TI POWER-SUPPLY FILTER ICs

New Product Update

Sharadh Navale
- Product Line Marketing

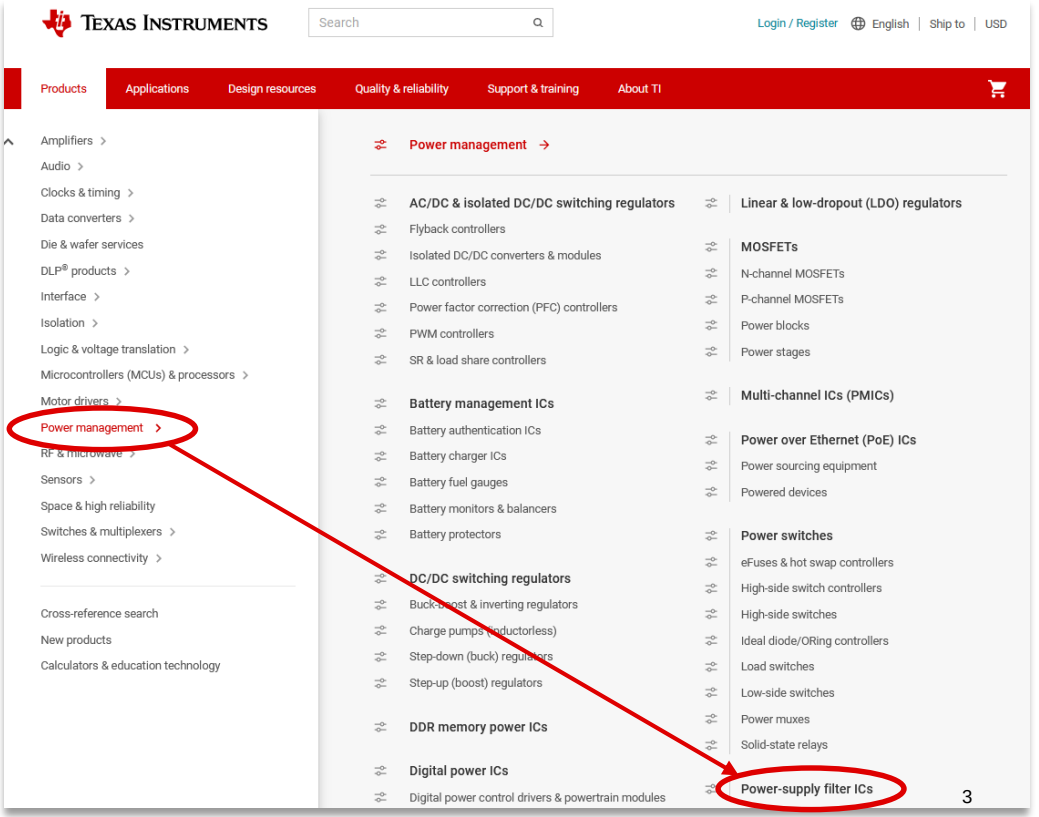
Agenda

- Introduction & background to a new product category
- Product overview of stand-alone AEF IC
- Results
- Design tools & resources

Please feel free to “chat” with Ben Chan, Systems Engineer who is available to answer any questions you have throughout this presentation.

New product category on TI.com

Power supply filter ICs
Includes a new product family of
Common-mode active EMI filter ICs



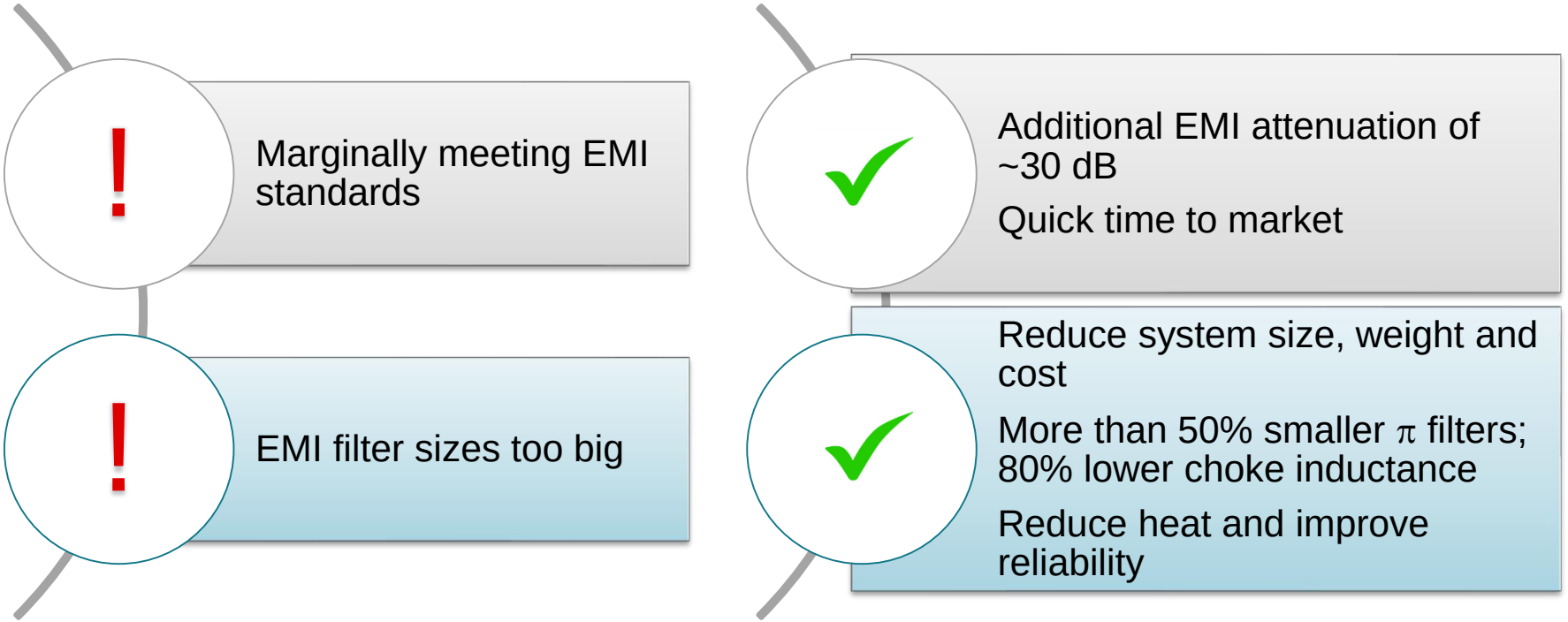
Power-supply filter ICs – active EMI filter ICs

Reduce system size, weight and cost with stand-alone AEF ICs

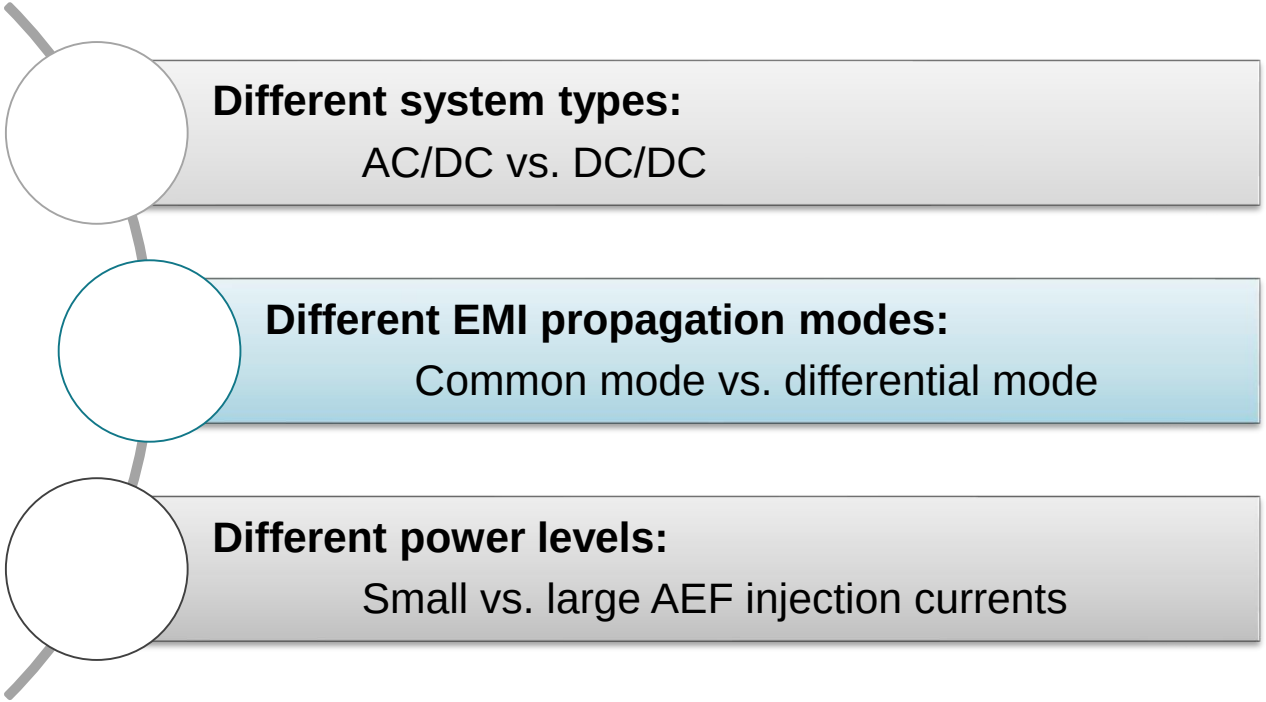
Mitigating electromagnetic interference (EMI) has become more challenging given the large passive filters in power-supply systems.

By acting as a capacitance amplifier, the active EMI filter (AEF) integrated circuits (ICs) in our new power-supply filter IC portfolio make it possible to achieve up to 30 dB of additional EMI attenuation, reducing the inductance value of chokes in common-mode filters as much as 80%.

Solving key design challenges with AEF ICs



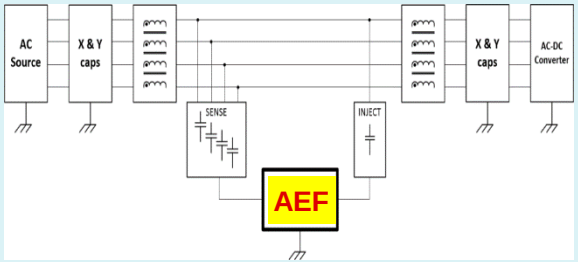
Where are AEFs used?



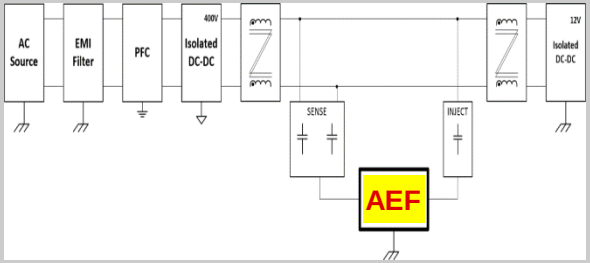
Where AEF can help

Address common-mode (CM) and differential-mode (DM) EMI challenges for AC/DC and DC/DC systems.

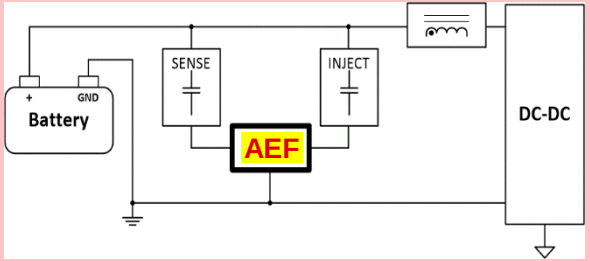
AC grid-side CM



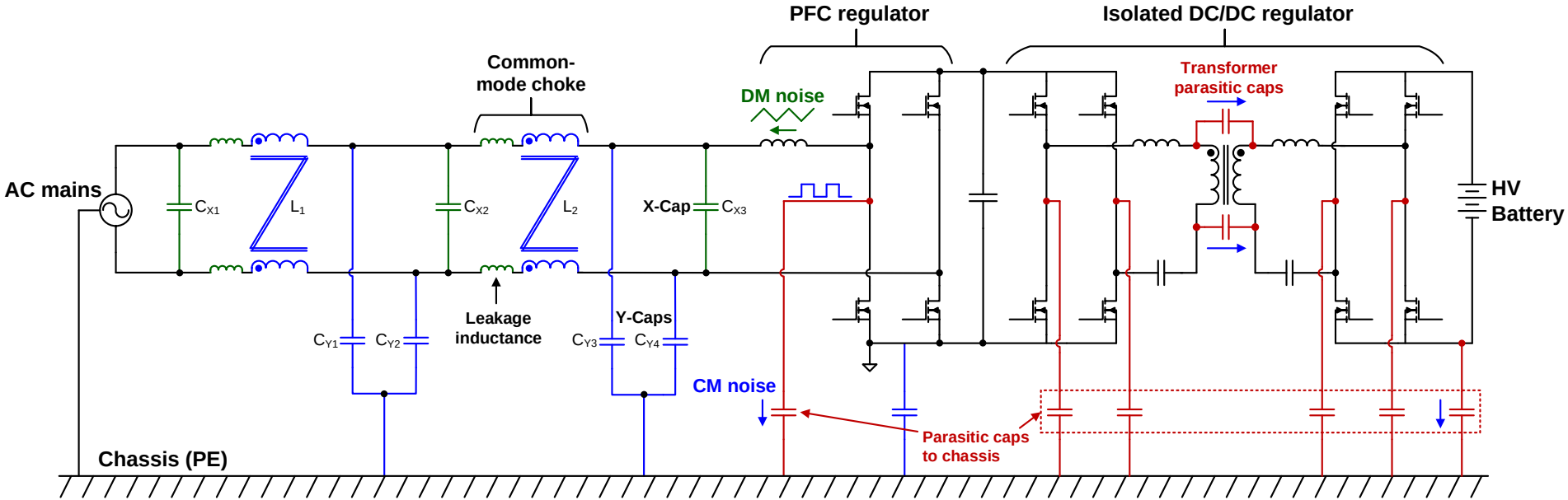
HV/LV DC-side CM



DC/DC-side DM

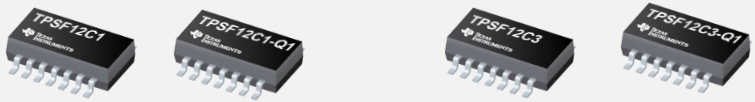


DM vs. CM filtering in high-power applications



- Both DM noise and CM noise are filtered using multi-stage LC filters
- For **DM filtering**, C is large valued (~µF), so **L can be relatively small (~µH) – typically obtained from leakage inductance of the CM choke**
- For **CM filtering**, allowed Y-cap is limited (~nF) by leakage-current regulatory requirements (touch current), so **L_{CM} needs to be large (~mH) – CM choke dominates the total size of the EMI filter**

Mitigate common-mode emissions to meet stringent EMI standards with stand-alone active EMI filters



TI's active EMI filter ICs meet IEC 61000-4-5 surge immunity requirements, thus minimizing the need for external protection components, such as transient voltage suppression (TVS) diodes.

CISPR

Engineers will be able to address EMI design challenges and meet CISPR 11, CISPR 32 and CISPR 25 EMI requirements.

High-power applications for active EMI filters

Automotive on-board chargers (OBCs)

Single-phase and three-phase industrial systems

Power delivery – Server rack PSUs

Communications systems

- High-power applications in highly constrained system environments
- Strict EMI standards
- Common-mode (CM) emissions dictate filter size

Reduce the size, weight and cost of traditional passive EMI filter designs with **TI's active filter solution**

TPSF12C3/-Q1 3-ϕ common-mode AC/DC active EMI filter

Features

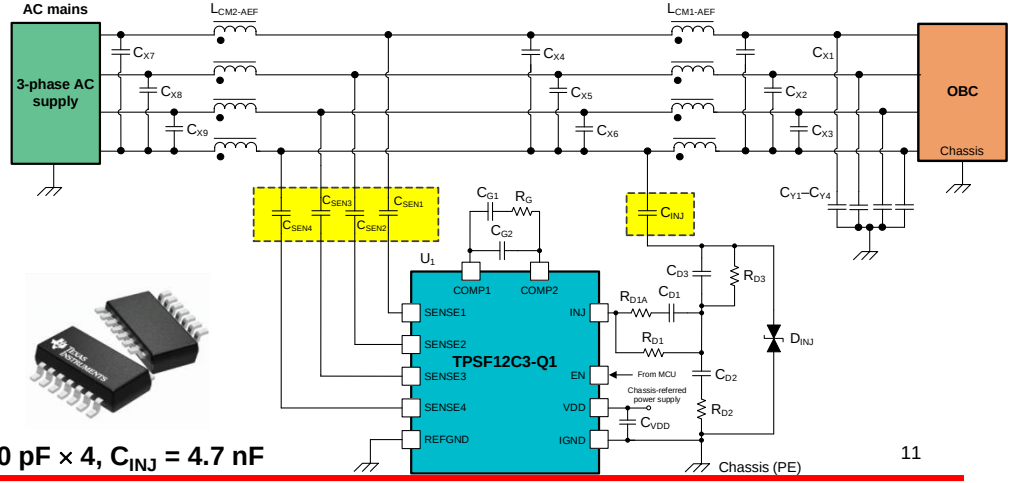
- **Low impedance over EMI concerned frequency range:**
  - 150 kHz to 3 MHz
- **Internal/external protection for IEC 61000-4-5 surge** (5 kV)
- **Fundamental converter frequency**: supports up to 500 kHz
- **Supports low-value capacitors** (sense, inject)
- **Integrated compensation network**
- **Simple external configuration**
- **Wide power supply range:** 8 V to 16 V
- **Enable pin feature**
- **Temperature ranges:**
  - IC junction: –40°C to 150°C
  - Operating ambient: –40°C to 105°C
  - Thermal shutdown: 175°C
- **14-pin TSOT-23 package**

Applications

- **On-board charger (OBC) for electrical vehicles (EVs), BMS**
- **PD for Servers, Avionics, Test & Measurement, FA**
- **Telecom AC/DC rectifiers**

Benefits

- **Reduces the size and cost of the required front-end filter**
  - CISPR 25 (Class 5) and CISPR 11, 32 (Class A or B)
- **Supports high-power (10+ kW), high-voltage applications**
- **Optimized for high-frequency, high-power systems**
- **Low line-frequency leakage current** (typ ~700 µA @ 253 Vac)
- **Easy to use – no loop compensation required**
- **Low BOM cost solution**
- **Applicable to three-phase systems with or without neutral wire**

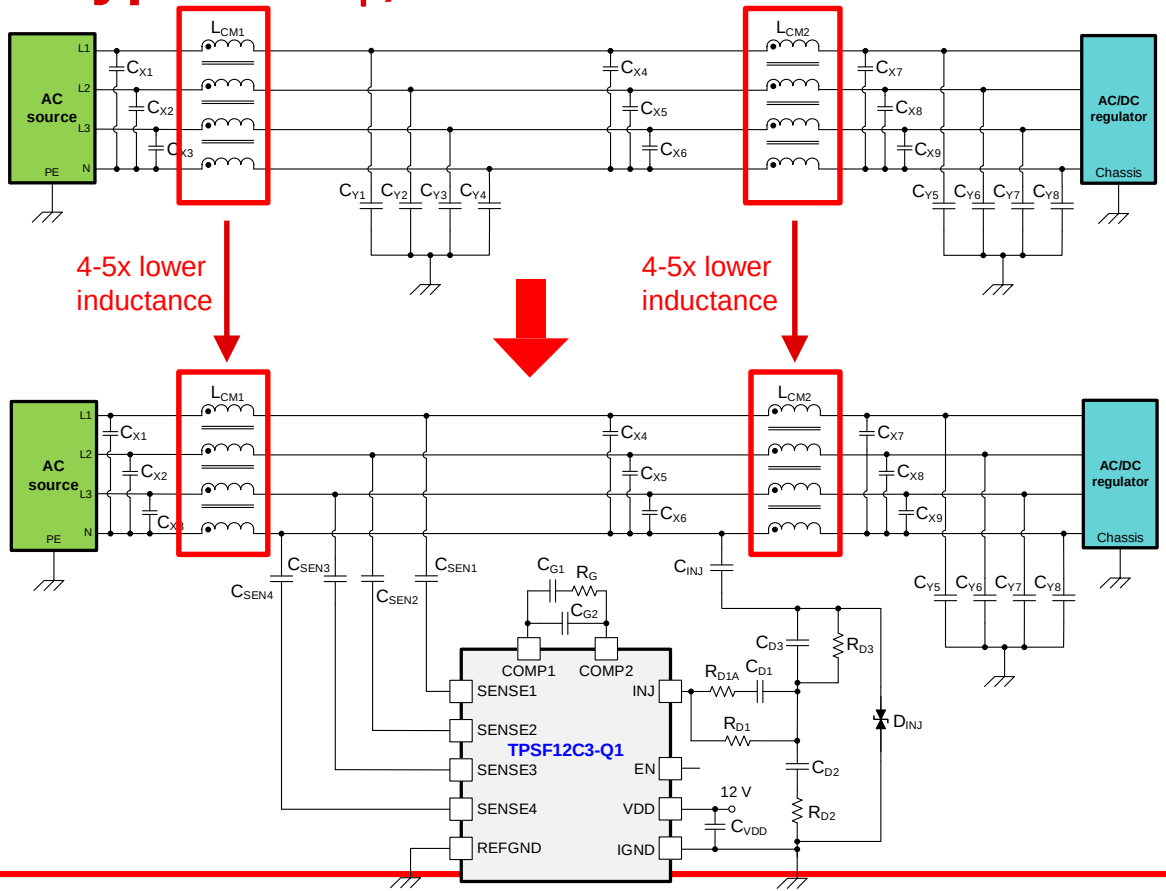


C_{SEN1-4} = 680 pF × 4, C_{INJ} = 4.7 nF

AEC-Q100 Grade 1

Texas Instruments

Typical 3-ϕ, 4-wire AEF schematic

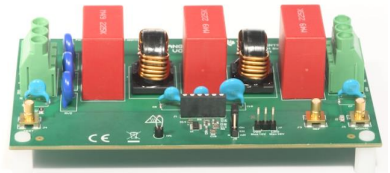


Three-phase schematic without AEF:

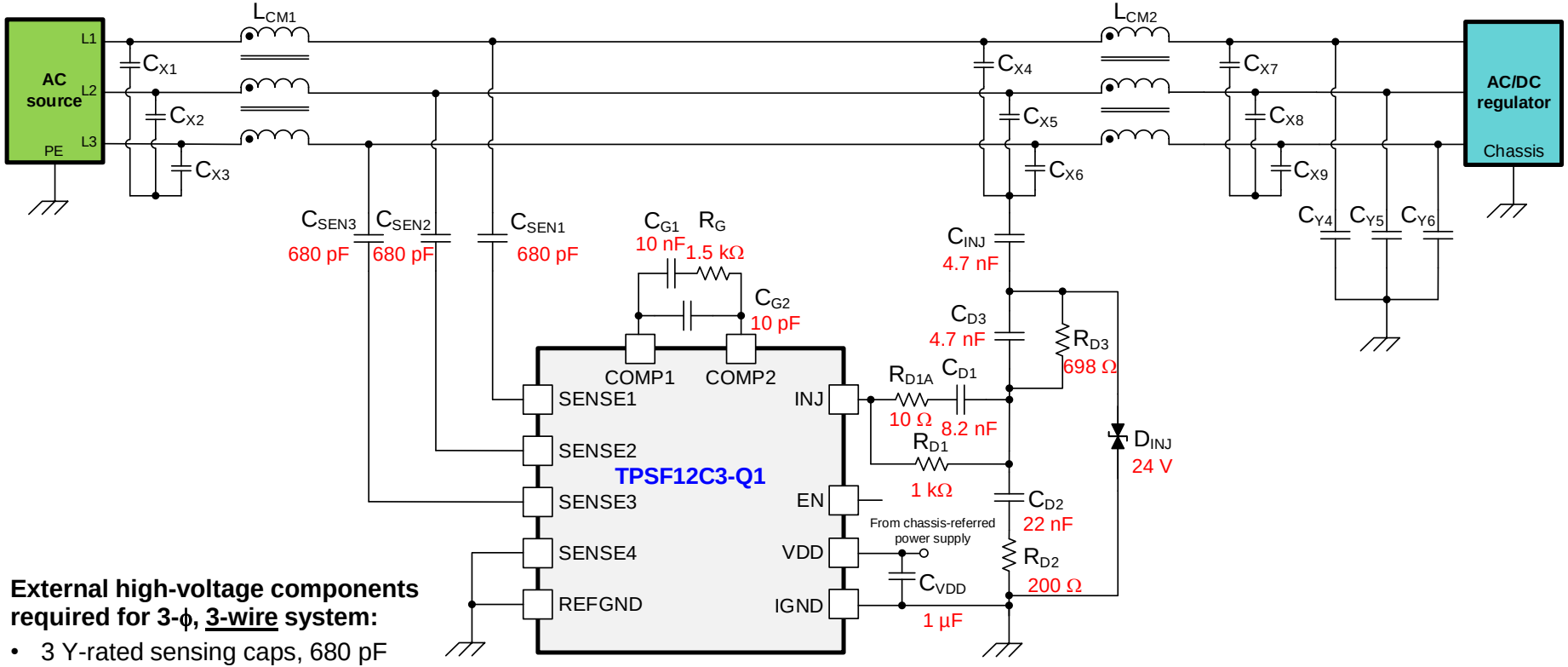
- Two-stage **passive** filter circuit with three-phase mains input
- CM chokes L_{CM1} and L_{CM2} dominate the total filter size
- Total Y-capacitance is limited

Three-phase schematic with AEF:

- Equivalent **active filter circuit**
- CM chokes L_{CM1} and L_{CM2} are each 4-5× lower in inductance with AEF
- Four sense capacitors, one inject capacitor
- No change in touch current amplitude during fault conditions



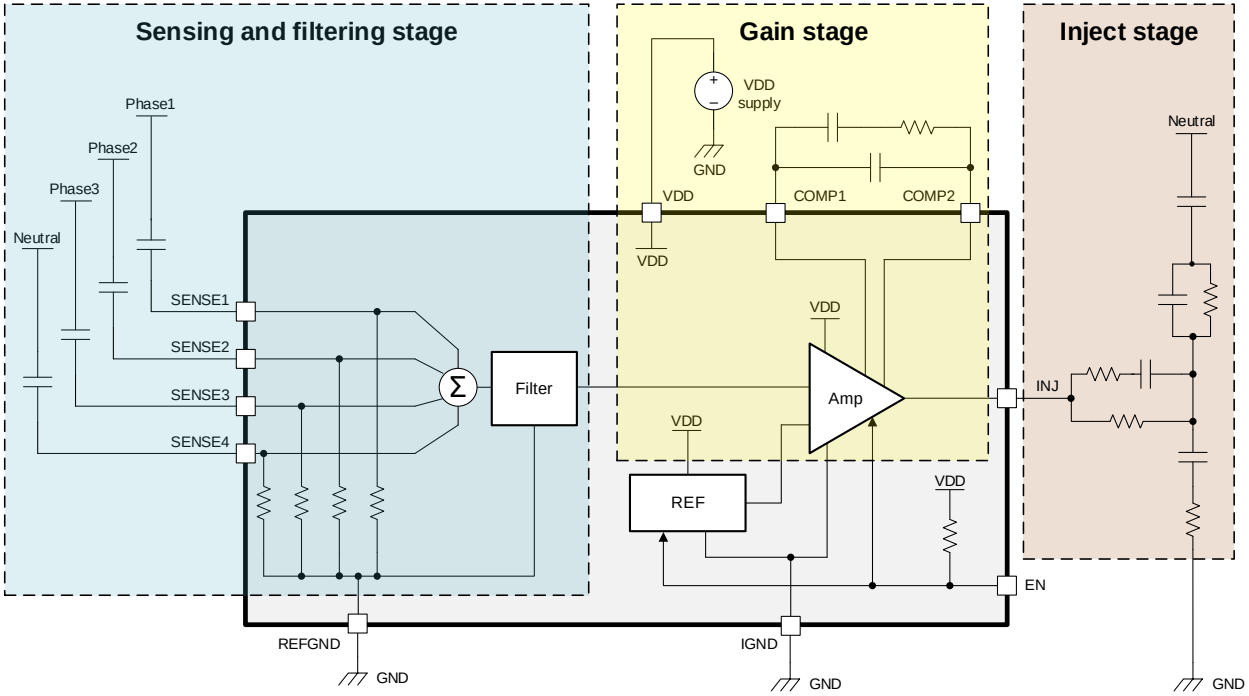
Typical 3-ϕ, 3-wire AEF schematic (no neutral)



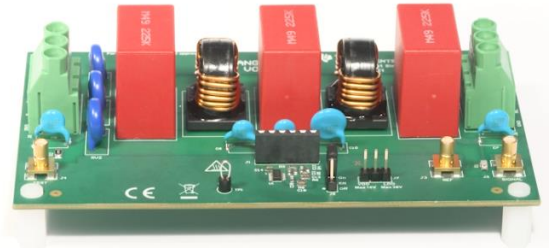
External high-voltage components required for 3-ϕ, 3-wire system:

- 3 Y-rated sensing caps, 680 pF
- 1 Y-rated inject cap, 4.7 nF

Functional block diagram of a three-phase AEF circuit



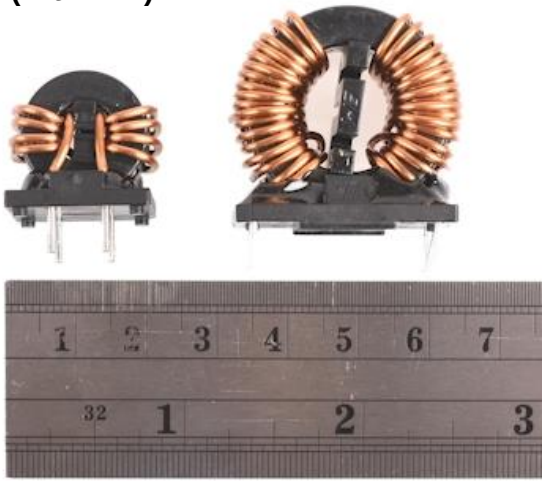
- The AEF IC rejects AC line frequency (50 Hz, 60 Hz) and differential-mode disturbances
- The design includes sensing, gain and inject stages

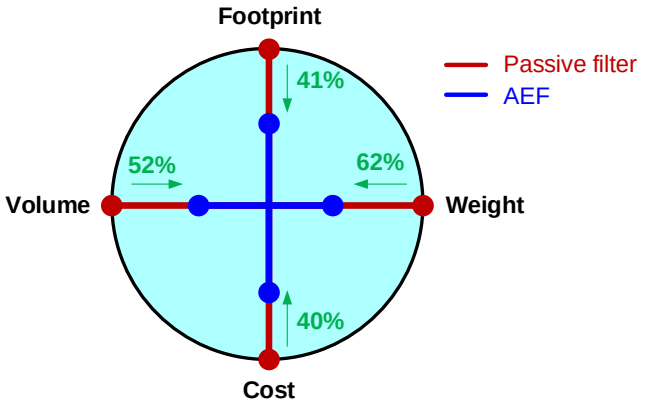


CM choke comparison – Active vs. passive designs

2 mH (with AEF)

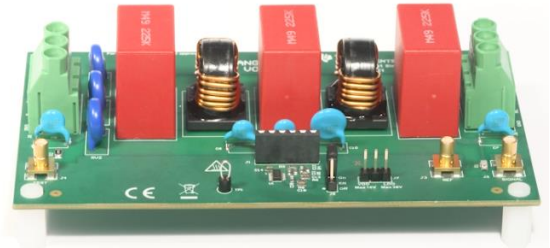
12 mH (no AEF)





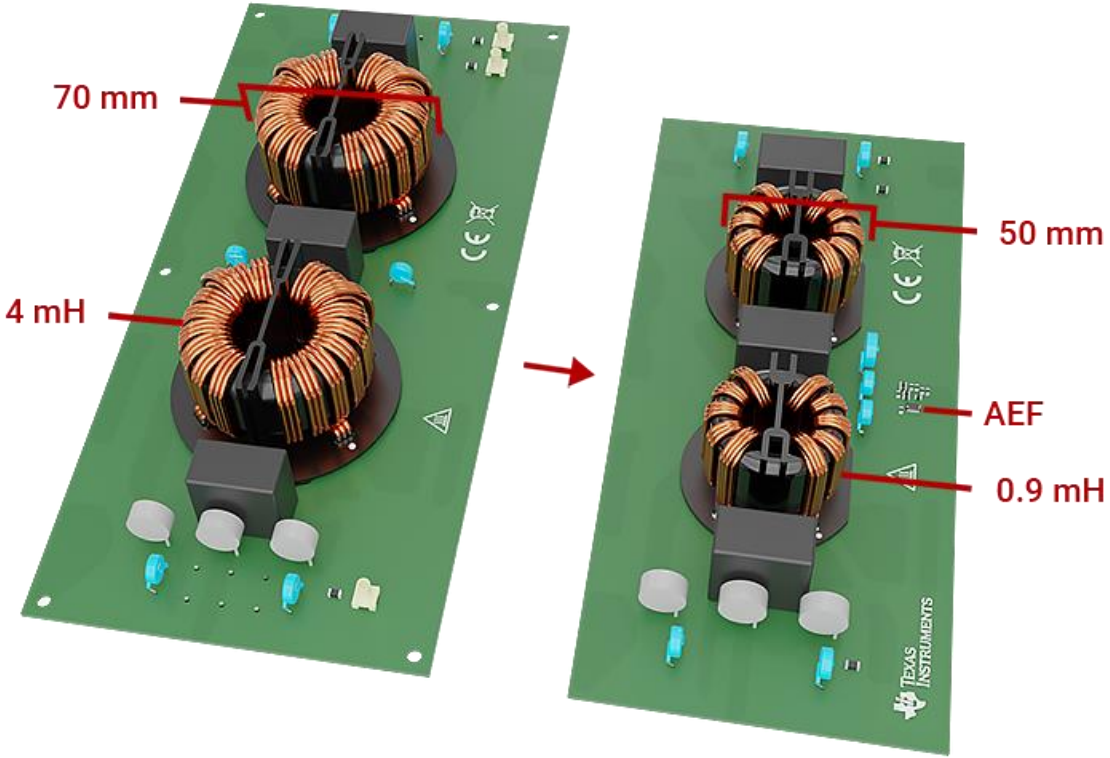
- Consider a single-phase design rated for 10 A
- CM chokes decrease from 12 mH (passive design) to 2 mH (active design), while achieving similar EMI performance
- Large reductions in CM choke parameters: footprint, volume, weight, power loss and cost

Filter	CM choke part number	Qty	Inductance (mH)	Winding DC resistance (mΩ)	Size (L × W × H, mm)	Total mass (g)	Power loss (W)
Passive	7448051012	2	12	15	23 × 34 × 33	72	6.0
Active	7448031002	2	2	6	17 × 23 × 25	20	2.4



AEF acts as a capacitive amplifier enabling the EMI filter chokes to be significantly reduced.

Example of filter size reduction using AEF for a design rated at 40 A



- CM chokes reduce from 4 mH (no AEF) to 0.9 mH (with AEF)
- Component diameter reduces from 70 mm to 50 mm

TPSF12C1/-Q1 1-ϕ common-mode AC/DC active EMI filter

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Applications

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Benefits

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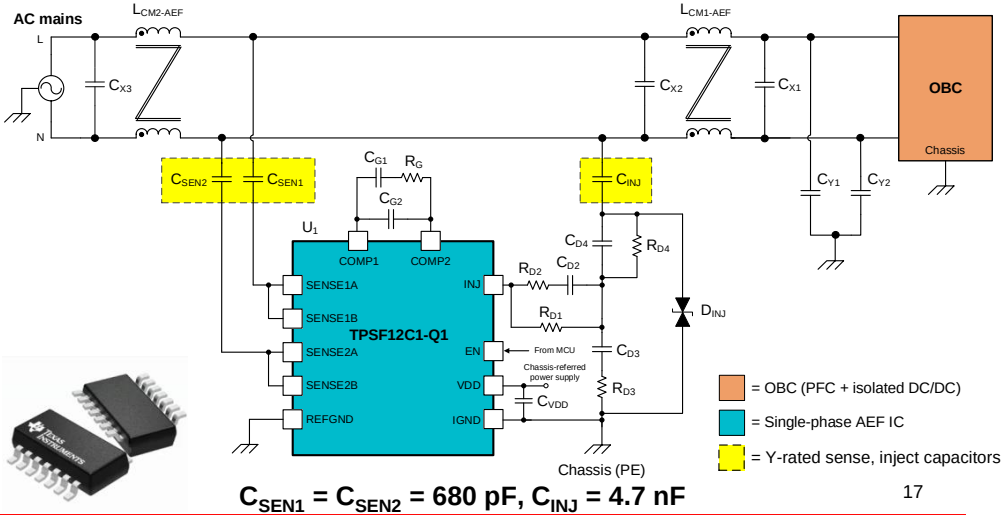
  - CISPR 25 (Class 5) and CISPR 11, 32 (Class A or B)
- **Supports high-power (1kW+), high-voltage applications**
- **Optimized for high-frequency, high-power systems**
- **Low line-frequency leakage current** *(typ ~570 µA @ 253 Vac)*
- **Easy to Use – no loop compensation required**
- **Low BOM cost solution**



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AEC-Q100 Grade 1

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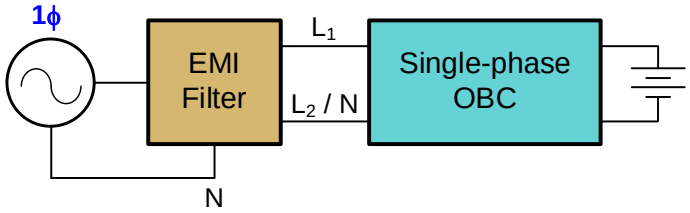
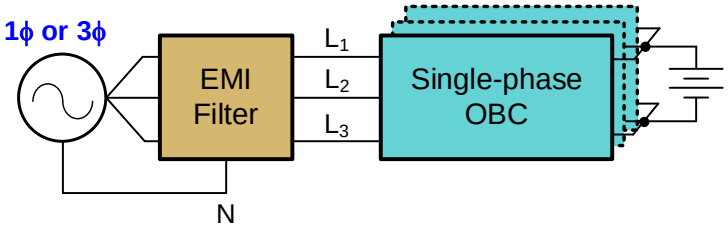
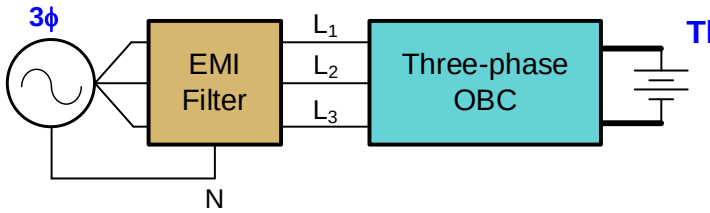
Automotive on-board charger (OBC) application example



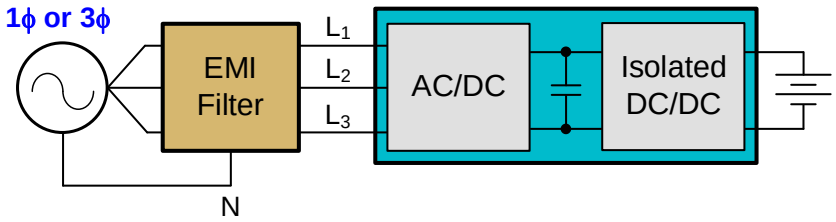
Single-phase OBC architecture (1-ϕ input only)



Single-phase modular OBC architecture (1-ϕ or 3-ϕ combo input)



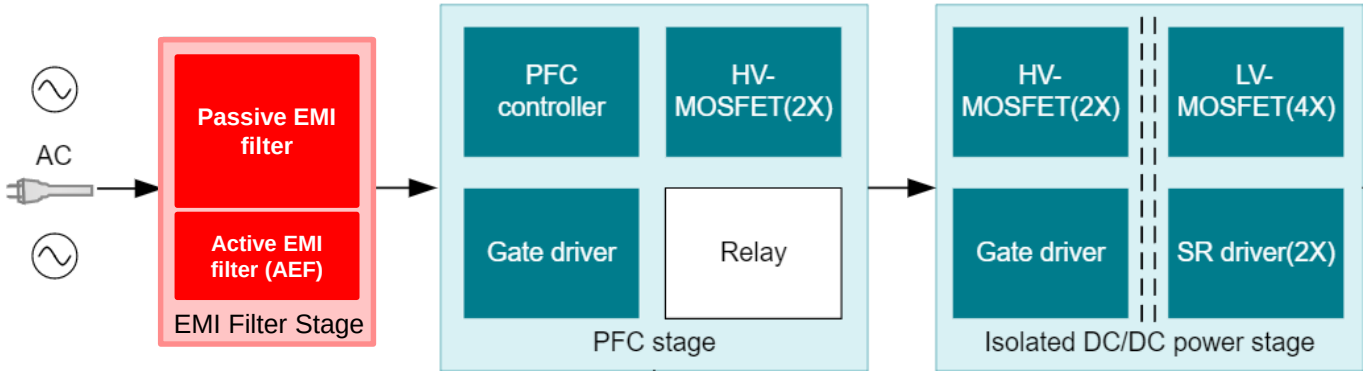
Three-phase OBC architecture (1-ϕ or 3-ϕ combo input)



OBC *two-stage* approach – PFC front-end + isolated DC/DC for V_{BATT} and I_{BATT} regulation

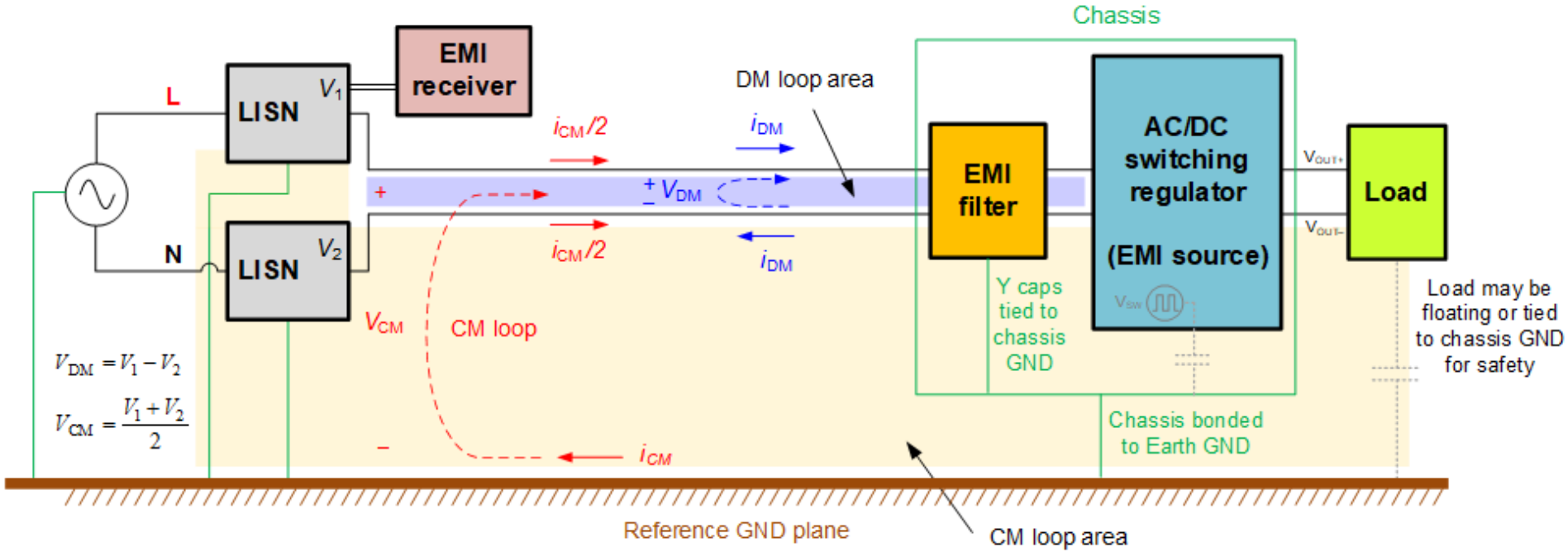
- Level 1 charging (residential): 1ϕ – 1.92kW to 7.4kW – 120V/240Vac (US), 230Vac (EU)
- Level 2 charging (commercial): 3ϕ/1ϕ – 11kW, 22kW – 208Vac to 400Vac
- Y-cap leakage current – limited for safety
- EMI filters ~30% of the overall volume

Server power supply unit (PSU) application example

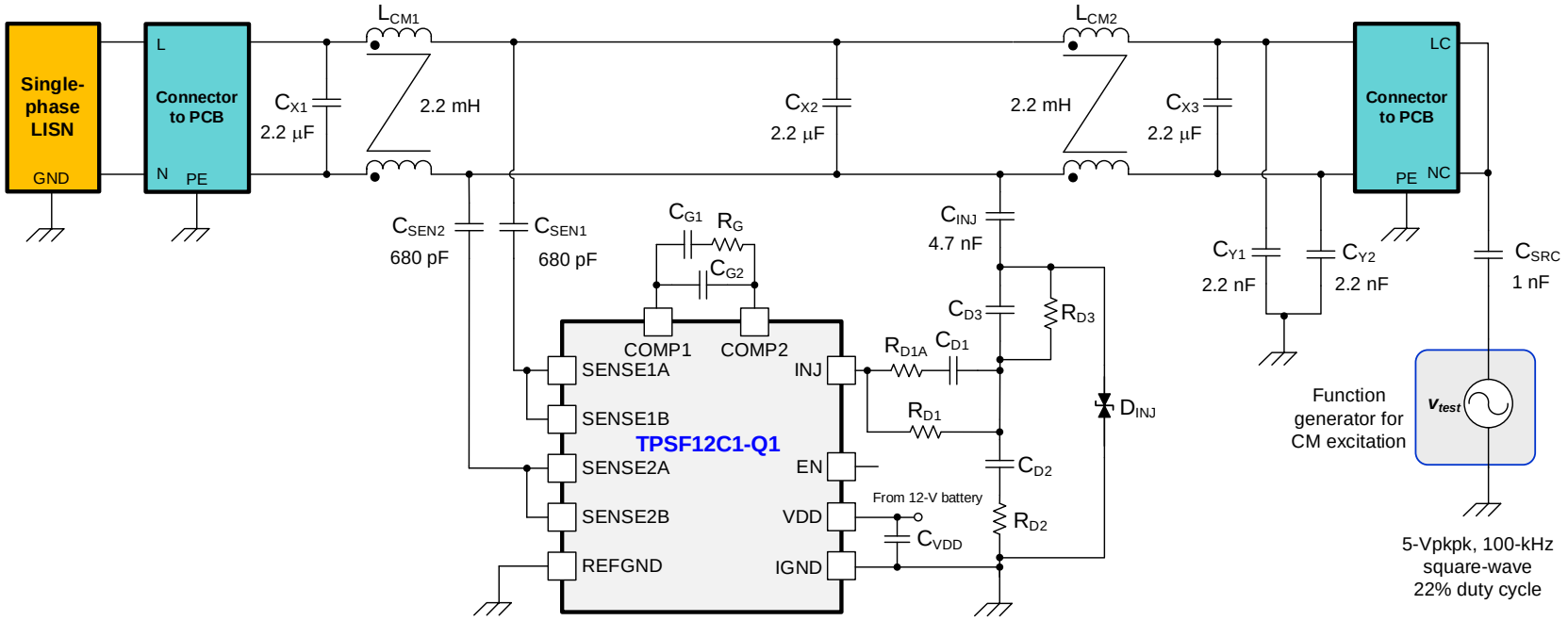


- Effective common-mode (CM) EMI mitigation in typical server power delivery (PD) systems
  - 1ϕ AEF for 1.5 to ~3kW
  - Tight spec on leakage/touch current (e.g. 0.75mArms) implies low total Y-capacitance
- AEF benefits align with key care abouts in server PSU designs
  - Size reduction
  - Reduced heat dissipation
- Server PSU reference designs available on ti.com

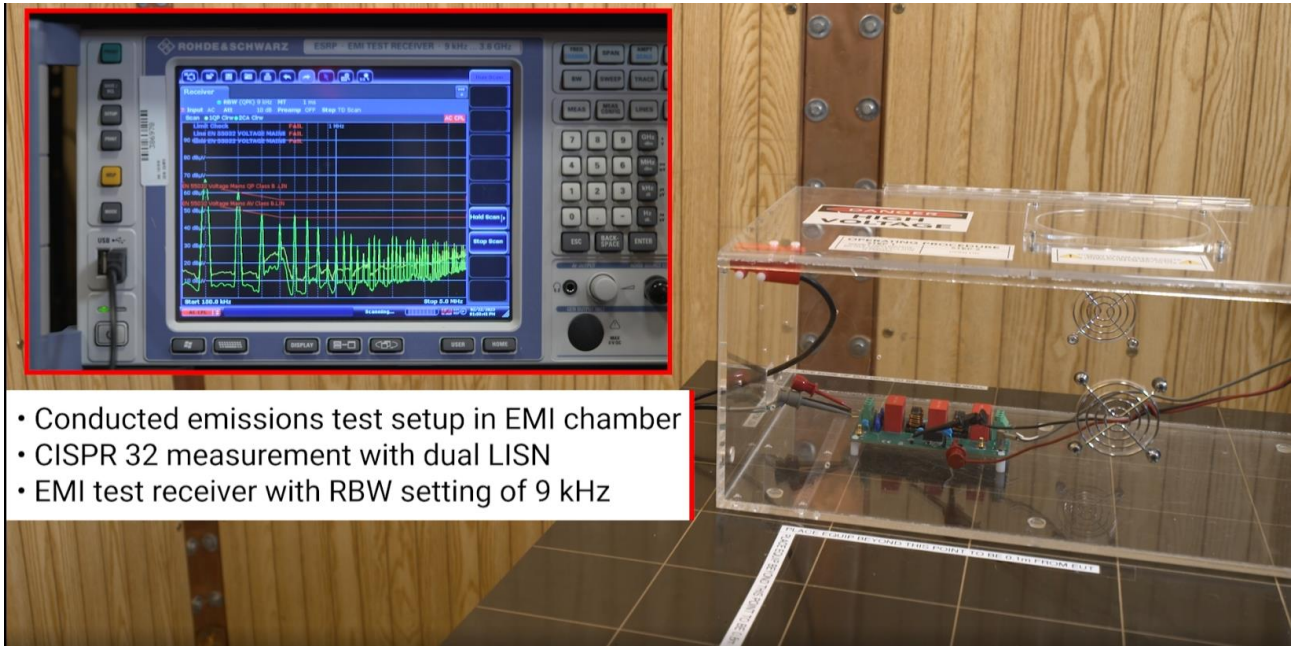
1-ϕ EMI measurement setup



Low-voltage test setup – with square wave signal injection



EMI chamber – CISPR 32 measurement setup

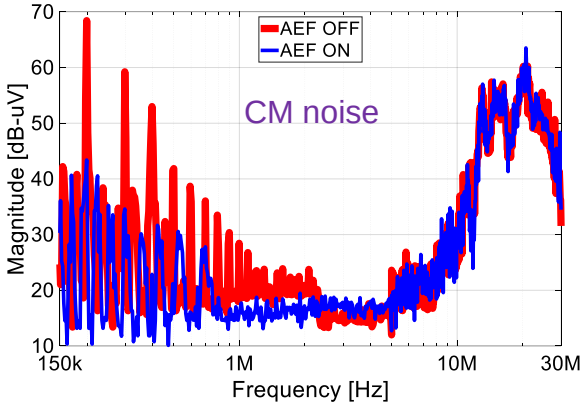


- CISPR 32 conducted emissions test setup in EMI chamber
- CISPR 32 measurement with dual LISN
- EMI test receiver with RBW setting of 9 kHz
- TPSF12C1-Q1 tested with square wave signal of 5Vpkpk at 100kHz

Measured results – with single-phase PFC

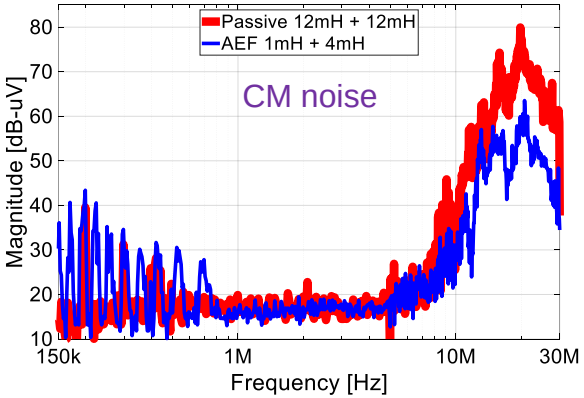
Prototype IC tested with TI reference design **TIDM-1007** totem-pole PFC converter

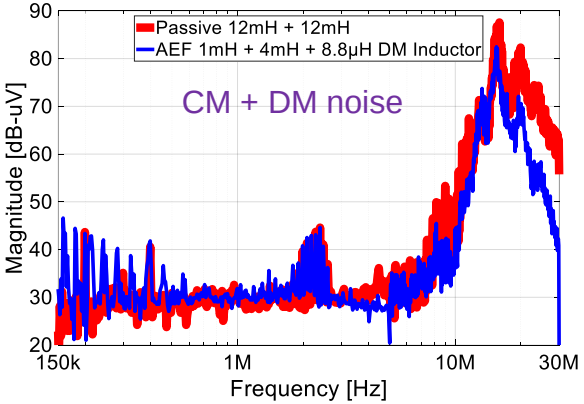
15-30dB more attenuation
with AEF ON vs OFF



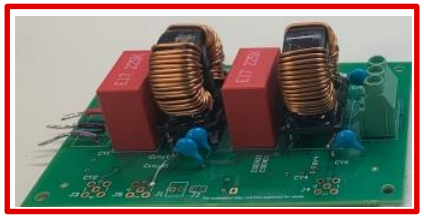
- AEF effective from 150 kHz up to few MHz
- Smaller chokes enabled by AEF have smaller parasitic capacitance → lower noise @ 10–30 MHz

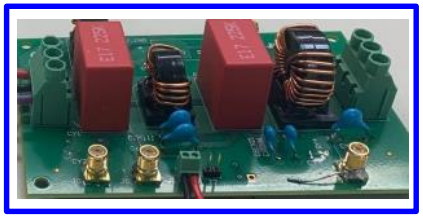
55% smaller chokes
for comparable EMI performance





Passive



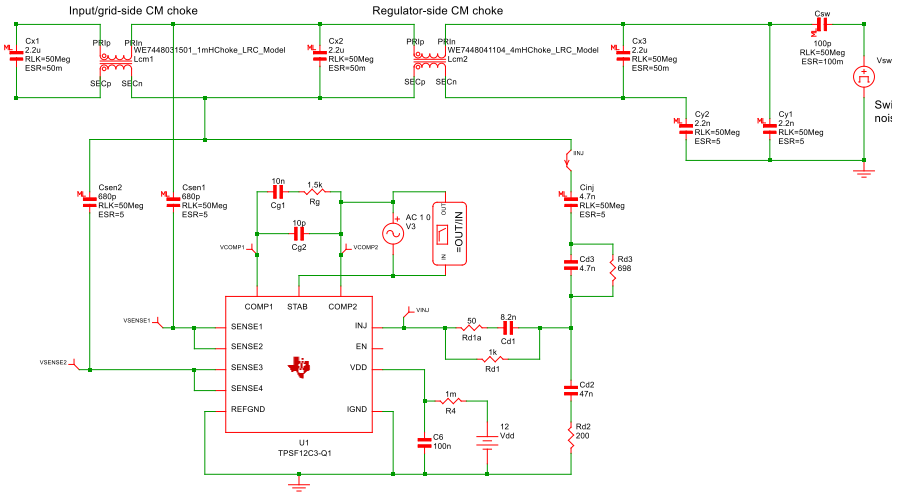


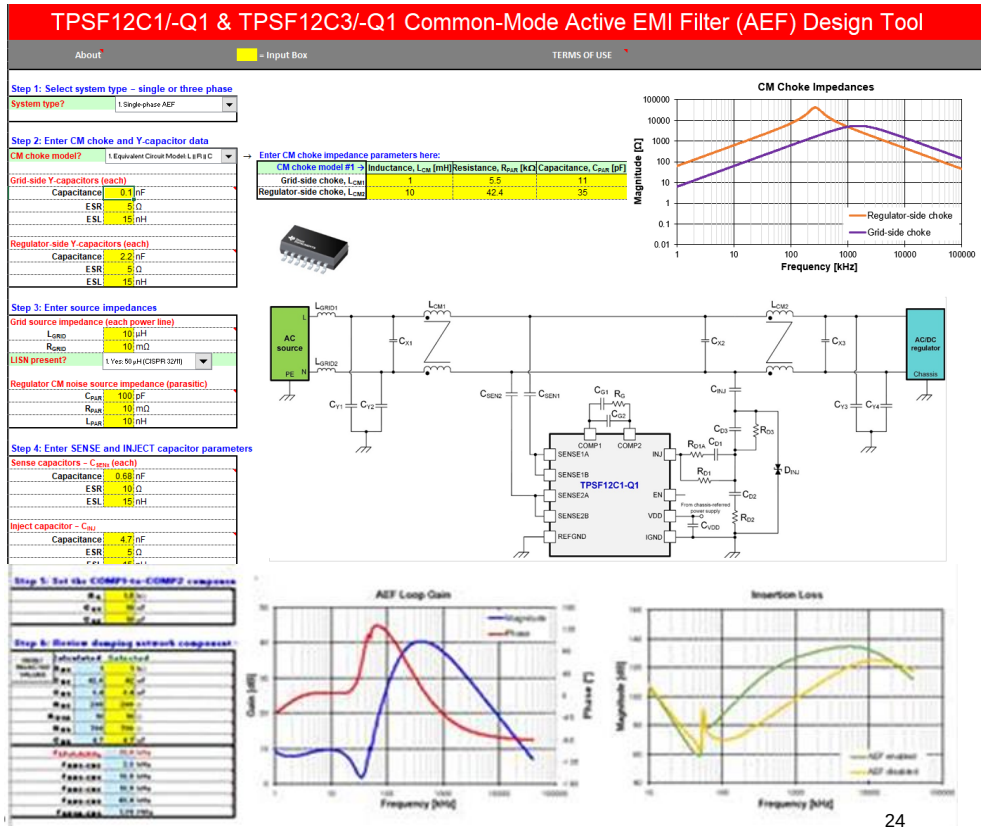
Active

Design tools and resources

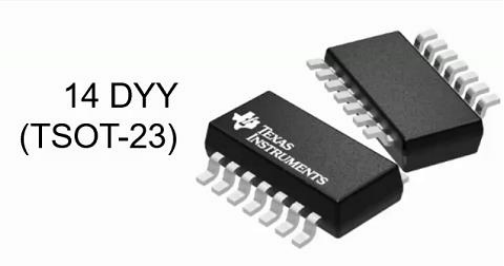
Resources on TI.com:

- Simulation models – PSPICE and SIMPLIS
- Quickstart calculator – Excel
- PCB layout – Altium source files



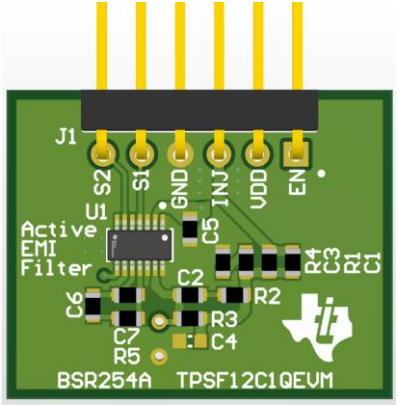


AEF IC package and evaluation modules



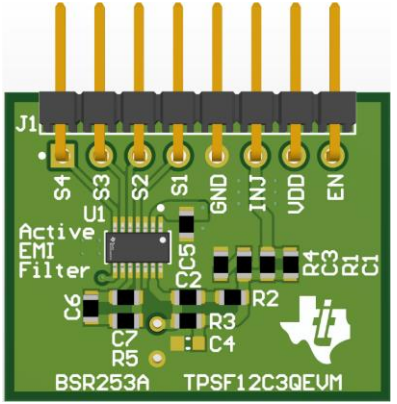
Specs	14-pin DYY
Package body size	4.2 × 2.0mm
Body size with leads	4.2 × 3.26mm
Thermal $R_{\Theta JA}$	94˚C/W
Max junction temperature	150˚C

Single-phase EVM



20 mm × 25 mm × 5.3 mm

Three-phase EVM



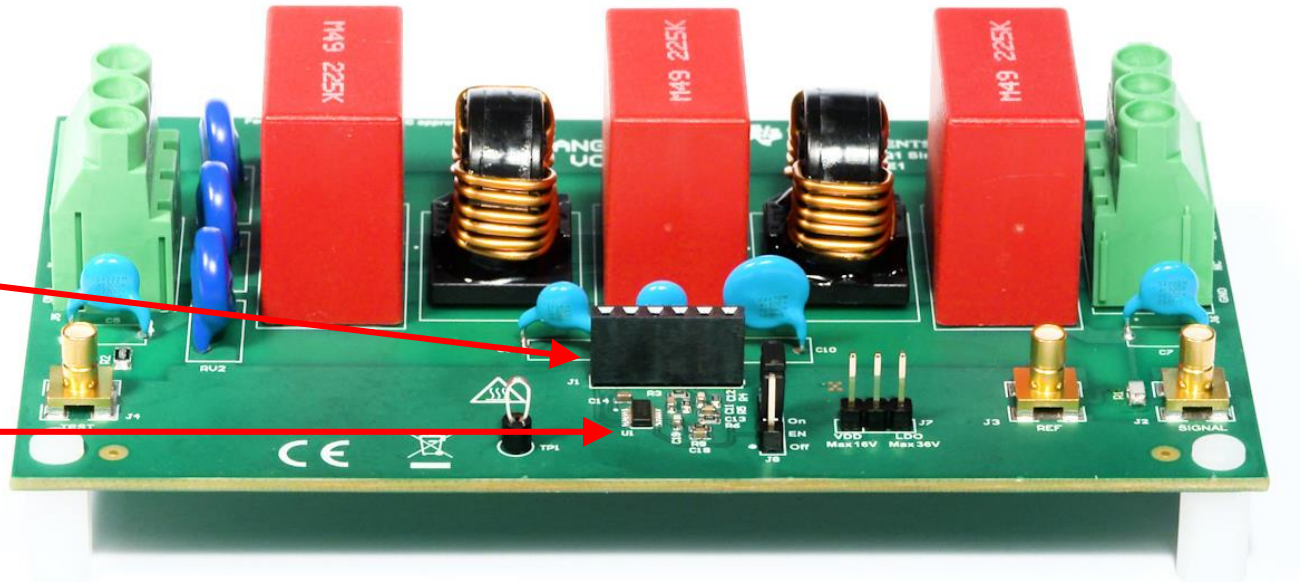
20 mm × 25 mm × 5.3 mm

- EVMs comprise IC (TSOT-23 package) and low-voltage passives
- Single-phase EVM has:
  - 6-pin header with 2.54 mm (100 mil) pin pitch; example: TSW-106-08-G-S-RA
  - Can mate with female header on EMI filter board; example: SSW-106-01-G-S
- Three-phase EVM has:
  - 8-pin header with 2.54 mm (100 mil) pin pitch; example: TSW-108-08-G-S-RA
  - Can mate with female header on EMI filter board; example: SSW-108-01-G-S

AEF system integration options

Option 1: plug the EVM into the EMI filter board

Option 2: put IC and LV passive components directly on the EMI filter board



Visit www.ti.com/AEF

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For more information on the New Product Update series, calendar and archived recordings

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Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265