mounting
MultiAx (all versions)	50°C (122°F)	18.75	37.5	350W	40W

3.5 When to use a braking resistor

When a motor is decelerated, or the drive is preventing the motor from gaining speed due to mechanical influences, energy is returned to the drive from the motor. When this energy is too great for the drive to absorb, the DC-bus voltage is raised, which increases the possibility of the drive tripping due to excessive DC-bus voltage.

Depending on the braking requirements, an external braking resistor can be used for absorbing the returned energy. The braking resistor is then switched into circuit by an internal transistor when the DC-bus voltage reaches 780V.

The required value for the braking resistor is determined by the maximum required braking torque, while the required power rating is determined by the amount of energy to be dissipated, the duty cycle and repetition time, as well as the cooling available for the resistor.

CAUTION

It is important that the braking resistor is adequately rated otherwise the drive could trip due to excessive DC-bus voltage; braking will then cease, allowing the motor to coast uncontrolled.

Braking resistor data

Table 3-4 External braking resistor

Minimum permissable value	30Ω
Operating voltage	780V at switch-on 760V at switch-off
Maximum possible braking current (through 30Ω) (I_{bMAX})	26.0A
Peak power rating for 30Ω	20kW
Continuous power rating	See *Braking-resistor calculations* later in this chapter

The instantaneous power rating refers to the power dissipated during the conducting periods (milliseconds) of the braking transistor (this operates under a form of pulse width modulation during braking). Higher resistance values require proportionately lower instantaneous power ratings.

Braking resistor precautions

WARNING

Electric shock risk
The voltages present on the braking resistor, its associated components and terminals on the drive are capable of inflicting a severe electric shock and may be lethal.

WARNING

Thermal overload protection
When an external braking resistor is used, it is essential that a thermal overload protection device is incorporated in the braking-resistor circuit in order to minimise the risk of fire in the event of unexpectedly high current, or loss of control of the braking circuit. A typical protection circuit is shown in the following section Thermal protection circuit for an external braking resistor.

WARNING

High temperatures
Braking resistors can attain high temperatures and should be segregated from temperature-sensitive equipment and personnel.

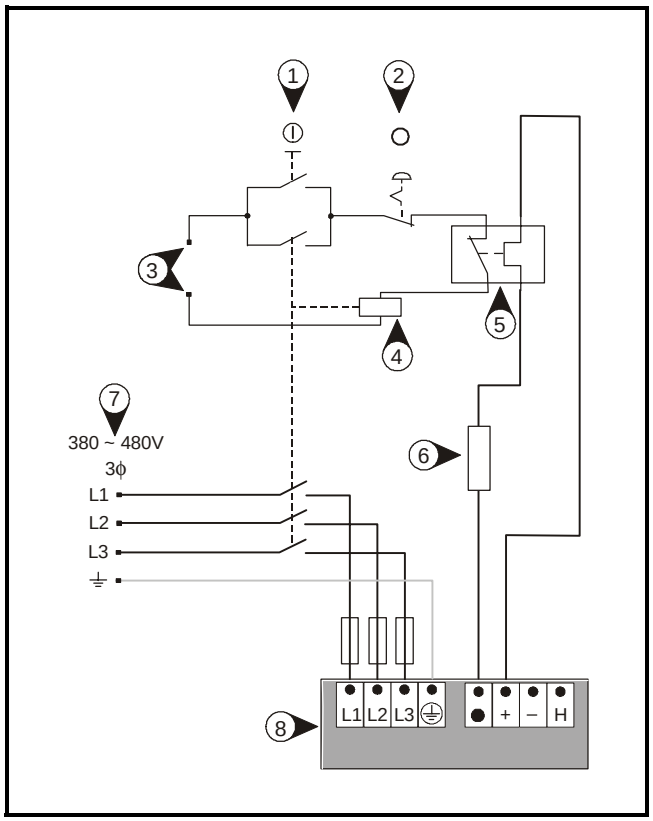
When a braking resistor is to be used, ensure the following:

- Include a lock-out circuit that will prevent the AC supply from being re-connected to the drive until the cause of a trip has been fully investigated.

- An external braking resistor should be capable of tolerating thermal shock; pulse rated resistors are recommended.
- It is essential that the instantaneous and average power ratings of the braking resistor are sufficient for the most extreme braking duty that is likely to be encountered.
- When an external braking resistor is mounted inside the enclosure, the heat dissipated by the resistor will increase the ambient temperature inside the enclosure.(The value of heat dissipation is used for calculating the enclosure size or ventilation which are described later in this chapter.)
- Always use shielded or steel wire armoured cable for connecting an external braking resistor.

When an external braking resistor is used, a thermal-protection circuit must be added. This must disconnect the AC supply from the drive if the braking resistor becomes overloaded. For guidance, Figure 3-1 shows a typical circuit arrangement (complete circuit diagrams for the power connections appear later in this chapter).

Figure 3-1 Typical protection circuit for an external braking resistor



1. START/RESET switch (momentary)
2. STOP switch (latching)
3. Control-circuit supply
4. Contactor coil
5. Thermal overload protection relay
6. External braking resistor
7. 380 ~ 480Vac supply to the drive
8. Drive power connectors

Braking resistor example calculations

Conditions

- **Drive**
  Combined total peak ouput current ($\mathbf{I_{pk}}$) from the drive (for 2 seconds): 37.5A
  Minimum permissible braking-resistor value: 30Ω
  Operating voltage ($\mathbf{V_R}$) at switch on: 780V
- **Motors** (for this example all three motors are of the same type)
  Full-load rated speed (**n**) of motor: 3000 RPM
  Nominal torque ($\mathbf{T_{cs}}$): 8.9Nm
  Motor $\mathbf{K_T}$ = 1.6 Nm/A
  Motor inertia ($\mathbf{J_M}$): 1.66 x 10^{-3}kg m^2
  Load inertia ($\mathbf{J_L}$): 8.3 x 10^{-3}kg m^2
  Total combined inertia ($\mathbf{J_T}$ = 3 x [$\mathbf{J_M}$ + $\mathbf{J_L}$]): 29.88 x 10^{-3}kg m^2
- **Braking**
  Required deceleration time for all axes simultaneously braking ($\mathbf{t_d}$): 0.5 seconds
  Repeat cycle time for deceleration ($\mathbf{t_r}$): 15 seconds

Minimum permissible deceleration time

The minimum permissible deceleration time is limited by the following:

- The peak current of the drive (Ipk)
- The intermittent torque limit of the motor (the value of torque that the motor can deliver for a specified time – see the motor manufacturer's data)

1. Calculate the maximum total torque that the three motors would produce when the drive is delivering peak current (37.5A), as follows:
   $\mathbf{M_{bMAX} = I_{pk} \times K_T = 37.5 \times 1.6 = 60Nm}$
   The drive would cause this value of torque to be produced for up to 2 seconds.
2. Refer to the the motor manufacturer's data to obtain the permissible overload (continuous stall torque) for 2 seconds. Then use this figure to calculate the intermittent torque limit for the motor for a 2-second duration. For this example, 3 times the nominal torque rating is assumed for all three motors, as follows:
   $\mathbf{M_{bINT} = T_{CS} \times 3 \times 3 = 8.9 \times 3 \times 3 = 80.1Nm}$
3. For calculating the minimum permissible deceleration time ($\mathbf{t_{bMIN}}$), use the lower of the two calculated values, as follows:
   $\mathbf{M_{bMAX} = 60Nm}$
4. The following equation is used as the basis for the calculations:

   $$M_b = \frac{J_T n}{t_b} \times \frac{\pi}{30} \quad (Nm)$$

   Use the following derivative of the equation to calculate the minimum permissible deceleration time ($\mathbf{t_{bMIN}}$) for stopping the motor from full-load speed:

   $$t_{bMIN} = \frac{J_T \pi n}{30 M_{bMAX}}$$

   $$t_{bmin} = \frac{29.88 \times 10^{-3} \times \pi \times 3000}{30 \times 60} = 0.16 seconds$$

   Check that $\mathbf{t_{bMIN}}$ is less than $\mathbf{t_d}$;if not,system design must be reconsidered.

Resulting torque

Calculate the torque that results from the required deceleration time, as follows:

$$M_b = \frac{J_T n}{t_d} \times \frac{\pi}{30} (Nm)$$

$$M_b = \frac{29.88 \times 10^{-3} \times \pi \times 3000}{0.5 \times 30} = 18.8Nm$$

Power rating of the braking resistor

1. Calculate the kinetic energy ($\mathbf{E_K}$) that will be dissipated in the braking resistor, as follows:

   $$E_K = 0.5 \times J_T \times \left(\frac{n \times \pi}{30}\right)^2$$

   $$E_K = 0.5 \times 29.88 \times 10^{-3} \times \left(\frac{3000 \times \pi}{30}\right)^2$$

   $$E_K = 1.5kJ$$

2. Calculate the average power over deceleration time (**td**):

$$P_{PK} = \frac{E_K}{td}$$

$$P_{PK} = \frac{1.5}{0.5} = 3kW$$

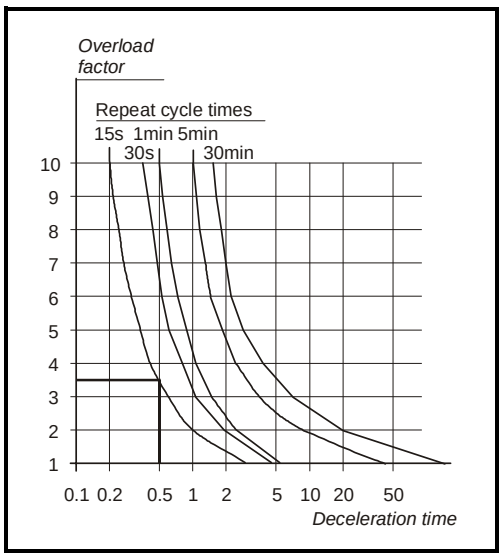
3. Calculate the average power (P_{av}) that will be dissipated over the whole cycle:

$$P_{av} = \frac{E_K}{tr}$$

$$P_{av} = \frac{3000}{15} = 200W$$

4. Since braking is planned to occur intermittently, the resistor can be rated for intermittent rather than continuous power dissipation so that the overload factor of the resistor can be used. This factor can be obtained from cooling curves for the resistor, as shown.

Figure 3-2 Example cooling curves for power resistors (in practice, refer to the cooling curves for the resistor to be used)



5. The cooling curves indicate that for a braking time of 0.5 second and repeat cycle time of 15 seconds, the overload factor (F) is 3.5.

6. Calculate the minimum required power rating of the resistor, as follows:

$$P_{RMN} = \frac{P_{PK}}{F} = \frac{3 \times 10^3}{3.5} = 857W$$

If the braking resistor is to be mounted inside the enclosure, make a note of this value; you will need it when calculating the enclosure size.
In practice, use a resistor having a power rating higher than the calculated value. For this example: P_R = **1kW**

Value of the braking resistor

1. Calculate the maximum suitable value for the braking resistor, as follows:

$$R_{MAX} = \frac{(V_{MAX})^2}{P_{PK}} = \frac{780^2}{3 \times 10^3} = 203\Omega$$

2. In practice, use a resistor having a preferred value close to and lower than the calculated value. This is because the calculated value would cause the braking transistor to be switched on almost continuously during braking. In this case, the drive will not have full control of the DC-bus voltage. A lower value of braking resistor will cause the braking transistor to act as a chopper which will then allow the drive to control the DC-bus voltage more accurately. The reduction in value does not increase the power dissipation since the average voltage across the resistor is reduced by the braking transistor operating as a chopper.
For this example: **R** = **200Ω**

Current setting for the thermal overload protection relay

1. Calculate the maximum permissible continuous current through the braking resistor that is to be used, as follows:

$$I_{RMAX} = \sqrt{\frac{P_R}{R}} = \sqrt{\frac{1000}{200}} = 2.2A$$

where:
P_R is the continuous power rating of the resistor to be used (not the minimum required power rating)
R is the actual value of the braking resistor (not the calculated value)

2. Select a model of thermal overload relay that can be set at **2.2A**

3. Calculate the maximum current that could flow through a resistor (e.g. due to the braking resistor becoming short circuit), as follows:

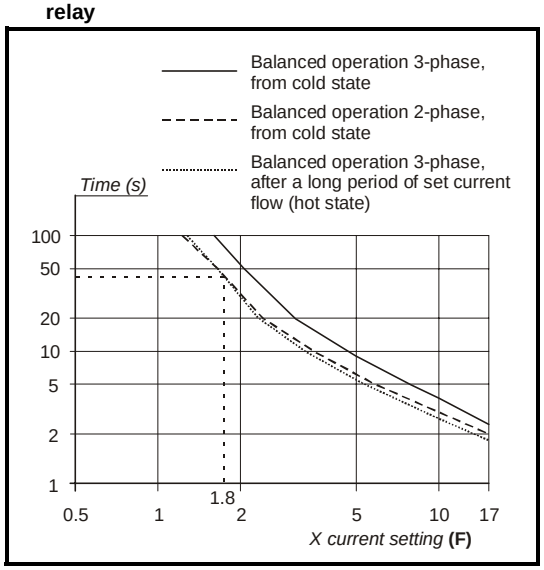
$$I_{Rpk} = \frac{V_R}{R} = \frac{780}{200} = 3.9A$$

4. Calculate the overload factor for this condition, as follows:

$$F_{S\backslash C} = \frac{I_{Rpk}}{I_{SET}} = \frac{3.9}{2.2} = 1.8$$

5. Use the tripping curves to find the time that the thermal overload relay will take to trip (e.g. 40 seconds approximately).

Figure 3-3 Example tripping curves for a typical thermal overload relay



6. Check that the braking resistor can tolerate the overload current (I_{Rpk}) for this duration.

NOTE

Parallel connection of DC buses

When a number of MultiAx units are used in a system, it is possible to connect their DC buses in parallel in order to allow energy sharing, especially when one or more motors are being braked.

Operation in this manner is not covered by this guide; cable sizes and other information can be obtained from the supplier of the MultiAx.

3.6 Method of Mounting

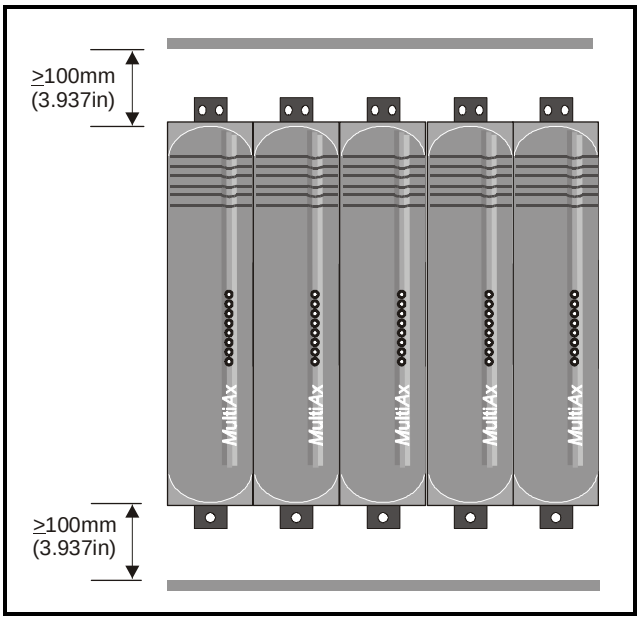
The two mounting brackets fitted to the drive are intended for mounting the drive on the back-plate of the enclosure. Exhaust heat from the drive is emitted in front of the back-plate. (Mounting instructions are given later in this chapter.)

Alternatively the drive can be mounted through an aperture in the back-plate to allow the exhaust heat to be emitted behind the back-plate. In this case, the two mounting brackets used to mount the drive must be removed and fitted in the alternative positions. (Mounting instructions are given later in this chapter.)

3.7 Enclosure Layout

Refer to Figure 3-4 for minimum clearances above and below the drive. The *bookcase* format allows drives to be mounted in rows with no need for horizontal spacing.

Figure 3-4 Minimum clearances above and below the drive



EMC compliance

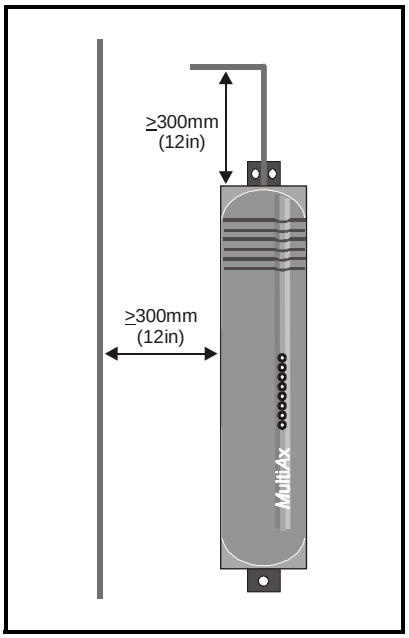
When compliance with EMC emission standards is required, additional precautions must be taken; see section 3.16 *EMC emission standards – compliance information* on page 15.

3.8 Clearances for the signal cables

Recommended clearances are shown overleaf; they are required for routine EMC precautions as well as for compliance with EMC emission standards.

Clearance from the MultiAx

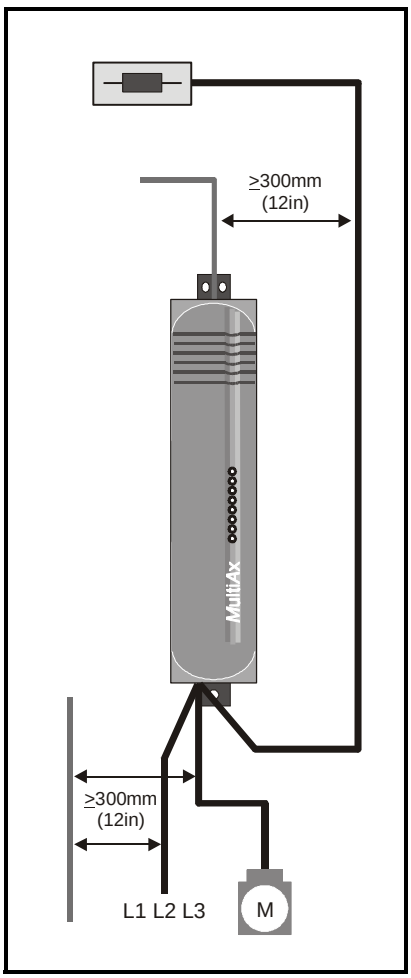
Do not locate sensitive signal circuits or pass signal cables within 300mm (12 in) of the MultiAx.



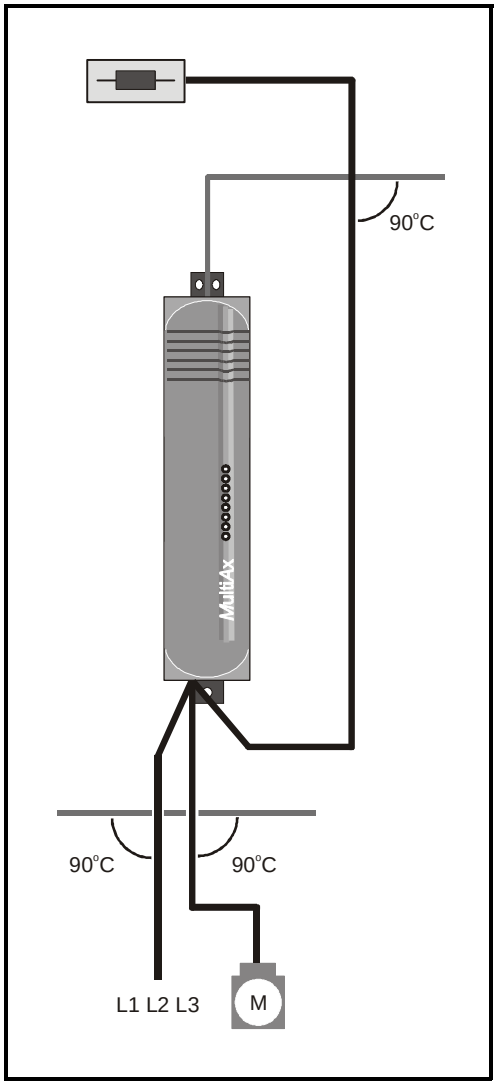
Clearance from power cables

Do not pass signal cables within 300mm (12 in) of:

- Motor cables
- Braking resistor cables
- AC supply cables



Crossing angle
When power and signal cables cross, the crossing angle must be 90°.



3.9 Enclosure calculations for heat removal

Decide whether the enclosure is to be sealed or ventilated, as follows:

Sealed enclosure

A sealed enclosure can give a high ingress-protection rating, but with reduced heat removal capabilities. If possible, locate heat-generating equipment (other than braking resistors) in the lower part of the enclosure to encourage internal convection. If necessary, a taller enclosure, and/or air-circulation fans inside the enclosure, can be used. For calculating the minimum size of sealed enclosure that will adequately cool the drive (and other drives), see Enclosure calculations later in this chapter.

Ventilated enclosure

If a high ingress-protection rating is not required, a ventilated enclosure can be used with a fan to supply forced air cooling; this can give a lower ambient temperature than a sealed enclosure. For calculating the minimum required volume of cooling air, see *Enclosure calculations* later in this chapter.

Total heat dissipation

1. Add the dissipation figures from 3.4 *Output current, Ambient temperature, Heat dissipation, De-rating* on page 5) for each drive that is to be installed in the enclosure. Make a note of the total value.
2. If an RFI filter is to be used with each drive, add the dissipation figures from *Installing an RFI Filter* on page 16 for each RFI filter that is to be installed in the enclosure. Make a note of the total value.
3. If the braking resistor is to be mounted inside the enclosure, add the average power dissipation ($\mathbf{P_{av}}$) from *Power rating of the braking resistor* on page 7 for each braking resistor that is to be installed in the enclosure. Make a note of the total value.
4. Make a note of the total heat dissipation (in Watts) of any other equipment to be installed in the enclosure.
5. Add the heat dissipation figures obtained (as appropriate) from lines 1, 2, 3 and 4 above. This gives a figure in Watts for the total heat that will be dissipated inside the enclosure. Make a note of this figure.

Calculating the size of a sealed enclosure

The enclosure transfers internally generated heat into the surrounding air by natural convection (or external forced air flow); the greater the surface area of the enclosure walls, the better is the dissipation capability. Only the surfaces of the enclosure that are unobstructed (not in contact with a wall or floor) can dissipate heat.

Calculate the minimum required unobstructed surface area $\mathbf{A_e}$ for the enclosure from:

$$\mathbf{A_e} = \frac{\mathbf{P}}{\mathbf{k}(\mathbf{T_i} - \mathbf{T_{amb}})}$$

Where:

$\mathbf{A_e}$	Unobstructed surface area in m^2 ($1m^2 = 10.8ft^2$)
$\mathbf{T_{amb}}$	Maximum expected ambient temperature in °C outside the enclosure
$\mathbf{T_i}$	Maximum intended ambient temperature in °C inside the enclosure
P	Power in Watts dissipated by all heat sources in the enclosure
k	Heat transmission coefficient of the enclosure material in $W/m^2/°C$

NOTE

Take care when performing these calculations in order to ensure the ambient temperature inside the enclosure does not exceed 50°C (122°F) as appropriate, (see Table 3-3 on page 5).

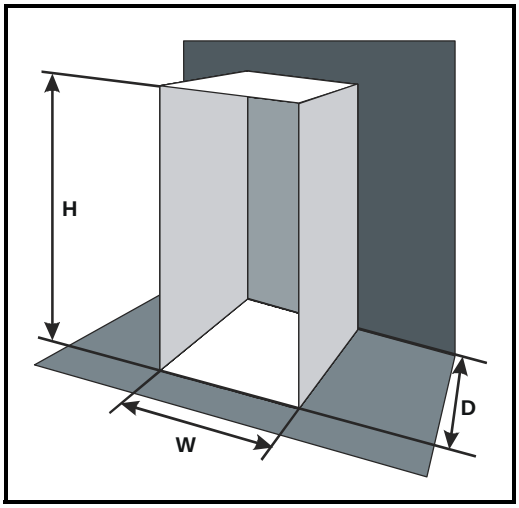
Example

To calculate the size of an enclosure for the following:

- Two MultiAx SAC
- Each drive is to have an external braking resistor mounted inside the enclosure
- An RFI filter (model 4200-3258) to be used with each drive
- Maximum ambient temperature inside the enclosure: 50°C
- Maximum ambient temperature outside the enclosure: 30°C
- Enclosure calculations for heat removal

Dissipation of the drive: 350W (from Table 3-3 on page 5)
Average dissipation from the braking resistor: 200W (from *Power rating of the braking resistor* on page 7)
Dissipation of each RFI filter: 11.83W (max) (from 3.17 *EMC emission standards – instructions* on page 16)
Total dissipation: 2 x (350 + 200 + 11.83) = 1124W
The enclosure is to be made from painted 2mm (0.079in) sheet steel having a heat transmission coefficient **k** of $5.5W/m^2/°C$. Only the top, front, and two sides of the enclosure are to be free to dissipate heat.

Figure 3-5 Enclosure having front, sides and top panels free to dissipate heat



Insert the following values:

T_i	50°C
T_{amb}	30°C
k	5.5
P	1124W

The minimum required heat conducting area is then:

$$A_e = \frac{1124}{5.5 \times (50 - 30)} = 10.2m^2(111ft^2)$$

Estimate two of the enclosure dimensions - the height (H) and depth (D), for instance. Calculate the width (W) from:

$$W = \frac{A_e - 2HD}{H + D}$$

Inserting **H** = 2m and **D** = 0.6m, obtain the minimum width:

$$W = \frac{10.2 - (2 \times 2 \times 0.6)}{2 + 0.6} = 3m(9ft10in)$$

If the enclosure is too large for the space available, it can be made smaller only by attending to one or all of the following:

- Reducing the ambient temperature outside the enclosure, and/or applying forced-air cooling to the outside of the enclosure
- Removing other heat-generating equipment, e.g. braking resistors
- Reducing the number of drives in the enclosure
- Add air circulating fans inside the enclosure

Calculating the air-flow in a ventilated enclosure

The dimensions of the enclosure are required only for accommodating the equipment. The equipment is cooled by the forced air flow.
Calculate the minimum required volume of ventilating air from:

$$V = \frac{k_a k_p P}{T_i - T_{amb}}$$

Where:

V	Air-flow in m^3 per hour
T_{amb}	Maximum ambient temperature in °C outside the enclosure
T_i	Maximum ambient temperature in °C inside the enclosure
P	Power in Watts dissipated by all heat sources in the enclosure
k_p	Ratio of $\frac{P_0}{P_1}$

Where:

P_0 is the air pressure at sea level

P_1 is the air pressure at the installation

Typically use a factor k_a of 1.2 to 1.3, to allow also for pressure-drops in dirty air-filters.

Example

To calculate the required air flow in an enclosure for the following:

- Two MultiAx SAC
- Each drive is to have an external braking resistor mounted outside the enclosure
- Maximum ambient temperature inside the enclosure: 50°C
- Maximum ambient temperature outside the enclosure: 30°C
- At sea level (k_p = 1 for the example)

Dissipation of each drive: 350W (from Table 3-3 on page 5)

Total dissipation: 2 x 350 = 700W

Insert the following values:

T_i	50°C
T_{amb}	30°C
k_a	1.3
P	700W

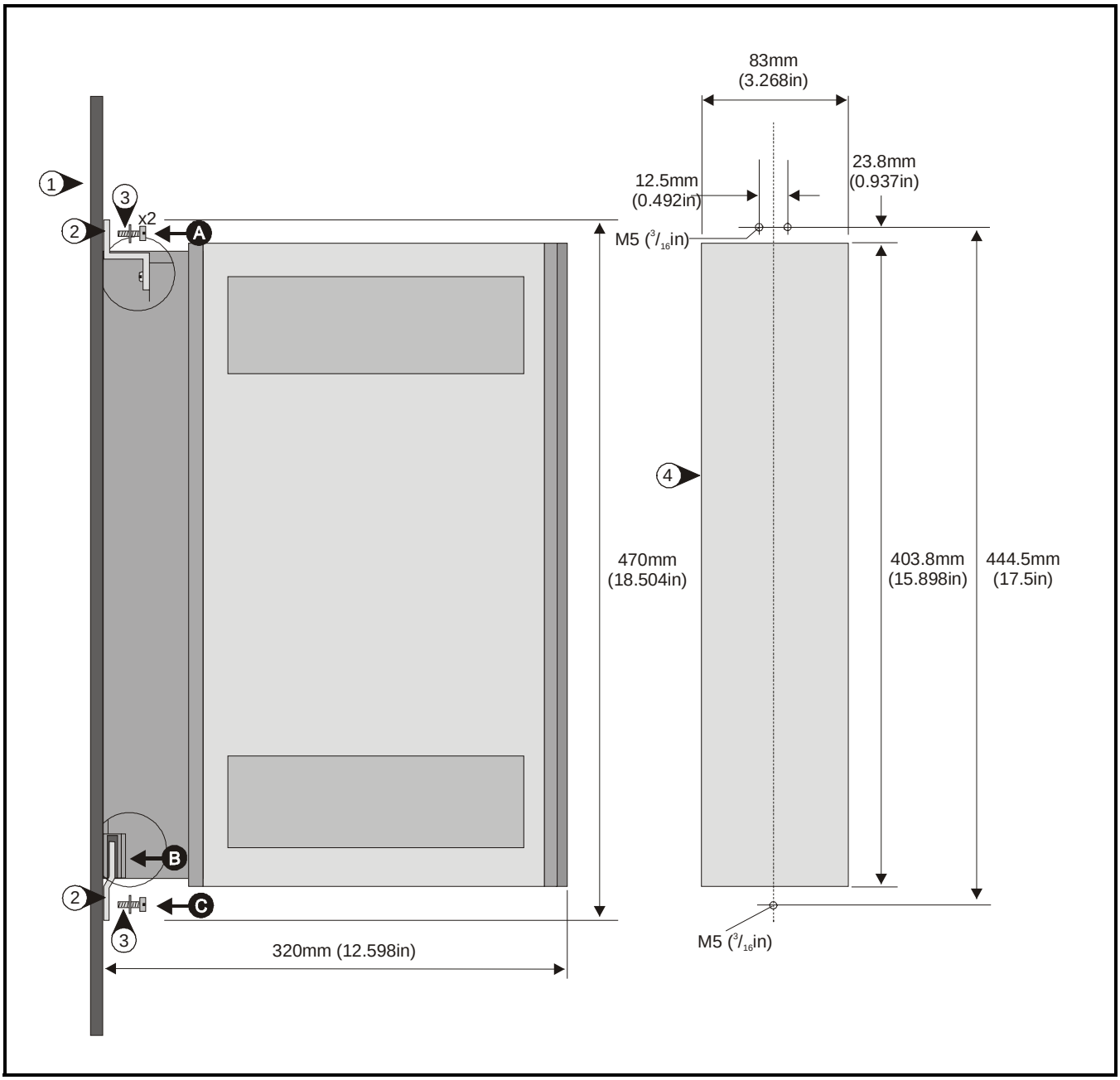
Then:

$$V = \frac{2 \times 1.3 \times 700}{50 - 30} = 91m^3\text{\hr}(54ft^3\text{\min})$$

($1m^3$/hr = $0.59ft^3$/min)

3.10 Mounting the MultiAx

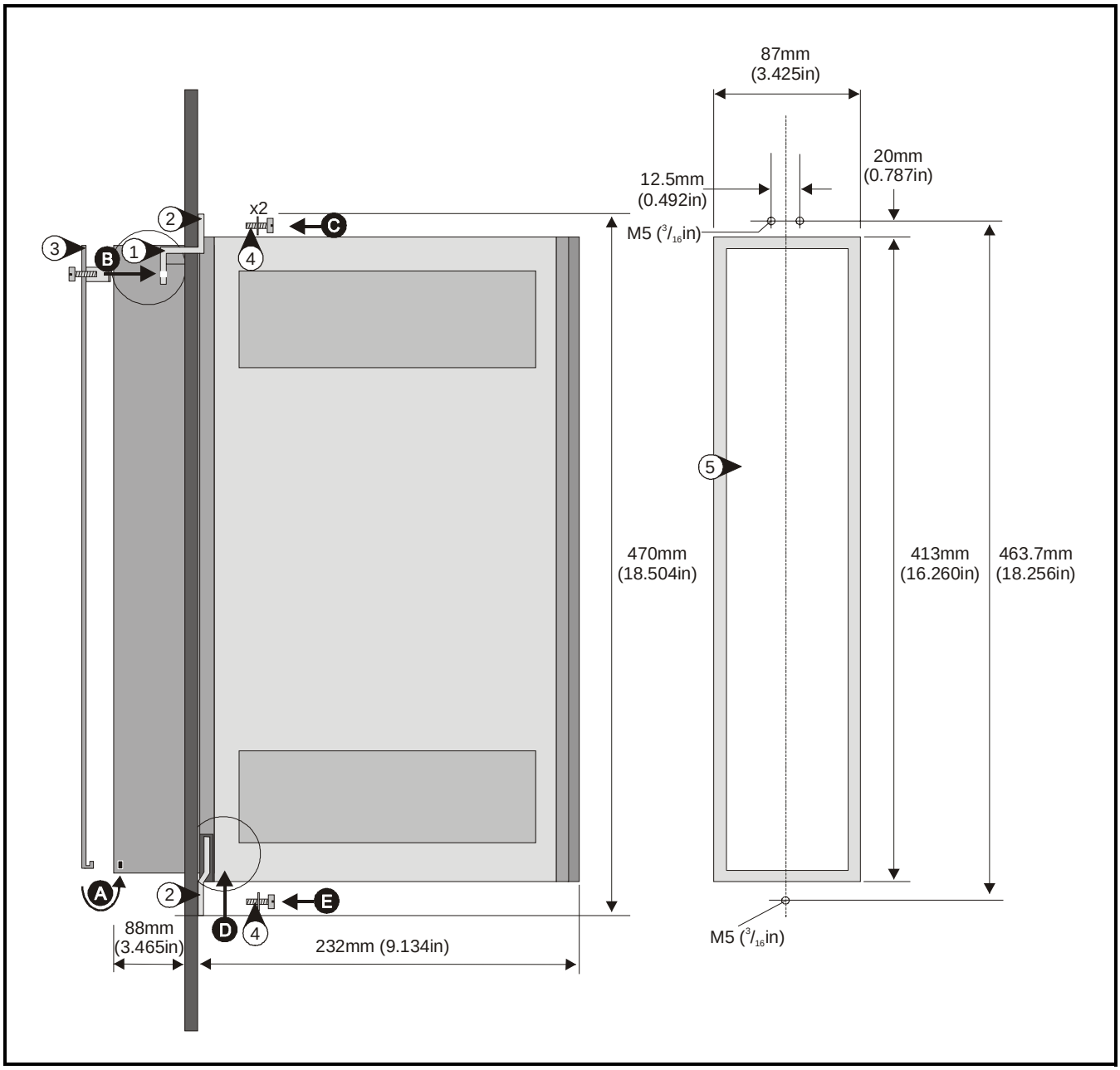
Figure 3-6 Surface-mounting details for the MultiAx



1. Back-plate to form a continuous duct in conjunction with the heatsink fins.
2. If compliance with EMC emission standards is required, both brackets must make direct electrical contact with the back-plate; the screw holes should be threaded.

3. M5 ($^3/_{16}$ in) screws and washers.
4. Area occupied by the MultiAx.
5. Fitting order: (A) to (C).

Figure 3-7 Through-panel mounting details for the MultiAx



1. Reverse the upper bracket.
2. If compliance with EMC emission standards is required, both brackets must make direct electrical contact with the back-plate; the screw holes should be threaded.
3. Baffle-plate (part no. 6521-0321) must be fitted to form a continuous duct in conjunction with the heatsink fins.
4. M5 ($^3/_{16}$ in) screws and washers.
5. Area to be cut out of the back-plate.
6. Fitting order: (A) to (E).

Table 3-5 Parts supplied

Quantity	Part
1	Lower mounting bracket
1	Ground bracket
5	Plug-in 4-way connectors (keyed)
5	Cable clip
1	Self-adhesive sealing strip
1	Upper mounting bracket

3.11 Precaution for making power connections

Electric shock risk
The voltages present in the following locations can cause severe electric shock and may be lethal:

- **AC supply cables and connections**
- **Output cables and connections**
- **Many internal parts of the drive**
- **An auxiliary back-up supply when connected in addition to the AC supply.**

Isolation device
The AC supply must be disconnected from the MultiAx using an approved isolation device before any cover is removed from the MultiAx or before any servicing work is performed.

WARNING

Stored charge
The drive contains capacitors that remain charged to a potentially lethal voltage after the AC supply has been disconnected. If the drive has been energized, the AC supply must be isolated at least five minutes before work may continue.

WARNING

AC supply by plug and socket
Special attention must be given if the MultiAx is installed in equipment which is connected to the AC supply by a plug and socket. The AC supply terminals of the MultiAx are connected to the internal capacitors through rectifier diodes which do not give isolation. If the plug terminals can be touched when the plug is disconnected from the socket, a means of automatically isolating the plug from the MultiAx must be used (eg. a latching relay).

WARNING

ENABLE function
Disabling the ENABLE function does not remove dangerous voltages from the MultiAx.

WARNING

Safety ground connection
The ground loop impedance must conform to the requirements of local safety regulations.
The electrical safety of the installation depends on the correct fitting and use of the ground bracket supplied with the MultiAx. All ground connections to the MultiAx must be made to this ground bracket.
The ground bracket must be grounded by a connection capable of carrying the prospective fault current until the protective device (fuse, etc) disconnects the AC supply.
The ground connections must be inspected and tested at appropriate intervals.

3.12 Terminal sizes and tightening torques

WARNING

To avoid a fire hazard and maintain validity of the UL listing, adhere to the specified tightening torques for the power and ground terminals. Refer to the following table.

Table 3-6 Terminal sizes and tightening torques

Unit	Power terminals		Ground terminal	
	Size / Type	Torque	Size / Type	Torque
MultiAx	Plug-in terminal block	0.5Nm 4.4lb.in	M4 (Torx / slot-head screw)	0.5Nm 4.4lb.in
RFI Filter	Screw terminals	0.7Nm 6.lb.in	Screw terminals	0.7Nm 6.lb.in
Torque reference	±10%		±10%	

3.13 Power cables

WARNING

Wiring must be in accordance with local regulations and codes of practice. The table below shows typical cable sizes for power input and output wiring. In the event of a conflict, local regulations prevail.

Cable type and sizes
Use 105°C (221°F) PVC or PUR insulated cable of suitable voltage rating and having copper conductors.

For the following, use shielded cable or steel wire armoured cable having the appropriate number of conductors:
- MultiAx to motors (3 core + optional ground)
- MultiAx to braking resistor (2 core + optional ground)

Ground conductors
A ground conductor can be included in the motor and braking resistor cables, or a separate wire external to these cables can be used.

Typical cable sizes

Table 3-7 Power cable sizes

Connection	Typical cable size	
	MultiAx SAC MultiAx SDC	MultiAx HAC MultiAx HDC
AC supply to MultiAx (or RFI filter when used)	6mm^2 (10AWG)	6mm^2 (10AWG)
MultiAx to motor, axis A	2.5mm^2 (14AWG)	4mm^2 (12AWG)
MultiAx to motor, axis B	2.5mm^2 (14AWG)	2.5mm^2 (14AWG)
MultiAx to motor, axis C	2.5mm^2 (14AWG)	2.5mm^2 (14AWG)
MultiAx to braking resistor	4mm^2 (12AWG)	4mm^2 (12AWG)

WARNING

To avoid a fire hazard, 4mm^2 cable must used when a MultiAx HAC / HDC unit is operating with full current selected on Axis A.

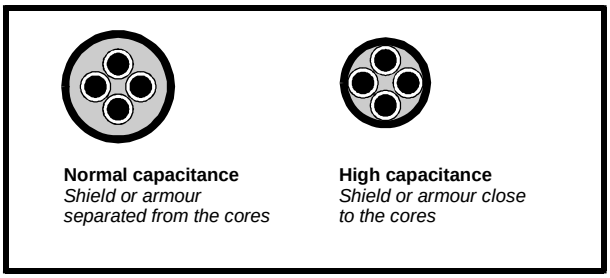
Motor cable
Most cables have an insulating jacket between the cores and the armour or shield; these cables have a relatively low capacitance. When using a cable of this type, observe the recommended maximum lengths stated in the following table.

Table 3-8 Maximum cable lengths

Model	Maximum cable length*	
	m	ft
MultiAx (all versions)	50	165

* Cable lengths in excess of the specified values may be used only when special techniques are adopted; refer to the supplier of the drive.
Typical capacitance for normal cable: 130pF/m (see *Cable capacitance* below)

Cable capacitance
Figure 3-8 Cable construction influencing the capacitance

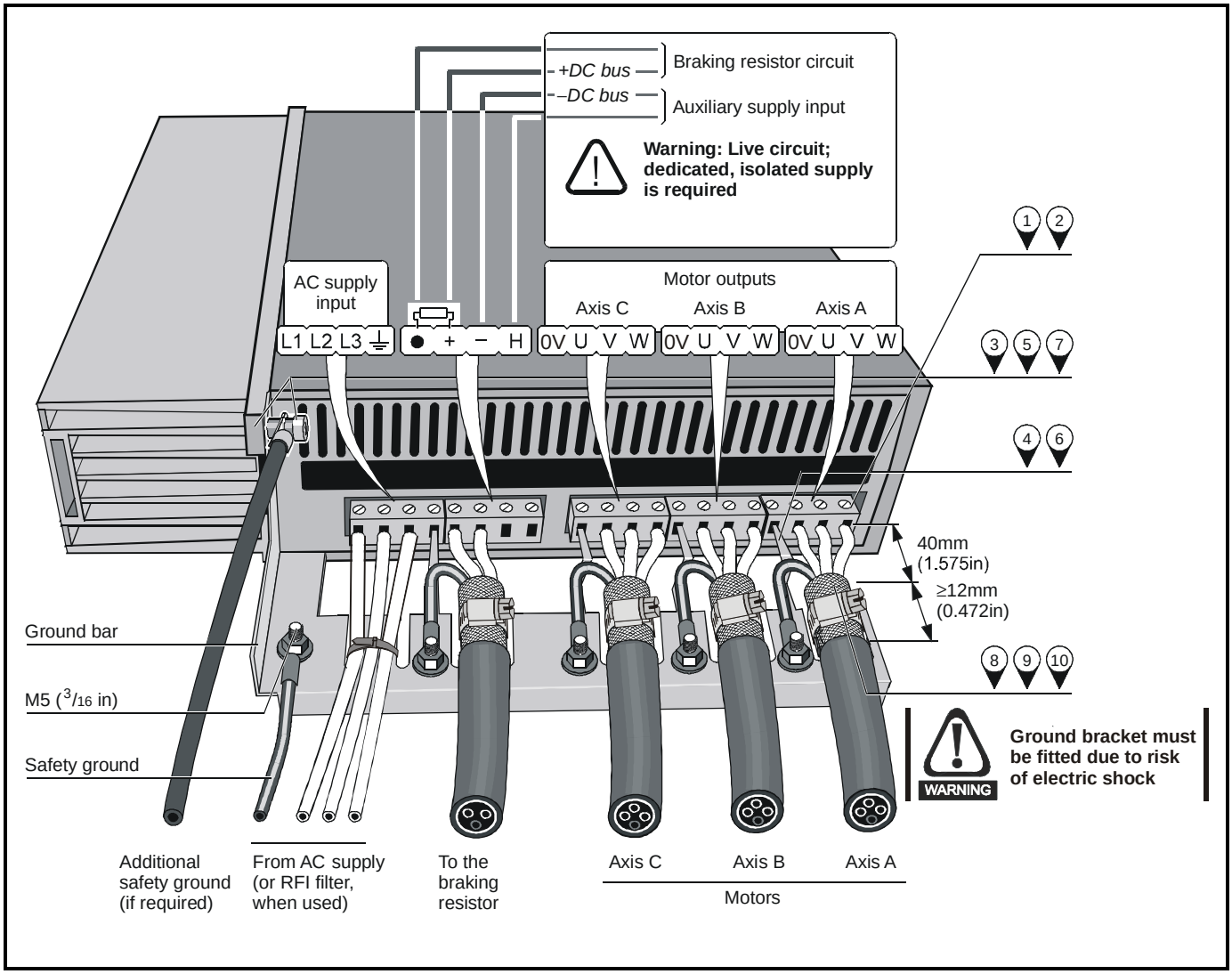


Normal capacitance
Shield or armour separated from the cores

High capacitance
Shield or armour close to the cores

3.14 Method of connecting power cables

Figure 3-9 Locations of the power connections and correct fitting of the ground bracket



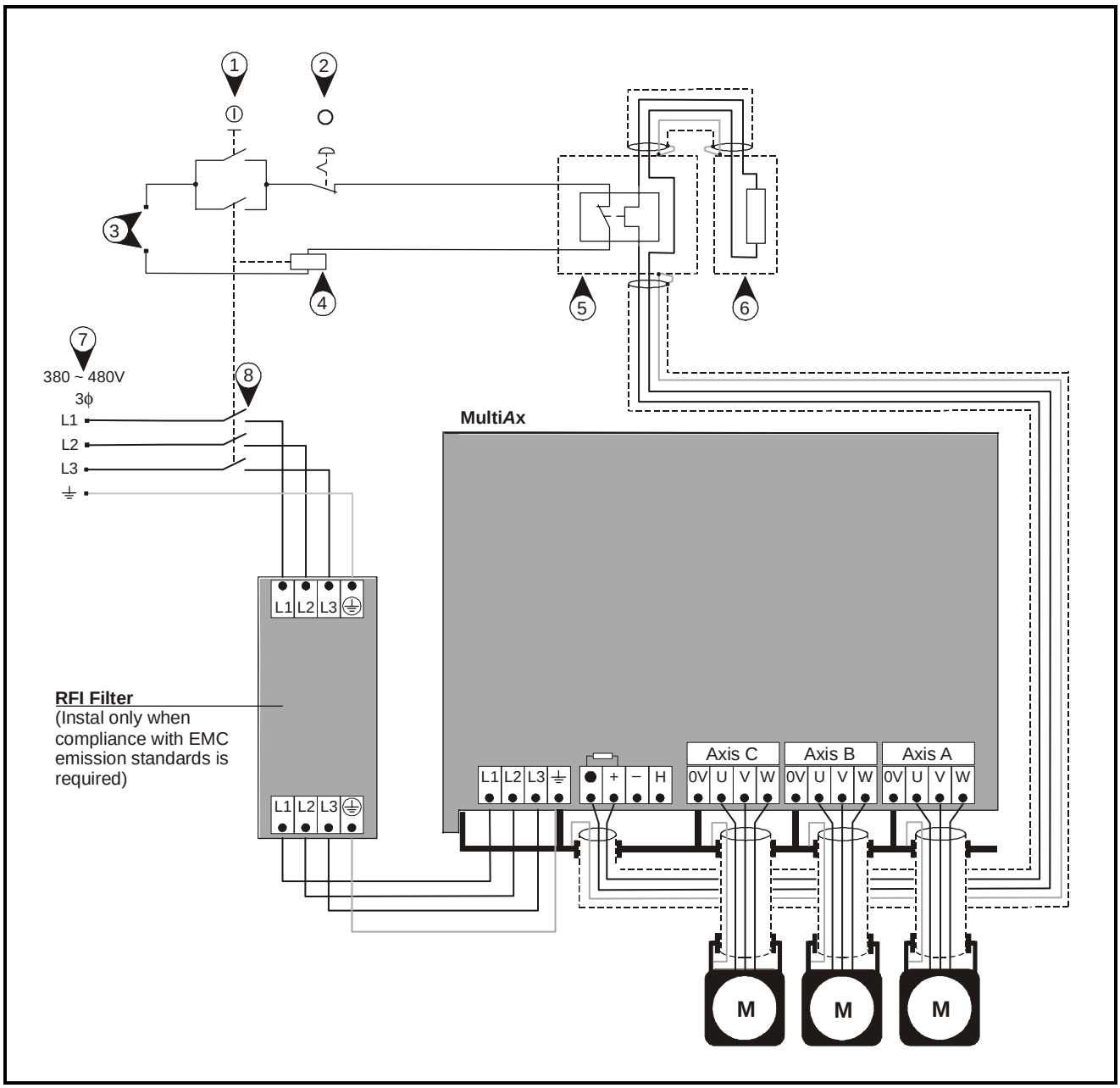
For electrical safety, the ground bracket must be fitted as shown. See also section 3.15 *Circuit diagram for the power connections* on page 15 and section 3.12 *Terminal sizes and tightening torques* on page 13.

Perform all of the following:

1. Fit a plug-in multi-way connector into each of the five 4-way sockets on the underside of the MultiAx.
2. Loosen the screw for each of the ground terminals of the 4-way connectors.
3. Taking care not to lose the recessed nut, remove the screw in the tab at the bottom of the heatsink flange.
4. Fit the four tongues of the ground bracket in the ground terminals of the 4-way connectors and align the hole in the ground bracket with the hole in the heatsink tab.
5. If an additional safety ground is required, fit an adequately rated safety-ground wire to the screw and fit the screw loosely in the tab in order to retain the ground bracket.
6. Tighten the screws in the four ground terminals to the specified torque.
7. Tighten the screw in the heatsink tab to the specified torque.
8. Strip back the insulating sheath on the shielded cables to expose at least 12mm (0.472in) of shield and 40mm (1.575in) of inner conductors.
9. Fit a hose clip over each cable shield to clamp it to the ground bracket. Ensure the hose clip makes good electrical contact with the shield or armour.
10. For the motor and braking resistor cables, connect each ground wire to the ground bracket using the related hole at the position shown. This applies whether the ground wire is inside or outside the cable.

3.15 Circuit diagram for the power connections

Figure 3-10 Power connections to be made, including a typical protection circuit for the braking resistor



Key to Figure

1. START/RESET switch
2. STOP switch
3. Control supply
4. Contactor coil
5. Thermal overload protection relay
6. Braking resistor
7. AC supply to the MultiAx
8. AC supply Isolator

3.16 EMC emission standards – compliance information

NOTES

Conditions for EMC compliance

The installer of the drive is responsible for ensuring compliance with the EMC regulations that apply where the drive is to be used.

The drive will comply with the standards for emission, such as EN50081–2, only when the instructions given in this section are adhered to closely.

Special note for EN61800-3 (EMC Power Drive Systems)
For installation in the "second environment", ie, where the low voltage supply network does not supply domestic premises, and where the rated input current of the drive system exceeds 100A, no filter is required in order to meet IEC61800-3 (EN61800-3).

CAUTION

Operating the Drive in this environment without an RFI filter may cause interference to nearby electronic equipment whose sensitivity has not been appreciated. The user must take remedial measures if this situation arises.
If the consequences of unexpected disturbances are severe, it is recommended that the emission limits of EN50081-2 be adhered to.
In any other case adhere to the precautions described in this section.

When the drive is used in the "first environment", i.e. where the low voltage supply network also supplies domestic premises, the following warning applies:

WARNING

This is a product of the restricted distribution class according to IEC 61800-3.
In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

3.17 EMC emission standards – instructions

Follow these instructions in addition to those given earlier in this chapter.

Enclosure
The enclosure must be made of metal but does not require special EMC features.

Back-plate
Ensure the enclosure back-plate is unpainted, but it may be zinc plated.

Mounting brackets electrically connected to the back-plate
Ensure the mounting brackets for the drive and RFI filter make direct electrical connection with the back-plate.

Grounding
For compliance with EMC emission standards, employ the grounding arrangements shown in this section. These arrangements are in addition to (not instead of) the safety requirements.
The fitting of an additional safety ground will not reduce the EMC performance.

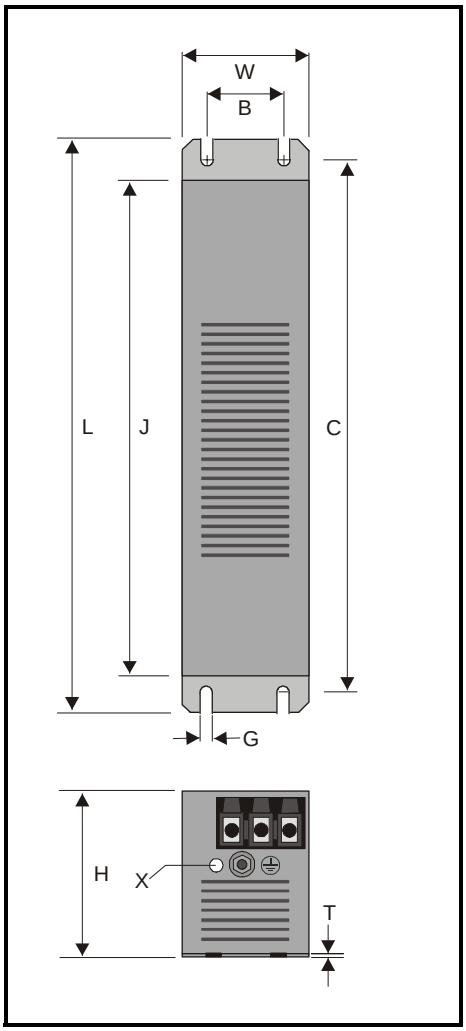
External braking resistor
When an external braking resistor is to be mounted outside the enclosure, ensure the following:
- The resistor housing will give electromagnetic shielding (without compromising ventilation)
- The braking-resistor wiring must be shielded/armoured

Installing an RFI Filter
For compliance with emission standards such as EN50081-1 or EN50081-2, use an RFI filter for each drive, as shown in the table below. (Standards that are met are specified in section B.2 *Optional RFI filter* on page 28.)

Model	RFI Filter		
	Part Number	Maximum power dissipation	Ingress Protection
MultiAx (all versions)	4200-3258	11.83W	IP20

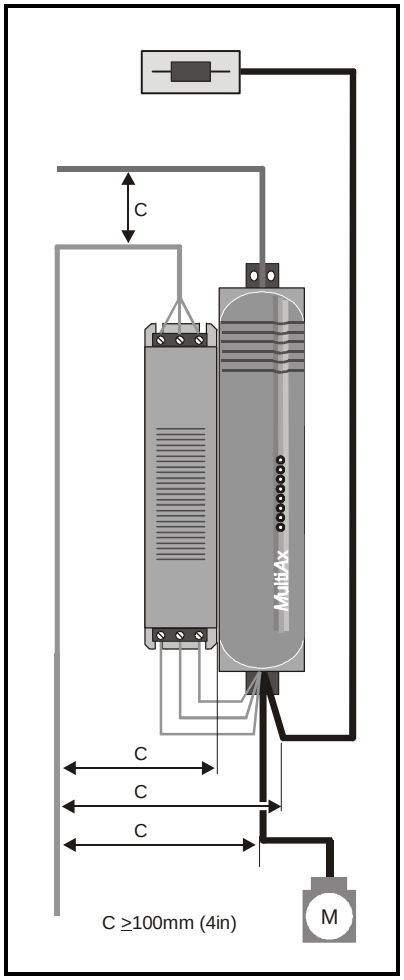
Make a note of the following for each RFI filter to be used:
- Part number
- Maximum power dissipation figure
- IP rating

Figure 3-11 Dimensions of the RFI filter



L	W	H	J	B	C	G	T		X
270	50	85	240	30	255	5.4	1.0	mm	M5
10.63	1.969	3.346	9.449	1.181	10.039	0.213	0.039	in	

Clearances from the RFI filter and AC supply cables



1. Mount the RFI filter as close as possible to the drive. No clearance is required either side of the RFI filter or the drive.
2. Make the wires connecting the RFI filter to the drive as short as possible.
3. Allow at least 100mm (4 in) clearance (C) between the AC supply cable and the following:
   - Signal cables
   - Drive
   - Braking resistors and cables
   - Motors and cables

3.18 Additional ground connections for the signal cables

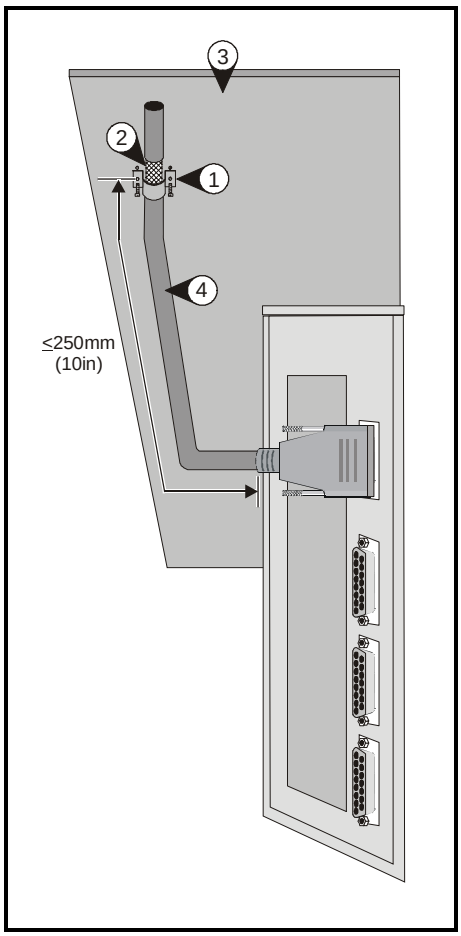
Electrically bond the shields of all the signal cables to the back-plate by direct grounding unless ground-loop currents cause problems . In this case, indirect grounding can be used to ground all the cables.

Refer to the next two diagrams.

Direct grounding

1. Using an uninsulated metal cable-clamp (1), electrically bond the shield (2) of the cable to the back-plate (3).
2. Ensure there is no more than 250mm (10 in) of cable length (4) between the clamp and the drive.

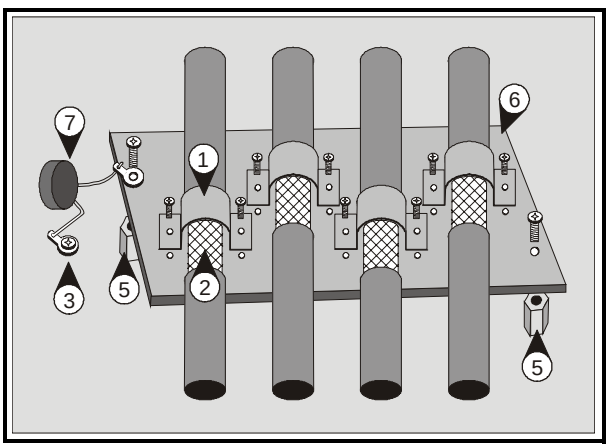
(For clarity, the upper mounting bracket has been omitted from this view.)



Indirect grounding

Indirect grounding uses a 10nF capacitor to prevent low-frequency ground-loop currents from occurring; these can cause problems in systems controlled by analog signals.

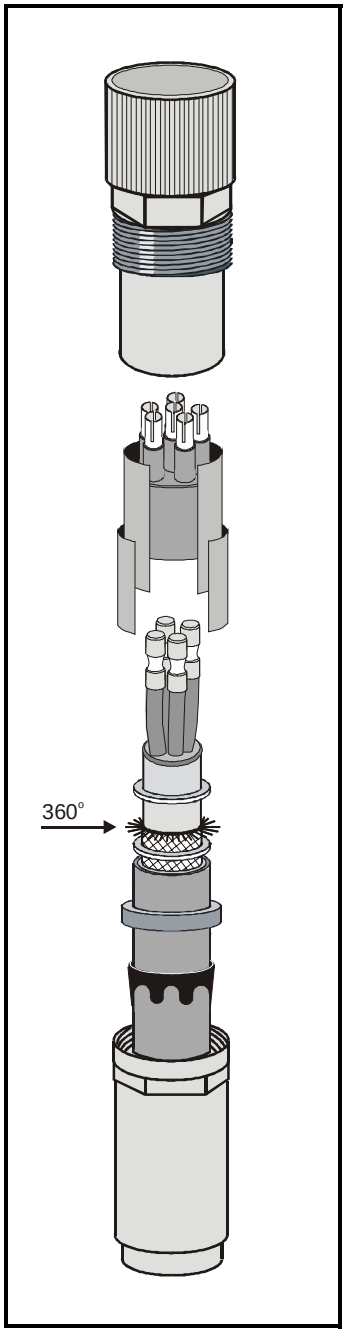
1. Use insulating studs (5) to mount an uninsulated metal plate (6) on the back-plate (3); the plate (6) must be insulated from the back-plate.
2. Using uninsulated metal cable-clamps (1), electrically bond the shield (2) of each cable to the metal plate (6).
3. Ensure there is no more than 250mm (10 in) of cable length (4) between each clamp and the drive. (Refer to the preceding diagram.)
4. Connect a 10nF 2kV ceramic disc capacitor (7) between the metal plate (6) and the back-plate (3). Maximum permissible length of each lead-out wire is 20mm (0.787in).



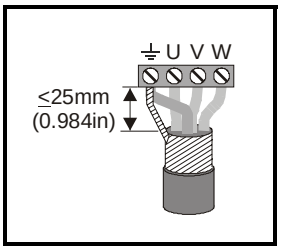
3.19 Bonding the cable shield to the motor frame

The shield of the motor cable must be electrically bonded to the motor frame. The preferred method of achieving this is to connect the shield to the ground terminal of the motor, as shown in the following two diagrams.

For motors that have a power input socket, a metal cable plug should be used and the cable shield make contact with the shell throughout its entire circumference (full 360° termination). (A typical plug is shown aside.)



If a full 360° termination is not possible (due to a plastic plug being used, or the motor having separate terminals and cable glands), a link no longer than 25mm (0.984in) between the shield and the terminal should be used.



4 Connecting the drive

Follow the instructions in this chapter for product familiarisation as well as permanent installation.

Personnel requirements
The drive must be installed and operated only by personnel having the necessary training or experience.

Motor safety
If this is the first time the drive has been operated, ensure that no damage or safety hazard could arise from the motor starting unexpectedly.
For product familiarisation as well as full installation, the motor must be fixed down and the shaft guarded against inadvertent contact.

Stored charge
The drive contains capacitors that remain charged to a potentially lethal voltage after the AC supply has been disconnected. If the drive has been energized, the AC supply must be isolated at least five minutes before work may continue.

For permanent installation...

Refer to the following:

- Chapter 1 *Safety Information*
- Chapter 3 *Installing the MultiAx*
- The remainder of this chapter
- Appendix C *Signal Connections*

For product familiarisation...

For operation make temporary power and signal connections (see next page), then follow Chapter 5 *Setting Up the MultiAx* on page 25.
For making the power connections, refer to Chapter 1 *Safety Information* and the following sections in Chapter 3 *Installing the MultiAx* :

- AC supply protection
- Power cables
- Signal cables and connectors
- Precautions for making power connections
- Terminal sizes and tightening torques
- Method of connecting the power cables
- Circuit diagrams for the power connections

Refer to the remainder of this chapter for making signal connections and Appendix C *Signal Connections* .

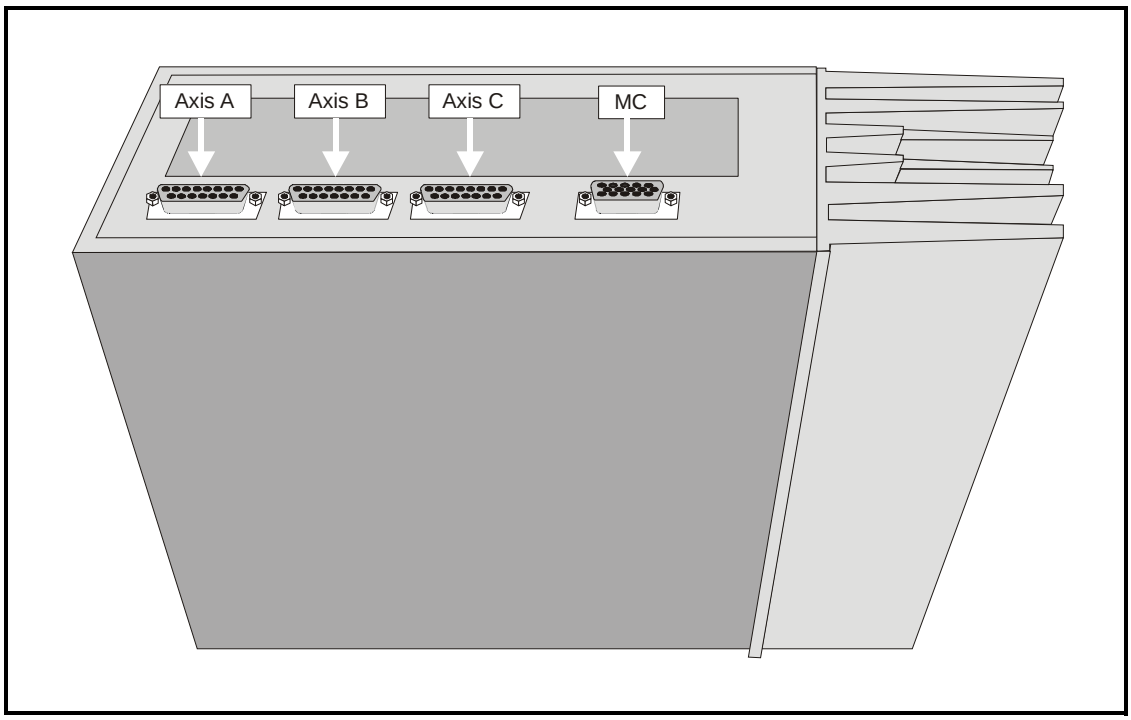
4.1 Making electrical connections

Setting up the drive without an AC supply...

If required, the drive can be set up for the application without the use of an AC supply. In this case, an Auxiliary supply must be connected. Before continuing, see *section 4.7 Back-up supplies* on page 22.

4.2 Locations of the signal connectors

Figure 4-1 Locations of the signal connectors on the MultiAx



4.3 Functions of the signal connectors

D-type connectors

MC

- ***SLM technology*** I/O to a motion controller for all axes
- **Global Hardware enable** input (electrical signal from a system or motion controller for all axes
- **Status-relay** contact
- **SLM supply** input can be applied when the drive is powered-down to retain position (see section 4.7 *Back-up supplies* on page 22)

Axis-C

- ***SLM technology*** I/O to axis C **SLM**
- **Hardware enable** input (electrical signal from a system or motion controller for axis C)
- 24Vdc supply to the **SLM**
- **Full current-scaling** input (electrical signal used to set the full scale current limit of axis C)

Axis-B

- ***SLM technology*** I/O to axis B **SLM**
- **Hardware enable** input (electrical signal from a system or motion controller for axis B)
- 24Vdc supply to the **SLM**
- **Full current-scaling** input (electrical signal used to set the full scale current limit of axis B)

Axis-A

- ***SLM technology*** I/O to axis A **SLM**
- **Hardware enable** input (electrical signal from a system or motion controller for axis A)
- 24Vdc supply to the **SLM**
- **Full current-scaling** input (electrical signal used to set the full scale current limit of axis A)

NOTE

The link is only checked on power-up. Do NOT change without re-commissioning.

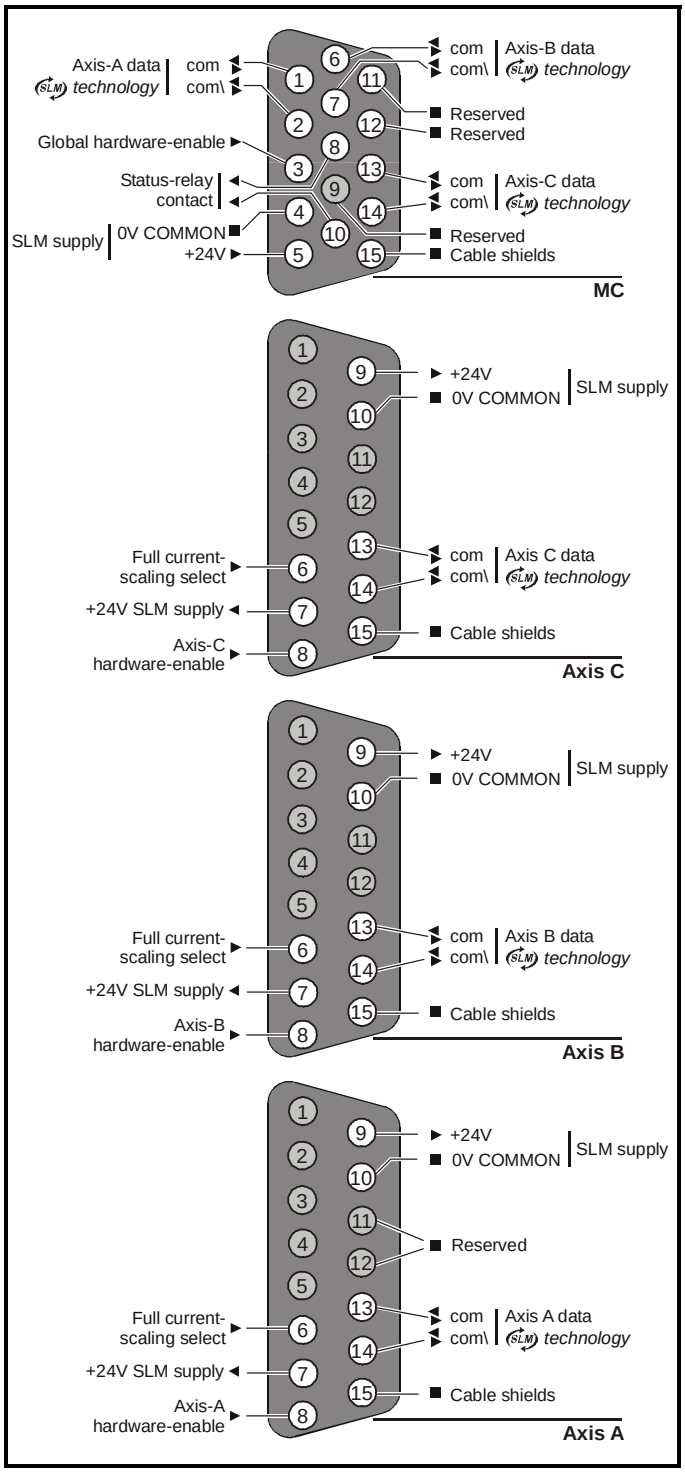
NOTE

The MultiAx will not respond to any enable / disable software commands via the SLM until the drive sees a rising edge on the Hardware enable signal after a drive power-up. The host controller must guarantee that the Hardware enable signal is not present at the drive power-up or toggle it afterwards. This is a safety feature to prevent any unintentional live power stage at drive power-up.

CAUTION

Wait 30 seconds after removing power to the drive before inserting or removing control cables as 'hot plugging' cables can result in damage to the drive or SLM.

Figure 4-2 Functions of the signal terminals



Parallel and multiple connections

The following functions are available on more than one connector (the related terminals are connected in parallel in the drive):

0V COMMON
+24V SLM supply
Axis-A data *SLM technology*
Axis-B data *SLM technology*
Axis-C data *SLM technology*

Hardware enable

For the MultiAx to run, **Hardware enable** and **Software enable** (described in Chapter 5 *Setting Up the MultiAx*) must be both be applied.

Since the hardware-enable function in the MultiAx is edge-triggered, **Hardware enable** signal(s) must be applied after the MultiAx has been powered-up.

Global or axis enable

When a **Global Hardware enable** is applied, it will simultaneously enable all three axes (each axis will also require a software enable, see *Hardware enable* above). It is also possible to apply a **Hardware enable** signal to individual axes if required. It is not necessary to apply global as well as axis hardware-enable signals.

Current-scaling modes

The MultiAx is supplied with all three axes operating in the default current-scaling mode. By connecting a wire link in the related D-type signal connector, one or more axes can be operated in the full current-scaling mode. This can assist with matching the MultiAx to the current-ratings of the motor.

NOTE

The correct cable MUST be used. Monitor (VDU) signal cables are NOT suitable for use with the MC connector.

D-type connectors

For connection to the following connectors on the MultiAx...

- **MC**

...use the following:

Cables

Multi-core cables having tinned-copper stranded twisted pair conductors, overall braided shield and braided outer sheath.
Maximum overall diameter: depends on the D-type connector being used.

Connectors

15-way High density D-type male / plug connector

- **Axis A**
- **Axis B**
- **Axis C**

...use the following:

Cables

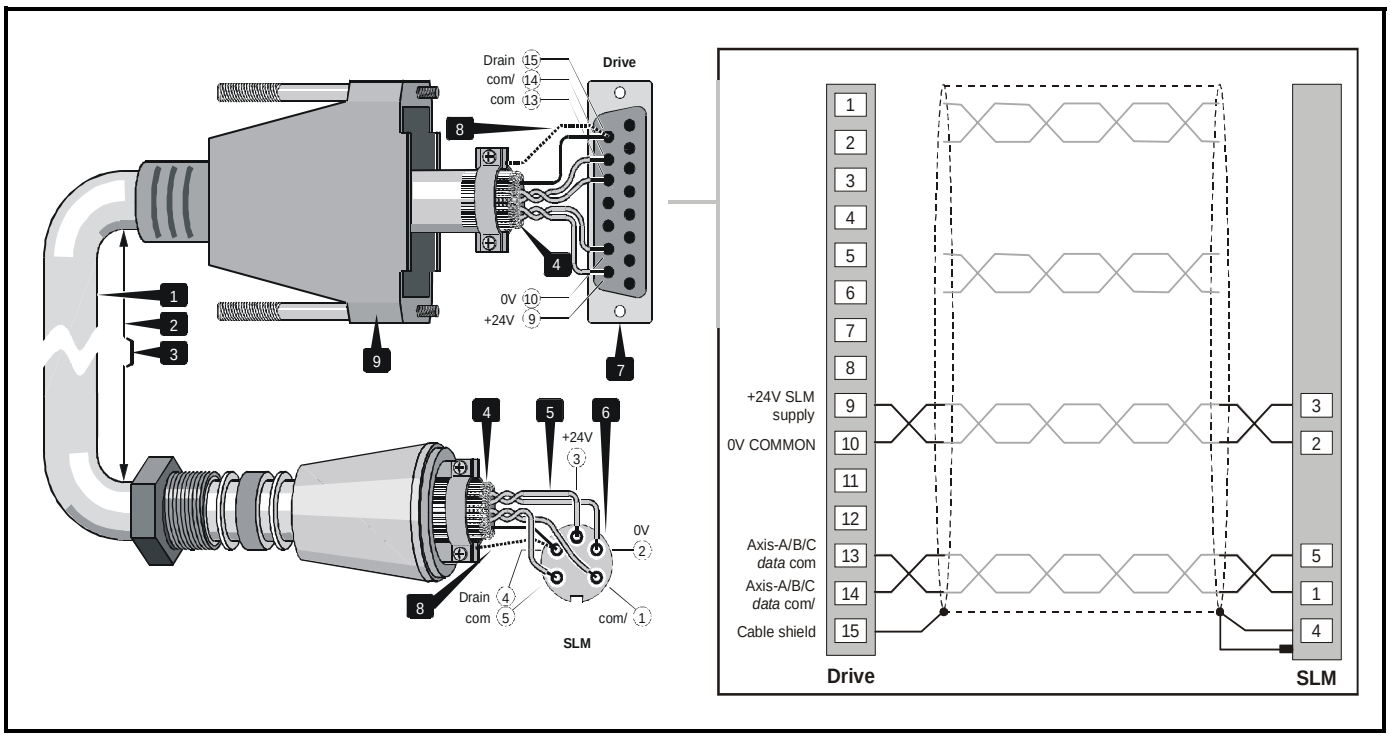
Up to four twisted-pairs having an overall shield (unused wires must not be connected to pins at the other end)
Maximum length: 50m (165ft)
Maximum overall diameter: depends on the D-type and SLM connector being used.
Static installations: for example, use BICC type **S-FTP patch**, four twisted pairs, 5.33mm diameter
Dynamic installations: for example, use Intercond type **3MBM 26P 02P**, 2 twisted pairs, 5.5mm diameter

Connectors

15-way D-type male / plug connector

4.4 SLM connections

Figure 4-3 Connecting the SLM cable to the connectors (only the relevant parts of the connectors are shown)



1. Two twisted-pairs having an overall shielded braid
2. Maximum length: 50m (165ft)
3. Route the cable by the shortest convenient path and so that it is no closer than 300mm (12in) from any power cable.
4. Overall shield of tinned copper braid. Comb out the braid at both ends, fold the strands back and trap them under the cable clamp to ensure good electrical contact with the connector shell.
5. Make the wire ends as short as possible (this affects performance).
6. 5-way screw-locking DIN connector meeting IP67.
7. Shielded high-density 15-way D-type male connector.
8. Drain connection between cable shielded braid and 0V (0V COMMON)
9. Metalised or diecast D-type connector shell

4.5 +24Vdc Supplies

The **+24V SLM supply** should be obtained from the motion controller and applied to the **+24V SLM supply** input (MC connector, pin 5). It is then passed direct to the **+24V SLM supply** outputs (Axis A, B, C connectors, pins 7, 9). The +24V SLM supply should also be used to supply the **Hardware enable** and **Global Hardware enable** inputs, and the **Full current scale select** inputs (see Appendix C.1 *Digital inputs* on page 30).

Permissible voltage for all inputs: 21.6Vdc ~ 26.4Vdc

4.6 Planning the signal-current consumption

Table 4-1 Digital input current requirements at 24V

Circuit	Current drawn
SLM	65mA each
Hardware enable input	6mA each
Global Hardware enable input	18mA
Full current select	13mA each

4.7 Back-up supplies

The following two types of back-up supply can be applied individually or concurrently to the drive.

SLM supply

This supply is totally independent of the drive at all times, which ensures that the position information is not lost in the SLM when the drive is powered-down for any reason.

The low current demand of an SLM (65mA each) makes it practical for a battery to be used for this back-up supply.

Auxiliary supply

The auxiliary supply supplies the control circuits in the drive.

Parameters can be accessed by the motion controller.

This supply can be used also for setting up the drive without an AC supply being connected. See *Auxiliary supply* on page 23.

SLM supply

Functions

- Maintains the 24V supply to the SLM
- Low-current requirements (65mA per SLM)
- The back-up supply can be at ground potential
- The back-up supply can supply one or more drives, and their SLMs, on condition the total current entering any one drive does not exceed 500mA

Requirements

The current from the back-up supply to each drive must be limited to 500mA by a fuse or other protection means.

By unregulated power supply or battery

Maximum permissible voltage: 28Vdc average (30Vdc peak including AC ripple peak)

Minimum permissible voltage: 17V (including AC ripple troughs)

Maximum current: 500mA

Maximum fuse I^2t-rating: $5A^2/_s$

Ensure that the motion controller used is suitable or compatable with a back-up or battery supply. (Refer to the motion controller user guide.)

See Figure 4-4.

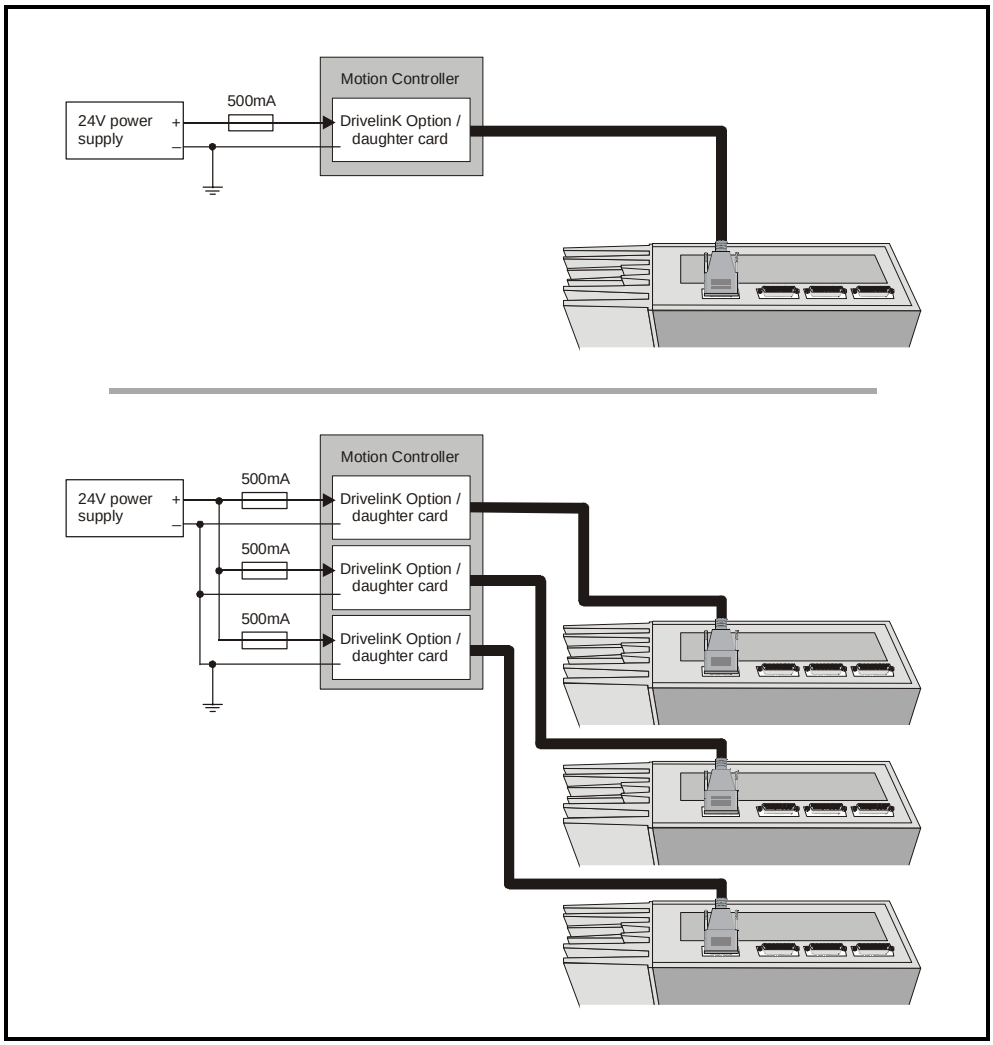


Figure 4-4 SLM and back-up supply connections

Auxiliary supply

CAUTION

Isolation
The *Auxiliary supply* must be isolated from ground since it is referenced to –DC of the DC bus. It must also be isolated from any other *auxiliary supply* except when the DC-buses of the drives are connected in parallel.
Failure to observe these requirements will result in damage to the back-up supplies and drive(s).

WARNING

The *Auxiliary supply* MUST be supplied using an isolating transformer.

Functions
- Maintains the DC supply to the control circuits of the drive.

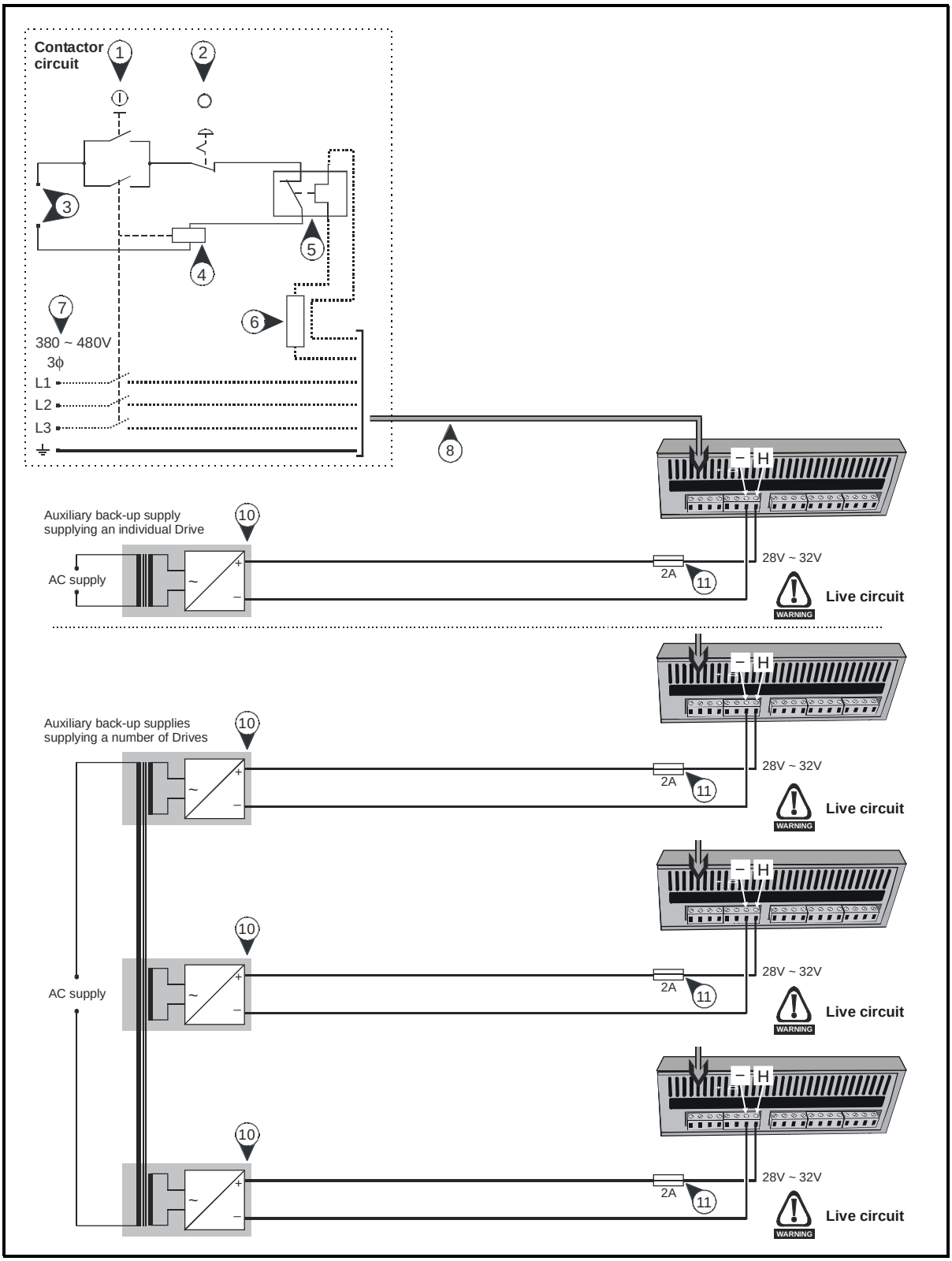
NOTE

The drive will be in a tripped state (undervolts) when using just the Auxiliary supply

Requirements
- Voltage: 28Vdc ~ 32Vdc
- Maximum current to the control circuits (of each drive): 2A

In addition to the appropriate connections, make connections shown in Figure 4-5.

Figure 4-5 Auxiliary supply connnections (these are additional to those shown in Figure 3-10)



Key

1. START/RESET switch (momentary)
2. STOP switch (latching)
3. Control-circuit supply
4. Contactor coil
5. Thermal-overload protection relay for braking resistor
6. Optional external braking resistor
7. 380 ~ 480Vac supply to the drive
8. Power connectors on the drive
9. Interlock relay in contactor circuit
10. Isolated power supply
11. 2A fuse to protect the control circuits

5 Setting Up the MultiAx

WARNING

Read Chapter 1 *Safety Information* before applying AC power to the MultiAx or any associated equipment.

NOTE

Since the MultiAx can be used with different types of motion controller, the setting-up instructions and information in this chapter are not specific to operation with any type of controller; for certain controllers additional instructions and information may be required. Refer also to the documentation for the motion controller.

5.1 Commissioning

To commission the MultiAx refer to the machine, system or motion controller user guide.

5.2 Primary axis

The MultiAx can be used to run up to 3 motors. For applications that use a MultiAx with only one or two axes, Axis-A MUST always be configured for use. I.e. Axis-A must NOT be the redundant axis.

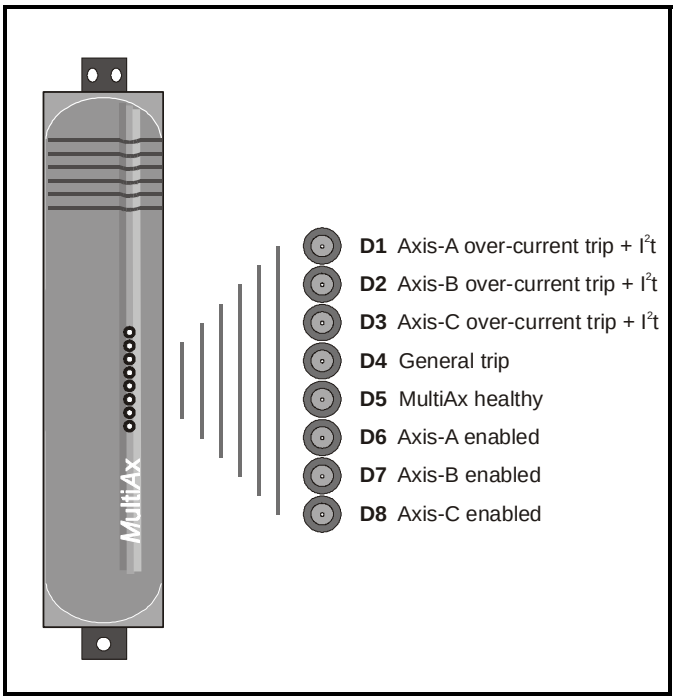
5.3 Diagnostics

WARNING

Users must not attempt to repair a drive if it is faulty, nor carry out fault diagnosis other than through the use of the diagnostic features described in this section. Under no circumstances must the casing of the drive be opened when the AC supply is connected.
If a drive is faulty, it must be returned to an authorised Control Techniques distributor for repair.

Status indicators

Figure 5-1 Status indicators on the front panel of the MultiAx



When the MultiAx is operating normally, indicator **D5** is continuously lit. If the MultiAx trips, **D5** is extinguished and other indicator(s) are lit, as follows:

D1, **D2**, **D3**
- Excessive instantaneous output current
- The value of I^2t for the related axis has reached the trip level

D4
- The trip has been caused by a fault other than those above (see controller fault finding guide)

D6, **D7**, **D8** are lit when their related axis has received a **Hardware enable** (global or axis) plus a **Software enable**. If an SLM trips, the axis becomes disabled (the **Software enable** is removed) and the related indicator becomes extinguished.

5.4 Clearing trips

1. Remove the cause of the trip (see *Fault finding*).
2. Reset the MultiAx using the motion controller or by removing and re-applying the AC supply
3. Re-position the motor shafts, as required.

5.5 Fault finding

Refer to the machine or system user guide for fault codes and their meanings.

Appendix A UL Listing Information

The drive conforms to UL listing requirements only when the following are observed:

- The drive is installed in a type 1 enclosure, or better, as defined by UL50
- UL-listed fuses class CC 600Vac are used in the AC supply
- Class 1 60/75°C (140/167°F) copper wire only is used in the installation
- The ambient temperature does not exceed 50°C (122°F) when the drive is operating
- The terminal tightening torques specified in Table 3-6 on page 13

A.1 AC supply specification

The drive is suitable for use in a circuit capable of delivering not more than 5000 RMS symmetrical Amperes at 528Vac RMS maximum.

A.2 Maximum continuous output current

The drive models are listed as having the maximum continuous output currents (FLC) shown in Table A.1 *Maximum continuous output current* , (see Appendix B *Data* on page 27 for details).

Table A.1 Maximum continuous output current

Model	FLC (A)		
	Axis		
	A	B	C
MultiAx SAC / SDC	9.375	9.375	9.375
MultiAx HAC / HDC	15	9.375	9.375

NOTE

MultiAx HAC, MultiAx SDC and MultiAx HDC are pending UL approval.

Appendix B Data

B.1 MultiAx Data

Output current ratings

Table B.1 Current ratings

Model		Output current					
		Maximum continuous			Maximum peak (2s max.)		
		Axis			Axis		
		A	B	C	A	B	C
 MultiAx SAC / SDC	Default current mode	2.5			5.0		
	Full current scaling selected. Pin 6 & 7 on each axis connector linked	9.375			18.75		
MultiAx HAC / HDC	Default current mode	2.5			5.0		
	Full current scaling selected. Pin 6 & 7 on each axis connector linked	15.0	9.375		30	18.75	

NOTE

All MultiAx are supplied in a default state where all axis are configured to 2.5A continuous and 5.0A overload. (See Appendix C Signal Connections on page 30 for configuration).

NOTE

The above table refers to the individual axis current limits. The sum of all three axes can NOT exceed 18.75A continuous or 37A peak without the drive tripping.

Supply currents

Model	Typical total supply current	Maximum total supply current
All MultiAx Models	15.6A	31.2A

NOTE

Typical supply currents apply to a balanced AC supply having a fault current of no greater than 5kA. Maximum supply currents apply to an AC supply having 2% negative phase-sequence and a fault current of 16kA.

AC supply requirements

380V to 480V ±10%

3-phase

48 to 62Hz

Maximum supply imbalance: 2% negative phase sequence (equivalent to 3% voltage imbalance between phases)

Over-voltage categories

The drive can be operated on AC supplies in the following (or better) over-voltage categories...

Grounded star supply:
Over-voltage category 3
Grounded delta and IT supplies:
Over-voltage category 2

For operation on an AC supply in a poorer category, refer to the supplier of the drive for advice on suitable varistors to connect to the AC supply.

Refer also to *Altitude* later in this Appendix.

Temperature, humidity and cooling method

Ambient temperature range:

All MultiAx models
0°C to 50°C (32°F to 122°F) at rated maximum continuous output current (FLC). (See *Output current ratings* earlier in this Appendix)

Cooling method: Internal fan

Maximum humidity: 95% non-condensing at 50°C (122°F)

Storage temperature range: –40°C to 55°C (–40°F to 131°F)

Maximum storage time: 12 months

Altitude

Altitude range without derating: 0 to 2000m (6600ft)

When additional precautions are taken, the drive can be operated at altitudes from 2000m to 4000m (13000ft); for information, contact the supplier of the drive.

Vibration

Random vibration according to IEC 68–2–34

$0.01g^2$/Hz over 5 to 20 Hz, reducing at –3dB/octave from 20 to 500 Hz (0.89g RMS) applied for 30 minutes in each orthogonal axis

Ingress protection

IP20

Suitable for use in a Pollution Degree 2 environment

Overall dimensions

H Height including mounting brackets
W Width
D Projection forward of panel when surface mounted
F Projection forward of the front surface of the panel when through-panel mounted
R Projection rear of the front surface of the panel when through-panel mounted

Dimensions		
H	470mm	18.504in
W	92mm	3.622in
D	320mm	12.598in
F	232mm	9.134in
R	88mm	3.465in

Weight

All models: 10kg (22lb)

Dissipation

Model	Output current			Heat dissipation	
	$T_{AMB\ max}$	Max. continuous	Max. overload (2 secs. max)	Surface Mounting	Through-panel Mounting
MultiAx (all versions)	50°C (122°F)	18.75	37.5	350W	40W

Starts per hour

By electronic control: unlimited

By interrupting the AC supply: ≤20

SLM supply input

Voltage: 17V to 28V

Maximum current: 500mA

CAUTION

A current limit in excess of 500mA can result in damage to the MultiAx.

Auxiliary supply input

Voltage: 28Vdc ~ 32Vdc
Maximum current: 2A
This supply is referenced to –DC. For isolation requirements, see section 4.7 *Back-up supplies* on page 22.

CAUTION

An *Auxiliary supply* must be isolated from ground and any other auxiliary back-up supply. Failure to observe these requirements will result in damage.

Braking resistor

External resistor

Minimum permissible value	30Ω
Operating voltage (V_R)	780V at switch-on 760V at switch-off
Maximum possible braking current (through 30Ω) (I_{bMAX})	26.0A
Peak power rating for 30Ω	20kW
Continuous power rating	(See *Braking resistor example calculations* on page 6)

Electromagnetic compatibility (EMC)

This is a summary of the EMC performance of the drive when installed in accordance with the instructions given in Chapter 3 *Installing the MultiAx* . For full details, refer to the *MultiAx EMC Data Sheet* which can be obtained from a Drive Centre or distributor listed at the end of this guide.

Immunity

Compliance with immunity standards does not depend on installation details. The drive meets EN50082–2 (generic immunity standard for the industrial environment) and the following specifications from the IEC61000–4 group (derived from IEC801):

- Part 2, Electrostatic discharge: Level 3
- Part 3, Radio frequency field: Level 3
- Part 4 Transient burst:
  - Level 4 at the control terminals
  - Level 3 at the power terminals
- Part 5, Surge (at the AC supply terminals):
  - Level 4 line-to-ground
  - Level 3 line-to-line (as specified by EN50082–2 informative annex)
- Part 6, Conducted radio frequency: Level 3

Emission

Compliance with emission standards depends on rigorous adherence to the installation guidelines, including the use of the specified RFI filter in the AC supply circuit. Compliance also depends on the length of the motor cable. For full details, refer to the *MultiAx EMC Data Sheet* which can be obtained from a Drive Centre or distributor listed at the end of this guide.

Summary

Conducted and radiated emission meet EN50081–2 (generic emission standard for the industrial environment) over a wide range of conditions. This is similar to CISPR11 and EN55011 Class A.
The optional RFI filter, part number 4200-3258, must be used.

Compliance with EN61800-3 (standard for Power Drive Systems)

Meeting the requirements of this standard depends on the environment that the Drive is to be operated in, as follows:

Operation in the first environment

Observe the wiring guidelines given in the whole of Chapter 3 *Installing the MultiAx* , including the Compliance with EMC emission standards sections.
Note the warning given on page 16.

Operation in the second environment

Where the rated input current of the drive system is less than 100A:
Observe the wiring guidelines given in the whole of Chapter 3 *Installing the MultiAx* , including the Compliance with EMC emission standards sections.
Where the rated input current of the drive system exceeds 100A:
Observe the wiring guidelines given in Chapter 3 *Installing the MultiAx* , excluding the section Compliance with EMC emission standards.

B.2 Optional RFI filter

Main ratings

Part number	4200-3258
Max. continuous current	30A
Power dissipation at rated current	11.83W

Maximum ambient temperature at rated current and frequency range: 50°C (122°F)
Ingress protection: IP20

AC supply ratings

Maximum operating voltage: 480V ±10% at up to 50°C (122°F)
AC supply frequency: 48 to 62 Hz

Ground leakage current

Ground-leakage current phase-to-phase and phases-to-ground is as follows:

Balanced supply, all phases present: 33mA
Two phases disconnected: 192mA

These figures apply for an AC supply of 400V at 50Hz. For other AC supply voltages and currents, scale the values of leakage current proportionally.

Discharge resistors

330KΩ star network between the AC supply phases; the star point is connected by a 1MΩ resistor to ground. These resistors are fitted internally.

Maximum current overload

150% of rated current for 60 seconds.

Overall dimensions

Part Number	Dimension		
	Height	Width	Depth
4200-3258	270mm (10.63in)	50mm (1.969in)	85mm (3.346in)

Weight

Part Number	kg	lb oz
4200-3258	1.2	2lb 10oz

B.3 Motor cables

Ordering motor cables

Cables of the required lengths and type of sheath, and fitted with appropriate terminations to suit the MultiAx and CT-Dynamics SL motors, are supplied by Control Techniques Dynamics Ltd. For ordering, create the required order code (see below) and contact the supplier of the MultiAx.

The order code is constructed as follows:

??	?	?	?	???
1	2	3	4	5

See below for the details of the code.

1	Number of conductors
PS	3-phase + ground
PB	3-phase + ground + motor-brake control

2	Type of sheath
B	PUR Use for dynamic applications (motor mounted on a moving structure) – increased oil resistance

3	Conductor size (phases and ground)	Current rating
A	2.5mm^2	22A
B	4.0mm^2	30A

4	Cable terminations	
	For connection to the MultiAx	For connection to the motor
A	Termination ferrules	6-way size-1 plug
C	Termination ferrules	Termination ferrules
K	Termination ferrules	6-way size-1.5 plug
M	Termination ferrules/Ring for MultiAx	6-way size-1 plug
X	Cut ends	Cut ends

5	Cable length
	Specify length in meters Minimum: 003 (3 meters) Maximum: 050 (50 meters)

Example:

PS B A M 010

10m Unimotor connection to ferrules power cable for a dynamic application.

To avoid a fire hazard, 4mm^2 cable must used when a MultiAx HAC / HDC unit is operating with full current selected on Axis A.

B.4 SLM Signal cables

Ordering signal cables

Cables of the required lengths and fitted with connectors as required are supplied by Control Techniques Dynamics Ltd. For ordering, create the required order code (see below) and contact the supplier of the MultiAx.

The order code is constructed as follows:

SL	?	A	?	???
1	2	3	4	5

Details of the code are shown below.

1	Type of cable
SL	Two twisted pairs in overall shield

2	Type of sheath
B	PUR Use for dynamic applications (motor mounted on a moving structure) – increased oil resistance

3	Options
A	Standard

4	Cable termination		
D	15-way standard density D-type	5-way DIN connector	MultiAx to SLM
E	15-way standard density D-type	Cut end	
X	Cut end	Cut end	

5	Cable length
	Specify length in meters Minimum: 003 (3 meters) Maximum: 050 (50 meters)

Example:

SL B A D 010

10m MultiAx-to-SLM cable for a dynamic application.

Isolation

The signal connections are isolated from the power circuits by basic insulation only. Ensure that all external control circuits connected to this connector are separated from human contact by at least one layer of insulation rated for use at the AC supply voltage.

Wait 30 seconds after removing power to the drive before inserting or removing control cables as 'hot plugging' cables can result in damage to the drive or SLM.

Appendix C Signal Connections

WARNING

Isolation
All the signal connections are isolated from the powercircuits by basic insulation only. Ensure that all external control circuits are separated from human contact by at least one layer of insulation rated for use at the AC supply voltage.

C.1 Digital inputs

Logic sense: Positive
Voltage range: –0.3V ~ +30V
Isolation: optical
Input current: 6-18mA at 24V

Current-scaling modes

The MultiAx is supplied with all three axes operating in the default current mode. By connecting a wire link in the related D-type signal connector, one or more axes can be operated in the full current-scaling mode. This can assist with matching the MultiAx to the current-ratings of the motor.

NOTE

The link is only checked on power-up. Do NOT change without re-commissioning.

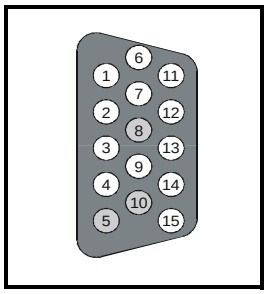
Hardware enable
Hardware enable is a positive-logic input. Time delays are as follows:
Enable time: <250µs
Disable time: <500µs

C.2 Functions of the terminal

MC

Name	Pin	I/O	Function	Specification
Axis-A *data* com	1	I/O	SLM ***technology*** port for bi-directional communications with a motion controller	2-wire EIA485 Connecting cable: Shielded twisted pair
Axis-A *data* com\	2			
Global Hardware-enable	3	I		See section 4.3 *Functions of the signal connectors* on page 20
0V COMMON	4		For use with: SLM *technology* com and com\ Hardware-enables Global hardware-enable 24V SLM supply	0V COMMON must not be interchanged with 0V
+24V SLM supply input	5	I	+24Vdc supply for the SLMs and Hardware-enable inputs	
Axis-B *data* com	6	I/O	SLM *technology* port for bi-directional communications with a motion controller	2-wire EIA485 Connecting cable: Shielded twisted pair
Axis-B *data* com\	7			
Status relay contact	8 10	O	DRIVE HEALTHY Relay contact opens if the drive trips	Voltage rating: 50V AC/DC category 2 Current rating: 0.5A resistive Isolation: 500V Update period: 1ms
Reserved	9 11 12		Do not use	Do not connect
Axis-C *data* com	13	I/O	SLM *technology* port for bi-directional communications with a motion controller	2-wire EIA485 Connecting cable: Shielded twisted pair
Axis-C *data* com\	14			
Cable shield	15 Shell		Connect all the cable shields to the connector shell	

Figure C.1 Female D-type connector pin locations (as seen from the top of the drive)



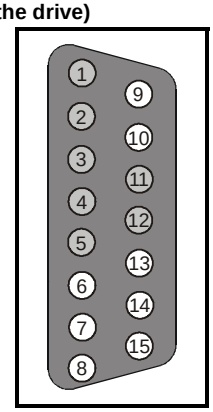
NOTE

The MultiAx will not respond to any enable / disable software commands via the SLM until the drive sees a rising edge on the Hardware enable signal after a drive power-up. The host controller must guarantee that the Hardware enable signal is not present at the drive power-up or toggle it afterwards. This is a safety feature to prevent any unintentional live power stage at drive power-up.

Axis A, B and C

Name	Pin	I/O	Function	Specification
(No connection)	1 2 3 4 5			
Full current-scaling select	6	I	Connect to pin 7 to select high current scaling	See section C.1 *Digital inputs* on page 30
+24V SLM supply	7 9	O		
Axis-A/B/C hardware-enable	8	I	Connect to pin 7 to select axis	See section 4.3 *Functions of the signal connectors* on page 20
0V COMMON	10		For use with: SLM *technology* com and com\ Hardware-enables Global hardware-enable 24V SLM supply	0V COMMON must not be interchanged with 0V
Reserved	11 12		Do not use	Do not connect
Axis-A/B/C *data* com	13	I/O	SLM *technology* port for bi-directional communications with a motion controller	2-wire EIA485 Connecting cable: Shielded twisted pair
Axis-A/B/C *data* com\	14			
Cable shield	15 Shell		Connect all the cable shields to the connector shell	

Figure C.2 Female D-type connector pin locations (as seen from the top of the drive)



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