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Mitigating EMI Problems

&

Filter Selection

By
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EMI Noise Generators

A change of state (On/Off) in an Electronic component has the potential to generate EMI. Typical examples are Electronic Switchers, Clocks, Electronic controls, Power Supplies, Inverters, Fluorescent lights, Motor Brushes, etc."

EMI noise could;

Conduct through the power lines and it could be;

Common Mode, between Line or Neutral to Ground
Differential Mode, between Line and Neutral

Radiate through Air

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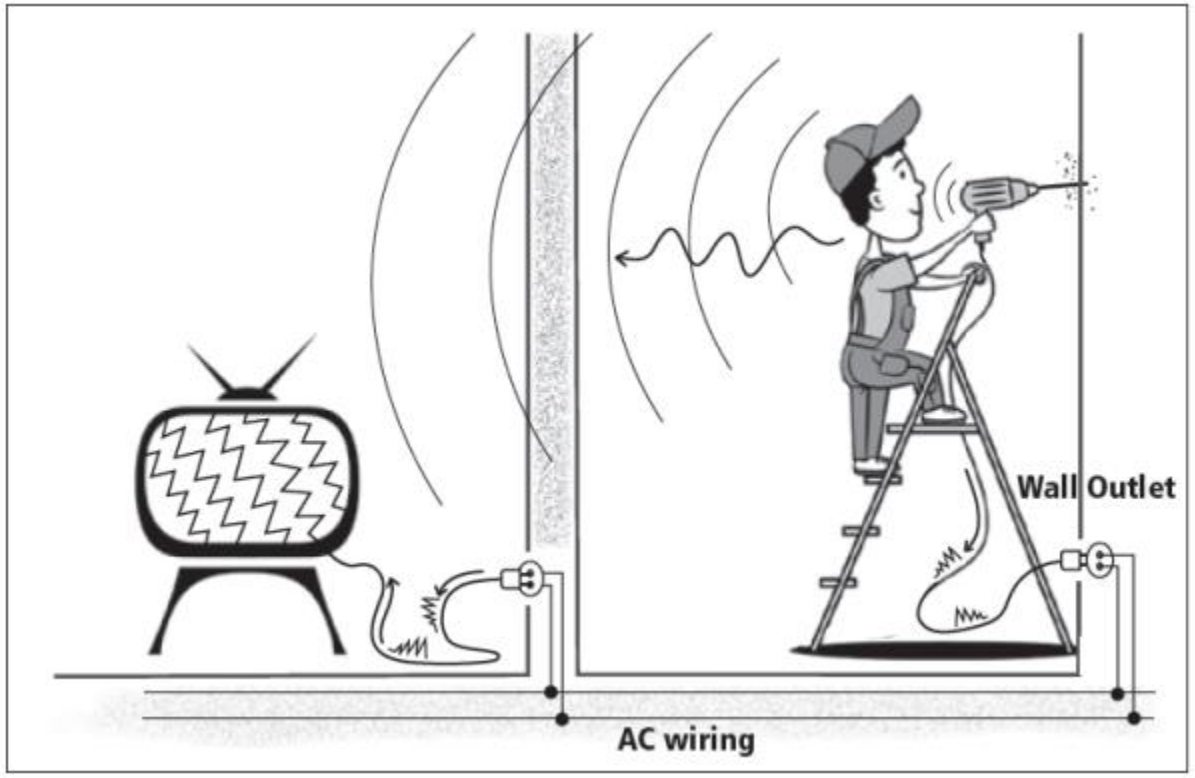

Curtesy of EMC consultant, France

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How to mitigate EMI?

EMI is known as **"Black Magic"**. No one wants to deal with it because it has no perceived market value, it is an economical burden which is ignored until one starts reading the paragraphs in fine print which reads;

"The system must meet the EMI requirements of …"

Which means it is

"TIME FOR 911 CALL"

Most of the times the engineer is in a lab and the unit failed EMI test and the most common question is
"Do you have a filter which passes MIL-STD-461 or …"

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MIL-STD's and EN's Provide:

- EMI limits
- Detail test methods
- Test procedures
- Test apparatus
- What they don't or can't provide obviously is how much noise the DUT generates

EMI filters are application specific and they provide:

- "X" dB at certain frequency
- Off the shelf (OTS) filters are designed to attenuate CM noise above 150KHz for commercial applications
- The OTS filters are not suitable for most military applications because the EMI test frequency starts at 10KHz
- CM components have little effective below 100KHz, therefore DM components are necessary to suppress the lower frequency noise

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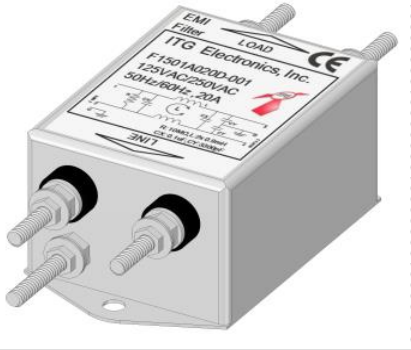
TYPICA EMI FILTERS



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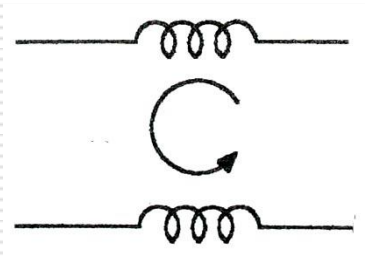
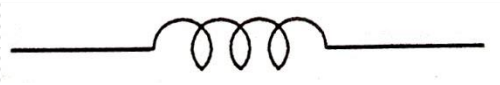
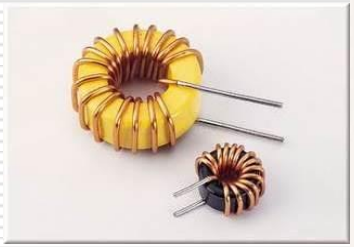
Power Line Filters Components

Common Mode Coil



Differential Mode Coil





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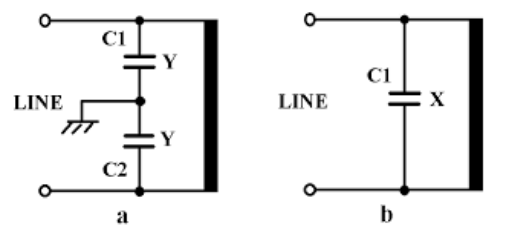
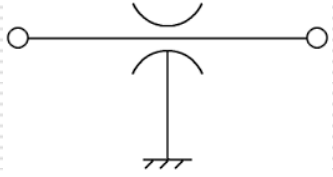
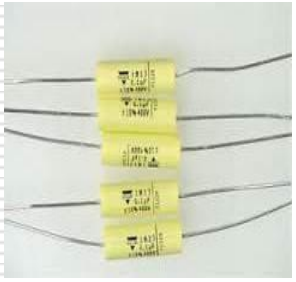
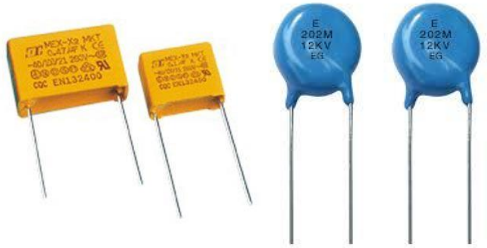
"X", "Y" or By-Pass Capacitors



"F/T" Capacitor







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Following are the minimum information required to start a filter design/selection

- Filter application Military, industrial or Commercial
- Voltage rating, DC or AC
- Power line frequency, 50/60/400Hz
- Current rating
- Leakage current
- Single or three phase
- Three phase Delta or WYE
- Required attenuation (dB VS frequency)
- Or results from EMI test w/o a filter installed
- Available volume
- Mounting means
- Termination (fast-on, screw, Mil connectors, etc.)
- Environmental requirements

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Things to know when choosing an EMI filter

1. In commercial world the conducted emissions measurement starts from 150KHz to 30MHz, the radiated Emissions starts from 30MHz to 300KHz, and up.

2. In military world the conducted emissions measurement starts from 10KHz to 10MHz, the radiated Emissions starts from 10MHz to 1GHz and up.

3. Whether in an EMI lab or in house performing EMI test if you are lucky the DUT will pass, but if it fails save/print the results.

4. Perform a Common Mode noise test save/print the results.

5. Record the failed frequency starting from the lowest frequency and corresponding dB values above the limit line.

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Continued;

6. If the failed frequencies are at 150KHz and up you may start with a simple LC or PI configuration filter.

7. Use the recorded data dB Vs frequency and compare with data sheets provided by filter manufacturer and choose a filter and repeat EMI test.

8. If EMI test results are better but not quite there yet, what you need to know is each filter component in theory provide:

    - 6dB additional attenuation when its value is doubled
    - 6dB less attenuation when its value is cut in half
    - 6dB additional attenuation per octave (every time the frequency is doubled)
    - 20dB additional attenuation per decade (every time the frequency is multiplied by 10)
    - Additional component increases the filters attenuation by 20 dB

Note: you may use the above during system simulation.

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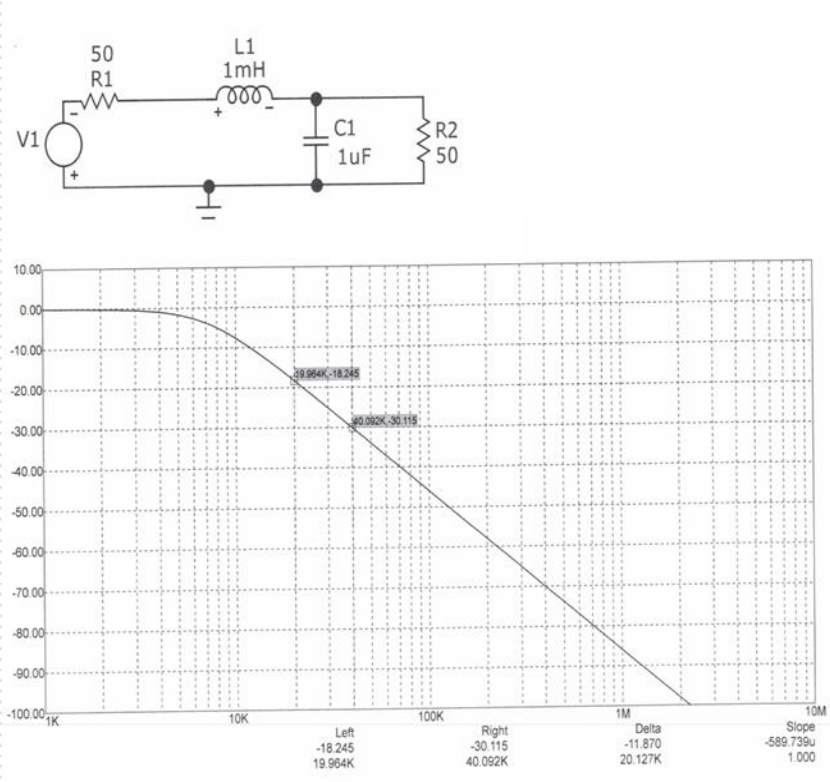
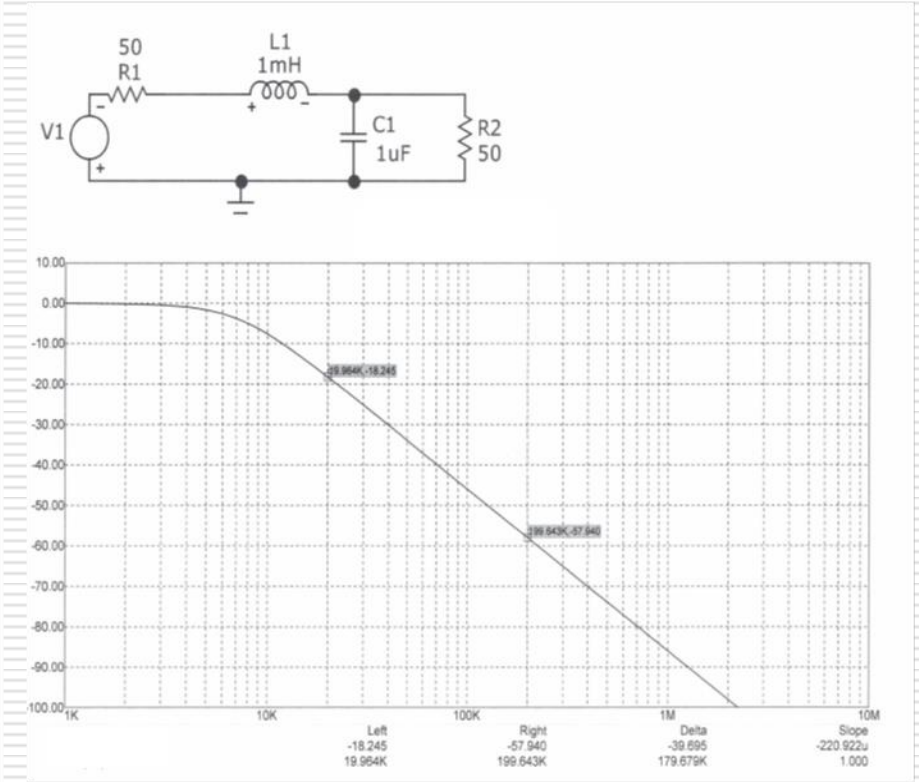
Typical filter circuit and it's attenuation response in ideal situation



6dB attenuation per Octave



20dB attenuation per Decade

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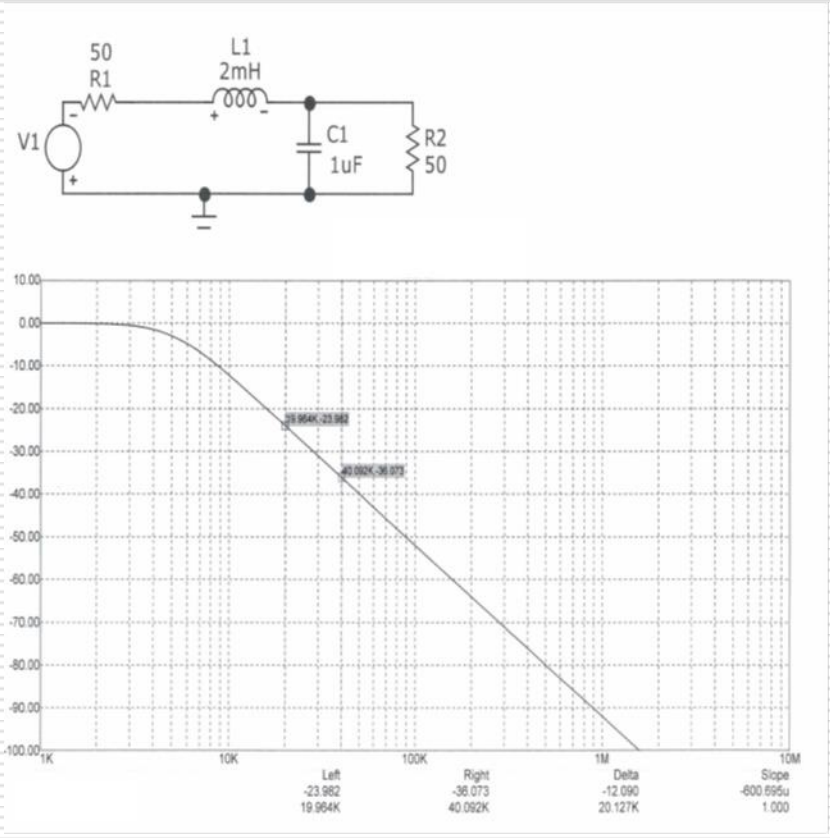
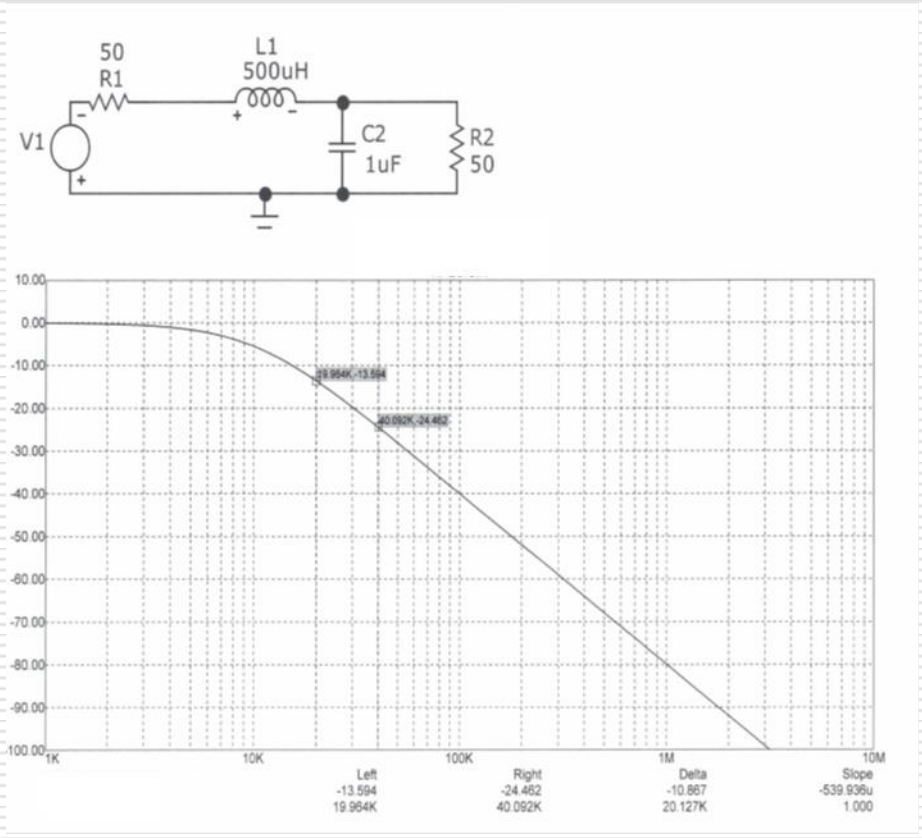


2L 6dB more attenuation



1/2L, 6dB less attenuation

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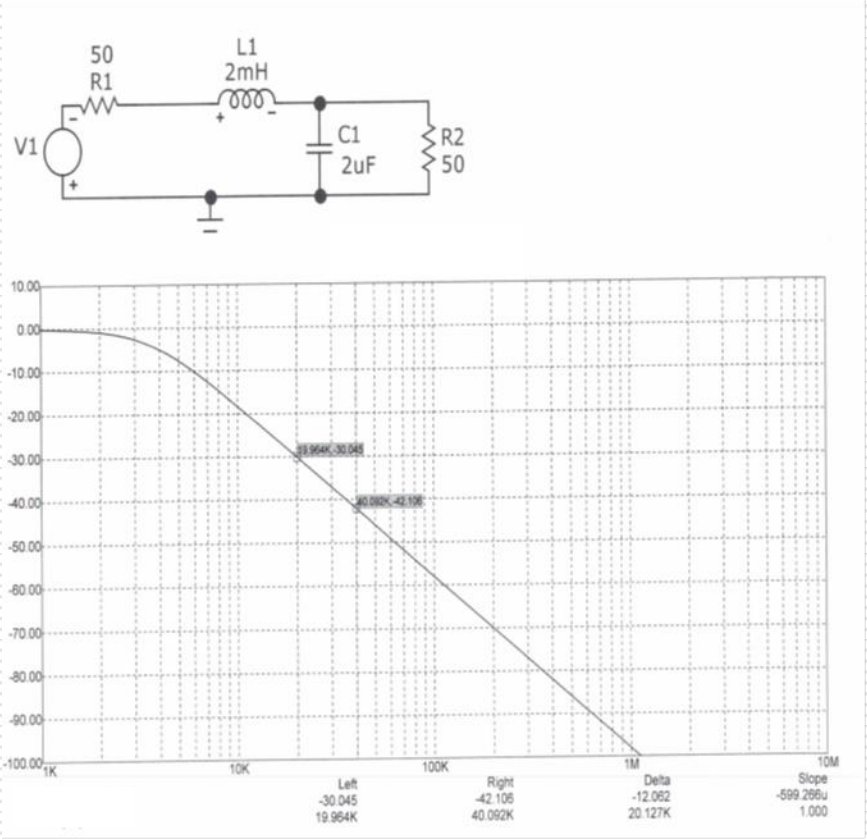
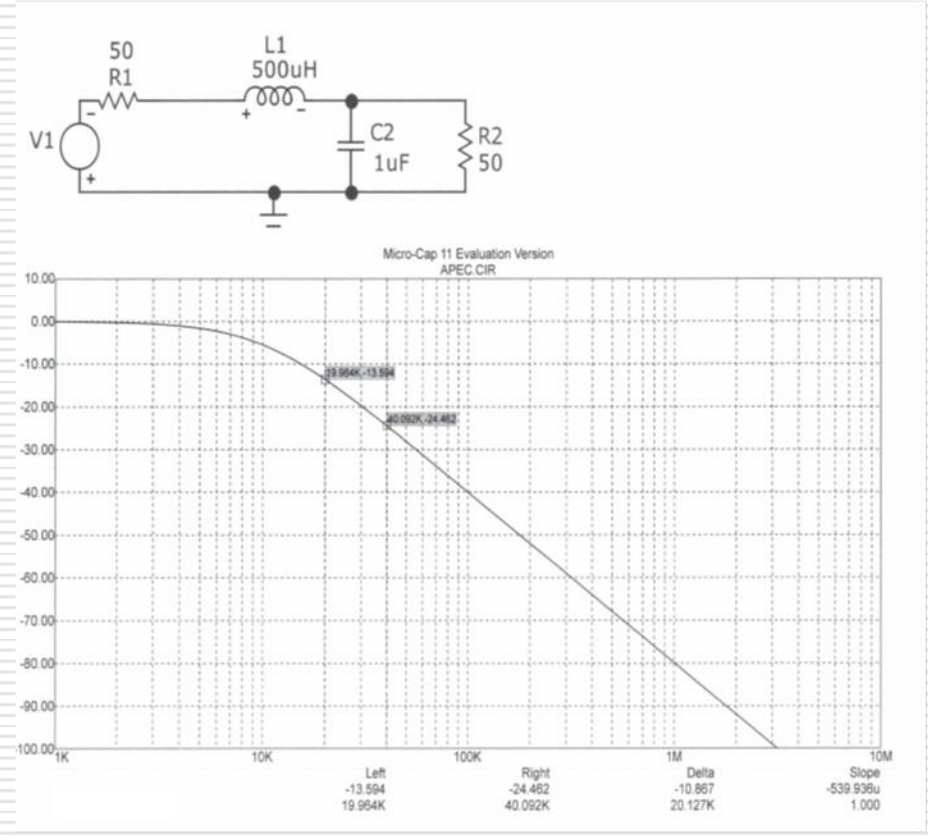


2xL & 2xC, 12dB more attenuation



1/2xL 1/2xC, 6dB less attenuation

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Case Study
EMI Filter Design based on EMI test results
480VAC 60Hz 200A Inverter

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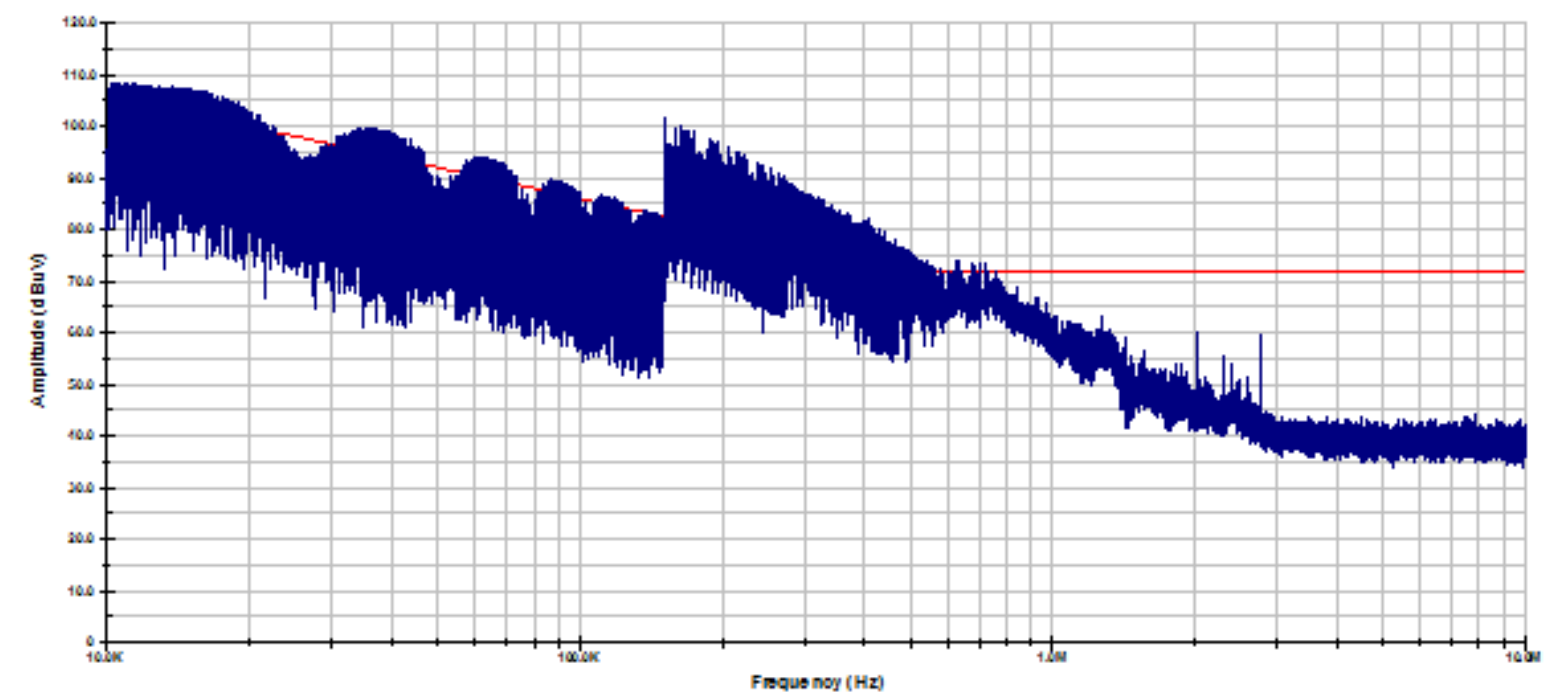
MIL STD-461, CE102 test results without EMI filter



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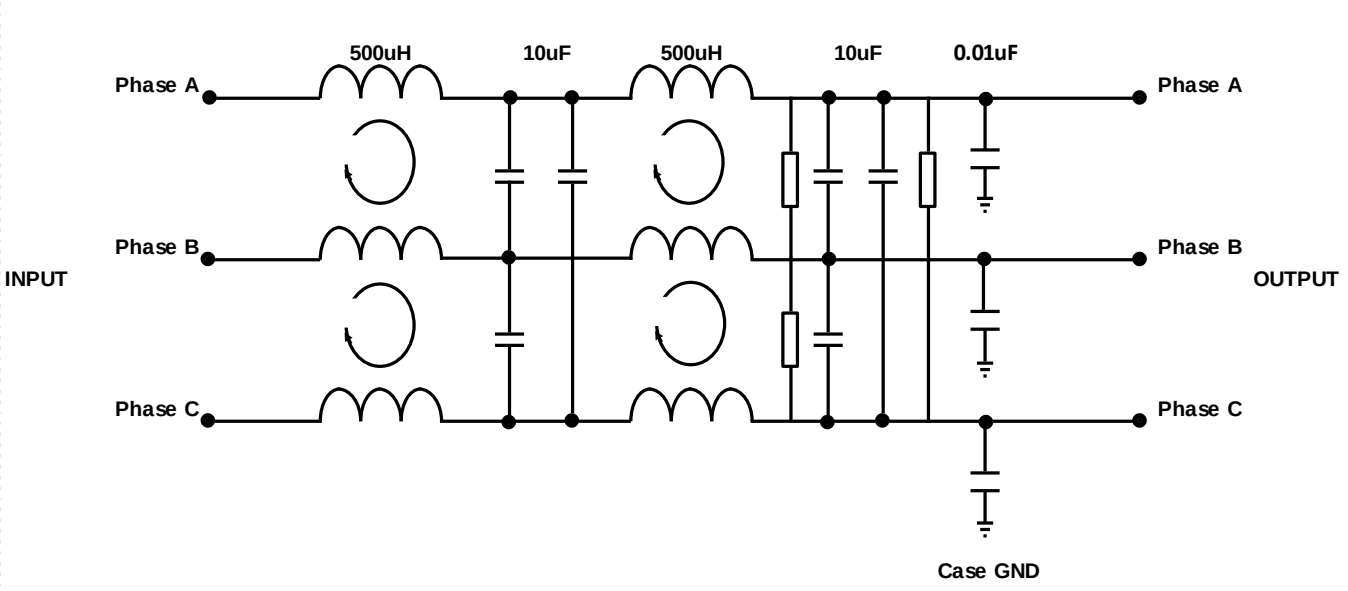
Initial open frame prototype



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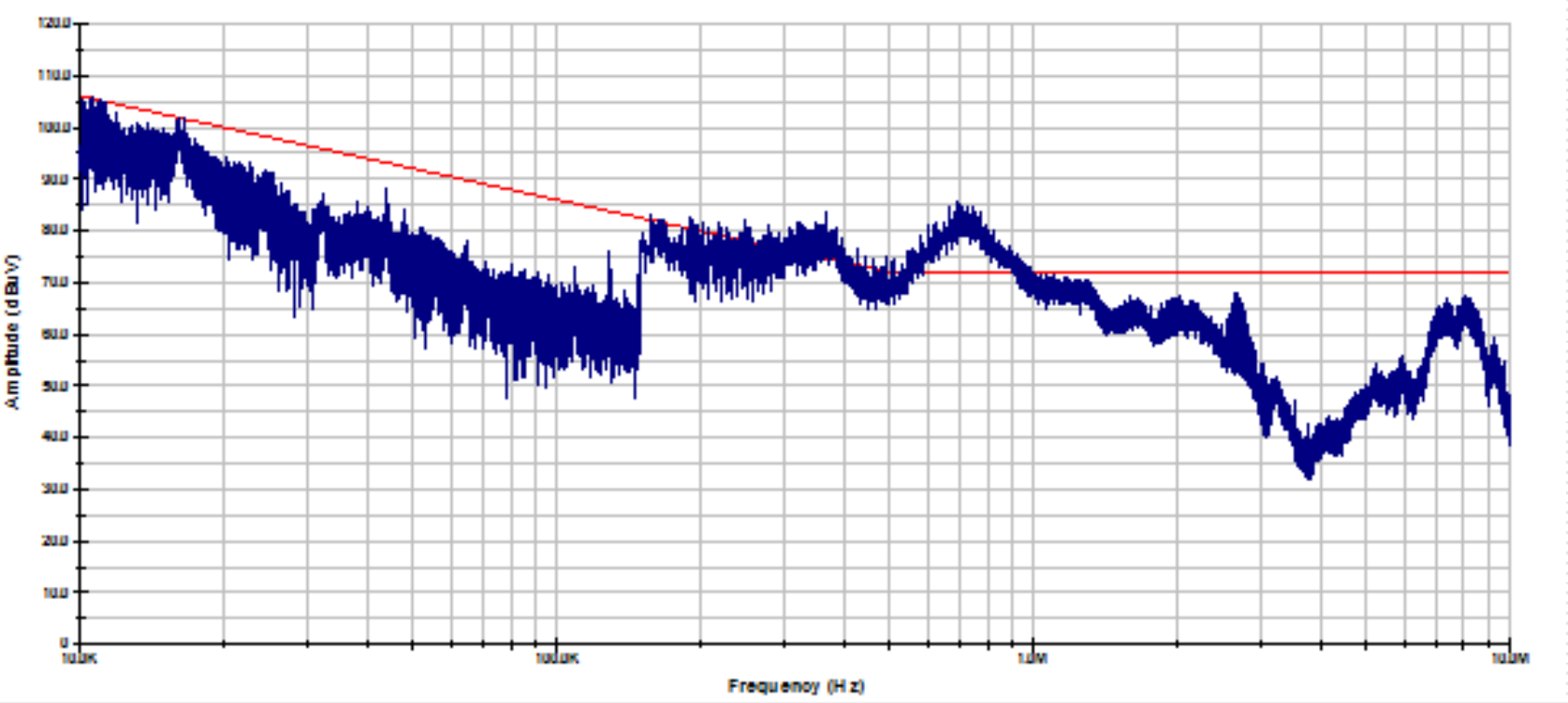
MIL STD-461, CE102 test results with prototype filter



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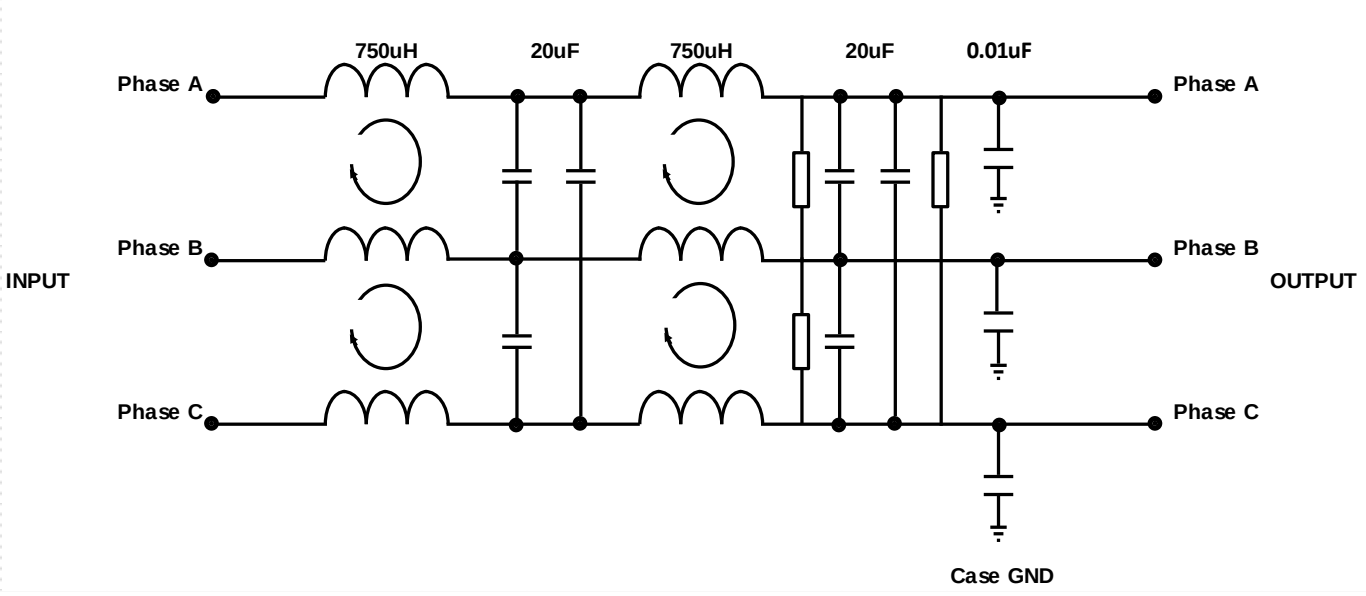

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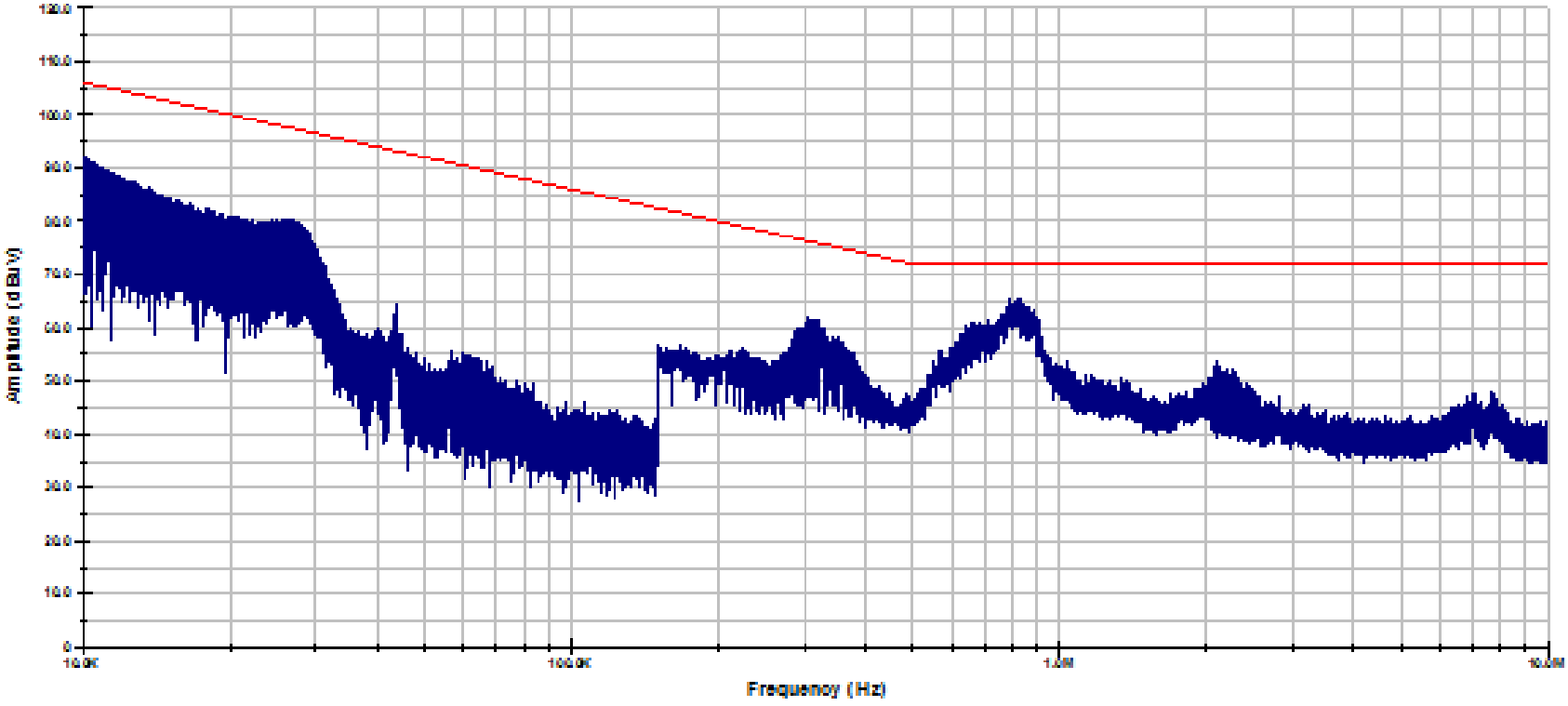
MIL STD-461, CE102 test results with final EMI filter installation



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Does and don’ts during electronic design

Where possible:

- Use multilayer PCB design with ground planes in between layers
- Short traces where possible to reduce antenna affect
- Place noisy components in one area
- Avoid sharp (90 degree) trace bends, round off the trace edges and corners
- Use wire harness
- Separate noisy cables from power line cables
- If using shielded cables connect shield to ground at least one end
- Do not daisy chain ground wires, have one common ground and ground wires as short as possible
- Use shielding material around the covers and doors
- Make sure areas where shielded materials are used are not painted
- Read fine prints on your spec and if there is an EMI requirements make sure to leave space for an EMI filter.
- Perform EMI test during prototype design phase

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- Military and Commercial EMI test are performed in a 50 ohms system using LISN's (Line Impedance Stabilization Network)
- Conducted emissions testing is performed on power cables entering the equipment. The reason is to prevent EMI noise generated by electronics switches is contained in the chassis and will not transmit through the power cables and adversely effect the performance of other equipment connected to the same power line
- Military and commercial EMI spec provide limits and test procedures not solution guide lines
- If emissions measured exceeds the allowable limits EMI filters are required
- EMI Filters are bi-directional and they mitigate conducted emissions. They are most effective at lower frequencies and their harmonics at higher frequency spectrum
- To enhance the performance of the EMI filters they should be installed at the power line entering the equipment, preferably input terminals protruding out of the enclosure isolated from filter output terminals
- The isolation will prevent cross talk between input (dirty) and output (clean) terminals and will positively effects the radiated emissions test results

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1. While in the EMI lab doing EMI test if the product fails, the very first thing to do is print the results.
2. Perform a Common Mode noise test (most labs know how to perform this test) and print the results.
3. Write down the failed frequency and corresponding dB margin above the limit line.
4. In the commercial world the conducted emissions measurement starts from 150KHz to 30MHz, the radiated Emissions starts from 30MHz to 300KHz, or 1GHz depending on the product under test.
5. In the military world the conducted emissions measurement starts from 10KHz to 10MHz, the radiated Emissions starts from 10MHz to 1GHz and up depending on the product under test.
6. If the failed frequencies are at 150KHz and up you may start with a simple LC filter. Here is what you need to know, every element initially provides 6dB attenuation, an LC filter will provide total 12db attenuation above the cut off frequency. If the L or C or both component values are doubled, each will provide 6dB additional attenuation per element.
7. Each filter component element provides:
    a) 6dB attenuation per octave (every time the frequency is doubled)
    b) 20dB attenuation per decade (every time the frequency is multiplied by 10)
    c) 6dB attenuation when the value of a component is doubled
    d) 6dB less attenuation when the value of a component is cut in half
    e) Additional component adds 20dB attenuation

Conclusion

The EMI solution once designed will work for years, as long as the filter components are properly selected for voltage fluctuation and maximum operating current and environmental requirements. EMI solutions do not need regularly scheduled maintenance. What is important is the manufacturing consistency of the system the EMI solutions are designed for. Any changes no matter how insignificant the they are it is recommended to repeat EMI test to prevent future costly field recalls because of EMI failure. As you can see EMI solution is not "Black Magic" it is based on a technology from past, which is reliable and most importantly it still works

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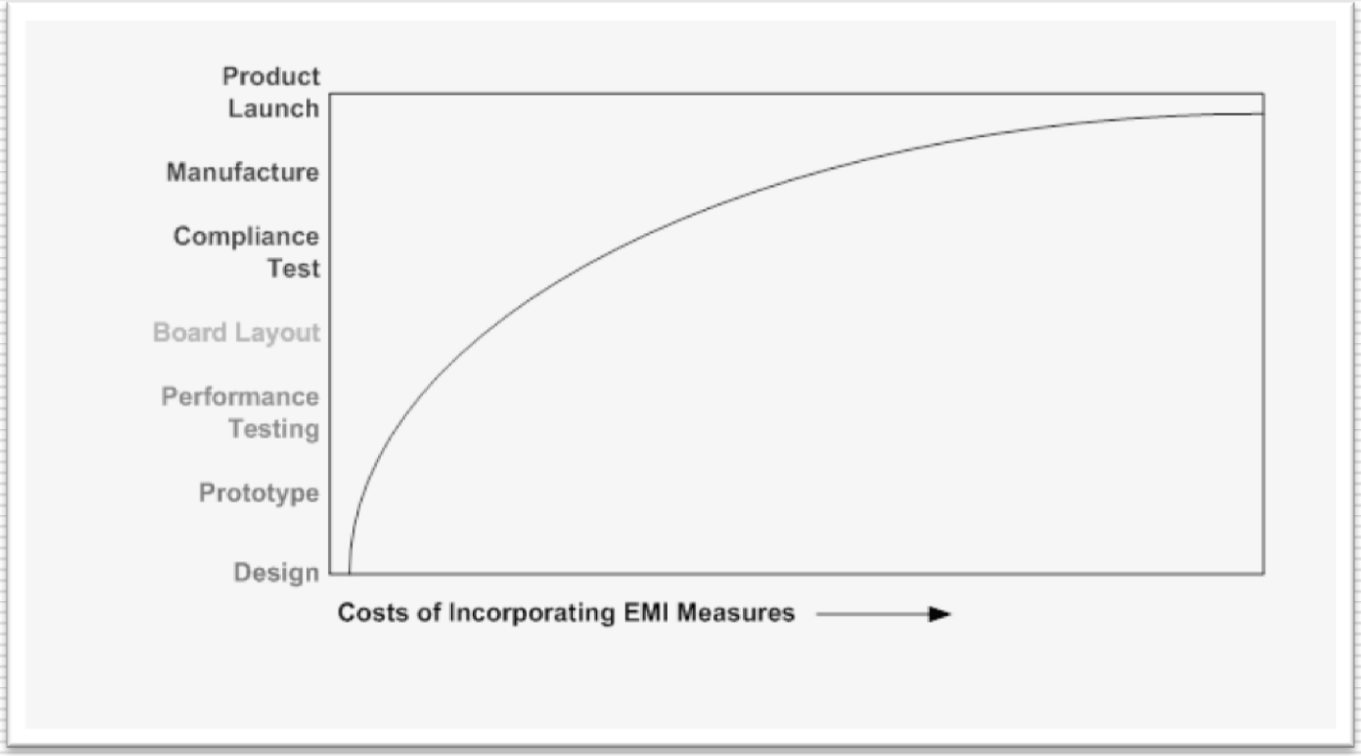
Cost of Incorporating EMI solution



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Worldwide Support Team:

- ✓ We work closely with customers on new design activity as well as supplies and demand management.
- ✓ Inventory in LA, Elmsford NY, Hong Kong and Shanghai, China to support regional demand.

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