WE MEET
@ DIGITAL DAYS

SIC/GAN CHALLANGES

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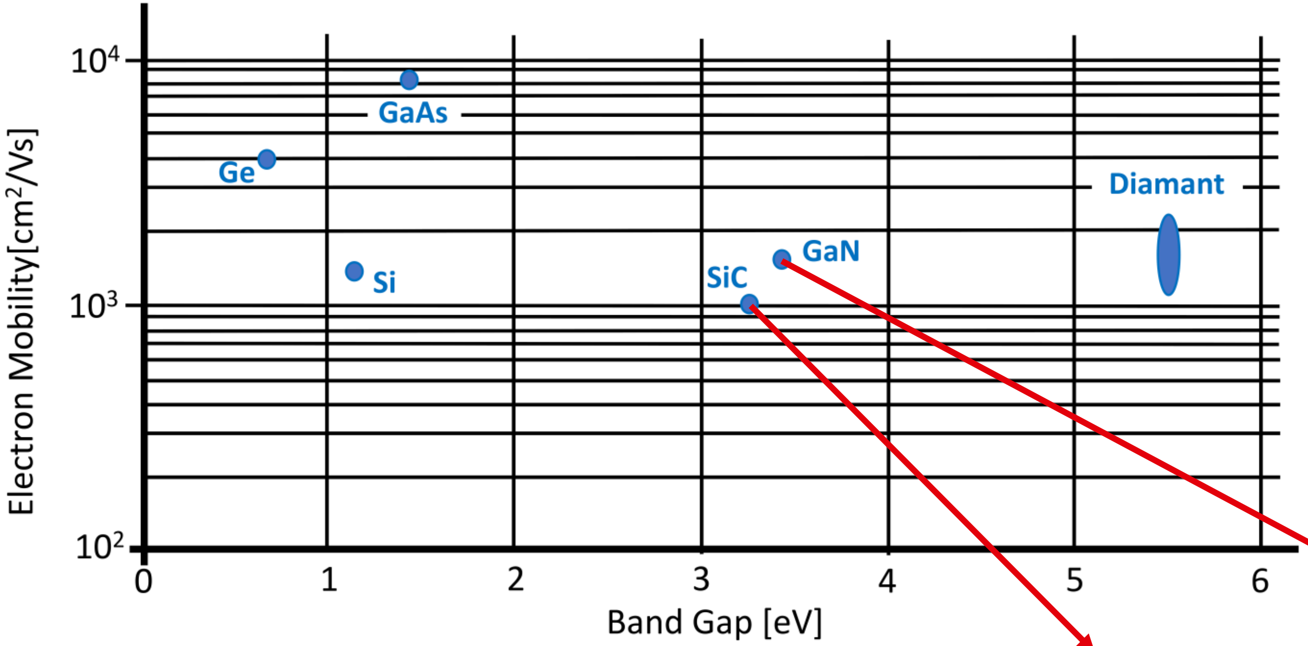
Field Application Engineer

AGENDA

- WBG ADVANTAGES
- WHY ISOLATED GATE DRIVE SUPPLY?
- ISOLATED TOPOLOGIES FOR WBG GATE DRIVE
- EMC AND DESIGN ISSUES
- LAYOUT EXAMPLE
- HIGH CURRENT INDUCTOR FOR GAN DCDC

WBG ADVANTAGES

Overview of the Key Parameters

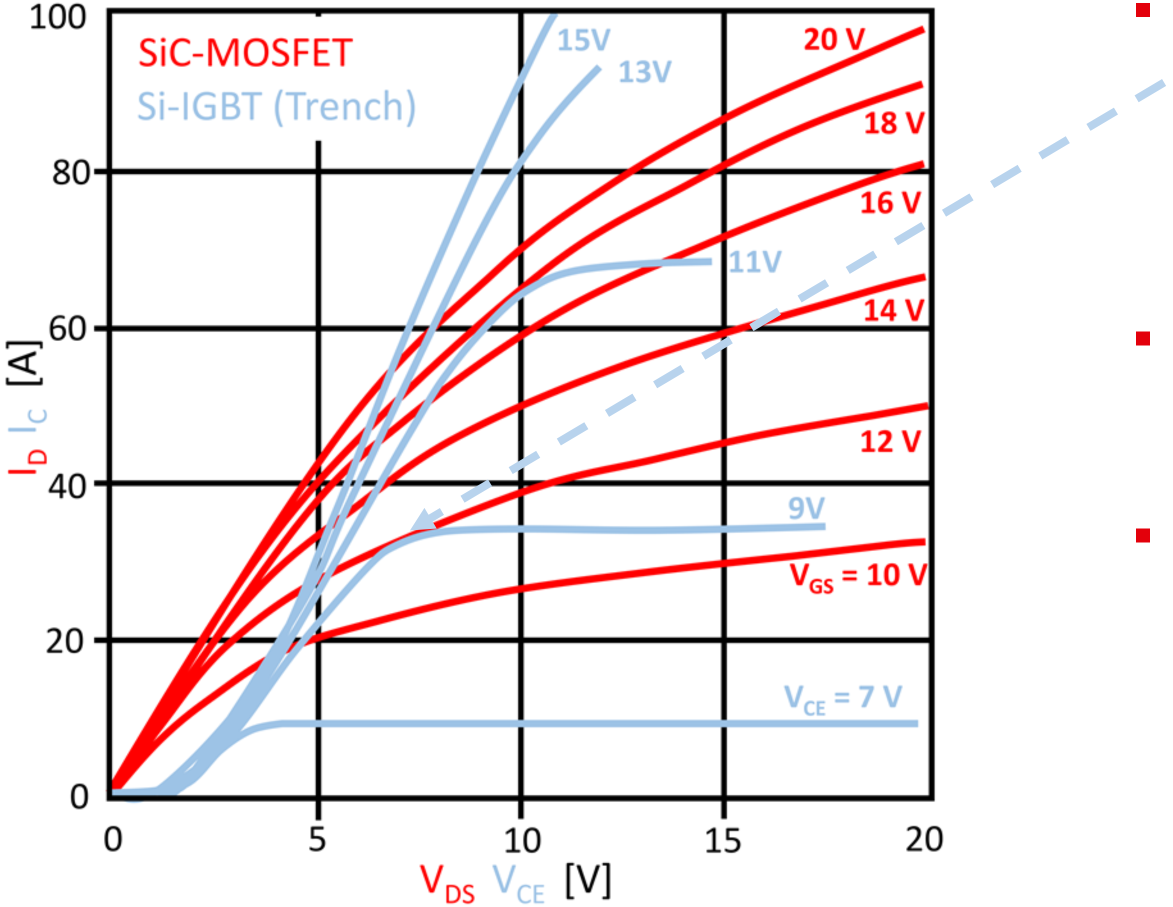


The significant difference in the technical parameters is due to the “Band Gap", which is the energetic distance between valence and conduction band in the atom.

Parameter	4H-SiC	2H-GaN
Band gap (eV)	3.2	3.4
Beak through field strength (MV/cm)	2 to 3	3
Electron mobility (cm²/Vs)	800	1600
Hole mobility (cm²/Vs)	50	10 **problem!**
Thermal conductivity (W/mK)	700	max. 200

SIC GATE DRIVE

SiC-MOSFETs, use in practice



Transmission slopes ($I_D - U_{DS}$ and $I_C - U_{CE}$ @ TJ = 125 °C)

- SiC-MOSFET:
  Kink from linear triode-like behavior ("ohmic") to saturation range (constant current) is missing.

- Lower slope (dI_D/dU_{DS}) of the SiC-MOSFETs.

- SiC MOSFET behaves more like a voltage-controlled resistor than a voltage-controlled current source.

SIC GATE DRIVE

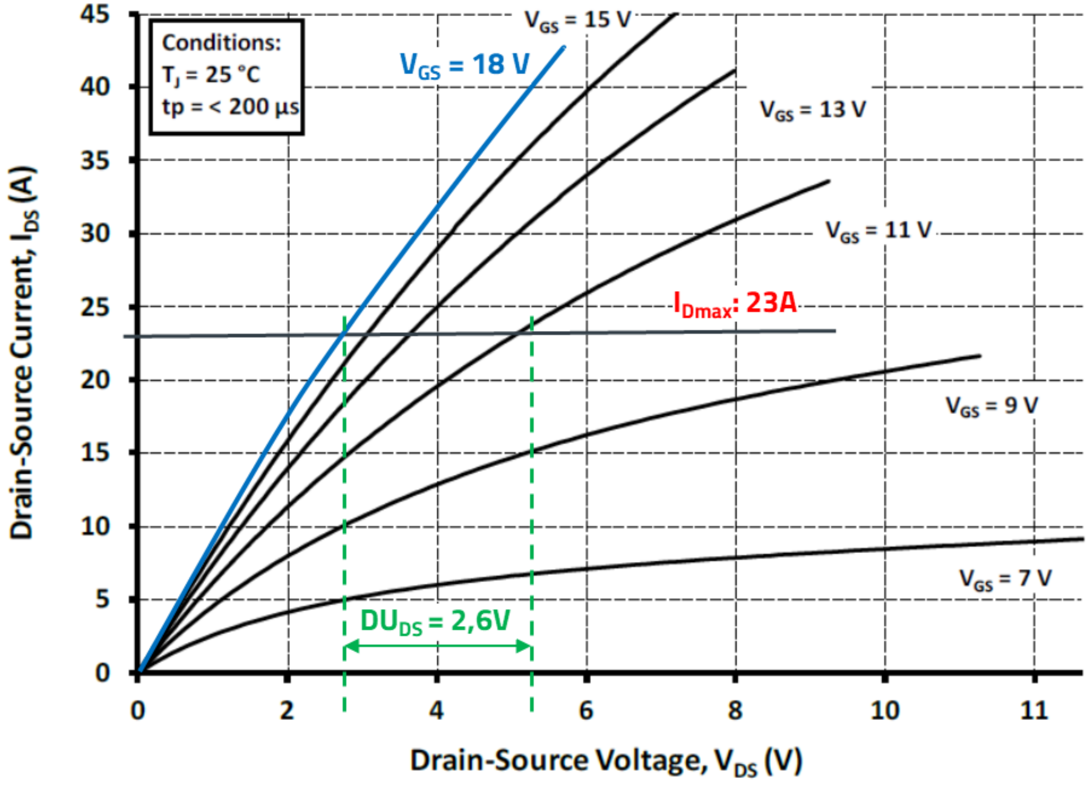
Circuit design, necessary gate-source voltage V_{GS} (2/2)

- The maximum drain current ID can already be reached at a low VGS voltage of 11 - 13 V.
- If the voltage is increased further, this leads to a significantly lower voltage drop at the transistor.

⬇

- Apply the maximum gate voltage recommended by the manufacturer → Lower losses!
  - $P_v = U_{DS} \times I_D$
  - $\Delta P_v = \Delta U_{DS} \times I_D = 2{,}6V \times 23A = 59{,}8W!$

    (Peak power, duty cycle not considered here)

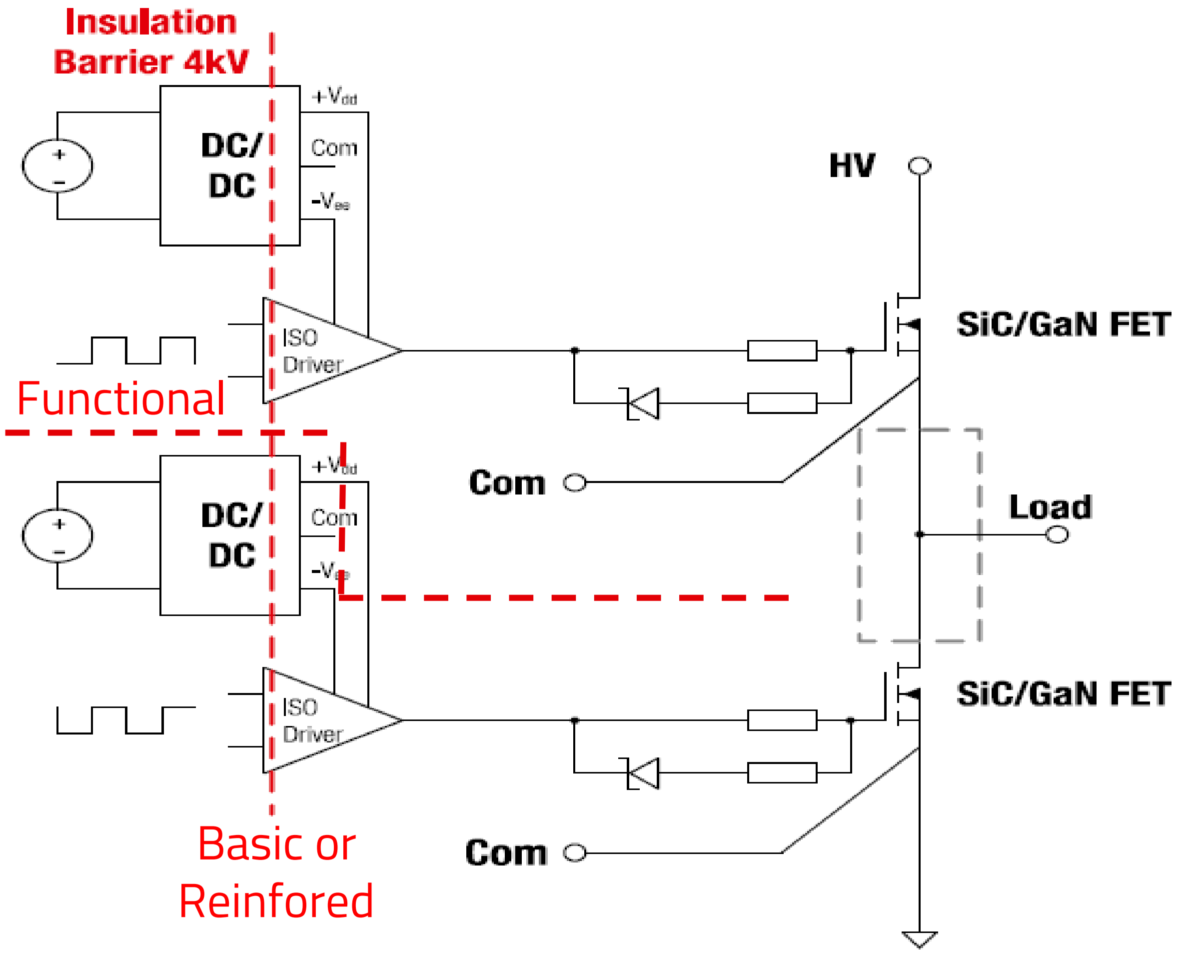


V_{GSmax}	Gate - Source Voltage (dynamic)	-8/+19	V
V_{GSop}	Gate - Source Voltage (static)	-4/+15	V

ISOLATED GATE DRIVE

Why isolated gate drivers and supply?

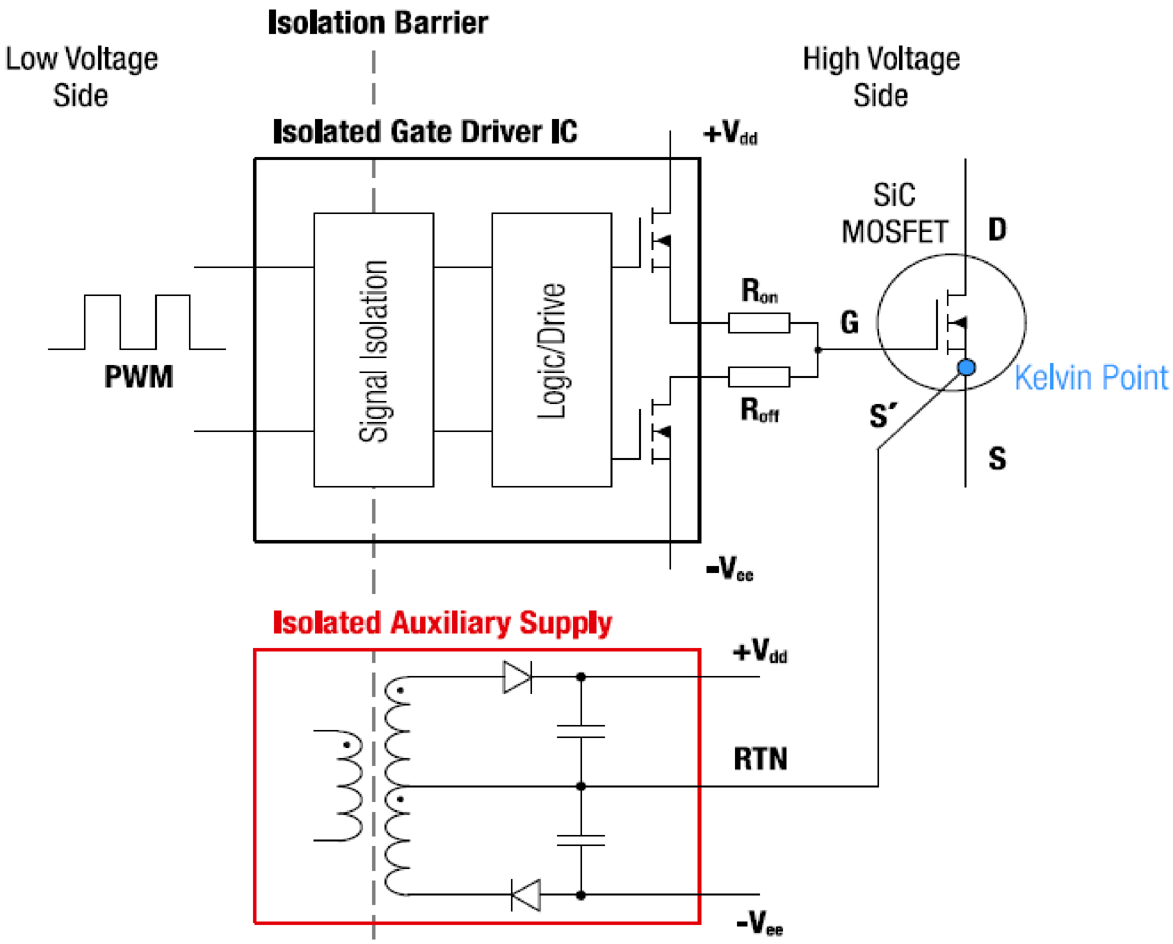
- Protection against electrical shock
- Protection of the control circuit
- Protection against EMI (high CMTI)
- Easier control of the highside FET



ISOLATED GATE DRIVE SUPPLY

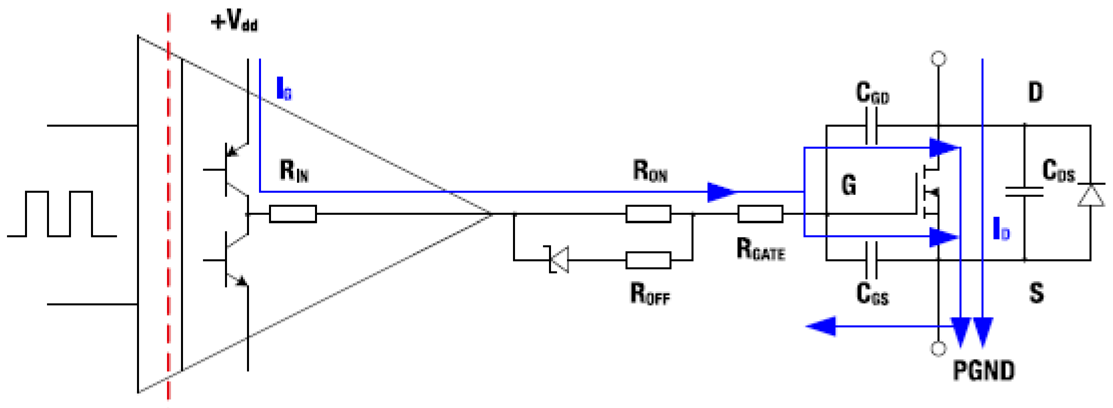
GaN / SiC gate drive voltage levels

- 5V to 6V turn on voltage for GaN
- -2V to 0V turn off voltage for GaN
- 15V to 20V turn on voltage for SiC
- -5V to 0V turn off voltage for SiC

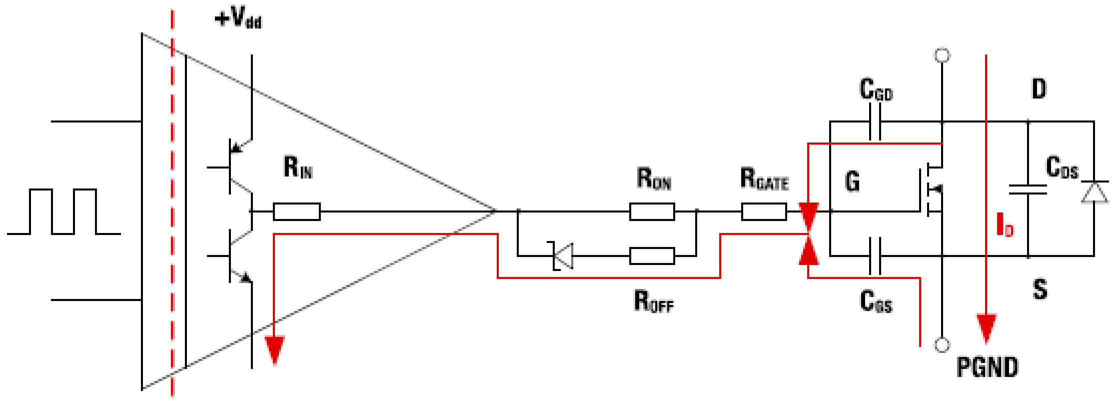


CURRENTS & LAYOUT GATE DRIVE

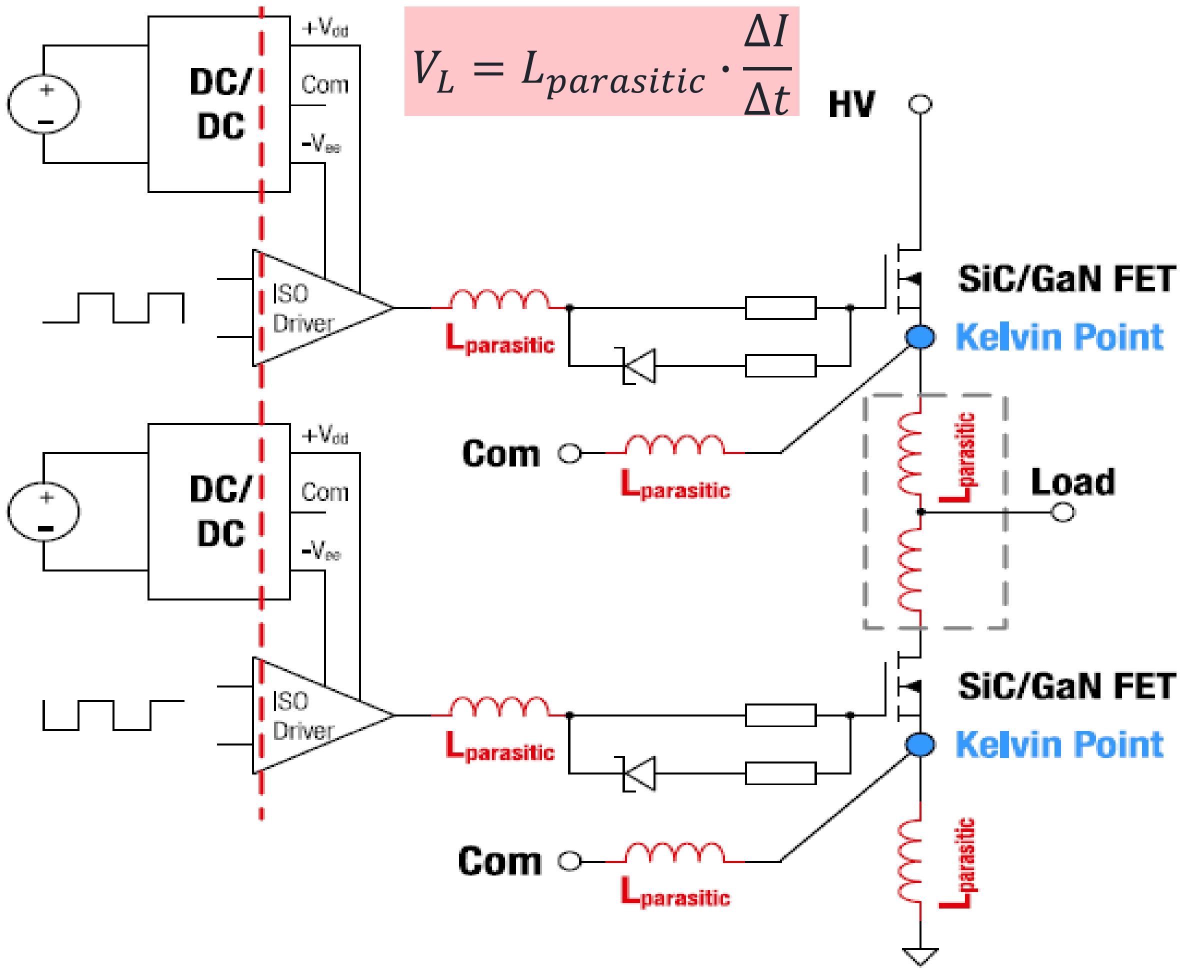
Gate drive current flow → Ground bounce due to parasitc inductance



High ΔI/Δt current paths on turn-ON of SiC/GaN FET.

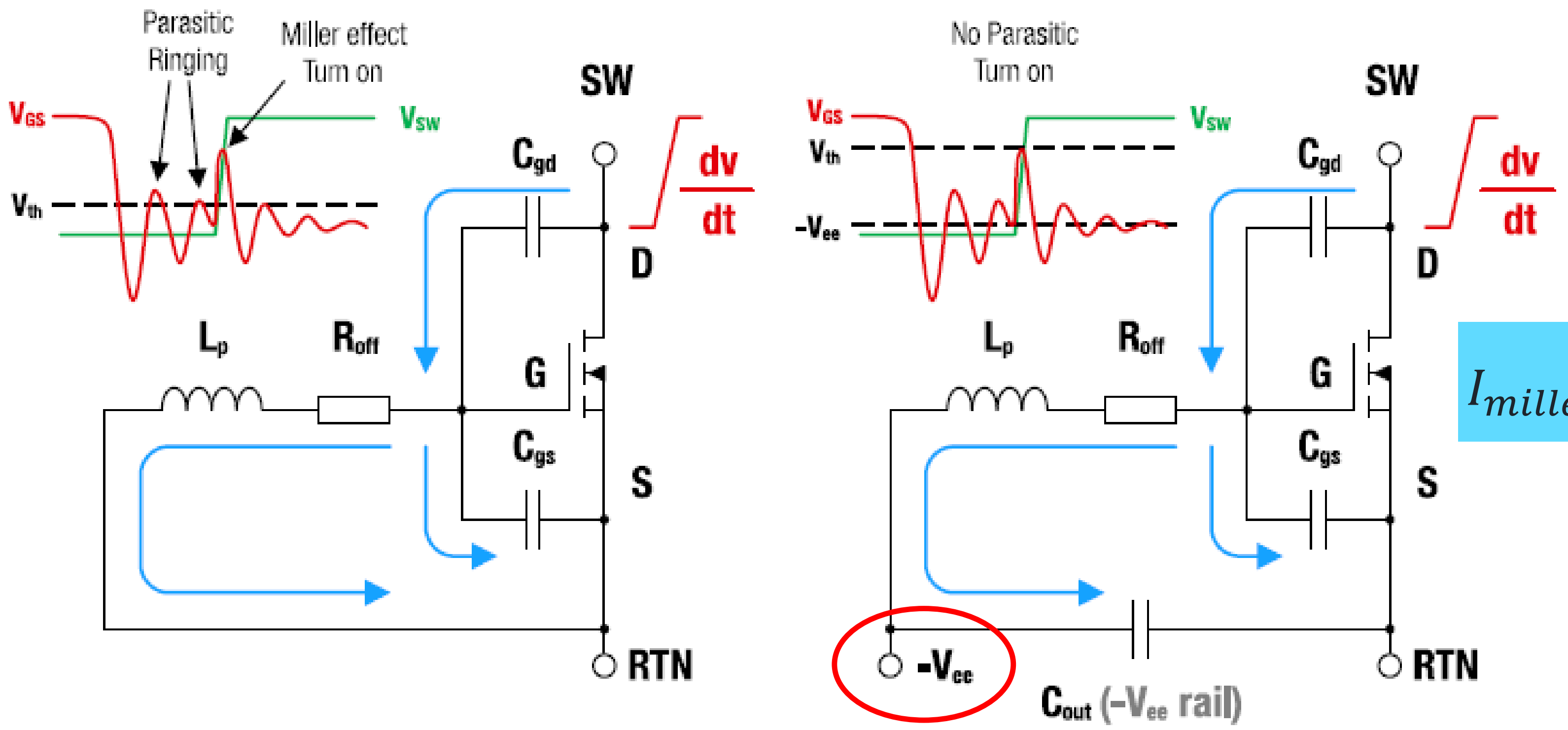


High ΔI/Δt current paths on turn-OFF of SiC/GaN FET.



CURRENTS & LAYOUT GATE DRIVE

False turn on due to Miller-Effekt

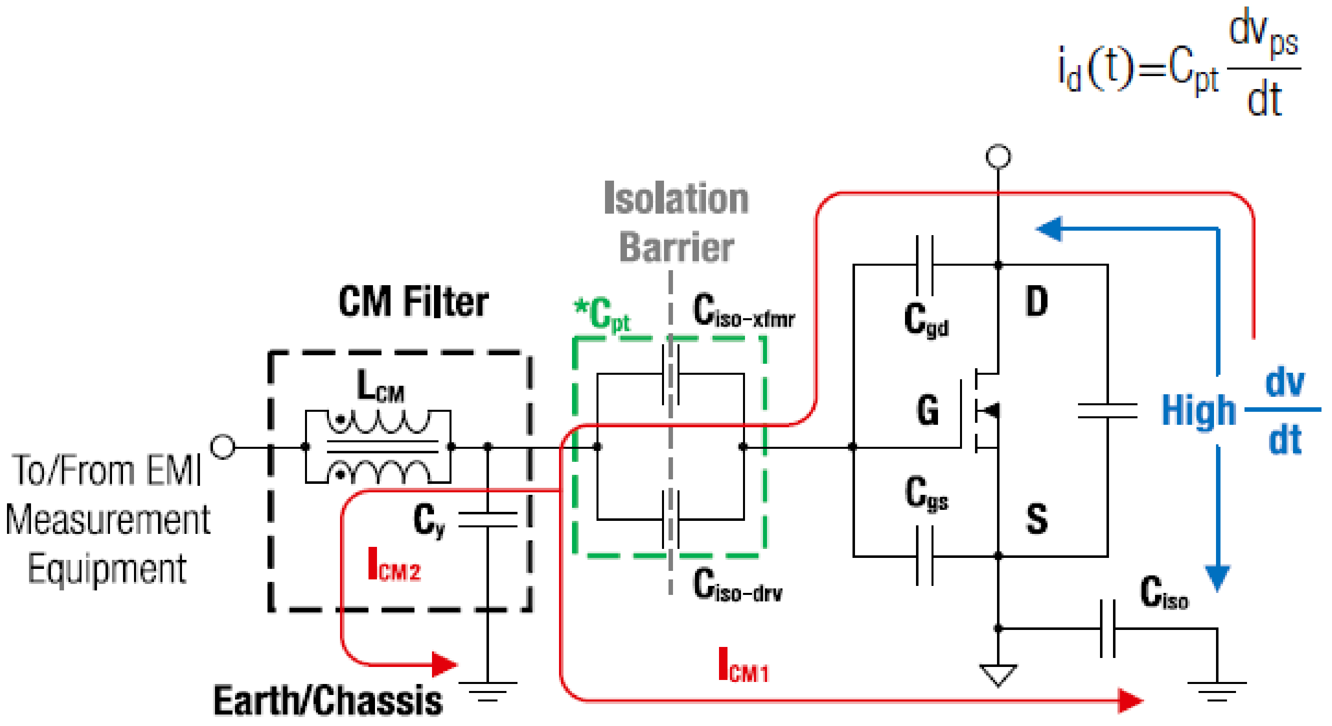


$$I_{miller} = C_{miller} \cdot \frac{\Delta v}{\Delta t}$$

Turn-off transient. Parasitic turn-on without $-V_{ee}$ rail connection due to Miller effect and gate resonant ringing (left) and with $-V_{ee}$ rail connection (right).

EMC ISSUES ISOLATED GATE DRIVE

Common mode currents over isolation barrier



$*C_{pt} = C_{iso\text{-}xfmr} + C_{iso\text{-}drv}$

C_{pt} = Total Distributed Capacitance across isolation barrier

L_{CM}= Equivalent Cm Choke

C_y = Y-type (Line-Earth) Capacitor

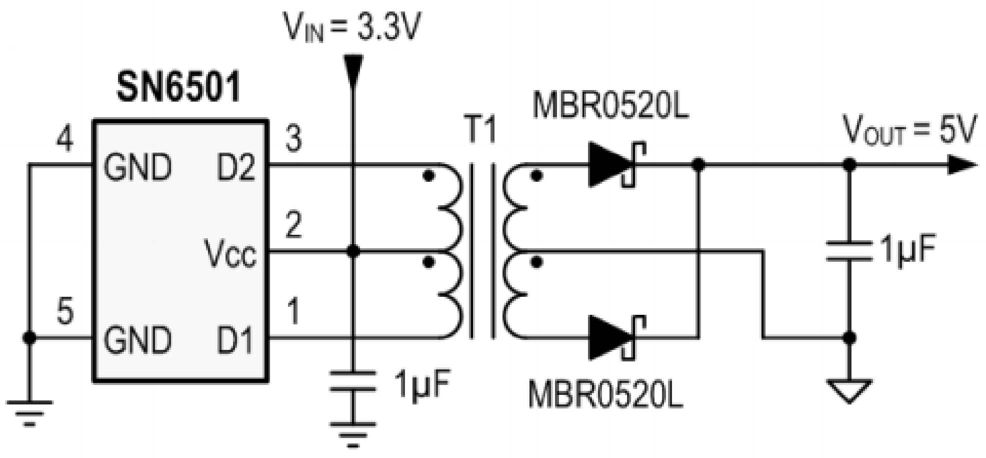
If C_{pt} is reduced, its impedance is increased and I_{cm1} and I_{cm2} are reduced as a result

I_{cm2} needs to be minimized for better EMI performance

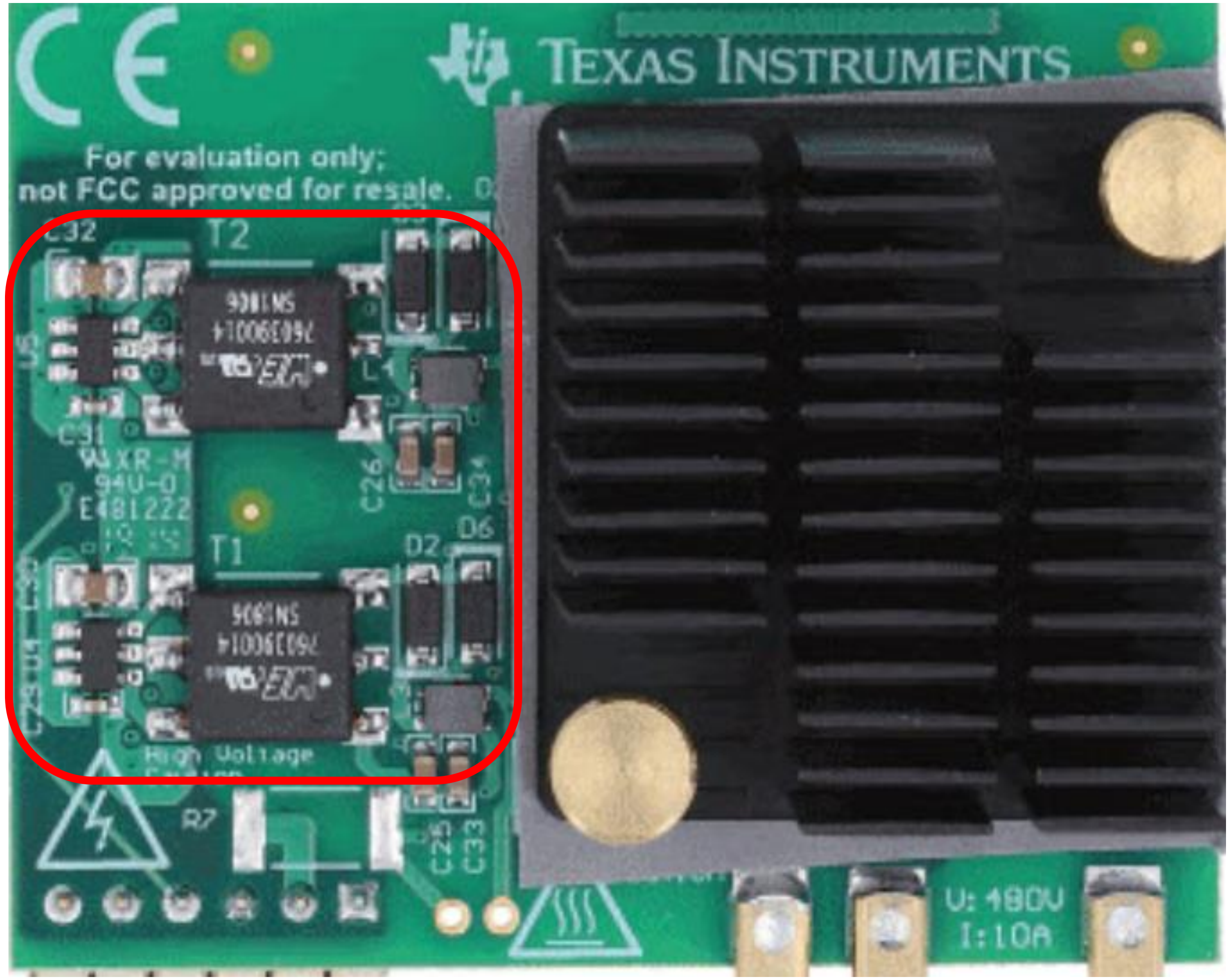
TOPOLOGIES FOR ISOLATED GATE SUPPLY: PUSHPULL

Application example TI

- Cheap and fast solution
- Unregulated output voltage
- Tight input voltage range



Simplified Schematic



TOPOLOGIES FOR ISOLATED GATE SUPPLY: PUSHPULL

WE Push Pull Transformer

MID-PPTI Push-Pull Transformers for Texas Instruments

Characteristics

- Small size
- Surface mount
- Low profile
- Operating temp: -40°C to 125°C
- Standards detail: IEC60950-1, EN60950-1/CSA60950-1 and AS/NZS609501.1
- Standards detail for high voltage series: IEC60664-1, IEC60950-1 and IEC60601-1
- Standards detail for SN6505B supplementary insulation series: IEC61010-1
- Functional, supplementary or reinforced insulation

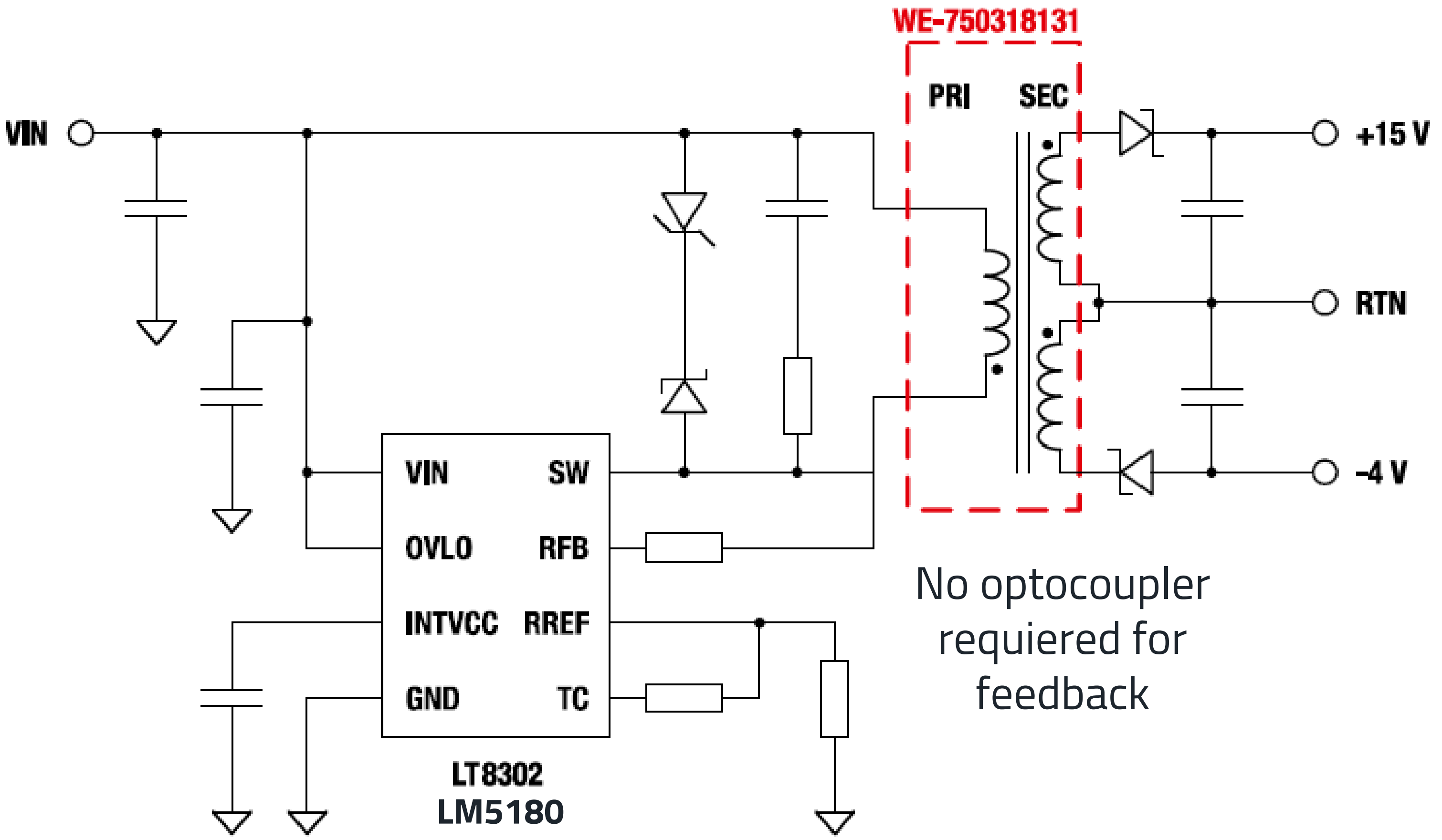
Applications

- Isolated interface power supply for CAN, RS-485, RS-422, RS-232, SPI, I2C, lower-power LAN
- Industrial automation
- Process control
- Medical equipment
- PLC analog and digital I/O modules
- Isolated gate driver power supplies
- AC motor drives
- Uninterruptible power supplies (UPS)
- Solar inverters
- Polyphase energy meters

TOPOLOGIES FOR ISOLATED GATE SUPPLY: FLYBACK

Application example from WE with LT8302/LM5180 controller

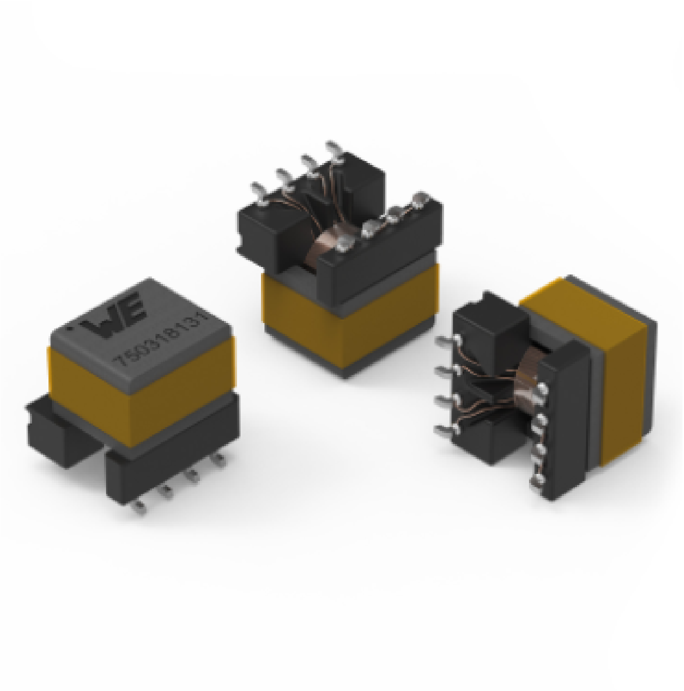
- More expensive and complex
- Regulated output voltage
- Wide input voltage range
- Multiple output voltage levels



No optocoupler requiered for feedback

TOPOLOGIES FOR ISOLATED GATE SUPPLY: FLYBACK

GaN / SiC / IGBTs up to 6W gate drive power : WE-AGDT



		Size	L (mm)	W (mm)	H (mm)	Mount
NEW		EP7	11.3	10.95	11.94	SMT

Applications

- Industrial drives
- AC motor inverters
- Electric vehicles
- Powertrain
- Battery chargers
- Solar inverters
- Data centers
- Uninterruptible power supplies
- Active power factor correction
- SiC-MOSFET based power converter

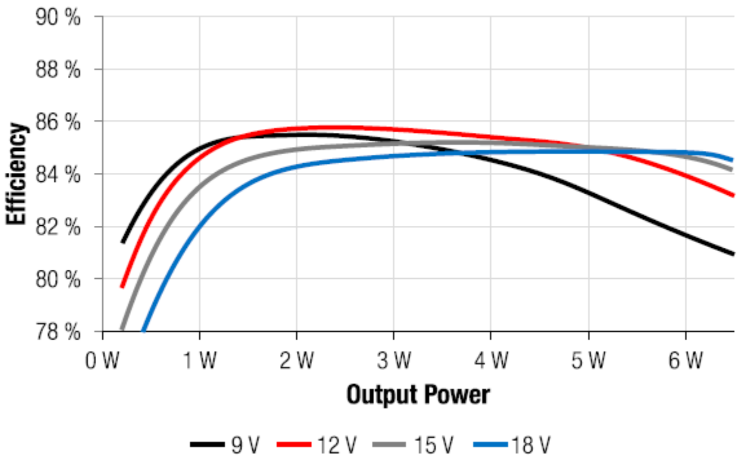
Characteristics

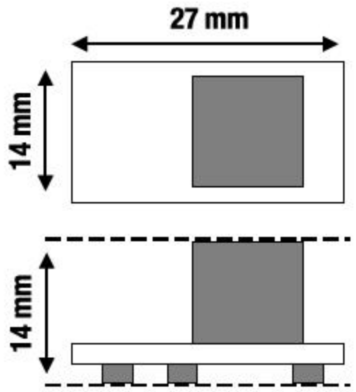
- Interwinding capacitance down to 6.8 pF
- Tiny surface mount EP7 package
- Dielectric insulation up to 4 kV AC
- Basic insulation
- Safety: IEC62368-1 / IEC61558-2-16
- Common control voltages for SiC MOSFET's
- Flyback with primary side regulation
- Wide range input voltages 9 V to 36 V
- High efficiency and very compact solution
- Reference designs with Analog Devices and Texas Instruments
- Operating temperature: -40 °C up to +130 °C

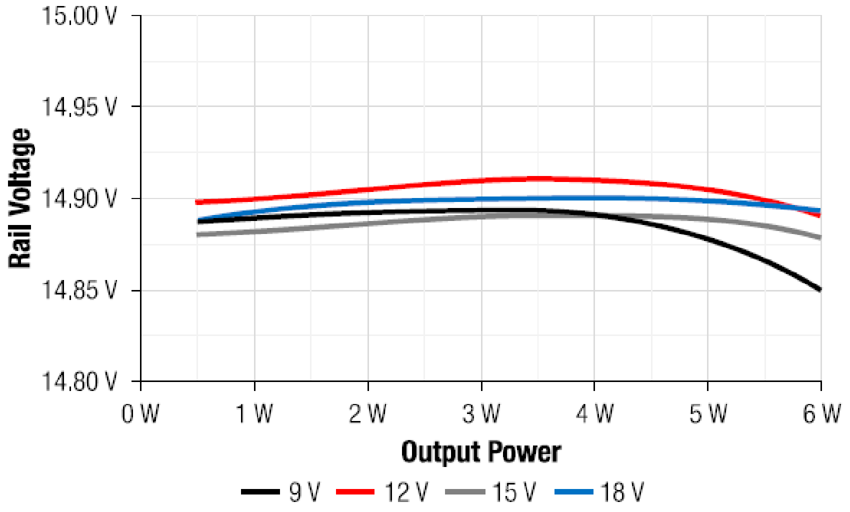
- ANP082 Gate Driver Power Supply for SiC-MOSFET PDF
- RD001 Reference Design 6W Isolated auxiliary power supply for SiC - MOSFET gate driver PDF

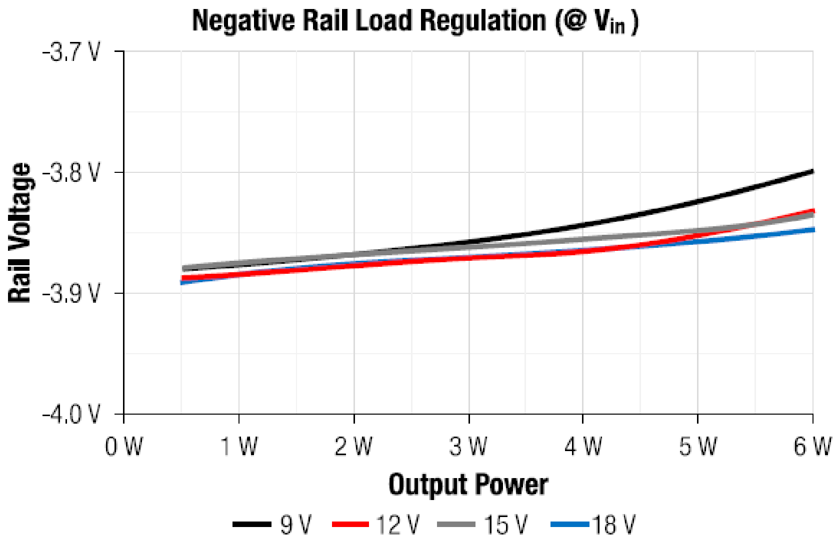
WE-AGDT

for GaN / SiC / IGBTs up to 6W → Most compact solution on the market



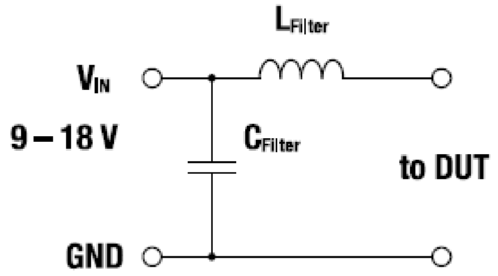




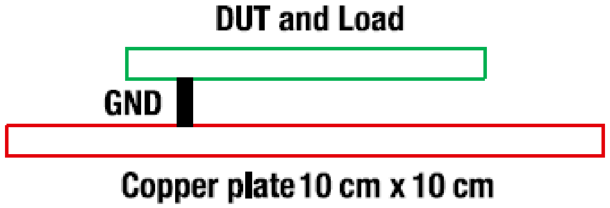


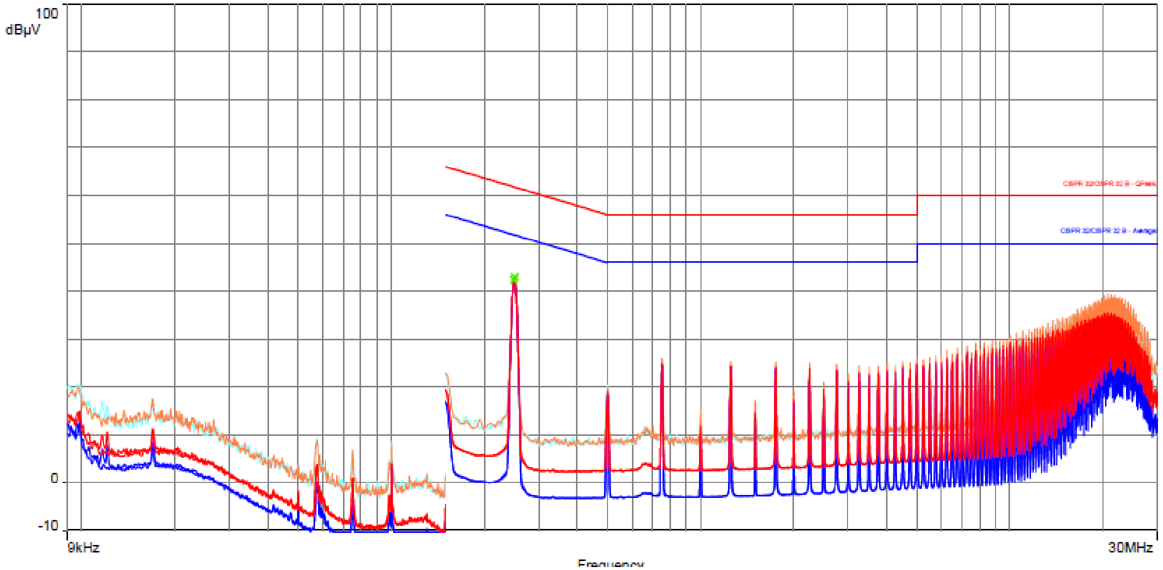
WE-AGDT

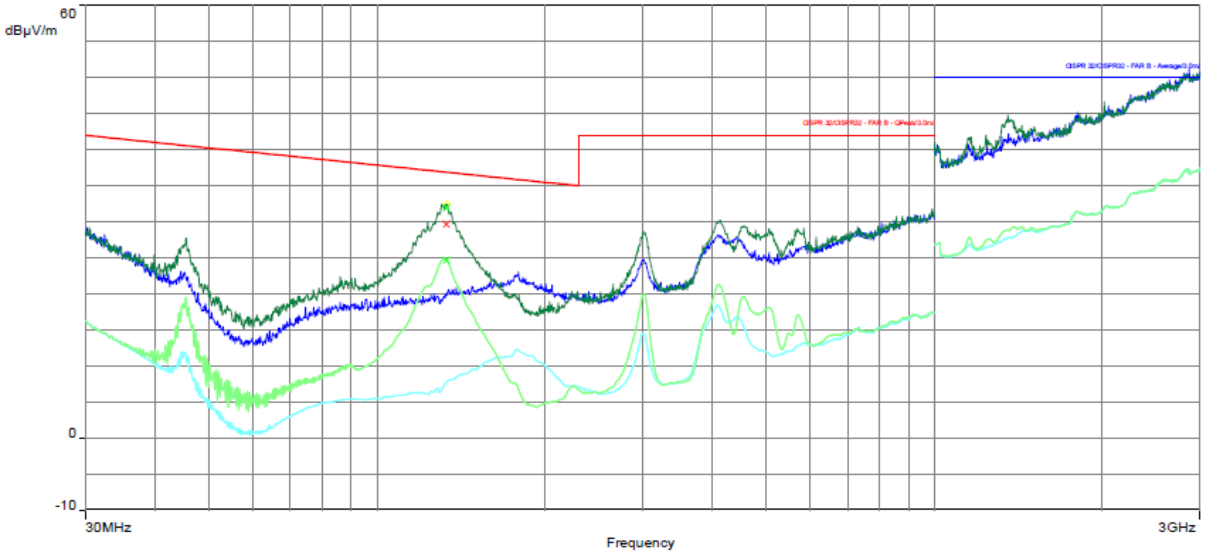
Reference design EMC test CISPR32-B



L_{filter} : WE-MAPI 74438324100
C_{filter} : 2x WCAP-CSGP 885012209048

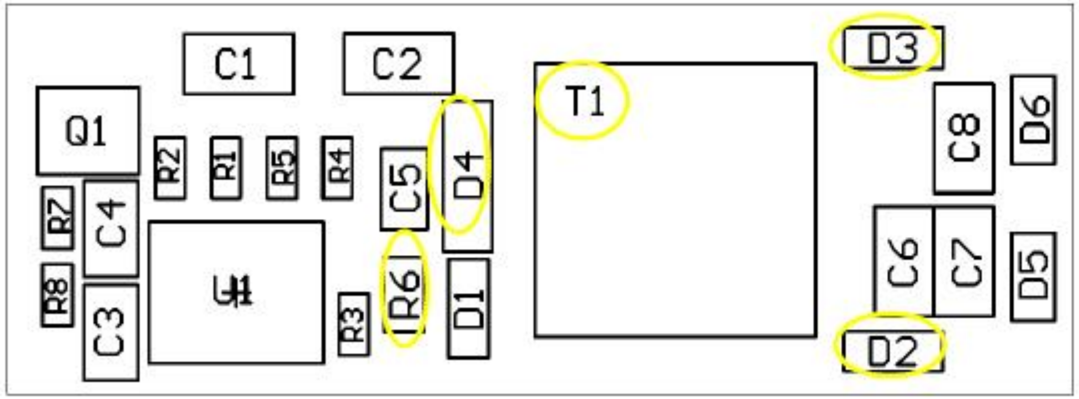


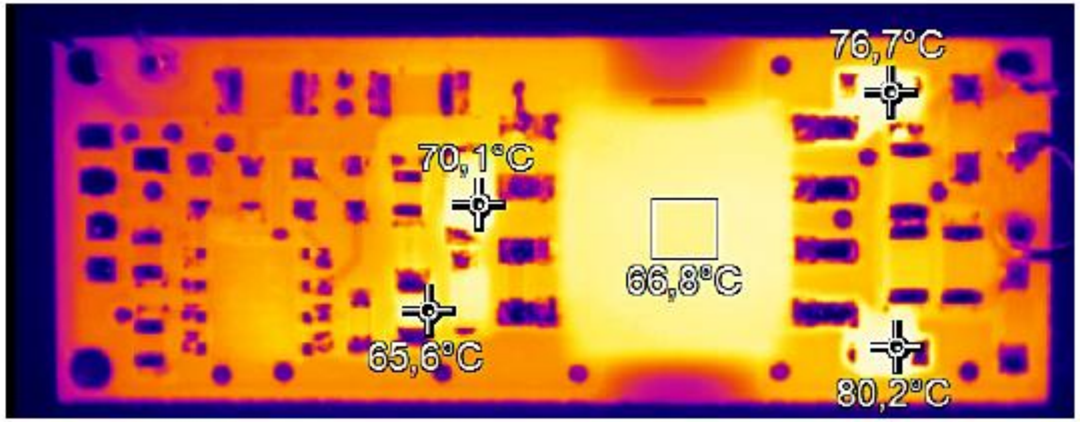


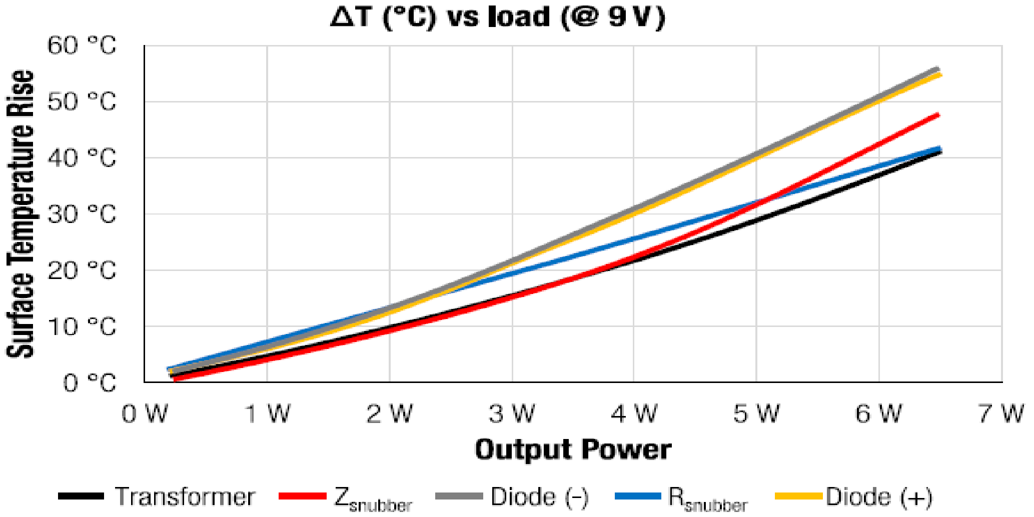


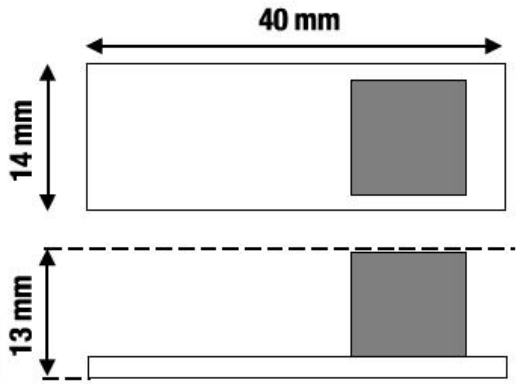
WE-AGDT

Reference design thermal result



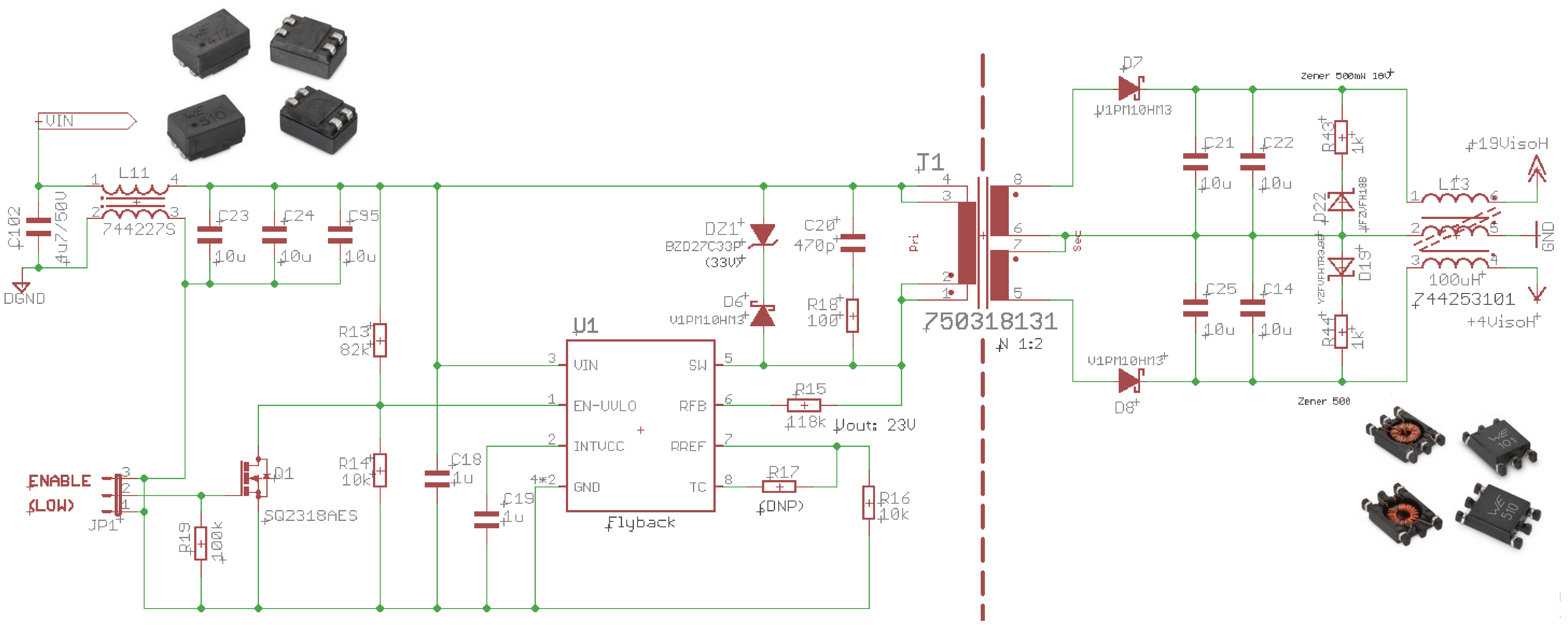






EMC FILTERS FOR WBG ISOLATED GATE DRIVE

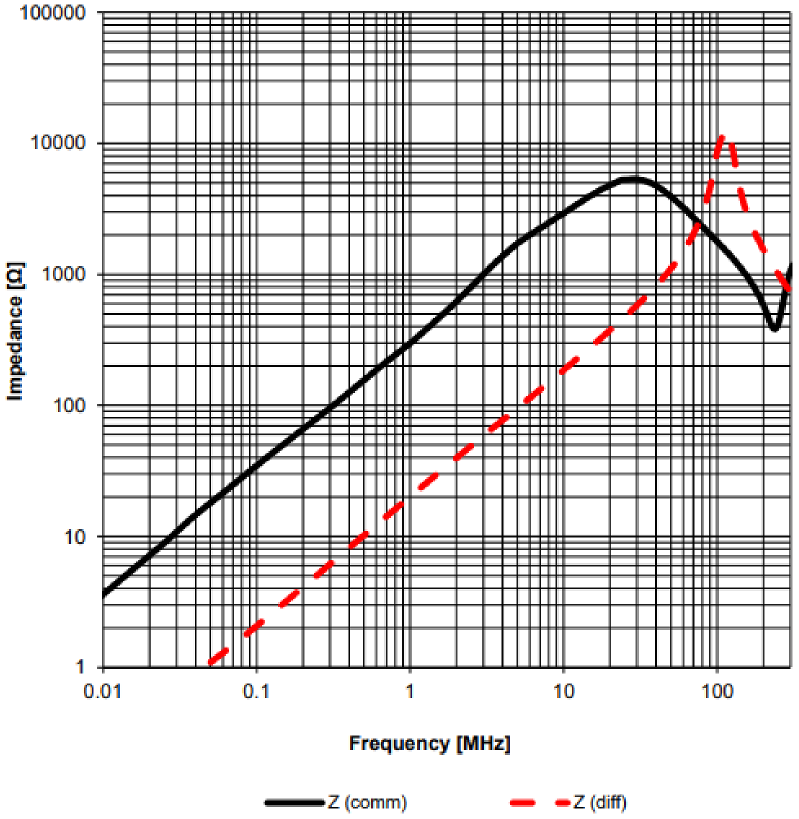
Possible filter solutions for isolated DCDC



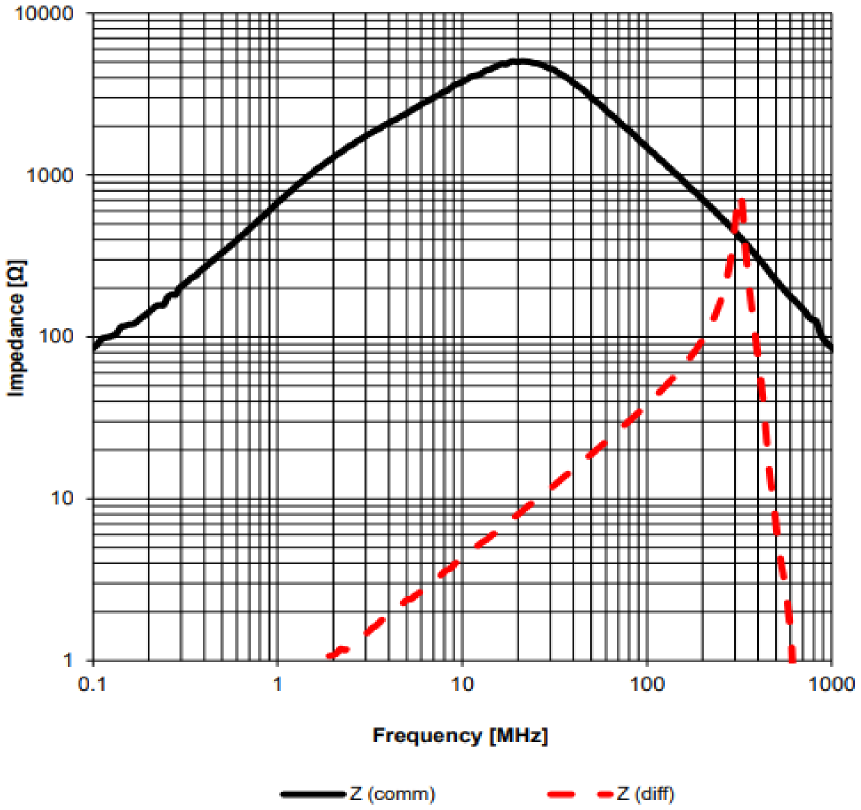
EMC FILTERS FOR WBG ISOLATED GATE DRIVE

Impedance curves of the used CMC´s

WE-SL2 744227S

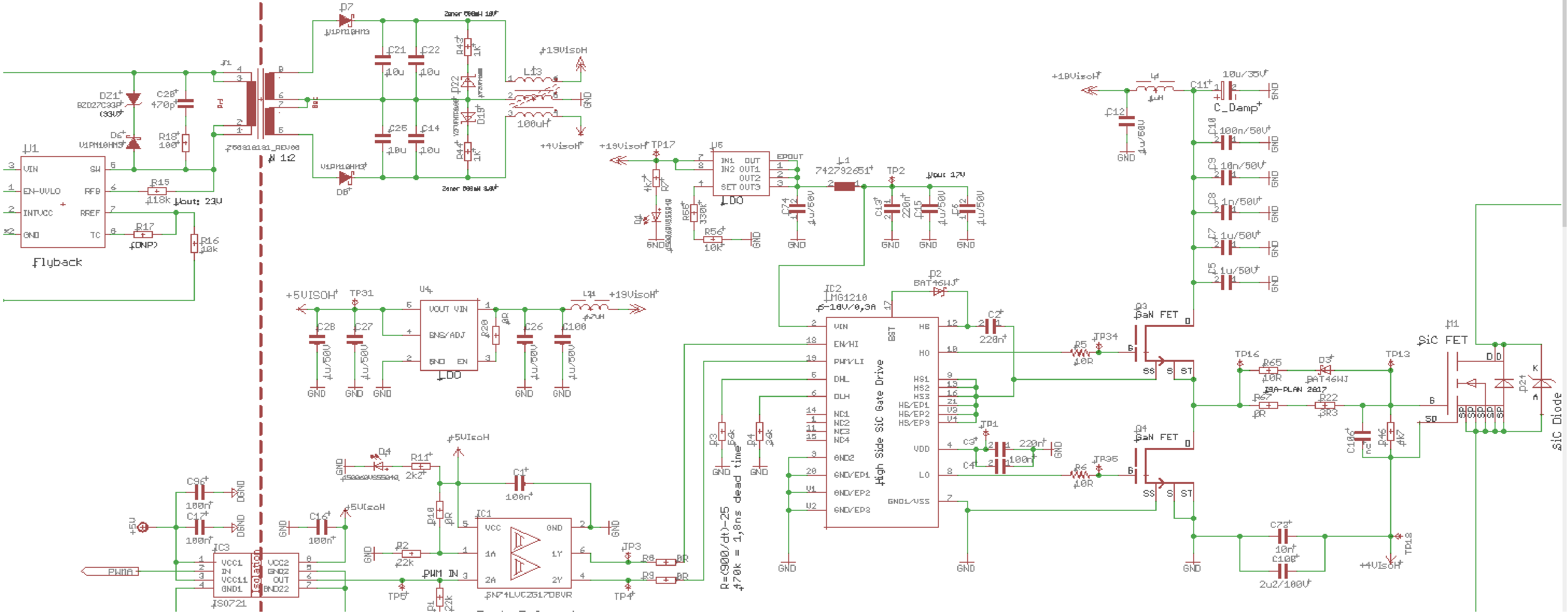


WE-SL3 74453101



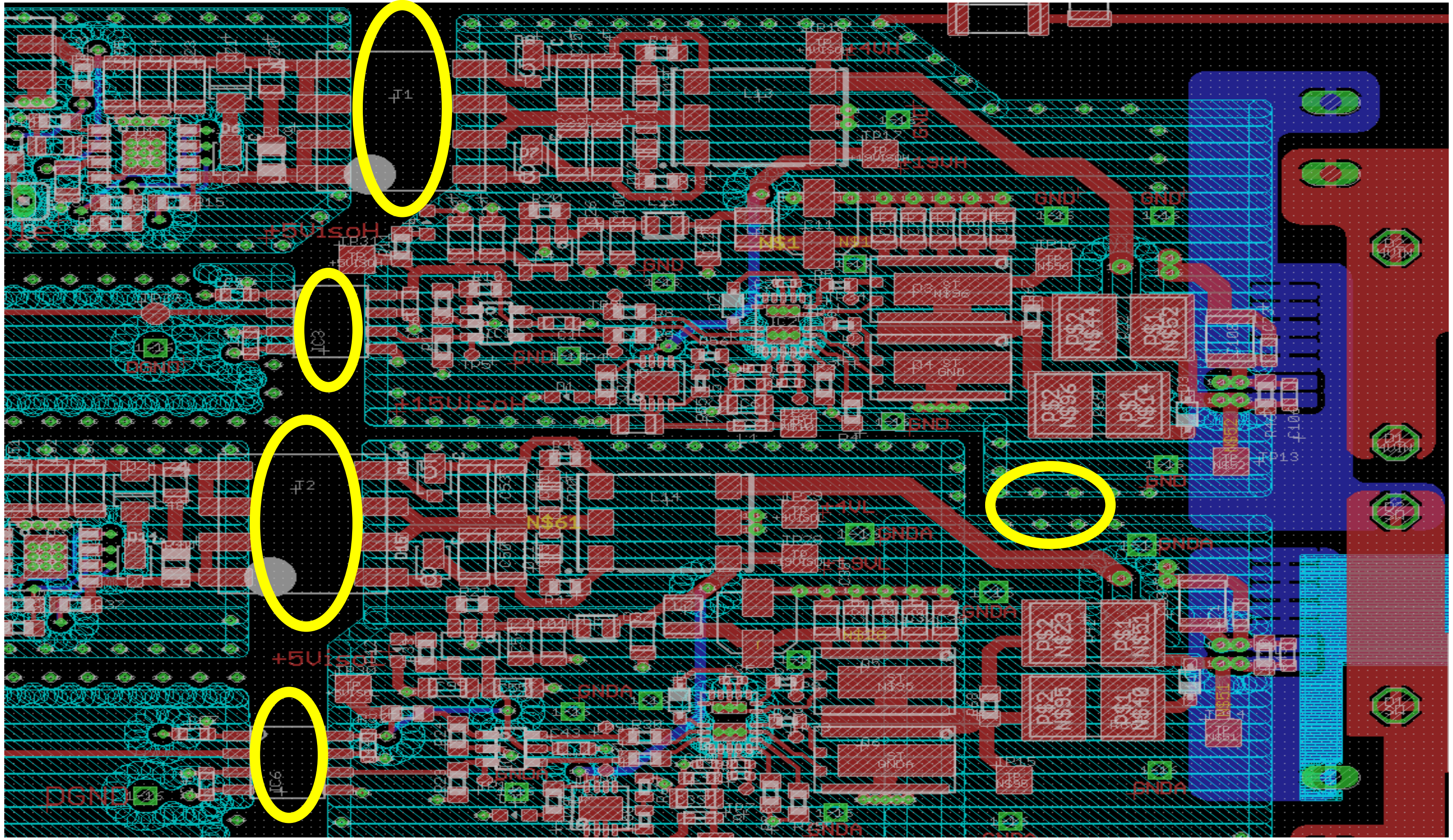
WBG 400W DEMONSTRATOR FROM WÜRTH ELEKTRONIK

4MHz GaN totempole SiC driver



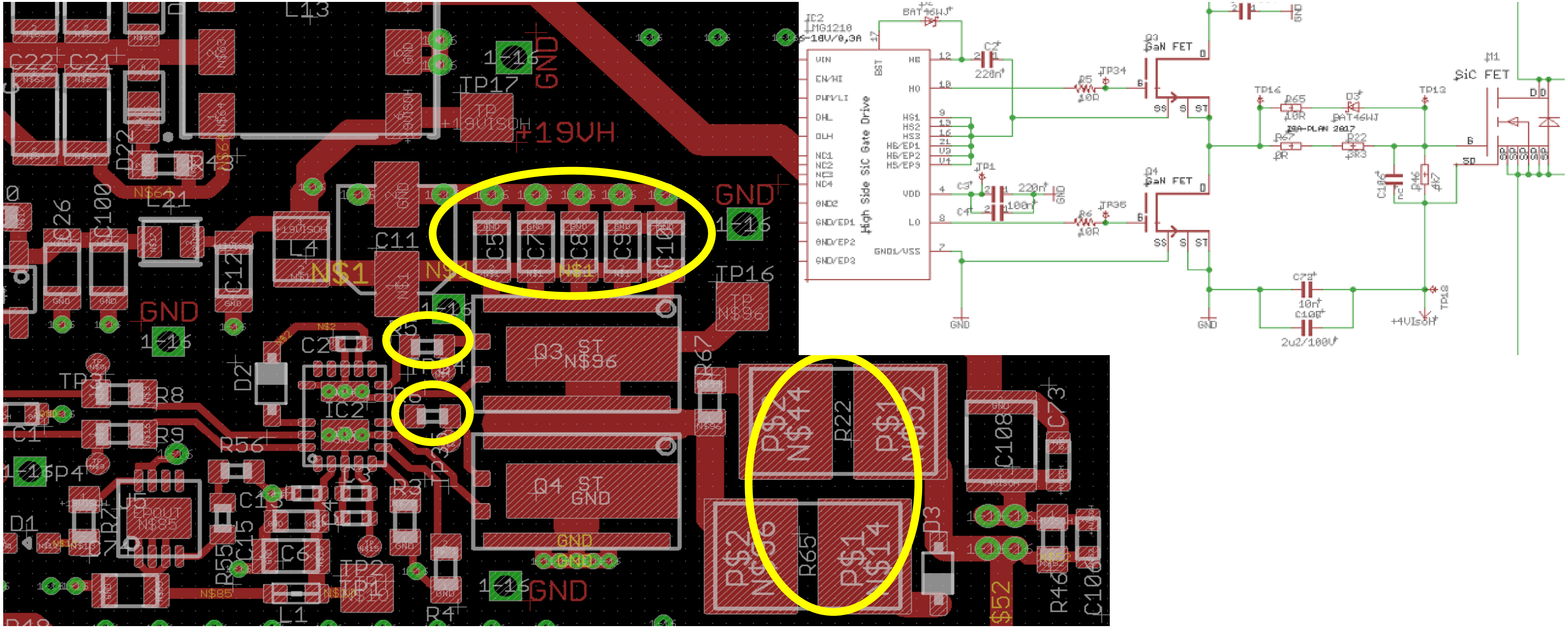
ISOLATED GATE DRIVE LAYOUT

Isolation on PCB HV to LV side



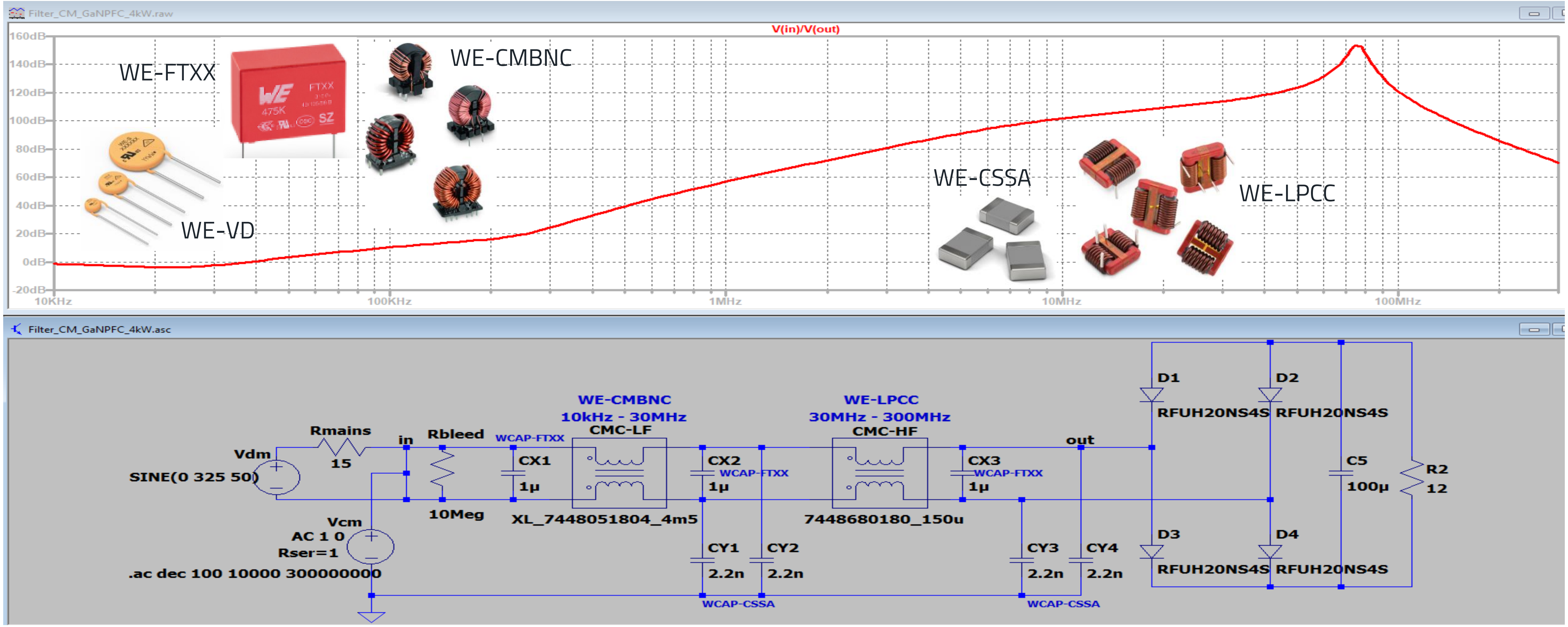
LAYOUT OF THE GATE DRIVE

Gate drive of GaN/SiC



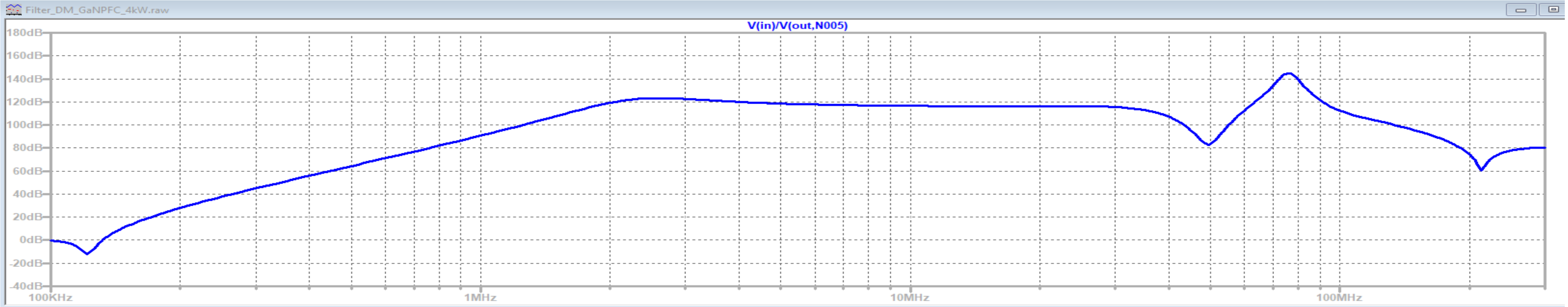
BROADBAND MAINS FILTER FOR 1-PHASE 4kW

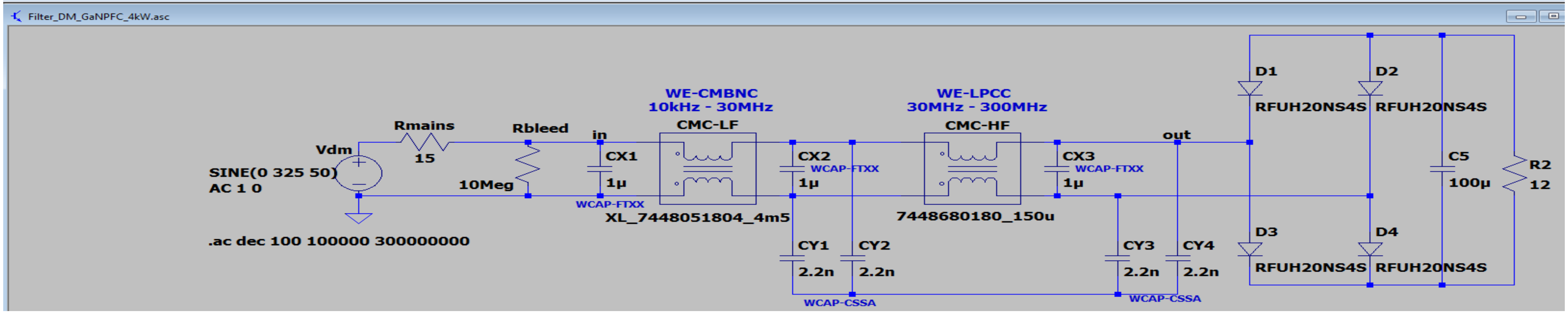
LT spice common mode simulation



BROADBAND MAINS FILTER FOR 1-PHASE 4kW

LT spice differential mode simulation

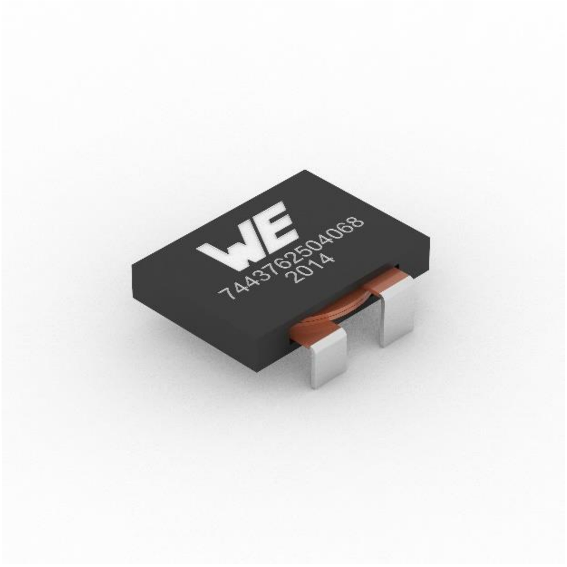




LOW VOLTAGE GAN FETS FOR DCDC?

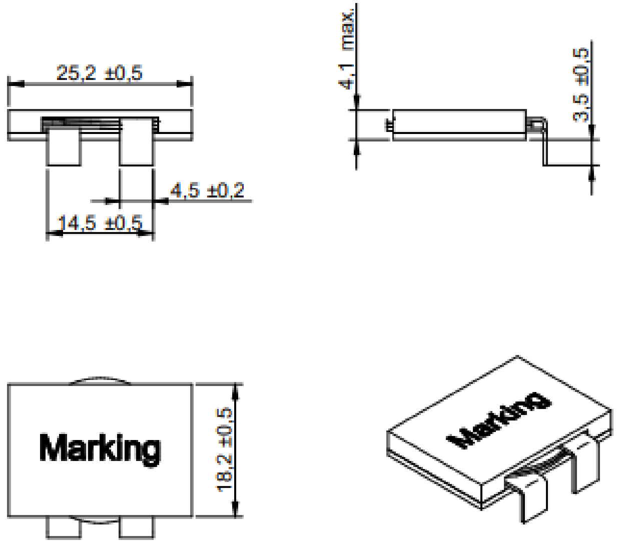
What is the advantage of using GaN in DCDC converters?

- Duty Cycle can be very small due to the fast switching edges
- Advantageous for e.g. high step down ratios: 48V → 1,2V/20A with only one DCDC stage
- Switching frequency is usually still below 1MHz due to efficiancy
- For high current and best efficiancy a new inductor has been developed
- WE-HCFT (2504 Package) 4.1mm Flat



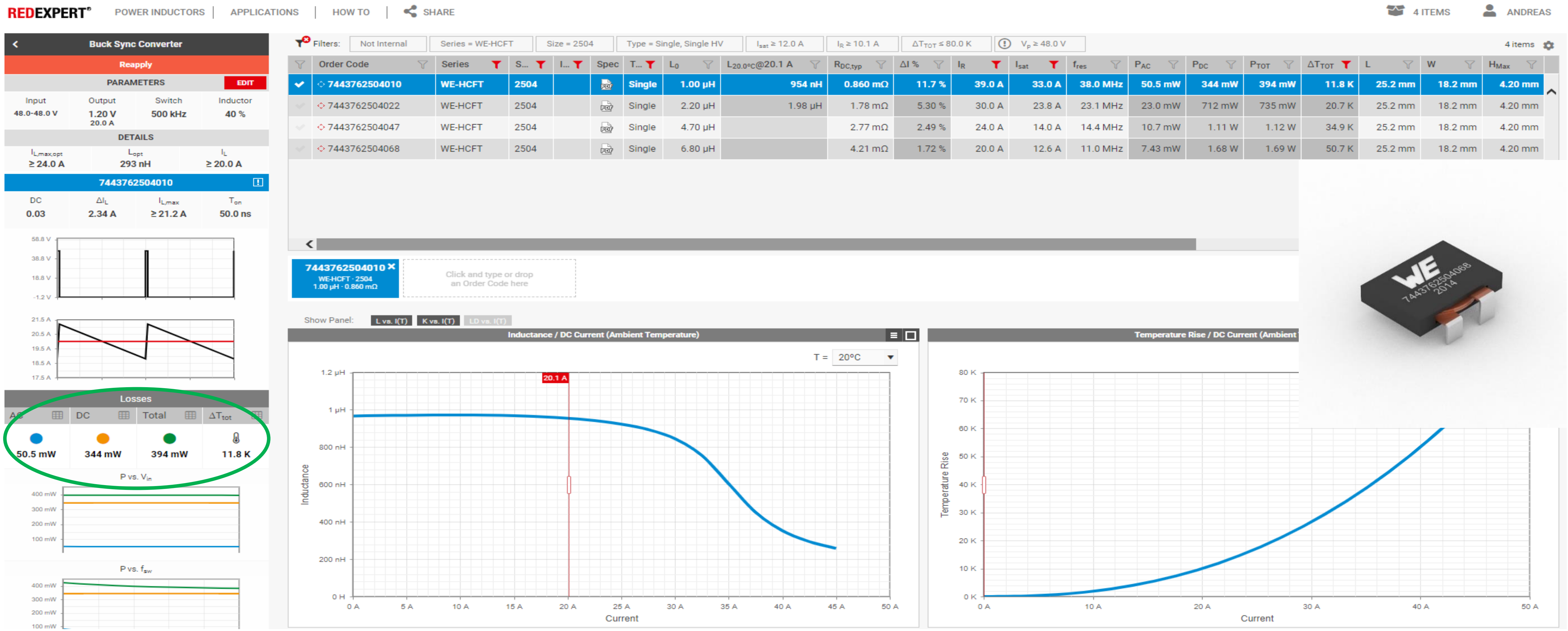
Electrical Properties:

Properties		Test conditions	Value	Unit	Tol.
Inductance	L	100 kHz/ 10 mA	1	µH	±20%
Rated Current	I_R	ΔT = 50 K	39	A	max.
Saturation Current	I_{SAT}	|ΔL/L| < 30 %	33	A	typ.
DC Resistance	R_{DC}	@ 20 °C	0.86	mΩ	typ.
DC Resistance	R_{DC}	@ 20 °C	0.95	mΩ	max.
Self Resonant Frequency	f_{res}		38	MHz	typ.
Operating Voltage	V	DC	80	V	max.



REDEXPERT SIMULATION OF THE NEW INDUCTOR

Buck sync   48V→1,2V   20A   500kHz



Order Code	Series	S...	I...	Spec	T...	L_0	$L_{20.0°C}$@20.1 A	$R_{DC,typ}$	ΔI %	I_R	I_{sat}	f_{res}	P_{AC}	P_{DC}	P_{TOT}	$ΔT_{TOT}$	L	W	H_{Max}
7443762504010	WE-HCFT	2504		PDF	Single	1.00 µH	954 nH	0.860 mΩ	11.7 %	39.0 A	33.0 A	38.0 MHz	50.5 mW	344 mW	394 mW	11.8 K	25.2 mm	18.2 mm	4.20 mm
7443762504022	WE-HCFT	2504		PDF	Single	2.20 µH	1.98 µH	1.78 mΩ	5.30 %	30.0 A	23.8 A	23.1 MHz	23.0 mW	712 mW	735 mW	20.7 K	25.2 mm	18.2 mm	4.20 mm
7443762504047	WE-HCFT	2504		PDF	Single	4.70 µH		2.77 mΩ	2.49 %	24.0 A	14.0 A	14.4 MHz	10.7 mW	1.11 W	1.12 W	34.9 K	25.2 mm	18.2 mm	4.20 mm
7443762504068	WE-HCFT	2504		PDF	Single	6.80 µH		4.21 mΩ	1.72 %	20.0 A	12.6 A	11.0 MHz	7.43 mW	1.68 W	1.69 W	50.7 K	25.2 mm	18.2 mm	4.20 mm