

(1.1) Glossary

1. Rated Voltage

The voltage when EMI filter is working under the appointed frequency.(250V, 50Hz in China; 230V, 50Hz in Europe, 115V, 60Hz in the United States)

2. Rated Current

The maximal allowable continuous current (I_{max}) when EMI filter is working under rated voltage and appointed environment temperature (it's 40°C if not appointed specially). The allowable I_{max} in the specific temperature is a function and can be got by the formula like

this: $I_{op} = I_{n} \sqrt{(85 - \theta) / 45}$

3. Test Voltage

The voltage applied between the appointed terminals in the specific time. There are two kinds of test voltage. One is line-to-line test voltage that is applied between two terminals of the EMI filter. Another is line-to-earth test voltage that is applied between one terminal and the case or specific terminal.

4. Leakage Current

A current which passes through phase line or neutral line to the ground at the rated voltage, Directly related to the capacitance to ground in the filter. calculated by the formula:

$$I_{LC} = 2 \times \pi \times F \times C \times V$$

F= Line frequency

C= Capacitance

V= L-G voltage

5. Insertion Loss

It's a general measure of a filter's performance. It's the ability of EMI filter to attenuate interference signal. It is the ratio of the signal voltage between the terminals before and after the insertion of EMI filter. When the source impedance equals to the load impedance of 50Ω , insertion loss can be expressed in terms of the voltages like:

$$IL = 20 \lg(E_0/E_1)$$

IL-Insertion Loss(dB)

E0-The voltage between terminals before the insertion of EMI filter (V)

E1-The voltage between terminals after the insertion of EMI filter (V)

6. IEC Climatic Category

It means the EMI filter's working Climatic Category. According to the IEC, the letters of the climatic classification are coded as follows: XX/XXX/XX

First letter: lowest working temperature

Middle letter: highest working temperature

Last letter: the testing days for the type test

7. Insulation Resistance

It's the resistance between line or neutral line to the ground. Generally, we use special insulation resistance meter to test it.

8. ElectroMagnetic Interference (EMI)

This term is often used interchangeably with RFI (radio-frequency-interference). Technically, EMI refers to the type of energy (electromagnetic), while RFI refers to the frequency range of the noise frequency). Our filters are used to eliminate the unwanted signals of both EMI and RFI.

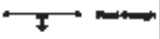
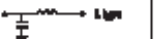




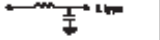

9. FREQUENCY RANGE

Generally, the band of frequencies of electromagnetic energy expressed in Hz (cycles per second), kHz (thousand of cycles per second). The typical frequency range of power line filter's attenuation is 150kHz to 30MHz (above 30 MHz noise mainly is radiated).

10. Impedance mismatch

A filter works best when its impedance in the RFI frequency range on the line and load side is greatly different from the impedance on the line and load circuits to to which it is connected. This is called **impedance mismatch**.

Table 1 Properly select the input and output impedance of EMI filter in the standard situation

		Load Impedance (Z _L)	
		High	Low
Filter Impedance (Z _F)	High	 Pass-through	 L type
	Low	 π type	 Shunt L type
Filter Impedance (Z _F)	High	 π type	 Shunt L type
	Low	 L type	 T type
		High	Low
		Pass-through	Shunt L type

11. OPERATING FREQUENCY

The nominal frequency of the power line filters are 50/60 Hz (50Hz for China and Europe, 60Hz for North America (60 Hz). However, operation at DC or 400 Hz does not impact the effectiveness of the filter.

(1.2) The Function of Power Line Filter

1. What is Radio Frequency Interference (RFI)?

RFI is unwanted electromagnetic energy in the frequency range generally used for radio communications. For conducted phenomena, the frequency ranges of interest are 10kHz. For radiated phenomena, it's 30MHz to 1Ghz.

2. Why Be Concerned with RFI?

People must concern themselves with RFI for two reasons: (1) Their equipment must operate properly in the application environment, however it always in the presence of significant levels of RFI, and (2) Their equipment must not emit RFI to make sure not to interfere with RF communications which often vital to health and safety. The necessity for reliable RF communications has given rise to legal regulations ensuring RFI control for electronic equipment.

3. What are the Modes of Propagation of RFI?

RFI is spreaded via radiation (electromagnetic waves in free space) and by conduction over signal lines and AC power systems.

Radiated - One of the most significant contributors to radiated RFI from electronic equipment is the AC power cord. The power cord is often an efficient antenna since its length approaches a quarter wave length for the RFI frequencies present in digital equipment and switching power supplies.

Conducted - RFI is conducted over the AC power system in two modes. Common mode (asymmetrical) RFI is present on both the line and neutral current paths with reference to the ground or earth path. Differential mode (symmetrical) RFI is present as a voltage between the line and neutral leads.

4. What is a Power Line Interference Filter?

With the fast development of today's world, more electrical energy is being generated at increasing levels of power, and more and more low power energy is being used for the transmission and processing of data. The result is caused increasing noise or interference, which can disrupt and even destroy your electronic devices.

A power line interference filter is a main tool to control conducted RFI both into the equipment (potential equipment malfunction) and out of the equipment (potential interference to other system Elements or RF communication). By controlling the RFI conducted onto the power cord, a power line filter also contributes significantly to the control of radiated RFI.

A power line filter is a multiple-port network of passive components arranged as a dual low-pass filter; one network for common mode attenuation, another network for differential mode attenuation. The network provides attenuation of RF energy in the stop band of the filter (typically above 10kHz), while passing the power current (50-60Hz) with little or no attenuation.

5. How Does a Power Line Interference Filter Work?

As passive, bilateral networks, Power line interference filters have complex transfer characteristics, which are extremely dependent upon source and load impedance. The magnitude of this transfer characteristic describes the attenuation performance of the filter. In the power line environment, however, the source and load impedance's are not defined. Therefore the industry has standardized practices to verify filter uniformity through measurement of attenuation with 50ohm resistive source and load terminations. This measurement is defined to be the Insertion Loss (I.L.) of the filter:

$$I.L. = 10 \log * (P(l)(Ref)/P(l))$$

P(l)(Ref) is the power transferred from the source to the load without the filter;

P(l) is the power transferred when a filter is inserted between the source and load.

The Insertion Loss may also be expressed in terms of voltage or current ratios as shown:

$$I.L. = 20 \log *(V(l)(Ref)/V(l)) \quad I.L. = 20 \log *(I(l)(Ref)/I(l))$$

V(l)(Ref) and I(l)(Ref) are measured without a filter ;

V(l) and I(l) are measured with a filter.

It is important to note that Insertion Loss does NOT describe the RFI attenuation provided by a filter in the power line environment. In the power line environment the relative magnitudes of the source and load impedances must be estimated and the appropriate filter configuration selected such that the greatest possible impedance mismatch occurs at each termination. This dependence of filter performance on terminating impedances is the basis for the concept of "mismatching networks".

6. How to Perform Conducted Tests?

Conducted testing requires a quiet RF environment (usually a shielded enclosure) with a line impedance stabilization network, and an RF voltage measurement instrument such as a tuned receiver or spectrum analyzer. The RF ambient of the test environment should be at least 20dB below the desired compliance limit to get accurate results. The line impedance stabilization network (LISN) is required to establish a defined source impedance for the power line input. This is an important part of the test procedure, since this impedance directly affects the measured emission levels. The correct bandwidth for the measurement receiver is a critical test parameter as well.

(1.3) Parameters and Measure for Power Line Filter

1. What are the Important Specification of EMI Filter?

It is very important that supplier and customer use the same techniques to verify Electrical specifications. In this way, we can assure an uninterrupted flow of quality components.

Three specifications that must be clearly understood are Hipot Testing, Leakage Current, and Insertion Loss.

2. How is Insertion Loss Measured?

The most popular set-up is to make the source and load impedances each 50 ohms resistive. The most important aspect of insertion loss measurement is consistency. The standard method of insertion loss measurement is given below.

Use a spectrum analyzer or tuned receiver and a tracking generator to test. First establish a zero dB reference without the filter. Then insert the filter and record the attenuation provided over the desired frequency range. For a power line filter we are interested in signal attenuation in two different modes:

Common Mode (CM) - signals present on both line (L)-to –earth (E) and neutral line (N)-to-earth (E).

Differential Mode (DM) - signals present on line (L) to neutral line (N).

Since EMI filter can control both interference signal of CM and DM, it has CM and DM

insertion losses.

When CM insertion loss is measured, one method is that terminals of L and N are connected together, the signal from the source is applied between these terminals and the ground, then the attenuated signal is measured by a receiver, shown in Fig.6. When tested DM insertion loss, an unbalance-balance converter is inserted in front of the EMI filter, and a balance-unbalance converter is inserted in rear of the EMI filter, shown in Fig.7.

The insertion loss data shown in this manual is measured according to the above mentioned.

It would be emphasized that the EMI filter in your system controls the interference signal to the level that is not equal to the insertion loss data shown in this manual, sometimes it is much difference. This is because the data shown in this manual is measured when source impedance is equal to load impedance of 50Ω. But in practice they are not equal to 50Ω in your system. This is the essential reason that causes the difference.

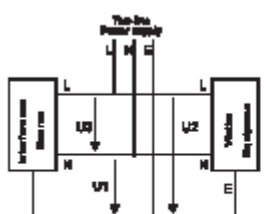


Fig.6 CM insertion loss test circuit

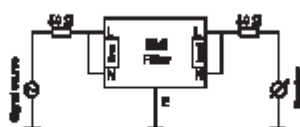


Fig.7 DM insertion loss test circuit

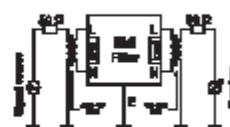


Fig.8 DM insertion loss test circuit

3. What Can Insertion Loss Data be Used For?

Standardized insertion loss data will not accurately get a filter's performance in your equipment. But it can be used as an important tool for verifying product consistency through incoming inspection.

The criterion for acceptance is that the measured insertion loss must either meet or exceed the published data in this catalog when tested in the standardized manner. That is to say, "typical" insertion loss data is not meaningful. The data to which you test should be minimum values. All the insertion loss data published in this catalog are guaranteed minimums, and as such can be tested for a positive indication of component consistency.

4. Hipot Testing

The term "hipot" means "high potential." Hipot testing stresses capacitors of a filter and the insulation assembly by applying a voltage much higher than is usually experienced in normal operation. The purpose of hipot specifications is to assure safety and reliability. All the major safety agencies require hipot testing for qualification of power line filters, and also require that each production unit undergo hipot testing to verify the integrity of the line-to-ground components and insulation. Each filter is hipot tested twice; one is during assembly and another is after completion. Applying hipot testing as an incoming inspection procedure requires a thorough understanding of its uses and limitations.

Hipot test voltages are applied from each line (both lines tied together for VDE) to ground and from line-to-line. The line-to-ground voltages are always higher. Test voltages may

be specified as AC or DC, with the DC voltages at least 1.414 times the A C voltages. For incoming inspection testing, we recommend using the voltages given as "hipot rating" for each filter in the catalog.

According to the international Safety Standard, the procedure for test voltage is following:

- 1) Without the load on the output terminals.
- 2) Gradually applied the voltage to the appointed value in some rate.
- 3) Hold this voltage in the specific time. The EMI filter shall not be destroyed.

Something should be reminded:

- 1) THESE VOLTAGES CAN BE LETHAL - use the utmost safety precautions to protect the test operator.
- 2) Filter might be destroyed if this voltage between terminals is applied many times. This voltage has been applied into each AERODEV's EMI filter twice. According to China Communication Standard YD/T777-1999 terms 5.5 and some international safety requirements if the test voltage is checked and applied by users, at least 25% voltage value should be reduced.
- 3) Test voltage should be applied and gradually increased into the appointed value. It might destroy EMI filters if the voltage is applied suddenly.
- 4) For the type test, the test voltage is applied and kept for 60s, however, it is only 2-5s for the production line test.
- 5) For line-to-line hipot testing, most filters have a bleeder resistor (typical value 100kohms to 10Mohms) to discharge the line-to-line capacitors. Be sure to set the trip point of the hipot tester above the current level that will flow through the bleeder resistor: 10mA is usually a safe value.
- 6) Test voltage for 3 phases' EMI filter is applied the same as the above.

5. Understanding Leakage Current

Leakage current is an important specification of power line filters. Though it is not a function of the quality of the components, but it is a direct function of the line-to-ground capacitance value. The larger the capacitance, the lower the impedance to Common Mode currents, and the greater the Common Mode interference rejection. Hence, leakage current is a measure of filter performance--the higher the better.

The reason why safety agencies need to specify a maximum allowable leakage current is to limit the magnitude of expected ground return currents. The line-to-ground capacitors provide a path for 50/60Hz current to flow to the chassis. As long as the equipment is grounded, these currents will flow in the ground circuit and present no hazard. But we shall know, in the unlikely but always possible circumstance where the ground circuit is faulty, the earth connection may be established by the body of a person . If this should occur, the maximum leakage current specification limits the ground return current to a safe value, typically 0.5 to 5.0mA. The limits set by safety agencies are based on end user equipment specification, such as those given below.

Country	Standard	Limits for grounded equipment (level 1)
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USA	UL1950	3.5mA,120V.60Hz
Canada	C22.2 No.950	3.5mA,120V.60Hz
Europe	EN60950	3.5mA,250V.60Hz

EMI filter's leakage current is tested as the following:

- 1) Without load on the outlet. For safety, it is suggested to insert a isolation transformer between the power-line system and the tested filter.
- 2) The ampere-meter is connected between switch S and terminal E. A switch installed can connect with terminals L,N alternatively
- 3) Applied the rated voltage, as the switch S is connected with L or N alternatively, 2 numerical values can be obtained from the ampere-meter. Both values should be less than the appointed leakage current.



(1.4) Power Line Filter Selection and Notice

1. How to Select a Power Line Interference Filter?

Some users may think that the value of insertion loss is higher, the EMI filter is better and more stages of the filtering networks, the EMI filter is better. But in fact, this is not always true to select EMI filter. Otherwise, more stages of the filtering networks, the EMI filter becomes very heavy and expensive. The only way to select and qualify a power line interference filter is to test the unit in your equipment. As mentioned above, the performance is highly dependent on equipment load impedance. Filter performance cannot be derived from single impedance (50 ohm) insertion loss data. Performance is a complex function of filter element impedances and equipment impedances which vary in magnitude and phase over the frequency spectrum of interest. Filter selection testing should be performed in your equipment to your required level of performance for both conducted emission control (FCC, VDE) and susceptibility control.

2. Do All Filter Networks with the Same Circuit and Element Values Perform Identically?

All filter networks with the same circuit and element values do not perform identically. Element values are specified and measured at a single frequency (usually 1kHz). Filter performance is required over the entire frequency spectrum, not just at the frequency of component measurement. The type of component construction and method of incorporation into a filter are extremely important to filter performance.

3. Is Installation Important to Filter Performance?

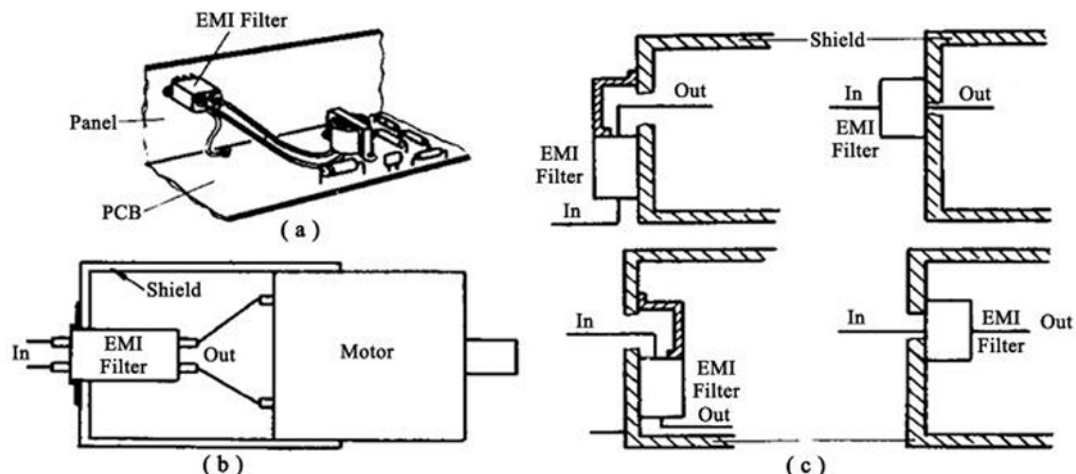
Mounting and wiring of the filter are critical influences on its performance. A power line filter is best installed at the power input point of your equipment. The filter is a barrier to high frequency signals. Its purpose must not be defeated by stray capacitance coupling the power input leads to the power output leads, or to any other conductors in the protected equipment.

When doing assembling, pay attention to below items.

- 1) Well connected with filter's housing and equipment's grounding side. Do not assemble it on insulated or spray-painted panel. It must be put on metal ones. Besides, it should be avoided to use too long grounding line, which will decrease common mode performance a lot.
- 2) While packing equipment's cable, do not pack "In" and "Out" cable together, which will cause much coupling between filter's "In" and "Out" terminal and destroy the restraining performance of EMI Filter.
- 3) Do not assemble EMI filter into the internal side of equipment's shielding, which will destroy the restraining performance of EMI Filter.
- 4) Using the current shielding of equipment, try to well isolate the "In" and "Out" terminal to control the coupling into lowest level.

Normally the case of the filter is bolted to the framework or chassis of the electronic equipment it protects. The line side leads should be kept short and well separated from the load side leads. The ideal isolation system is a bulkhead-mounted filter incorporating a line cord connector.

See attached recommended installation of EMI filter:



Recommended Installation of EMI Filter

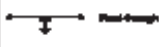
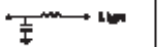


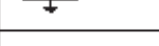



(a) Fixed on panel of equipment;

(b) Well control electromagnetic coupling between "In" and "Out" terminal of filter;

(c) Using shield of equipment to well control electromagnetic coupling between "In" and "Out" terminal of filter.

4. Recommended Impedance mismatch

Table 1 Properly select the input and output impedance of EMI filter in the considered situation

		Load impedance (Z _L)	
		High	Low
Source impedance (Z _S)	High	 Parallel-Resonant	 L-type
	Low	 T-type	 Double-L type
Low	High	 Parallel-Resonant	 L-type
	Low	 T-type	 Double-L type

(1.5) Safety Approval for Power Line Filter

1. Why Be Concerned With Safety Agency Requirements?

All components in the AC power system, including power line filters, must be safe from potential fire and shock hazard. The standards set by the various safety agencies, such as UL, CSA and VDE provide guidelines to assist the designer in specifying safe and reliable components. Components which carry the compliance symbols from these agencies have been designed and manufactured to comply with these standards.

2. International standard for EMI filter

- 1) IEC939-1: Complete filter units for radio interference suppression.
Part 1: Generic specification
- 2) IEC939-2: Complete filter units for radio interference suppression.
Part 2: Sectional specification. Selection of methods of test and general requirements
- 3) UL1283: Standard for Electromagnetic Interference Filters
- 4) CSA C22.2 No.8: Electromagnetic Interference (EMI) Filters
- 5) CISPR — 17 : Methods of measurement of the suppression characteristics of passive radio interference filters and suppression components
- 6) UL1414: Standard for Capacitors and Suppressors for Radio and Television Type Appliances
- 7) IEC335 — 1: Standard for Safety of Household and Similar Electrical Appliances.
Part 1: General Requirements
- 8) EN60939: Complete filter units for radio interference suppression
- 9) EN60384-14: Fixed capacitors for use in electronic equipment. Fixed capacitors for electromagnetic interference suppression and connection to the supply mains. Assessment level DZ

3. Safety mark and its standard



UL Recognition
UL 1283



CSA certification
CSA C22.2 No.8



Semko Approval
EN60939



VDE Approval
EN60939