Test Report: PMP22845 Isolated 5-V Bias Supply for Automotive CISPR 25, Class 5 Emissions, Reference Design

TEXAS INSTRUMENTS

1 Description

This reference design demonstrates EMI mitigation techniques required for a high-frequency, reinforced $5 \text{-}kV_{\text{RMS}}$ 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 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



Test Prerequisites



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			
А	100 pF	50 pF			
В	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.

www.ti.com

Receiv	er												
	RB	W (QP	K) 120 kHz	MT	100 ms								<u>,</u>
Input A	AC 👄 Att		10 dB	Preamp	D OFF	Step TD :	Scan						
Scan 🤆)1Pk Clr∖	w ⊝ 2QP	P Clrw⊖3CA	Clrw									
EN 55085	i Autoeral	tive Vo	ltage QP Cla	ss 5.LIN	PASS		M1	[1]			:	25.37	dBµV
Line	EN 550	25 AU	ΙΤΟΜΟΤΙΥΕ	VOLTA	PASS		0.0	100 s			49.1	7000	D MHz
CC Cline	EN 550	25 AU	ΙΤΟΜΟΤΙΥΕ	VOLTA	PASS		M2	[2]				19.96	dBµV
Line 70 dB⊔V-	EN 550	25 AU	ΙΤΟΜΟΤΙΥΕ	VOLTA	PASS		0.0				81.7	8000	J MHZ
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60 dBµV-													
			1								1		
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Scan	N1	NG1	1	49.	17 MHz	25.37	' dBuV	<u> </u>	SCION	ru	netion K	ssuit	
Scan	N2		2	81.	78 MHz	19.96	i dBµV						
Scan	N3		3	81.	78 MHz	17.11	. dBµ∨						
) (Measu	ring			1:	2/09/20	20
-								-			- 06	:10:59	PM ///

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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.

sting and Results					www.ti.co
Beceiver					Ē
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גטאי (ע Input AC 🚍 Att	10 dp	MI IUU MS	ton TD Coop		
$\frac{1111}{2} \text{Scan} \bigcirc 10^{1} \text{Bk} \bigcirc 10^{1} \text{Scan} \bigcirc 20^{1} \text{Scan} \bigcirc 10^{1} \text{Bk} \bigcirc 10^{1} \text{Scan} \odot 10^{1} Sc$		A Clow	step to scall		
Limit Check			- Mi	101	14 16 dBu
Line EN 55025 A		E VOLTA PASS	0.	000 5	24.668250 MH
80 dBuV		E VOLTA PASS	M	1[1]	27.96 dBu
Line EN 55025 A	υτοΜοτιγ	E VOLTA PASS	0.	000 s	8.182500 MH
EN 55025 Automotive V	oltage PK Cl	ass 5.LIN			
:					
60 dBµV					
EN 55025 Automotive V	oltage QP C	lass 5.LIN	-		
EN 55025 Automotive V	oltage AV Cl	ass 5.LIN			
40 - 40 - 42					
40 aBµV					
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Scan N1	1	8.1825 MHz	27.96 dBuV	ranotion	r anoton Rosan
Scan N2	2	24.66825 MHz	14.88 dBµV		
Scan N3	3	24.66825 MHz	14.16 dBµV		
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Figure 3-2. Conducted Configuration A, 150 kHz–30 MHz Range

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

Receive	۶r									ſ	
	RB	W (QP	K) 120 kHz	MT	100 ms						
Input A	C 👄 Att		10 dB	Preamp	OFF	Step TD S	can				
Scan 😑	1Pk Clrv	v 🔵 2 Q F	P Clrw⊖3CA	Clrw							
EN 5506តុម	A <mark>atloena</mark> t	ive Vo	ltage QP Cla	ss 5.LIN	PASS		M1[1]			22.25 dB	۶µ۷
en deuv-	EN 550	25 AU	ΤΟΜΟΤΙΥΕ	VOLTA	PASS		0.000	s		49.350000 M	IHz
Co apare	EN 550	25 AU	ΤΟΜΟΤΙΥΕ	VOLTA	PASS		M2[2]			17.54 dB	γµγ
ZO dBuV-	EN 550	25 AU	ΤΟΜΟΤΙΥΕ	VOLTA	PASS		0.000	s		81.960000 M	iHz
/0 00p.			1								
60 dBuV-			1						1		
50 dBuV-											
40 dBµV—					1 1 1	-		1	1		
<u> 30 dBµV—</u>					-				1		
					M1						
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Start 30	.0 MHz								S	top 108.0 MF	-lz
Marker											_
Diagr	Туре	Ref	Trc	Stimulu	s	Respon	se 📋 I	Function	Functi	on Result	
Scan	N1		1	49.:	35 MHz	22.25	dBµV				
Scan	N2		2	81.	96 MHz	17.54	dBµV				
Scan	N3		3	81.	96 MHz	13.46	dBµV ∣				
							Measuring	g 🚺 🕅		12/09/2020 04:04:18 PM	

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

Scan C	1Pk Clrv	vo2QP	P Clrw()3CA Clrw						
EN 550ខ្ពស	Actionat	ive Vo	ltage C	P Class 5.LIN PASS		M3	[3]		15.91	L dBμV
Line	EN 550	25 AU	ломо	TIVE VOLTA PASS		0.0	100 s		49.20000	0 MHz
SU UBUV-	EN 550	25 AU	ломо	TIVE VOLTA PASS		M1	[1]		21.88	3 dBµV
ZO dBuild	EN 550	25 AU	ломо	TIVE VOLTA PASS		0.0	100 s		32.55000	0 MHz
/o uoµv-			1							
60 dBuV-				1			1	1	1	
50 dBuV-			1					1		
00 app v								1		
40 dBuV-			1				1	1	1	
10 0001										
30 dBuV-									_	
M1										
-20. dBuV-	. <u>.</u>			Anna Maria		~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	· ·		man	
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Marker		n _6		ostinuo luon	D	1	F	1		
Geop	туре	Ret	1		Respoi	nse Eduw	Function	<u> </u>	iction Result	
Scan	N2		2	48,75 MHz	16 93	3 dBuV				
Scan	N3		3	49.2 MHz	15.9	1 dBµV				
						Measu	ring		12/07/2	020
									06:00:35	РМ ///

Step TD Scan

100 ms

OFF

Date: 7.DEC.2020 18:00:35

30-108 MHz:

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

RBW (QPK) 120 kHz MT

10 dB

Preamp

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

Receiver

Input AC 👄 Att

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

Receiv	er								
	RBV	V (QPK) 1	.20 kHz	MT 10	10 ms				
Input A	C 👄 Att		10 dB	Preamp	OFF	Step TD Scan			
Scan 🤆)1Pk Clrw	⊙2QP Clr	w 😑 3CA	Clrw					AC CPL
Limi	it Check		1 M	Hz PÁ	SS		M3[3]		15.94 dBµ\
Line	EN 550	25 AUTO	ΙΟΤΙΥΕ	VOLTA PAS	SS		0.000 s		49.050000 MH
SU UBUV-	EN 550	25 AUTO	NOTIVE	VOLTA PAS	SS		M1[1]		22.53 dBµ\
Line	EN 550;	25 AUTOR	ΙΟΤΙΥΕ	VOLTA PAS	SS		0.000 s		48.810000 MH
EN 55025	Automoti	ve Vøltagi	e PK Cla	ss 5.LIN					
60 dВµV-									
EN 55025	Automoti	ve Voltagi	e QP Cla	ss 5.LIN					
EN SECOS	Automoti	vo Voltagi							
EN DOUZO	Automoti	ve vuitagi	a Av Cia	SS D.LIN					
40 d <mark>8</mark> µV-									
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Start 15	50.0 kHz		· · · · ·	·			· · · · I		Stop 108.0 MHz
Marker									
Diagr	Type	Ref Tro	:	Stimulus		Response	Functi	on 📋	Function Result
Scan	N1		1	48.81	MHz	22.53 dBµ	IV VI		
Scan	N2		2	49.29	MHz	18.91 dBµ	VI		
Scan	<u> N3</u>		3	49.05	MHz	15.94 dBµ	<u> </u>		
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Date: 7.DEC.2020 18:20:06

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

	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	

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

10:08:20 AM,	Thursday, I	December 1	0, 2020	4	c	c	7	Compa Conta	any: TI/PR1296 act: Josh Mano	69 lelcorn
Frequency	AVE Limit	AVE Data_	_3 _AVE Margin_ dB	QP Limit	QP Data dBuV	QP Margin_ dB	PK Limit	PK Data PK Data	PK Margin	
49.20 MHz 57.30 MHz	18.000 18.000 18.000	4.229	-13.771 -20.574	100.000	8.082 3.939 4.401	-91.918 -96.061	28.000 28.000 28.000	16.367 9.134	-11.633 -18.866 -17.631	
81.80 MHz 180.00 MHz	18.000 16.000	-3.599	-21.599 -12.629	25.000			28.000		-40.479 -10.748	
240.00 MHz CISPR25 RE 301 Broadcast (Cla stitch11pF Yca Run2	16.000 MHz - 300MI ss 5 Limit; p50pF noFB	5.416 Hz(Polarit)	y V)		_12.564		26.000	17.914	-8.086	

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

11:46:08 AM,	Thursday, I	Company: TI/PR129669 Contact: Josh Mandelcor								
	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	
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 2 Broadcast (Cl stitch11pF Yo Run4 with pow	200MHz-1GHz(1 Lass 5 Limit cap50pF noFB wer on	Polarity H)							

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

Operator: J.Vu

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