SPECIFYING EMI FILTERS

Careful attention to filter specification can reduce costs and maximize effectiveness.

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INTRODUCTION

Filter specification is a complex and time-consuming task. Design options, size and configuration, and cost factors are among the innumerable variables which must be considered. No one specification fits all applications and types of filters. This article offers a practical approach to EMI filter specification as it is presented in a sample specification format, which can be used by design engineers as a concise and comprehensive guide. It is based on MIL-F-15733 and MIL-F-28861. This approach is written specifically for multi-circuits; MIL-F-15733 and MIL-F-28861 are not. However, adjustments can be made and this specification can be used for single circuit filters also. While reference should be made to those specifications for additional details, this format is an attempt to eliminate much of the unnecessary verbiage while maintaining the necessary details.

Before delving into the sample specification, some additional guidelines are warranted. In writing a specification, buyers should bear in mind that requirements are legitimate only if a test method exists or can be designed to ensure performance of that requirement. In other words, in order for any requirement to be considered valid, the terms of performance should be defined and the test methods specified.

Buyers should also be aware of a difference between MIL-F-15733 and MIL-F-28861. The latter provides for "two levels of product assurance requirements." However, the filters required in the two specifications are the same. The manufacturers of the filters for the two specifications will be the same. The only *real* difference is in the tests required. For instance, Group A of 28861 adds thermal shock and voltage conditioning (burn-in with voltage only) and X-ray. Accordingly, the typical specification presented can be used for the general requirements of either. If additional testing is required, a paragraph(s) specifying those tests can be added easily.

Buyers should also remember that testing adds to the manufacturer's cost. When a quotation from one manufacturer is considerably different from that of another, the differences may very well be a result of specified testing. Test requirements that are written into specifications should not be ignored. In fact, some suppliers tend to ignore important details when quoting to a customer's specification. Often there are defects, contradictions or specified parameters which obviously cannot be met, yet no exceptions are offered in the quotation. Buyers must share some of the responsibility in perpetuating this problem in that they do not want to see exceptions on a quotation because they are inconvenient. However, it may be that the supplier taking the exceptions is one who has read the requirements conscientiously and is honestly acknowledging a limitation.

SPECIFICATION, EMI FILTER

1.0 Scope

Pertinent information concerning the application may be inserted in this paragraph. Also the general requirements of MIL-F-15733 and the detail requirements are specified herein.

2.0 Applicable Documents

MIL-F-15733 documents should be referenced whenever possible since filter manufacturers are familiar with them. All of the documents referenced in the specification should be included in this section. If they are not referenced, they should not be included.

3.0 Requirements

3.1 Ratings

3.1.1 Voltage Ratings

The actual working voltage expected to be applied to the filter, with respective terminals as defined by the schematic, should be specified. If a component overvoltage rating is required, that is listed as a separate requirement.

3.1.2 Current Rating

The actual working current which is expected to pass through the filter under normal conditions (not overloaded or peak), with respect to terminals, should be specified.

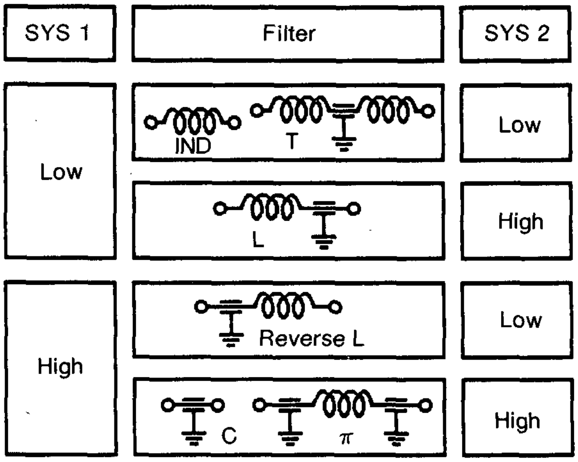
3.1.3 Schematic Diagrams

The schematic may be in block diagram form. If the schematic defines the component details, the user must be certain that other requirements, such as insertion loss, can be met and that the manufacturer agrees that all other requirements can be met. All input, output and ground connections are specified. Any common or parallel terminals should be shown. Transient suppressors may be specified by inclusion on the schematic and with a paragraph of suppression requirements. Selection of a filter circuit type should follow the procedure defined in Figure 1.

3.1.4 Temperature Range

The actual temperature range over which the filter is expected to

******See advertisement on page 390.***



1. System 1 is determined to be of high or low impedance at the frequency of interest. The filter with the opposite (inverse) impedance is chosen. If the systen is high impedance, the filter should be low impedance. If the system is low impedance, the filter should be high impedance.
2. The same is done for the opposite side of the filter (System 2).

- Power lines should be considered low impedance.
- When performing EMC testing such as in MIL-STD-461, a 10 μf capacitor is specified in the line (low impedance); therefore, a filter of high impedance should be used, such as an "L" (with the inductor toward the 10 μf capacitor) or select a "T" configuration.

Figure 1. Procedure for EMI Filter Selection.

operate is specified. Never specify a temperature range wider than that actually required. Also, the non-operating temperature range must be included if it differs from the operating range. It should be noted that many of the parts specified in MIL-F-15733 and MIL-F-28861 use high dielectric constant ceramics, which do not hold some characteristics at temperature extremes although the operating temperature range is specified in this paragraph. If these dielectrics are to be used, the characteristics are specified for room temperature only.

3.2 Physical Design and Construction

3.2.1 Case Configuration

After consulting with the manufacturer, the user should specify the approximate dimensions and means of mounting. Only the dimensions required should be specified. Listing tighter tolerances than those actually required only adds to costs. Maximum and minimum dimensions are used where possible. The most popular mounting means are threaded inserts, but they are also the most expensive. Other mounting means include external studs and flanges. To achieve an EMI seal, inserts or studs may be specified for the same surface as the input terminations. This arrangement is recommended. However, if the filter is large or if it extends too far from the mounting surface, additional support via mounting means from another surface may also be required. This additional support requires additional space and adds to the cost. The filter in Figure 2 achieves the necessary support with mounting means on one surface and achieves an EMI seal by use of a jam nut connector.

3.2.2 Case Material and Finish

Case material of steel in accordance with QQ-S-698 is a common material for multi-circuit filters. Other material, such as MU-Metal may be used but increased cost and limited availability are decided disadvantages.

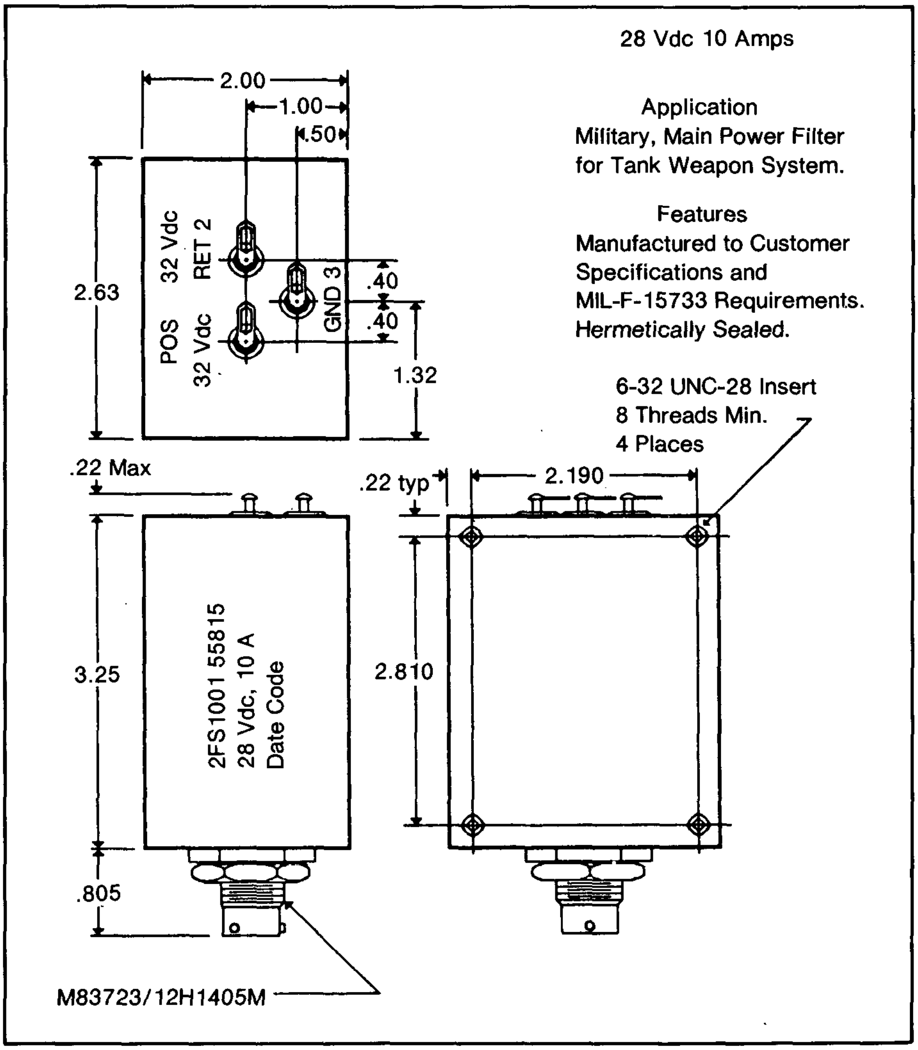


Figure 2. A Typical Multi-circuit EMI Filter.

When a definite material type is not required, "metal case" is specified. The most common finish for filters of all types is "tin plating" in accordance with MIL-T-10727. For a superior quality finish of the electro-tin plating, a hot oil dip, sometime referred to as "fusing," is also recommended. Fusing is more costly but is worthwhile. It is similar in appearance to bright tin plating but of far superior quality. Bright tin is not recommended. Other types of finish which are available are:

- Silver plate in accordance with QQ-S-365
- Gold plate in accordance with MIL-G-45204
- Hot tin dip in accordance with MIL-T-10727

3.2.3 Electrical Terminations

If it is required that the filter mate with a connector, the exact connector to be used on the filter is specified. If a hermetic seal is required, it too should be specified. Epoxy cannot be considered a hermetic seal. If necessary, a manufacturer can make recommendations. Many types of terminals are available. Commonly glass-to-metal seals are soldered into hermetically-sealed filters. The seals can have solder lug terminations or threaded stud-type terminations. Several factors are involved in determining terminal types. These include creepage and clearance, field use (or abuse) and current rating. In general, however, the current rating will determine the terminal type. Up to 15 amps, a solder lug of the proper size can be used. Above that rating, a threaded stud terminal should be specified.

3.2.4 Weight

The manufacturer can supply initial weight estimates. As a general

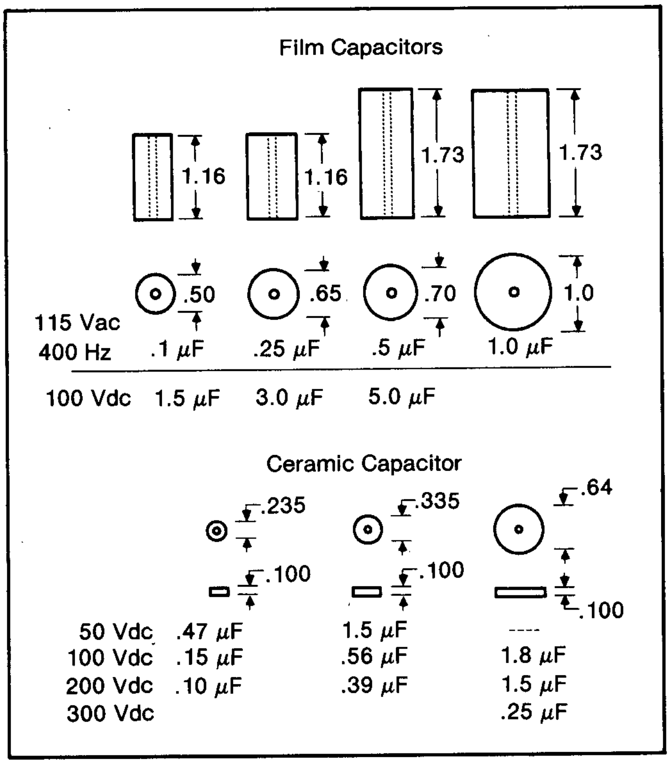


Figure 3. Relative Capacitor Size Chart.

rule, the filter should weigh a maximum of one-tenth pound per cubic inch.

3.2.5 Marking

Marking should be kept to the minimum. Where physical size precludes the required marking, minimum marking on the part and full marking on the package can be specified.

3.2.6 Potting Compounds

Potting compounds adequate for both encapsulation and insulation should be used. They must not react chemically with other components. Wax and tar should not be used.

3.3 Seal

If there is no requirement for a sealed part, this requirement is not applicable. If a non-hermetic terminal or connector is specified, the part is not hermetically sealed.

3.4 Capacitance

Capacitance may not be specified and may be termed "not applicable." For purposes of filter size determination, Figure 3 is presented to give an idea of relative capacitor physical size for multi-circuit filters. It must be remembered that the heart of an EMI (RFI) filter is the feed-through capacitor. This is the part that provides isolation between input and output while providing a path to ground for unwanted signals. The method of manufacturing varies with each filter manufacturer. Also, there are many factors to consider in capacitor selection including temperature range, temperature coefficient, dissipation factor, insulation resistance and dielectric absorption. However with any capacitor, a crucial characteristic is dielectric thickness, which determines the size of the capacitor.

Since EMI filters are usually in the power line, the power voltage is constantly applied to the capacitor. One capacitor manufacturer may use 1000 volts/mil as a design guide while another uses 400 volts/mil. The first manufacturer will be able to build a smaller filter; but when the cost of a failure is considered, the second manufacturer's filter would be preferable choice.

Figure 4 depicts relative inductor sizes. The design of ac and dc inductors is different, and the sizes on the chart are approximate for both. This size chart, considered along with the information on capacitors in Figure 3, allows the would-be purchaser to conceptualize the approximate overall filter size. The values shown are at full load.

3.5 Dielectric Withstanding Voltage

The magnitude of test voltage should be 2.5X rated dc voltage for dc circuits. For ac circuits the voltage is dc with a magnitude of 4.2X rated rms voltage. The dielectric withstanding voltage should be used with caution and repeated application of the voltage to the same circuit is not recommended.

3.6 Insulation Resistance

Insulation resistance varies with capacitance, test voltage and temperature. In general it can be specified at 1000 megohm microfarads but seldom needs to be greater than 10,000 megohms, even with smaller capacitances. A manufacturer can answer specific questions.

3.7 Voltage Drop

The ac and dc voltage drop methods differ as defined in paragraph 4.6.8 of MIL-F-15733. Also dc resistance, instead of voltage drop for dc circuits, may be specified.

3.8 Insertion Loss

Insertion loss is defined as follows:

$$\text{Insertion loss} = 20 \log(E1/E2)$$

where:

E1 = Voltage across the signal

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generator with the filter in the circuit at a given frequency.

E2 = Voltage across the signal generator with no filter in the circuit at the same frequency.

The test method is specified in MIL-STD-220. Much has been written concerning the inadequacies of MIL-STD-220; however, it remains the *only standard* by which parts may be tested and various lots compared. It should be pointed out that MS220 specifies insertion loss under load conditions between the frequencies of 100 kHz and 20.0 MHz only. Because of inductor saturation, the insertion loss specification presented by some manufacturers can be rather misleading. Seemingly insertion loss at a lower frequency is greater than the loss at a higher frequency. Actually the two frequencies were at different load conditions.

MIL-STD-461 is the standard for testing military systems for radiated and conducted emissions and susceptibility. *Filters are not tested to MIL-STD-461*, but they enable the system to meet that requirement. For accurate calculation of the insertion loss under MIL-STD-461, a low source impedance should be used with a load impedance equal to the voltage divided by current. Some fairly elaborate test circuits have been defined to simulate a MS461 insertion loss test method; however, no standard exists for this simulation, and not everyone has the capability of performing to such non-standard methods.

3.9 Temperature Rise

Large filters of the multi-circuit type cannot be suspended by their terminals because most terminals used cannot withstand the weight.

3.10 Overload

This test method specifies that filters will "be suspended by their terminals." On some multi-circuit filters, this is not possible; and the procedure should be discussed with the manufacturer.

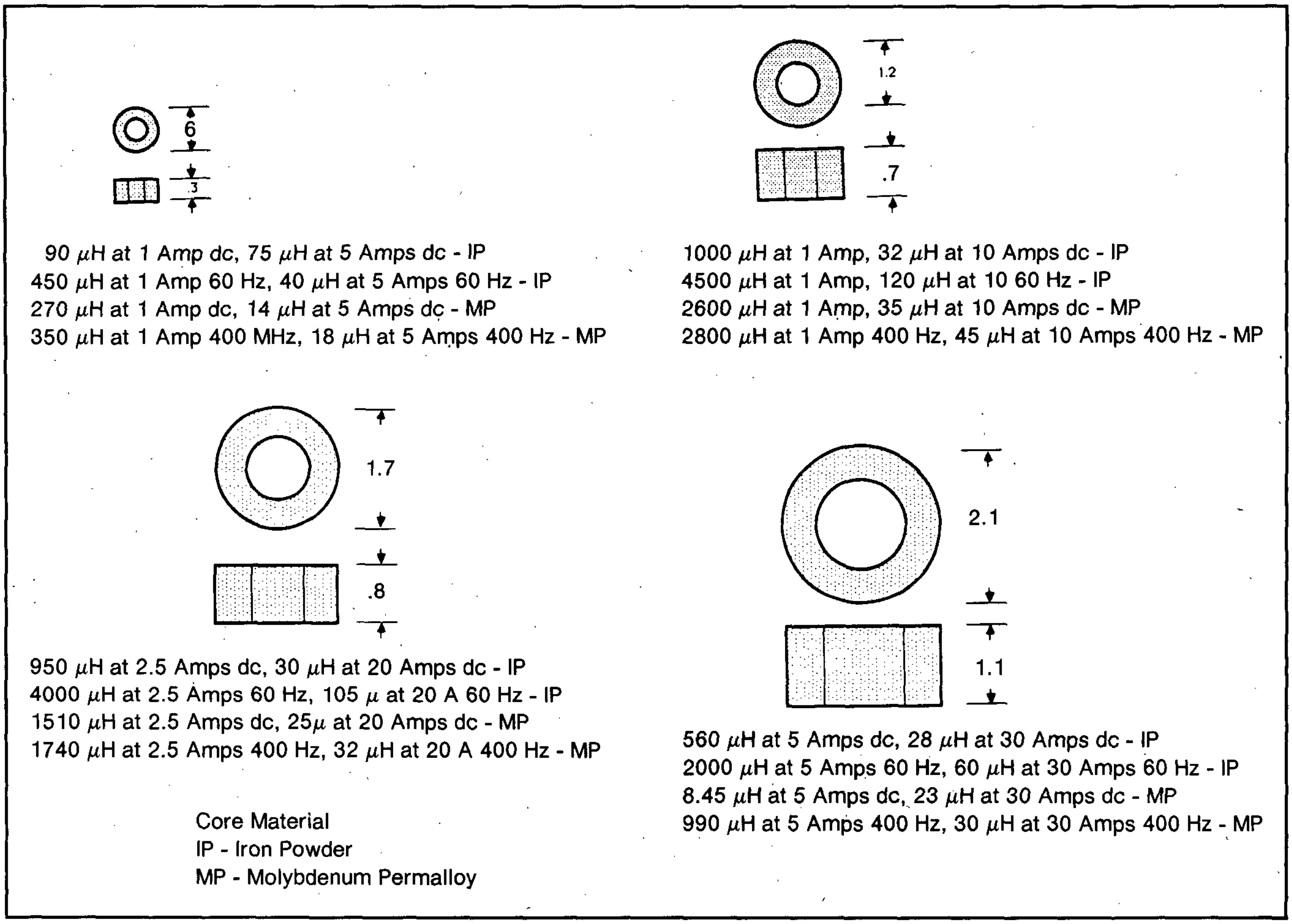

Figure 4. Relative Inductor Size Chart.

3.11 Environmental

Resistance to soldering heat, solvents, salt spray, thermal shock and immersion, mechanical shock, and vibration should be included. Also moisture resistance, solderability and life should be specified using established military specifications. It should be noted that there are post tests, usually one or more of the "A" tests, to ensure that the part has successfully passed these environmental tests.

4.0 QUALITY ASSURANCE PROVISION

4.1 Qualification Inspection

Qualification tests are those tests performed to prove that the part is capable of meeting all of the requirements. Unless changes are made, they are usually performed only one time on a specified quantity of a given part.

4.2 Quality Conformance Inspection

Quality conformance tests are sometimes referred to as "acceptance tests" or "inspection of product for delivery". They performed by the manufacturer prior to shipping to ensure that the user receives good parts. The tests for requirements in paragraphs 3.2 through 3.8 are the same as, and are sometimes referred to as, "Group A" or simply "A" tests of MIL-F-15733. As a minimum the user should expect that these tests be done. Groups "B" and "C" tests of the military specifications are usually considered destruct tests. They are not used in production and are carried out on a smaller sample than the "A" tests. Any additional testing, such as burn-in, will usually bring additional expenses. In fact, the manufacturer should quote additional testing separately. This separate quotation will ensure that the manufacturer has not overlooked the requirement, and it gives the user a basis for comparison. If additional tests such as thermal shock or burn-in are required, they can be added to this section of the specification. The additional cost of having these tests performed should be considered. Multi-circuit filters with various voltages and current ratings can require several power supplies and loads, and considerable setup time.

5.0 Packaging

5.1 Preparation for Delivery

5.2 Marking

6.0 Notes

This paragraph may be used to add any informative or applicable notes.

CONCLUSION

A military specification format based on MIL-F-15733 and MIL-F-28861 enables buyers to define their filter needs comprehensively and concisely. The use of this format ensures buyers that filter characteristics which need definition will not be overlooked. As in any procurement activity, buyers should bear in mind that over-specification adds cost and under-specification jeopardizes performance. ■