TECHNICAL NOTE

RF Current Monitoring Probes for EMC/EMI Conducted Emissions Testing

Comprehensive Guide: Theory, Applications, and Industry Standards

Featuring Com-Power Corporation Current Probe Solutions

January 2026

1. Introduction

This technical note describes one of the most valuable tools in the EMC engineer's toolkit – the high-frequency (RF) current probe. Current probes are invaluable for measuring high-frequency common-mode (CM) currents flowing on wires or cables, making them essential for EMC compliance testing and troubleshooting.

Experience has proven that poorly terminated (bonded or filtered) cable shields are the number one cause for radiated emissions failures during EMC compliance testing. By measuring the CM currents (sometimes referred to as "antenna" currents) on these cables, it's possible to troubleshoot and apply fixes to a product right in the development lab.

Engineers can also predict, with good accuracy, whether a given cable current will pass or fail in the measurement chamber. This saves significant time and resources by enabling fixes before formal compliance testing.

2. Understanding Common-Mode Currents

Common-mode currents are not intuitive—current travels in the **same direction** through both the signal and signal-return wires in a cable or PC board. Due to finite impedance in system grounding, including circuit board signal/power return planes, there will be a voltage difference between any two points within that return plane or ground structure.

For example, simultaneous digital switching causes current peaks ("ground bounce") in the ground return plane, creating voltage drops which drive CM currents throughout the system. These CM currents propagate throughout common cabling or circuit traces and between circuits or sub-systems.

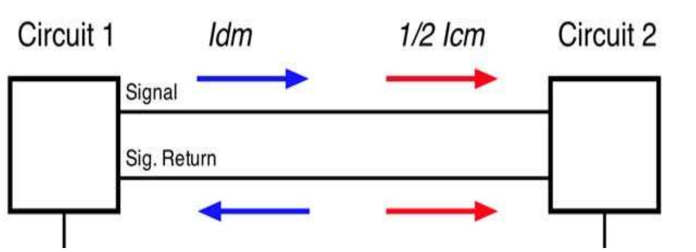


Figure 1: Digital signal currents depicted by differential mode (DM) currents (blue arrows). The undesired common mode (CM) currents (red arrows) arise from ground bounce and impedances in ground return planes.

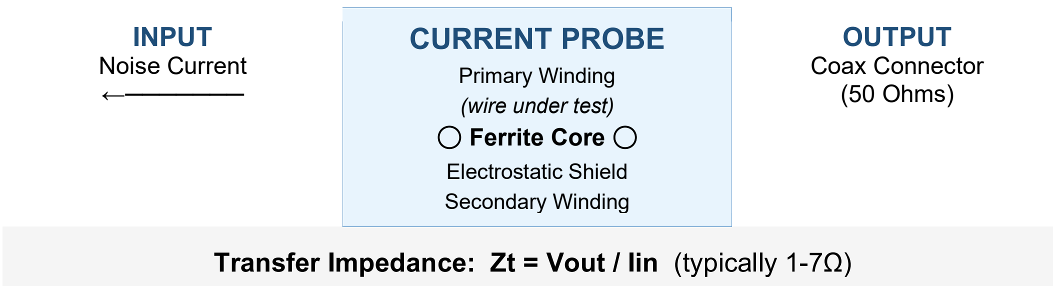
3. Current Probe Theory of Operation

3.1 Toroidal Transformer Theory

The RF current probe is an "inserted-primary" type of radio frequency current transformer. When the probe is clamped over the conductor or cable in which current is to be measured, the conductor forms the primary winding. The clamp-on feature enables easy placement around any conductor or cable—this is essentially a broadband high-frequency transformer.

The primary is considered as one turn since the CM currents flow through the conductor and return to the source via a return conductor such as a frame, common ground plane, or earth. On some current probe models, the secondary output terminals are resistively loaded internally to provide substantially constant transfer impedance over a wider frequency range.

Figure 2: RF Current Probe Structure



The probe contains a ferrite core with secondary windings that sense magnetic flux from RF currents in the primary conductor.

3.2 Transfer Impedance

Transfer impedance is simply the voltage at the probe port divided by the current in the measured wire or cable. The CM current (Ic) in microamps is determined from the probe output (V) in microvolts divided by the transfer impedance (Zt) in Ohms:

$$I_c = V / Z_t \quad \text{(in standard units)}$$

$$I_c(\text{dB}\mu\text{A}) = V(\text{dB}\mu\text{V}) - Z_t(\text{dB}\Omega) \quad \text{(in dB)}$$

For the Com-Power CLCE-400 probe with a transfer impedance of approximately 7Ω (+5 dBΩ), a 1 mA current will produce a 7 mV output voltage. **Note: It only takes 5 to 8 µA of high-frequency current to fail the FCC or CISPR Class B test limits.**

4. Current Probes vs. LISNs for Conducted Emissions

When assessing conducted emissions, engineers can choose between an RF current probe or a Line Impedance Stabilization Network (LISN). The choice depends on whether the goal is troubleshooting or formal compliance testing.

Parameter	RF Current Probe	LISN
Primary Use	Troubleshooting, diagnostics	Formal compliance testing
Measurement	CM only (or DM with routing)	Vector sum of CM + DM
Output	Current (converted via Zt)	Voltage (dBμV)
Setup Required	Minimal – clamp on cable	Ground plane, specific distances
Standards	Diagnostic tool	Required by CISPR, MIL-STD
LISN Type	N/A	5 μH (DC/Auto) or 50 μH (AC)

Table 1: Comparison of RF Current Probes and LISNs for EMC Testing

4.1 Key Differences

The LISN outputs a voltage that is the **vector sum** of both CM and DM currents, while the RF current probe normally measures only CM when clamped around a cable. If the power wiring is inserted into the probe aperture such that the differential currents add, then the DM measurement can be recorded. A current probe can measure either CM or DM, but not both together.

5. Measurement Techniques

5.1 Measuring Common-Mode Currents

To measure common-mode cable currents (including power cables), simply snap the current probe around the cable under test. It's good practice to slide the probe back and forth to maximize the harmonics—some frequencies will resonate in different places due to standing waves on the cable.

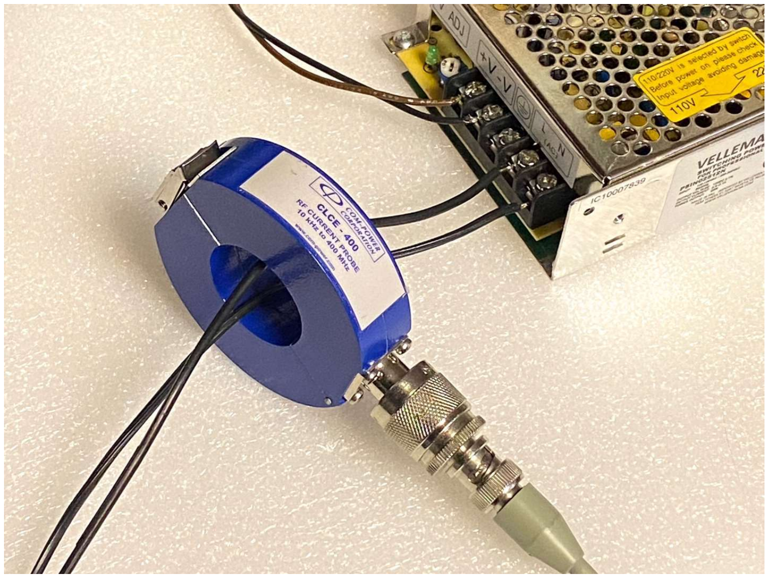


Figure 3: When both mains wires pass through the probe aperture together, you measure common-mode harmonic emissions.

5.2 Measuring Differential-Mode Currents

A standard RF current probe can also measure DM currents by routing the power wiring differently through the aperture. By looping one side of the mains in the opposite direction, the common-mode currents cancel and you measure twice the differential-mode current (a 6-dB increase).

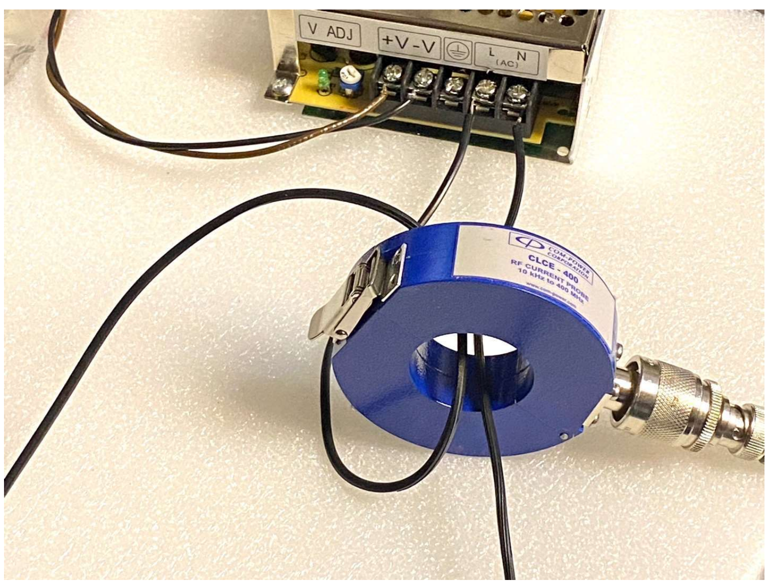


Figure 4: By looping one conductor in the opposite direction through the aperture, CM currents cancel and you measure 2× the DM current.

6. Industry Standard Test Setups

6.1 CISPR 11/32 Conducted Emissions

Conducted emissions testing for industrial, scientific, commercial, consumer and medical products is performed according to CISPR 11 or 32. This requires a 50 μH LISN between the AC (or DC) line voltage source and the product under test. Frequencies are tested from 150 kHz to 30 MHz using average or quasi-peak detection.

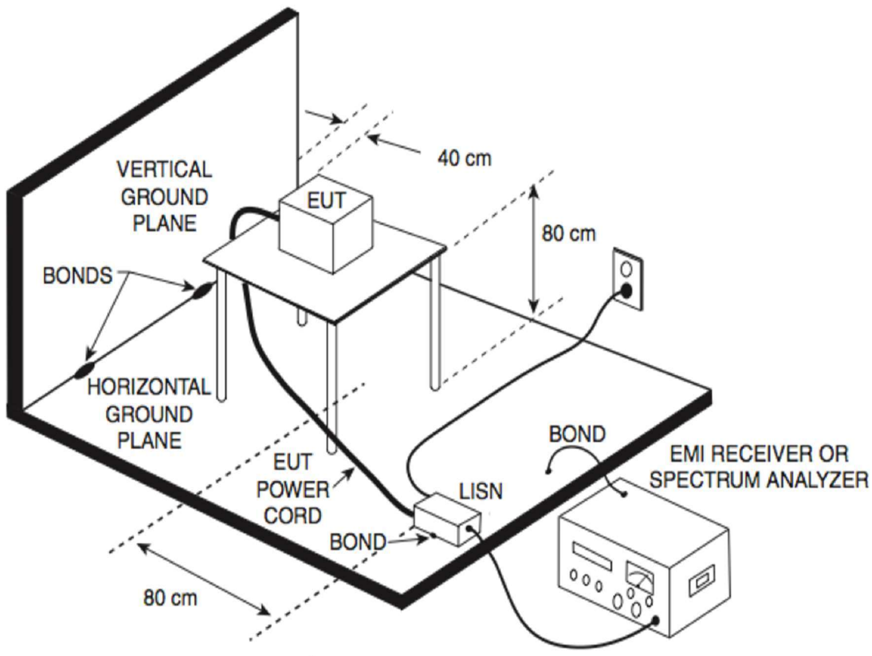


Figure 5: Basic test setup for CISPR 11/32 conducted emissions. The EUT is positioned 40 cm from the vertical ground plane and 80 cm from the horizontal plane edge.

6.2 CISPR 25 Automotive Testing

For automotive testing of components, modules, or systems according to CISPR 25, a 5 μH LISN is used. A metal tabletop and specific cable arrangement is required. Automotive manufacturers often have their own specific standards and limits based on CISPR 25.

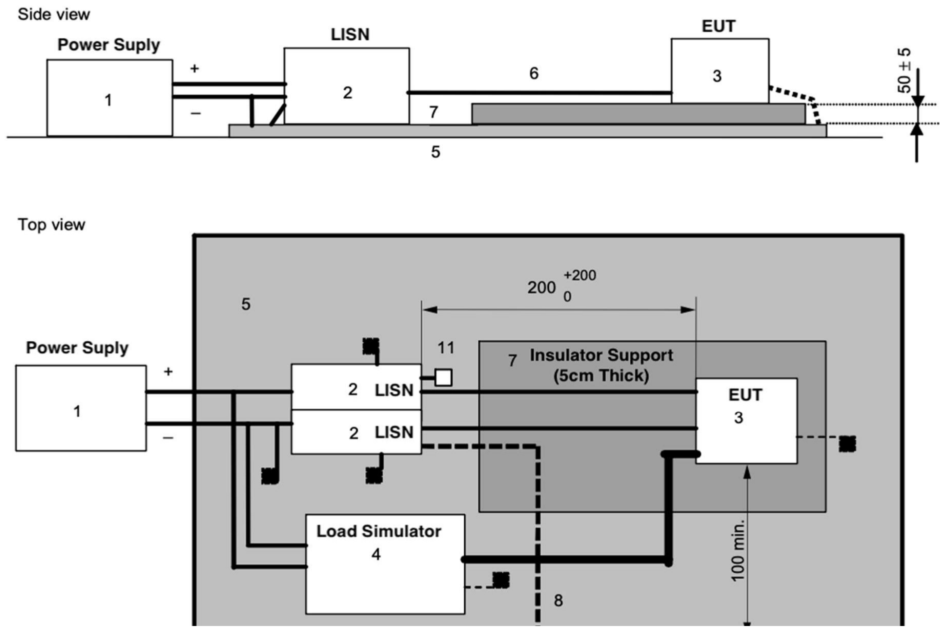


Figure 6: General test setup for CISPR 25 automotive conducted emissions testing.

6.3 MIL-STD-461G CE102

The CE102 test setup per MIL-STD-461G uses a 50 µH LISN. Most military EMC tests simulate the installation environment, so testing is generally performed on a metal tabletop with the power cable running 5 cm above the metal plane and stretched to 2 m length. Frequencies are tested from 10 kHz to 10 MHz.

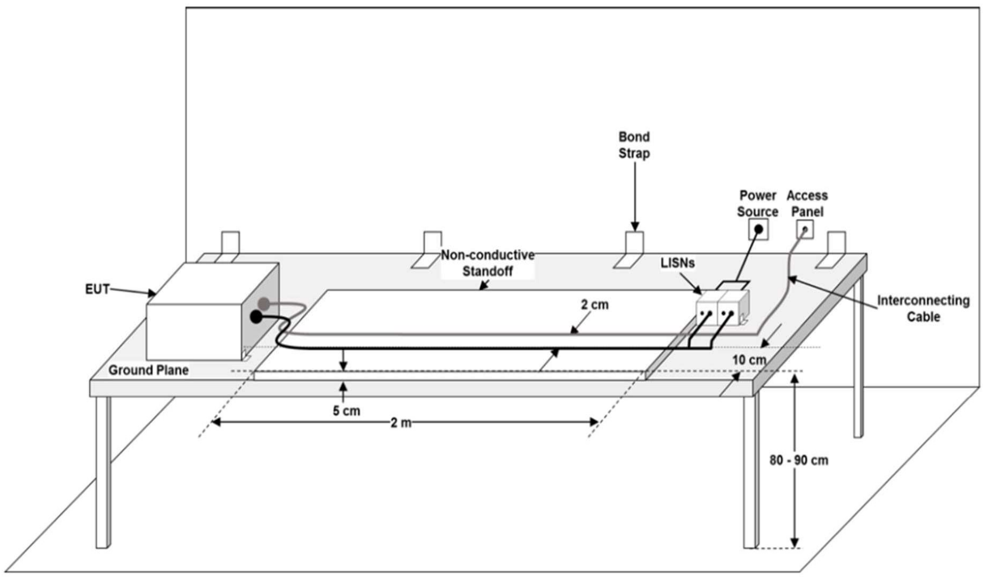


Figure 7: Test setup for CE102 conducted emissions per MIL-STD-461G, showing the metal ground plane, LISN positioning, and cable routing requirements.

7. Com-Power Current Probe Product Line

Com-Power Corporation manufactures a comprehensive range of RF current monitoring probes designed for EMC compliance testing. All models feature split-core design for clamp-on operation, Type-N female connectors, and NIST-traceable calibration.

Model	Freq. Range	Aperture	Max Current	Standards
CLCE-332	9 kHz – 300 MHz	32 mm	42 A @ 400 Hz	CISPR, MIL-STD-461, DO-160
CLCE-400	10 kHz – 400 MHz	32 mm	100 A @ 400 Hz	CISPR, MIL-STD-461, DO-160
CLCE-438	9 kHz – 400 MHz	38 mm	30 A @ 400 Hz	CISPR, MIL-STD-461, DO-160
CLCE-452	9 kHz – 400 MHz	52 mm	100 A @ 400 Hz	CISPR, MIL-STD-461, DO-160
CLCE-1032	9 kHz – 1 GHz	32 mm	135 A @ 400 Hz	CISPR, MIL-STD-461, DO-160
CLCE-252	9 kHz – 230 MHz	52 mm	200 A @ 400 Hz	CISPR, MIL-STD-461, DO-160

Table 2: Com-Power RF Current Probe Specifications

Figure 8: Com-Power CLCE-400 RF current probe measuring line cord common-mode harmonic emissions on a product under test.

8. EMC Troubleshooting Guide

8.1 Troubleshooting vs. Pre-Compliance Testing

General troubleshooting is usually performed with a current probe and spectrum analyzer or oscilloscope. The goal is to identify sources of RF harmonic currents in attached I/O or power cables and determine fixes that reduce emissions. For troubleshooting, engineers mainly look for relative changes.

Pre-compliance testing attempts to duplicate compliance test methods and compare with actual test limits. This requires copying the test setup used by compliance test labs and using a calibrated LISN.

8.2 Practical Troubleshooting Tips

1. Run a baseline plot on the analyzer using "Max Hold" mode (EUT off) to capture ambient noise floor.
2. Activate additional traces for "before" and "after" measurements with fixes applied.
3. Slide the current probe along cables to find resonance points where harmonics are maximized.
4. Identify the frequencies of the top several harmonics, then work backwards to identify sources.
5. Use the transfer impedance chart to calculate actual current at each harmonic frequency.

8.3 Bench Top Quick Testing

For quick bench top troubleshooting, place aluminum foil on the workbench, bond the LISN to it with copper tape, and place the EUT on top. This ground plane allows a path for common-mode currents to return to the LISN. While not a formal test setup, this will reveal any "red flags" before formal compliance testing.

9. Probe Calibration

Accurate calibration of RF current probes requires a calibration fixture. Com-Power offers calibration fixtures (e.g., FCLCE-1000) that maintain a 50Ω impedance. A 50Ω load is connected to the output port while a calibrated network analyzer is connected to the input port. The probe is clamped around the fixture and frequency is swept while measuring probe output.

Transfer impedance is plotted graphically: $Z_t(\text{dB}\Omega) = V(\text{dB}\mu\text{V}) - I_c(\text{dB}\mu\text{A})$. With a 50Ω system where the fixture produces a reference current, $Z_t(\text{dB}\Omega) = V(\text{dB}\mu\text{V}) - 73$.

10. Conclusion

Common-mode currents in I/O or power cables cause frequent EMC compliance test failures. The RF current probe is an essential tool for measuring these harmonic currents and is vital during the troubleshooting process. Poorly bonded cable connectors can be readily identified and fixed right at the designer's workbench, without the expense of a third-party test facility.

While the LISN provides the formal measurement method specified by standards, the current probe offers a complementary approach for troubleshooting and diagnostics. Com-Power Corporation offers a complete range of current probes, LISNs, and calibration fixtures to support all EMC testing requirements from troubleshooting through formal compliance.

11. References

6. Com-Power Corporation, "Using the RF Current Probe," Application Note.
7. Com-Power Corporation, "RF Current Probes versus LISNs for Assessing Conducted Emissions," Application Note.
8. U.S. Department of Defense, MIL-STD-461G: Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment, 2015.
9. RTCA, Inc., DO-160G: Environmental Conditions and Test Procedures for Airborne Equipment, Section 21: Emission of Radio Frequency Energy, 2010.
10. IEC CISPR 16-1-2: Specification for radio disturbance and immunity measuring apparatus and methods – Coupling devices for conducted disturbance measurements, 2014.
11. IEC CISPR 11: Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics, 2019.
12. IEC CISPR 25: Vehicles, boats and internal combustion engines – Radio disturbance characteristics, 2021.
13. Ott, H.W., "Electromagnetic Compatibility Engineering," John Wiley & Sons, 2009.
14. Paul, C.R., "Introduction to Electromagnetic Compatibility," 2nd Edition, Wiley Interscience, 2006.
15. Andre and Wyatt, "EMI Troubleshooting Cookbook for Product Designers," SciTech Publishing, 2014.