Varney EMC Solutions
Electronic Design Services & EMC | EMI | Noise Consulting

General Guidance for Troubleshooting and Mitigating Conducted Emissions Interfering with Communications Protocols

High-frequency conducted noise can propagate along interconnecting wires or harnesses between PCBs in electronic systems. This noise may couple into communication interfaces, transceivers, or associated power/ground paths, leading to degraded signal integrity or errors across various protocols (e.g., CAN, RS-485, SPI, I^2C, Ethernet, or others).

Testing Methods to Identify and Quantify Conducted Noise

Use direct measurements of noise currents and voltages on interconnect paths and at the affected communication circuitry. These techniques follow standard conducted emissions practices (e.g., current-probe methods referenced in CISPR 25 or similar approaches in MIL-STD-461) and apply regardless of the noise source or specific protocol.

- Time-correlated functional monitoring Apply protocol-specific diagnostics where available (e.g., error counters, link status flags, CRC/frame errors, or bus analyzers) or general signal integrity checks (oscilloscope waveform observation, bit-error detection). Correlate disruptions or elevated error rates with periods of system operation or known switching activity.
- Conducted current measurements on the interconnect harness (primary method) Clamp a suitable current probe (such as a wideband probe covering at least 9 kHz–several hundred MHz) around the full wire bundle or on individual wires (power, ground returns, control, etc.) between the PCBs.
- Connect the probe to a spectrum analyzer (or EMI receiver) for frequency-domain spectra and to an oscilloscope for time-domain waveforms.
- Measure at multiple locations along the harness (near each PCB) to help localize noise sources or propagation.
- Capture both common-mode (probe around the entire bundle) and differential-mode content where practical.
- Look for elevated broadband or peaked noise across relevant frequency ranges.
- Voltage probing on power, ground, and communication signal lines Use high-bandwidth differential or single-ended probes at the connector entry on the affected PCB or directly at transceiver/power pins for the communication interfaces. Capture HF transients, ripple, or common-mode voltage shifts.
- Common-mode vs. differential-mode analysis on communication links Measure CM currents/voltages on communication cables or harness sections versus differential content on pairs or single-ended lines. Differential protocols can be vulnerable to CM noise exceeding transceiver common-mode range or reducing noise margin.

- Spectrum analysis setup Use peak and average detection with appropriate resolution bandwidth (e.g., 9 kHz or 120 kHz). Span from ~150 kHz to well above 1GHz as needed. Employ max-hold, triggered, or continuous acquisition during normal operation or suspected noisy periods to characterize the conducted emission spectrum. Compare results before and after changes.

Configuration sweeps for isolation

- Temporarily add clip-on ferrites, simple filters, or shielding on specific wires or harness sections and re-evaluate both conducted noise levels and communication stability/integrity.
- Vary harness routing, bundling, or grounding/bonding between the PCBs.
- Route communication cables separately or add temporary shielding/ferrites and compare performance.
- Test under different operating conditions to identify factors that increase conducted noise coupling.
- These measurements help identify dominant conducted noise paths on the interconnect and verify the effectiveness of mitigations.

Recommended Fixes Targeting Conducted Emissions Paths

Implement layered mitigations beginning with the interconnect harness (primary propagation path) and extending to the communication interfaces. These practices provide broad protection against conducted emissions for any protocol.

- Pi-section filters on interconnect wires (high-priority mitigation) Install symmetric pi low-pass filters on wires entering the affected PCB from the other PCB. Place components as close as possible to the connector/entry point with short, low-inductance ground returns for the shunt capacitors.
- Target a cutoff frequency well below typical problematic conducted noise frequencies (e.g., ~10 MHz) to achieve strong attenuation at higher frequencies.
- For a nominal 50 Ω characteristic impedance: Series inductor L≈1.6" " μH, Each shunt capacitor C≈680" " pF(C0G/NP0 ceramic capacitors with appropriate voltage rating and high self-resonant frequency).
- Select inductors with sufficient current rating and low saturation risk for the expected wire currents.
- This directly attenuates conducted high-frequency noise before it reaches downstream circuitry, protecting all communication protocols. Common-mode chokes or ferrite beads can be used as alternatives or supplements depending on current and layout constraints.
- Communication interface hardening against conducted noise
- Add or verify common-mode chokes on differential pairs (beneficial for many protocols), located close to connectors or transceivers.

- Strengthen local power supply decoupling for communication transceivers (multiple low-ESL capacitors on relevant rails, placed immediately adjacent to the pins).
- PCB layout best practices: Maintain solid contiguous ground planes under transceivers and associated circuitry, minimize loop areas on communication traces, separate noisy and sensitive routing, and use dense via stitching to ground. Follow impedance control and layout guidelines appropriate to the signaling rates of the protocols.
- Grounding and bonding improvements Establish or enhance low-impedance, low-inductance ground connections (e.g., wide braid, multiple parallel conductors, or direct chassis bonding) between PCBs. This reduces common-impedance coupling and ground potential differences that facilitate conducted noise transfer.

Supporting system measures

- Optimize cable routing: Keep communication cables physically separated from noisy harnesses or power lines. Use shielded cabling with proper termination where suitable for the protocol and environment.
- Apply local filtering or decoupling at noise sources on the originating PCB where accessible.
- After changes, re-measure conducted noise levels on the harness using the current probe method and confirm improved communication performance with reduced error rates under relevant operating conditions.

These measures systematically address conducted noise propagation and coupling in systems with interconnect harnesses, offering robust protection for communications protocols.