Conducted Emissions and Power Supply Filters

IEEE EMC Society – Central Texas Chapter

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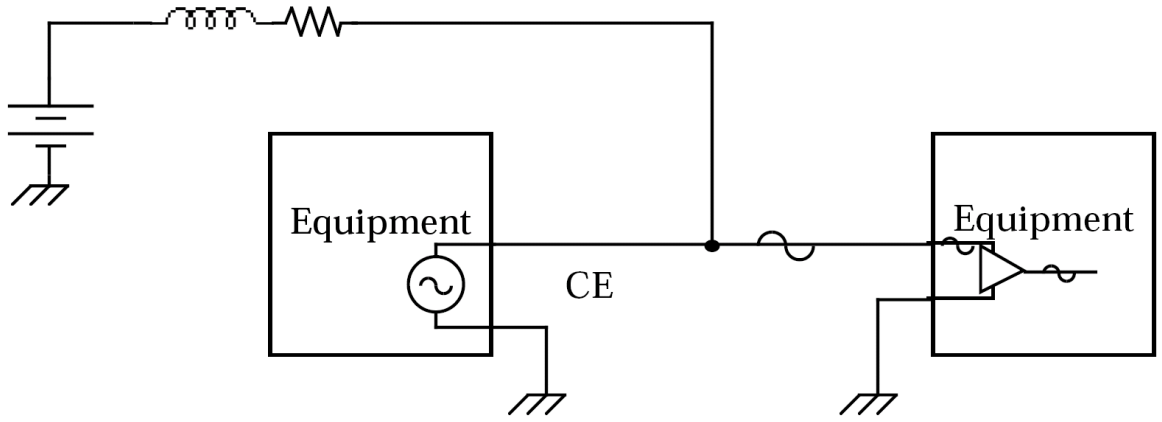
Outline

- Description of Conducted Emissions
- Conducted Emissions (CE) Regulations
- The “Line Impedance Stabilization Network” (LISN)
- Common-mode and Differential-mode current
- Power Supplies and Filters

Definition of Conducted Emissions

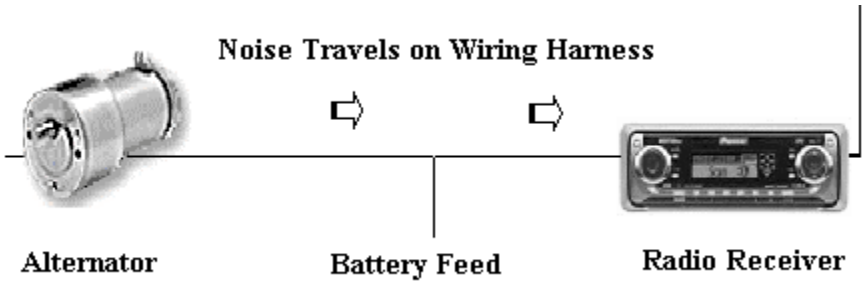
- Conducted emissions (CE) are currents that travel on circuit wiring or conductive portions of assemblies and structures.
- CE are typically from 10's of kHz to 10's of MHz, can occur on power and/or signal wires.



Causes and Implications of CE

- CE can occur as a result of:
  - Circuit intended design (schematic).
  - Current flow along unintended paths.
- This is a concern is for two reasons:
  - It may affect system functionality.
  - It may not meet regulatory of performance requirements.

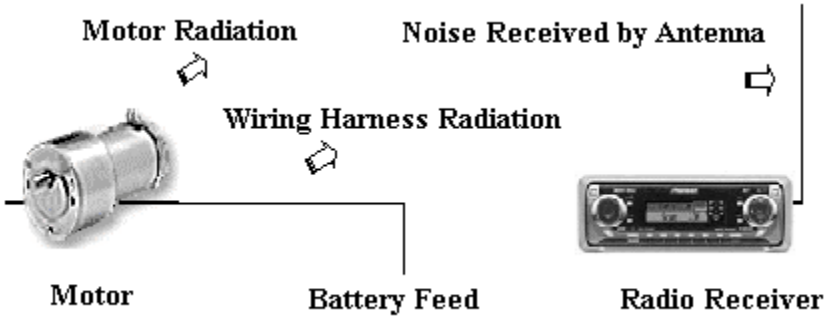
Example of CE



- Noise from vehicle alternator is conducted along primary vehicle wiring to radio – thus affecting radio performance.
- High levels of CE may actually cause damage to components.

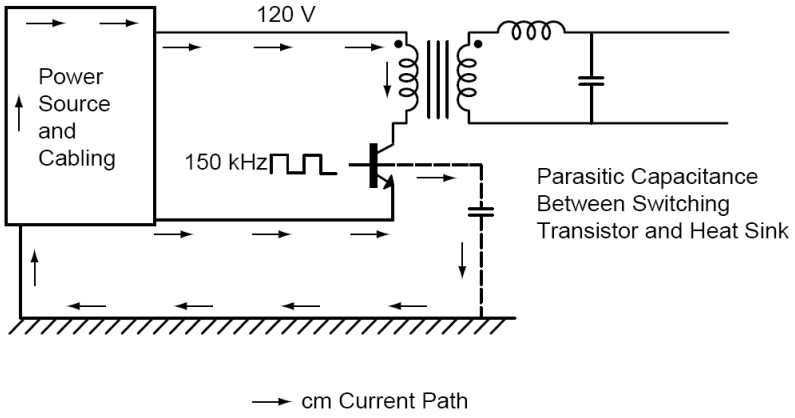
Additional Concern of CE

- Depending on wiring length and frequency of CE noise, this may result in a radiated emission condition.
- Proper attention to CE can prevent additional issues.



“Unseen” Causes of CE

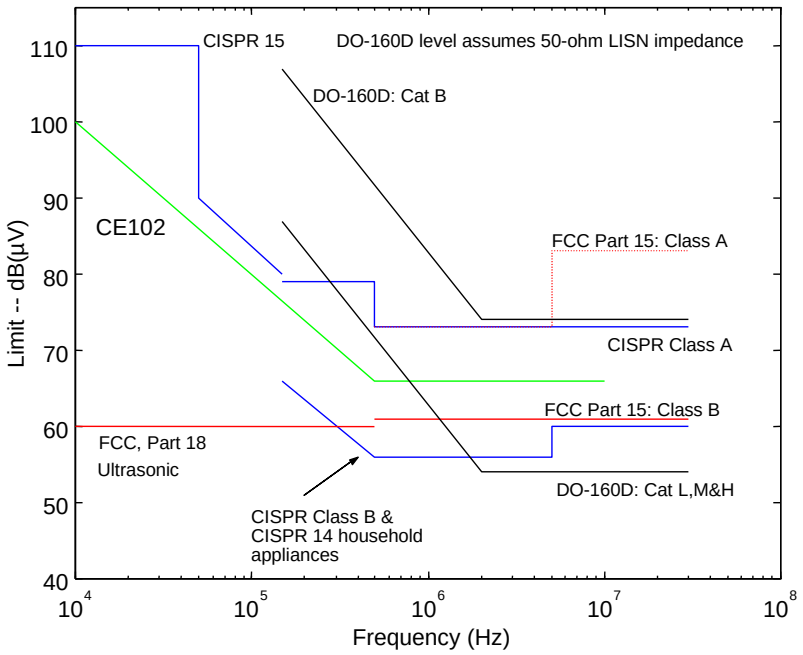
- CE may also be due to conductive chassis as electrical paths (sometimes un-intentional).
- Example - parasitic capacitance completes current path – resulting in CE current.



Conducted Transient Emissions (CTE)

- CTE can be described as a short duration type of CE and can occur due to the use of various type of electromechanical devices (solenoid, relays).
- Extreme cases of CTE frequently cause system functionality issues.
- Is due to the inductive nature of circuit wiring or loads and is a result of “L (di / dt)”.

Conducted Emission Regulatory Requirements



- Legislated requirements exist that define the maximum CE levels permitted.
- Figure shows comparison of typical requirements.

Control of CE

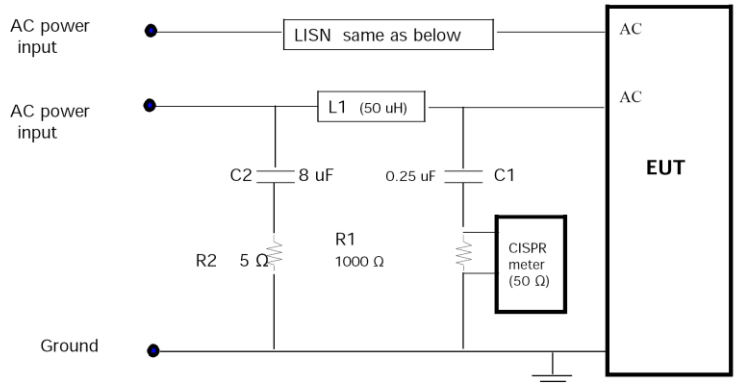
- Since the transfer path of CE is known (compared to radiated emissions) – it may be easier to correct compared to unknown path of radiated emissions.
- CE can be addressed by application of various types of filters connected to the conductor(s) or through inductively coupled devices (such as ferrite materials – discussed later).

The Line Impedance Stabilization Network (LISN)

- The method used to determine compliance to CE requirements involves the use of the "LISN".
- A LISN performs the following functions:
  - Allows power to be supplied to a device.
  - Separates the CE from the power current.
  - Provides a port for measurement of CE levels.

CE Testing With LISN

- At right is a LISN and it's connection to an equipment under test (EUT).
- The desired goal is to have a constant LISN impedance over the CE measurement range.



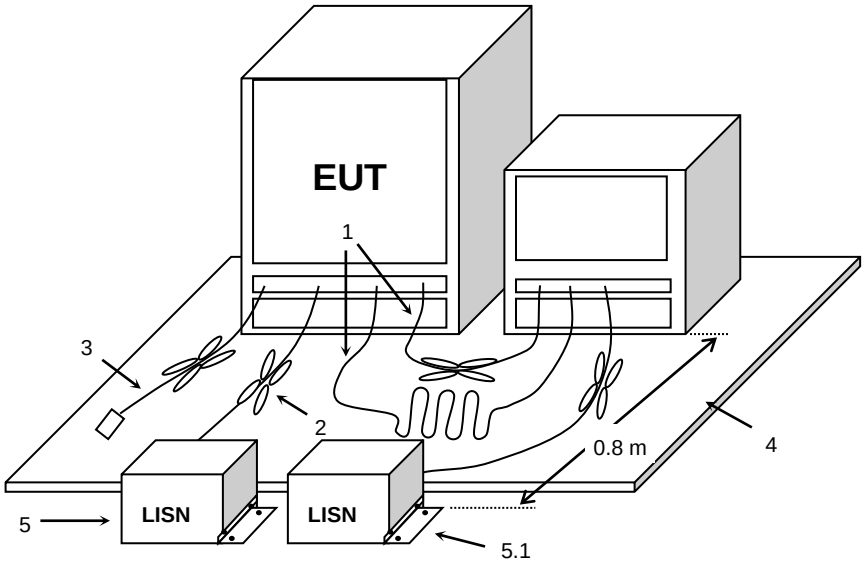
(neglecting the effects of C1, C2 and R1)

Frequency	Equivalent Impedance (ohms)
10 kHz	5.36
20 kHz	7.25
40 kHz	11.99
50 kHz	14.41
100 kHz	25.11
200 kHz	37.74
500 kHz	47.21
1.0 MHz	49.26
2.0 MHz	49.80
5.0 MHz	49.98
8.0 MHz	50.00
30.0 MHz	50.00

Two (2) Purposes of LISN

- To provide a constant impedance to measure CE which means:
  - Measurement not dependent upon power line characteristics.
  - Assures repeatability from test location to test location.
- To provide a measurement port to determine the CE levels.

Component CE Test Set-up



1.Excess I/O cables shall be bundled in center. If bundling is not possible, the cables shall be wound in turns. Bundling shall not exceed 40 cm in length.
2.Excess power cords shall be bundled in the center or shortened to appropriate length.
3.I/O cables which are not connected to a peripheral shall be bundled in the center. The end of the cable may be terminated if required using correct terminating impedance. If bundling is not possible, the cable shall be wound in turns.
4.EUT and all cables shall be insulated from ground plane by 3 to 12 mm.
5.EUT connected to one LISN. LISN can be placed on top of, or immediately beneath ground plane
5.1All other equipment powered from second LISN.

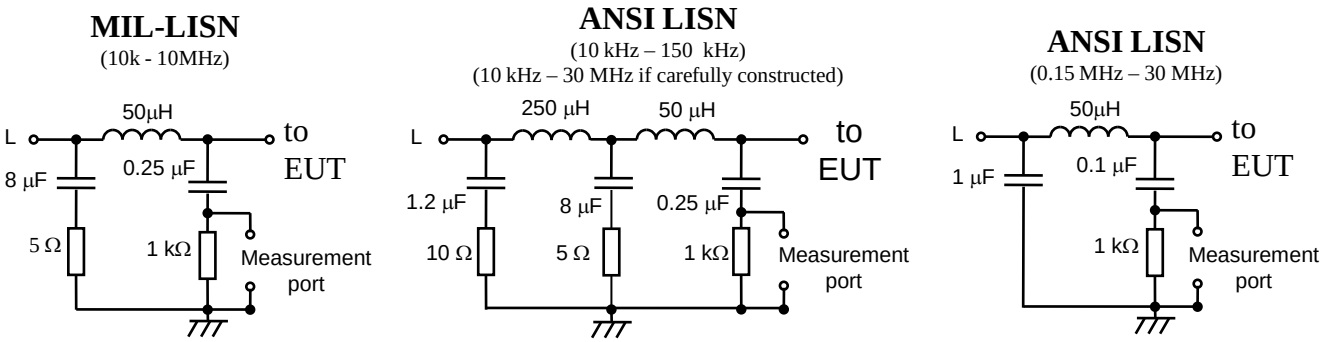
- Used in component testing when all parts can be place on a test table.
- LISN's located away from EUT, with defined separation.

LISN “Myth Buster”

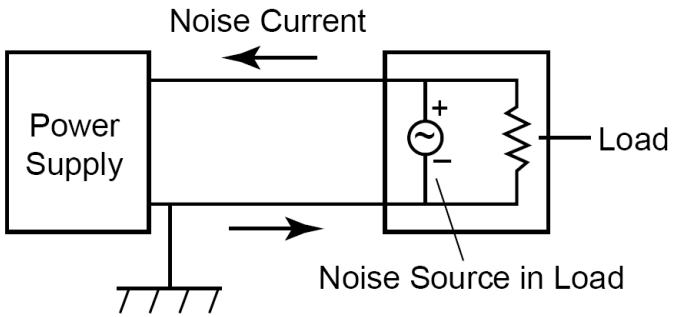
- Sometimes it is stated that the intent of the LISN is to duplicate the wiring harness for the EUT. *This is not true!*
- Although there is empirical evidence that systems have wire harness inductance of:
  - Large systems = 50 uH (such as aircraft)
  - Small systems = 5 uH (such as automotive)
- LISN's should be selected based on the frequencies of the measurements required.

Examples of Standard LISN's

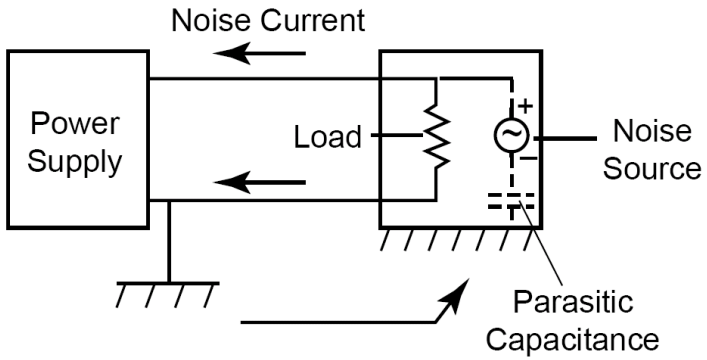
- Different internal component values may be required depending on the application.
- Usually specified in testing requirements documentation.



Common Mode and Differential Mode Current



Differential Mode



Common Mode

- Differential Mode Current – Current that flows in opposite direction on conductors in a system.
- Common Mode Current – Current that flows in the same direction on conductors in a system.

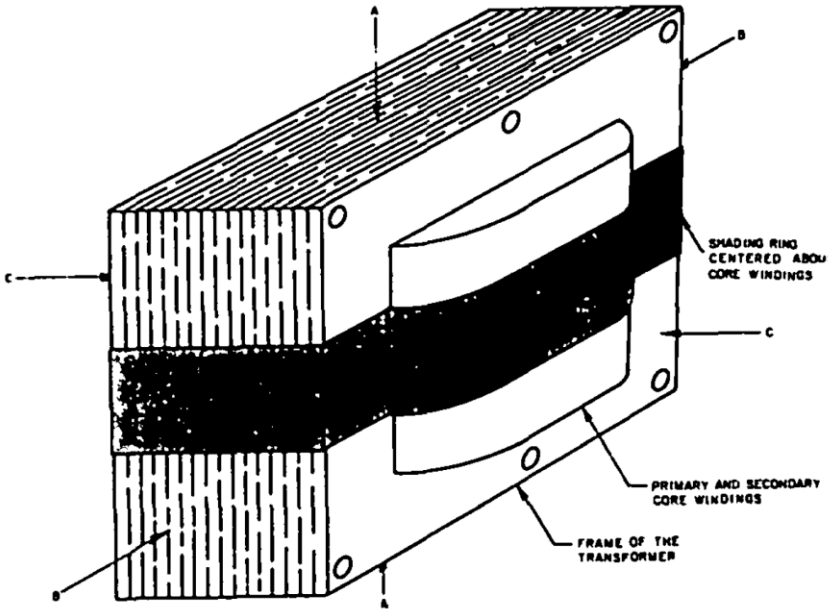
Characteristics of DM and CM Current

- Differential mode current is typically the "intended" or "functional" current that can be identified on schematics.
- Common mode current is an "unintended" current flow path that may not be known.
  - May be caused by conductive assemblies.
  - Parasitic capacitance can cause CM current.

Types of Power Supplies

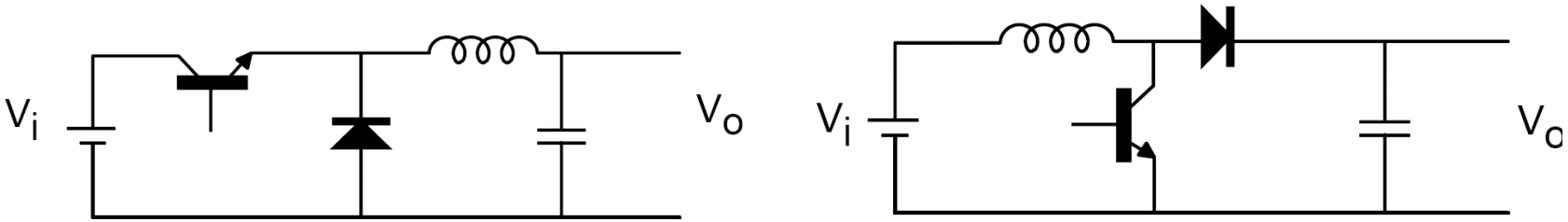
- Two (2) types of power supplies in use today.
  - Linear
  - Switch Mode Power Supply (SMPS)
- Each type has characteristic that can impact EMC performance.
  - Linear power supplies are inherently quieter with regard to EMC emissions due to the method used to generate the output power.
  - Switching power supplies can be effectively designed to meet EMC requirements

Linear Power Conversion



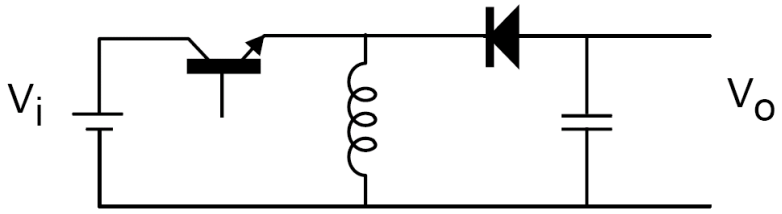
- Key to the power supply is the conventional transformer.
- Operation is based upon conversion of the primary power sine wave into output voltage and current.

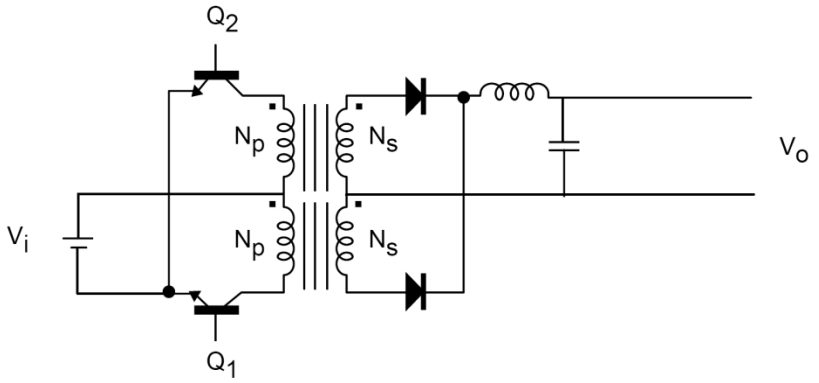
Common Types of SMPS – part 1



- The circuit on the left is known as a "Buck Converter". It interrupts the input current and then filters the output, the output voltage is dependent on the duty cycle of the switching.
- On the right is a "Boost Converter" – this can provide a step-up voltage conversion.

Common Types of SMPS – part 2



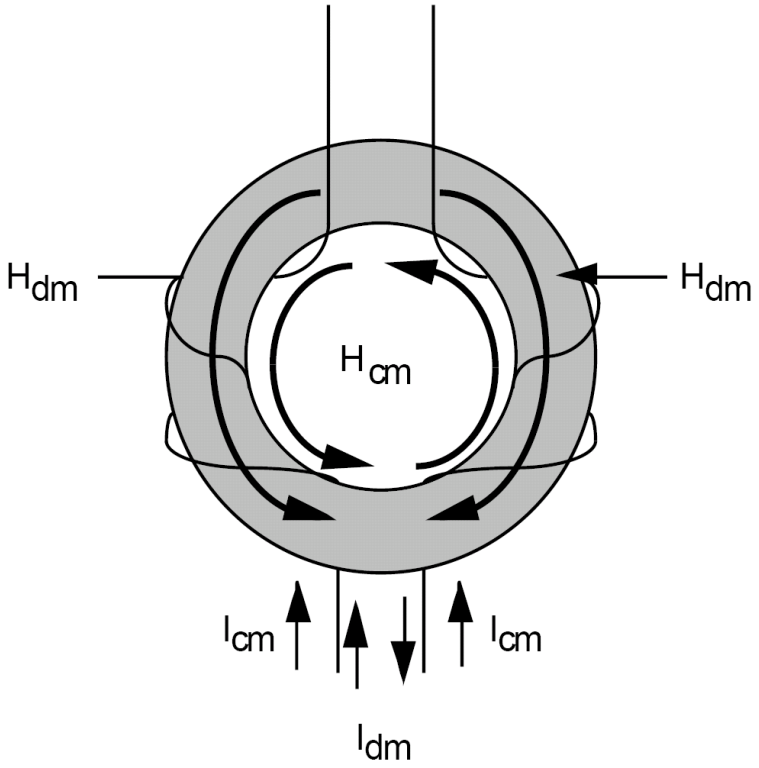


- On the left is a "Buck-boost" converter. This combines the buck and boost methods.
- The circuit on the right shows a "Push-Pull" converter.
  - This uses transistors to perform the switching actions.
  - Has reduced current through the diodes compared to other designs.

Operation of SMPS

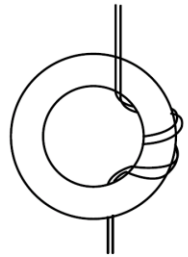
- Typical SMPS in use today are using switching frequencies from 100’s of kHz to 1 MHz.
- Can have very high efficiency at the higher frequency.
- CE issues also increase due to the currents that may flow due to the very efficient capacitive coupling at the high frequency.

Addressing Common Mode CE

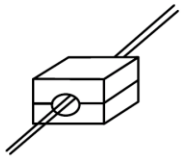


- In-line inductor can be incorporated to suppress CM current and not affect DM current.
- Magnetic flux created by DM current on each conductor causes cancellation of field.

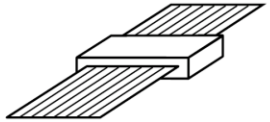
Typical CM Chokes



Multi Turn
Common Mode
Choke



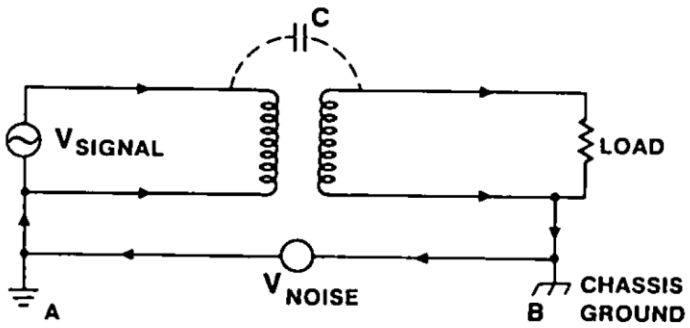
Single Turn
Common Mode
Choke

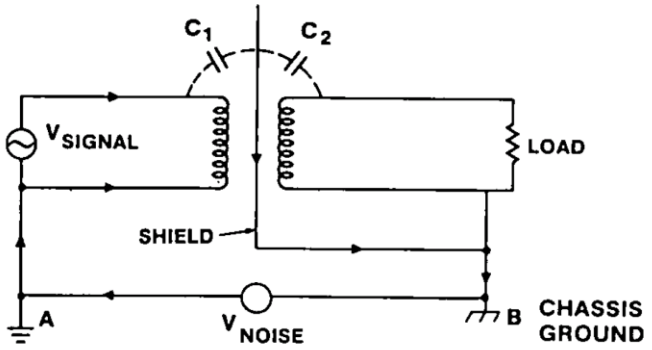


Single Turn
Common Mode
Choke Over
Ribbon Cable

- Consists of toroids, cylinders, or rectangles made from ferrite material.
- Frequently used to enable component to pass CE requirements without circuit modifications.

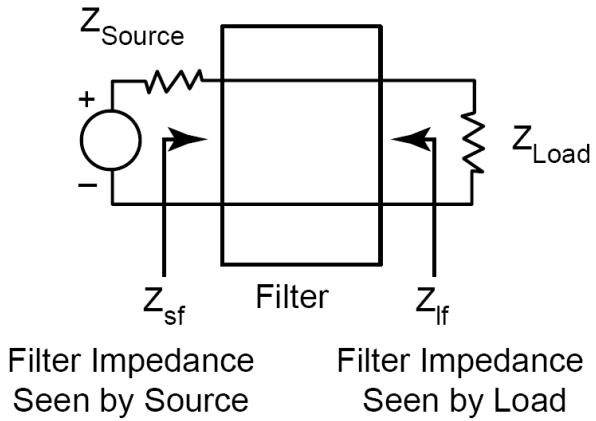
Additional Filtering Methods





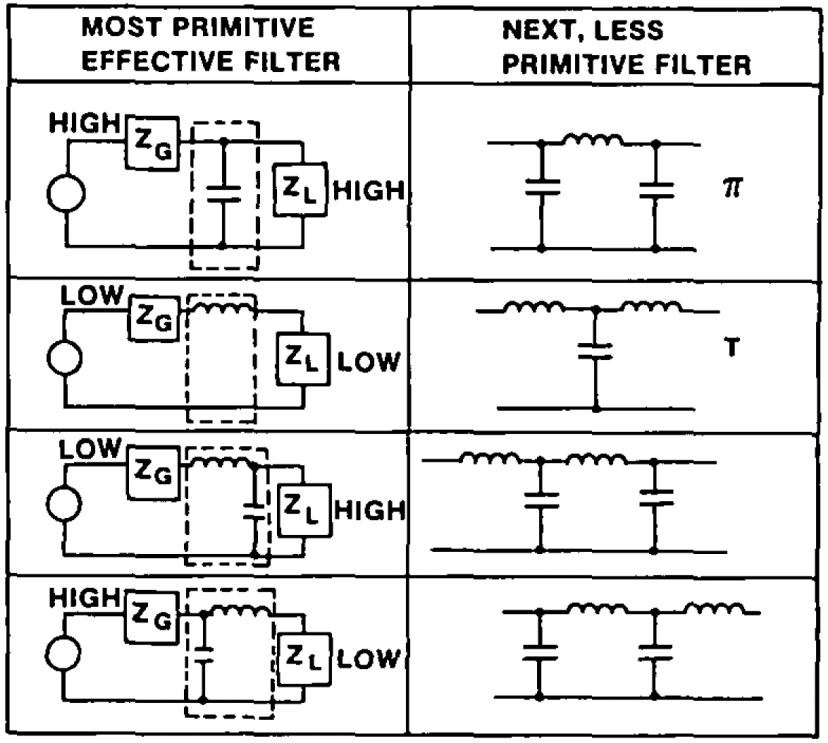
- CE can be caused by parasitic capacitive coupling between the primary and secondary of transformers used in power supplies.
- One way to eliminate this is to introduce an electrical field shield between the windings.

Power Supply Filter Theory



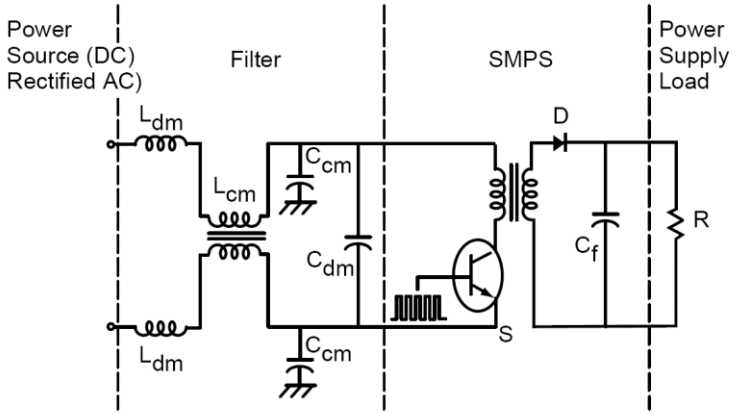
- Goal is to provide maximum suppression of conducted noise.
- This can be accomplished by designing for a maximum impedance mismatch from the circuit to the filter. (High Z source – Low Z input to filter.)

DM Suppression Methods



- Can be used when CE is caused by DM noise current.
- Typically consist of series inductance and parallel capacitance.
- Can be designed to have minimal impact upon desired current.

Controlling SMPS CE



- Incorporation of “X” and “Y” capacitors in the input filter design can address CE caused by DM current.
- Cdm = “X” capacitor, Ccm= “Y” capacitor

Summary

- Conducted Emissions (CE) are caused by noise on wires or conductive assemblies.
- Regulations define the maximum levels of CE that are permitted.
- Differential mode (DM) and Common mode (CM) current can cause CE.
- Power supply filtering can determine the ability to meet CE requirements.