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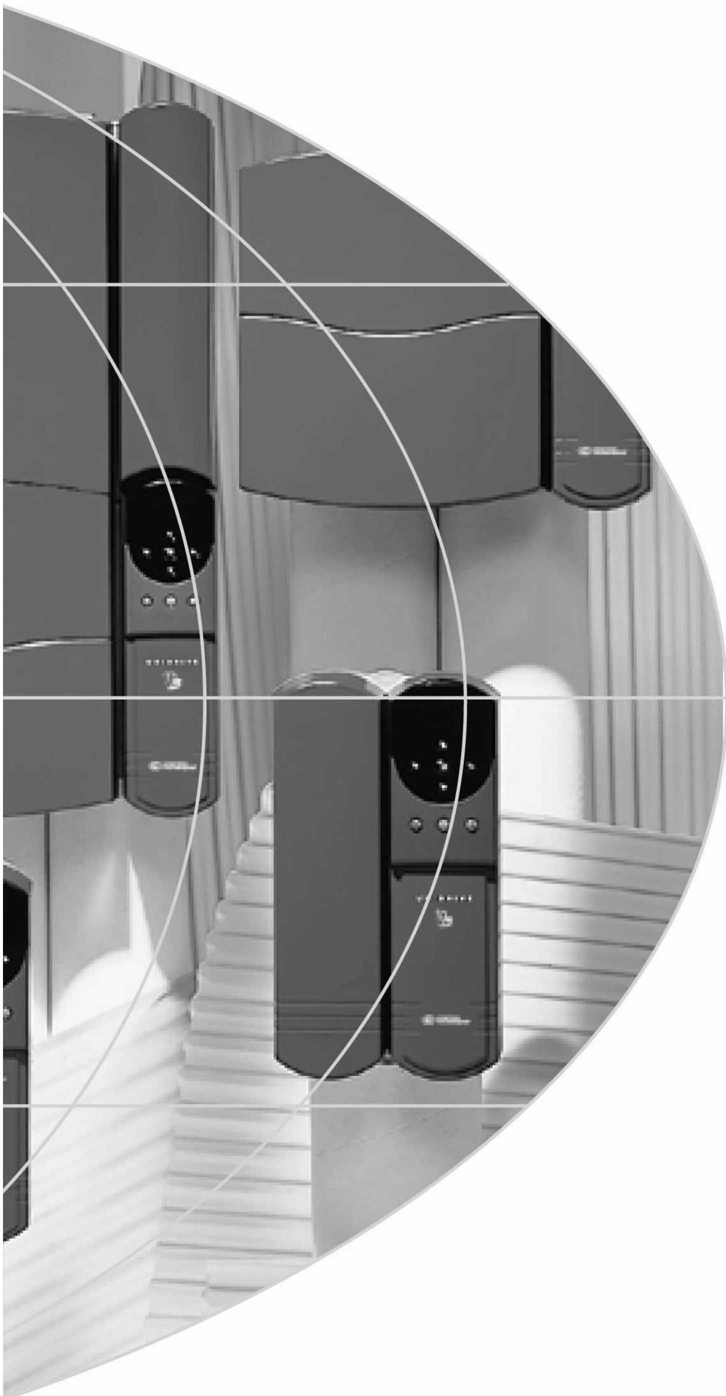

Installation Guide

Unidrive Regen

Part Number: 0460-0026-02
Issue Number: 2

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 variable speed drive with the motor.

The contents of this 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 guide, without notice.

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This product is supplied with the latest version of software. If this product is to be used in a new or existing system with other drives, there may be some differences between their software and the software in this product. These differences may cause this product to function differently. This may also apply to drives returned from a Control Techniques Service Centre.

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Issue Number: 2

Contents

1 Introduction

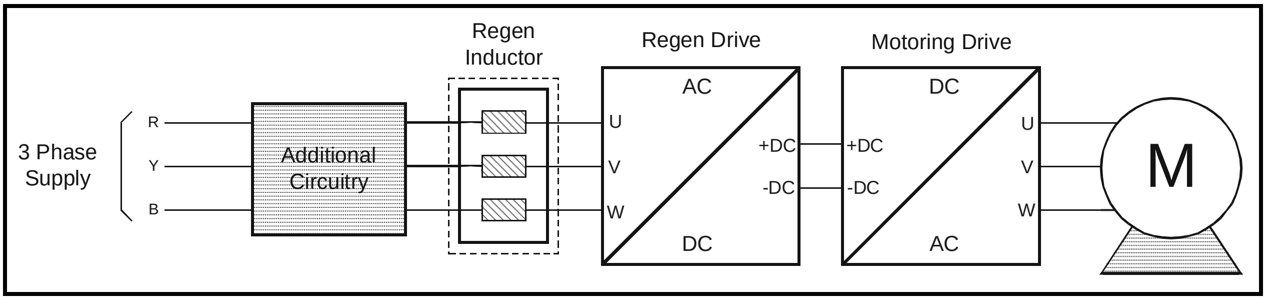
Any standard Unidrive can be configured as an AC Regenerative Unit (hereafter referred to as Regen drive).

This Installation guide covers the following:

- Principles and advantages of operation in Regen mode
- Details of additional components required
- Configuration of Regen systems

At least two Unidrives are required to form a complete Regenerative system - one connected to the supply and the second one to the motor. A Unidrive in Regen mode converts the AC mains supply to a controlled DC voltage which is fed into other drive(s) to control a motor.

Figure 1-1 Regen drive system connection



1.1 Principles of operation

The input stage of a non-regenerative AC drive is usually an uncontrolled diode rectifier, therefore power cannot be fed back into the AC mains supply.

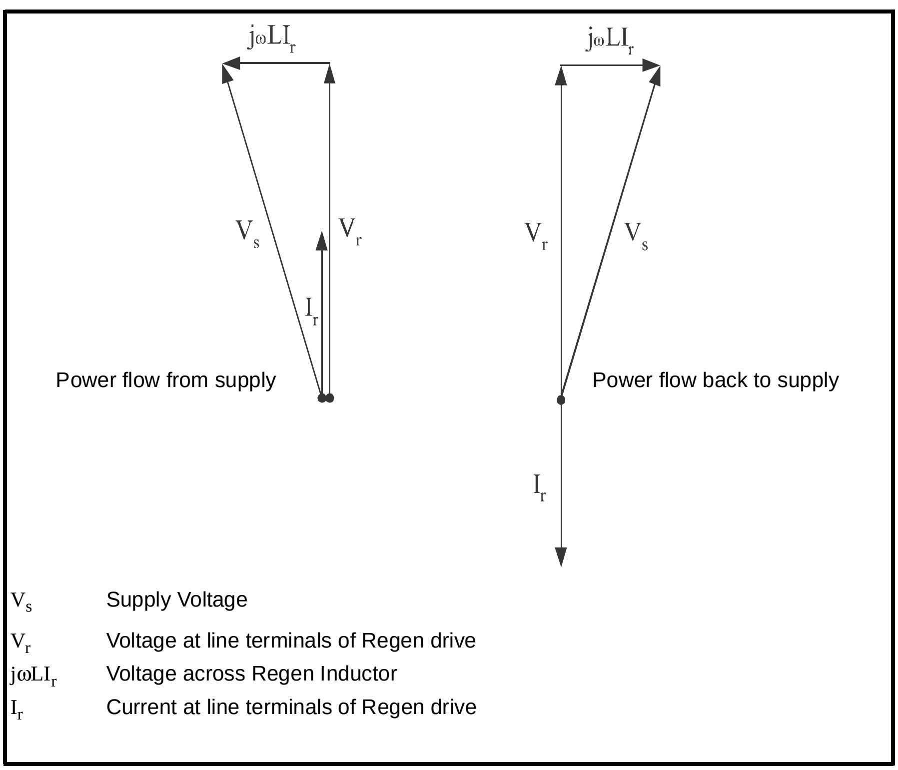
In the case of a Unidrive operating in Regenerative mode, the IGBT bridge is used as a sinusoidal rectifier, which converts the AC supply to a controlled DC voltage. This DC voltage can then be used to supply one or more Unidrives which control motors, commonly known as motoring drives.

A Regen drive produces a PWM output voltage which has a sinusoidal fundamental at an amplitude and phase which are almost the same as those of the AC supply voltage. The difference between the drive PWM line voltage and the supply voltage occurs across the Regen drive's inductors. This voltage has a high frequency component which is blocked by the Regen inductor and a small sinusoidal component at line frequency. As a result, currents flowing in these inductors are sinusoidal with a small high frequency ripple component.

NOTE

Terminals L1, L2 and L3 and the associated diode rectifier are not connected and are redundant on drives used in a Regen configuration.

Figure 1-2 Phasor diagram



1.2 Power flow

The phasor diagram in Figure 1-2 illustrates the relationship between the supply voltage and the Regen drive voltage. The angle between the two voltage vectors is approximately 5° at full load, giving a power factor which is near unity.

The direction of the power flow can be changed relative to the supply voltage, by making small changes to the Regen drive output voltage and phase. A fast transient response is achieved by means of a space vector modulator.

1.3 Advantages of Unidrive operating in Regen mode

The main advantages for an AC Regen system are:

- Energy saving
- The input current waveform is sinusoidal
- The input current has a near unity power factor
- The output voltage for the motor can be higher than the available AC mains voltage
- The Regen drive will synchronise to any frequency between 30 and 100Hz, provided the supply voltage is between 380V -10% and 480V +10%
- Under conditions of AC mains instability, a Unidrive Regen system can continue to function down to approximately 150Vac supply voltage without any effect on the DC bus voltage and hence on the operation of the motoring drives (increased current will be taken from the AC supply to compensate up to the current limit of the Regen drive)
- The Regen and motoring drives are identical

2 Sizing of a Regen system

Refer to Appendix E *Unidrive Regen specifications* on page 44, for the specifications of the Unidrive Regen.

The sizing of a Regen system must take into account the following factors:

- Line voltage
- Motor rated current, rated voltage and power factor
- Maximum load power and overload conditions

In general, when designing a Regen system, equal Regen and motoring drive rated currents will work correctly. However, care must be taken to ensure that under worst case supply conditions the Regen drive is able to supply or absorb all the required power. In multi-drive configurations, the Regen drive must be of a sufficient size to supply the net peak power demanded by the combined load of all the motoring drives and the drive losses.

If the Regen drive is unable to supply the full power required by the motoring drive, the DC bus voltage will drop and in severe cases may lose synchronisation with the mains and trip. If the Regen drive is unable to regenerate the full power from the motoring drive into the DC bus, then the Regen/motoring drive will trip on over-voltage.

The following are two examples of how the required ratings of a Regen drive can be calculated.

NOTE

The Regen drive's current limits are set at 150% and are not adjustable.

In the case of a 25A, UNI2403 operating in Regen mode from a 400V supply, and a UNI2403 driving a 400V rated, 0.85 pf motor:

The rated power of the Regen drive is $= \sqrt{3} \times$ Rated current $\times$ Supply voltage
$= 1.73 \times 25 \times 400$
$= 17.3$kW

The motoring drive can supply power $= \sqrt{3} \times$ Rated current $\times$ Motor voltage $\times$ Power factor
$= 1.73 \times 25 \times 400 \times 0.85$
$= 14.7$kW

When the motoring drive is supplying rated current to the motor, the Regen drive only needs to provide 14.7kW, plus drive losses. The Regen drive can supply 17.3kW at rated current, which is ample, in this case.

Conversely, in some cases, a Regen drive of the same rating as the motoring drive, may not be able to supply enough power, as the following example shows:

Example

In the case of a 156A, UNI4403 operating in Regen mode, and a UNI4403 driving a 75kW, 400V, 0.95pf motor:

If the motoring drive is supplying 175% maximum current and the Regen drive has its 380V supply at the lower limits of -10% (342Vac), then, at the Regen current limit of 150%:

The Regen drive max. available power is $= \sqrt{3} \times 150\% \times$ Rated current $\times$ Supply voltage
$= 1.73 \times 1.5 \times 156 \times 342$
$= 138.6$kW

The motoring drive max. power is $= \sqrt{3} \times 175\% \times$ Rated current $\times$ Motor voltage $\times$ Power factor
$= 1.73 \times 1.75 \times 156 \times 400 \times 0.95$
$= 179.7$kW

The Regen drive is also required to supply the Regen and motoring drive losses. However, this Regen drive is only capable of supplying approximately 138.6kW and therefore a drive of a larger current rating is required.

Due to the effects of increased DC bus capacitance, there is a limit to the number of motoring drives that can be supplied from a Regen drive. This is true irrespective of the balance of power between the motoring drives and the Regen drive.

NOTE

If the system consists of one Regen Unidrive and more than three motoring drives, Control Techniques Technical Support MUST be consulted about the design of the system.

3 Power connections

The following section covers the power connections required for Unidrive Regen systems. Note that with Unidrive Regen systems there are no AC supply connections made to L1, L2 or L3 drive terminals.

NOTE

For control circuit connections refer to Chapter 4 *Control circuit connections* on page 8.

3.1 Overall system layout

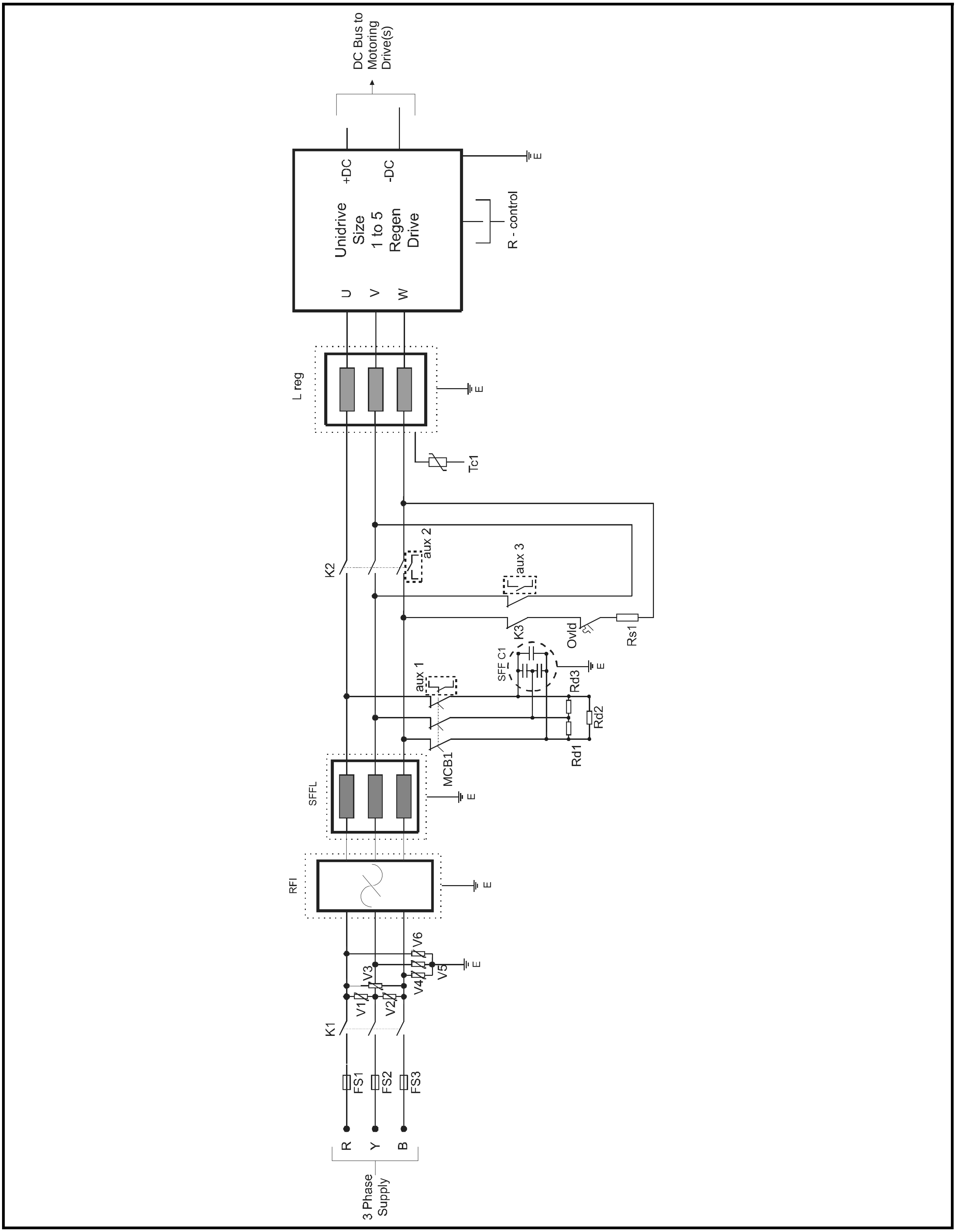
The table below shows the key to the following system layout diagrams.

Table 3-1 Key to Figure 3-1 and Figure 3-2

E	Ground connection point
RFI	EMC filter
SFFL	Switching frequency filter inductor
L regx	Regen inductor
V1, V2, V3	Varistor network 550V (line to line)
V4, V5, V6	Varistor network 680V (line to ground)
Rsx	Softstart resistor
R-control	Ribbon cables to control pod (Unidrive size 5 only)
R-parallel	Ribbon cables between power modules (Unidrive size 5 only)
Fsx	AC supply fusing
Fx	AC Regen fusing (Unidrive size 5 only)
SFF Cx	Switching frequency filter capacitor
Rdx	Switching frequency filter capacitor discharge resistor
Tcx	Thermocouple
K1	Supply contactor
K2	Main contactor
K3	Auxiliary contactor
MCB1x	Switching frequency filter capacitor MCB
aux1x	Switching frequency filter MCB auxiliary through which Regen drive enable is connected
aux2	Main contactor auxiliary for “main contactor closed signal”
aux3	K3 auxiliary with coil supply for K2
Ovld	Thermal, Magnetic overload

3.1.1 Standard single Regen, single/multiple motoring system

Figure 3-1 Power connections: Single Regen



3.1.2 Standard multiple Regen, multiple motoring system

If the total power requirement is too great for one Unidrive size 5 Regen drive to supply, more than one drive can be used.

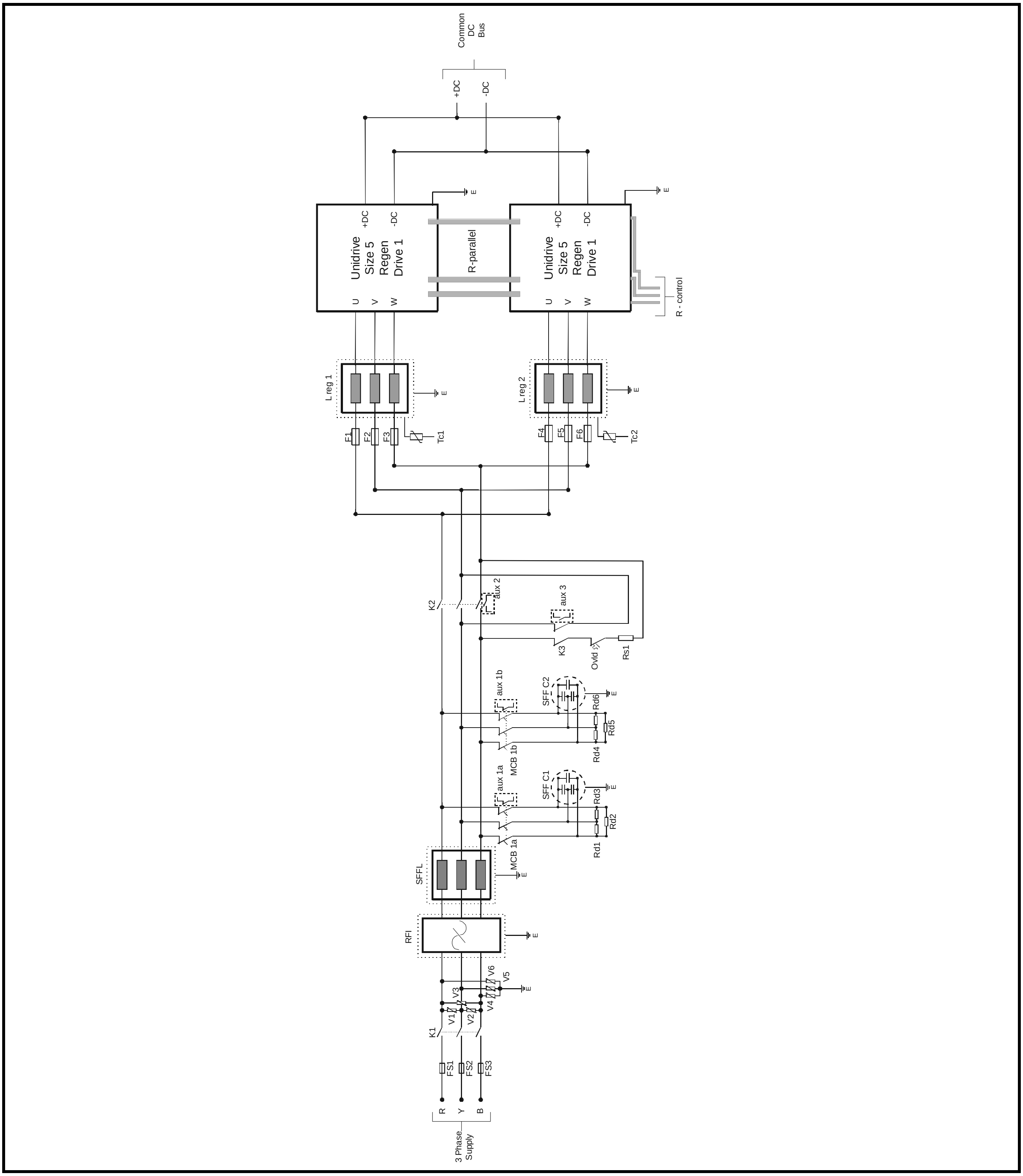
One Regen system can consist of multiple Unidrive size 5 Regen drives, which can supply multiple Unidrive size 5 motoring drives, providing that the total load power does not exceed the rating of the Regen drives. See figure 3-2 for a dual size 5 Regen configuration.

NOTE

High power set-ups should use Unidrive size 5. This is the only module which is designed for parallel Regen operation.

For systems with more than two Unidrive size 5 drives in parallel Regen operation, contact CT Technical Support.

Figure 3-2 Power connections: Unidrive size 5 multiple Regen



3.2 Non standard configurations

There are a number of possible options available when designing a Unidrive Regen system depending on the user requirements and the nature of the AC supply. Non standard systems can be created where favourable supply conditions exist, allowing cost and space savings to be achieved by reducing the number of components.

3.2.1 Switching frequency filter

If the supply to the Regen drive is shared with other equipment, then it is strongly recommended that a switching frequency filter be incorporated in order to avoid the risk of interference or damage to the other equipment.

3.2.2 Supply assessment

The following guidelines should be used when assessing whether or not a switching frequency filter is required.

Symbols used are:

I_{Drive} Nominal drive 100% current rating.

I_{SC} Short circuit current of supply at point of coupling with other equipment.

I_{Supply} Rated current of supply.

The switching frequency filter may be omitted if the following relation is true:

$$\frac{I_{Drive}}{I_{SC}} < \frac{1}{140}$$

If the short-circuit current is not known, then a reasonable estimate can be made if it is assumed that the fault current of the supply is 20 times the rated current. This is very commonly the case where the supply is derived through a distribution transformer from a higher voltage supply with a high fault level.

Then:

$$\frac{I_{Drive}}{I_{Supply}} < \frac{1}{7}$$

This second relation is helpful but must be used with care. It is reliable where the Regen drive is supplied through its own cable run from a point close to the distribution transformer terminals. If the Regen drive shares a long cable run with other equipment, then the effect of the cable impedance on the fault level must be taken into account if a risk of disturbance to the other equipment is to be avoided.

This procedure will normally be applied when assessing a non-dedicated low-voltage supply. It may also be applied to the medium/high voltage supply where the low-voltage supply is dedicated to the drive. In that case the currents used must be referred to the high voltage side of the transformer.

3.2.3 RFI filter

Whether or not an RFI filter is required is dependent upon the user requirements and the AC supply network. For further details refer to Chapter 7 *Unidrive Regen EMC information* on page 19. An RFI filter must not be fitted without a switching frequency filter present in the system.

4 Control circuit connections

All power circuit connections should be made as shown in Chapter 3 *Power connections* on page 4.

4.1 Digital / Analog I/O set-up in Regen mode

The following table lists the default functions of the analog and digital I/O on a Regen drive. The terminals which are listed as “Fixed” have dedicated functions for Regen operation. They must be connected to perform their allocated function and cannot be re-programmed.

Table 4-1 Functions of the analog and digital I/O

Terminal No.	Terminal Description	Fixed or Programmable	Function in Regen Mode
1	Drive relay	Fixed	Output - close auxiliary contactor*
2	Drive relay	Fixed	Output - close auxiliary contactor*
5	Analog input 1	User-programmable	
7	Analog input 2	User-programmable	
8	Analog input 3	User-programmable	
9	Analog output 1	User-programmable	Output - Supply current
10	Analog output 2	User-programmable	Output - Supply power
24	Digital output 1	Fixed	Not used
25	Digital output 2	Fixed	Output - Enable other drive
26	Digital output 3	User-programmable	Drive healthy
27	Digital input 1	User-programmable	Input - Reset
28	Digital input 2	Fixed	Input - Main contactor closed
29	Digital input 3	User-programmable	
30	Enable	Fixed	Enable

***** Pr **8.25** must be set by the user. See Table 4-2.

Figure 4-1 shows typical control connections for a Regen and motoring drive. In this example the motoring drive is configured for 4-20mA Speed / Torque reference and sequencing Mode 4 with Run Forward and Run Reverse inputs.

NOTE

All control connections for the Regen drive must be made as shown in *Figure 4-1*.

The Regen drive healthy signal can be taken from digital output 3 on terminal 26 (if the Regen drive is disabled, trips, or detects that the mains supply is lost this output then becomes inactive).

Table 4-2 Configuration of drive relay

Parameter	Description	Drive
Pr **8.25** - Relay Source	The Regen drives relay on terminal 1 and 2 has to be configured to close the auxiliary contactor on power up and remove the softstart circuit. Set Pr **8.25** to Pr **15.14**	Regen drive

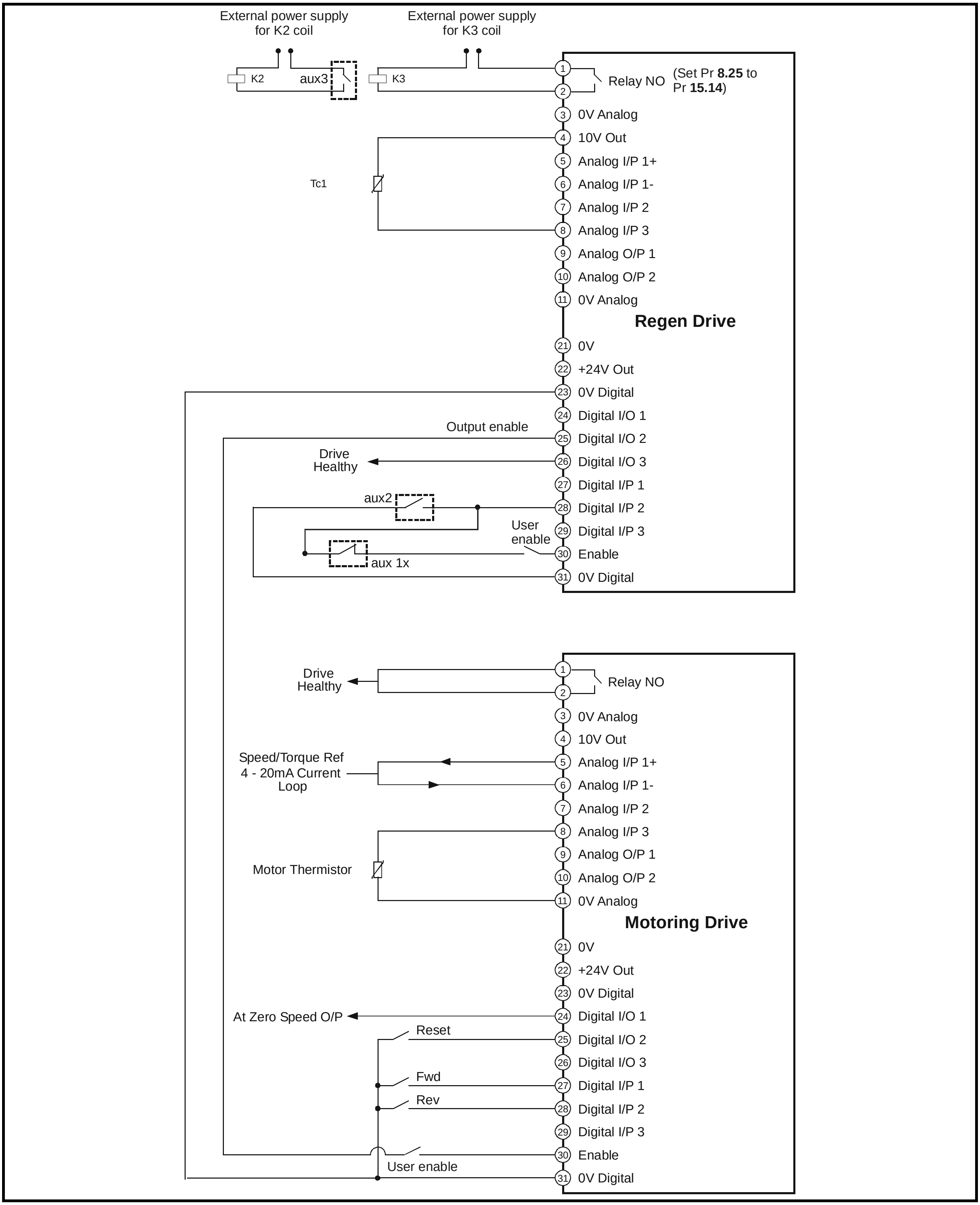
NOTE

Unidrive Regen has been designed to operate in negative logic as default. In order for the drive to be configured to operate in positive logic alterations must be made to the control connections and parameter settings (contact C.T. Technical Support for this information).

4.2 Regen inductor thermistors

Each of the Unidrive 3-phase Regen Inductors has a thermistor fitted; when the system consists of multiple Regen drives the thermistors should be connected in series due to there only being a single thermistor input on the Regen drive.

Figure 4-1 Control connections - (negative logic configuration)



5 Components

The following parts are required to assemble a Unidrive Regen system:

- Motoring drive
- Regen drive
- Regen inductor
- Softstart resistor
- Contactors, MCBs and overload
- Switching frequency filter (optional)
- RFI filter (optional)
- Varistors
- Fuses

NOTE

The Regen inductor and softstart resistor duty cycle is very arduous. Therefore, correct component selection is critical. The most sensitive aspects are line-inductor linearity, saturation current and resistor-energy pulse rating. Only inductors and softstart resistors as specified in this Installation Guide should be used.

5.1 Motoring drive

Unidrive in Open Loop, Closed Loop or Servo mode. Any software version.

This controls the motor by converting the DC bus voltage to a variable voltage, variable frequency supply. Power flow is between the DC bus and the motor. There are no AC supply connections.

5.2 Regen drive

Unidrive in Regen mode. (Must be software version 2.10.04 or higher).

The Regen drive converts the AC supply to a regulated DC voltage. It also provides bi-directional power flow and sinusoidal input currents.

5.3 Regen inductor

The Regen inductor supports the difference between the PWM voltage from the Regen drive and sinusoidal voltage from the supply.

NOTE

Regen inductors are special parts. Under no circumstances must a part be used other than those listed in Table 5-1.

Table 5-1 3-phase Regen inductors

Drive Model	Rated power kW	Rated current A rms	Inductance mH	Number required per Regen drive	CT part number
UNI 1405	4	9.5	6.3	1	4401-0001
UNI 2401	5.5	12	5.0	1	4401-0002
UNI 2402	7.5	16	3.75	1	4401-0003
UNI 2403	11	25	2.4	1	4401-0004
UNI 3401	15	34	1.76	1	4401-0005
UNI 3402	18.5	40	1.5	1	4401-0006
UNI 3403	22	46	1.3	1	4401-0007
UNI 3404	30	60	1.0	1	4401-0008
UNI 3405	37	70	0.78	1	4401-0009
UNI 4401	45	96	0.63	1	4401-0010
UNI 4402	55	124	0.48	1	4401-0011
UNI 4403	75	156	0.38	1	4401-0012
UNI 4404	90	180	0.33	1	4401-0013
UNI 4405	110	202	0.30	1	4401-0014
UNI 5401	160	300	0.24	1	4401-0015

5.4 Softstart resistor

The start-up circuit limits the amount of current flowing into the DC bus of the Regen drive and into the motoring drives.

5.4.1 Single systems

The softstart resistor for single Regen applications must be as specified in the following table. Energy rating and overload are non-standard and both are important.

Table 5-2 Single Regen, single motoring, Unidrive size 1 to 5

Drive size	Number of parallel resistors	Total value Ω	Resistors	
			CT part number	Value Ω
1	1	150	1270-3157	150
2	1	150	1270-3157	150
3	1	48	1270-2483	48
4	2	24	1270-2483	48
5	2	24	1270-2483	48

Table 5-3 Softstart resistor data

Drive size	Resistors	Rms current A	Charging current A
1	1270-3157	0.4	5
2	1270-3157	0.4	5
3	1270-2483	0.5	15
4	1270-2483 x 2	0.6	32
5	1270-2483 x 2	1.2	32

The above figures have been calculated assuming a peak supply voltage of 480 Vac +10%. Refer also to Appendix B *Component Sizing Calculations.*

5.4.2 Multiple systems

In non standard cases, e.g. multiple motoring, multiple Regen systems, the soft-start resistor size and rating must be recalculated due to the charging characteristics changing. For the method of calculating the new resistor size and rating, refer to Appendix B *Component sizing calculations* on page 36.

5.4.3 Protection

Protection for the softstart circuit is provided using a thermal overload to protect against a high impedance short circuit, and a separate magnetic overload to protect against a direct short circuit. For multiple systems the softstart resistor size must be recalculated resulting in resizing of the thermal magnetic overload required. Refer to Appendix B *Component sizing calculations* on page 36.

Table 5-4 Thermal magnetic overload

Drive size	Rated Current A	Rated Voltage Vac	Number of Poles	CT part number
1 & 2	0.3	480	1	4133-0117
3	1	480	1	4133-0217
4 & 5	2	480	1	4133-0277

5.5 Contactors, MCBs and overload

Contactors and MCBs are required as follows:

Table 5-5 Contactors and MCBs

Function	Ref	Description	Specification
Main contactor	K2	3 pole NO + auxiliary NO contact. Coil voltage selected to suit available supply.	Current rating equal to total current requirement. Voltage rating equal to AC mains supply voltage.
Auxiliary contactor	K3	2 pole NC + auxiliary NO	Coil must not exceed 240Vac 5A resistive load. Installation category 1.
Switching frequency filter MCB	MCB 1x	3 pole + auxiliary NC	Current rating sized to rms current of switching frequency filter capacitors and charging current at power up. (Refer to Table 5-6).
Thermal magnetic overload	Ovld	Single pole	Sized to the softstart resistor to protect thermally and magnetically. (Refer to Appendix B *Component sizing calculations* on page 36).

MCB 1x is fitted between the switching frequency filter capacitors and the AC supply. The MCB should have an auxiliary which the enable for the Regen and motoring drive is connected through. This will act as a safe guard and prevent the system running with a fault on the switching frequency filter. Also refer to Appendix B *Component sizing calculations* on page 36.

5.6 Switching frequency filter

The AC input terminals of a Regen drive produce a PWM output voltage, which has a sinusoidal component at line frequency, plus significant harmonics at the switching frequency and its multiples.

This filter prevents switching frequency harmonic currents getting back into the supply. If the filter is not fitted, the presence of currents in the kHz region could cause supply problems or disturbance to other equipment.

NOTE

The switching frequency filter inductors need to be rated to the total current requirement.

The following inductors are standard 3-phase inductors (rated at drive rated current for a single Regen system or rated at total current requirement for multiple Regen system), they carry only 50/60Hz current with a negligible amount of high frequency current.

The capacitors specified below are suitable for operation at any switching frequency. These capacitors are sized for operation at 3kHz however operation above 3kHz is possible with the capacitors being more effective.

Table 5-6 Switching frequency filter

Drive		3-phase inductor		3-phase capacitor		MCB rating	
Model	Rated current A	Lfilt mH	CT part number	Cfilt μF	CT part number	rms current A	Peak current A
UNI 1405	9.5	3.160	4401-0162	5.7	1610 - 5752	2.1	28
UNI 2401	12	2.500	4401-0163				31
UNI 2402	16	1.875	4401-0164				36
UNI 2403	25	1.200	4401-0165				45
UNI 3401	34	0.880	4401-0166	24	1665 - 2244	15	106
UNI 3402	40	0.750	4401-0167				115
UNI 3403	46	0.650	4401-0168				124
UNI 3404	60	0.500	4401-0169				142
UNI 3405	70	0.390	4401-0170				160
UNI 4401	96	0.315	4401-0171	48	1665 - 2484	25	252
UNI 4402	124	0.240	4401-0172				262
UNI 4403	156	0.190	4401-0173				325
UNI 4404	180	0.165	4401-0174				348
UNI 4405	202	0.135	4401-0175				385
UNI 5401	300	0.100	4401-0176	80 (x1)	1665 - 2804	35 per capacitor	580
UNI 5402	600	0.050	4401-0177	80 (x2)			580
UNI 5403	900	0.034	4401-0178	80 (x3)			580
UNI 5404	1200	0.025	4401-0179	80 (x4)			580
UNI 540X	300 x X	0.100 / X		80 (xX)			580

X = number of size 5 drives

5.6.1 Protection

An MCB should be fitted between the AC supply and the capacitor. This is to protect the wiring between the capacitor and the main bus bar.

NOTE

For multiple Regen systems, refer to Appendix B *Component sizing calculations* on page 36 for sizing of the MCB.

5.7 RFI filter

In common with conventional drives, significant ground currents are generated by the capacitance of the motor to ground, the motor cables to ground, and the drive power circuits to their heatsinks.The RFI filter will provide a relatively short return path for ground currents back to the drives power circuit.

Table 5-7 RFI filter data

CT Model Number	Volts Vac	Maximum power kW	Filter current rating A	Mounting style	Motor cable length m	CT part number
UNI1405	480	4	10	Book End	100	4200-6105
				Footprint or Book End	100	4200-6104
UNI2401 to 2402	480	7.5	16	Book End	100	4200-6109
				Footprint or Book End	100	4200-6108
UNI2403	480	11	25	Book End	100	4200-6114
				Footprint or Book End	100	4200-6113
UNI3401 to 3403	480	22	50	Book End	100	4200-6116
UNI3404	480	30	63	Book End	100	4200-6117
UNI3405	480	37	100	Book End	100	4200-6106
UNI4401 to 4402	480	55	150	Book End	100	4200-6107
UNI4403 to 4404	480	90	180	Book End	100	4200-6111
UNI4405	480	110	220	Book End	100	4200-6112
UNI5401	480	160	300	Book End	100	4200-6115

CAUTION

Do not use an RFI filter without the specified switching frequency filter, as failure of the RFI filter will occur, due to the switching currents.

5.8 Varistors

AC line voltage transients can typically be caused by the switching of large items of plant, or by lightning strikes on another part of the supply system. If these transients are not suppressed, they can cause damage to the insulation of the Regen input inductors, or to the Unidrive Regen drive electronics.

Table 5-8 Varistors

Configuration	Drive size	Varistor voltage Vac	Varistor energy J	Type number	Quantity	CT part number
Line to line	1 to 5	550	400	Z500NS	3	2482-1501
Line to ground	1 to 5	680	450	Z680LNS	3	2482-0680

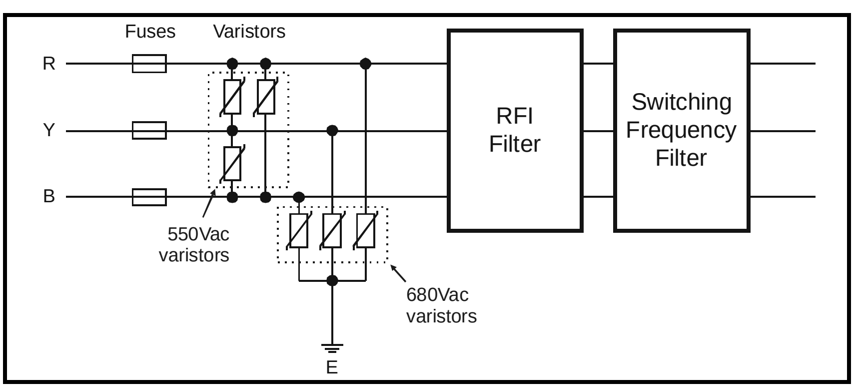
NOTE

Seven varistors are required when operating with an IT supply as shown in Figure 3-1 on page 5, Figure 3-2 on page 6 and Figure A-2 on page 32.

5.8.1 Configuration

Varistors should be fitted after the supply fuses, as shown in Figure 5-1:

Figure 5-1 Fitting of Varistors



5.9 Fusing

Fusing for the Regen system is required in order to protect the following:

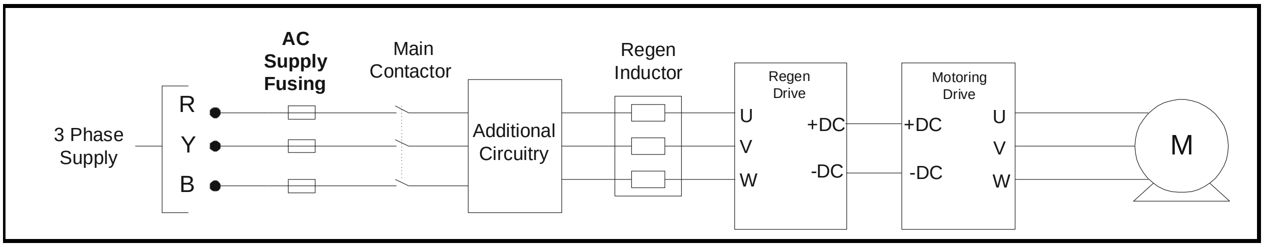
- Supply transformer
- Supply cables
- Regen inductor
- Regen drive
- Motoring drive

In the event of failure, the fusing will prevent fire by limiting the amount of energy allowed into the Regen and motoring drive units. The AC supply fusing should be rated to the Regen system's continuous rated current. The Regen AC fusing when used with each multiple size 5 Regen drive should be rated to the 450A continuous rated current of the drive. The ±DC bus fusing when used with multiple motoring drives should be rated to 2 x motoring drive rated current and ≥ 750Vdc.

5.9.1 Standard systems

Fusing for a standard Regen system, single Regen plus single motoring drive (both drives of the same rating) should consist of AC supply fusing as shown below:

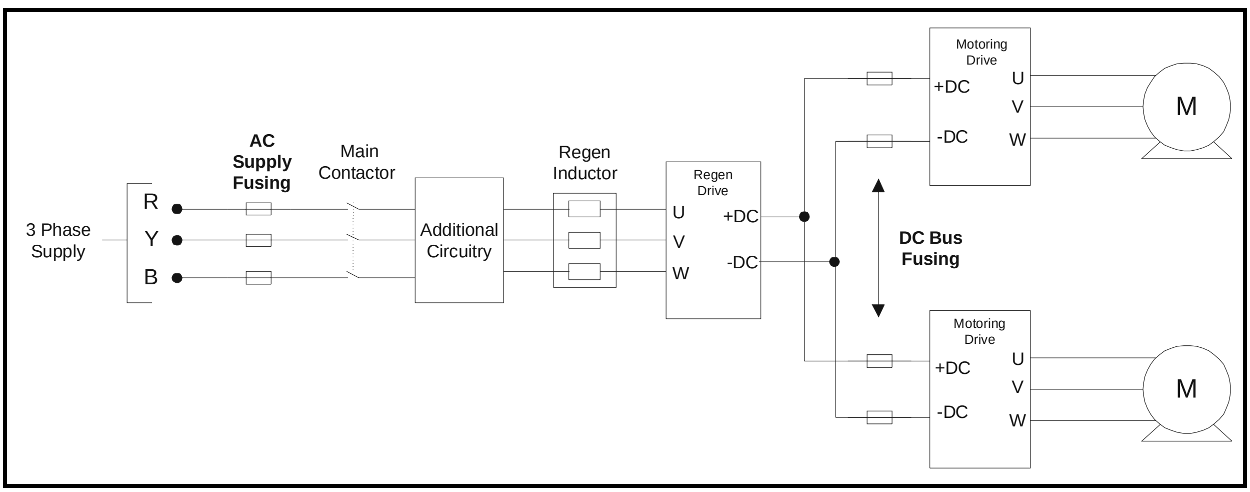
Figure 5-2 Fusing: Standard systems



5.9.2 Multiple size 1 to 4 motoring drives

When a Regen system consists of multiple size 1 to 4 motoring drives, AC supply fusing and ±DC bus fusing should be fitted as shown below:

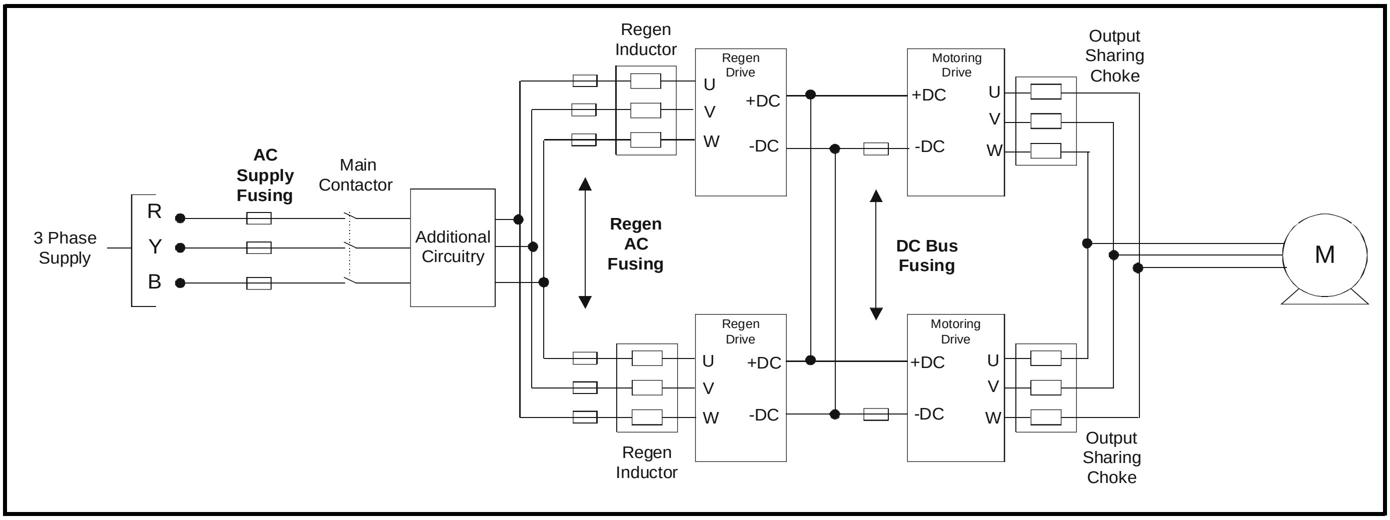
Figure 5-3 Fusing: Multiple size 1 to 4 motoring drives Regen system



5.9.3 Multiple size 5 Regen

When a Regen system consists of multiple size 5 Regen and motoring drives, AC supply fusing and -DC bus fusing should be fitted as shown below:

Figure 5-4 Fusing: Multiple size 5 Regen system



6 Important considerations

6.1 Fundamentals

6.1.1 You must

- Use Regen inductors of the correct type and value, as specified.
- Use a start-up resistor of the correct type and value, as specified.
- Connect the Regen drive output enable signal to the enable input on the motoring drive(s).
- Use a switching frequency filter if an RFI filter is present or the AC supply is **not** dedicated solely to the Regen drive.
- Fit fuses where specified, and ensure they are of the correct rating.
- Ensure that the cubicle is correctly sized and ventilated, taking into account the losses generated by all of the circuit components.

6.1.2 You must not

- Connect a circuit of any type between a Regen and motoring drive's DC bus.
- Attempt to use a Unidrive size 1-4 Regen in parallel configuration **(only Unidrive size 5 Regen can be used in parallel configuration)**.

6.2 Unidrive size 3 and 4

If a **Unidrive size 3** or **4** of any other variant except the Regen variant is to be used in a **Regen** system, an internal modification is required to both the **Regen** and **motoring** drive(s).

CAUTION

Damage to the drive(s) will result if this modification is not carried out.

NOTE

Modification of the drive must only be carried out by CT authorised personnel. If any details are required, contact C.T. Technical support.

6.3 Ventilation

When designing a Regen System, considerations must be made for the additional ventilation requirements due to the introduction of the Regen and Switching Frequency filter inductors.

CAUTION

The inductors have normal operating temperatures of approx. 150°C depending upon the ambient and the motor cable lengths. Care must be taken so that this does not create a fire risk.

A Regen System can operate in an ambient temperature range of 0°C to 50°C (32°F to 122°F) for Unidrive sizes 1 to 5. An output current derating must be applied with ambient temperatures between 40°C and 50°C. For derating figures see the *Unidrive Size 1 to 5 User Guide*.

Ventilation for both the Regen and motoring drives in the system should be as specified in the *Unidrive Size 1 to 5 User Guide*. Provided the maximum cable lengths in Table 6-3 on page 18 have not been exceeded, natural air flow ventilation through the Regen and switching frequency filter inductors is adequate. In special conditions, where the maximum cable length (refer to Table 6-3 on page 18) has been exceeded, forced cooling should be introduced for the Regen Inductor as specified in Appendix C *Long cables* on page 41.

When sizing the cubicle(s) for the Regen system considerations must be made for the systems losses.

System Losses	Documented In...
RFI Filter	*Unidrive Size 1 to 5 User Guide*
Regen drive	
Motoring drive	
Control Module, Unidrive size 5	
Power Module, Unidrive size 5	

Table 6-1 3-phase Regen inductor

Drive size	Rated current A rms	Inductance mH	No per Regen Drive	CT part number	Total losses W
UNI 1405	9.5	6.3	1	4401-0001	125
UNI 2401	12	5.0	1	4401-0002	146
UNI 2402	16	3.75	1	4401-0003	175
UNI 2403	25	2.4	1	4401-0004	210
UNI 3401	34	1.76	1	4401-0005	285
UNI 3402	40	1.5	1	4401-0006	310
UNI 3403	46	1.3	1	4401-0007	320
UNI 3404	60	1.0	1	4401-0008	345
UNI 3405	70	0.78	1	4401-0009	415
UNI 4401	96	0.63	1	4401-0010	515
UNI 4402	124	0.48	1	4401-0011	585
UNI 4403	156	0.38	1	4401-0012	645
UNI 4404	180	0.33	1	4401-0013	775
UNI 4405	220	0.30	1	4401-0014	845
UNI 5401	300	0.24	1	4401-0015	1760

Table 6-2 3-phase switching frequency filter inductor

Drive size	Rated current A rms	Inductance mH	No per Regen Drive	CT part number	Total losses W
UNI 1405	9.5	3.160	1	4401-0162	28
UNI 2401	12	2.500	1	4401-0163	35
UNI 2402	16	1.875	1	4401-0164	37
UNI 2403	25	1.200	1	4401-0165	40
UNI 3401	34	0.880	1	4401-0166	52
UNI 3402	40	0.750	1	4401-0167	60
UNI 3403	46	0.650	1	4401-0168	60
UNI 3404	60	0.500	1	4401-0169	80
UNI 3405	70	0.390	1	4401-0170	90
UNI 4401	96	0.315	1	4401-0171	100
UNI 4402	124	0.240	1	4401-0172	110
UNI 4403	156	0.190	1	4401-0173	130
UNI 4404	180	0.165	1	4401-0174	170
UNI 4405	220	0.135	1	4401-0175	180
UNI 5401	300	0.100	1	4401-0176	220
UNI 5402	600	0.050	1	4401-0177	400
UNI 5403	900	0.034	1	4401-0178	530
UNI 5404	1200	0.025	1	4401-0179	700

6.4 Cable length restrictions

There are 3 significant cable lengths which must be taken into account when designing a Regen system. Refer to Figure 6-1 on page 18.

6.4.1 AC supply connection

A is the AC cable length between the Regen inductor and the Regen drives terminals.

In general, no special precautions are necessary for the AC supply wiring in respect to the Regen drive. However the voltage in the wiring between the Regen inductor and the Regen drive terminals is a source of radio frequency emission. To minimise emissions, these cables should be kept as short as possible. Ideally, the inductors should be mounted close to the drive terminals.

If it is necessary to use a cable longer than 5m, a screened cable should be used with the screen grounded as shown in Figure 6-1 on page 18.

6.4.2 DC bus connection

B is the DC bus connection between the Regen and motoring drive, the ± DC bus connections between the drives should be treated as a single two core cable and not two individual cable / bus bar lengths.

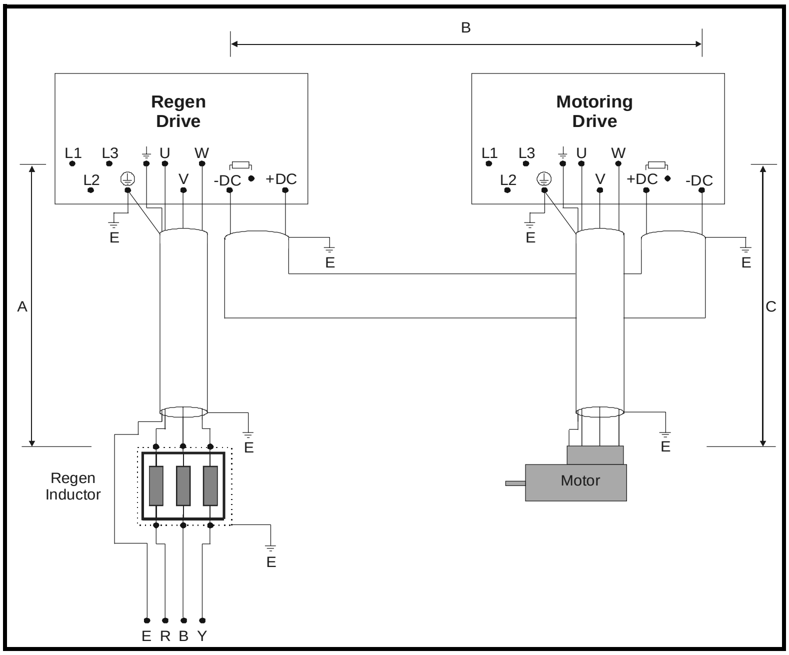
The DC power output from the Unidrive which is used as the input stage to the motoring drive(s) carries a common-mode high frequency voltage comparable with the output voltage from a standard drive. All precautions recommended for motor cables must also be applied to all cables connected to this DC circuit.

If it is necessary to use a cable longer than 5m, a screened cable should be used with the screen grounded as shown in Figure 6-1.

6.4.3 Motor connection

C is the AC cable length between the motoring drive and the motor.

Figure 6-1 Calculating the cable length of the Regen system



6.4.4 Maximum cable length

The sum total length of the DC bus and motor cables (B and C in Figure 6-1) must not exceed the values shown in the table below:

Table 6-3 Cable lengths

Regen drive size	Power rating kW	Maximum cable length m
1	4	50
2	5.5 - 11	100
3	15 - 37	200
4	45 - 110	200
5	132	200 per Regen drive

If the cable length in the above table is exceeded, additional components are required. Refer to *Appendix C Long cables* on page 41.

7 Unidrive Regen EMC information

7.1 Immunity

The immunity of the individual drive modules is not affected by operation in the regenerative mode. See drive EMC data sheets for further information.

This Guide recommends the use of varistors between the incoming AC supply lines. These are strongly recommended to protect the drive from surges caused by lightning activity and/or mains supply switching operations.

Since the regenerative input stage must remain synchronised to the supply, there is a limit to the permitted rate of change of supply frequency. If rates of change exceeding 100Hz/s are expected then C.T. Technical Support should be consulted. This would only arise under exceptional circumstances e.g. where the power system is supplied from an individual generator.

7.2 Emission

Emission occurs over a wide range of frequencies. The effects are divided into three main categories:

- Low frequency effects, such as supply harmonics and notching
- High frequency emission below 30MHz where emission is predominantly by conduction
- High frequency emission above 30MHz where emission is predominantly by radiation

7.3 Dedicated supplies

The nature of the mains supply has an important effect on the EMC arrangements. For a dedicated supply, i.e. one which has no other electrical equipment fed from the secondary of its distribution transformer, normally neither an RFI filter or a switching frequency filter are required. Refer to *section 3.2.2 Supply assessment* on page 7.

7.4 Other supplies

Wherever other equipment shares the same low voltage supply, i.e. 400Vac, careful consideration must be given to the likely need for both switching frequency and RFI filters, as explained in section 7.7 *Switching frequency emission* and section 7.8 *Conducted RF emission* .

7.5 Supply voltage notching

Because of the use of input inductors and an active rectifier the drive causes no notching - but see section 7.7 *Switching frequency emission* for advice on switching frequency emission.

7.6 Supply harmonics

When operated from a balanced sinusoidal three-phase supply, the regenerative Unidrive generates minimal harmonic current.

Imbalance between phase voltages will cause the drive to generate some harmonic current. Existing voltage harmonics on the power system will cause some harmonic current to flow from the supply into the drive. Note that this latter effect is not an emission, but it may be difficult to distinguish between incoming and outgoing harmonic current in a site measurement unless accurate phase angle data is available for the harmonics. No general rule can be given for these effects, but the generated harmonic current levels will always be small compared with those caused by a conventional drive with rectifier input.

7.7 Switching frequency emission

The Regen drive uses a PWM technique to generate a sinusoidal input voltage phase-locked to the mains supply. The input current therefore contains no harmonics of the supply unless the supply itself contains harmonics or is unbalanced. It does however contain current at the switching frequency and its harmonics, modulated by the supply frequency. For example, with a 3kHz switching frequency and 50Hz supply frequency there is current at 2.95, 3.15, 5.95, 6.05kHz etc. The switching frequency is not related to that of the supply, so the emission will not be a true harmonic - it is sometimes referred to as an “interharmonic”. The possible effect of this current is similar to that of a high-order harmonic, and it spreads through the power system in a manner depending on the associated impedances. The internal impedance of the Regen drive is dominated by the series inductors at the input. The voltage produced at switching frequency at the supply point is therefore determined by the potential divider action of the series inductors and the supply impedance; *section 3.2.2 Supply assessment* on page 7 gives guidelines to help in assessing whether a switching-frequency filter is required. In case of doubt, unless the drive operates from a dedicated supply not shared with other loads, it is strongly recommended that the filter be fitted.

CAUTION

Failure to fit a switching frequency filter may result in damage to other equipment, e.g. fluorescent light fittings, power factor correction capacitors and RFI filters.

7.8 Conducted RF emission

Radio frequency emission in the frequency range from 150kHz to 30MHz is mainly conducted out of the equipment through electrical wiring. It is essential for compliance with all emission standards, except for IEC61800-3 second environment, that the recommended RFI filter and a shielded (screened) motor cable are used. Most types of cable can be used provided it has an overall screen. For example, the screen formed by the armouring of steel wired armoured cable is acceptable. The capacitance of the cable forms a load on the drive and should be kept to a minimum.

When an RFI filter is used the switching frequency filter discussed above must also be used. Failure to observe this may result in the RFI filter becoming ineffective and being damaged.

CAUTION

When used with the recommended filters, the Regen drive system complies with the requirements for conducted emission in the following standards:

Table 7-1 Requirements for conducted emission

Motor cable length (m)	Switching frequency (kHz)				
	3				
1.5	I				
100	I				
Key to table	**Standard**	**Description**	**Frequency range**	**Limits**	**Application**
I	EN50081-2	Generic emission standard for the industrial environment	0.15 - 0.5MHz	79dBμV quasi peak 66dBμV average	AC supply lines
			0.5 -30MHz	73dBμV quasi peak 60dBμV average	
	EN61800-3 IEC1800-3	Product standard for adjustable speed power drive systems	Input current >25A: Requirements for the first environment[1]: Unrestricted distribution Input current <25A: Requirements for the first environment[2]: Restricted distribution		
1	The first environment is one where the low voltage supply network also supplies domestic premises				
2	Restricted distribution means that drives are available only to installers with EMC competence				

For installation in the “second environment”, i.e. where the low voltage supply network does not supply domestic premises, no filter is required in order to meet IEC61800-3 (EN61800-3):1996.

Operation without a filter is a practical cost-effective possibility in an industrial installation where existing levels of electrical noise are likely to be high, and any electronic equipment in operation has been designed for such an environment. There is some risk of disturbance to other equipment, and in this case the user and supplier of the drive system must jointly take responsibility for correcting any problem which occurs.

CAUTION

7.8.1 Recommended RFI filters

These are the same filters as recommended for standard (non-regenerative) operation:

Table 7-2 Recommended filters

Drive	Motor cable length m	RFI filter: C.T. part number
UNI 1405	100	4200-6105
UNI 2401 - 2402		4200-6109
UNI 2403		4200-6114
UNI 3401 - 3403		4200-6116
UNI 3404		4200-6117
UNI 3405		4200-6106
UNI 4401 - 4402		4200-6107
UNI 4403 - 4404		4200-6111
UNI 4405		4200-6112
UNI 5401		4200-6115

7.8.2 Related product standards

The conducted emission levels specified in EN50081-2 are equivalent to the levels required by the following product specific standards:

Table 7-3 Conducted emission from 150kHz to 30MHz

Generic standard	Product standard	
EN50081-2	EN55011 Class A Group 1 CISPR 11 Class A Group 1	Industrial, scientific and medical equipment
	EN55022 Class A CISPR 22 Class A	Information technology equipment

7.9 Radiated emission

Radio frequency emission in the frequency range from 30MHz to 1GHz is mainly radiated directly from the equipment and from the wiring in its immediate vicinity. Operation in regenerative mode does not alter the radiated emission behaviour, and the EMC data sheet for the individual Unidrives used should be consulted for further information.

NOTE

Theoretically the use of two drives physically close together can cause an increase in emission level of 3dB compared with a single drive, although this is usually not observed in practice. All Unidrives have sufficient margin in respect of the generic standard for the industrial environment EN50081-2 to allow for this increase.

7.10 Wiring guidelines

The wiring guidelines provided for the individual drives also apply to regenerative operation, except that the switching frequency filter must be interposed between the input drive and the RFI filter. The same principles apply, the most important aspect being that the input connections to the RFI filter should be carefully segregated from the power wiring of the drives which carries a relatively high “noise” voltage.

7.11 Multi-drive systems

It is common for regenerative drive systems to be constructed using numbers of drives with a single input stage, or other more complex arrangements. It is generally not possible to lay down specific EMC requirements for such systems, since they are too large for standardised tests to be carried out. In many cases the environment corresponds to the “second environment” as described in IEC61800-3, in which case no specific limit to conducted emission is required. National legislation such as the European Union EMC Directive does not usually require that complex installations meet specific standards, but only that they meet the essential protection requirements, i.e. not to cause or suffer from electromagnetic interference.

Where the environment is known to include equipment which is sensitive to electromagnetic disturbance, or the low voltage supply network is shared with domestic dwellings, then precautions should be taken to minimise conducted radio frequency emission by the use of a filter at the system power input. For current up to 300A the Control Techniques filters listed previously are suitable.

For currents exceeding 300A up to 2400A suitable filters are available from the following manufacturers:

Siemens B84143.A250.S (range up to 2500A)
Schaffner FN3359-300-99 (range up to 2400A)

These filters may not give strict conformity with EN50081-2, but in conjunction with the relevant EMC installation guidelines they will reduce emission to sufficiently low levels to minimise the risk of disturbance.

8 Parameter descriptions

Key to parameter codes:	
⇳	Range of values
⇨	Default value
RW	Read/Write
RO	Read Only
Bit	Two state only parameter, 0 or 1.
Bi	Bipolar - can have positive and negative values.
Uni	Unipolar - can have positive values only.
Txt	Parameter value is represented on the display with strings of Text.
P	Parameter is Protected from being controlled by programmable inputs and functions.

Note that the equivalent Menu 0 parameter appears in the box preceding the parameter description.

8.1 Menu 15: Sinusoidal rectifier

A Unidrive can be used as a sinusoidal input current power unit to supply one or more Unidrives via their DC buses. When this mode is selected as the drive type, menu 15 appears. This menu is used to set up the Unidrive. At the same time, menu 0 defaults to showing Pr **15.01** to Pr **15.13** as Pr **0.11** to Pr **0.28**.

15.01	0.11	Supply current magnitude

⇳	± Maximum drive current	⇨		A	RO	Bi			P

This parameter gives the rms phase current from the supply. The sinusoidal rectifier controls the current so that the fundamental current and voltage are in phase at the power terminals of the drive. There is a small phase shift across the input inductors, and so the current magnitude and the real component of current are approximately equal. If power is flowing into the sinusoidal rectifier the current magnitude is negative, and if power is flowing out (back into the supply) the current magnitude is positive.

15.02	0.12	Supply voltage

⇳	0 to 528	⇨		Vac	RO	Uni			P

When the sinusoidal rectifier unit is active the supply voltage is given by this parameter. If the unit is not active this parameter shows zero.

15.03	0.13	Supply power

⇳	± Drive max. current x **5.09** x √3/1000	⇨		kW	RO	Bi			

Total supply power of the drive is calculated from the product of the line voltage and current which is equivalent to **15.01** x **15.02** x √3. Note that as the power factor is approximately unity the power is equal to the volt-amperes. The power shown is that flowing out of the drive, hence when power is flowing from the supply to the Regen drive Pr **15.03** is negative, and when power is flowing from the Regen drive back into the supply Pr **15.03** is positive.

15.04	0.14	DC bus voltage

⇳	0 to 830	⇨		Vdc	RO	Uni			P

Voltage at the DC output of the drive.

15.05	0.15	Supply frequency

⇳	±100	⇨		Hz	RO	Bi			P

When the sinusoidal rectifier unit is active this parameter gives the supply frequency. Positive values indicate positive phase sequence and negative values indicate negative phase sequence. If the unit is not active this parameter shows zero.

15.06	0.16	Input inductance							
⇳	0.001 to 100	⇨		mH	RO	Uni			P

At power-up this parameter is zero. Each time the unit is enabled the supply inductance is measured and displayed by this parameter. The value given includes the supply inductance and the inductors inserted at the supply to the sinusoidal rectifier unit. The value given is only approximate, but will give an indication as to whether the input inductance is correct for the sinusoidal rectifier unit size.

15.07	0.17	DC bus voltage set-point							
⇳	0 to 800	⇨	700	Vdc	RW	Uni			

The sinusoidal rectifier unit will attempt to hold the DC bus at the level specified by this parameter. The higher the bus voltage the better the performance of the unit as there will be more voltage available to control the input current. The bus voltage must always be higher than the peak of the line to line supply voltage if the unit is to operate correctly. The voltage can be set to a level up to 800V, but this only leaves 30V headroom below the over-voltage trip level. Therefore it is best to use the default value of 700V unless the supply voltage is such that it must be raised above this level.

Supply voltage Vac	Minimum Vdc	Recommended Vdc	Maximum Vdc
380	650	700	800
415	680	700	800
480	780	780	800

15.08	0.18	Switching frequency							
⇳	0 to 4: [3, 4.5, 6, 9, 12]	⇨	0:[3kHz]	kHz	RW	Txt			P

This parameter sets the PWM frequency and also determines the sample frequency for loops.

The sampling frequency of the control system is based on the switching frequencies as follows:

Current control

Switching frequency kHz	Control frequency kHz
3	3
4.5	4.5
6	6
9	4.5
12	6

DC bus voltage control and synchronisation with the supply

Switching frequency kHz	Control frequency kHz
3	3
4.5	2.25
6	3
9	2.25
12	3

15.09	0.19	High stability space vector modulation							
⇳	0 ~ 1	⇨	0		RW	Bit			

Setting this parameter to 1 modifies the IGBT switching pattern so as to reduce the number of switching events. This has the following effects:

- Slightly reduced power loss in the Regen drive.
- Increased acoustic noise from input inductors.

15.10	0.20	Quasi-square operation select						
⇳	0 ~ 1	⇨	0		RW	Bit		

The rate at which the DC bus voltage can be reduced by the drive depends on the headroom between the bus voltage and the supply voltage. If quasi-square mode is selected this headroom can be effectively increased at some points within a supply cycle. This can give better performance, particularly when the supply voltage is high or the bus voltage set-point is low.

15.11	0.21	Sinusoidal rectifier synchronising						
⇳	0 ~ 1	⇨			RO	Bit		

When the drive is enabled it must detect the phase and frequency of the mains. During this period this bit is set. Once synchronisation has been completed successfully this bit is cleared. If the supply is very severely distorted or a phase is missing the drive will repeatedly attempt to synchronise until it is disabled or synchronisation is completed.

15.12	0.22	Sinusoidal rectifier synchronised						
⇳	0 ~ 1	⇨			RO	Bit		

When the drive has been enabled and successfully synchronised this bit will be set to 1. If the drive is disabled, the unit trips or detects that the mains is lost, this bit will be set to 0.

15.13	0.23	Sinusoidal rectifier phase loss						
⇳	0 ~ 1	⇨			RO	Bit		

If a supply phase is not present the sinusoidal rectifier unit will not synchronise when it is enabled. However, if a phase is lost after synchronisation one of the following will occur:

- Lightly loaded: the unit will continue to operate normally.
- Medium load: the unit will continue to operate, but the phase loss bit is set.
- Heavy load: the unit will detect mains loss, disable itself and attempt to re-synchronise.

15.14	0.24	Close soft start contactor						
⇳	0 ~ 1	⇨			RO	Bit		

When the Regen drive has powered up through the soft start resistor and the DC bus voltage stabilised this bit will change from 0 to 1. This bit must be routed to a digital output terminal which is used to energise the soft start contactor coil.

15.15	0.25	Soft start contactor is closed						
⇳	0 ~ 1	⇨			RO	Bit		

When the close contactor output goes active the soft-start contactor should operate and short out the soft-start resistor. This bit should be set as the destination parameter for a digital input connected to an auxiliary contact on the soft start contactor. If this input becomes inactive when bit Pr **15.14** is set then after a 100ms (approx.) delay the drive will inhibit so as to protect the soft-start circuit.

15.16	0.26	Enable motor drive						
⇳	0 ~ 1	⇨			RO	Bit		

When the unit has been enabled and successfully synchronised this bit will be set to 1. If the Regen drive is disabled, the unit trips or detects that the mains is lost, this bit will set to 0.

This bit should be routed to a digital output and used to enable the motoring drive(s) connected to the DC bus of the Regen drive.

15.17 | 0.27 | Line synchronisation trip enable

⇳	0 ~ 1	⇨	0		RO	Bit				

When the drive is enabled and the main contactor is closed it will try and synchronise the line supply. If this bit is 0 then the drive will continue to try and synchronise to the line continually until disabled, even if it does not synchronise successfully. If this bit is set to a 1 and the drive has not successfully synchronised after trying for 30 seconds then the drive will trip 'LI.SYNC'.

15.18 | 0.28 | Line synchronisation status

⇳	0 ~ 5	⇨			RO	Txt				P

This parameter is the line supply synchronisation status. It is intended to give some diagnostic information if the drive fails to synchronise to the supply. If no attempt to synchronise to the supply has been made since the drive was switched on, if the drive is synchronised to the supply and running, or if it has been running then this parameter will show 'SYNC'. If the drive can not synchronise to the supply then this parameter will show the reason why synchronisation failed. If the drive does fail to synchronise to the supply the most likely reasons are that the supply is very distorted, or there are large voltage notches / spikes on the supply.

0	**SYNC**	Successfully synchronised to line supply
1	**Ph Det**	Failed to correctly detect the phasing of the supply
2	**Fr Lo**	Line frequency too low
3	**Fr Hi**	Line frequency too high
4	**PLL OI**	Over current during final synchronisation of PLL to supply
5	**PLL Ph**	Phasing error during final synchronisation of PLL to supply

15.19 | | Current control proportional gain

⇳	0 to 30,000	⇨	110		RW	Uni				

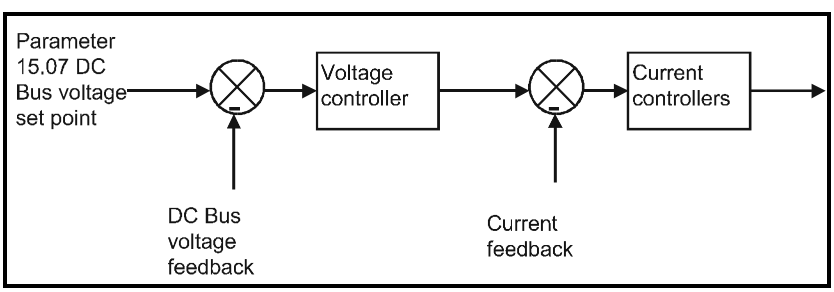
15.20 | | Current control integral gain

⇳	0 to 30,000	⇨	1,000		RW	Uni				

NOTE

These parameters are only available when the software version is 3.01.07 or higher

When the drive is operated as a Regen drive it uses a DC bus voltage controller with inner current controllers as shown below:



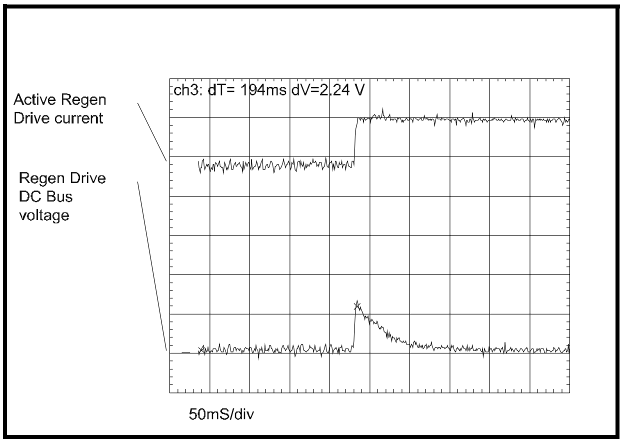
The gains of the voltage and current controllers affect the stability of the Regen drive control system and incorrect gain settings can result in over-voltage or over-current trips. (The gain of the voltage controller is set by Pr **15.21**). In most applications the default gains given for the current conditions will be suitable, however, it may be necessary for the user to change these if the inductance or resistance of the supply plus the Regen inductors varies significantly from the expected values.

The most critical parameter for stability is the current controller proportional gain and the required value for this is dependent on the Regen drive input inductance. If the inductance of the supply is a significant proportion of the recommended Regen inductor (i.e. >60mH/I_{DR}. where I_{DR} is the drive rated current), then the proportional gain may need to be increased. The supply inductance is likely to be negligible compared to the Regen inductor value with small drives, but is likely to be significant with larger drives. The proportional gain should be adjusted so that

Pr **15.19** = 1800 x Total input L x I_{DR}

The current controller integral gain is not so critical, and in a majority of cases the default value is suitable. However, if it is necessary to adjust this parameter a value between 80 x I_{DR} x R and 320 x I_{DR} x R (where R is the supply resistance of one phase) should be used.

Even when the gains are set correctly there will be a transient change of DC bus voltage when there is a change in the load on any drive connected to the Regen drive. If the power flow from the supply is increased (i.e. more power is taken from the supply or less power is fed back into the supply) the DC bus voltage will fall, but the minimum level will be limited to just below the peak rectified level of the supply provided the maximum rating of the drive is not exceeded. If the power flow from the supply is reduced (i.e. less power is taken from the supply or more power is fed back into the supply) the DC bus voltage will rise. During a rapid transient the bus will rise and then fall as shown below:



The example shown is for a very rapid load change where the torque reference of the motoring drive has been changed instantly from one value to another. In most applications where the motoring drive is operating under speed control the speed controller may only require a limited rate of change of torque demand, reducing the rate of change of power flow, and also reducing the size of the transient voltage. If the set point voltage (Pr **15.07**) plus the transient rise exceed the over-voltage trip level (830V for a medium voltage drive) the Regen drive will trip.

When a 400V motor is operated above base speed from a drive in vector mode, fed from the Regen drive supplying a DC voltage of 700V, and an instantaneous change of torque is demanded (i.e. - 100% to +100%) the peak of the voltage transient (ΔV) is approximately 80V if the current controllers are set up correctly. (Operating with maximum voltage on the motor, i.e. above base speed, gives the biggest transient of power and hence the biggest value of ΔV).

If ΔV is required for a different load change it can be calculated from

ΔV = 80V x load change / 200%

If the motor voltage is not 400V or the DC bus voltage set point is not 700V, ΔV is calculated from

ΔV = 80V x (motor voltage / 400) x (700 / DC bus voltage set point)

In some applications, particularly with a high DC bus voltage set point and low switching frequency it may be necessary to limit the rate of change of power flow to prevent over voltage trips. A first order filter on the torque reference of the motoring drive (i.e. using Pr **4.12**) is the most effective method to reduce the transient further. (A fixed limit of the rate of change of torque demand is less effective). The following table gives an approximate indication of the reduction in ΔV for different time constants. As already mentioned the value of ΔV given if for an instantaneous change of torque representing the worst case. In most applications where a speed controller is used in the motoring drive the transient will already include a filter.

Time constant	Change in ΔV
20ms	x 0.75
40ms	x 0.5

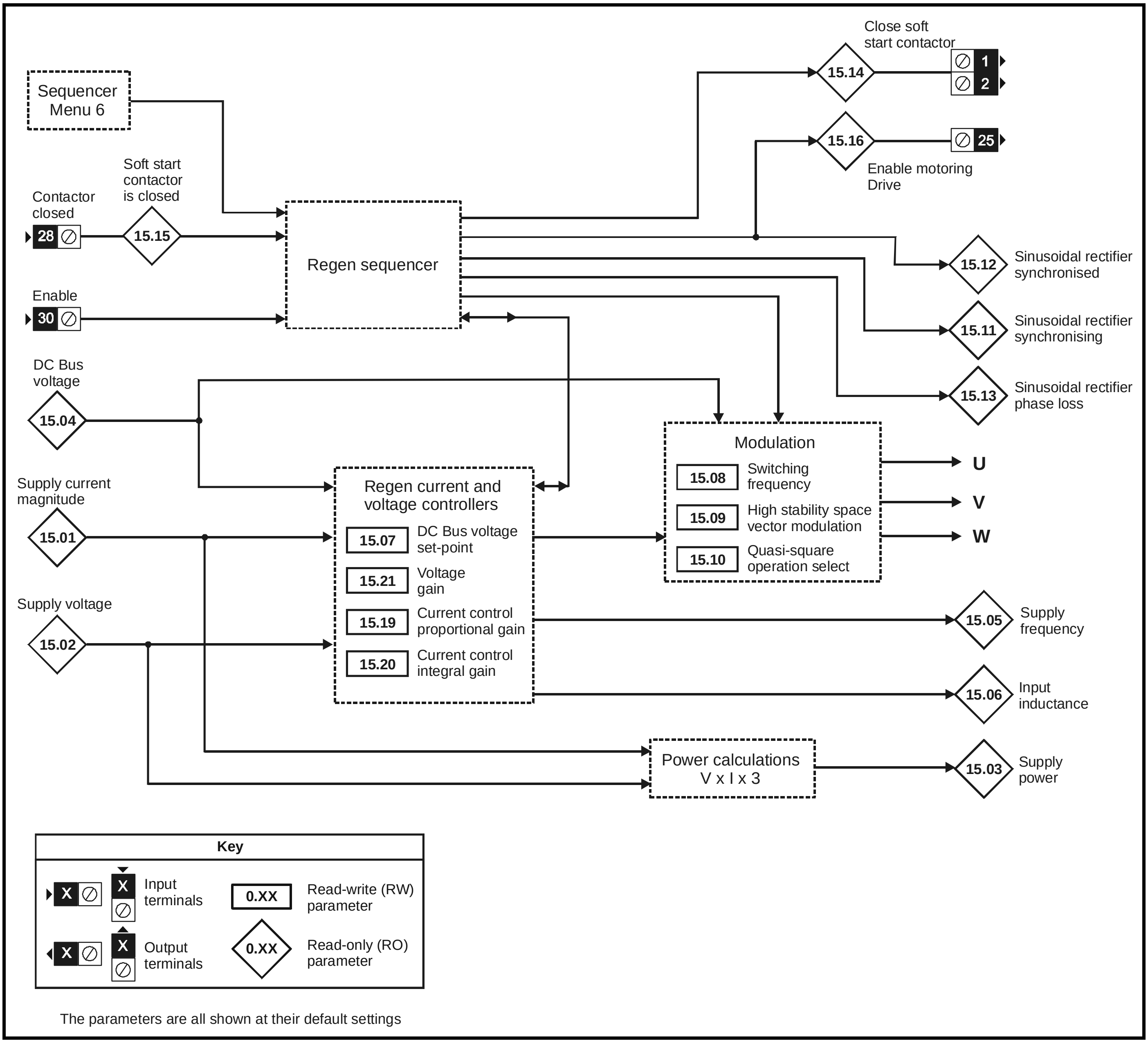
15.21		**Voltage control P gain**							
⇳	0 to 30000	⇨	4000		RW	Uni			

NOTE

This parameter is only available when the software version is 3.01.07 or higher.

The voltage controller gain is set to a value that is suitable for most applications. The per drive capacitance of each size of drive is not always the same, and so the drive compensates so that the gain is set for twice the capacitance of an individual drive as this is the normal situation with a Regen drive and motoring drive of equal rating. The transient voltage with a sudden change of load, ΔV, is affected proportionally by this parameter. Therefore the gain may be changed when the DC bus capacitance is not equal to twice the Regen drive capacitance. However, care must be taken to ensure that the gain is not too high as this can cause excessive ripple in the DC bus voltage.

Figure 8-1 Menu 15 logic diagram



9 Commissioning and operation

9.1 Regen parameter settings

9.1.1 Switching frequency Pr 15.08 (Pr 0.18)

Set the switching frequency on the Regen drive to the required value (3kHz default value).

A higher switching frequency setting has the following advantages:

- Line current ripple at the switching frequency is reduced, giving improved waveform quality.
- Acoustic noise produced by the line inductors is reduced.
- Dynamic DC bus voltage response is improved.

NOTE

In some cases, setting the switching frequency to a value greater than the default 3kHz results in current derating. Refer to the Unidrive size 1 to 4 / 5 Installation Guide.

9.1.2 DC bus voltage set point

The DC bus voltage set point, see Pr **15.07** (Pr **0.17**), should be set to a level that is suitable for the AC supply voltage being used. The table below defines these levels, assuming a tolerance of ±10% on the supply voltage (default value is 700V). The minimum value is defined as the peak input voltage plus some headroom. Headroom is required by the drive to allow correct control of the current. It is advisable to set the voltage below the maximum value to give more allowance for transient voltage overshoots. Note that Pr **15.07** (Pr **0.17**) can be set to any value between 0 and 800V.

Table 9-1 DC bus voltage set point - Pr 15.07 (Pr 0.17)

Supply Voltage Vac	Minimum Vdc	Recommended Vdc	Maximum Vdc
380	650	700	800
415	680	700	800
480	780	780	800

9.2 Regen drive sequencing

When a Regen drive is enabled, it goes through a line synchronisation sequence. During this procedure, test pulses are applied to the incoming line to determine the voltage and phase. When it has been successfully synchronised to the line, the DC bus voltage controller is enabled and the DC bus voltage rises to the target voltage.

Only when all of these stages have been completed successfully is the motoring drive enabled. If at any time there is a fault, or the Regen drive is disabled, the motoring drive will also be disabled.

This sequence of events is important to prevent damage to the Regen drive, motoring drive or external power circuit components.

The sequence of events is as follows:

Power applied:

- both contactors de-energised
- DC bus charges through start-up resistor
- DC bus voltage equals √2 Vac
- if DC bus voltage > UU trip level then auxiliary contactor is energised. This closes the main contactor and shorts out the start-up circuit.
  Enable input made active:
  - wait for DC bus voltage to stabilise
  - apply test pulses to line to determine magnitude and phase
  - attempt to synchronise to the line
  - if synchronisation is successful then enable the DC bus voltage controller
    DC bus voltage controller active:
    - DC bus voltage rises to reference level
    - Motoring drive enabled by digital output from Regen drive
      Motoring drive active:
      - the motor may now be energised and rotated
      - power flows to and from the line as necessary via Regen drive
      - DC bus voltage remains stable
        Whilst running if:
        the line voltage dips too low
        OR the DC bus voltage goes out of regulation
        OR there is any trip on the Regen drive
        OR the main contactor is de-energised
        OR the Regen drive is disabled
        OR the MCB trips
        then:
        - the Regen drive will inhibit
        - the motoring drive will be disabled by the Regen drive
        - the DC bus voltage will fall to √2 Vac

9.3 Regen drive commissioning

- Ensure power and control connections are made as specified in this Installation Guide.
- Ensure the Regen and motoring drives are not enabled.
- Switch on the AC supply.
- Both the Regen and motoring drives should now power up through the start-up circuit in standard open loop mode.
- On the Regen drive, configure the drive type Pr **11.31** (Pr **0.48**) to REGEN and set the additional parameters up for the auxiliary contactor (refer to Chapter 4 *Control circuit connections* on page 8).
- The Auxiliary and Main contactors should now close; the start-up circuit is disabled at this point.
- On the Regen drive, set up the switching frequency and DC bus set point voltage to the required values in either Menu 0 or Menu 15, refer to Chapter 8 *Parameter descriptions* on page 22. Save the parameters.
- The Regen drive can now be enabled, the Regen drive should display *ACT*.
- The commissioning of the motoring drive(s) can now be carried out.

9.4 Motoring drive commissioning

The setting of certain parameters in the motoring drive must be given special consideration when used in a Regen system.

Ramp Mode - Pr 2.04 (Pr 0.15)

When a motoring drive is used in a Regen system, the ramp mode should be set to *FAST*. The default setting of standard control will result in incorrect operation.

Voltage Control Mode - Open loop only Pr 5.14 (Pr 0.07)

The default setting of *UR_I* does not function correctly in the motoring drive when used in a Regen system. When the system is powered up, the motoring drive is disabled while the Regen synchronises to the AC supply. The resultant delay before the motoring drive is enabled means that the stator resistance test cannot be completed. When open loop vector operation is required the voltage mode should be set to *UR_S*.

Drive Enable Function - Open loop only Pr 8.07

The default setting for terminal 30 in the open loop motoring drive is an external trip (*Et*) function. When the Regen drive has synchronised to the AC supply and the enable signal is applied to the open loop drive, a drive reset is required to clear the external trip. If a reset signal is not available or desirable, then Pr **8.09** should be set to a 1. Terminal 30 then acts as a non latching input with the drive displaying *INH* when disabled.

AC Supply Loss Mode - Pr 6.03

The motoring drive will not operate correctly if the AC supply loss mode is set to *STOP*. If the AC supply is lost, the Regen drive disables the motoring drive and prevents a controlled stop from being completed.

Auto Start - Pr 6.02

The Auto Start function will not operate correctly when used in a Regen system due to the delay in applying the enable signal to the motoring drive as described above in *Voltage Control Mode*. The delay means that the run latch has already cleared when the enable signal is applied.

9.5 Trip codes

Below are the trip codes which are specific to Unidrive in Regen mode. These are in addition to the trips listed in the *Unidrive size 1 to 5 User Guide*.

Table 9-2 Trip codes

Trip Code	Description
LI.SYNC	Regen sinusoidal rectifier failed to synchronise to line voltage
Ph Det	Failed to correctly detect the phasing of the supply
Fr Lo	Line frequency to low
Fr Hi	Line frequency to high
PLL OI	Overcurrent during final synchronisation of PLL to supply
PLL Ph	Phasing error during final synchronisation of PLL to supply

Table 9-3 Status display

Status Display	Description
STOP	Drive Enabled but AC voltage too low, or DC bus voltage still rising, or DC bus voltage still falling. Waiting for correct conditions to synchronise onto line
SCAN	Drive enabled and synchronising to line
ACT	Drive enabled, synchronised and active

Appendix A Unidrive Regen as a Brake Resistor Replacement

A.1 Introduction

The Regen drive has been designed to provide a regulated DC supply to other motoring drives. The Regen drive gives bi-directional power flow with sinusoidal currents and a near unity.

In many applications, the motoring power can be significantly higher than the braking power. If sinusoidal input currents are not required, it is difficult to justify the cost of a Regen drive rated at the full motoring power. In these applications it may be desirable to take the lower cost option of a smaller Regen drive which is only used to return the braking energy to the AC supply. This is the mode of operation described in this Appendix.

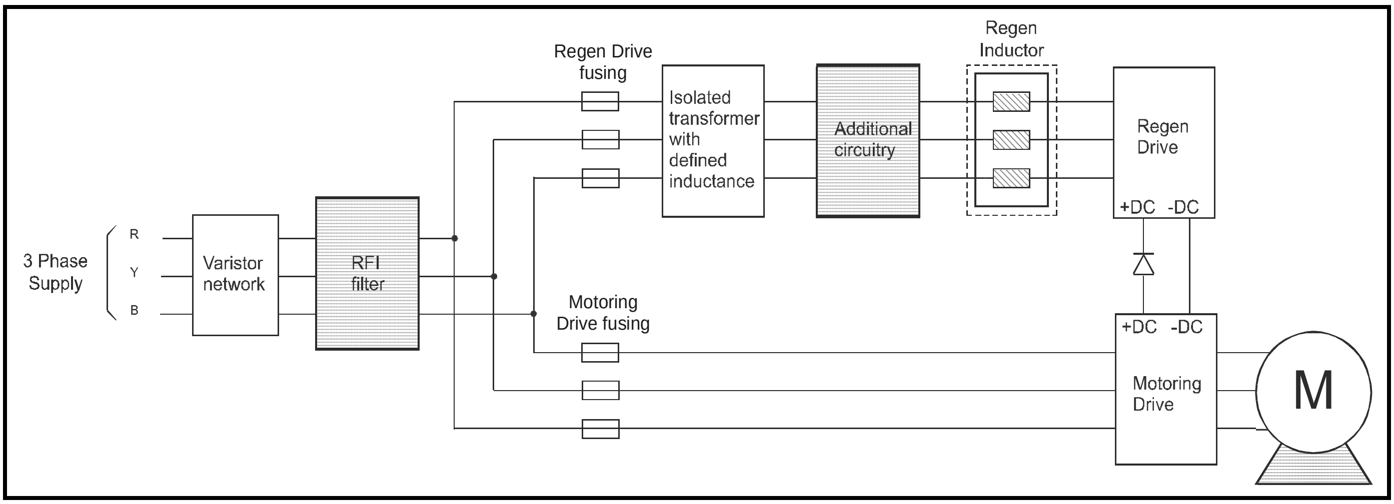
NOTE

When using the Regen drive as a brake resistor replacement, the information given in earlier sections of this guide must also be referred to.

A.2 Drive configurations

When a Regen drive is used as a dynamic brake resistor replacement, connections must be made as shown in Figure A-1.

Figure A-1 Brake resistor replacement system connection



NOTE

The single RFI filter shown in the above configuration should be rated to the motoring drive's rated current.

The AC supply is connected to both the Regen drive and the motoring drive. **Note, however, that the Regen drive receives its supply via an isolating transformer.** This is necessary because when the Regen drive is switching, its DC bus voltage moves with respect to both ground and the supply neutral point. However, on the motoring drive, the DC bus voltage remains relatively fixed with respect to ground. As a result of the difference between the two voltages, it is not possible to connect both drives to the same AC supply. **A DC bus diode is fitted to ensure that power flows from the motoring drive to the Regen drive only.**

A.3 When to use a Regen drive as a brake resistor replacement

The important factor when considering the use of a Regen as a brake-resistor replacement is the ratio of motoring power to braking power, as this has implications for the power rating of the Regen drive.

Motoring power $\leq$ 1.5 $\times$ Braking power.

If the maximum motoring and braking power are approximately equal, a Regen drive should be used as the main supply and not solely as a brake-resistor replacement. This is because, in this instance, the Regen drive and motoring drive ratings are equal, so the full advantage of a standard Regen configuration can be exploited.

1.5 $\times$ Braking power $<$ Motoring power $\leq$ 4 $\times$ Braking power.

In this range of motoring and braking power, a Regen drive will work well as a brake-resistor replacement.

The Regen drive power rating is equal to the braking power.

Motoring power $>$ 4 $\times$ Braking power.

If the motoring power is greater than approximately four times the braking power, it is not possible to use a Regen drive rated only for its braking power. This is because the small Regen drive is unsuitable for connection to the large capacitance of the motoring drives. If the motoring power is greater than four times the braking power, then the following can be used.

- An over-rated Regen drive with a current rating at least equal to 0.25 x motoring drive power.
- Conventional brake resistor.

A.4 Regen and motoring drive ratings

NOTE

The Regen drive's current limits are set at 150% and are not adjustable.

In general the Regen drive must be rated at a power greater than, or equal to, the maximum braking power.

Example:

- Two 30kW motoring drives are each driving 30kW motors. The load is such that only one drive is braking at a time.

If each motor supplies between 20 and 30kW motoring, and the braking power varies from 0 to 30kW, the maximum total braking power is 30 - 20 = 10kW, which is what the Regen drive should be rated for.

In drive configurations where the motoring drive power rating is several times the expected braking power, it is necessary to consider the peak braking power returned from the load.

Example:

- The motoring drive is a 75kW Unidrive. Motoring power is 75kW. Steady state braking power is 20kW.

From these figures, it may appear that a 22kW Regen drive will provide sufficient braking power. However, dynamically the peak braking power could be much greater. If the 75kW drive current limits are set at 150% for motoring and braking (default settings), the peak brake power could be:

$\sqrt{3} \times 156A \times 400V \times 150\% = 162kW$

This is much greater than the 22kW Regen drive is able to return to the supply, hence a larger drive is required.

NOTE

If the Regen drive is not rated for the required braking power, then the drives will trip on DC bus over-voltage.

A.5 Power circuit connections and components

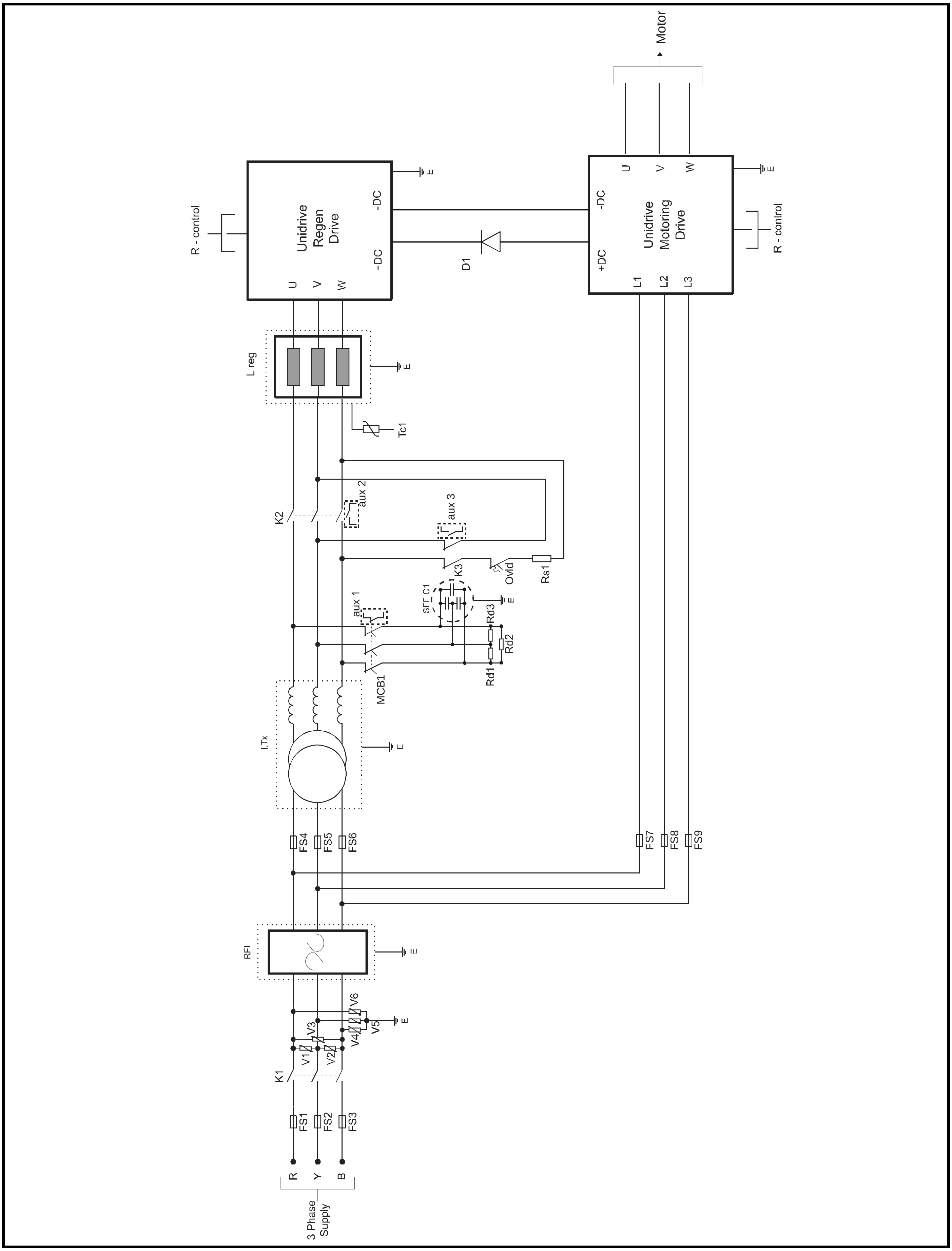
Figure A-2 shows the power connections required when using a Unidrive, operating in Regen mode as a dynamic brake resistor replacement. The Regen drive control terminals are connected as shown in Figure A-3.

Table A-1 shows the key to the following system layout diagram.

Table A-1 Key to Figure A-2

E	Ground connection point
RFI	EMC filter
I.Tx	Isolated transformer
SFFL	Switching frequency filter inductor
L regx	Regen inductor
V1, V2, V3	Varistor network 550V (line to line)
V4, V5, V6	Varistor network 680V (line to ground)
Rsx	Softstart resistor
Fsx	AC supply fusing
SFF Cx	Switching frequency filter capacitor
Rdx	Switching frequency filter capacitor discharge resistor
Tcx	Thermocouple
K1	Supply contactor
K2	Main contactor
K3	Auxiliary contactor
MCB1x	Switching frequency filter capacitor MCB
aux1x	Switching frequency filter MCB auxiliary through which Regen drive enable is connected
aux2	Main contactor auxiliary for "main contactor closed signal"
aux3	K3 auxiliary with coil supply for K2
Ovld	Thermal, Magnetic overload

Figure A-2 Power connections: Single Regen



There are three main connection differences compared with normal operation.

- There are AC supply connections to both the Regen and motoring drives.
- The DC bus connection between the Regen and motoring drives is via diode D1.
- The switching frequency filter inductors are replaced with an isolating transformer T1 with a defined leakage inductance

For details of the standard Regen components and their connections, refer to Chapter 3 *Power connections* on page 4 and Chapter 5 *Components* on page 10.

A.5.1 DC bus diode

Table A-2 DC bus diode

Diode type	Recovery time	Current rating	Voltage rating
	μS	A	V
Fast or Ultra Fast	<1	3 x current rating of Regen drive	1,200

A suitable supplier for the above diode can be Semikron™ with the **SKKD xxx F 12** or **SKKE xxx F 12** diode modules.

The diode must be mounted on a suitable heatsink. Heatsink sizing should be based on:

- Maximum device case temperature of 80°C
- Power loss = 2V x Regen drive rated current

A.5.2 Isolating transformer T1

This is a three phase transformer which provides isolation between the AC supply and the Regen drive. One isolating transformer can only supply one Regen drive with the current rating equal to the Regen drive continuous current rating. The transformer leakage inductance forms the switching frequency filter inductance. The inductance value for the switching frequency filter is specified in Chapter 5 *Components* on page 10.

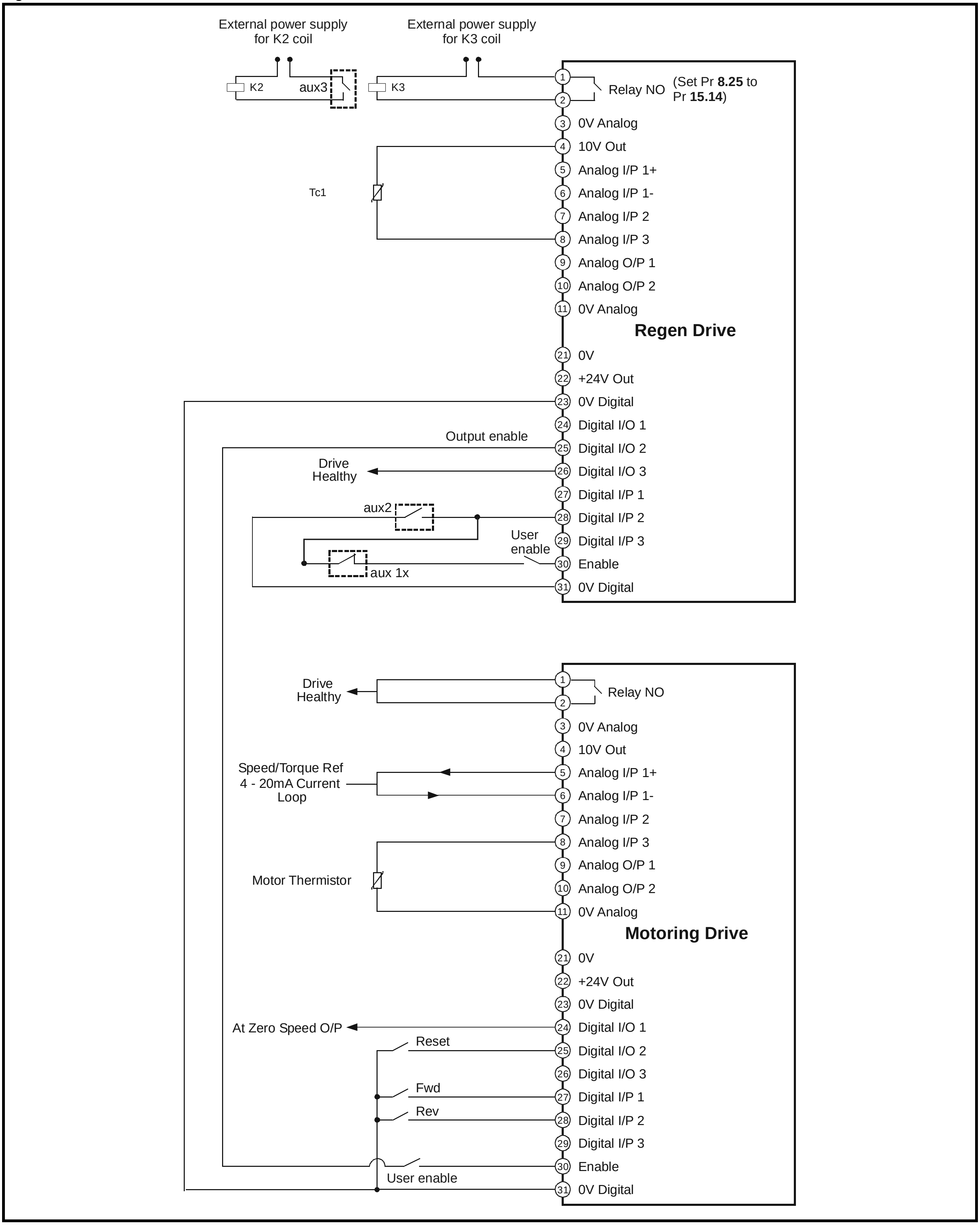
NOTE

A non isolating transformer cannot be used under any circumstances.

A.6 Control circuit connections

Figure A-3 shows the control connections that should be made between the Regen and motoring drive.

Figure A-3 Control Circuit Connections.



A.7 Regen brake drives in operation

A.7.1 Sequence

If the Regen brake drive and motoring drive are supplied from a separately switched AC supply then the Regen brake drive supply should be energised first (or both at the same time). Similarly the Regen brake drive should also be powered down first (or both at the same time).

The motoring drive must only be enabled when the Regen drive is enabled, healthy, and synchronised to the AC supply. This will prevent any damage to the Regen start-up circuit and prevent OU trips.

A.7.2 Regen parameter settings

It is very important that the Regen drive DC bus voltage set point is set above the peak AC supply voltage. If this is not done then power will flow from the AC supply into the motoring drive, through the DC bus diode and back through the Regen drive to the AC supply. This will continue until the Regen drive trips or part of the circuit is damaged. If possible the DC bus voltage set point should be at least 50V above the peak AC supply voltage. With a larger difference between the peak AC supply voltage and the DC bus voltage set point there is more energy storage available for transient peaks in the braking power. Table A-3 gives recommended DC bus voltage set points.

Table A-3 DC bus voltage set points - Pr 15.07 (Pr 0.17)

Supply Voltage Vac	Recommended Vdc	Maximum Vdc
380	700	800
415	700	800
480	780	800

Appendix B Component sizing calculations

B.1 Sizing of MCB for switching frequency filter

The current rating of the MCB must be calculated; taking into account the switching frequency filter inductance and capacitance, the initial charging current and the AC supply voltage. switching frequency filter inductance and capacitance values can be found in Chapter 5 *Components* on page 10.

L = 2 x **Lf**	**Lf** = Switching frequency filter inductance
C = 3**Cf** / 2	**Cf** = Switching frequency filter capacitance
Vc = V_{LL} peak	**Vc** = Charging voltage
Zc = $\sqrt{\frac{L}{C}}$	**Zc** = Charging impedance
Tc = $\pi\sqrt{LC}$	**Tc** = Charging time
Ic = **Vc** / **Zc**	**Ic** = Charging current

Example:

Unidrive size 5 Regen

Switching frequency filter Inductance 100μH

Switching frequency filter Capacitance 80μF

Supply Voltage 480v + 10%

L =	2 x 100μH =	**200μH**
C =	3 x 80μF / 2 =	**120μF**
Vc =	480 + 10% x √2 =	**747V pk**
Zc =	$\sqrt{\frac{200\mu H}{120\mu F}}$ =	**1.29Ω**
Tc =	$\pi\sqrt{200\mu H \times 120\mu F}$ =	**487μs**
Ic =	747 / 1.29 =	**579A**

The MCB should be rated to the peak charging current of 579A for 487μs, with an rms current of 35A. Refer to Table 5-6 for a full list of ratings. A suitable MCB should have the following ratings and features:

Voltage rating: 480 + 10%
Peak current rating: 579A
rms current rating: 35A
3 pole with auxiliary (for enable)

Table B-1

Drive size	Power rating (kW)	Total DC bus capacitance (μF)
1	4.0	340
2	5.5	470
	7.5	470
	11.0	680
3	15.0	1,100
	18.5	1,100
	22.0	2,200
	30.0	2,200
	37.0	2,200
4	45	3,300
	55	3,300
	75	4,400
	90	6,600
	110	6,600
5	150	8,800

B.2 Resistor sizing for multiple motoring systems

The softstart resistor must be recalculated for the multiple motoring system due to the increased inrush current and therefore increased power dissipation.

For applications where the total DC bus capacitance of the motoring drives is greater than that of the Regen drive (one large drive supplying several smaller drives). The following procedure and tables should be used to recalculate the resistor(s) required:

B.2.1 Procedure

1. Calculate the total capacitor bank energy rating of the system (Table B-3).
2. Calculate the minimum number of resistors required to meet this energy value (round up to the nearest one), (Table B-2).
3. Calculate the series parallel arrangement of resistors to produce the total resistor value in the required range (Table B-5 and Table B-2).
4. Calculate the total rms resistor current (Table B-4).
5. Calculate the power dissipation in the resistor bank [I_{rms}^2 x R]. If the power dissipation exceeds the rating of the resistor bank, add more resistors, then go back to step 3 (Table B-2).

Table B-2

Resistor data			
Resistor value Ω	**Power rating** W	**Energy rating** J	**CT part number**
150	53	170	1270-3157
48	148	1,700	1270-2483

Table B-3

Capacitor bank	
Drive size	**Energy per drive** J
1	75
2	200
3	600
4	1800
5	2500

Table B-4

RMS resistor current data	
Drive size	**RMS current** A
1	0.4
2	0.4
3	0.5
4	0.6
5	0.6

Table B-5

Total resistor value data	
Drive size	**Total softstart resistor value** W
1	75 to 150
2	28 to 150
3	9 to 48
4	3 to 24
5	2 to 24

Example:

Unidrive size 4 Regen with (3 x Unidrive size 3) and (5 x Unidrive size 1) motoring drives

1. Capacitor bank energy = 1800 + (3 x 600) + (5 x 95) = 4075J
2. Using resistors 1270-2483 (4,075 / 1,700) you will need at least 2.39 resistors = 3
3. Three 48Ω resistors can be arranged to achieve 16Ω. In this case 16Ω is satisfactory for a Unidrive size 4, so parallel connection can be used.
4. Total rms current needed = 0.6 + (3 x 0.5) + (5 x 0.4) = 4.1A
5. Power loss in 16Ω bank (85W per resistor) = 256W, resistor bank maximum rating = 3 x 148W = 444W, so the 16Ω resistor arrangement is suitable.

B.3 Multiple Unidrive size 5 systems

Table B-6 Resistors for Unidrive size 5 multiple systems

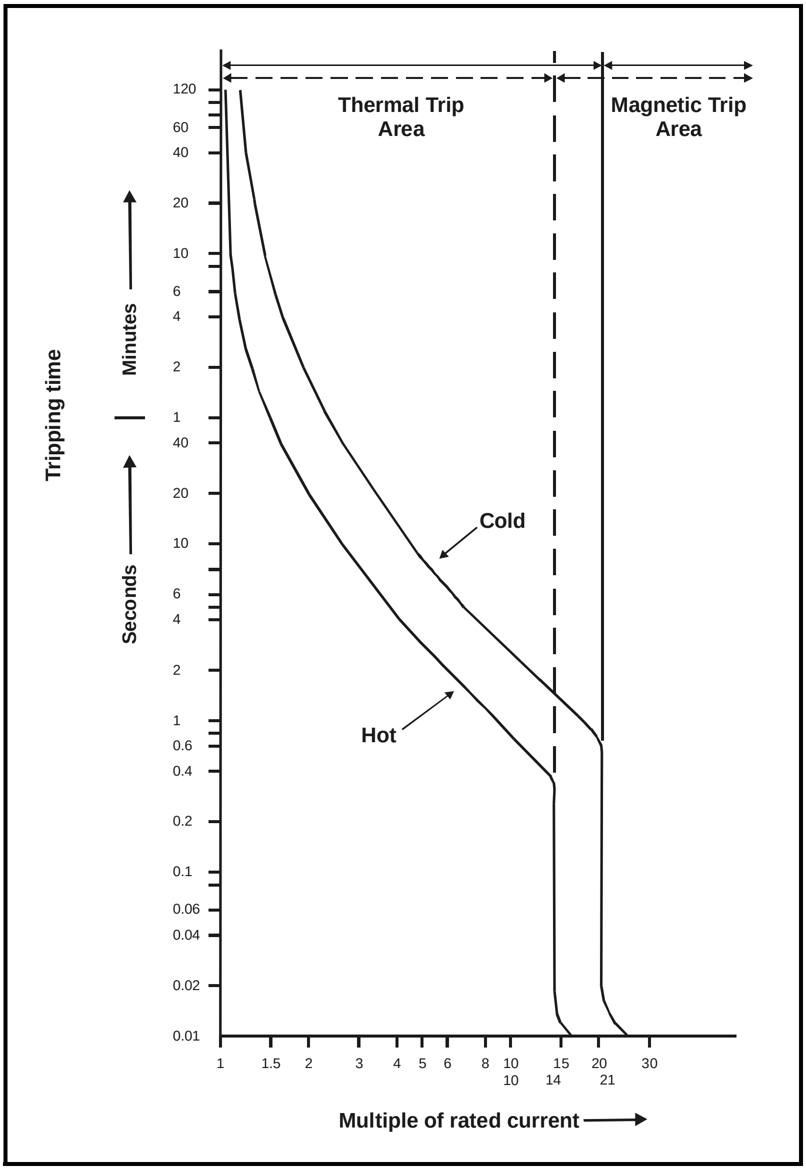
Drive size	Number of parallel resistors	CT part number
5	Equal to total number of modules in the system (Regen and motoring)	1270-2483

B.4 Thermal / magnetic overload protection for soft start circuit

Thermal / magnetic protection for the softstart resistor should be provided to protect against a high / low impedance short circuit and the risk of fire. A recommended device being a thermal magnetic overload. The overload should be sized as following to provide thermal and magnetic protection:

B.4.1 Thermal / magnetic overload characteristics

Figure B-1 Example of tripping characteristic



B.4.2 Sizing of magnetic overload

The magnetic overload should be selected to the peak current and charging time at power up with the trip being at for example 20 times the nominal rated current of the overload. Therefore for a 20A peak current a 1A overload could be used.

The charging of a system takes a total of 5 time constants with this having a decaying exponential current due to the RC network, therefore at 5 time constants the system will have charged up with the current being at approximately zero as shown in Figure B-2 on page 39.

The peak current and charge time during power up can be calculated using the following formula.

Peak current

Unidrive 5401 x 4, 480Vac supply +10%, total softstart resistance of 6Ω (4 x 24Ω in parallel):

I^{peak} = Vac(+10%) x 1.414 / $Resistance^{softstart}$

(480 + 48) x 1.414 / 6 = 124.08A I^{peak}

Charging time

Unidrive 5401 x 4, total softstart resistance of 6Ω (4 x 24Ω) in parallel, and a total DC bus capacitance of 4 x 8,800µF = 35,200µF

$T^{constant}$ = $Resistance^{softstart}$ x Total $Capacitance^{DC\ bus}$

$T^{constant}$ x 5 = T^{charge}

6 x (35,200 x 10^{-6}) x 5 = 1.056sec

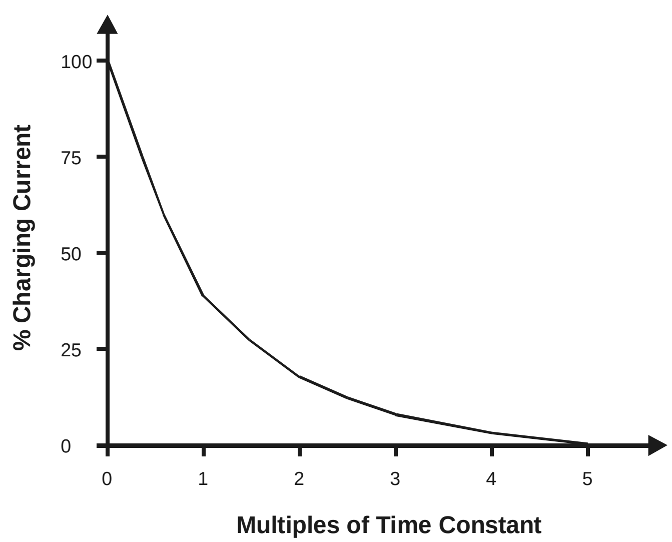
Selection

From the above calculations for a peak charging current of 124.08A with a charge time of 1.056sec a magnetic overload with the following characteristics can be used:

8A nominal rating
O/L = 15.5

Plotting the exponential charging current for the soft start circuit against the trip characteristic curve for the overload will also ensure no spurious tripping during charging time.

Figure B-2 Example of charging characteristics



Calculating current level on exponential curve

As shown in Figure B-2, after 5 time constants the charging current is approximately zero. In some cases, due to the characteristic of the overload, the current may have to be calculated after 4 time constants to ensure that the thermal trip area of the overload is not activated. Refer to the following formula:

I at given Time Constant = Exp [-1 (Time Constants)] x I^{peak}

The following example calculates the current level after 3 time constants with a peak charging current of 100A:

Exp [-1 (3)] x 100 = 4.97A

B.4.3 Sizing of thermal overload

The thermal overload should be sized to provide protection against a high impedance short circuit. Under this condition the current flowing would not be high enough to result in the magnetic overload tripping, but the power dissipated would exceed the nominal power rating resulting in heating of the resistor.

In order to size the thermal overload correctly, the power rating and overload characteristics of the resistor are required. The power characteristic curve for the resistor should be converted from multiples of power to current in order to size the thermal overload correctly.

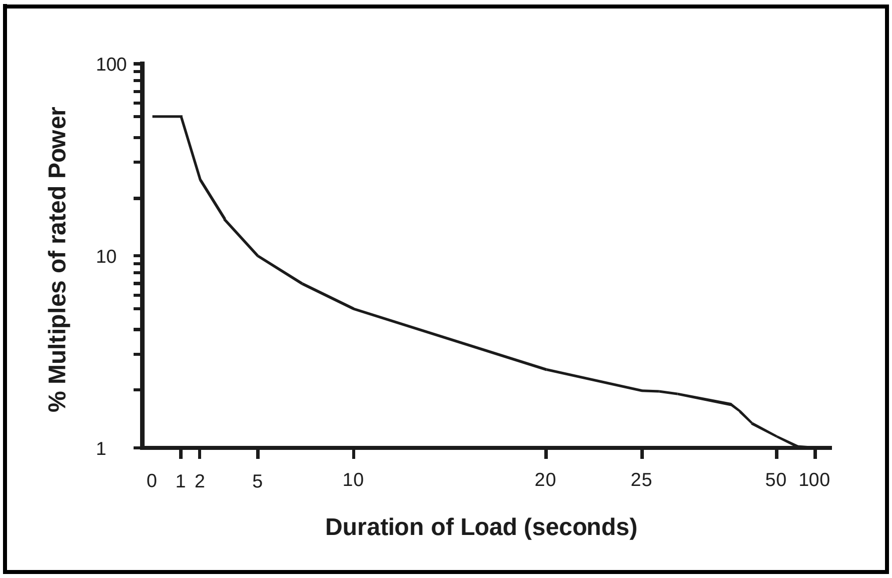
√P / R = ICalculation to convert from power to current

Example:

Assuming a system fault which results in a continuous power of 10 x the nominal power being dissipated by the resistor.
Resistor, 24Ω 296W
Peak current at power up = 528Vac / 24Ω = 22A
Thermal / Magnetic overload current rating = 22A / 20 = 1.1A (use 1.6A)
10 x nominal power = 2.960kW
Current flowing during overload √2960 / 24 = 11.01A

From Figure B-3 it can be seen that an overload of 10 times the nominal power is allowable for 5 seconds. From this plotting the 10 times overload on Figure B-1 it can be seen that for a current of 11.10A when using a 1.6A breaker that the overload will trip at 7 x the nominal current (11.10/1.6 = 6.9), which equates to approximately 5 seconds trip level worst case.

Figure B-3 Example of overload characteristic



Appendix C Long cables

C.1 Exceeding the maximum cable length

If the total maximum length specified is exceeded, the increased circulating currents caused by the extra cable capacitance will have an effect on the other parts of the system. This will necessitate additional components to be added to the standard arrangement.

C.1.1 Regen inductor

If the maximum cable length specified is exceeded this will introduce unnecessary heating of the Regen Inductor. To overcome the additional heating forced cooling should be introduced into the system as specified in the following table.

The forced cooling should be positioned to provide the specified airflow directly onto the Regen inductor windings.

Table C-1

Drive size	Maximum cable length		Cooling requirement
	without additional ventilation m	with additional cooling m	
1	50	250	One 120mm fan, air flow ≥ 160m^3 / hr.
2	100	500	One 120mm fan, air flow ≥ 160m^3 / hr.
3	200	1,000	One 120mm fan, air flow ≥ 160m^3 / hr.
4	200	1,000	Two 120mm fans, air flow ≥ 160m^3 / hr., per fan
5	200 per Regen drive	1,000 per Regen drive	Two 120mm fans, air flow ≥ 160m^3 / hr., per fan

C.1.2 RFI filter

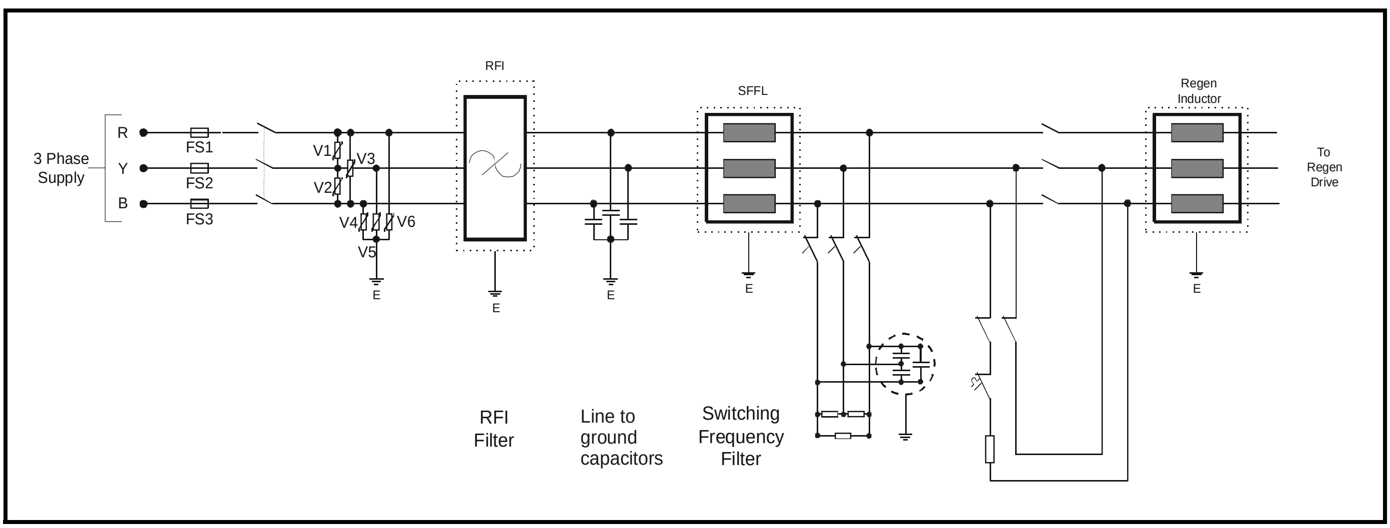
When an RFI filter is used the capacitors to ground carry common mode current.

When the maximum cable length without additional ventilation specified is exceeded, extra circulating currents can result in heating and saturation of the RFI filter. To prevent this, some capacitance line to ground should be provided as an additional path for this current, as shown in Figure C-1.

NOTE

If the maximum cable length exceeds the maximum cable length with additional cooling, Control Techniques Technical Support must be consulted.

Figure C-1 Unidrive Regen layout



C.1.3 Line to ground capacitors for multi-drive systems

Selection of line to ground capacitors for Regen systems with long cables.

In order to select the appropriate capacitors, the rms value of the current line to ground, the AC supply voltage and minimum capacitance values are required.

A minimum capacitance value of 1µF per phase should be used with the final capacitance value being determined by the value of the current line to ground. In practice, to carry the required level of current the capacitor will generally have a higher capacitive value. The current rating of the capacitors should be at a high frequency such as 100kHz at the relevant supply voltage. Polypropylene type capacitors are the most suitable because of their low loss at high frequency.

The rms value of the current can be estimated from the following formula:

$$I_{RMS} = 2.8 \times 10^{-4} kV_{DC} \sqrt{\Sigma lf_s}$$

Where:

k is 1 for simple rectifier-input systems, √2 for Regen systems
V_{DC} is DC bus voltage
$\sum lf_s$ is the sum of the products of motor cable lengths and switching frequencies of all drives in the system, including in the case of regenerative systems the Regen drive with the total DC cable length
l is total cable length in metres
f_s is switching frequency in kHz
If all drives operate at 3kHz, the expression can be simplified to:

$$I_{RMS} = 4.85 \times 10^{-4} kV_{DC} \sqrt{l}$$

Example

A Regen system operating with a supply of 400Vac giving a DC bus voltage of 620V at 3kHz switching frequency and a cable length of 1km (motors + DC) has an I_{RMS} of:

$$I_{RMS} = 4.85 \times 10^{-4} kV_{DC} \sqrt{l}$$

$$I_{RMS} = 4.85 \times 10^{-4} \times \sqrt{2} \times 620 \times \sqrt{1,000}$$

$$I_{RMS} = 13.4A$$

The I_{RMS} is the total current line to ground, therefore each capacitor will have to carry 4.5A.

WARNING

Ground leakage current

The value of capacitance required means that the ground leakage current exceeds the usual safety limit of 3.5mA. The user should be aware of the high leakage current. A permanent fixed ground connection must be provided to the system.

WARNING

Discharge time

Resistors must be fitted in parallel with the capacitors to ensure that they discharge when the supply is removed. The resistor values should be chosen so that the discharge time is no longer than for the drive itself. Typically values of about 5MΩ are suitable, and are high enough not to cause the system to fail a simple insulation test.

Appendix D Regen kits

D.1 Single Regen, single motoring systems

Standard kits of Regen components for Unidrive Regen systems which consist of a single Regen drive and a single motoring drive. Refer to Table D-1 for details.

Table D-1 Standard kits

Drive size	CT kit part number	Content of kit			
		Varistors	SS Resistor	SFF Cap	Soft Start O/L
1	80700000009400	9500-0023 kit bag	1270-3157 x 1	1610-5752 x 1	4133-0117
2	80700000009500		1270-3157 x 1		
3	80700000009600		1270-2483 x 1	1665-2244 x 1	4133-0217
4	80700000009700		1270-2483 x 2	1665-2484 x 1	4133-0277
5	80700000009800		1270-2483 x 2	1665-2804 x 1	

Regen inductors and switching frequency filter inductors are also available but must be ordered separately. Refer to Table D-2 for details.

Table D-2 Standard kits

Drive kW	Regen inductor	Switching frequency filter inductor
1405	4401 - 0001	4401-0162
2401	4401 - 0002	4401-0163
2402	4401 - 0003	4401-0164
2403	4401 - 0004	4401-0165
3401	4401 - 0005	4401-0166
3402	4401 - 0006	4401-0167
3403	4401 - 0007	4401-0168
3404	4401 - 0008	4401-0169
3405	4401 - 0009	4401-0170
4401	4401 - 0010	4401-0171
4402	4401 - 0011	4401-0172
4403	4401 - 0012	4401-0173
4404	4401 - 0013	4401-0174
4405	4401 - 0014	4401-0175
5401	4401-0015 x 1	4401-0176
5402	4401-0015 x 2	4401-0177
5403	4401-0015 x 3	4401-0178
5404	4401-0015 x 4	4401-0179

D.2 Single Regen, multiple motoring and multiple Regen, multiple motoring systems

Standard kits of parts are not available for non standard systems. All of the items used in a standard system are still required, however, some components may need resizing. Refer to Appendix B *Component sizing calculations* on page 36 for details.

For non standard systems, components should be ordered independently.

Appendix E Unidrive Regen specifications

Table E-1 Drive ratings in 40°C ambient

<table>
<tr><th rowspan="2">Model</th><th rowspan="2">Rating</th><th colspan="5">Maximum permissible continuous output current</th><th>Maximum overload time</th></tr>
<tr><th>3kHz</th><th>4.5kHz</th><th>6kHz</th><th>9kHz</th><th>12kHz</th><th>60sec</th></tr>
<tr><td>UNI 1405</td><td>4kW</td><td colspan="2">9.5A</td><td>8.5A</td><td>7A</td><td>5.5A</td><td rowspan="14">150%</td></tr>
<tr><td>UNI 2401</td><td>5.5kW</td><td colspan="4">12A</td><td>11.7A</td></tr>
<tr><td>UNI 2402</td><td>7.5kW</td><td colspan="3">16A</td><td>14.2A</td><td>11.7A</td></tr>
<tr><td>UNI 2403</td><td>11kW</td><td>25A</td><td>21.7A</td><td>18.2A</td><td>14.2A</td><td>11.7A</td></tr>
<tr><td>UNI 3401</td><td>15kW</td><td colspan="3">34A</td><td>28A</td><td>23A</td></tr>
<tr><td>UNI 3402</td><td>18.5kW</td><td colspan="2">40A</td><td>37A</td><td>28A</td><td>23A</td></tr>
<tr><td>UNI 3403</td><td>22kW</td><td colspan="2">46A</td><td>40A</td><td>32A</td><td>26.6A</td></tr>
<tr><td>UNI 3404</td><td>30kW</td><td>60A</td><td>47A</td><td>40A</td><td>32A</td><td>26.7A</td></tr>
<tr><td>UNI 3405</td><td>37kW</td><td>70A</td><td>56A</td><td>46A</td><td>35A</td><td>28A</td></tr>
<tr><td>UNI 4401</td><td>45kW</td><td colspan="2">96A</td><td>88A</td><td>70A</td><td></td></tr>
<tr><td>UNI 4402</td><td>55kW</td><td>124A</td><td>104A</td><td>88A</td><td>70A</td><td></td></tr>
<tr><td>UNI 4403</td><td>75kW</td><td>156A</td><td>124A</td><td>105A</td><td>80A</td><td></td></tr>
<tr><td>UNI 4404</td><td>90kW</td><td>180A</td><td>175A</td><td>145A</td><td>110A</td><td></td></tr>
<tr><td>UNI 4405</td><td>110kW</td><td>202A</td><td>175A</td><td>145A</td><td>110A</td><td></td></tr>
<tr><td>UNI 5401</td><td></td><td>300A</td><td></td><td></td><td></td><td></td><td>120%</td></tr>
</table>

Table E-2 Drive ratings in 50°C ambient

<table>
<tr><th rowspan="2">Model</th><th rowspan="2">Rating</th><th colspan="5">Maximum permissible continuous output current</th><th>Maximum overload time</th></tr>
<tr><th>3kHz</th><th>4.5kHz</th><th>6kHz</th><th>9kHz</th><th>12kHz</th><th>60sec</th></tr>
<tr><td>UNI 1405</td><td>4kW</td><td>6.9A</td><td>5.9A</td><td>5.1A</td><td>4.0A</td><td>3.3A</td><td rowspan="14">150%</td></tr>
<tr><td>UNI 2401</td><td>5.5kW</td><td colspan="3">12A</td><td>11.6A</td><td>9.7A</td></tr>
<tr><td>UNI 2402</td><td>7.5kW</td><td colspan="2">16A</td><td>14.7A</td><td>11.6A</td><td>9.7A</td></tr>
<tr><td>UNI 2403</td><td>11kW</td><td>20A</td><td>17.3A</td><td>14.7A</td><td>11.6A</td><td>9.7A</td></tr>
<tr><td>UNI 3401</td><td>15kW</td><td colspan="2">34A</td><td>28A</td><td>21A</td><td>17.9A</td></tr>
<tr><td>UNI 3402</td><td>18.5kW</td><td>40A</td><td>34A</td><td>28A</td><td>21A</td><td>17.9A</td></tr>
<tr><td>UNI 3403</td><td>22kW</td><td>44A</td><td>36A</td><td>31A</td><td>24A</td><td>20.6A</td></tr>
<tr><td>UNI 3404</td><td>30kW</td><td>44A</td><td>36A</td><td>31A</td><td>24A</td><td>20.9A</td></tr>
<tr><td>UNI 3405</td><td>37kW</td><td>50A</td><td>41A</td><td>34A</td><td>26A</td><td>23A</td></tr>
<tr><td>UNI 4401</td><td>45kW</td><td>95A</td><td>85A</td><td>75A</td><td>60A</td><td></td></tr>
<tr><td>UNI 4402</td><td>55kW</td><td>105A</td><td>85A</td><td>75A</td><td>60A</td><td></td></tr>
<tr><td>UNI 4403</td><td>75kW</td><td>135A</td><td>105A</td><td>85A</td><td>65A</td><td></td></tr>
<tr><td>UNI 4404</td><td>90kW</td><td>180A</td><td>150A</td><td>125A</td><td>95A</td><td></td></tr>
<tr><td>UNI 4405</td><td>110kW</td><td>190A</td><td>150A</td><td>125A</td><td>95A</td><td></td></tr>
<tr><td>UNI 5401</td><td></td><td>240A*</td><td></td><td></td><td></td><td></td><td>150%</td></tr>
</table>

*No UL approval for Unidrive size 5 with 240A continuous in a 50°C ambient.

Appendix F Physical dimensions

The dimensions listed are for the following items, all of which are required to complete a Regen system. Note that the dimensions given apply only to the parts specified in this guide.

- Regen inductor
- Soft start resistor
- Switching frequency filter capacitor
- Switching frequency filter inductor
- RFI filter (Refer to the *Unidrive Size 1 to 5 User Guide*)
- Varistors

F.1 Regen inductor

Table F-1 Specifications

Drive rating (kW)	Amps	mH	L	D	H	WT Kg	CT part number	Type number
4	9.5	6.32	200	180	215	12	4401-0001	1
5.5	12	5.00	200	180	215	14	4401-0002	1
7.5	16	3.75	240	180	270	17	4401-0003	1
11	25	2.40	240	180	270	24	4401-0004	2
15	34	1.76	320	220	325	32	4401-0005	2
18.5	40	1.50	320	220	325	33	4401-0006	2
22	46	1.30	320	220	325	39	4401-0007	2
30	60	1.00	360	260	370	55	4401-0008	2
37	70	0.78	360	260	370	65	4401-0009	2
45	96	0.63	360	280	370	75	4401-0010	3
55	124	0.48	360	280	370	95	4401-0011	3
75	156	0.38	410	300	430	110	4401-0012	3
90	180	0.33	410	300	430	120	4401-0013	3
110	220	0.30	480	320	490	130	4401-0014	3
160	300	0.24	480	320	490	140	4401-0015	3

Figure F-1 Type 1 dimensions

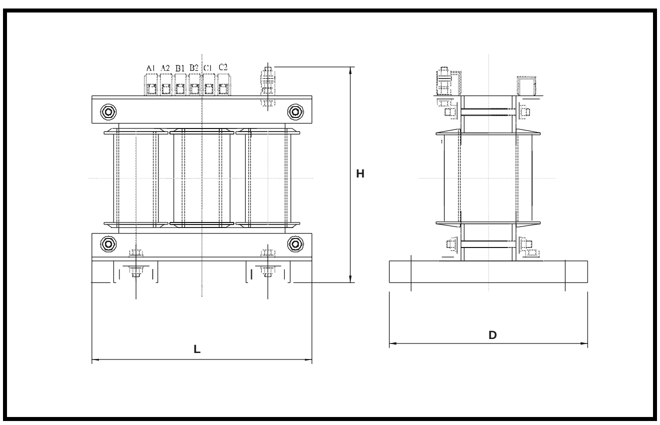


Figure F-2 Type 2 dimensions

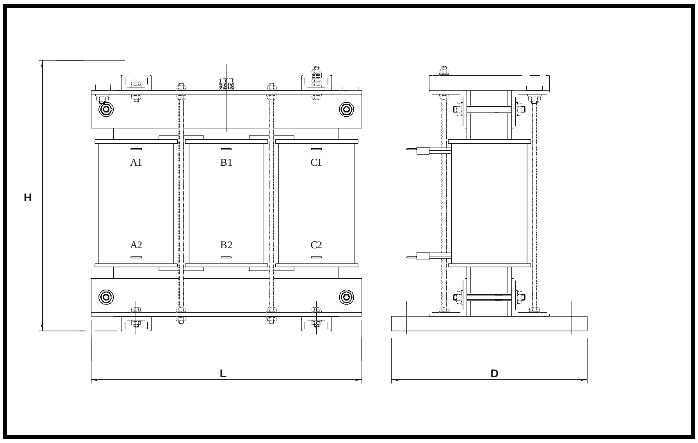
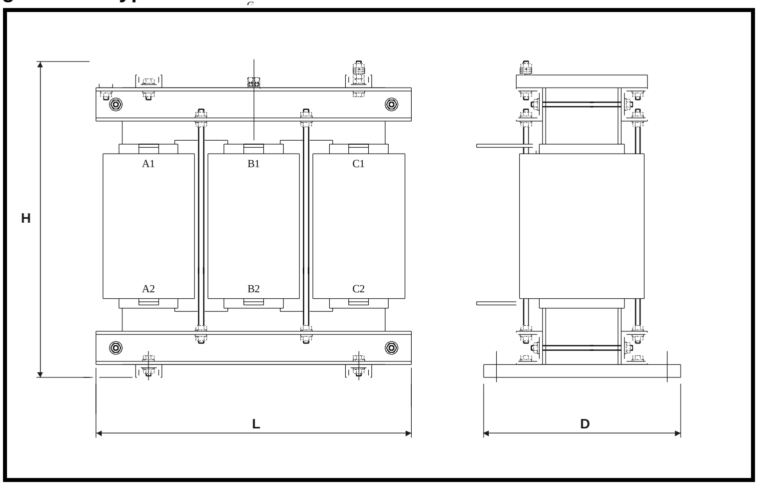


Figure F-3 Type 3 dimensions



F.2 Softstart resistor - type TG series

Figure F-4 Dimensions

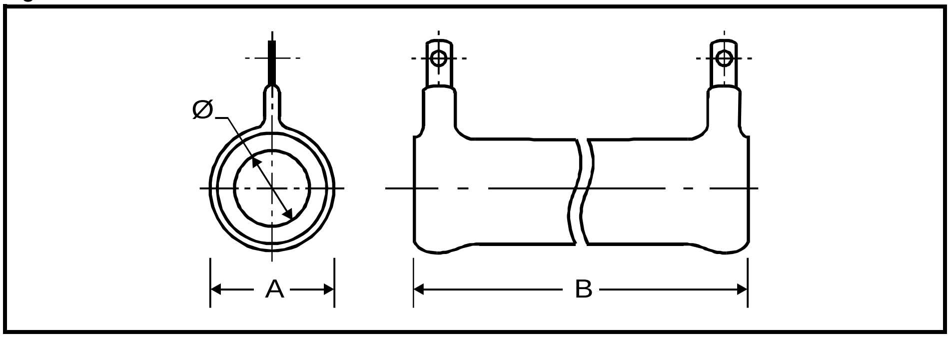


Table F-2 Specifications

Drive size	Resistance	Diameter (A)	Length (B)	CT part number
		mm	mm	
1 & 2	150Ω	19.1	73	1270-3157
3	48Ω x 1	22.2	165.1	1270-2483
4 & 5	48Ω x 2	22.2	165.1	1270-2483

Figure F-5 Resistor mounting bracket dimensions

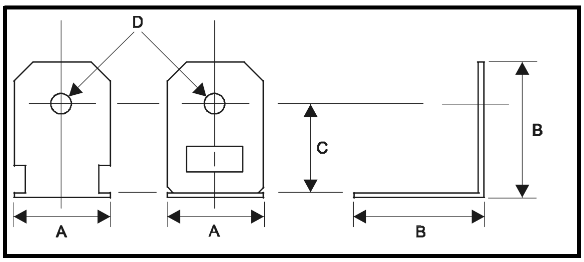


Table F-3 Resistor mounting bracket dimensions

Mounting bracket dimensions			
A	B	C	D
24.0mm	33.5mm	21.45mm ±0.2	∅5.0

F.3 Switching frequency filter capacitors

F.3.1 3-phase capacitors (size 1 and 2)

Figure F-6 Dimensions

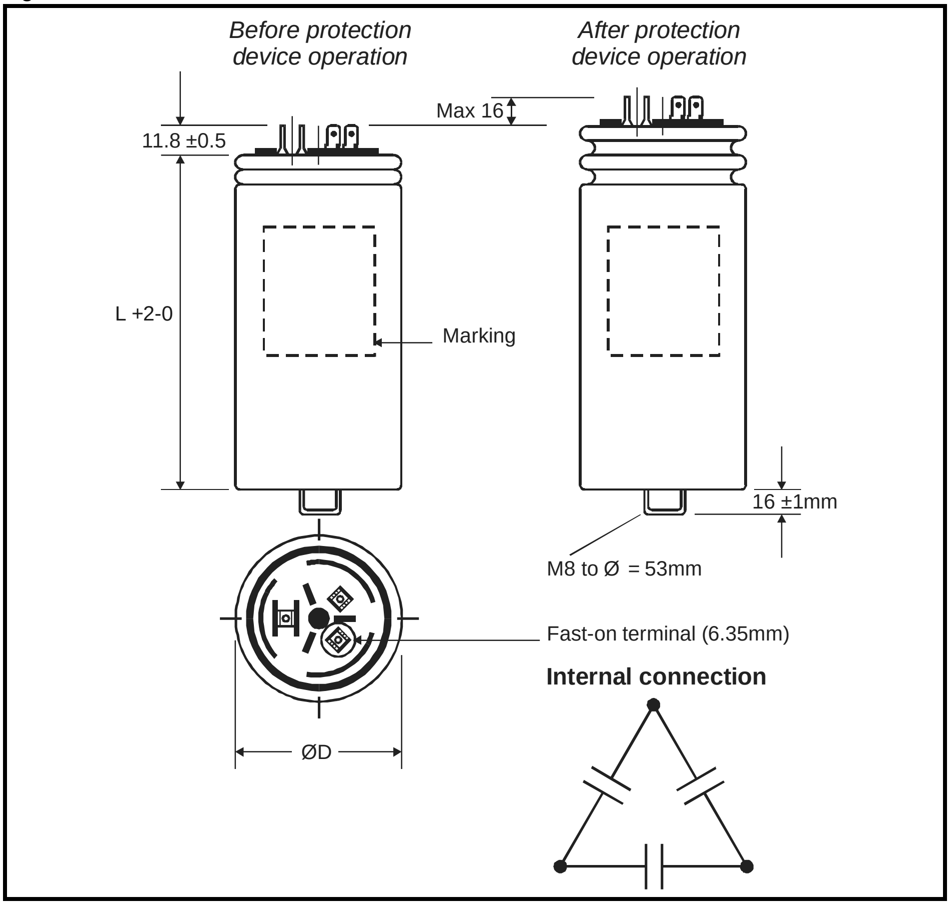


Table F-4 Specifications

Drive size	CN (µF)	∅ x L (mm)	Weight (kgs)	Mounting	CT part number
1 & 2	3 x 5.7	53 x 116	0.3	M8 Stud	1610-5752

F.3.2 3-phase capacitors (size 3 to 5)

Figure F-7 Dimensions

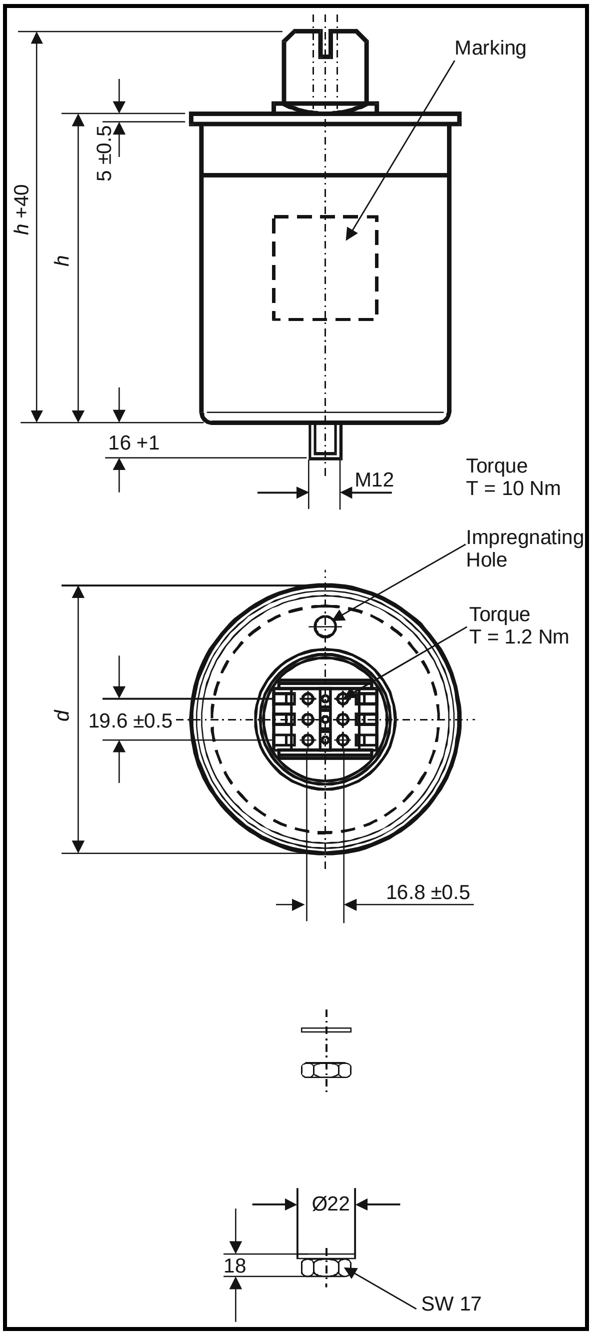


Table F-5 Specifications

Drive size	CN	d x h	Weight	Mounting	CT part number
	(µF)	(mm)	(kgs)		
3	3 x 24	121 x 164	1.1	M12 Stud	1665-2244
4	3 x 48	121 x 164	1.5	M12 Stud	1665-2484
5	3 x 80	142 x 200	2.2	M12 Stud	1665-2804

F.3.3 Discharge resistors

Discharge resistors for the switching frequency filter capacitors, for Unidrive size 3, 4 and 5, are supplied with the capacitor. These should be fitted during installation as shown in Figure F-8. For Unidrive size 1 and 2 the discharge resistors are fitted internally to the capacitor.

Figure F-8 Discharge resistor arrangement

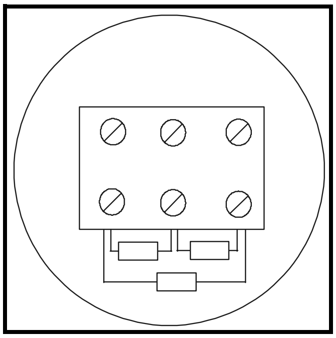


Table F-6 Specifications

Drive size	Capacitor value	Resistor value
1 & 2	5.7µF	Internal
3	24µF	3 x 390kΩ
4	48µF	3 x 390kΩ
5	80µF	3 x 270kΩ

F.4 Switching frequency filter inductor

Table F-7 Specifications

Drive size	Amps	mH	Losses W	L	D	H	Weight Kg	C.T part number	Type number
UNI 1405	9.5	3.160	28	150	90	150	4	4401-0162	1
UNI 2401	12	2.500	35	150	90	150	4	4401-0163	1
UNI 2402	16	1.875	37	180	100	190	6	4401-0164	1
UNI 2403	25	1.200	40	180	150	190	10	4401-0165	2
UNI 3401	34	0.880	52	180	160	190	12	4401-0166	2
UNI 3402	40	0.750	60	180	160	190	12	4401-0167	2
UNI 3403	46	0.650	60	180	160	190	13	4401-0168	2
UNI 3404	60	0.500	80	240	160	255	16	4401-0169	2
UNI 3405	70	0.390	90	240	170	255	20	4401-0170	2
UNI 4401	96	0.315	100	240	180	255	22	4401-0171	2
UNI 4402	124	0.240	110	240	190	255	25	4401-0172	2
UNI 4403	156	0.190	130	300	180	300	37	4401-0173	3
UNI 4404	180	0.165	170	300	180	300	37	4401-0174	3
UNI 4405	220	0.135	180	300	190	300	49	4401-0175	3
UNI 5401	300	0.100	220	300	200	300	50	4401-0176	3
UNI 5402	600	0.050	400	410	300	430	110	4401-0177	4
UNI 5403	900	0.034	530	480	320	500	140	4401-0178	4
UNI 5404	1200	0.025	700	480	320	560	170	4401-0179	4

Figure F-9 Switching frequency filter inductor (Type 1)

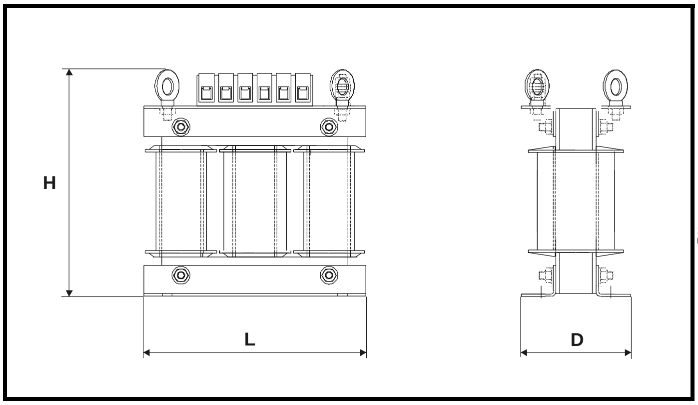


Figure F-10 Switching frequency filter inductor (Type 2)

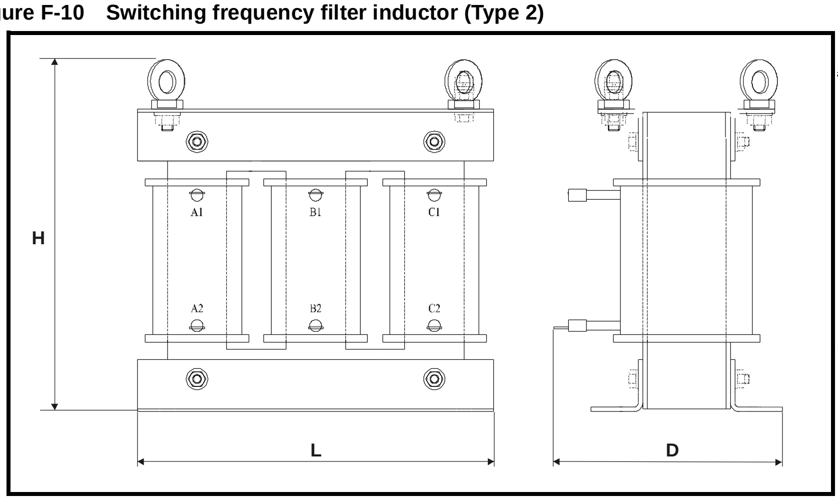


Figure F-11 Switching frequency filter inductor (Type 3)

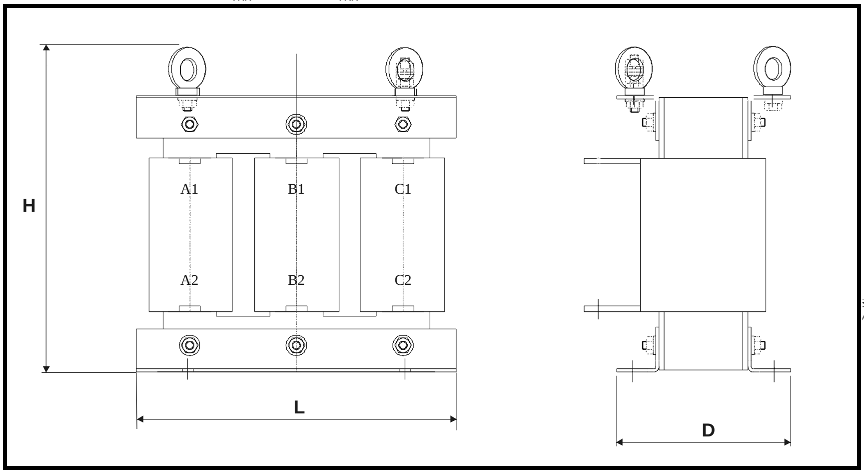
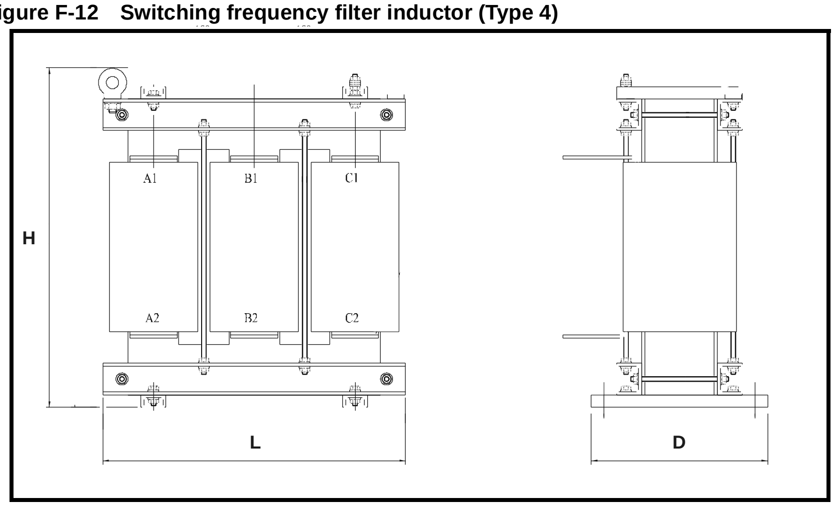


Figure F-12 Switching frequency filter inductor (Type 4)



F.5 Varistors

Figure F-13 Dimensions

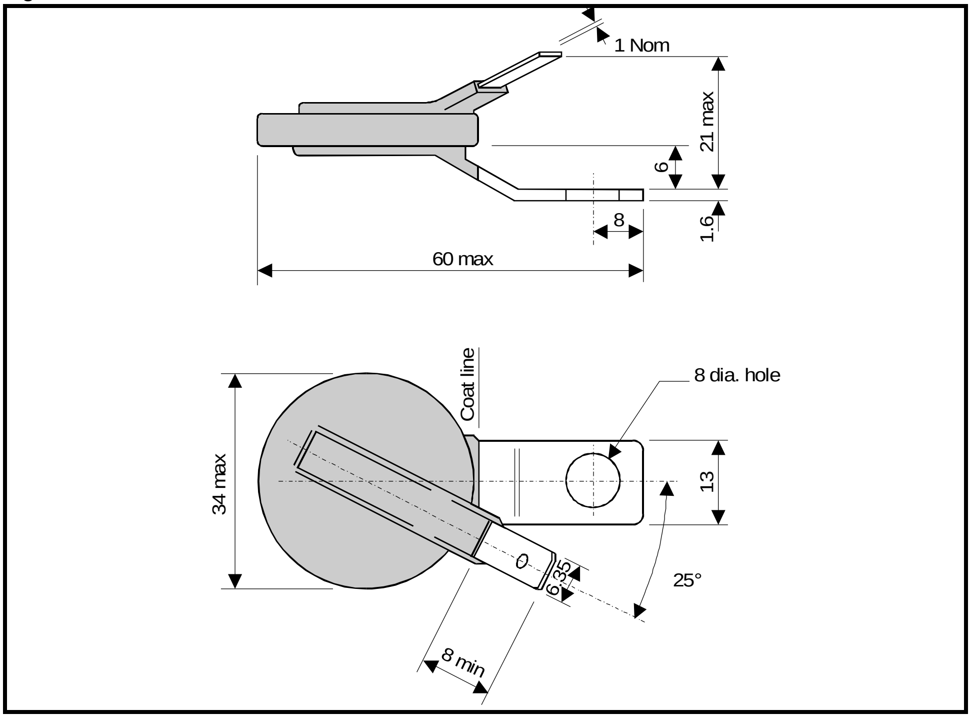


Table F-8 Specification

Drive size	Voltage Vac	Energy J	CT part number
1 to 5	550	400	2482-1501
1 to 5	680	450	2482-0680

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