Common Mode Noise

Noise in electronics

- noise is a random or undesired fluctuation in an electrical signal
- Conducted
  - Through circuitry, cables and components
- Radiated
  - EMI Coupled into circuitry through the air
    - To cables, PCB traces and components
- Differential (Normal Mode)
  - Between the feed and return for signal and power supply lines
- Common mode
  - Between the signal and power line and a common return path (chassis, shields and earth ground)
Impact of Common Mode Noise

- CMN can create EMI issues
  - Radiated and or conducted emission at system level
  - Results in circuit malfunctions
  - Interfere with measurement of sensitive circuitry and sensors
  - Coupled through AC line transients resulting in system malfunction.
  - Increases system level filtering requirements
Noise Path

Differential mode noise current is returned to the source through the return conductor for the signal or power.

Common mode noise current is returned to the source through a different path from the normal signal or power path, examples: chassis or earth ground, adjacent conductors. This is possible due to impedances to that conductor.
Sources of Noise from Power Supplies

- Predominately from switching power semiconductors.
- Coupled through parasitic impedances (capacitance, resistive or inductive)
- High dv/dt or di/dt present in SMPS
The switching nodes generate high dv/dt or di/dt. Dv/dt couples through capacitances and di/dt through magnetic field coupling. Generates noise currents which find their way back to the source.
Source of Noise

- SMPS can create both low frequencies (50/60Hz), medium frequency (~ 50-300KHZ) and high frequency (1MHz – 100’sHMZ) noise.
- Applications may be sensitive to a specific frequency or frequency range.
- Power Line Frequency
  - Coupled through primary to secondary isolation transformer and filter capacitors.
    - Class I AC input vs. Class II, consideration
      - Class II does not have a ground reference in the power supply.
Implications of Noise Source Frequency and Impedance

- **High impedance to ground in the end application -> higher CMN**
  - Lack of ground node to couple noise back to source
    - Results in noise current in end application
      - Through parasitic capacitance
        - Most noticeable in high impedance sensor application
    - Reduce primary to secondary coupling (capacitance)
    - Class I AC (earth ground connection) input can help
Why

- Power Supply Output CMN is typically not specified
  - Conflicting requirements
    - Floating/Isolated outputs vs. grounded outputs
    - Low leakage currents (medical and instrumentation apps)
- Most/many application do not have issues with CMN
  - Or are managed at the system level
- Customers do not typically specify CMN
  - Lack of understanding of issue or how to specify
- To Change the norm – need to specify what is required
Measurement Methods

- Understanding noise content helps
  - Determine which frequencies are the problem
    - Leads to mitigation choices

- High Frequency noise
  - Can be difficult to accurately measure
    - RF coupling
    - Use short leads
  - Noise with Low and High Frequency content (Mains Freq. & Switching Freq.)
    - Use low pass filter to measure only low frequencies
    - Use high pass filter to block low frequencies and measure only high frequencies.

- High Impedance circuits may need special high impedance probes
  - Measurement probes can load the noise source and reduce the measured noise level.

- When using a programmable AC source:
  - connect one of the AC outputs to ground (forms the Neutral) to reflect real world utilities, Neutral and Line feeds.
Low vs. High Frequency Noise Measurement Technique

Low Pass Filter for Low Frequency noise measurement
- Use when high frequency obscures low frequency noise
  - R-C filter, $f_c = \frac{1}{2\pi RC}$

High Pass Filter for block low frequency noise
- Use to measure high frequency noise
  - R-C filter, $f_c = \frac{1}{2\pi RC}$
CMN Measurement Methods

- **Open Circuit Voltage**
  - Measure output to earth/system ground
    - Can use an oscilloscope
    - Also spectrum analyzer but input impedance will load down the measurement point. Consider AC coupling.

- **Short Circuit Current**
  - Use an oscilloscope or spectrum analyzer and current probe to measure current through a short jumper wire from output return to chassis or earth ground.
Oscilloscope and RF Current Probe used to measure Common Mode current from output to earth ground
Common Mode Noise Measurements

CM current using a Tektronix P6022A 1mA/mV

High Freq. CM voltage using a Tektronix P6138A voltage probe

Low Freq. CM voltage using a Tektronix P6138A voltage probe

Note: 3KHz Low pass and high pass filters used for voltage measurements.
CM Noise vs. AC Line Voltage

CM current at 120VAC

CM Voltage at 120VAC

CM current at 240VAC

CM Voltage at 240VAC
Common Mode Noise Mitigation

- Use ferrite material to help impede noise path
- Couple noise back to source as close to noise source as possible
  - Caps across power supply input to electronics
  - Caps from return and feed lines to chassis/system ground
    - Select caps with appropriate resonant impedance
- Be careful not to create resonance between the source and load filter components

**Series RLC Filter**

- Resonant Freq.: \( f_{res} = \frac{1}{2\pi\sqrt{LC}} \)
- Damping Factor: \( \zeta = \frac{R}{2\sqrt{LC}} \)
Common Mode Noise Mitigation

- Minimize capacitive coupling between noisy signals
  - Separate power and signal lines
  - Shield noisy cables
- Minimize $dv/dt$
  - Ground output return to chassis/earth ground near power supply if possible
  - Shunt noise to power supply chassis near power output.
- Decouple noise from source to load
  - Add common mode inductor or ferrite core on power cables
    - Select Ferrite material that have high impedance in the offending frequency range
- Shield noise source from sensitive circuitry
- Select Power Supplies with acceptable CMN.
Summary

- Common Mode Noise is present in power systems and can cause interference issues
- Impact depends on the application
- Measure to understand the source well
- Follow a structured approach to Mitigation methods: measure, understand, apply solutions.