SCHAFFNER

EMC INSTALLATION GUIDELINES
for
MOTOR DRIVES

690-292B

Table of contents

Installing Motor Drives with minimum system RFI

Part 1
Installation Guidelines

Theses guidelines cover the basic points to be considered when installing a motor drive, this is in order to achieve minimum Radio Frequency Interference (achieving Electromagnetic Compatibility, EMC).

As in other areas of EMC, such guidelines exist but are often neglected because they have a cost impact. However it has been shown in the majority of cases that, when no measures are taken early on, the cost of fixing systems to meet EMC requirements is many times more than following simple guidelines.

For motor drives, there are three key areas to be covered, Earthing, Screening and Filtering.

1. EARTHING

- Use the largest area as ground conductor, for example the cabinet wall.
- Connect the different parts of the ground system together using low impedance connections. A flat wire has a much lower H.F. impedance then round one. Keep all ground connections as short as physically possible.
- It may be necessary to remove paint from cabinets etc. to achieve low impedance bonds.
- Follow all local safety regulations with regard to earthing.
- All points with regard to low impedance earthing should be checked as part of the routine service or the maintenance checks.

2. SCREENING

The purpose of screenings is to prevent any unwanted electromagnetic radiation escaping, or entering, a system. This implies that screening must be part of cabinets as well as cables.

- The drive with switching elements is the main source of interference. When mounted in a cabinet, it is the cabinet which then is the first screen.
- It is usually necessary that the cable from drive to motor be screened, this for EMC and for mechanical reasons.
- The motor housing itself is a solid, effective EMC screen.
- The three screens – cabinet, cable screen, motor housing – must be connected together to effectively form one screen.
- To achieve the above, it shall be clear that no interruptions in the cable screen are permitted.
- The connections in the screening system must be designed to have a low impedance in the Megahertz range. The use of special connectors for this purpose is recommended.
- Inside cabinets, it is important that all the panels are bonded together and have a low impedance at high frequencies.
- To achieve low impedance bonding inside the cabinets, additional screws may be needed, paint may have to be removed, or the use of EMC gaskets may be necessary.

3. FILTERING

When properly used, filters prevent interference currents passing down power lines. These currents can disturb the equipments sharing the power line or can be radiated from the power line to nearby equipment which can then be affected.

- Schaffner power line filters are rated for their full load in a 40°C ambient temperature without the need for forced cooling or heatsinking.
- The watts loss of Schaffner's FN350 / FN250 (single phase) and FN351 / FN251 (three phase) devices are given in individual data sheets as well as Appendix 1. This loss can be added to other losses in a cabinet to determine cabinet cooling requirements.
- The filter must be mounted on the same panel as the drive. Both drive and filter must be HF connected to this panel.
- The filter must be connected as close as possible to the drive input. If the separation between filter and drive exceeds around 30 cm (1 ft.) then a flat cable should be used for the HF connection between filter and drive.
- Schaffner filters are provided with an earth connection on each end of the filter. Both these connections are bonded to the filter housing.
- When mounting the filter to the panel, it is essential that any paint or other covering material be removed before mounting the filter.
- The filter can produce high leakage currents.

The filter must be earthed before connecting the supply !!!
Schaffner FN350/ 351's carry appropriate warnings.

- The filters will withstand four times their rated current for up to 10 seconds. Fuses or circuit breakers should be chosen accordingly.
- The filter rated current may be exceeded, provided that the RMS current is not exceeded. Filter current must be reduced above 40°C. For further details see Part 2.

- The capacitors within the filters have discharge resistors. The filters should not be touched for a period of 10 seconds after removal of the supply.

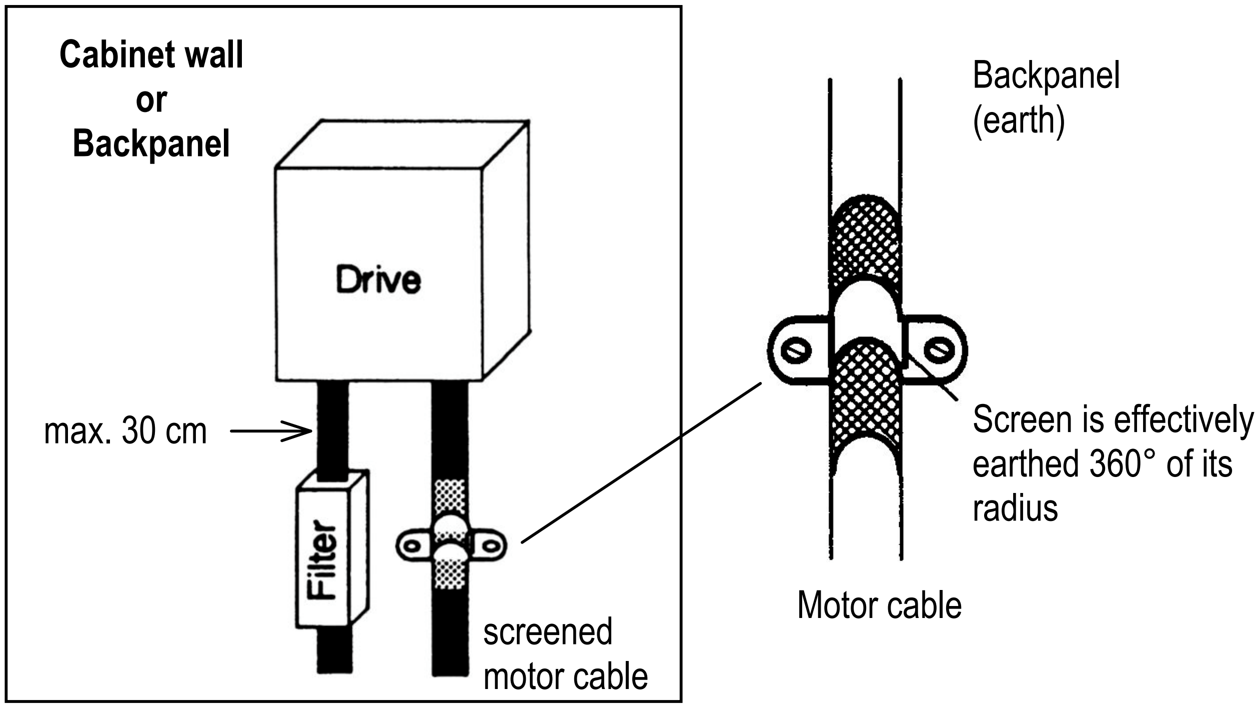
4. OTHER MEASURES

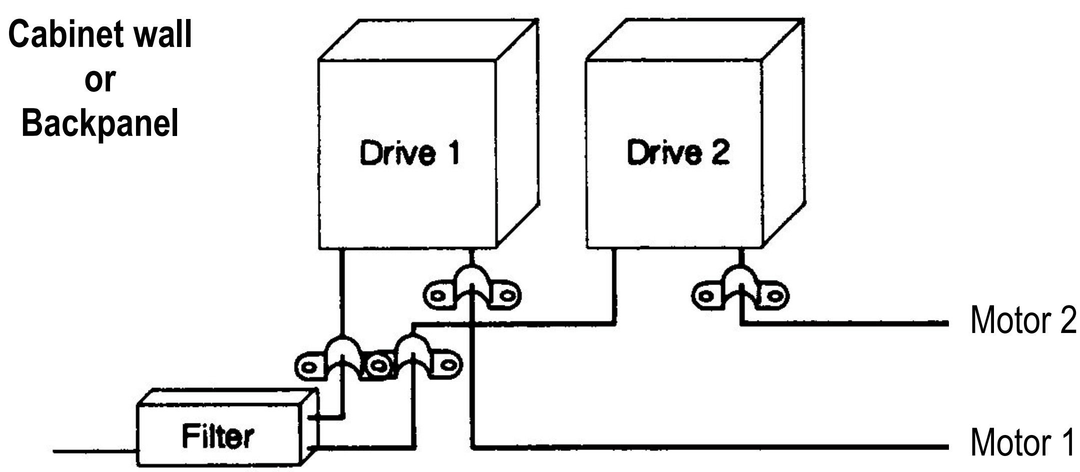
In addition to the earthing, screening and filtering measures, there are additional points which may prove effective in reducing interference.

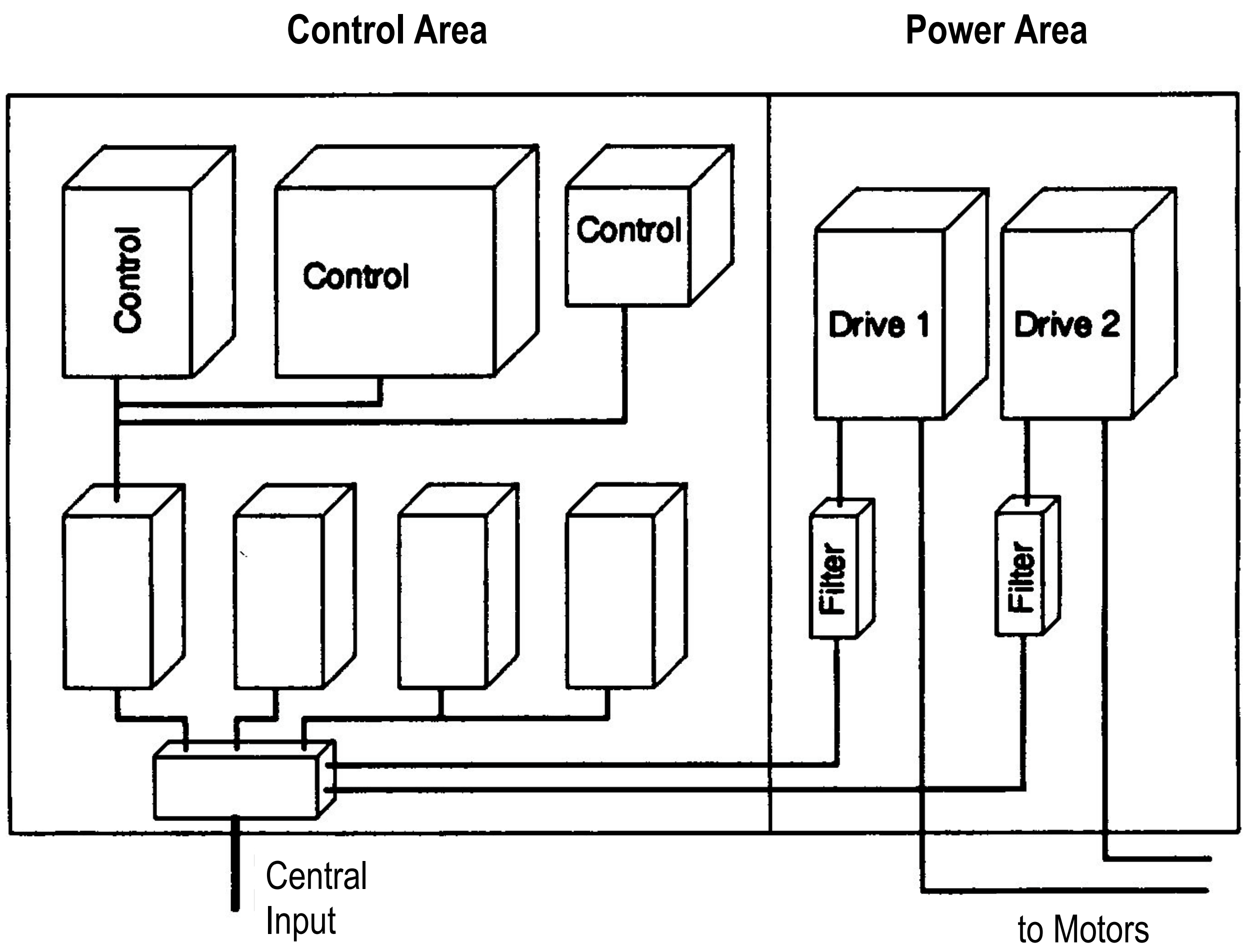
- Within the drive itself, capacitors connected from the positive and negative lines in the DC link to earth may prove effective, especially in smaller (>7.5 kW) drives. These capacitors being Y types of 100 nF or less.
- Control and signal cables must be separated from power cables. A distance of 20 cm (8") will be sufficient in most cases.
- Where control cables must cross power cables, this should be done with angle as near to 90 degrees as possible.
- Where a cabinet has more than one set of cables entering or leaving it, it will generally be found that filtering only one set of cables is ineffective. In such a case, replacing the filter with a higher performance filter will not bring very much improvement. Each set of cable should be filtered.

Note: It must be remembered that neglecting any of the above points during maintenance or service can cause interference. It may be necessary to include some control points as part of the maintenance/service schedules.

Some general hints to hardware positioning are shown in the following figures.


Cabinet wall
or
Backpanel
Drive
max. 30 cm
Filter
screened
motor cable
Backpanel
(earth)
Screen is effectively
earthed 360° of its
radius
Motor cable


Cabinet wall
or
Backpanel
Drive 1
Drive 2
Filter
Motor 2
Motor 1


Control Area
Power Area
Control
Control
Control
Drive 1
Drive 2
Filter
Filter
Central
Input
to Motors

Part 2
Technical Analysis

1. INTRODUCTION

Increasing numbers of motor drives and frequency inverters are being produced with fast switching semiconductors having Pulse Width Modulation (PWM) control.

The PWM switching frequency can be as high as 50 kHz, especially in low power drives. The use of PWM at such frequencies results in electromagnetic interference (EMI) at this switching frequency and harmonics of this frequency. This interference is still significant in frequencies up to tens of Megahertz.

Both for legal reasons and for operational reasons, these levels of interference may have to be suppressed. This application note deals with noise suppression of a drive/motor system. As EMI can involve very complex coupling modes, not all solutions can be easily found and explained. It is hoped, however, that over 80% of EMI problems can be solved using the guidelines in this application note.

2. LEGAL REQUIREMENTS

At present, there is still on going evolution in the legal situation with regard to EMI problems, especially in Europe. It was hoped that, as of 1 January 1992, throughout Europe the EMI regulations would have been the CENELEC (ENs) standards. However, this has not been possible and a transition period of four years has been introduced to allow change from the old national standards like VDE to new ENs. The CENELEC standards are not in themselves legal requirements, however, national standards bodies, like VDE, must adopt the ENs and at that point they have legal force.

All products brought onto the free European Market, or for use in the European Economic space, must meet these requirements. The manufacturer, his agent or product importer is required to show that standards are met. When this is shown, then he may apply the CE conformity symbol to the product. Enforcement of the regulations still varies from country to country; failure to meet requirements in one country can lead to the product being removed from the market in all countries. Motor drives in industrial environments will be required to meet conducted emissions levels of EN55011, Group1, ClassA.

In North America, especially in the USA, there are existing regulations, FCC Rules. In theory, these must be met also; however, the FCC is not in a position to realistically enforce their regulations, and as a result the EMI levels of FCC are often ignored by drives manufacturers. In the US the main problem with interference from drives is the disturbance they cause to AM radio reception.

3. PRACTICAL PROBLEMS

Motor Drives are such significant producers of EMI that the cost of building in noise suppression is prohibitive. Most often, a drive manufacturer will recommend suppression components as “add on” devices to be used, *should* problems occur. Due to the EMI intrinsically produced, these problems do always occur. The main problem is interference to nearby equipment, for example, industrial control equipment or, AM radios in housing blocks where an elevator has a motor drive.

Consider the system shown in Figure 1. Interference signals generated within the drive, especially from the semiconductors, are coupled into the earthing system, and on the cable form the drive to the motor. Once in the earth system, these interference currents circulate to other equipments, then the higher frequency components will radiate from the cables into other systems causing further problems.

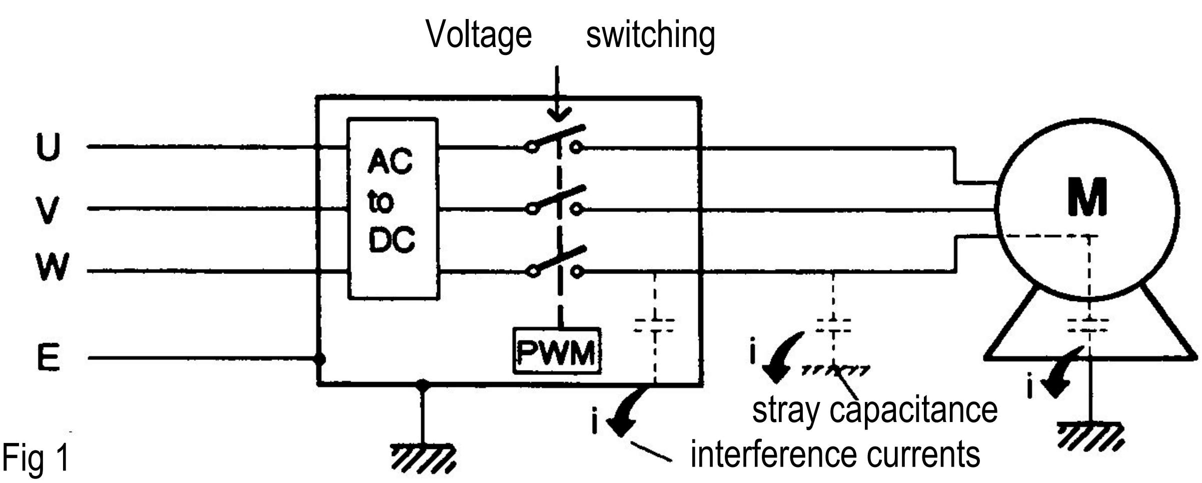


Fig 1

The aim of suppression would be to contain the PWM induced noise frequencies in and around the drive, using suppression components like filters. The higher EMI frequency must be prevented from radiating by using screened cable, good earthing and good bonding practice, and taking due care to prevent EMI coupling during installation. As there is more to the interference mechanism than just the drive itself, it may be clear that this requires a system solution.

Fig 1 shows that the coupling path for the EMI currents is through stray capacitance in the drive, cable and motor.

The drive and motor stray capacitances are fixed. The stray capacitance within the cable is a function of length. This means that longer cable runs provide a better coupling path for EMI and therefore higher EMI levels.

4. SOLVING THE PROBLEM

The classic EMI problem is shown in Figure 2. An EMI source interferes with the victim through a coupling medium.

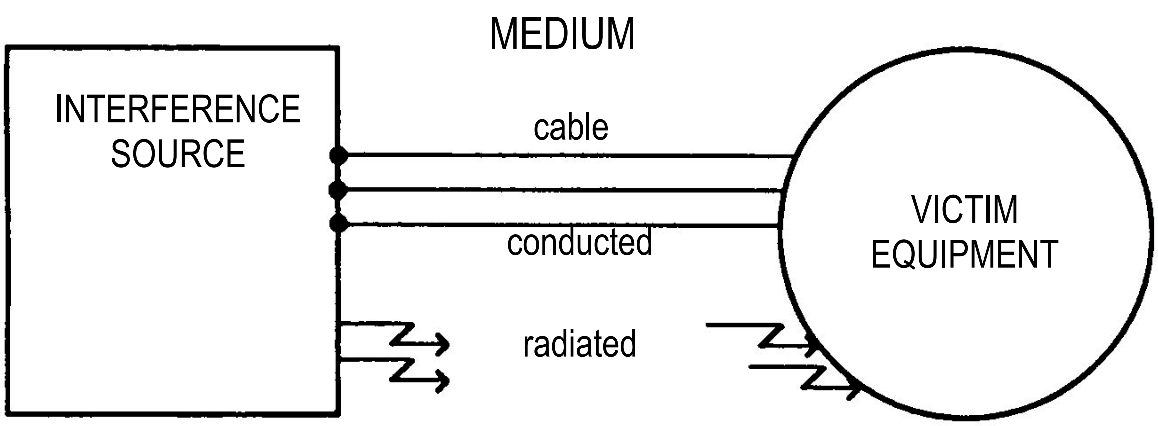


Fig 2

One can reduce the EMI source. In the case of drives, any attempt to reduce EMI at its source, the switching semiconductors, has a negative effect on the performance of the drive.

One can reduce the sensitivity of the victim to interference. Where possible, this may be the easiest solution; however, this is not recommended and often not possible.

As the only practical solution, one must alter the electrical coupling such that less EMI passes from source to victim. To change the coupling, the following points must be considered: **Filtering**, **Earthing** and **Screening**.

4.1 Filtering

The use of filters in suppressing EMI from drives is aimed at preventing the interference passing down powerlines and also aimed at changing impedance conditions so that EMI on the ground system is re-directed back to its source.

The filtering should be at the drive input and output. On the input side, the use of capacitors is effective in suppressing the EMI. Together with a choke, significant benefits can be seen when using such a filter.

On the drive output, however, the use of capacitors is severely restricted due to their effect on drive performance. Often the output side filter consists of a low value choke.

The positioning and installation of these devices is critical. Guidelines can be found in Part 1.

It must be quite clearly stated that a filter alone may not be the solution to the problem, because the EMI is being allowed to escape in other ways. In such a case, it is useless to replace the filter with another, higher attenuation filter, unless other measures are taken.

4.2 Earthing

It is definitively with earthing that most problems occur. There is a major difference between a safety earth and an EMI earth, especially at higher frequencies.

Drives are used in Class I installations where all accessible conducting parts are connected to an earth point, this being through 1.5 mm squared conductor for instance. Such a system is designed for safety purposes and as such is optimal. Interference currents, however, are at significantly higher frequencies, and such earthing systems are far form the optimal system for EMI.

What is needed for EMI is a low HF impedance earth system. The 1.5 mm square contacts present a relatively high impedance at HF, due to skin effect. This high impedance results in greater levels of radiation from the system (and increased sensitivity to external interference). There are several textbooks available on earthing and bonding for EMI suppression. Some guidelines are given in Part 1.

4.3 Screening

It is almost essential that the cable from drive to motor is screened. It is fortunate that, in many installations, the cables are screened or armoured, but more for mechanical than EMI purposes.

Adding a screen to the motor cable increases the stray capacitance of the cable to ground. As indicated previously, an increase in stray capacitance leads to higher conducted EMI.

Screened motor cables solve radiated EMI problems, however this may be at the cost of conducted EMI. Again the length of the cable is important.

This screen must be connected to both the motor and the drive and be continuous from drive to motor. It should be noted that the contact from the screen to drive, motor and other parts must be made by using as much contact area as possible. The screen must effectively become a continuation of the drive and motor housing. Connectors are available which allow such a system. The use of “Pig Tail” on the screens should be avoided.

5. SAFETY ASPECTS

Noise suppression of Motor and Drive systems involves consideration of the earthing system, and its effectiveness at high frequencies. It should not be forgotten that this is the safety system too and that safety must take priority over EMI.

The suppress the noise drives, the use of capacitance to earth is very effective. These capacitors conduct current from phase to earth; this can be in the order of hundreds of milliamperes. Appropriate safety measures should be taken to ensure that this potentially dangerous current flows to earth.

6. SELECTION OF THE CURRENT RATING OF A FILER

When selecting a power line filter for a drives application, there are three basic points to be considered:

- drive rating in kVA
- RMS load current
- ambient temperature

6.1 Drive rating

Drives are rated to match the horsepower ratings of motors. There is a standard range of ratings. Table 1 shows motor ratings up to 55 kW with the associated suggested filter rating.

Motor Rating		Typical Drive Rating	Typical Filter Rating*	
HP	kW	kVA	A, 415V, 3 Ø	A, 230V, 1 Ø
0.5	0.4	1.2	5 to 8	5 to 10
1.0	0.75	1.8	5 to 8	8 to 12
2.0	1.5	2.9	6 to 10	10 to 16
3.0	2.2	4.0	8 to 16	16 to 20
5.0	3.7	6.8	10 to 16	30
7.5	5.5	9.5	16 to 25	55
10	7.5	12.2	16 to 25	55
15	11	20	36	
20	15	26	50	
25	18.5	31	80 to 100	
30	22	37	80 to 100	
40	30	50	80 to 110	
50	37	60	110	
60	45	75	180	
75	55	85	180	
100	75	110	280	
120	90	135	280	

* The exact value depends upon the drive efficiency and the application type (RMS value).

6.2 RMS current

Filter current ratings, for instance 50A, is for continuous operation at 50A. If the load, for example a lift, does not draw a continuous current, then it may be possible to exceed the 50A rating.

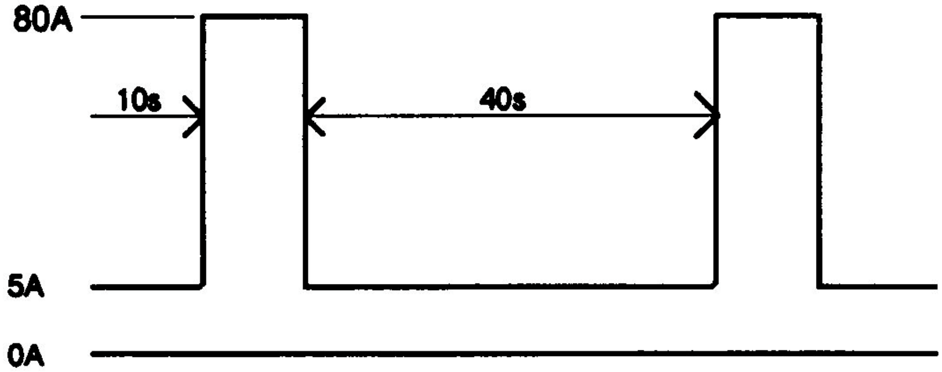


Fig 3

Consider the current waveform in Figure 3. A continuous load of 5A is drawn by the load. In a 50 second period, there is a 10 second period where the load rises to 80A. This could be in a lift application, for instance. The rms current is

$$I_{rms} = 5A + 80A$$

$$I_{rms} = 5A + 80\sqrt{\frac{10}{50}}\,A$$

$$= 5A + 35.8A$$

$$= 40.8A \text{ rms}$$

Provided that the duty ratio of 10 seconds in 50 seconds does not reduce, then a filter rated at 50A would be suitable for this application. Had we used peak currents only, we would have chosen a filter rated greater than 85A.

In the above example, if the duty cycle was 10 seconds load in every 30 seconds, we would have had:

$$I_{rms} = 5A + 80\sqrt{\frac{10}{35}}\,A$$

$$= 51.2A \text{ rms}$$

Here, a 50A filter would be insufficient.

6.3 Derating for temperature

Powerline filters are rated at 40 degree C ambient. In drives applications, however, there are ambient temperatures in excess of this. Where the ambient temperature exceeds 40 degrees C, the rms filter current must be reduced. The derating formula is

$$I = Inom \sqrt{(85\text{-}Tab)/45}$$

In a 60 degrees C ambient, the 50A filter which we selected above can be used for:

$$I = 50 \sqrt{\frac{85-60}{45}} \text{ A}$$

$$= 37.3\text{A}$$

This is unfortunately less than the 40.8A rms which we calculated. In this case, the next largest filter would have to be selected, i.e. 80A at 60 degrees C and:

$$I = 80 \sqrt{\frac{85-60}{45}} \text{ A}$$

$$= 59.7\text{A at 60 degrees C}$$

7. MOTOR RELIABILITY

It was mentioned earlier that the use of capacitors and chokes on the drive output can cause problems for the semiconductors. There are other problems here associated with capacitance and inductance in the cable. This may causes ringing on the drive output which creates excessive overvoltage when reaching the motor, see Figures 4 and 5 (next page).

The peak voltages, although insufficient to break down winding insulation, can cause heating in imperfections in the insulation. This leads to hot spots within the motor insulation and may eventually lead to breakdown in the windings.

It may be necessary to control the effect on the motor voltage of adding suppression devices. In some cases, the length of cable from drive to motor may have to be restricted in order to reduce stray capacitances and inductances.

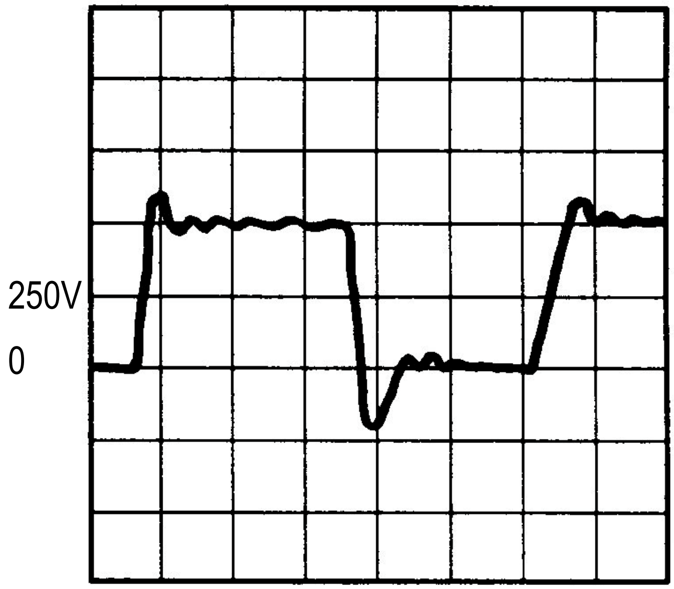


Fig 4 Output from drive

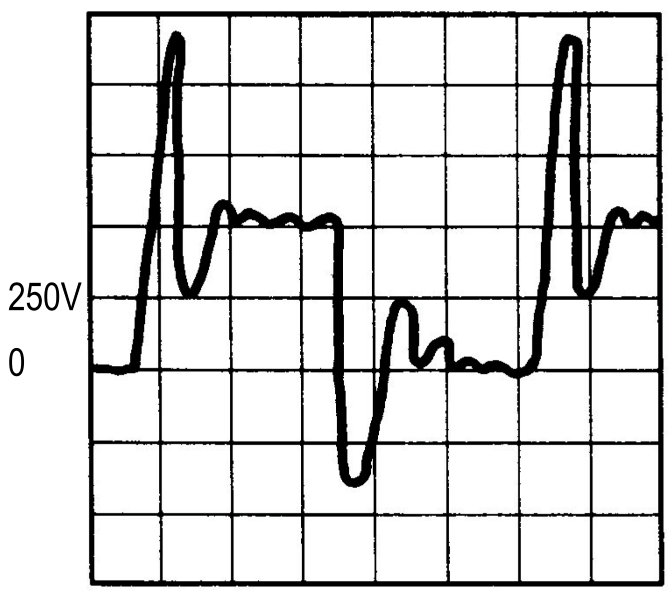


Fig 5 Motor input (100m long cable, 7kHz switching frequ.)

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