14A Active EMI Input Filter Module for $48V_{DC}$ Bus

Product Description

The QPI-21 active EMI filter attenuates conducted common-mode (CM) and differential-mode (DM) noise over the CISPR22 frequency range of 150kHz to 30MHz. The product is designed for use in $48V_{DC}$ bus (36 – $76V_{DC}$) systems, with $100V_{DC}$ surge capability. The QPI-21's 14A rating supports multiple DC-DC converter loads up to an ambient temperature of 65°C without de-rating. Designed for the telecom and ITE bus range, the QPI-21 supports the PICMG® 3.0 specification for filtering system boards to the EN55022 Class B limits.

In comparison to passive solutions, the use of active filtering reduces component size and therefore reduces the overall package size. The Vicor QPI-21 smaller size saves valuable board real estate and the reduced height enhances air flow.

The QPI-21 is available as a lidded or an open-frame SiP (System-in-Package) module with LGA mounting. Evaluation boards are available to allow for quick in-circuit testing of the QPI-21LZ within an existing system design.



Features & Benefits

- 45dB CM attenuation at 250kHz (50Ω)
- 80dB DM attenuation at 250kHz (50Ω)
- $80V_{DC}$ (max input)
- $100V_{DC}$ surge 100ms
- $1,500V_{DC}$ hipot hold-off to shield plane
- 14A rating
- Low-profile LGA package
- ~$1in^2$ area
- –40 to +125°C Ambient temperature (see Figure 12)
- Efficiency >99%
- Connect in series for higher attenuation
- Pads for additional X filtering capacitance
- cTÜVus approved to UL/CSA 60950-1 and EN 60950-1
- CE marked to the LVD and RoHS Recast Directive as applicable

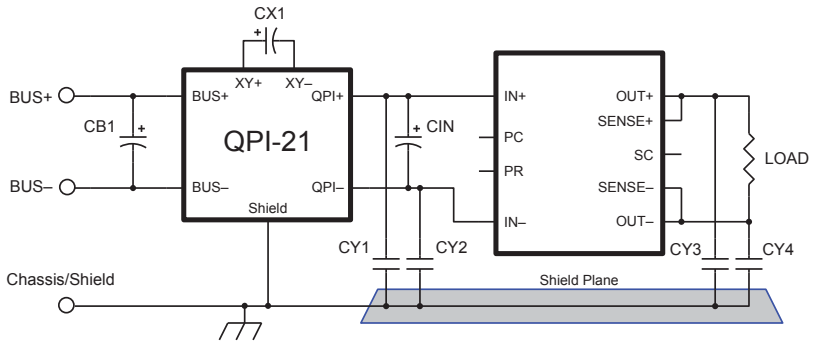
Applications

- ATCA Blades
- Telecom Base Stations
- IBA & Distributed Power
- Network Switches and Routers
- Optical Line-Cards
- TD-SCMA Wireless Infrastructure

Package Information

- 25.3 x 25.3 x 5.2mm lidded SiP (System-in-Package)
- 24.9 x 24.9 x 4.4mm open-frame SiP

Typical Application



Typical QPI-21 circuit with a Vicor Brick® converter; optional X (CX1) filter capacitor shown [a]

[a] CB1, CX1 capacitors, referenced in all schematics, are a 47µF electrolytic; United Chemi-Con EMVE101ARA470MKE0S or equivalent.

Contents

Order Information 3
Absolute Maximum Ratings 3
Electrical Characteristics 3
Package Pinout 4
Applications Information 5
- EMI Sources 5
- Passive EMI Filtering 5
- Active EMI Filtering 5
- EMI Management 6

Attenuation Test Set Ups 7
Attenuation Plots 8
Current De-Rating 9
QPI Application Circuits 10
QPI Insertion Loss Measurements and Test Circuits 11
Package Outline Drawings 12
Pad and Stencil Definitions 13
PCB Layout Recommendations 14
- PCB Layout 14
- Post-Solder Cleaning 14
- QPI-21 Mechanical Data 14

Revision History 15
Product Warranty 16

Order Information

Product	Description
QPI-21LZ [b]	QPI-21 LGA package, RoHS compliant
QPI-21LZ-01	QPI-21 LGA package, RoHS compliant, open-frame package

[b] QPI-21LZ is a non-hermetically sealed package. Please read the "Post-Solder Cleaning" section on page 14.

Absolute Maximum Ratings

Exceeding these parameters may result in permanent damage to the product. CY1 to CY4, referenced in all schematics, are 4.7nF high-voltage safety capacitors: Vishay VY1472M63Y5UQ63V0 or equivalent. CIN is the converter manufacturer's recommended value for input capacitor.

Name	Rating
Input Voltage, BUS+ to BUS–, Continuous	–80 to 80V_{DC}
Input Voltage, BUS+ to BUS–, 100ms Transient	–100 to 100V_{DC}
BUS+/ BUS– to Shield Pads, Hipot	–1500 to 1500V_{DC}
Input to Output Current, Continuous at 25°C T_A	14A_{DC}
Input-to-Output Current, 10 seconds at 25°C T_A	20A_{DC}
Power Dissipation, at 65°C T_A, 14A [c]	2.9W
Operating Temperature - T_A	–40 to 125°C
Thermal Resistance [c] - $R_{\theta J\text{-}A}$, using PCB layout in Figure 22	20°C/W
Thermal Resistance [c] - $R_{\theta J\text{-}PCB}$	8°C/W
Storage Temperature, JEDEC Standard J-STD-033B	–55 to 125°C
Reflow Temperature, 20s Exposure	245°C
ESD, Human Body Model (HBM)	–2000 to 2000V

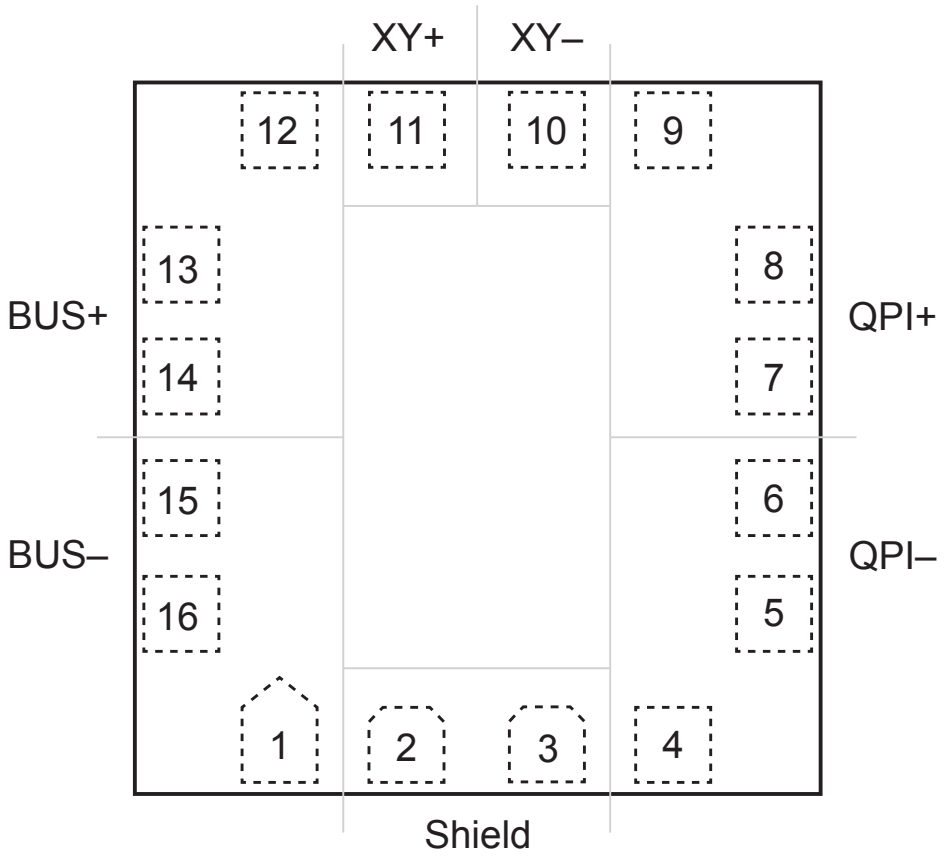
Electrical Characteristics

Parameter limits apply over the operating temperature range unless otherwise noted.

Parameter	Conditions	Min	Typ	Max	Unit
BUS+ to BUS– Input Range	Measured at 14A, 65°C ambient temperature [c]	30		80	V_{DC}
BUS+ to QPI+ Voltage Drop	Measured at 14A, 65°C ambient temperature [c]			156	mV_{DC}
BUS– to QPI– Voltage Drop	Measured at 14A, 65°C ambient temperature [c]			50	mV_{DC}
Common-Mode Attenuation	V_{BUS} = 48V, Frequency = 250kHz, line impedance = 50Ω		45		dB
Differential-Mode Attenuation	V_{BUS} = 48V, Frequency = 250kHz, line impedance = 50Ω		80		dB
Input Bias Current at 80V	Input current from BUS+ to BUS–		8		mA

[c] See Figure 12 for the current de-rating curve.

Package Pinout



Pad Number	Name	Description
12, 13, 14	BUS+	Positive bus potential
1, 15, 16	BUS–	Negative bus potential
7, 8, 9	QPI+	Positive input to the converter
4, 5, 6	QPI–	Negative input to the converter
2, 3	Shield	Shield connects to the system chassis or to a safety ground
10	XY–	Negative rail node for additional X filtering capacitance. Adding Y capacitors from this pin to ground is not recommended
11	XY+	Positive rail node for additional X capacitance. Adding Y capacitors from this pin to ground is not recommended.

Applications Information

EMI Sources

Many of the components in today's power conversion modules are sources of high-frequency EMI noise generation. Diodes, high-frequency switching devices, transformers and inductors, and circuit layouts passing high dV/dt or dI/dt signals are all potential sources of EMI.

EMI is propagated either by radiated or conductive means. Radiated EMI can be sourced from these components as well as by circuit loops that act like antennas and broadcast the noise signals to neighboring circuit paths. This also means that these loops can act as receivers of a broadcasted signal. This radiated EMI noise can be reduced by proper circuit layout and by shielding potential sources of EMI transmission.

There are two basic forms of conducted EMI that typically need to be filtered; namely common-mode (CM) and differential-mode (DM) EMI. Differential-mode resides in the normal power loop of a power source and its load; where the signal travels from the source to the load and then returns to the source. Common-mode is a signal that travels through both leads of the source and is returned to earth via parasitic pathways, either capacitively or inductively coupled.

Figures 7 – 10 are the resulting EMI plots, after filtering by the QPI-21, of the total noise, both common and differential mode, of a DOSA (Distributed-power Open Standards Alliance) compliant converter. These converters are mounted on a QPI-21 evaluation board and tested under various loads. The red and blue traces represent the positive and negative branches of total noise, as measured using an industry-standard LISN setup, as is shown in Figures 4 – 6.

Differential-mode EMI is typically larger in magnitude than common-mode, since common-mode is produced by the physical imbalances in the differential loop path. Reducing differential EMI will cause a reduction in common-mode EMI.

Passive EMI Filtering

The basic premise of filtering EMI is to insert a high impedance, at the EMI's base frequency, in both the differential- and common-mode paths as it returns to the power source. Passive filters use common-mode chokes and "Y" capacitors to filter out common-mode EMI. These chokes are designed to present a high impedance at the EMI frequency in series with the return path, and a low-impedance path to the earth signal via the "Y" caps. This network will force the EMI signals to re-circulate within a confined area and not to propagate to the outside world. Often two common-mode networks are required to filter EMI within the frequency span required to pass the EN55022 class B limits.

The other component of the passive filter is the differential LC network. Again, the inductor is chosen such that it will present a high-impedance in the differential EMI loop at the EMI's base frequency. The differential capacitor will then shunt the EMI back to its source. The QPI-21 was specifically designed to work with conventional switching frequency converters like Vicor Brick® products; Micro, Mini and Maxi modules; as well as converters from various vendors.

Active EMI Filtering

The QPI-21 active EMI filter uses the same basic principles for filtering as the passive approach, but its active common-mode filter can perform as well as a passive filter, when filtering lower frequencies, in much less board area and power dissipation.

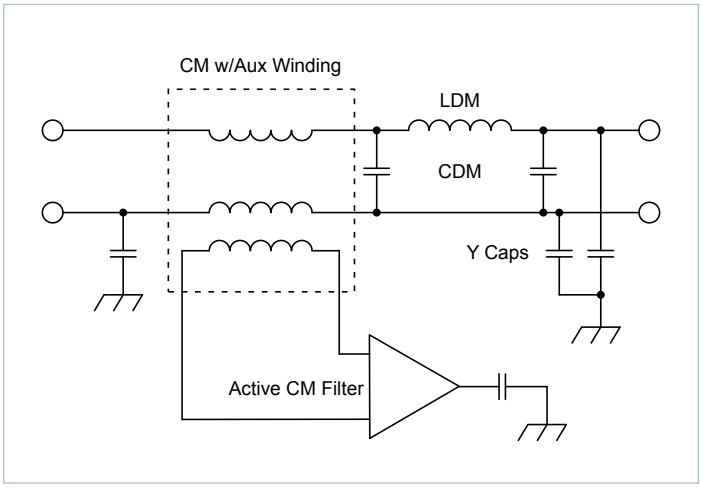


Figure 1 — *Simplified active EMI filter circuit.*

Typically, the lower the frequency the greater the needed inductance would be to properly filter the EMI signal. This means either a larger core or a greater number of turns on a smaller core. A larger core requires more board space, where a smaller core with more turns has a greater amount of unwanted parasitics that can affect the filters ability to attenuate EMI signals.

Figure 1 is a simplified schematic of the QPI-21's active and passive circuitry used for EMI filtering. The QPI-21's active filter uses a small high-frequency common-mode transformer to filter the higher frequencies and adds a sensing element to it so that the lower-frequency common-mode signal can be sensed and a correction signal can be generated and inserted into the shield connection. By this means, the QPI-21 is capable of providing EMI filtering of converters in far less space than standard passive filters and can provide filtering over the entire EN55022 class B range.

EMI Management

The more effectively EMI is managed at the source, namely the power converter, the less EMI attenuation will be required to meet a given standard. The addition of "Y" capacitors to the input and output power nodes of the converter will help to limit the amount of common-mode EMI that will propagate to the input source.

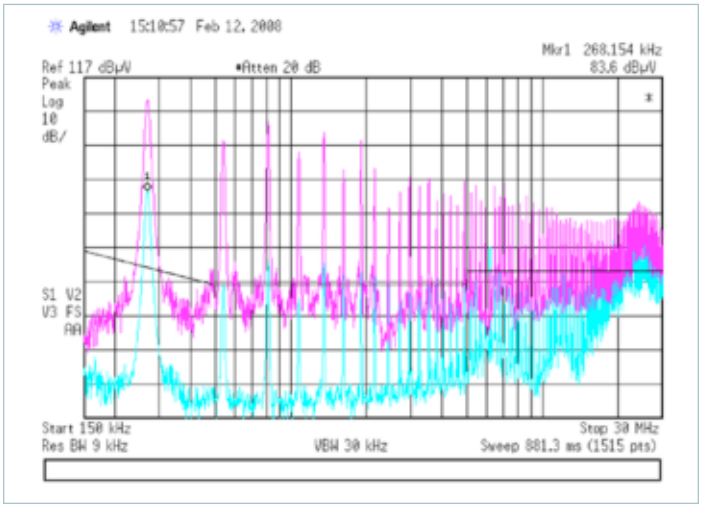


Figure 2 — *An unfiltered converter's response to "open-frame" (light blue) and "baseplate" (purple) EMI configurations*

There are two basic topologies for the connection of the re-circulating "Y" capacitors, referred to as "open-frame" and "baseplate."

Figure 2 illustrates how a converter's total conducted noise profile can vary with one topology versus another. The EMI generated by the "baseplate" configuration is much greater than that generated by the "open-frame" in this example. Selecting the right topology will greatly reduce the amount of EMI signal that needs to be filtered.

The typical application diagram shows the baseplate topology of re-circulating "Y" capacitors. Here, CY1 to CY4 are connected to each power node of the DC-DC converter, and then are connected together on a copper shield plane created under the converter. The addition of the copper shield plane helps in the containment of the radiated EMI, converting it back to conducted EMI and shunting it back to its source.

In Figure 3, the open-frame topology is shown where the "Y" capacitors (CY1 and CY2) re-circulate the EMI signals between the positive input and output, and the negative input and output nodes of the power conversion stage. Safety and system requirements may dictate that some converters must have the output return (–) directly connected to earth ground. This connection can impact performance of some filter solutions, where the QPI-21 works well in this configuration.

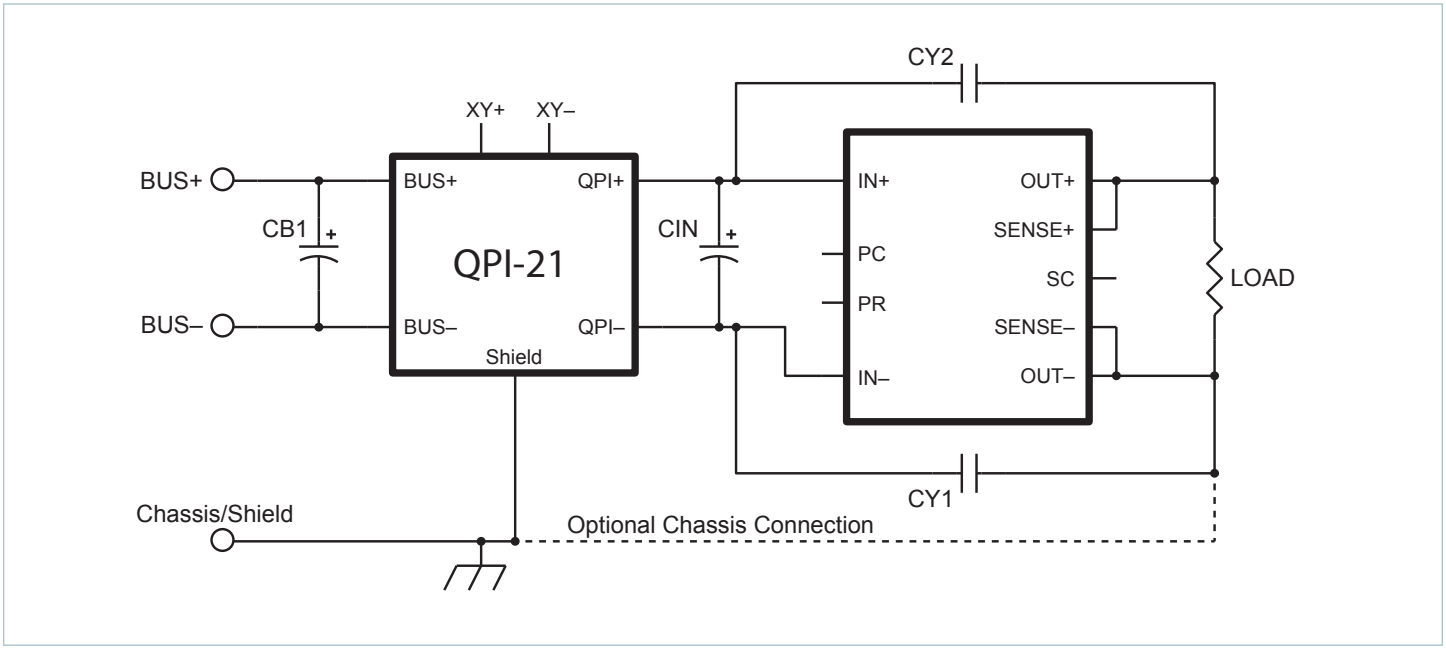


Figure 3 — *Typical "open-frame" application with an optional connection of the chassis to OUT– of the converter*

Attenuation Test Set Ups

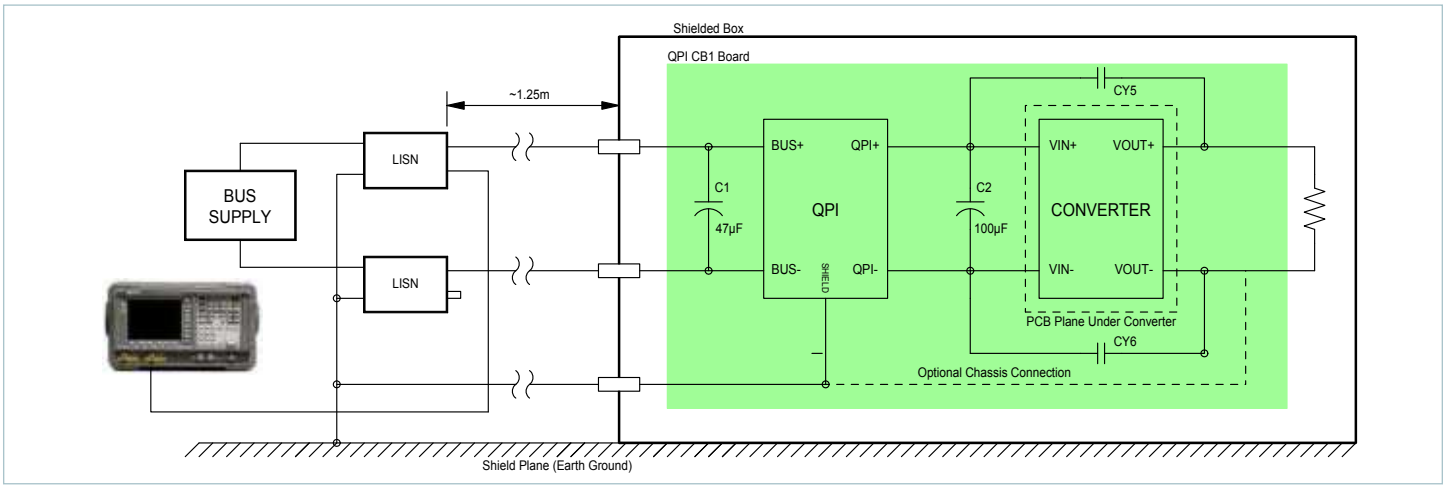


Figure 4 — *Open-frame EMI test set up using the QPI-21-CB1 carrier board with 48V converter*

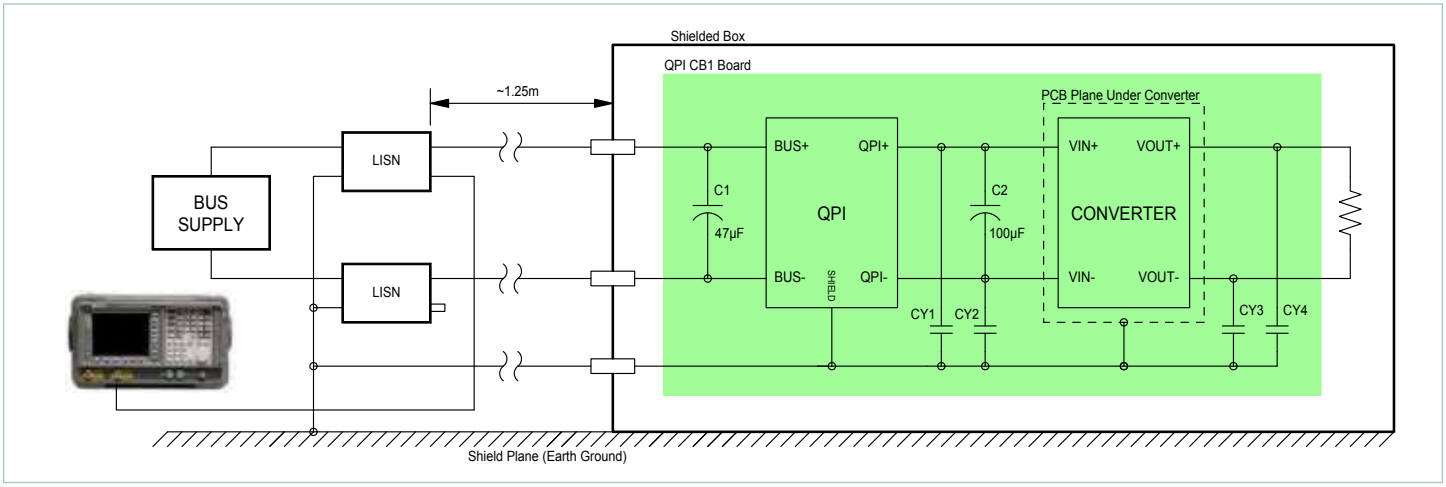


Figure 5 — *Baseplate EMI test set up using the QPI-21-CB1 carrier board with 48V converter*

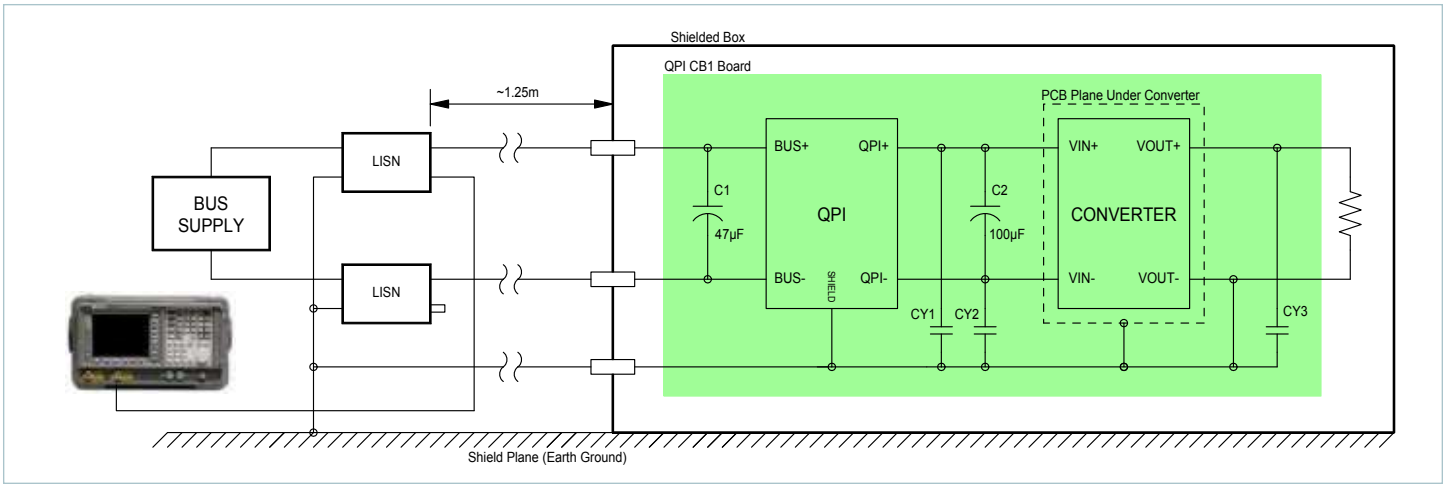


Figure 6 — *Baseplate EMI test set up using the QPI-21-CB1 carrier board with 48V converter*

In Figures 4 – 6, C1 is the required 47µF capacitor (United Chemi-Con EMVE101ARA470MKE0S or equivalent), C2 is a converter input cap (value dependent on converter), and the CY capacitors are high-voltage, 4.7nF ceramics (Murata GRM31BR73A472KW01L or equivalent).

Attenuation Plots

All converters have their output ground connected to chassis/earth ground.

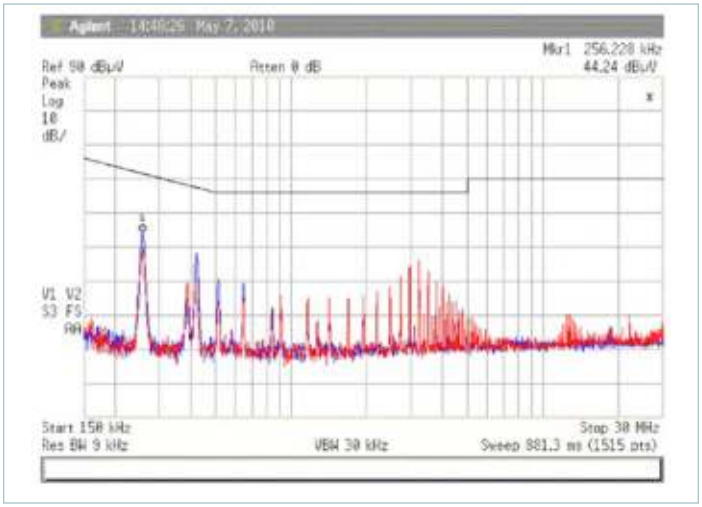


Figure 7 — *Ericsson PKM 4402NG using open-frame "Y" capacitors on QPI-21-CB1 evaluation board, 414W load*

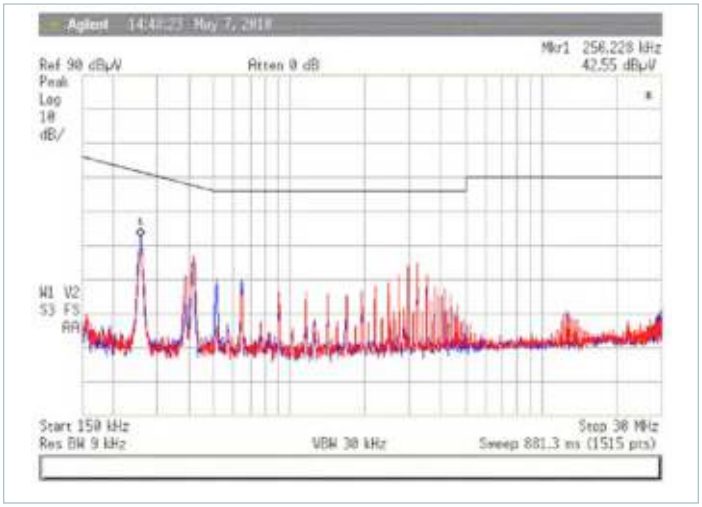


Figure 8 — *Ericsson PKM 4402NG using open-frame "Y" capacitors on QPI-21-CB1 evaluation board, 414W load, converter's ground connected to earth*

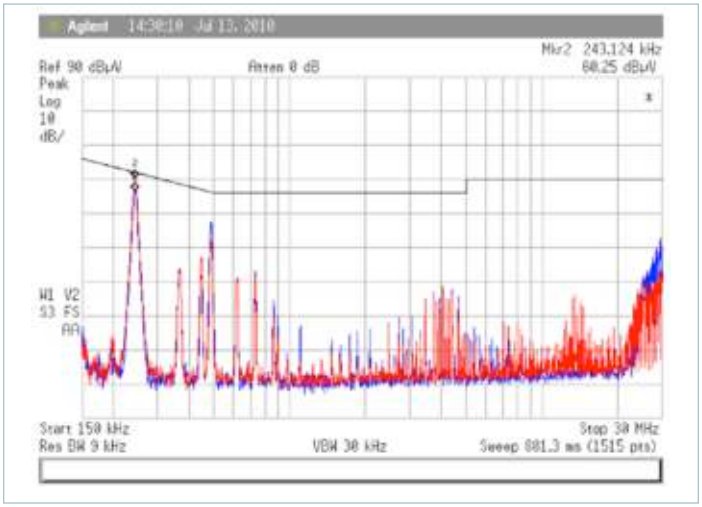


Figure 9 — *Ericsson PKM4304B PI using baseplate "Y" capacitors with a 360W load*

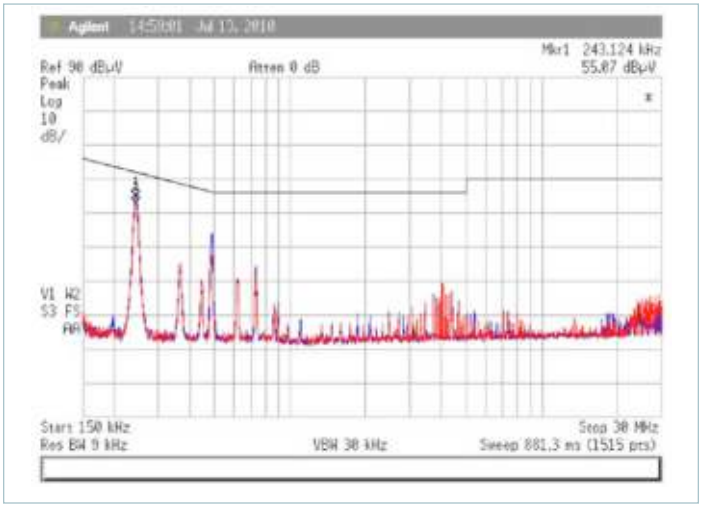


Figure 10 — *Ericsson PKM4304B PI using baseplate "Y" capacitors with a 360W load, CX1 = 47µF (see typical application on page 1)*

The EMI results shown in Figures 7 and 8 are of the total noise measured using the QPI-21 in an "open-frame" topology, as shown in Figure 3, with and without the converter's ground tied to chassis/earth.

The EMI results shown in Figures 9 and 10 are of the total noise measured using the QPI-21 in an "baseplate" topology, as shown in the typical application diagram on page 1, with and without the optional CX1 capacitor in use.

Using EMI splitters, the peak EMI at the fundamental switching frequency was determined to be mostly differential-mode current. The addition of a 47µF capacitor reduced the total peak by about 6dBµV, as shown in Figure 11.

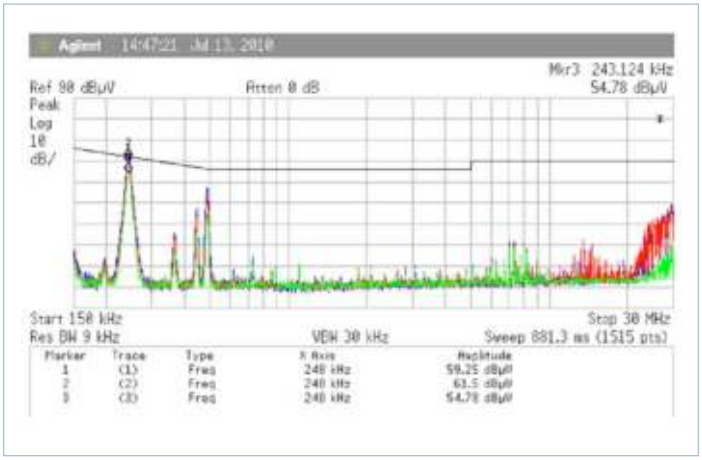


Figure 11 — *CM peak measurements with a 10µF and 47µF CX1 capacitor*

Current De-Rating

Mounted to QPI-21-EVAL1 evaluation board.

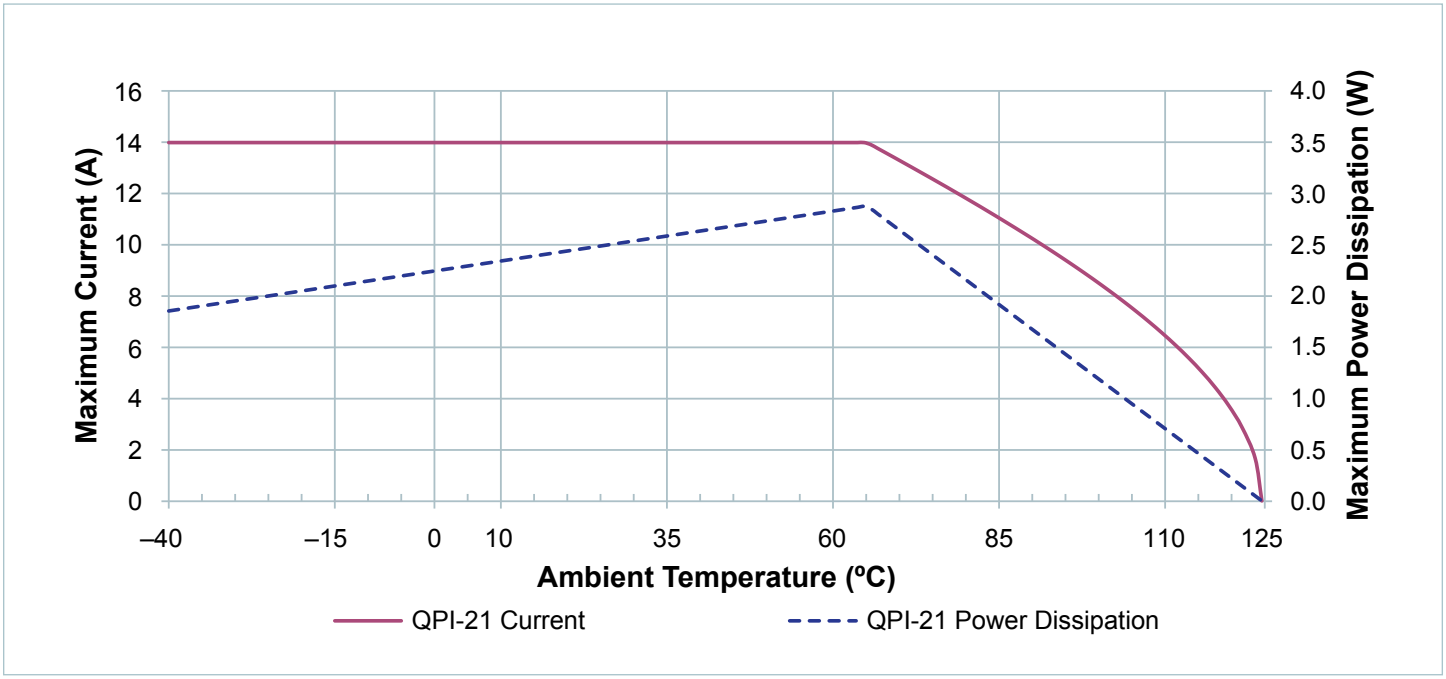


Figure 12 — *Current de-rating and power dissipation over ambient temperature range*

The de-rating curve in Figure 12 is based on the maximum allowable internal component temperature and the 14A maximum rating of the QPI-21. The power dissipation curve is based on the current squared multiplied by the internal resistance between the inputs and outputs of the filter. The internal resistance temperature coefficient is compensated for in the power dissipation curve. The left Y axis is in amps for the solid trace, the right Y axis is in watts for the dashed trace.

QPI Application Circuits

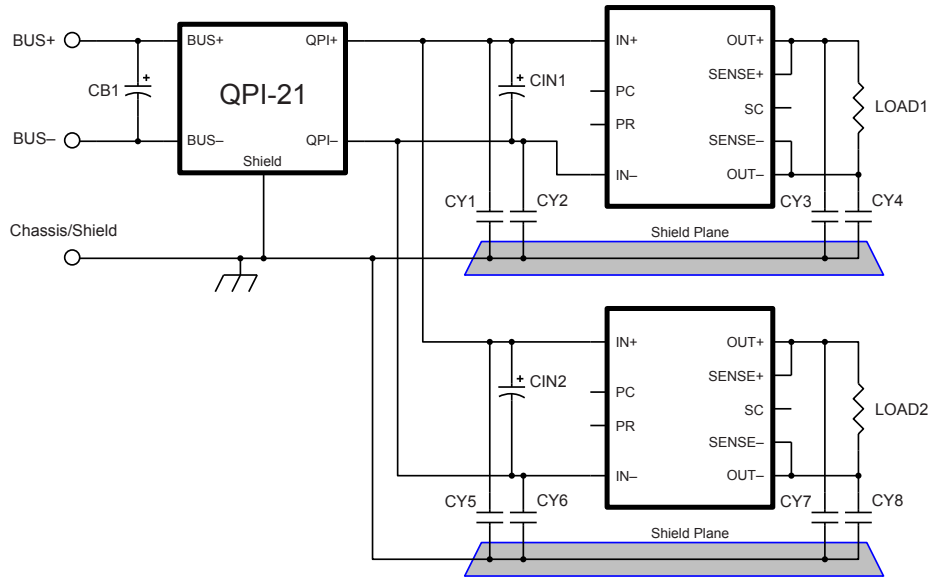


Figure 13 — *The QPI-21 filtering dual supplies, using a single RY resistor* [d]

The shield plane under the two converters in Figure 13 should be one contiguous plane under both. The circuit in Figure 13 is capable of filtering more converters than shown, up to the maximum current limit of the QPI-21. In Figure 14, the QPI+ and QPI– outputs of each filter should not be connected in parallel. The QPI-21 is not designed to be used in parallel with another QPI-21 to achieve a higher current rating, but it can be used multiple times within a system design.

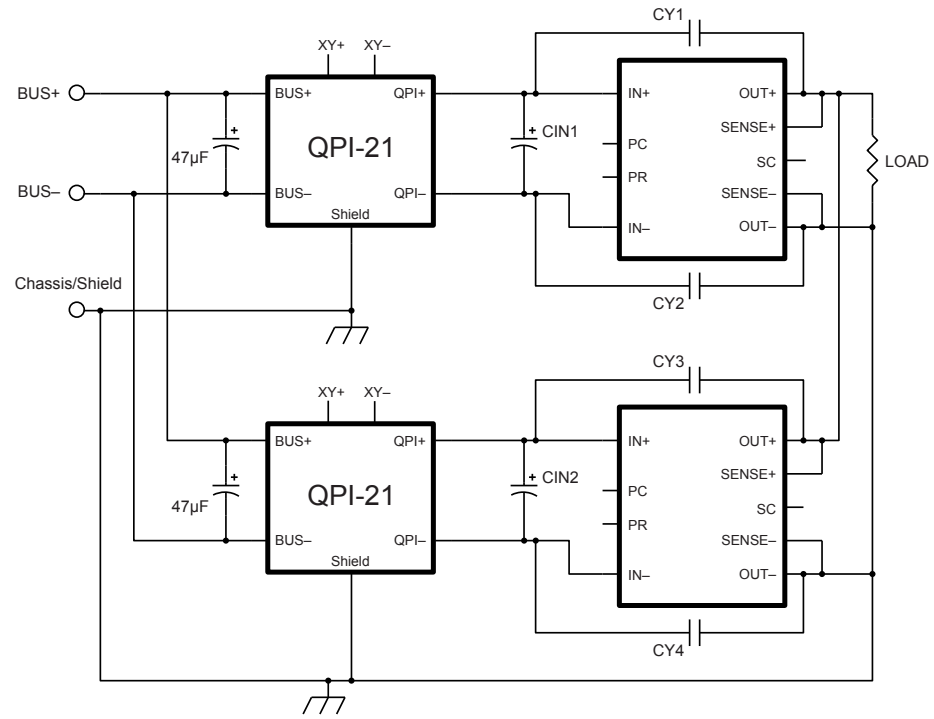


Figure 14 — *Dual QPI-21's filtering paralleled converters feeding a common load* [d]

[d] In Figures 13 and 14, CIN1, CIN2 and CY1– CY8 should be the value and voltage rating recommended by the converter's manufacturer

QPI Insertion Loss Measurements and Test Circuits

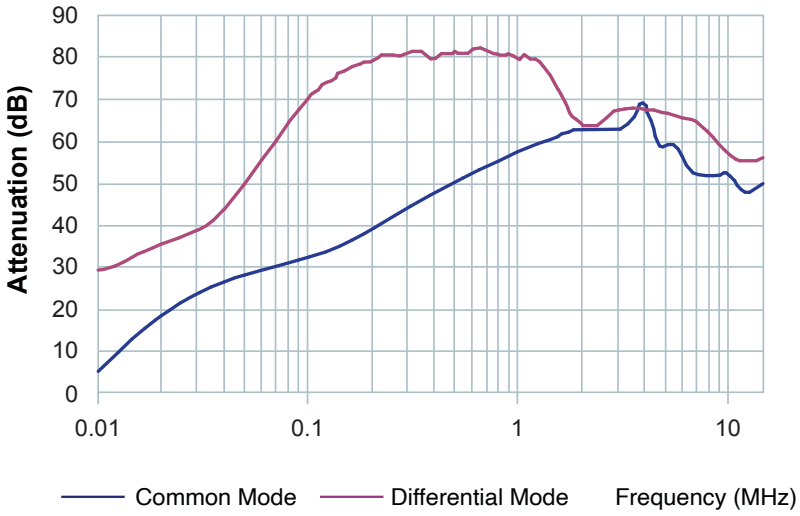


Figure 15 — *Attenuation curves into a 50Ω line impedance, bias from a 48V bus*

Insertion loss equation:

$$Insertion\ Loss\ =\ 20log\left(\frac{I_{INA}}{I_{INB}}\right)$$

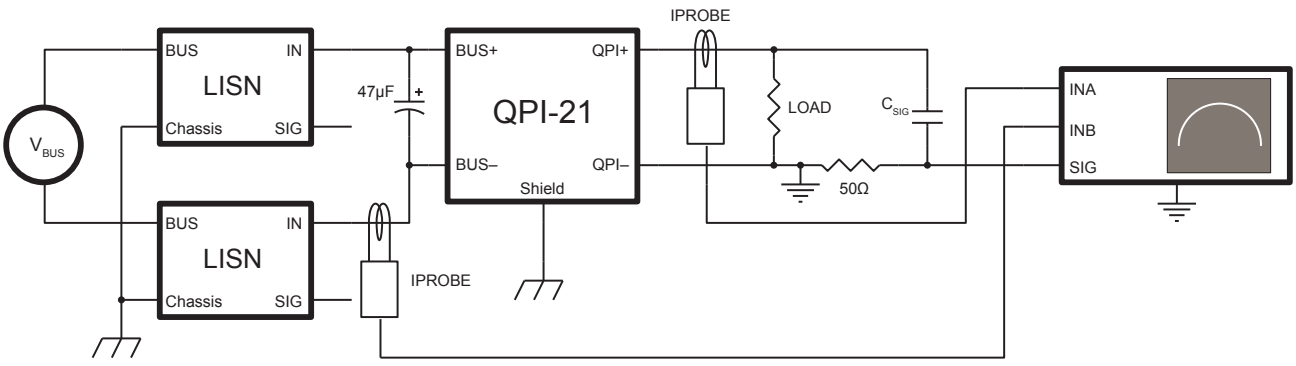


Figure 16 — *Test set up to measure differential-mode EMI currents in Figure 15*

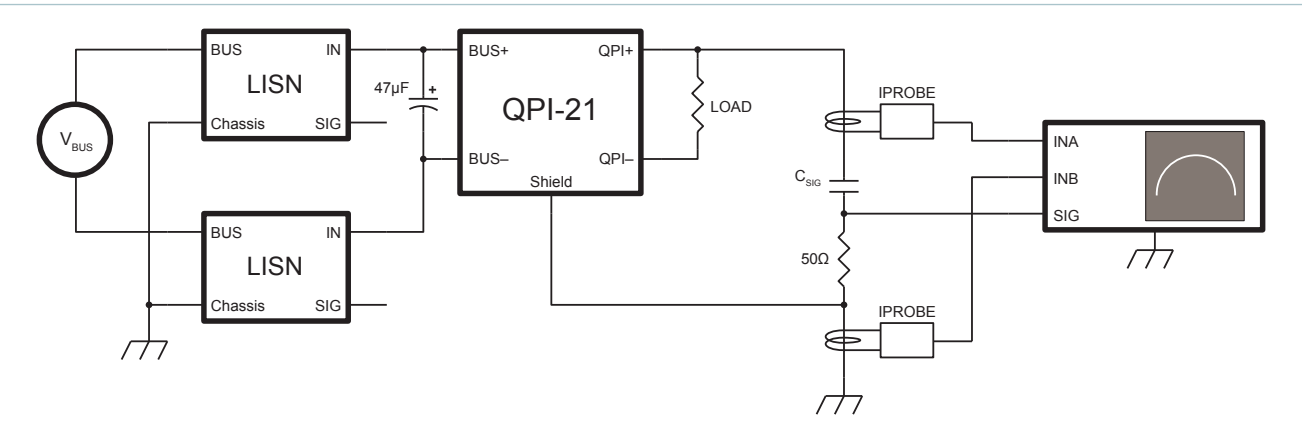


Figure 17 — *Test set up to measure common-mode EMI currents in Figure 15*

Package Outline Drawings

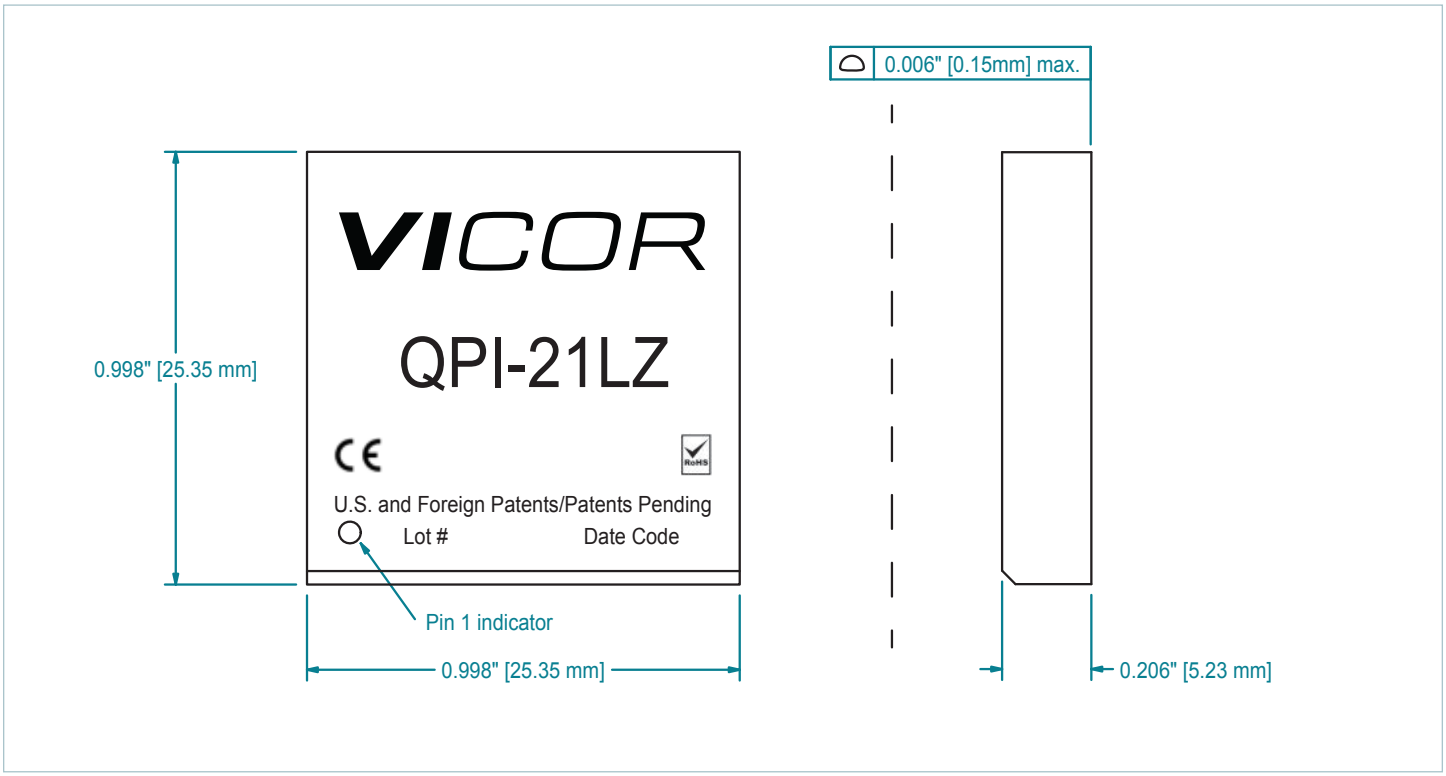


Figure 18 — *Lidded package dimensions, tolerance of ±0.004in*

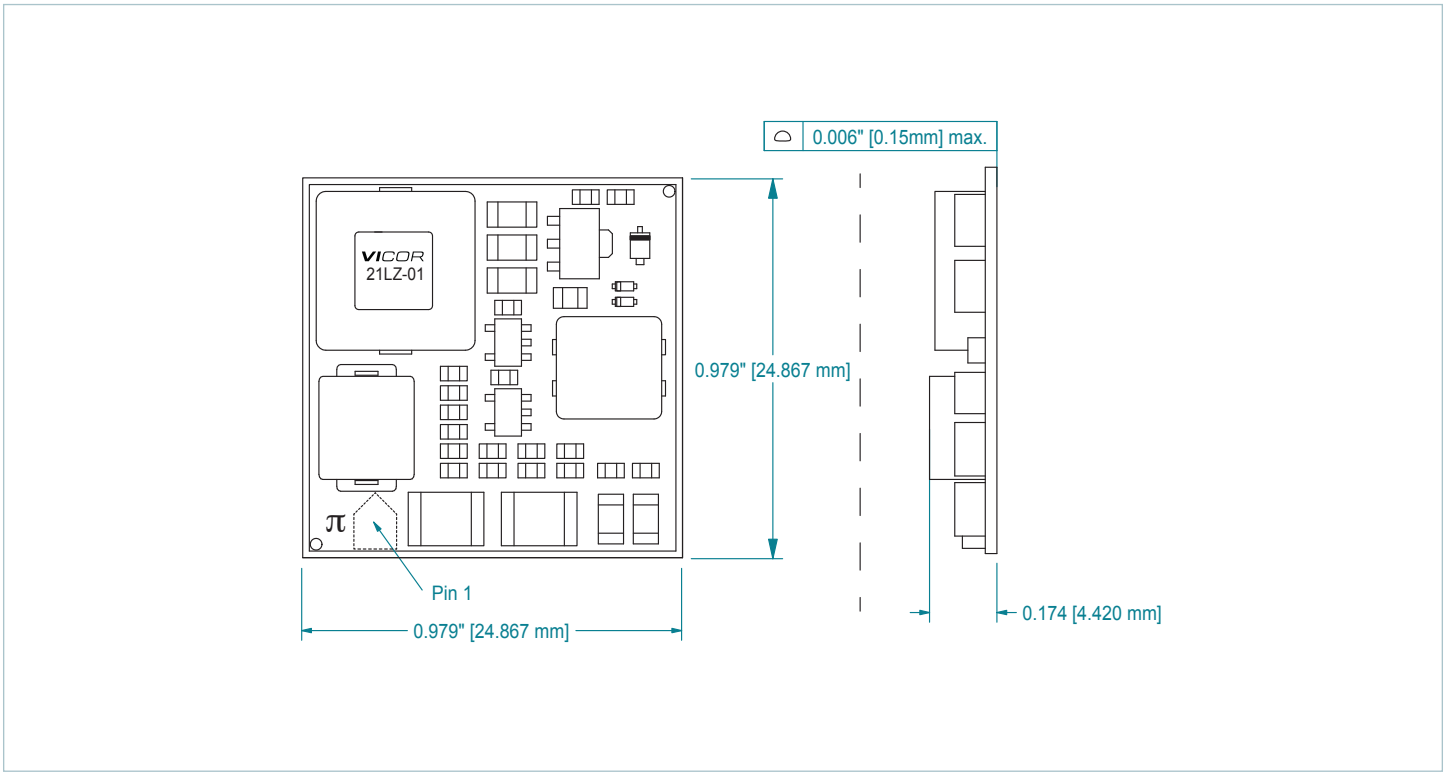


Figure 19 — *Open-frame package dimensions, tolerance of ±0.004in; pick-and-place from label center*

Pad and Stencil Definitions

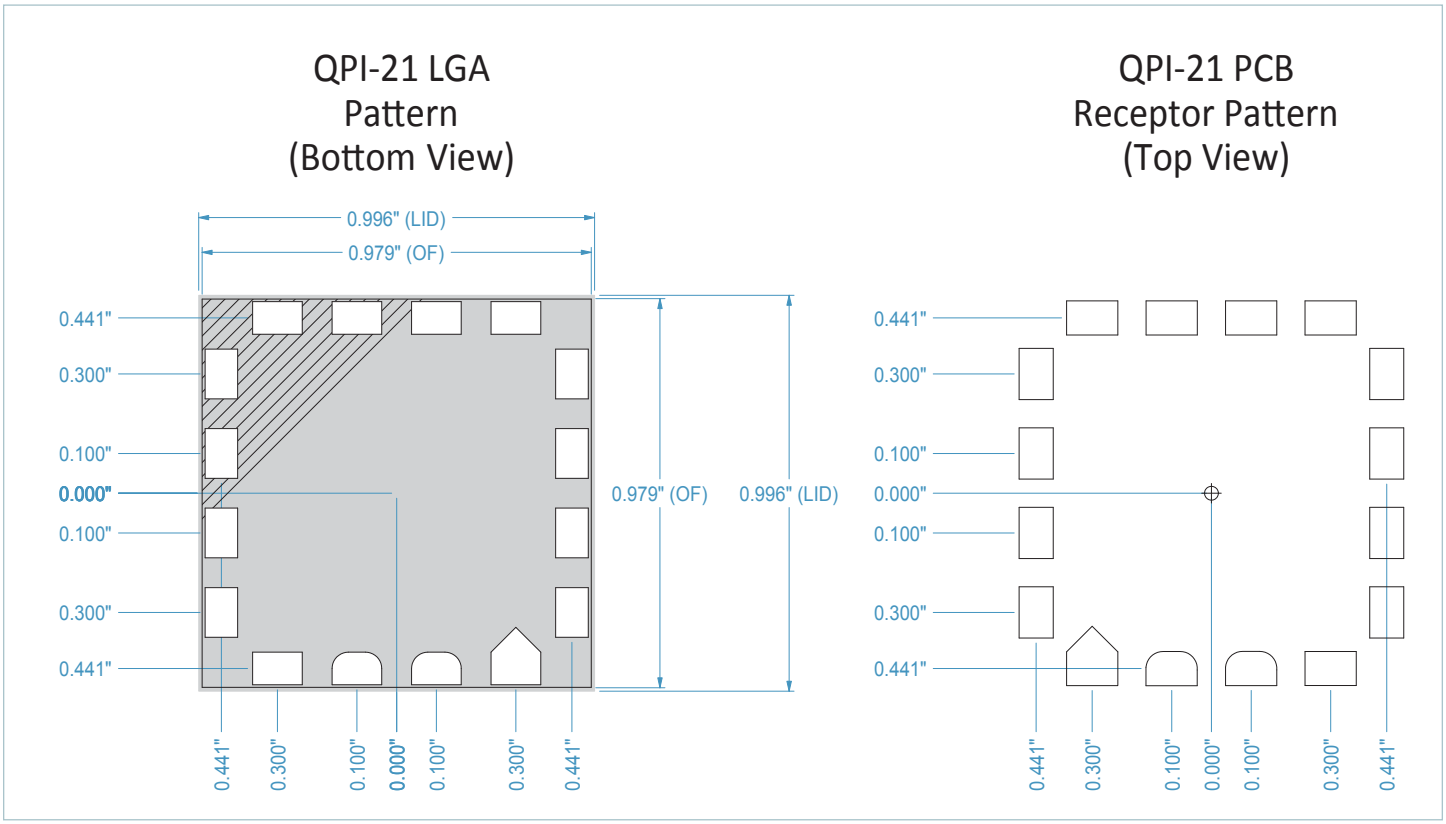


Figure 20 — *Bottom view of open-frame (OF) and lidded (LID) products (all dimensions are in inches)*

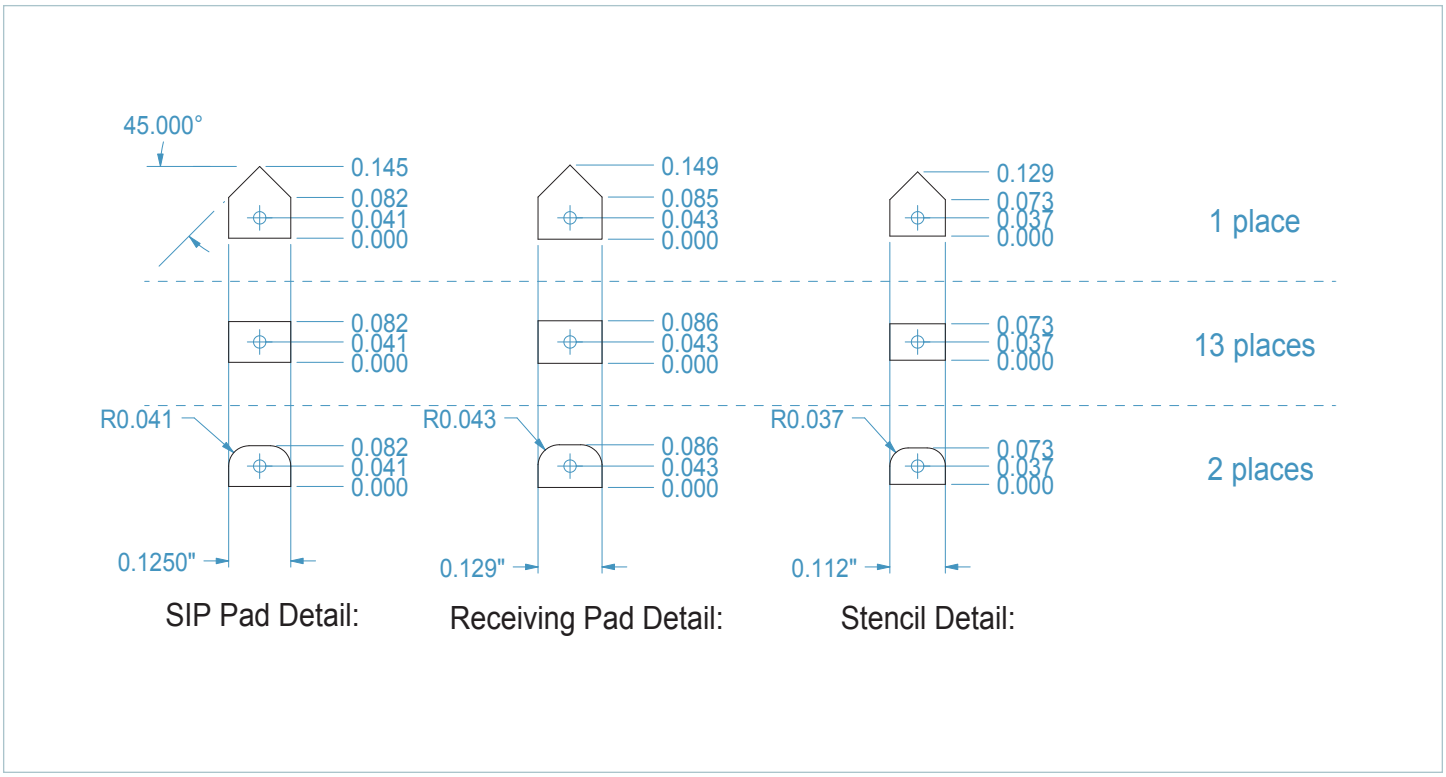


Figure 21 — *Recommended receptor and stencil patterns (all dimensions are in inches)*

Note: Stencil definition is based on a 6mil stencil thickness, 80% of LGA pad area coverage.
LGA Package dimensions are for both the open-frame and lidded versions of the QPI-21.

PCB Layout Recommendations

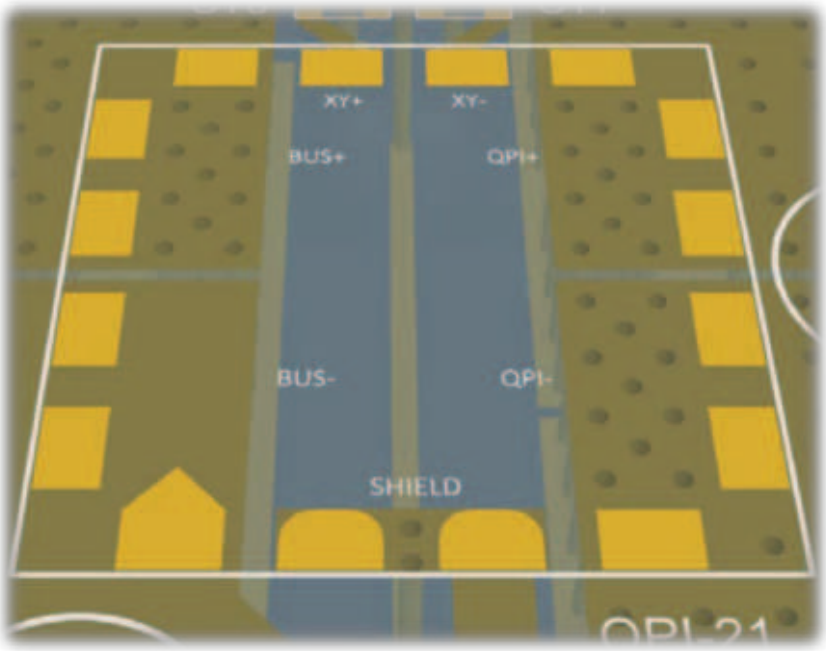


Figure 22 — *3D view of paralleling planes underneath the QPI-21*

PCB Layout

When laying out the QPI-21 EMI filter it is important for the designer to be aware of the radiated EMI field that all converters emit and to place the QPI-21 outside of this field area. It is also recommended that the bus lines feeding into the QPI filter are not routed such that they lie between the QPI and the converter, or that their copper planes overlap on inner layers. This can cause EMI noise to be coupled from input to output via the parasitic capacitance between the planes.

When using converters that have a large field of radiated EMI surrounding them, the QPI-21 must be located outside of this area of radiation, with the BUS voltage pins located on the side farthest away from the converter. This is to keep the radiated EMI from by-passing the filter and coupling directly to the BUS feeds.

Post-Solder Cleaning

LZ version QP SiPs are not hermetically sealed and must not be exposed to liquid, including but not limited to cleaning solvents, aqueous washing solutions or pressurized sprays. When soldering, it is recommended that no-clean flux solder be used, as this will ensure that potentially corrosive mobile ions will not remain on, around, or under the module following the soldering process. For applications where the end product must be cleaned in a liquid solvent, Vicor recommends using the QPI-21LZ-01, open-frame version of the EMI filter.

QPI-21 Mechanical Data

Datum	Units	QPI-21LZ	QPI-21LZ-01	Notes
FITS	Failure/Billion Hrs	208	208	FITS based on the BellCore Standard TR-332
MTBF	Million Hrs	4.8	4.8	MTBFs based on the BellCore Standard TR-332
Weight	grams	6.5	5.2	
MSL		3	3	
Peak Reflow Temperature	°C/20 seconds	245	245	IPC/JEDEC J-STD-020D

Revision History

Revision	Date	Description	Page Number(s)
1.6	07/31/26	Updated order information Corrected pad numbering for BUS– Updated branding and format	3 4 all

Vicor's comprehensive line of power solutions includes high density AC-DC and DC-DC modules and accessory components, fully configurable AC-DC and DC-DC power supplies, and complete custom power systems.

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Specifications are subject to change without notice.

Visit https://www.vicorpower.com/dc-dc-filters/qpi for the latest product information.

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