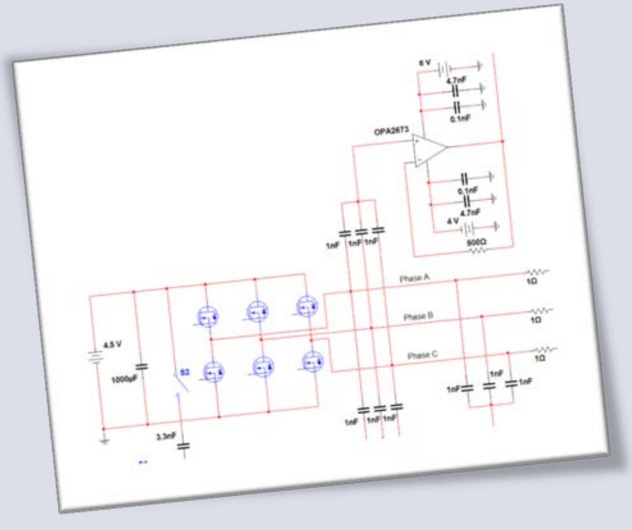
Methods for Reducing Emissions from Switching Power Circuits

A. McDowell, C. Zhu and T. Hubing

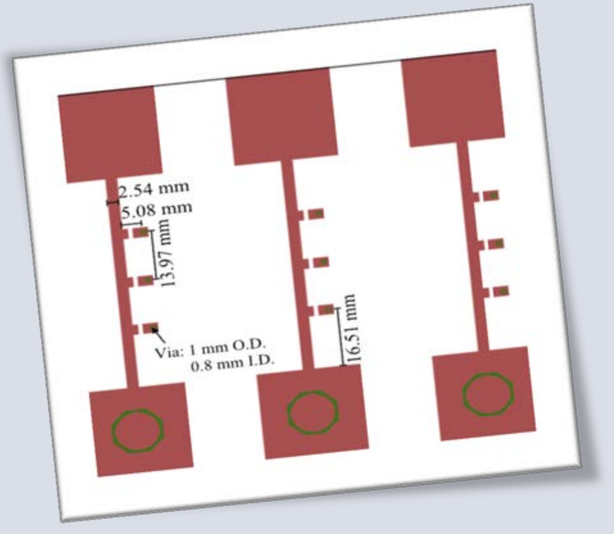
Objective

To reduce radiated emissions and other forms of interference from power inverter circuits, by eliminating or attenuating the common-mode currents on the attached cables.

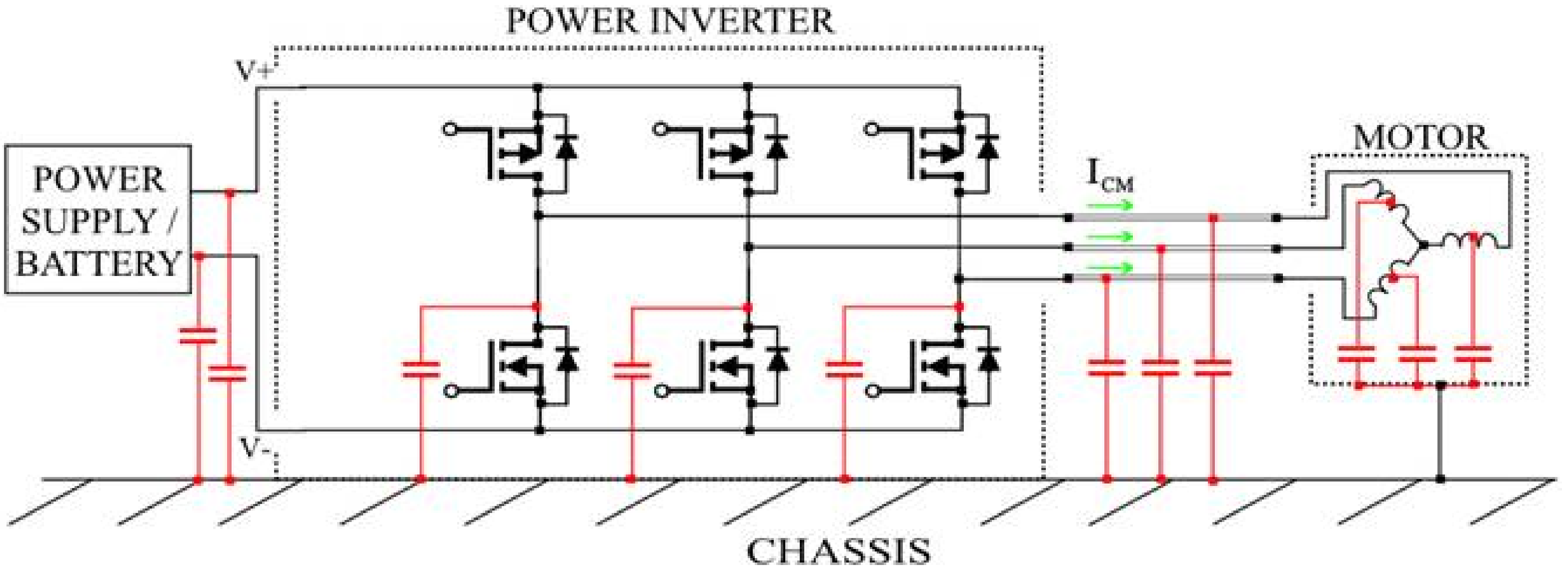
Through Active Cancellation of the CM Currents below 10 MHz



Through Intelligent Filtering/Balancing of the I/O above 10 MHz

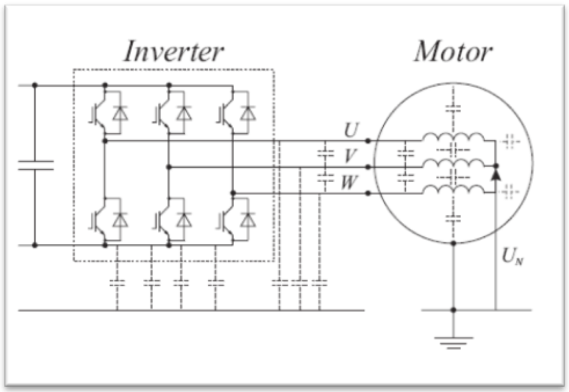


Common-Mode Sources



Common-Mode Sources

Common-Mode Current vs. Balanced Design



Imbalance arises from:

- ~~geometrical asymmetries~~ - unnecessary
- ~~unequal turn-on and turn-off times~~ – can compensate
- ~~unbalanced PWM control~~ – can use balanced method
- ~~unbalanced filtering~~ - unnecessary
- ~~switching device parasitics~~ – can compensate
- ~~imbalances in load impedance~~ – can compensate

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NSF I/UCRC for EMC - May 2010

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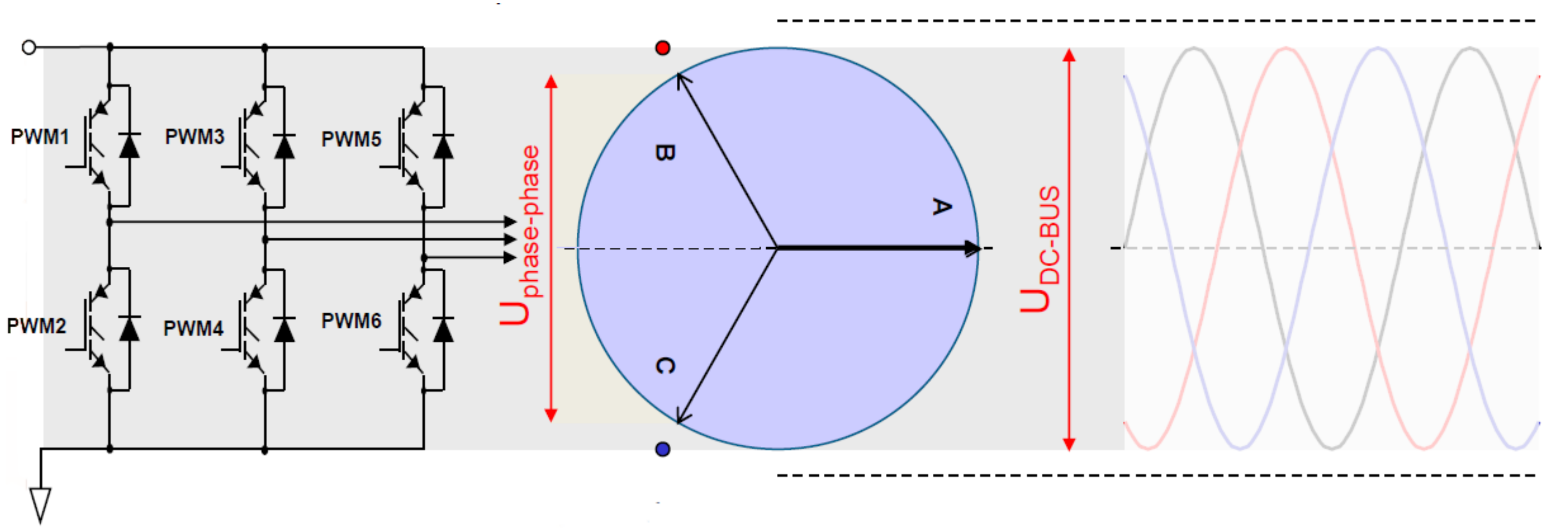
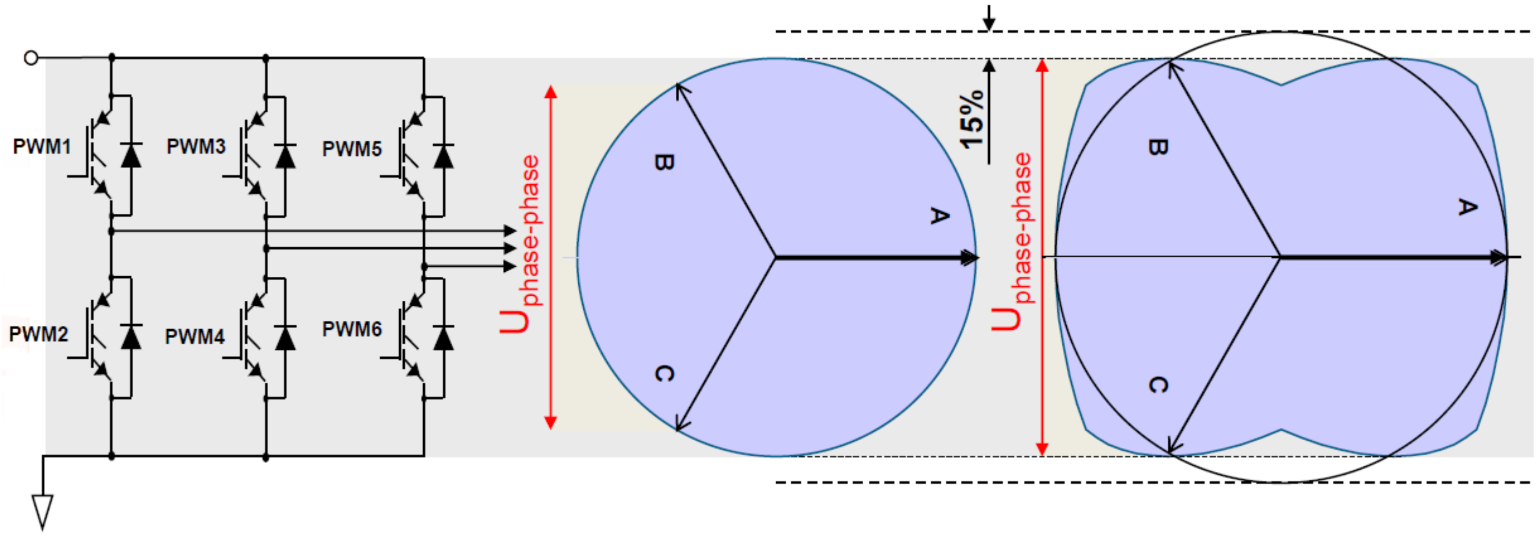
From May 2010 Center Meeting Presentation

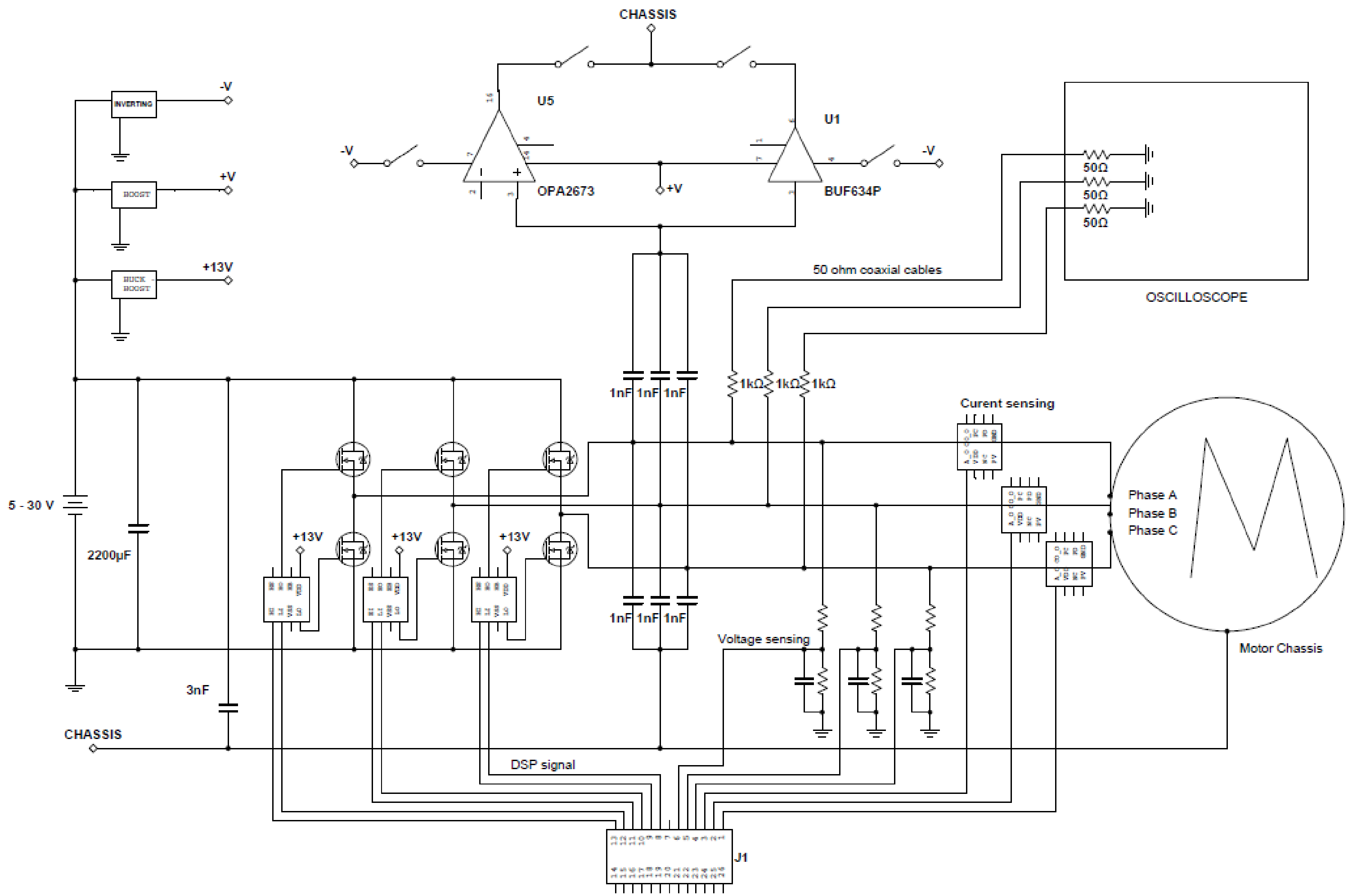
Yes, but…

Common-Mode Sources (State Variable Control)



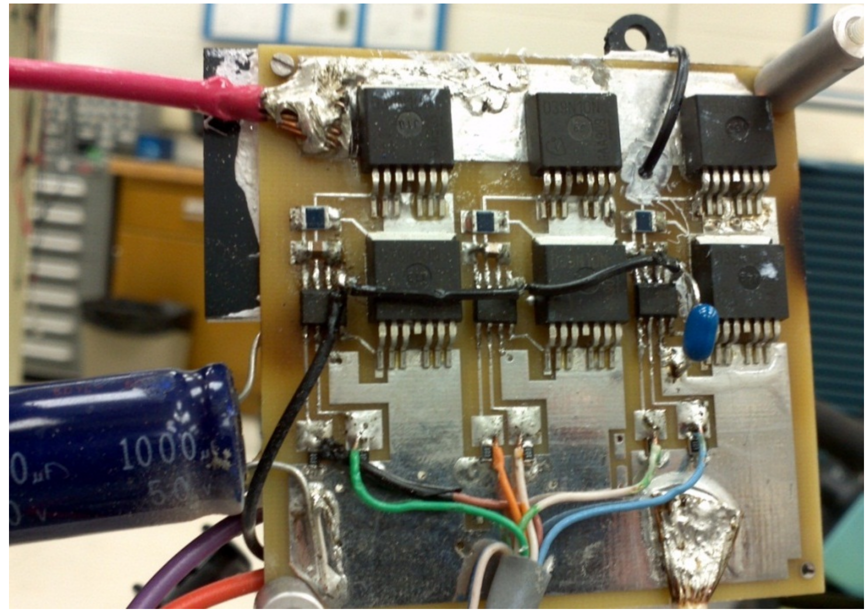


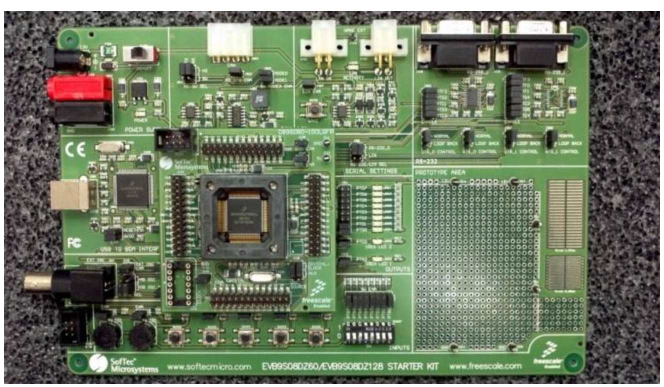
Active Cancellation



Active Cancellation

First-Pass Inverter circuit with active cancelation →

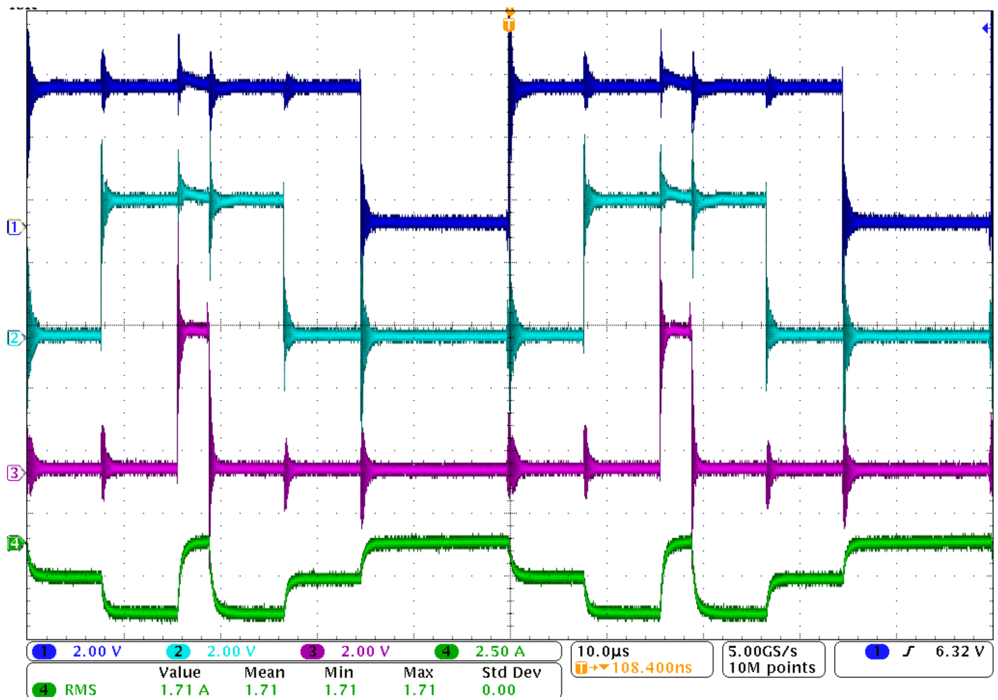




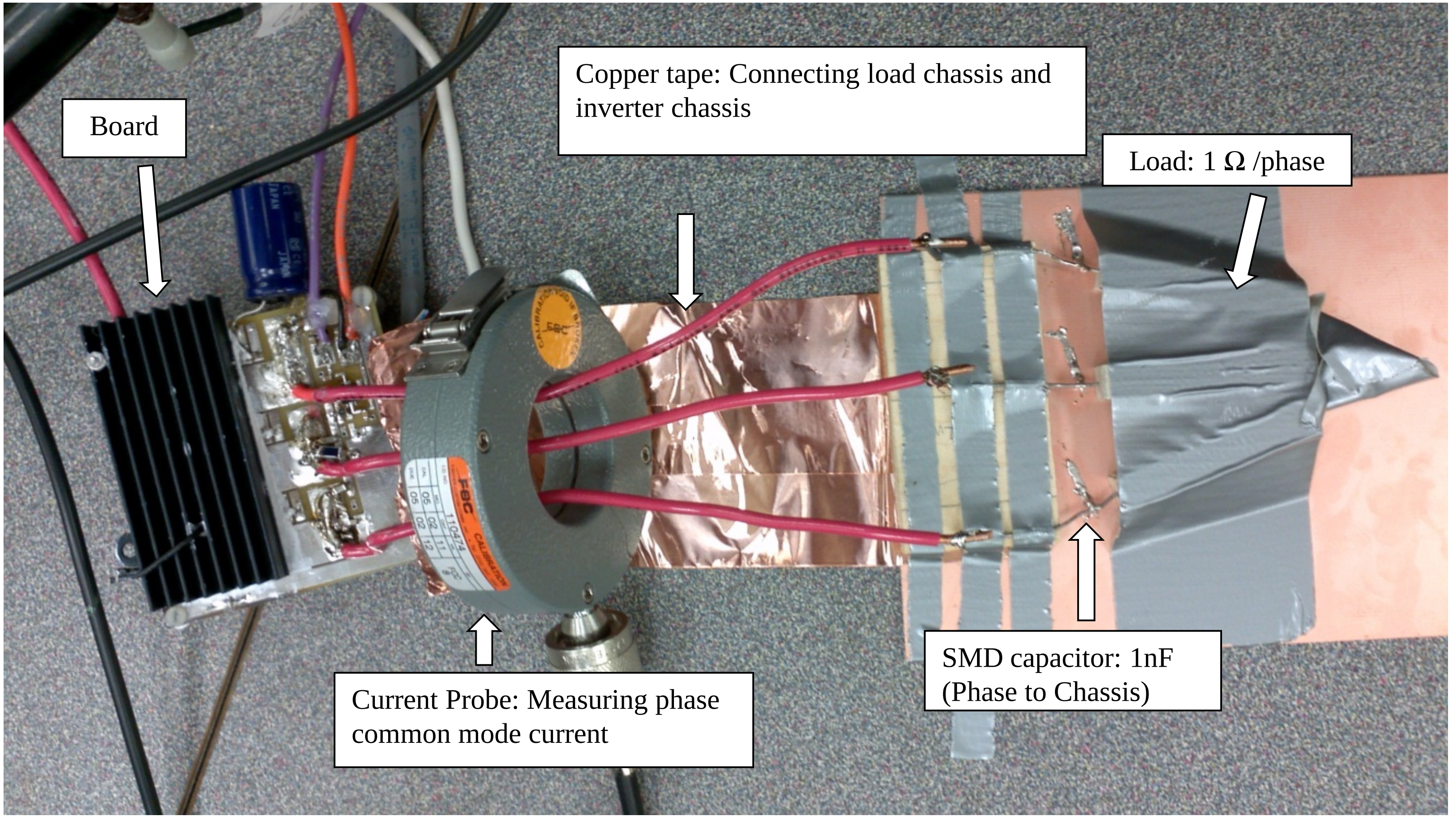
← Freescale board used to create SVC signals

Active Cancellation

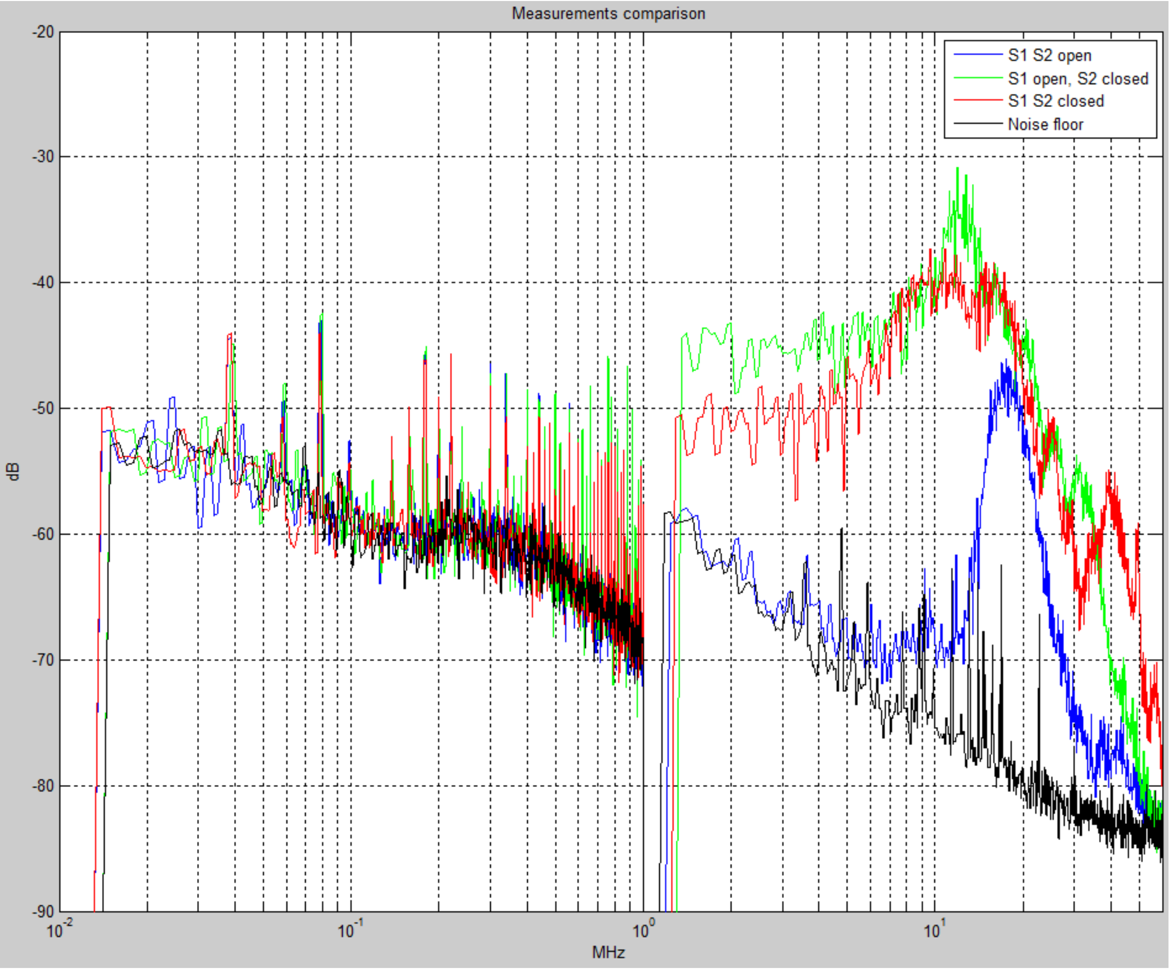
The measured phase voltages of the inverter circuit board under one of the programed drive schemes. The blue, cyan and purple curves represent Phase A, B and C to 0-volt ground voltages, respectively, and the green curve is the current in Phase A. Since the load is mainly resistive, the phase current is not as smooth as the one with motor connected. A high duty cycle was employed to achieve high phase current with a relatively low DC supply voltage.



Active Cancellation Measurement



Active Cancellation Measurement



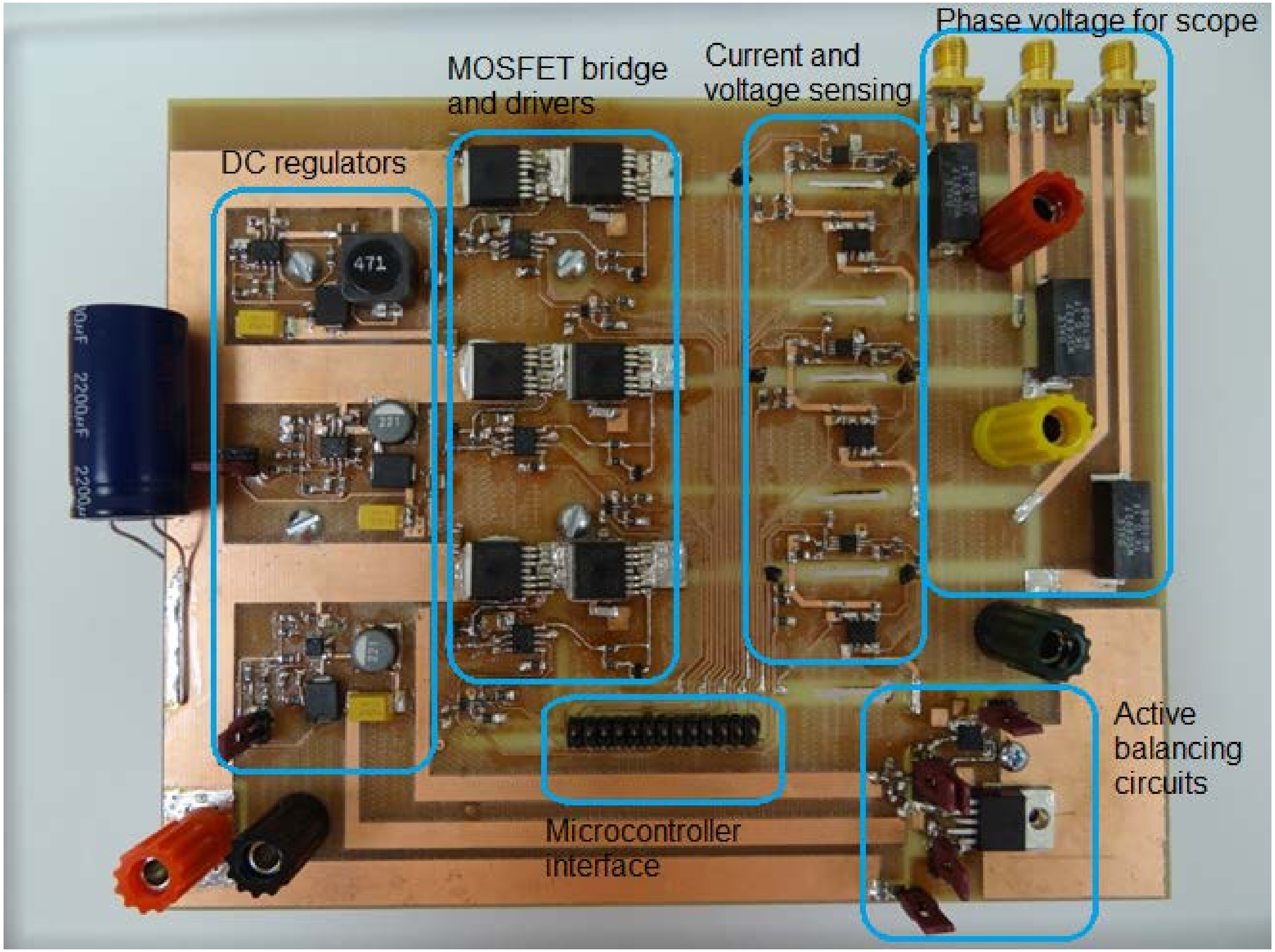
The blue curve exhibits the lowest common-mode current. It is obtained under the condition that there is no parasitic capacitance from the high-side MOSFET to the board chassis. This is the ideal situation as discussed in a previous technical report [1].

As soon as the parasitic capacitance was introduced by closing switch S2, the common-mode current increased tremendously as indicated by the green curve. This is the current situation in the CA6 inverter.

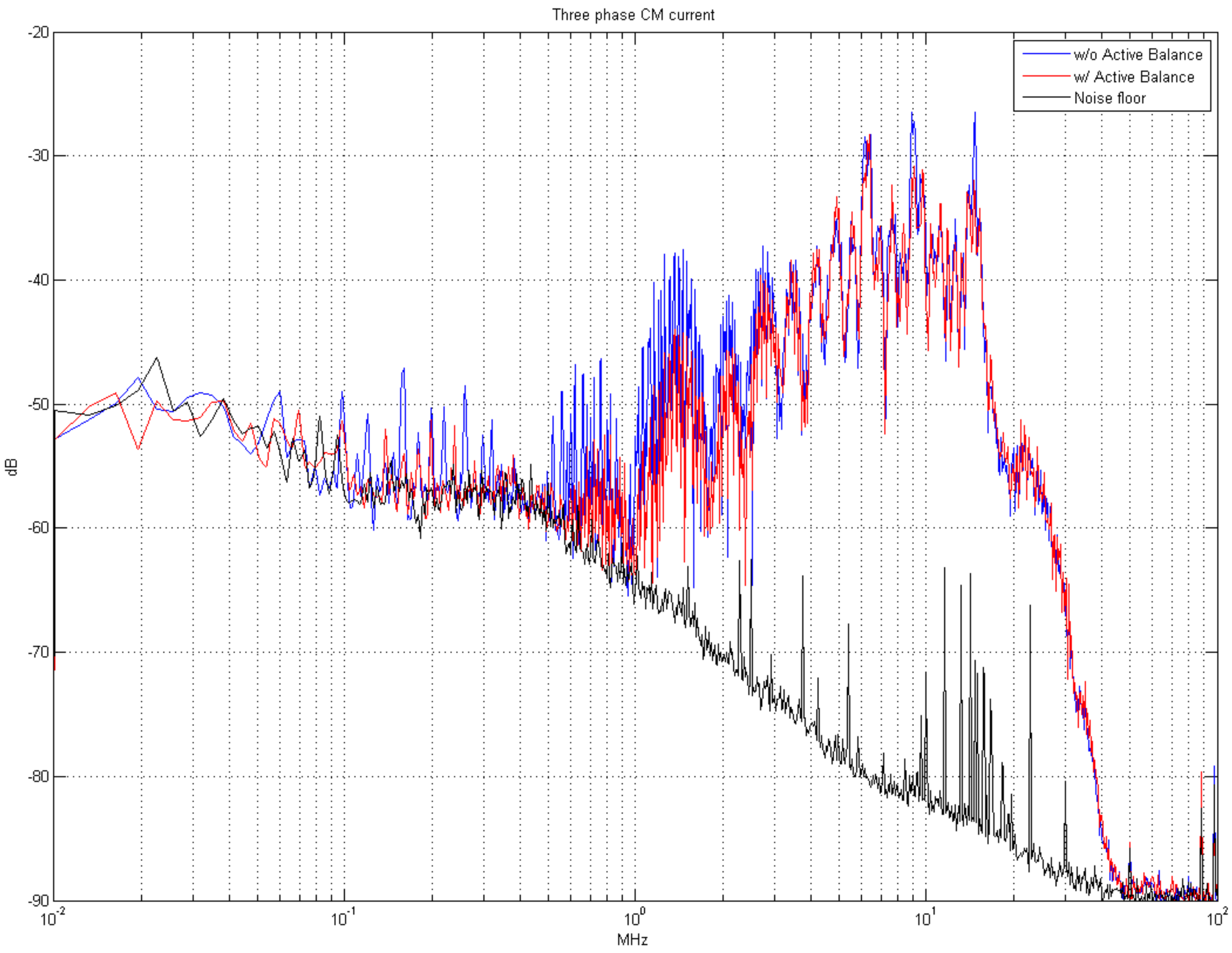
After applying the active balancing circuit by closing switch S1, the common-mode current below 12 MHz is reduced as much as 10 dB at the peak (red curve). However above 12 MHz, the active balancing circuit makes the noise worse. This is a problem which should be relatively easy to fix by filtering the op-amp input.

Active Cancellation Measurement

2nd-Pass Inverter circuit with active cancelation



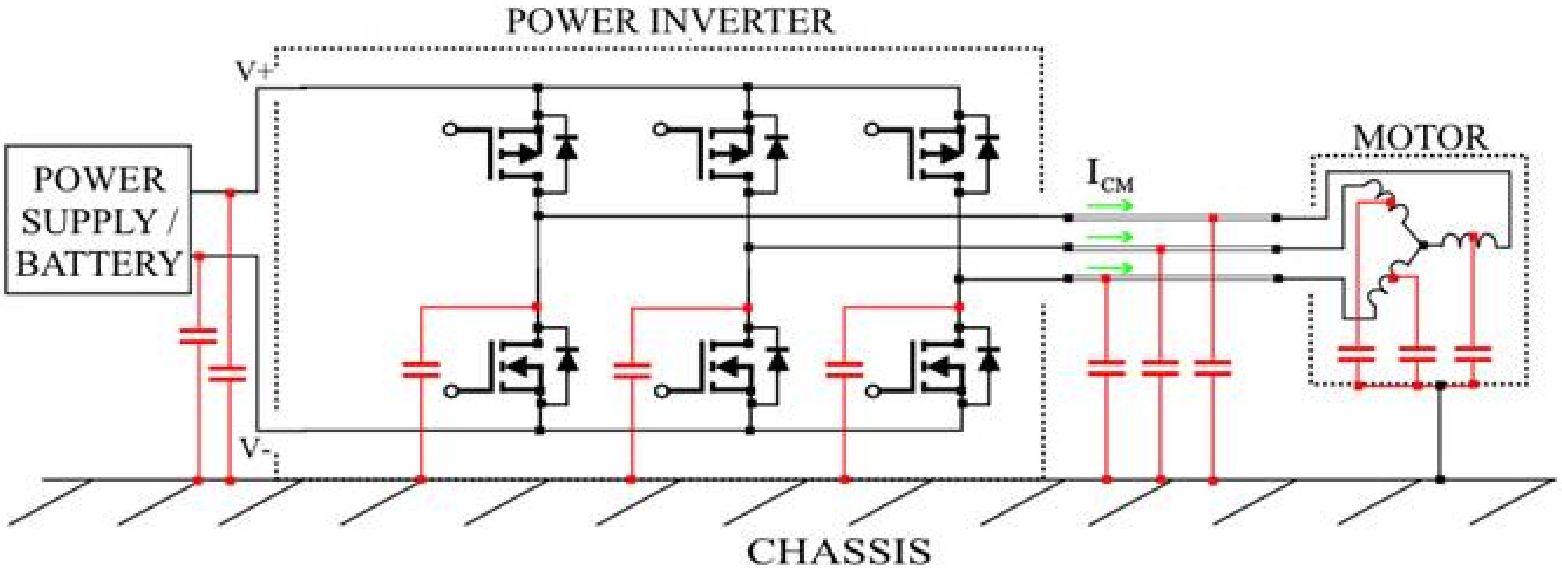
Active Cancellation Measurement



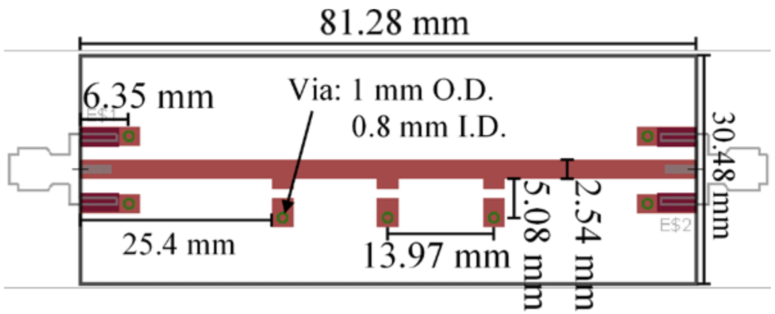
Active Cancellation Summary

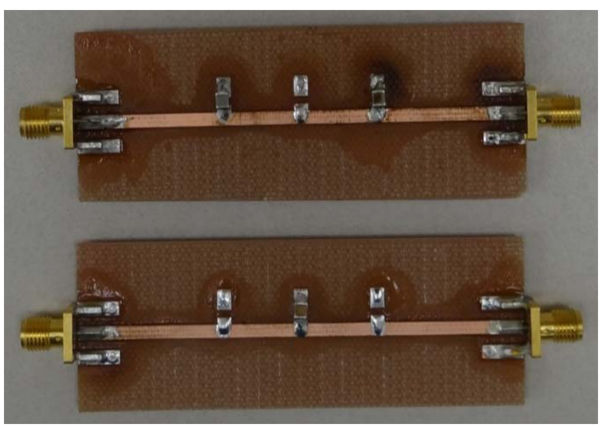
An active balancing circuit for a three-phase motor driver was designed to suppress the phase common-mode current. It actively compensates for the inherent imbalance caused by the SVPWM driving scheme by driving the 0-volt ground on the circuit board relative to the board chassis. A test circuit was constructed, tested and analyzed to demonstrate the effectiveness of the active balancing circuit. Results show as much as a 10-dB reduction in the common-mode current peaks between 10 kHz and 20 MHz.

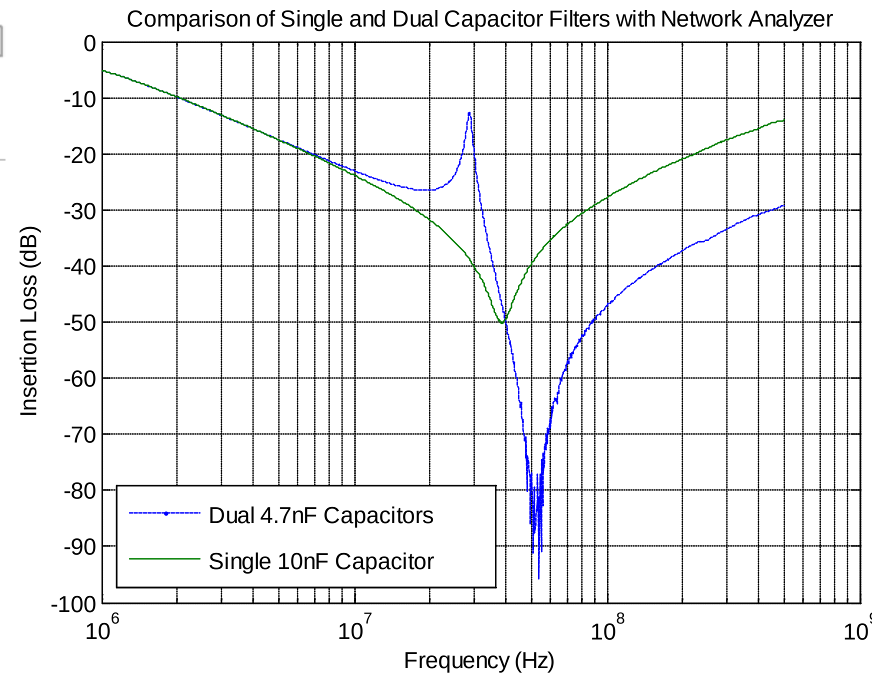
Intelligent Filtering



Intelligent Filtering

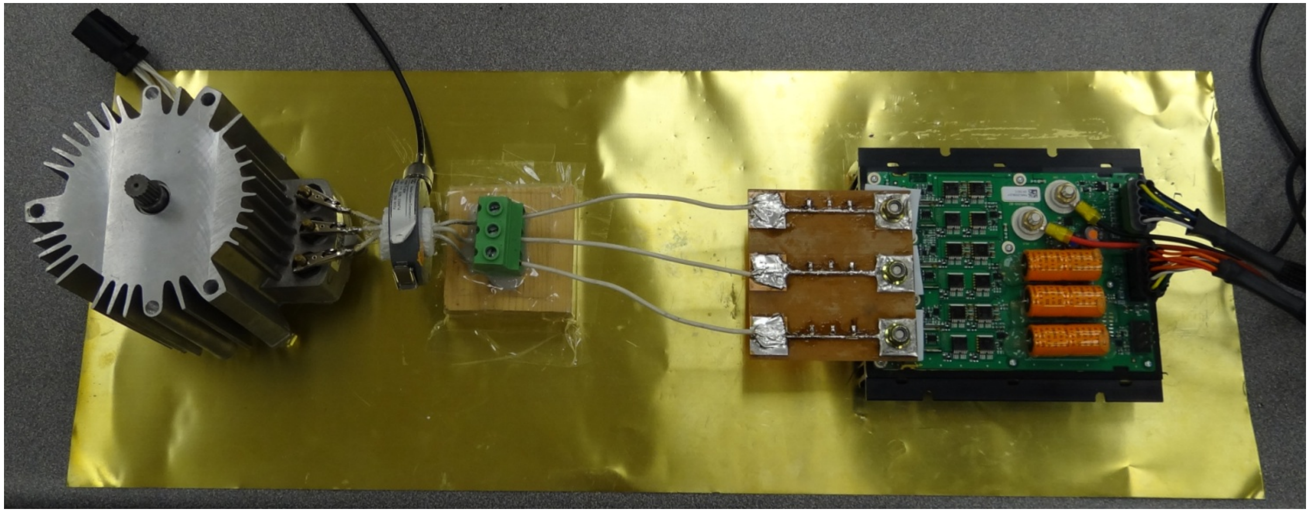




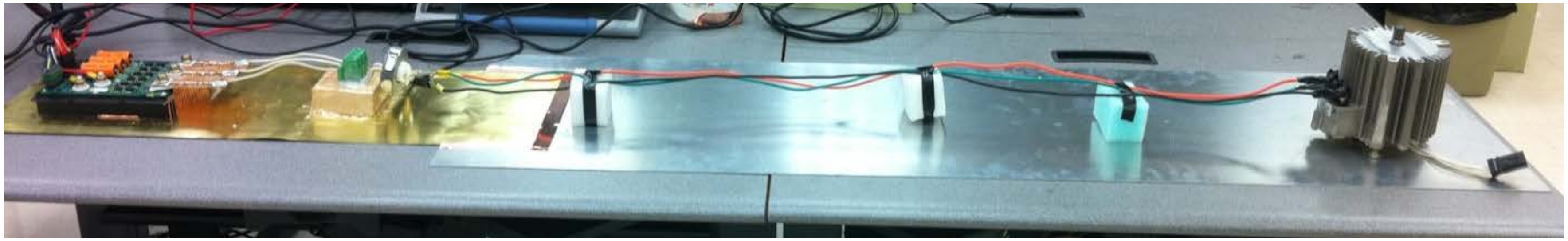


Intelligent Filtering

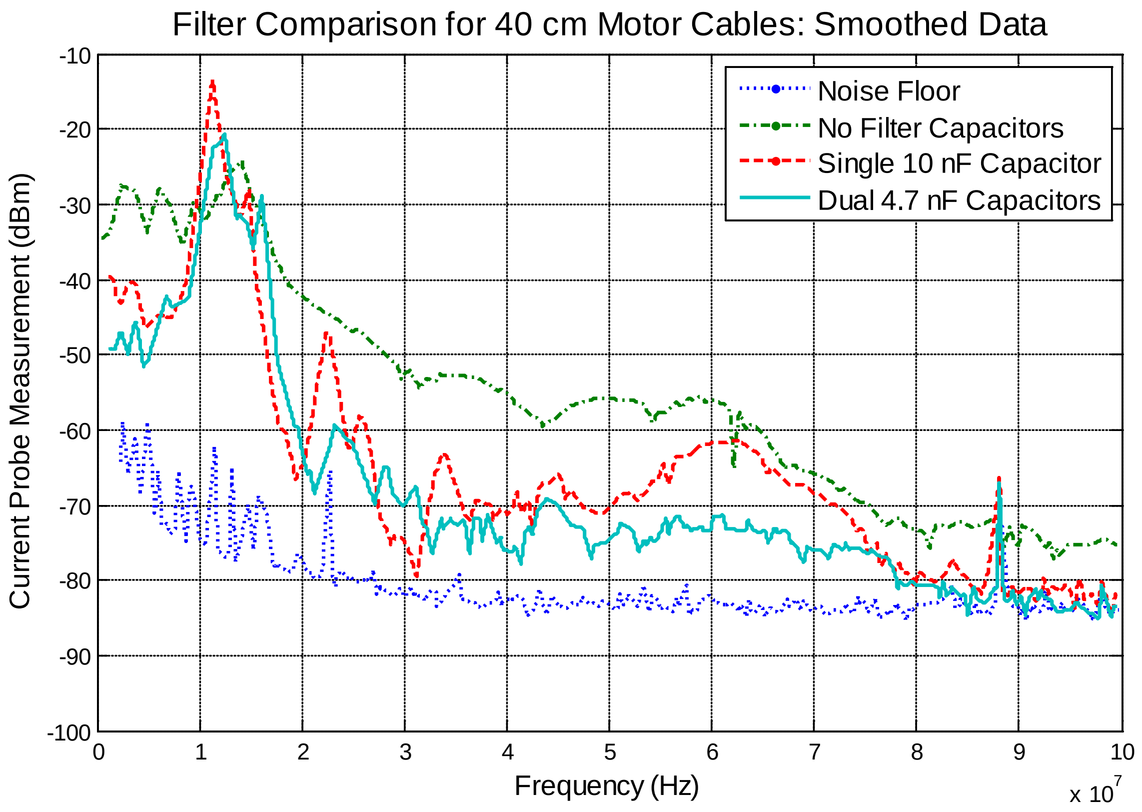
40-cm motor cables



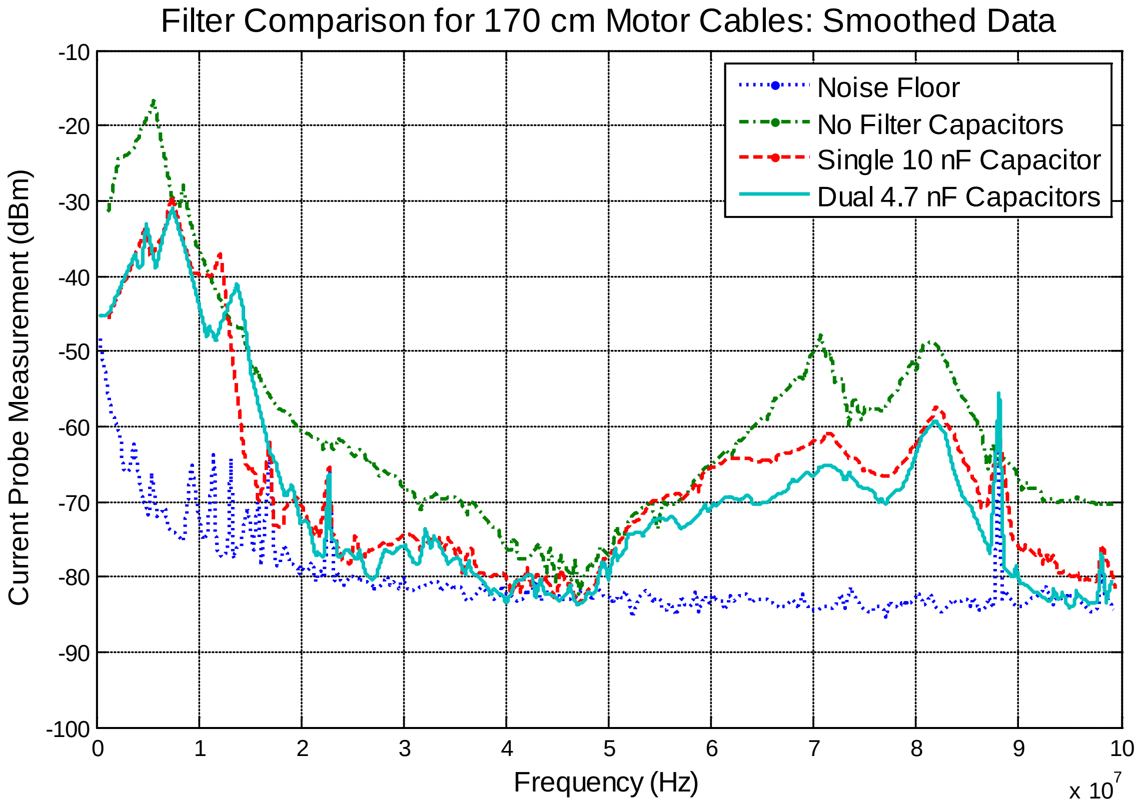
170-cm motor cables



Intelligent Filtering



Intelligent Filtering



Summary

- Active balancing circuits can be used to obtain significant reductions in the common-mode currents on cables attached to a power inverter at frequencies between 10 kHz and 20 MHz.

- Above 20 MHz, passive filtering using a dual-capacitor configuration significantly reduces common-mode currents.