Filtering Noise

Chapter Objectives

This chapter describes how low-pass filters and ferrite sleeves can reduce electrical noise coupling. This chapter covers the following topics:

- Understanding the filtering concept
- Filter performance
- Ultrasonic transducers
- AC line filters

Understanding the Filtering Concept

If sources and victims are connected by wiring, you can prevent noise coupling by filtering. Low-pass filters attenuate high frequency noise without affecting the low frequency signals.

Commercial AC Line Filters for Low Voltage Circuits

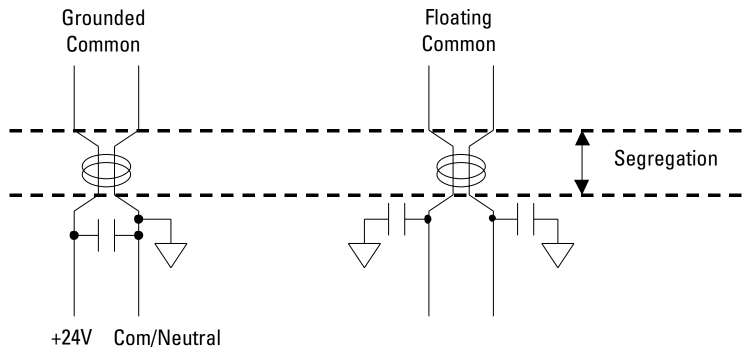
Provided that motor cable lengths are short, less than 20 m (60 ft), commercial AC line filters work well in low voltage circuits. Two-stage types are preferred.

If motor cable lengths are long, the natural ringing frequency is typically at too low a frequency (below 300k Hz) to be attenuated by commercial AC line filters. To determine if your cables are long, refer to the section *Installing Long Motor Cables* in *Appendix A*.

General Purpose 0-24V ac/dc Filters

The filter diagram shown below forms a classic LC low-pass filter.

Figure 5.1
Filter applied to 24V dc power circuit



IMPORTANT	The effectiveness of the LC low-pass filter depends on a perfect bond between the DIN rail and the ground plane panel.

Figure 5.2
Universal 0-24V ac/dc grounded common filter

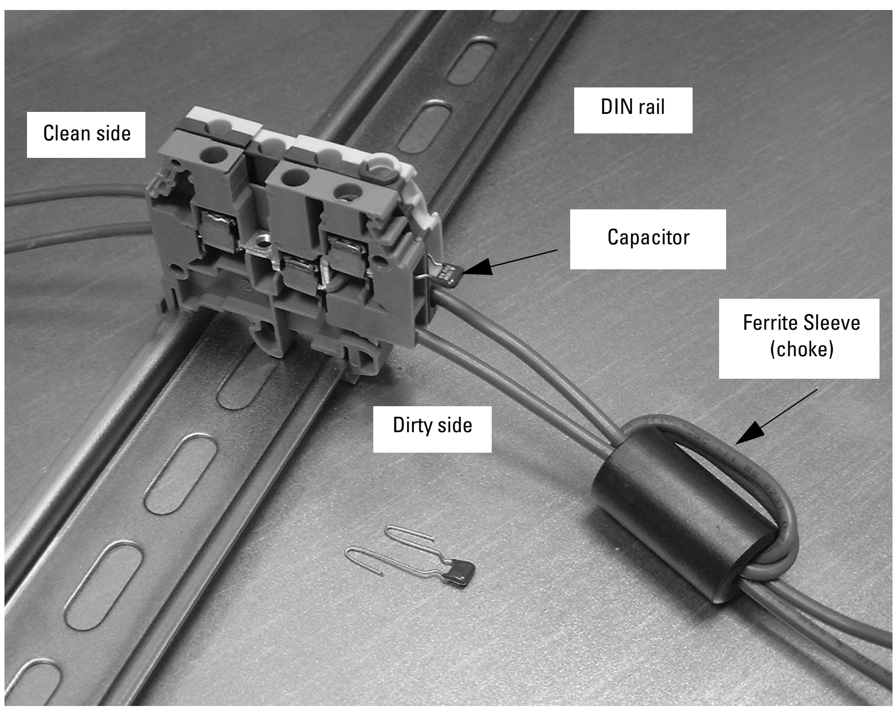
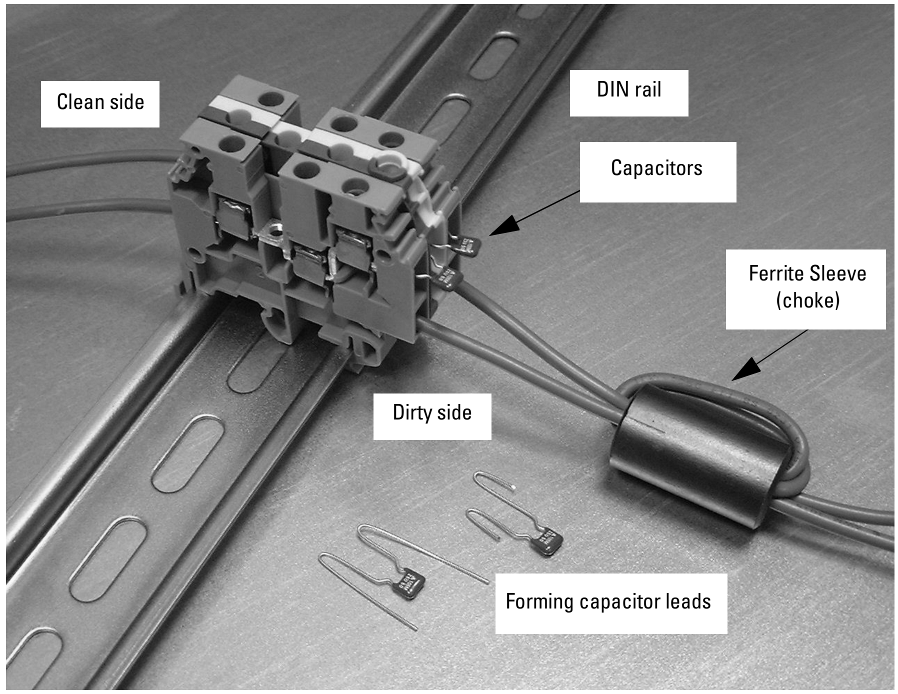


Figure 5.3
Floating-Common filter



The table below lists the part description and part numbers for the filters shown in Figure 5.2 and Figure 5.3.

Part Description	RS Components Part Number	Newark Part Number
Ground Terminal (1 in, 2 out type)	225-4372	N/A
Insulated Terminal (1 in, 2 out type)	426-193	N/A
1 μF, 50V Ceramic Capacitor[1]	211-5558	29F025
Small Ferrite Sleeve[2]	239-056[3]	91F6484

[1] Capacitor value is not critical, but it must be a ceramic type.

[2] The ferrite specification is not critical, but choose a low frequency type if possible.

[3] Alternative ferrite sleeve part numbers: Palomar (FB-102-43) or Schafner (2644665702)

Note: For more information regarding part vendors refer to *Appendix B*.

Filter Performance

The theoretical attenuation of one stage and two stage filters is shown in the table below.

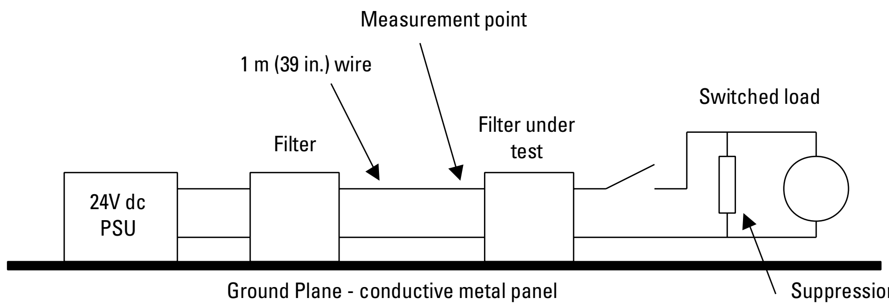
With this filter:	Attenuation @ 1M Hz is:
1 stage (2.8k Hz)	55 dB
2 stage (1.2k Hz	110 dB

Performance Test Set-up

The filter performance test included the following components:

- 24V dc power supply with grounded common filter
- Filter mounted to DIN rail
- Relay coil to simulate an inductive load
- 100M Hz sampling digital storage oscilloscope
- Test components mounted on a large zinc plated steel panel

Figure 5.4
Filter test block diagram



Test Results

This test condition:	With No filter:	With Capacitor only:	With Capacitor and ferrite sleeve:
No Suppression	200V pk	5.5V pk	674mV pk
R/C Across coil 100R/0.1uF	5.5V pk	932mV pk	168mV pk
R/C Across switch 100R/0.1uF	2.5V pk	103mV pk	70mV pk
Transorb Across coil	14.9V pk	1.8V pk	658mV pk
Transorb Across switch	8.1V pk	1.4V pk	1.2V pk
Diode	12V pk	63mV pk	63mV pk

Note: Voltages were measured between the measurement point and the ground plane (refer to Figure 5.4 for exact location.

Ultrasonic Transducers

Ultrasonic transducers often induce high noise levels onto their DC supply and signal lines. To reduce noise using ultrasonic transducers:

1. Mount two DC filters close to the device with ferrite sleeves between the capacitors and the sensor.
2. Feed the DC power supply through one sleeve.
3. Bring out the analog signal via the other sleeve.

Note: Use shielded cable for the analog signal.

The filter ground should be close coupled to the machine metalwork close to the sensor.

Xenon Flashing Beacons (strobe lights)

Strobe lights can generate high voltage transients on their 24V dc supply lines. To reduce this source of noise, try using one of these two alternatives.

- Mount a DC filter close to the lamp (ferrite sleeve on the lamp side) with its common attached to chassis ground.
- Use shielded cable between lamp and control panel, with DC filter at the point where the cable leaves the panel.

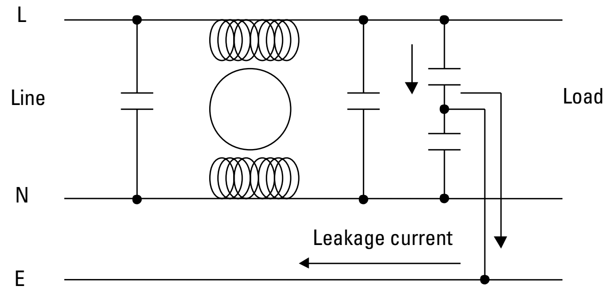
AC Line Filters

AC line filters contain capacitors connected between phase and the filter chassis. Line voltage is with respect to ground. The capacitor allows a small but potentially dangerous amount of current to flow to ground.

ATTENTION

To avoid personal injury and/or damage to equipment, ensure AC line filter capacitors are properly connected to safety (PE) ground.

Figure 5.5
Line filter earth leakage path



Three phase filters are theoretically balanced so the net ground current should be zero. However, a failure of any one capacitor or severe unbalance would cause ground current to flow and trip a circuit breaker.

Earth Leakage/Ground Fault

Earth Leakage Circuit Breakers (ELCB) and Ground Fault Interrupters (GFI) are typical European and US terms for the same device.

The ground/earth current may cause nuisance tripping of Earth Leakage Breakers. Uprated units may help in some cases.

Three phase filters, being balanced, are much less likely to give problems than single phase types.

Contact Suppression

Chapter Objectives

This chapter describes how contact suppressors for solenoids, relays, and various other switches can reduce electrical noise. This chapter covers the following topics:

- Understanding contact suppression for AC circuits
- Understanding contact suppression for 24V dc circuits
- Contact suppression effects

Understanding Contact Suppression for AC Circuits

The one potential noise source that the you can reduce directly is a contact switched load. Even circuits feeding resistive loads will produce significant switching noise. This is because the wiring both upstream and downstream of the contact is inductive. Thus, any switch contact will benefit from suppression.

IMPORTANT All switched, inductive loads in the system must be suppressed. This is standard practice in any PLC based control system.

Examples of AC devices requiring contact suppression include:

- Contactor controlled motors
- Solenoid coils
- Contactor coils
- Relay coils
- Transformer primaries
- Transformer driven indicator lamps
- Fluorescent cabinet lights (also require line filters close to the lamp)
- Line filters (often present an inductive load)

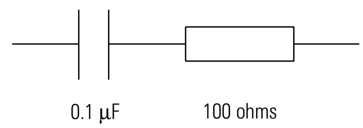
The only exception is a load driven by a Zero-Crossing Detector circuit such as Allen Bradley solid-state (Triac) output modules. Zero-crossing switches reduce noise generation virtually to zero. Preferred for frequent operation or close to clean zones.

Note: Sometimes the supply to a group of zero-crossing Triac outputs is switched by a mechanical contact for safety purposes. Suppress at the contact in this case.

Methods of AC Contact Suppression

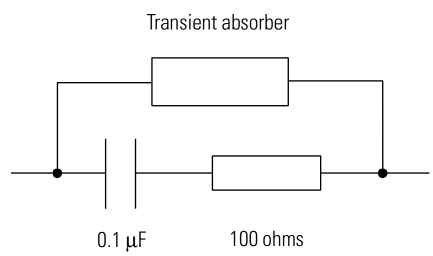
The typical RC suppressor circuit (shown below) consists of a 0.1 μF capacitor in series with a 100 ohm resistor. These components are readily available from many suppliers.

Figure 6.1
RC suppressor circuit



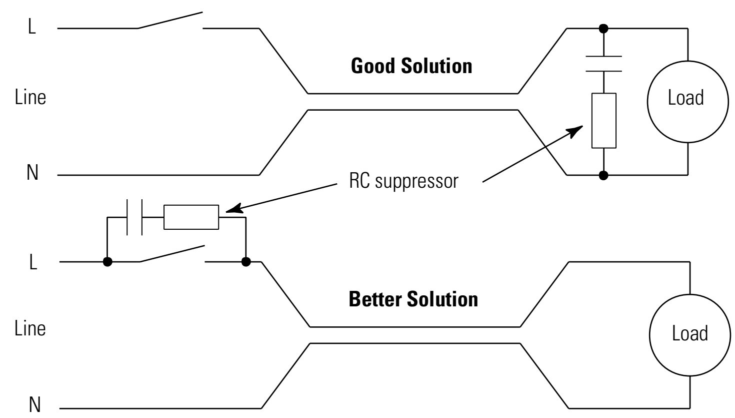
The typical RC plus transient absorber circuit (shown below) consists of the RC network shown in Figure 6.1 in parallel with a transient absorber. These are used in high current, high energy applications such as motor starters. A three-phase contactor requires three suppressors.

Figure 6.2
RC plus transient absorber circuit



The suppressor across the contact (as shown below, lower) reduces the noise from the wiring inductance as well as the coil inductance.

Figure 6.3
RC suppressor in circuit



Understanding Contact Suppression for 24V dc Circuits

Examples of DC devices requiring contact suppression include:

- Solenoid coils
- Contactor coils
- Relay coils

Methods of DC Contact Suppression

First choice for DC circuit suppression is a flywheel diode (shown in the figure below), but this does increase the release time which may not be acceptable in all applications. For the transient absorber method, refer to Figure 6.5.

Figure 6.4
Flywheel diode

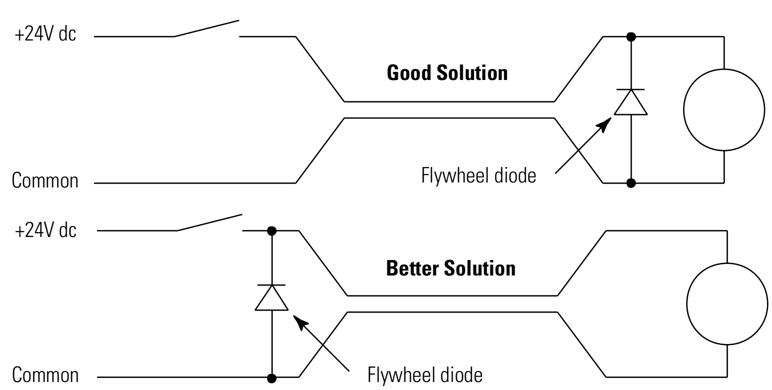
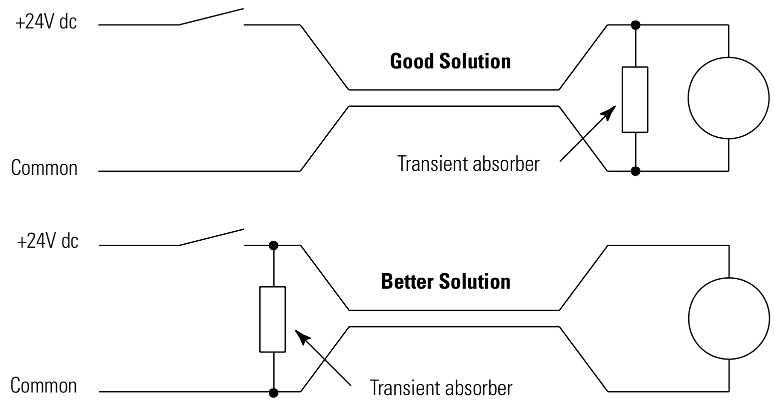


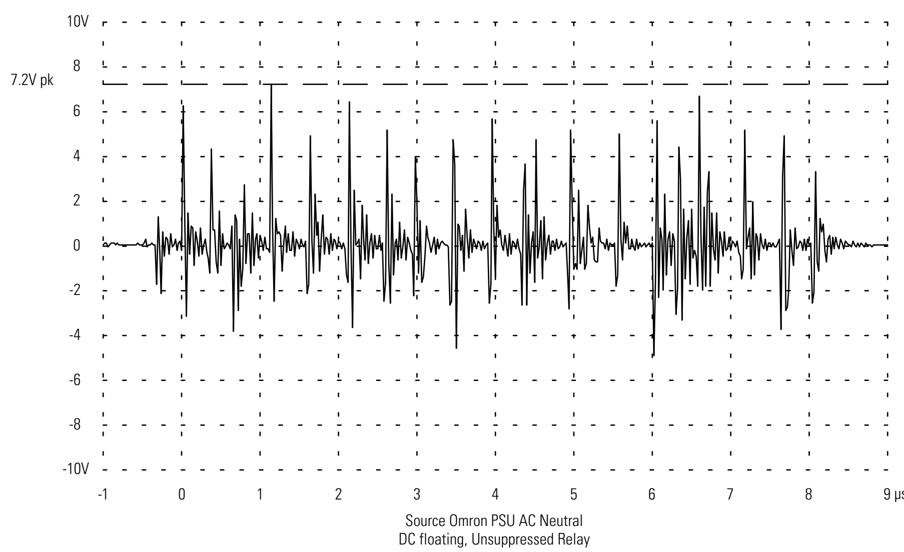
Figure 6.5
Transient absorber



Contact Suppression Effects

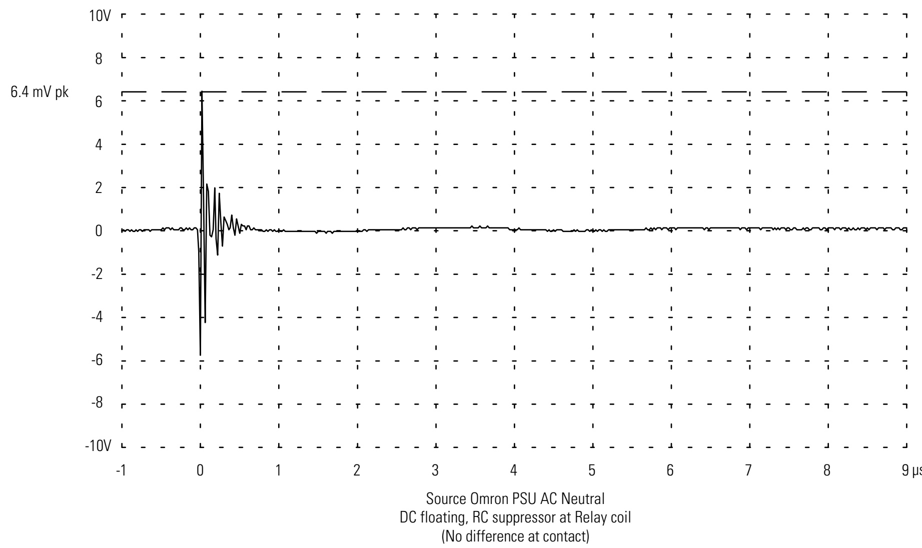
The waveform below displays 7.2V peaks across the AC terminals of a +24V dc power supply. Noise is due to load on the DC circuit being switched.

Figure 6.6
Unsuppressed inductive load on the DC circuit



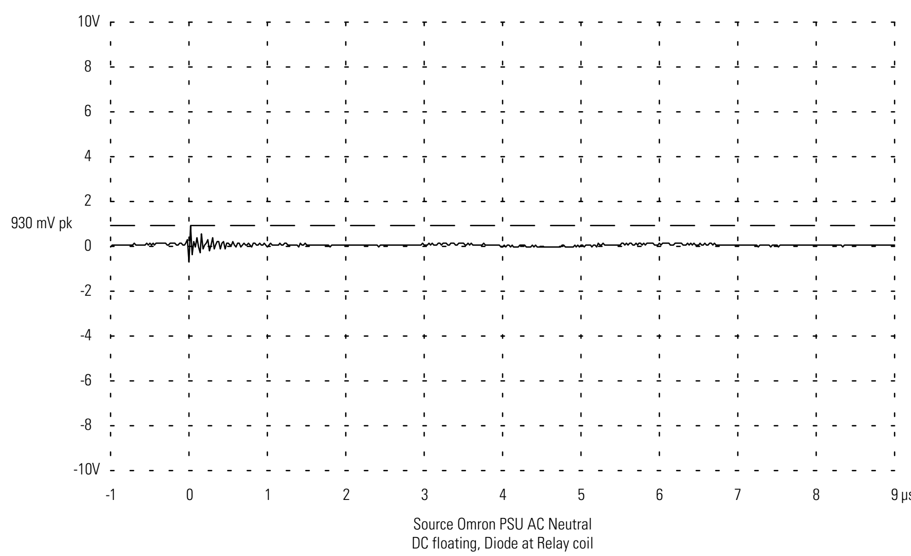
The waveform below displays the effects of an RC suppressor added across the coil on the noise shown in Figure 6.6. Peaks are reduced to 6.4V with significant reduction in duration. Refer to Figure 6.3 (upper) for example of RC suppressor across a coil.

Figure 6.7
Effects of RC suppressor mounted at the load



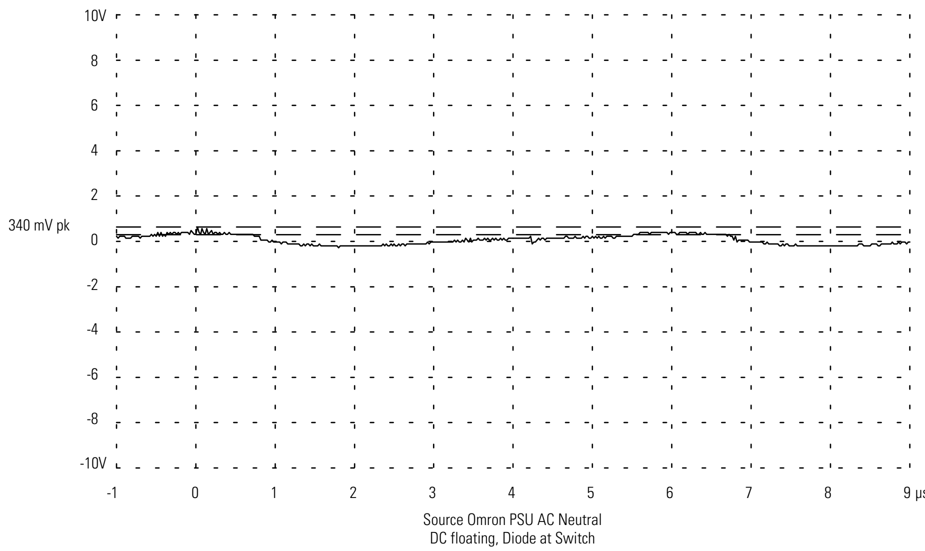
The waveform below displays the effects of a flywheel diode across the coil (refer to Figure 6.4, upper). The peak voltage is reduced to 0.9V.

Figure 6.8
Effects of Flywheel Diode at the load



The waveform below displays the effects of a flywheel diode across the switch (refer to Figure 6.4, lower). The peak voltage is reduced to 0.3V.

Figure 6.9
Effects of Flywheel Diode at the switch



The small additional noise reduction, when the suppressor is fitted across the switch, is because the wiring between switch and load is also inductive and creates the same inductive spike.

Power Distribution

Chapter Objectives

This chapter describes bonding, segregating, shielding, and filtering techniques when routing AC and DC power. This chapter covers the following topics:

- Understanding noise in power wiring
- Three-phase power supplies
- Single-phase power supplies
- 24V dc power supplies

Understanding Noise in Power Wiring

AC and DC power wiring usually extends to all parts of a system. Without precautions, noise coupled into any power wiring conductor is distributed throughout the entire system.

Three-Phase Power Supplies

To avoid noise related problems caused by three-phase power supplies, observe the following guidelines.

- Treat three-phase wiring as dirty.
- Include line filters for loads that create noise, such as PWM devices.

Line Filters

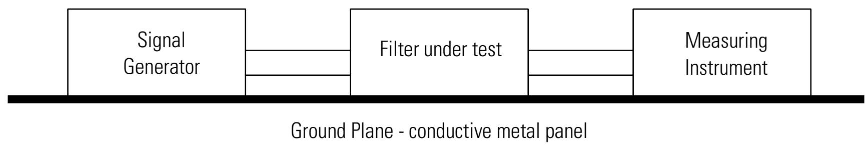
Observe the following guidelines when installing line filters.

- Install an individual filter as close as possible to each PWM load (this is the preferred configuration).
- Install the filter and PWM device on the same panel.
- Treat wiring between filter and drive as very-dirty (provide shielding as required).
- Segregate input and output wiring as far as possible.

IMPORTANT The effectiveness of the line filter depends solely on the HF bond between filter case and drive chassis.

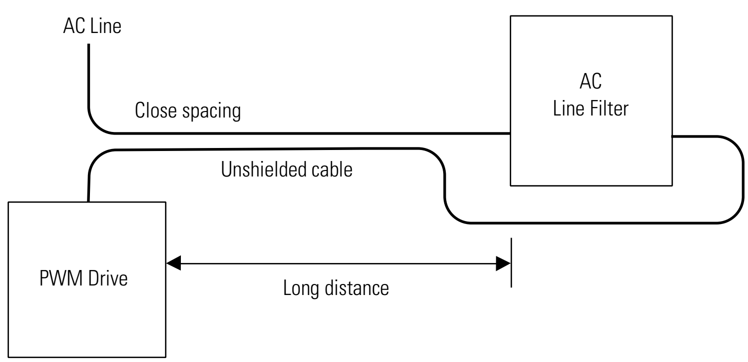
Commercial filters are tested, as shown in the figure below, with all devices properly bonded to a conductive metal ground plane. Proper bonding techniques are essential to achieve the published attenuation figures. Refer to the chapter *High Frequency (HF) Bonding* for more information on bonding.

Figure 7.1
Filter test set-up



In the example below, noise couples directly from the filter input wires to the filter output wires and bypasses the filter. You can avoid this common mistake by shielding and/or segregating the cables and reducing the cable length.

Figure 7.2
Improper line filter installation example

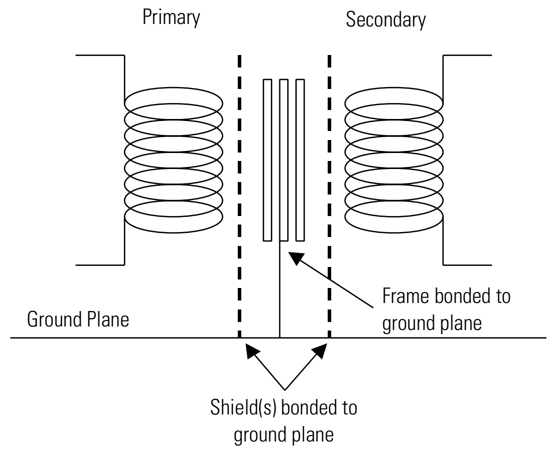


ATTENTION To avoid personal injury and/or damage to equipment, ensure AC line filter capacitors are properly connected to safety (PE) ground.

Transformers

An isolation transformer is frequently assumed to give good noise isolation. In fact, this only applies if the transformer is equipped with one or more electrostatic (ES) shields, as shown in the figure below.

Figure 7.3
Electrostatically shielded transformer



This technique is very effective, though generally EMC filters are required to meet European regulation standards. Observe the following guidelines when installing transformers.

- Install the transformer to the same panel as the rest of your system (or HF bond from panel-to-panel).
- Treat wiring between transformer and drive as very-dirty (provide shielding as required).
- Bond shield, if used, with braid directly to the panel. The transformer mounting bolts are useful for this purpose.
- Segregate input and output wiring as far as possible.

IMPORTANT The effectiveness of the transformer depends solely on the HF bond between shields and drive chassis.

Single Phase Power Supplies

To avoid noise related problems caused by single-phase power supplies, observe the following guidelines:

- Treat single-phase wiring as dirty.
- Include line filters for loads that create noise, such as PWM devices with DC switch-mode power supplies and fluorescent cabinet lights.
- Include line filters for potentially sensitive loads, such as PLC logic power.
- Mount the line filter as close to the load as possible.

24V dc Power Supplies

Switch-mode power supplies do not isolate noise and may generate common-mode noise on both AC and DC lines. Refer to the section *Switch-Mode DC Power Supplies* in *Appendix A* for more information.

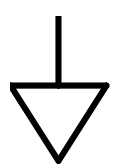
Linear power supplies normally generate very little noise, but AC line filters or DC output filters are required to attenuate incoming line noise to achieve a clean category.

To avoid noise related problems caused by 24V dc power supplies, observe the following guidelines.

- Connect the common through a ground terminal.
- Decouple the +24V dc line to the same ground terminal with a 1 μF, 50V ceramic capacitor to achieve the clean category.

The simplest method for making the ground connection is to use a ground terminal installed on the DIN rail fastened to a zinc plated panel. Refer to Figure 7.4 for an example of the symbol used in diagrams.

Figure 7.4
Ground Plane Symbol



24V dc Distribution

Route power wiring according to clean/dirty zones. Segregate the following load classifications:

- Clean loads that are potentially sensitive to noise and which do not create significant noise, e.g. controller logic supplies.
- Dirty loads that are insensitive to noise but may emit moderate levels of noise, e.g. relay circuits.

Note: Refer to the chapter *Segregating Sources and Victims* for a detailed listing of categories.

Note: Refer to the chapter *High Speed Registration Inputs* for special treatments of registration input devices.

24V dc PSU Zoning Methods

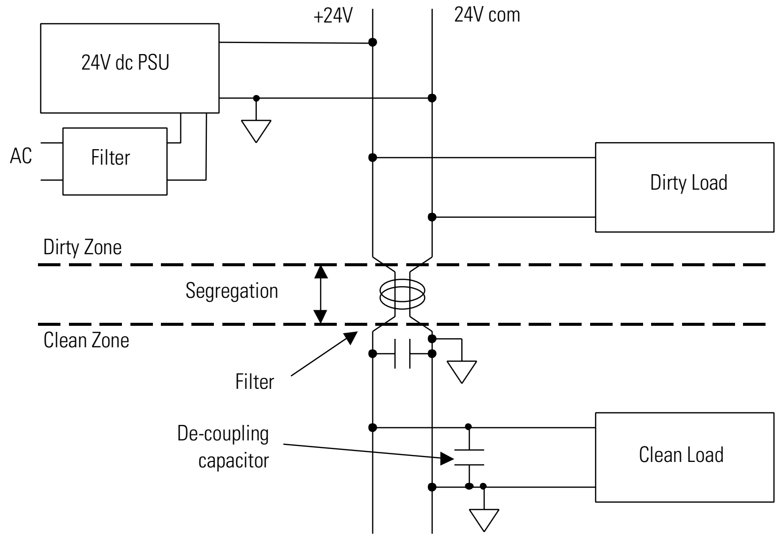
The following two methods of 24V dc power supply zoning are described in this chapter.

- Single 24 volt power supply with filtering between zones.
- Dual 24 volt power supplies.

Single 24V dc Switch-Mode PSU Zoning Example

In the figure below, a 24V dc supply is mounted in the dirty zone, because it may create noise. But, the noise is reduced by filtering before the output enters the clean zone.

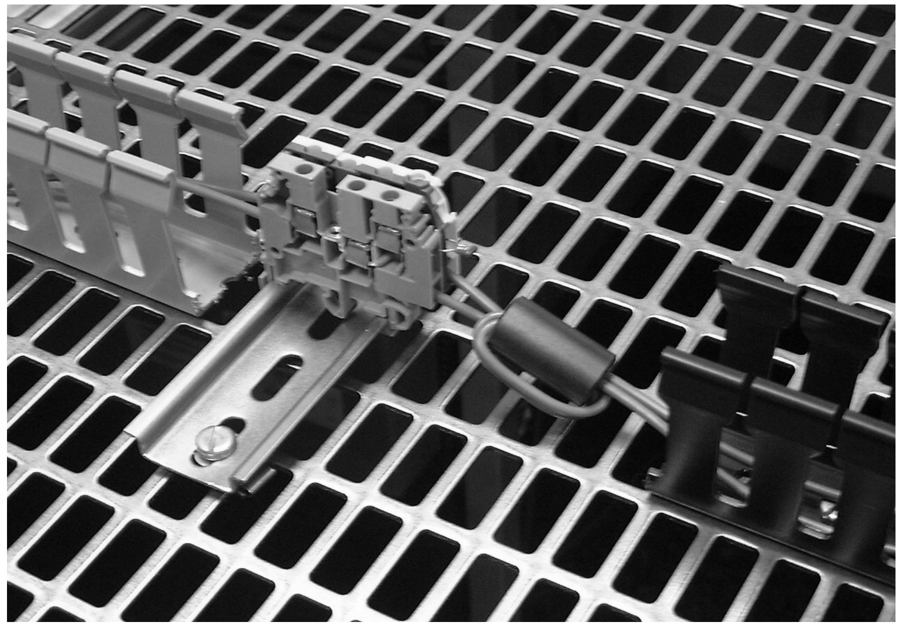
Figure 7.5
24V dc power distribution with single PSU



Grounded, de-coupling capacitors are used at each clean load (refer to the chapter *High Frequency (HF) Bonding* for details). Provided the system is correctly bonded, the multiple common/ground connections are not a problem. The copper becomes a backup conductor. No segregation or filtering is necessary for the load in the dirty zone.

In the figure below, a filter is pictured between the clean zone (grey wireway) and the dirty zone (black wireway). Refer to the chapter *Filtering Noise* for details regarding filters.

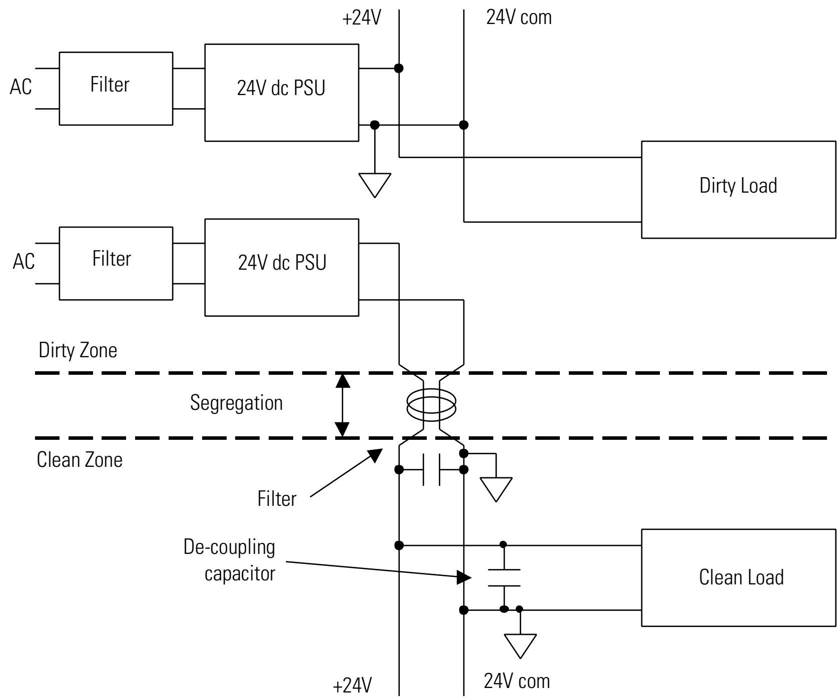
Figure 7.6
Filter between zones



Dual Switch-Mode 24V dc PSU Example

In the figure below, dirty and clean zone loads have dedicated power supplies. Segregation and filtering are used (as in Figure 7.5) to reduce the noise in the power supply for clean zone needs.

Figure 7.7
24V dc power distribution with dual PSU



Note: Clean PSU is mounted in the dirty zone because it typically generates noise in the switching process.

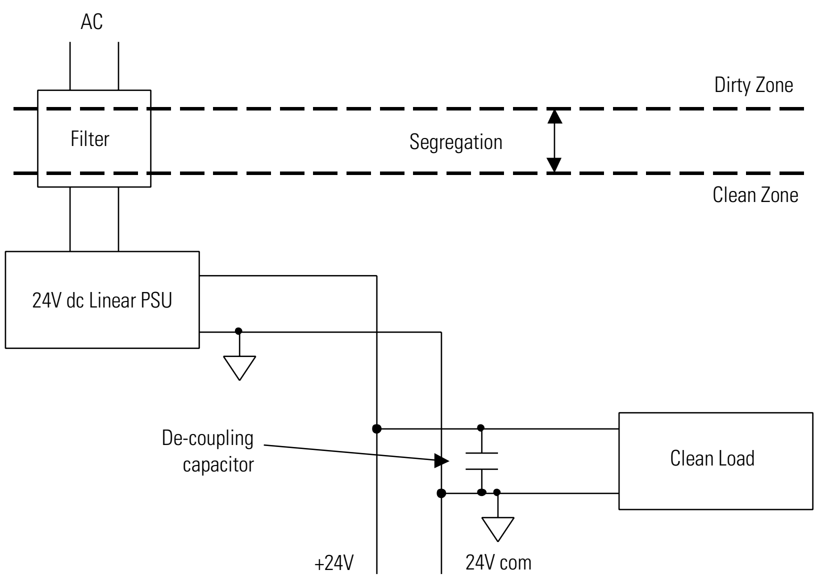
Linear PSU

The linear PSU does not generate noise on its AC terminals, as does a switch-mode supply, however, some noise reduction provisions are still recommended.

Linear PSU Mounted in Clean Zone

In the figure below, the linear power supply is mounted in the clean zone, but the AC line feeding it requires filtering. The AC line filter is positioned between zones and attenuates line noise which may otherwise be passed through to the DC circuit.

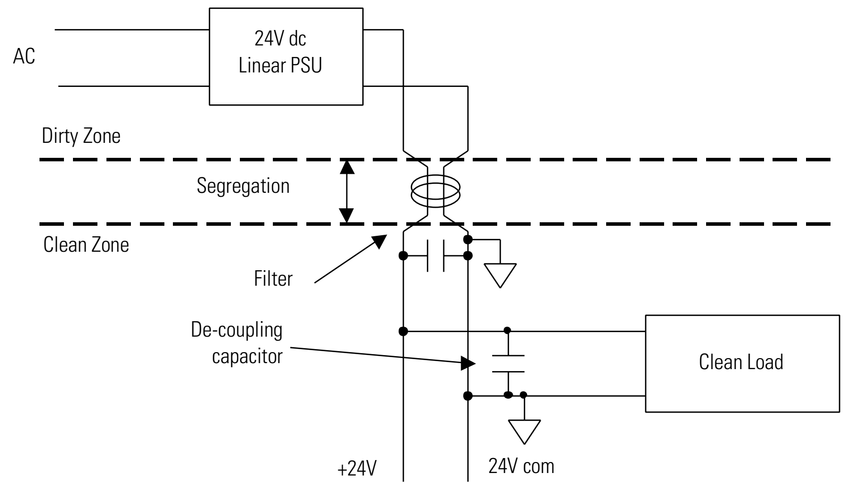
Figure 7.8
Linear PSU mounted in Clean Zone



Linear PSU Mounted in Dirty Zone

In the figure below no AC line filter is required because the linear PSU does not generate noise and the AC line noise is filtered by the DC filter.

Figure 7.9
PSU mounted in Dirty Zone



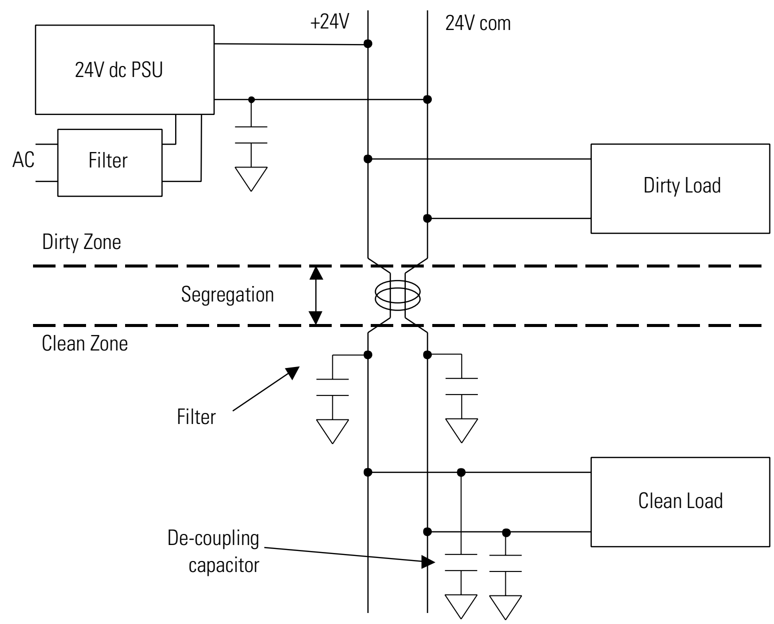
Special Applications for 24V dc PSUs

This section contains information considered application specific and does not apply to all installations.

Floating Requirement

If it is necessary to maintain a floating common, a modified filter may be used to ground the common at HF frequencies only. Refer to the chapter *Filtering Noise* for details regarding filters.

Figure 7.10
Floating Common

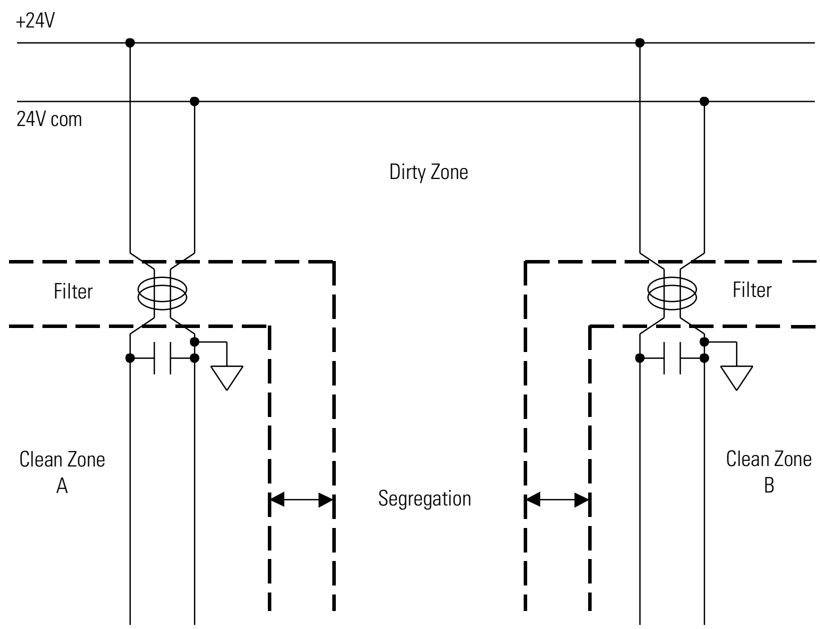


Segregation and Filtering Variations

Once the principles of segregation and filtering are understood it is possible to vary the strategy to suit special requirements.

For example, the clean zone does not have to be a single entity. As shown in the figure below, you can create separate local clean zones. Refer to the chapter *Segregating Sources and Victims* for guidelines on crossing zones.

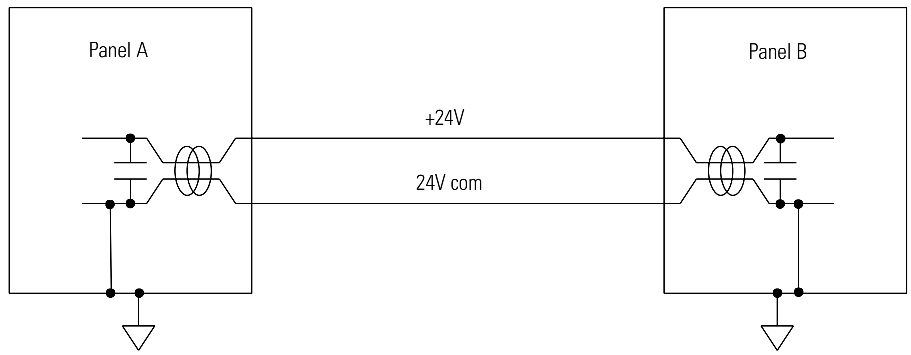
Figure 7.11
Separate Clean Zones



Long Power Cable Runs

The 24V dc lines entering or leaving panels that cannot be bonded together by flat strips (no longer than 10 times the width) should have filters at the point of entry.

Figure 7.12
Long cable runs between panels



Note: If heavy circulating currents at power frequency are likely, the floating filter technique or separate, local PSU's, may be safer to use.