Test Report: PMP22845

Isolated 5-V Bias Supply for Automotive CISPR 25, Class 5 Emissions, Reference Design

1 Description

This reference design demonstrates EMI mitigation techniques required for a high-frequency, reinforced 5-kV$_{RMS}$ isolated, 5-V bias DC/DC converter module to pass the automotive, CIPSR 25, class 5, EMC test standard. The design features a 500-mW, high-efficiency, bias supply with integrated transformer, control and power stage in a 2.65 mm height, SOIC 16 package solution. Typical bias examples include: digital isolators, voltage and current sensing, CAN transceivers and signal communication used in the design of traction inverters, onboard chargers, battery management systems, infotainment, charging cables and PTC heaters.

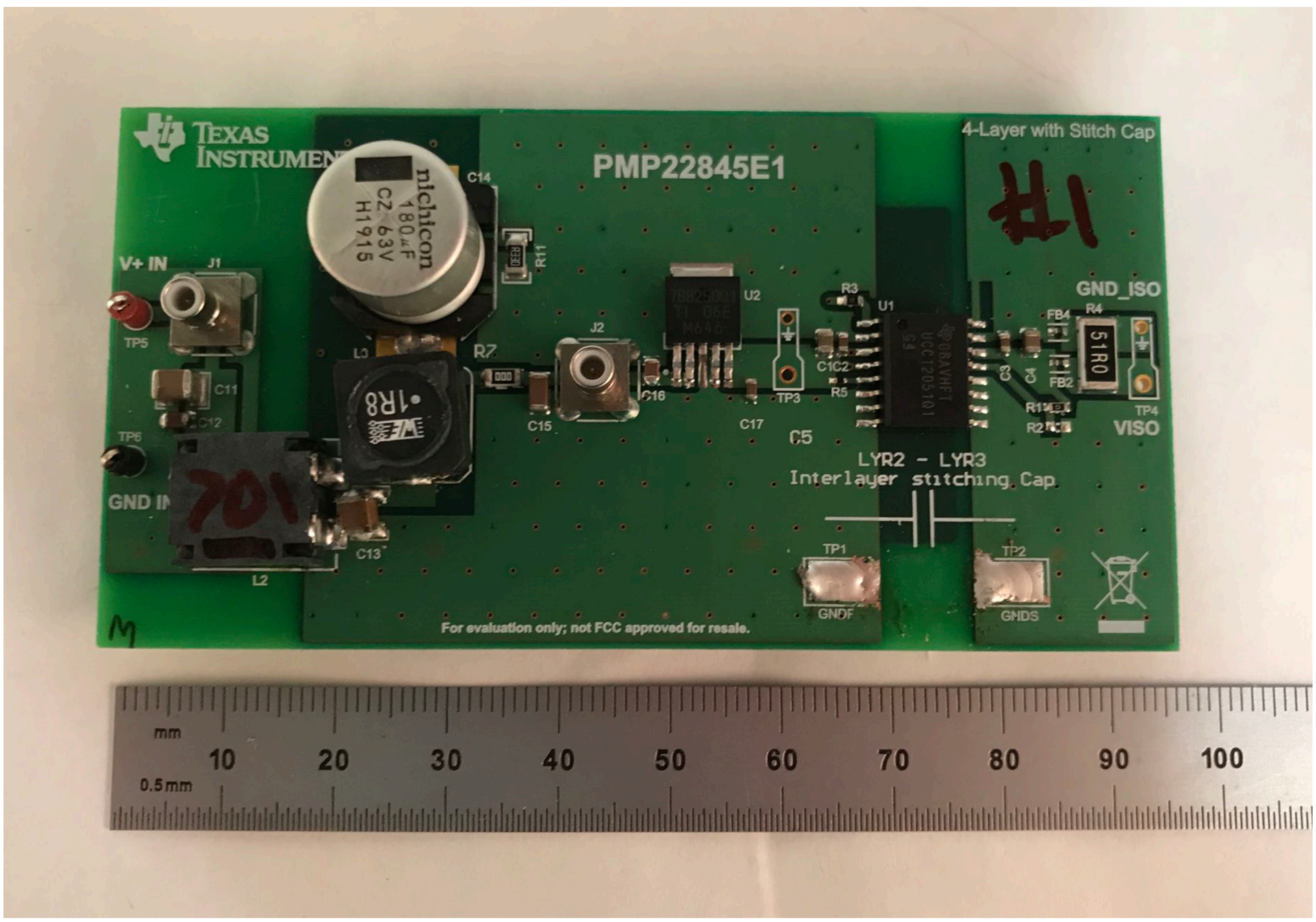


Figure 1-1. Top of Board

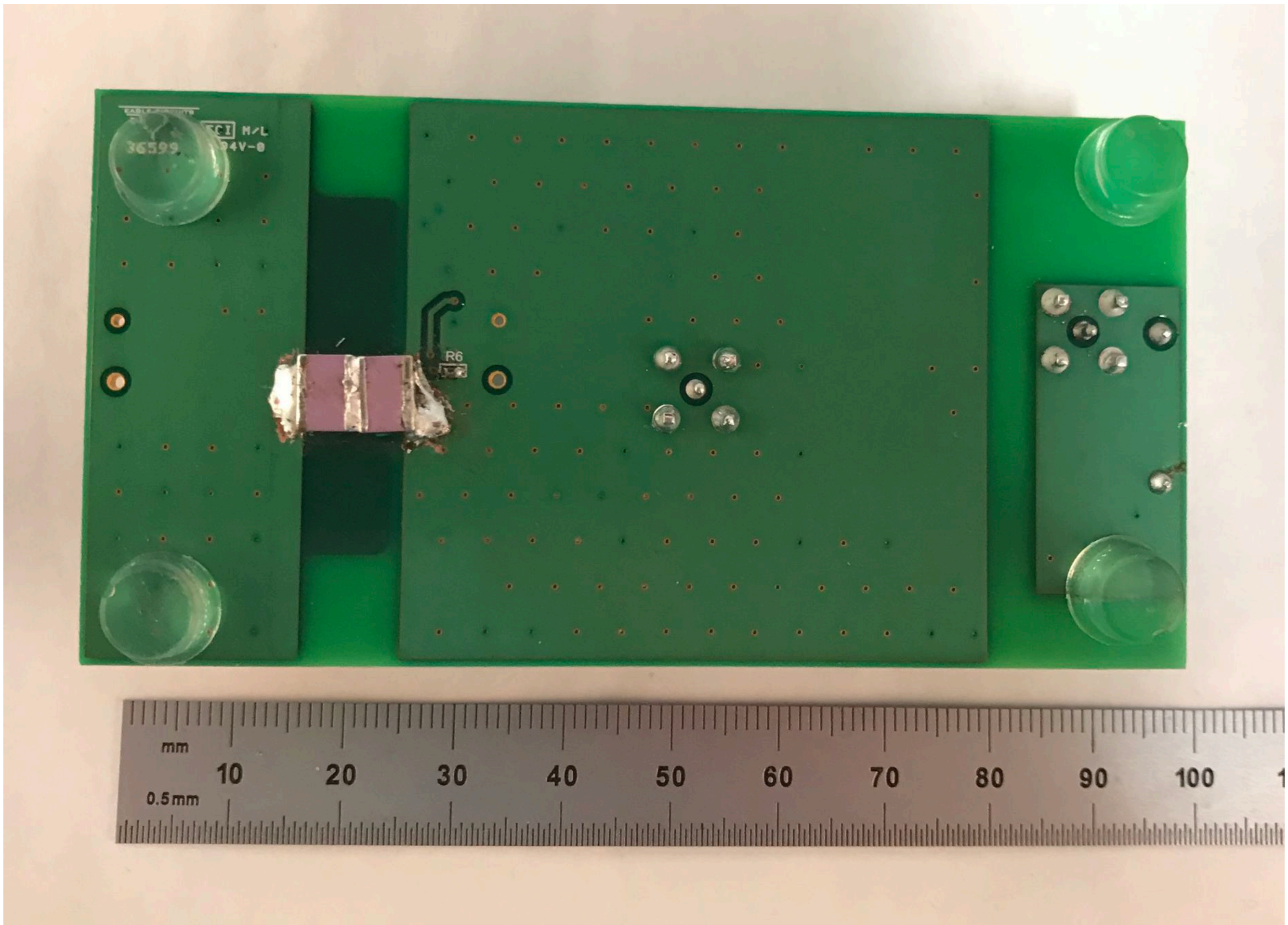


Figure 1-2. Bottom of Board

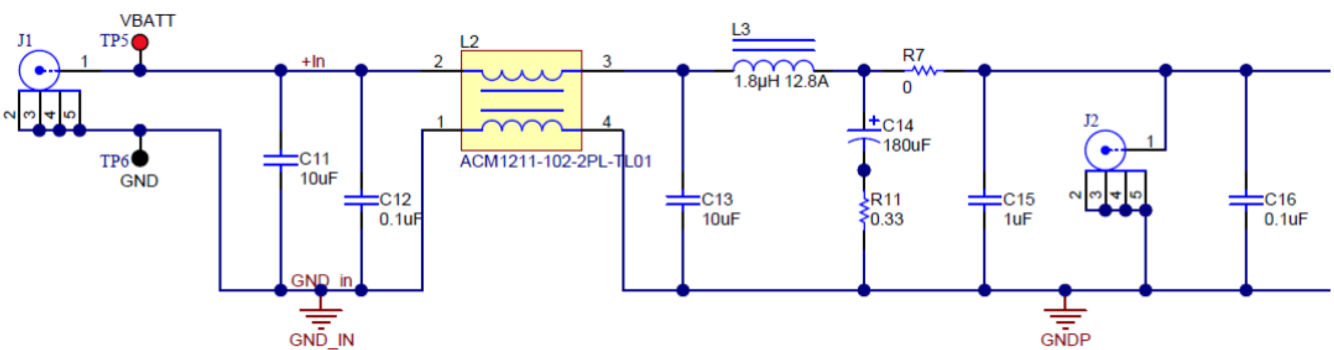


Figure 1-3. EMI Filter Schematic

Figure 1-3 shows the input EMI filter schematic as built.

2 Test Prerequisites

2.1 Voltage and Current Requirements

Table 2-1. Voltage and Current Requirements

Parameter	Specifications
Input Voltage	12 V–14 V
Maximum Current Draw	150 mA
Ouput Voltage	5 V
Output Current	100 mA (onboard resistor)

2.2 Required Equipment

- Battery cable with length per CISPR 25
- CISPR 25 Conduction Emissions Setup
- CISPR 25 Radiated Emmissions Setup & Chamber
- EMI Receiver

2.3 Dimensions

The board is approximately 95 mm x 45 mm.

2.4 Test Setup

The following images show the various test setups used along with a more in-depth look at the board and its setup.

Conducted testing introduction and initial testing:

CISPR 25 conducted test calls for a battery cable length of 200 mm–400 mm (about 8–16 inches), including the LISN connector. A 9-inch cable is used for the tests (see the following images).

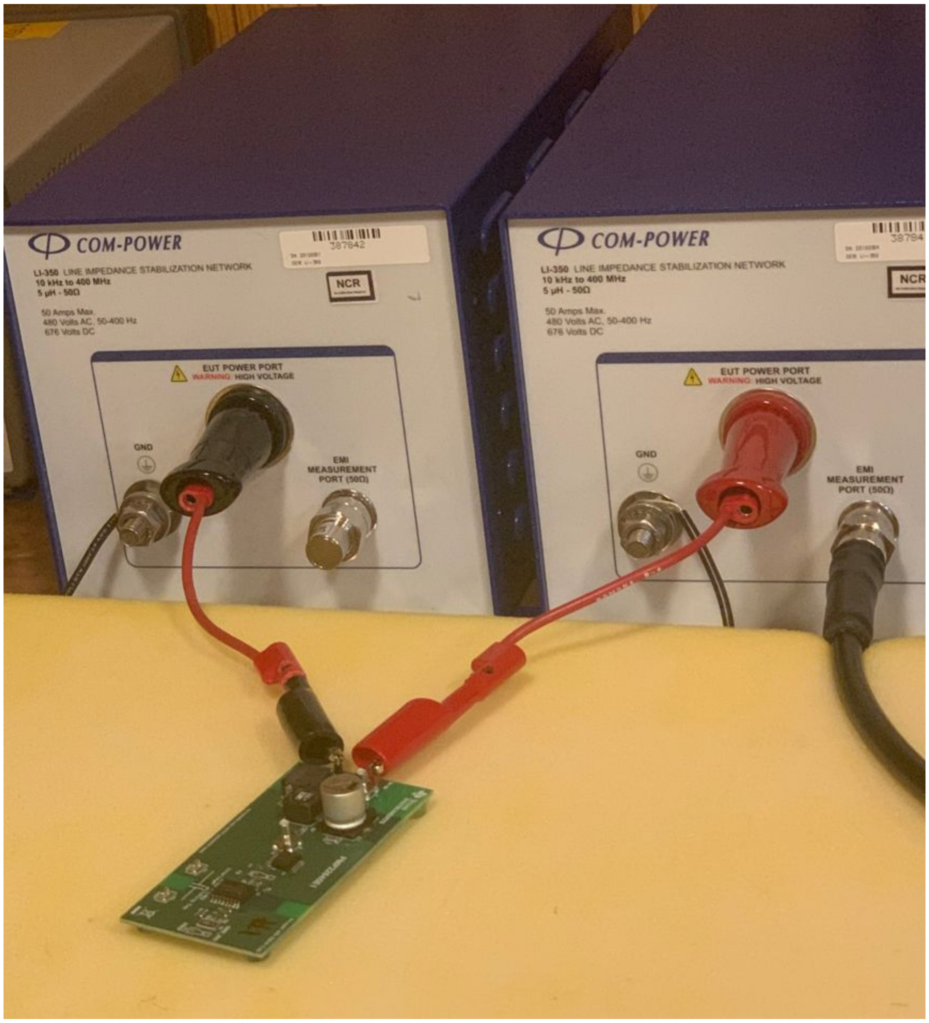


Figure 2-1. Conducted Test Setup

Passing cases with bottom side surface mount Y capacitor (Y cap).

The image shows two, size 1812 caps in series used to bridge the 8-mm primary to secondary gap. (581-1812HA101JAT1A Mouser / AVX MLCC - SMD/SMT 3KV 100 pF C0G 1812 5% HV) **for 50 pF effective Y cap.**

Also used higher value 220 pF surface mount Y caps **for the effective 110-pF cap** between primary and sec. 581-1825JA221KAT1A AVX / Mouser MLCC - SMD/SMT 4 KV 220 pF C0G 1825 10% Tol HV

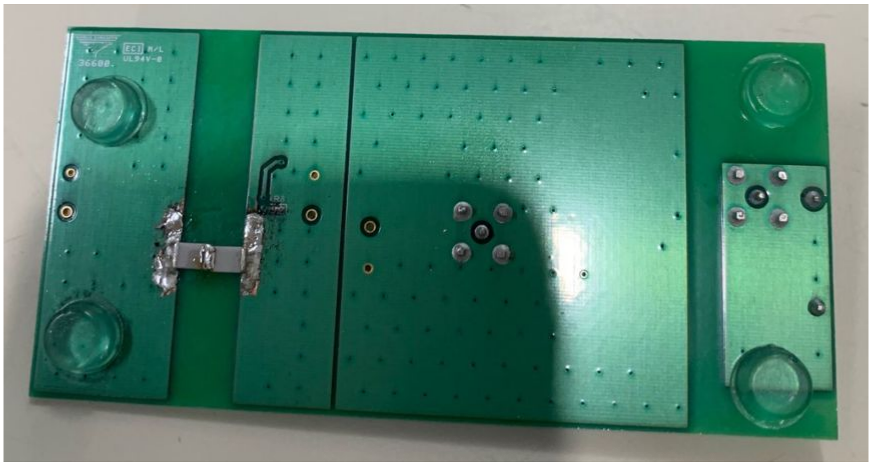


Figure 2-2. Bottom Side, Capacitor Bridge

Passing case with 220-pF top side through-hole Y cap added:

220-pF through-hole cap used TDK CC45SL3DD221JYNNA 2-kV rating, ceramic disc.

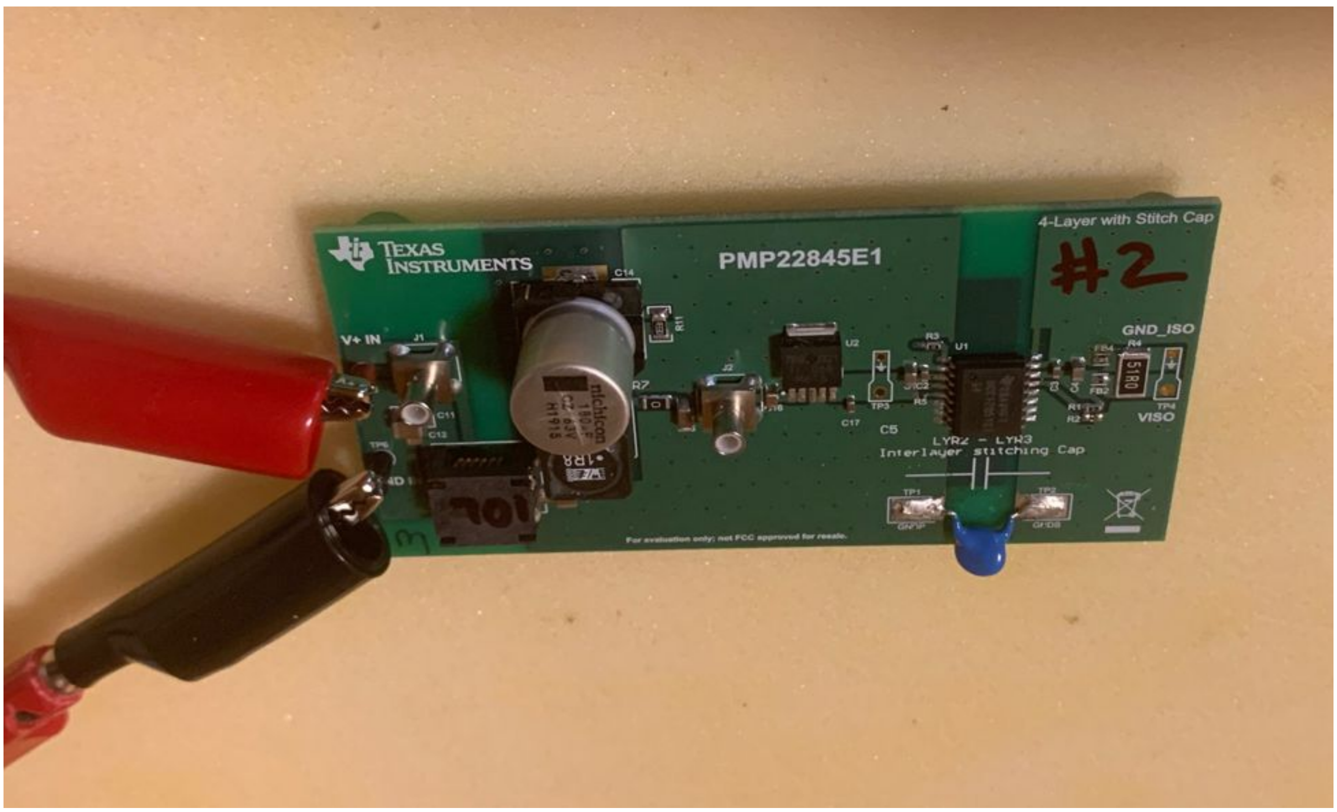


Figure 2-3. Top Side, Through Hole Y Cap Added

The following images show the EMI testing chamber and the different antenna configurations used.

Figure 2-4. 150 kHz–30 MHz Setup, Vertical Monopole Antenna

Figure 2-5. 200 MHz –1000 MHz Setup, Horizontal Log Periodic Antenna

Figure 2-6. 30 MHz –300 MHz Setup, With Biconical Antenna Horizontal

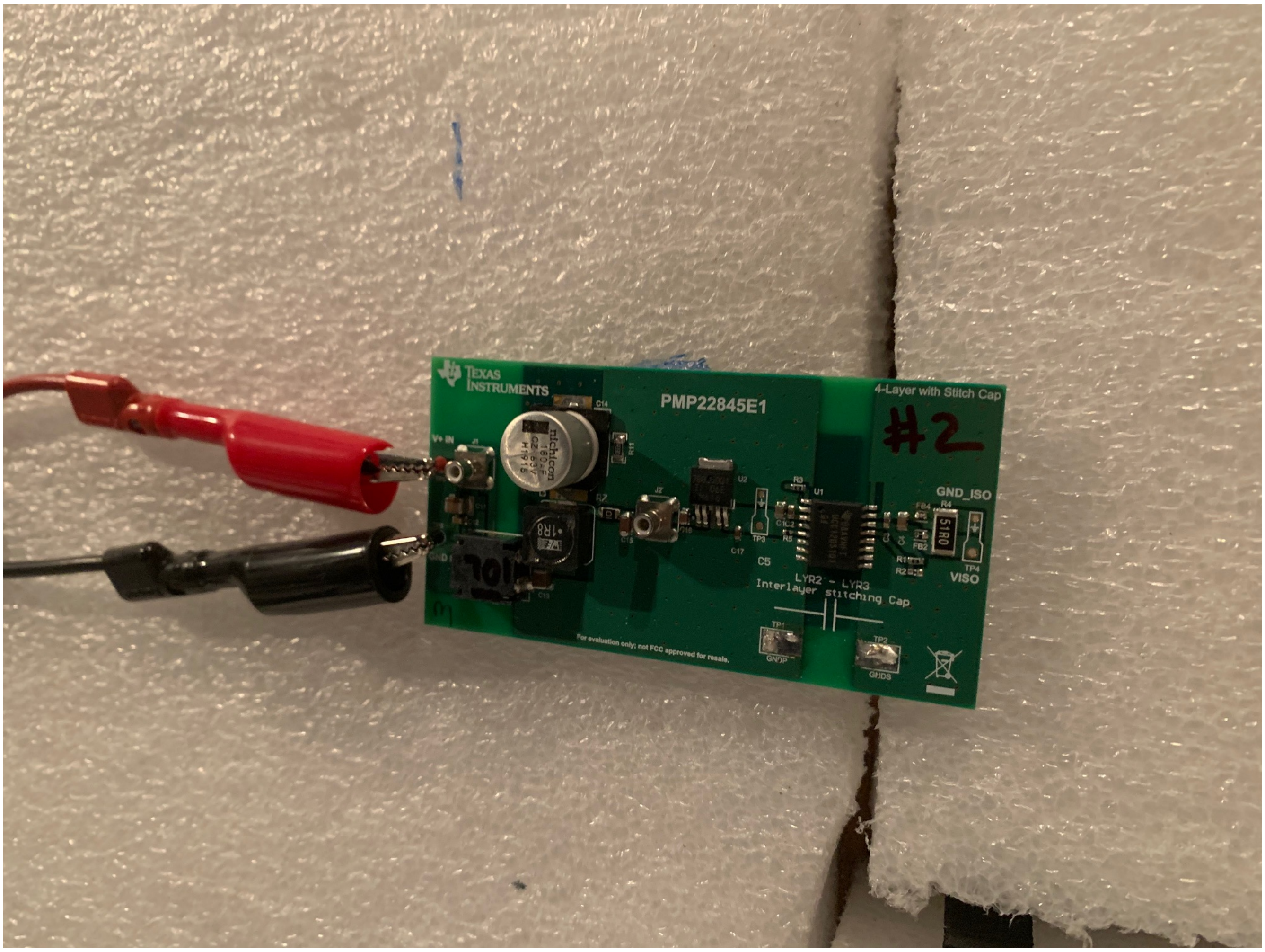


Figure 2-7. Unit Under Test: Top Side, Version With Stitch Cap

3 Testing and Results

Two different configurations of this design were tested, with the difference between them being the effective Y capacitance. Testing was also done with and without output beads but it was found that they had no noticeable impact on testing results. The following table highlights the differences in the two configurations.

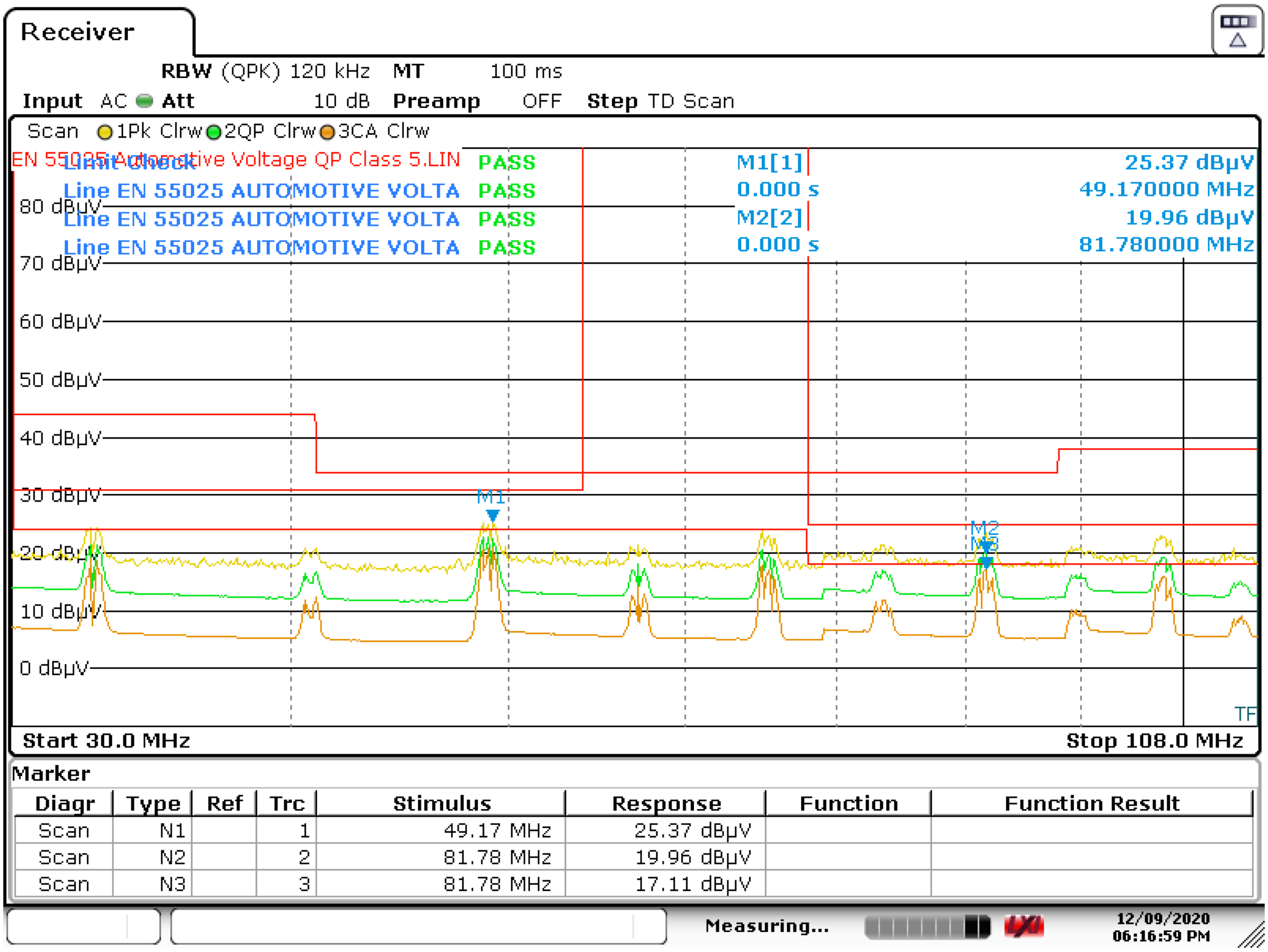
Configuration	Y-Cap Values (2 in Series)	Effective Capacitance
A	100 pF	50 pF
B	220 pF	110 pF

3.1 EMI

Conducted summary: This is for an application where a system-level common-mode inductor impedance of 700 Ω at 100 MHz already exists and the primary- to secondary-stitch capacitance in the PCB inner layers of 11 pF is allowed under the isolated 5-V to 5-V converter. Both the stitch capacitor of 11 pF plus the added Y capictor of approximately 50 pF, as in the case of configuration A, allows the passing of conducted through 108 MHz, but barely, by only one dB. Roughly doubling the Y cap value gives good passing margin of > 4 dB. Using a 220 pF through-hole Y cap as in configuration B on the top side gives even more margin, approximately 8 dB. Most runs were done in the 30 MHz–108 MHz range where noise came close to the limits. The first and last configurations were also done in the 150 kHz–30 MHz range to show passing by a wide margin in that range. The conductive scans that are summarized above are shown in the following images.

EMI conducted scans from RED LISN: December 9, 2020

PMP22845 Configuration A; Again this configuration utalizes two 100 pF “1812” size capacitors in series for effective 50 pF.

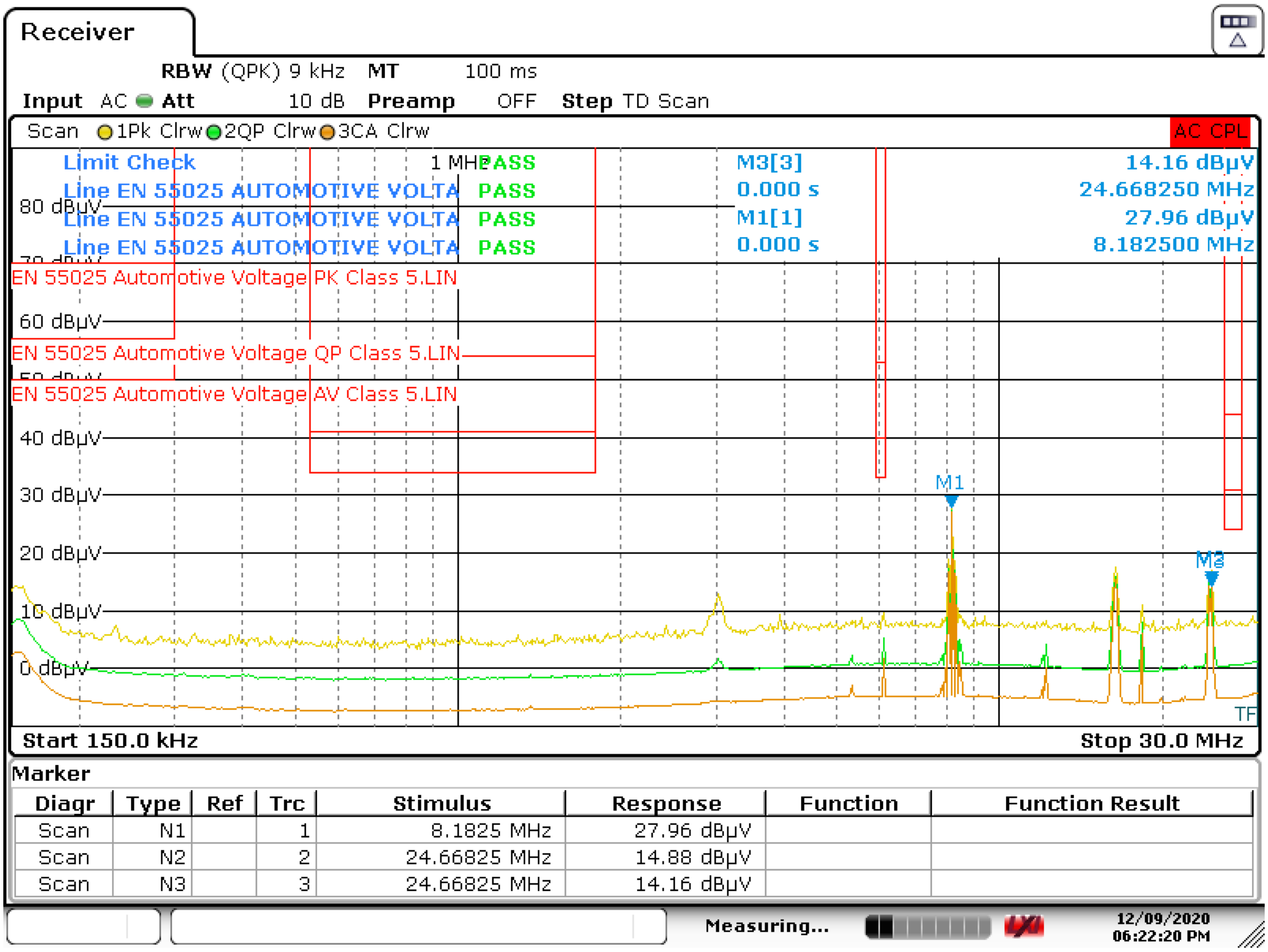


Date: 9.DEC.2020 18:16:58

30–108 MHz:
Peak detect: Passes with greater than 8-dB margin. Worst case 49 MHz.
Quasi-Peak (QP) detect: 5-dB margin, worst case 82 MHz.
CISPR average (CA) detect: 0.9-dB margin, worst case 82 MHz.

Figure 3-1. Conducted Board Configuration A, 30 MHz–108 MHz Range

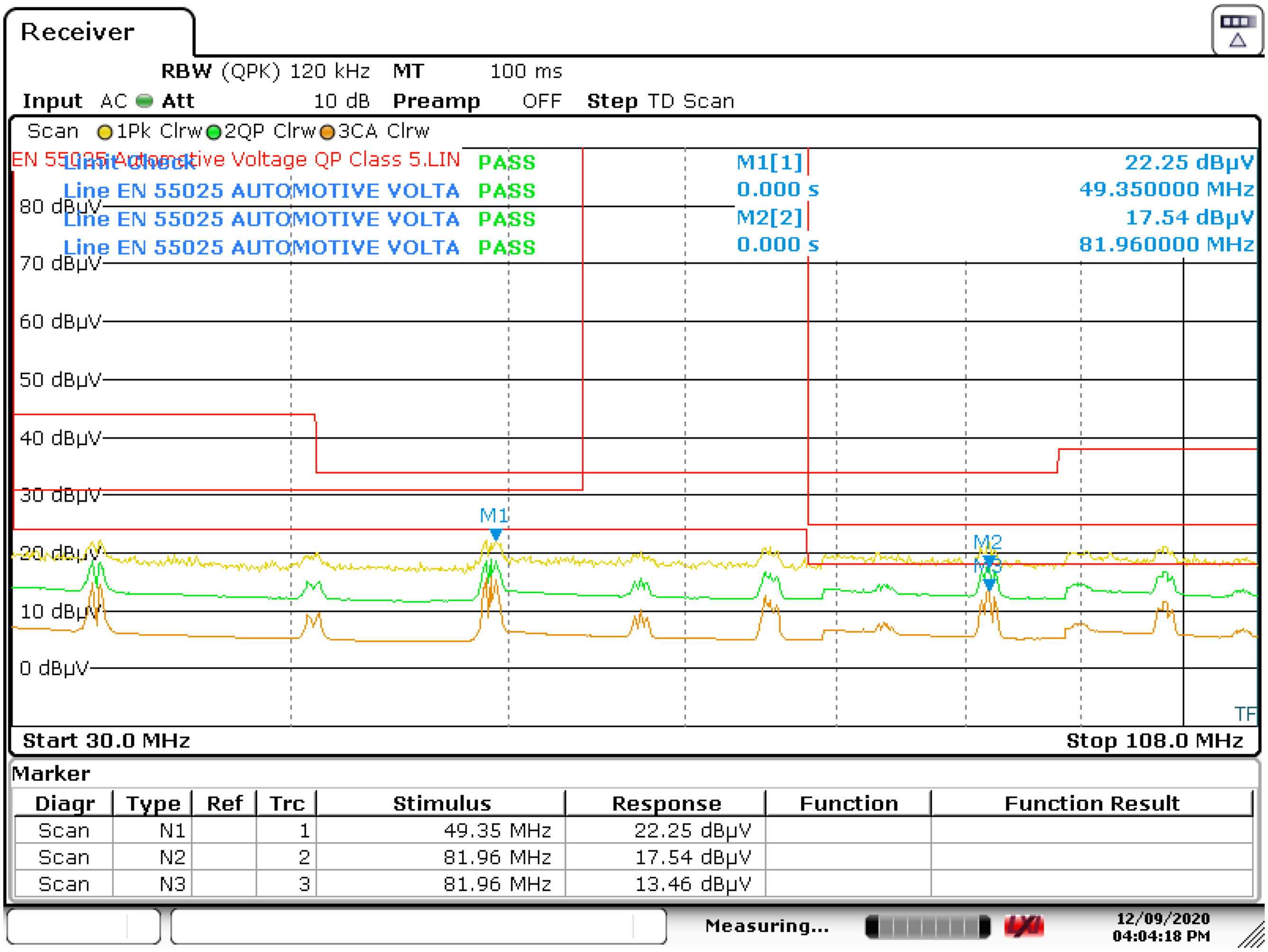
150 kHz–30 MHz range shown here: Average at 24.7 MHz is 10 dB below 26–28 MHz average limit.



Date: 9.DEC.2020 18:22:19

Figure 3-2. Conducted Configuration A, 150 kHz–30 MHz Range

PMP22845 Configuration A; Again this configuration utalizes two 220 pF through-hole capacitors in series for effective 110 pF.



Date: 9.DEC.2020 16:04:18

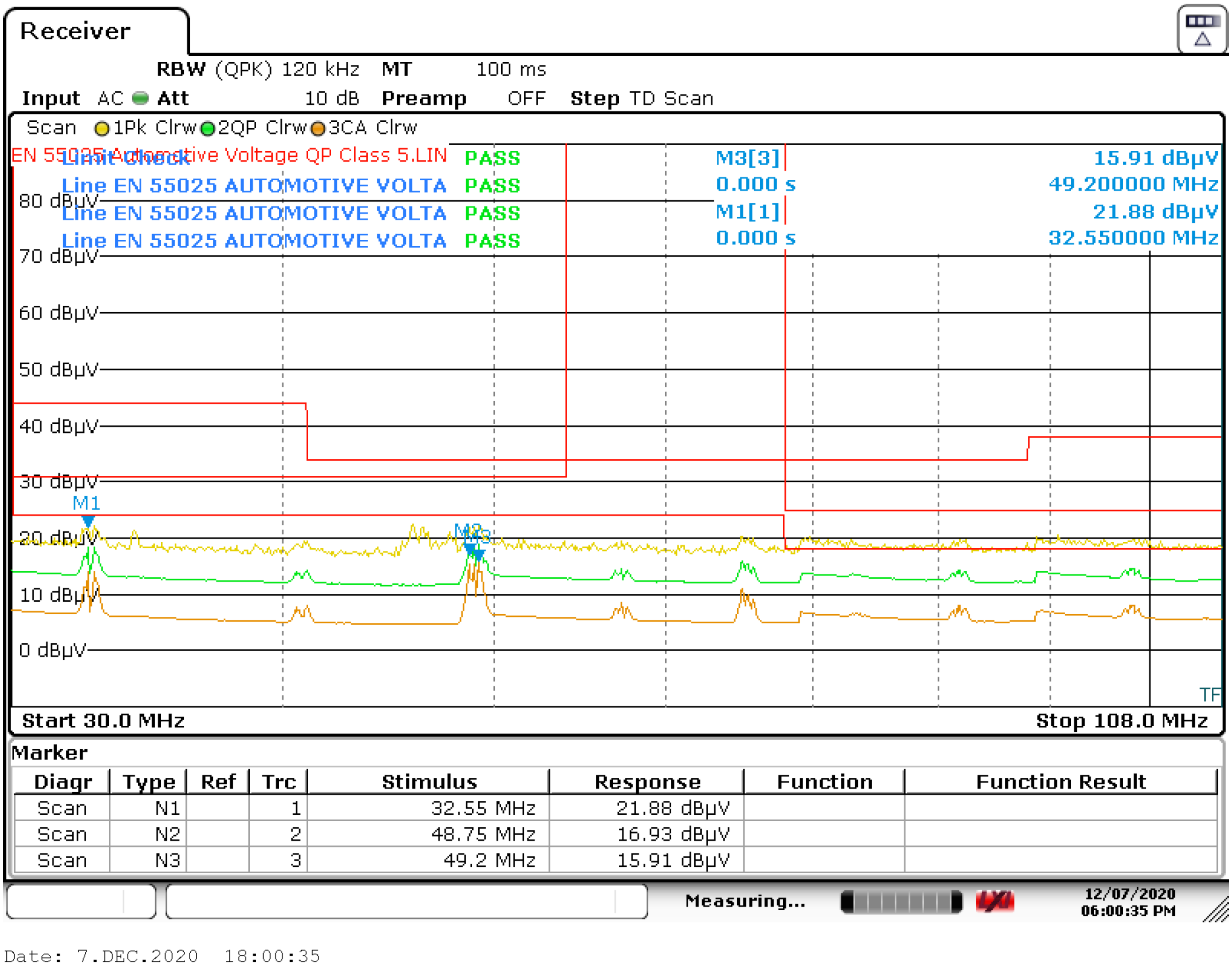
30-108 MHz:

Peak detect: Passes with greater than 11-dB margin. Worst case 49 MHz.

Quasi-Peak (QP) detect: Passes with 7.5-dB margin. Worst case 82 MHz.

CISPR average (CA) detect: Passes with 4.5-dB margin. Worst case 82 MHz.

Figure 3-3. Conducted Board Configuration B, 30 M–108 MHz Range



30–108 MHz:

Peak detect: Passes with greater than 12-dB margin.

Quasi-Peak (QP) detect: Passes with greater than 8-dB margin.

CISPR average (CA) detect: Passes with 8-dB margin. Worst case at 49 MHz.

Figure 3-4. Conducted Board Configuration B, 30 M–108 MHz Range

Same as previous, but full conducted spectrum down to 150 kHz: No large peaks below 30 MHz.

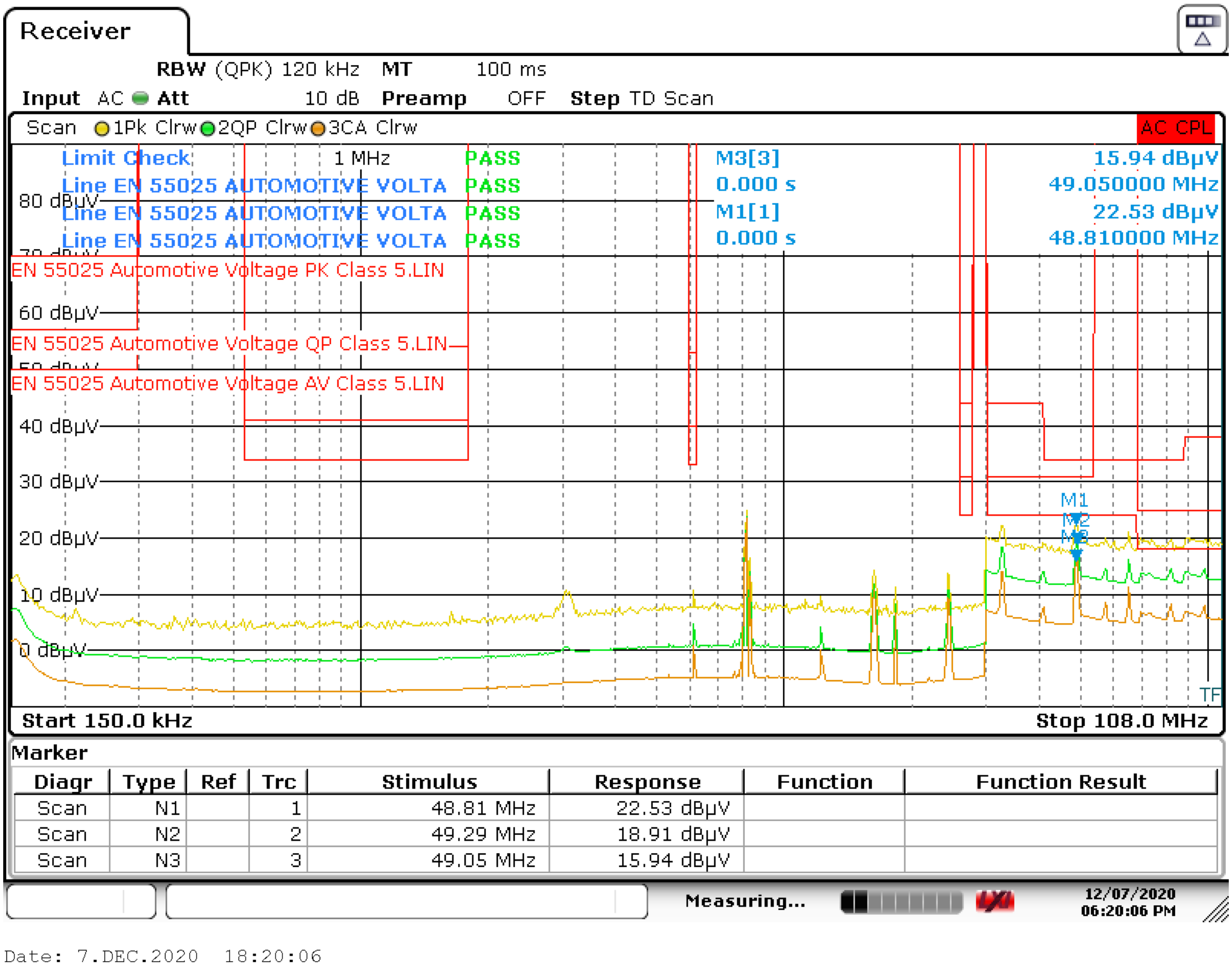


Figure 3-5. Conducted Board Configuration B, 150 kHz–108 MHz Range

Results Summary

Radiated testing at NTS December 2020 – Summary

PMP22845 (with stitching 11-pF cap primary ground to secondary ground at UCC12051-Q1) models were used.

Input filter off battery had 700 Ω (at 100 MHz) common mode filter plus differential mode Pi filter.

Added Y cap from primary ground to secondary ground under UCC12051-Q1 was 2 × 100 pF size 1812 caps in series to gap the 8-mm spacing between primary ground and secondary ground for an effective cap of 50 pF on configuration A of PMP22845. This previously passed conducted emissions with only one dB margin.

In general, conducted testing proved to be more severe than radiated for CISPR 25 Class 5.

Low frequency range 150 kHz–30 MHz with monopole never got within 6dB of the limits, even with the 3rd harmonic of the 8 MHz UCC12051-Q1 switching with maximum average being 1.5 dBuV versus the specification of 20 dBuV maximum in the 26–28 MHz range. See next page.

Mid-band of 30–300 MHz with biconical antenna is considered the range of greatest risk and had the greatest test focus. Configuration A passed by at least 10 dB. Antenna horizontal and vertical orientations gave similar results. See following two pages.

High band 200–1000 MHz range: Worst cases around 240 MHz and 800–900 MHz, but still passing with 7 dB at 240 MHz and > 10 dB in the 800–900 MHz range. The 7-dB margin at 240 MHz may be due to the noise floor, as passing at this frequency with biconical antenna was with > 10 dB. CISPR 25 allows either biconical or log periodic antenna in the 200–300 MHz range. See following figures.

Radiated low frequency 150 kHz–30 MHz range with vertical monopole: Worst of the runs with PMP22845 Configuration A: 24.7 MHz average still 18.5 dB below CB band average limit of 20 dBuV/m.

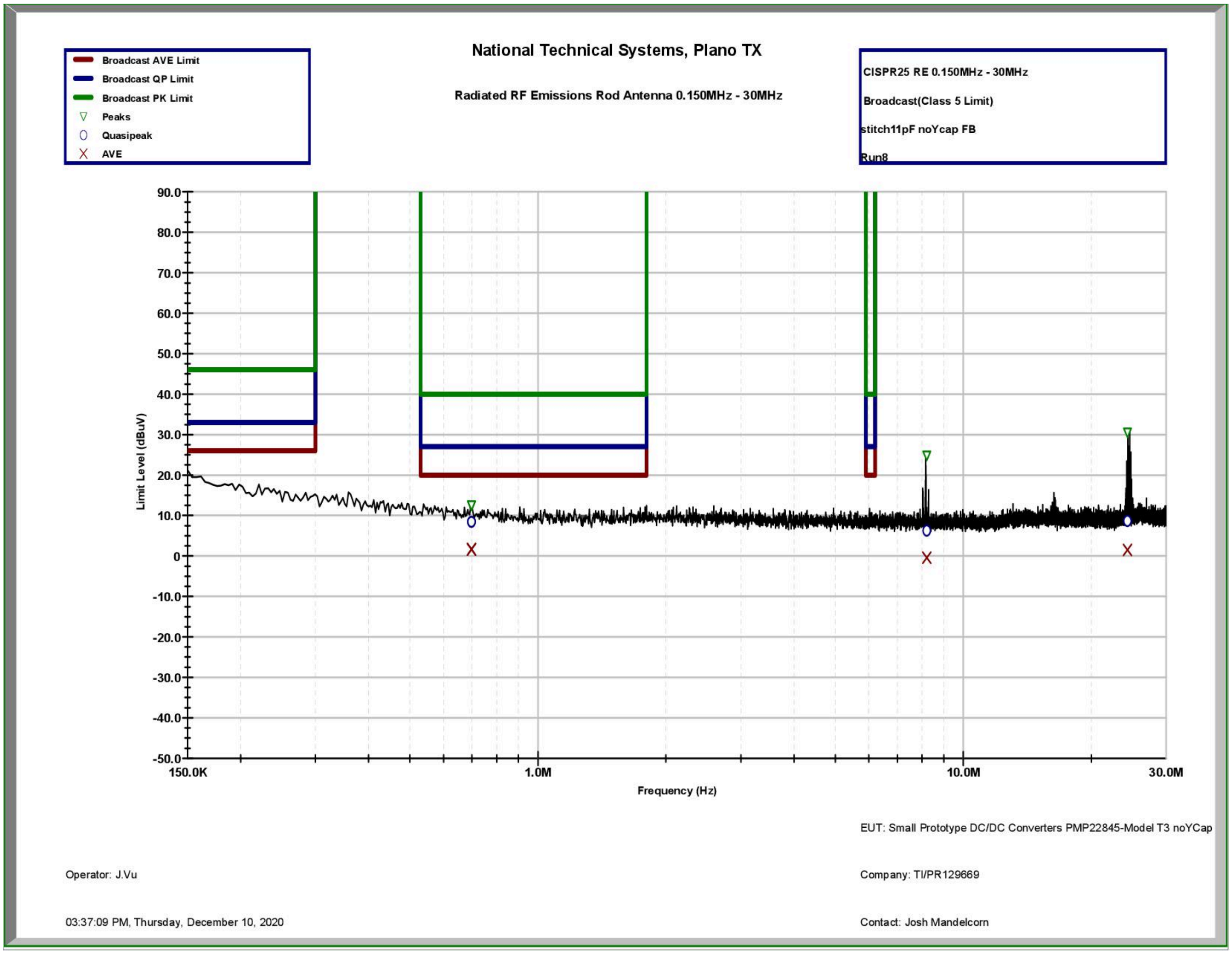


Figure 3-6. 150 kHz–30 MHz Range With Vertical Monopole

Radiated mid-band 30–300 MHz range with horizontal biconical: Worst of runs with PMP22845 Configuration A: Other runs very similar.

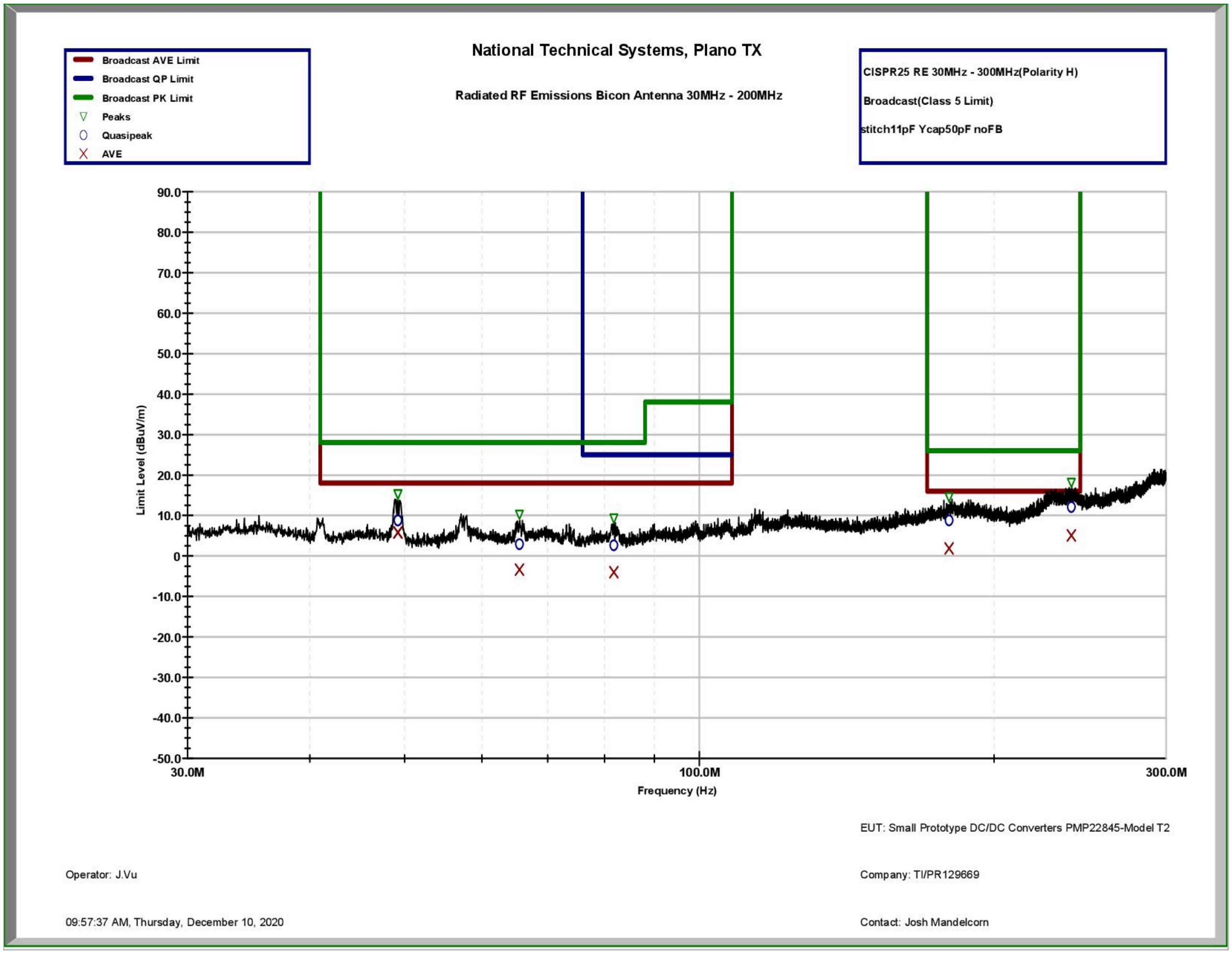


Figure 3-7. 30 MHz – 300 MHz Range With Horizontal Biconical

National Technical Systems, Plano TX
Conducted RF Emissions Bicon Antenna 30 - 200MHz

Operator: J.Vu

09:57:37 AM, Thursday, December 10, 2020

Company: TI/PR129669
Contact: Josh Mandelcorn

	1	2	3	4	5	6	7	8	9
Frequency	AVE Limit	AVE Data	AVE Margin	QP Limit	QP Data	QP Margin	PK Limit	PK Data	PK Margin
MHz	dBuV	dBuV	dB	dBuV	dBuV	dB	dBuV	dBuV	dBuV
49.20 MHz	18.000	5.733	-12.267	100.000	8.804	-91.196	28.000	15.379	-12.621
65.50 MHz	18.000	-3.400	-21.400	100.000	2.970	-97.030	28.000	10.269	-17.731
81.80 MHz	18.000	-4.031	-22.031	25.000	2.706	-22.294	28.000	9.419	-18.581
180.00 MHz	16.000	1.795	-14.205		8.791		26.000	14.569	-11.431
240.00 MHz	16.000	5.059	-10.941		12.077		26.000	18.296	-7.704

CISPR25 RE 30MHz - 300MHz(Polarity H)
Broadcast(Class 5 Limit)
stitch11pF Ycap50pF noFB

Figure 3-8. 30 MHz – 300 MHz Range With Horizontal Biconical Data

Radiated mid-band 30 MHz – 300 MHz range with vertical biconical: Worst of the runs with PMP22845 Configuration A: Other runs very similar within about 1 dB.

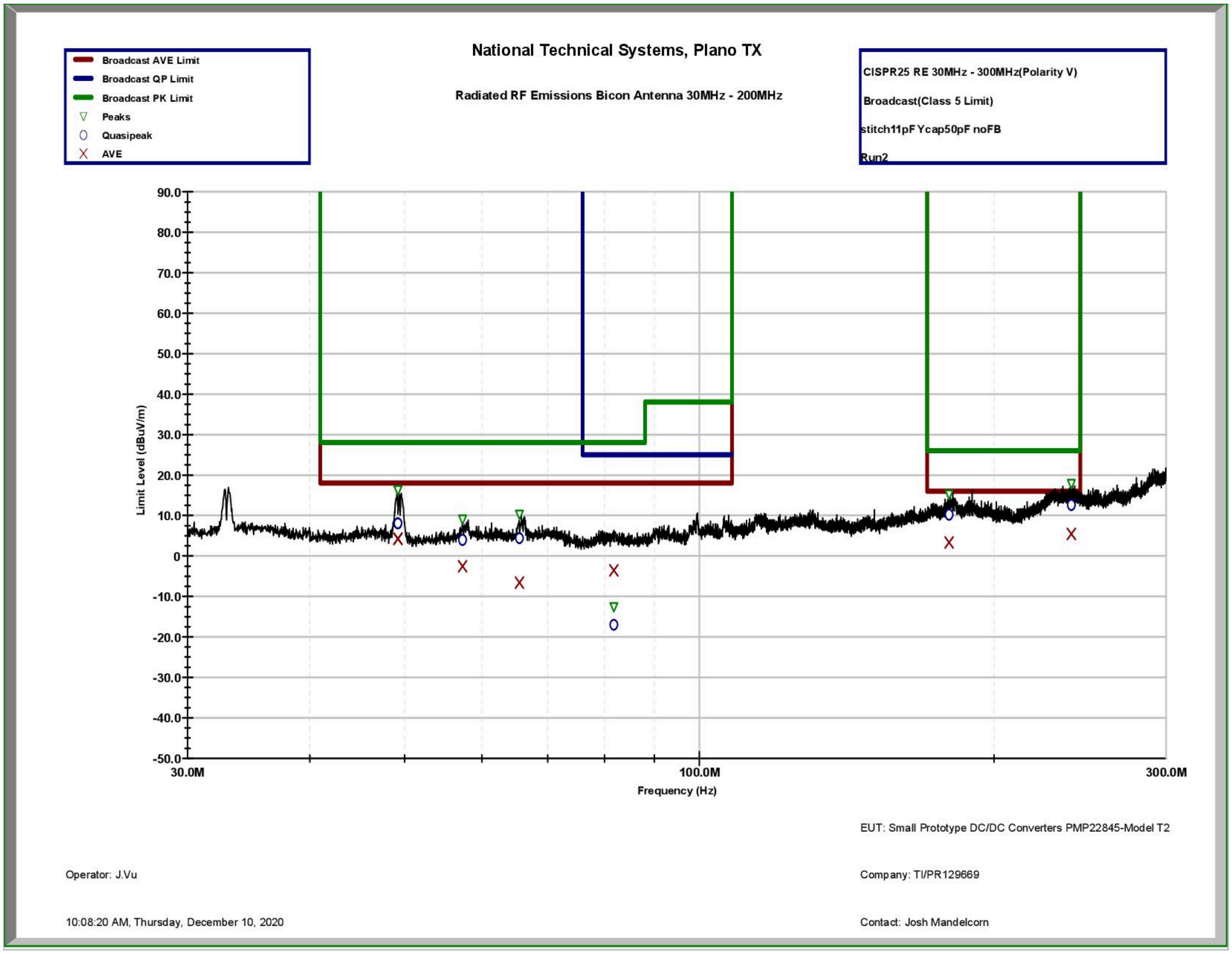


Figure 3-9. 30 MHz – 300 MHz Range With Vertical Biconical

National Technical Systems, Plano TX
Conducted RF Emissions Bicon Antenna 30 - 200MHz

Operator: J.Vu

10:08:20 AM, Thursday, December 10, 2020

Company: TI/PR129669
Contact: Josh Mandelcorn

	1	2	3	4	5	6	7	8	9
Frequency MHz	AVE Limit dBuV	AVE Data dBuV	AVE Margin dB	QP Limit dBuV	QP Data dBuV	QP Margin dB	PK Limit dBuV	PK Data dBuV	PK Margin dBuV
49.20 MHz	18.000	4.229	-13.771	100.000	8.082	-91.918	28.000	16.367	-11.633
57.30 MHz	18.000	-2.574	-20.574	100.000	3.939	-96.061	28.000	9.134	-18.866
65.50 MHz	18.000	-6.581	-24.581	100.000	4.401	-95.599	28.000	10.369	-17.631
81.80 MHz	18.000	-3.599	-21.599	25.000	-16.963	-41.963	28.000	-12.479	-40.479
180.00 MHz	16.000	3.371	-12.629		10.180		26.000	15.252	-10.748
240.00 MHz	16.000	5.416	-10.584		12.564		26.000	17.914	-8.086

CISPR25 RE 30MHz - 300MHz(Polarity V)
Broadcast(Class 5 Limit)
stitch11pF Ycap50pF noFB
Run2

Figure 3-10. 30 MHz – 300 MHz Range With Vertical Biconical Data

Radiated high band 200 MHz – 1000 MHz range with horizontal log periodic antenna: Configuration A stitch cap and Y cap of 50 pF

In this frequency range horizontal was several dB worse than vertical. Worst case 240 MHz with 7-dB margin.

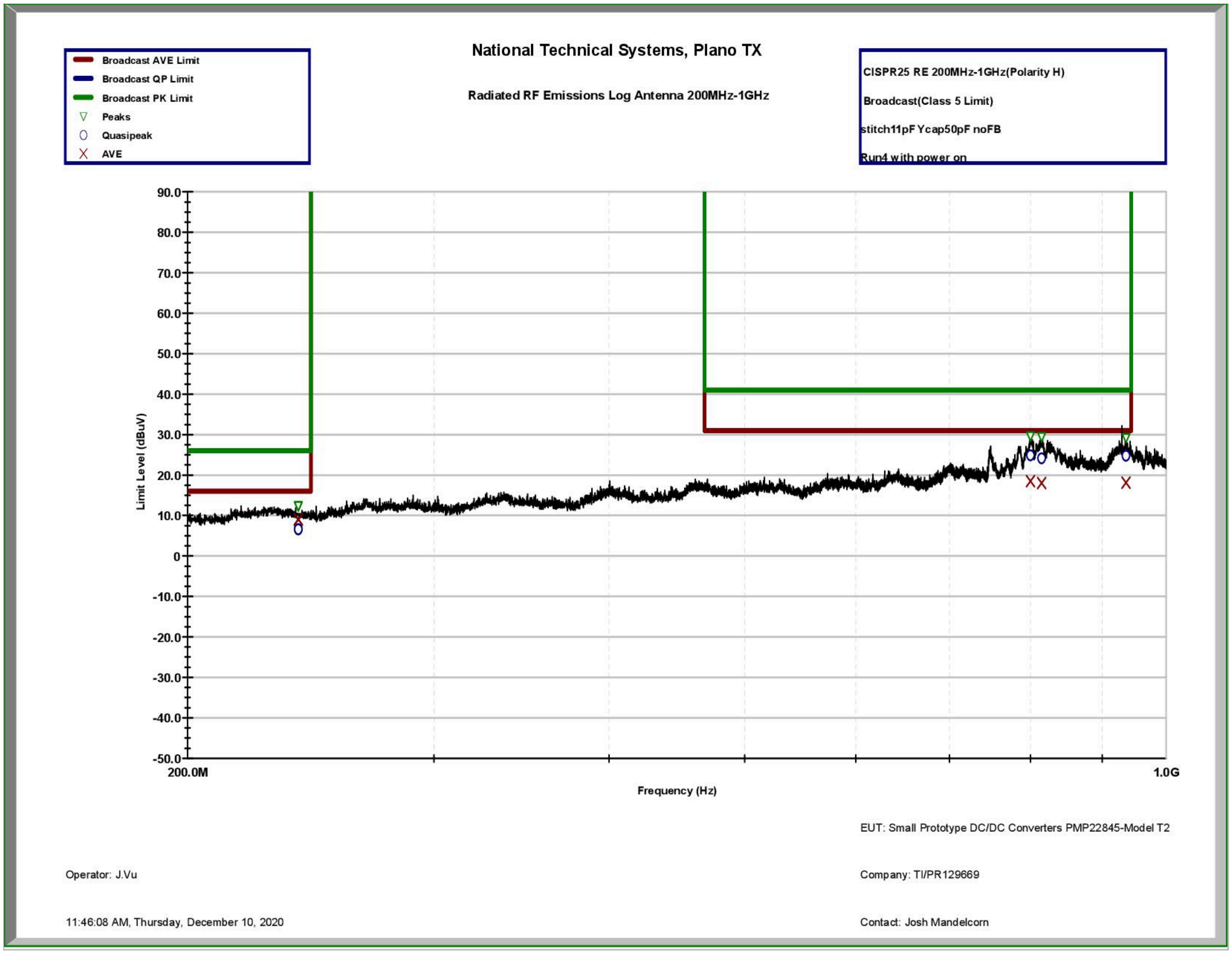


Figure 3-11. 200 MHz – 1000 MHz Range With Horizontal Log Periodic Antenna

National Technical Systems, Plano TX
Conducted RF Emissions Log Antenna 200MHz - 1GHz

Operator: J.Vu

11:46:08 AM, Thursday, December 10, 2020

Company: TI/PR129669
Contact: Josh Mandelcorn

	1	2	3	4	5	6	7	8	9
Frequency MHz	AVE Limit dBuV	AVE Data dBuV	AVE Margin dB	QP Limit dBuV	QP Data dBuV	QP Margin dB	PK Limit dBuV	PK Data dBuV	PK Margin dBuV
240.00 MHz	16.000	9.011	-6.989		6.610		26.000	12.375	-13.625
800.20 MHz	31.000	18.410	-12.590		24.930		41.000	29.659	-11.341
814.50 MHz	31.000	17.976	-13.024		24.168		41.000	29.477	-11.523
936.00 MHz	31.000	18.072	-12.928		24.793		41.000	29.193	-11.807
CISPR25 RE 200MHz-1GHz(Polarity H)									
Broadcast(Class 5 Limit)									
stitch11pF Ycap50pF noFB									
Run4 with power on									

Figure 3-12. 200 MHz – 1000 MHz Range With Horizontal Log Periodic Antenna Data

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