Unleashing GaN with High-Performance Gate Driving

MINDCET.
Custom
Integrated Power
Management
Solutions

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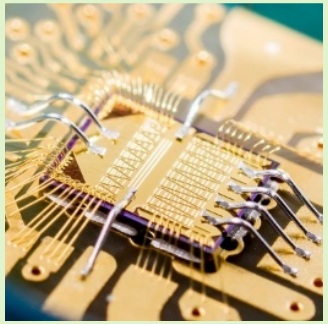
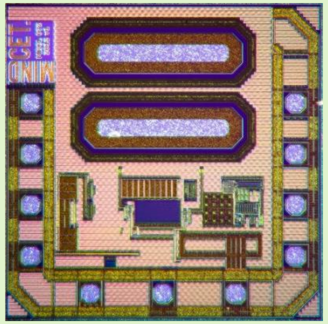
WE Meet @ Digital Days / 27.04.2021

kiwa ISO 9001 QUALITY
QUALITY MANAGEMENT





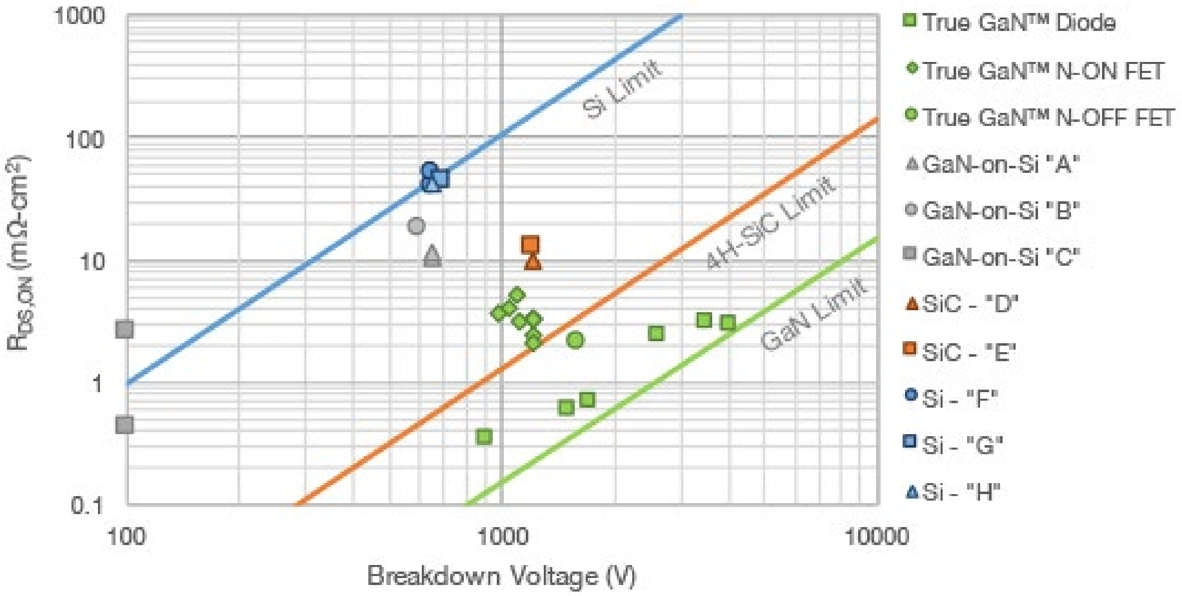
Contents

- Advantages of GaN
- Challenges of Driving GaN
- Our Answer: High-Speed GaN Gate-Driver
- MDC901 Evaluation Kit (EVK)
- Applications
- Thermal Performance
- Conclusions

Advantages of GaN

Compared to Silicon MOSFETs

- Faster switching transitions
- Improved $R_{ds(on)}$ x GateCharge
- Lower C_{oss}, C_{iss}, C_{rss}
- No reverse recovery
- Higher temperature capability



⇒ Theoretically enables higher SMPS efficiencies

⇒ But how can we enable this?

Source : *nexgen powersystems*

Challenges of Driving GaN

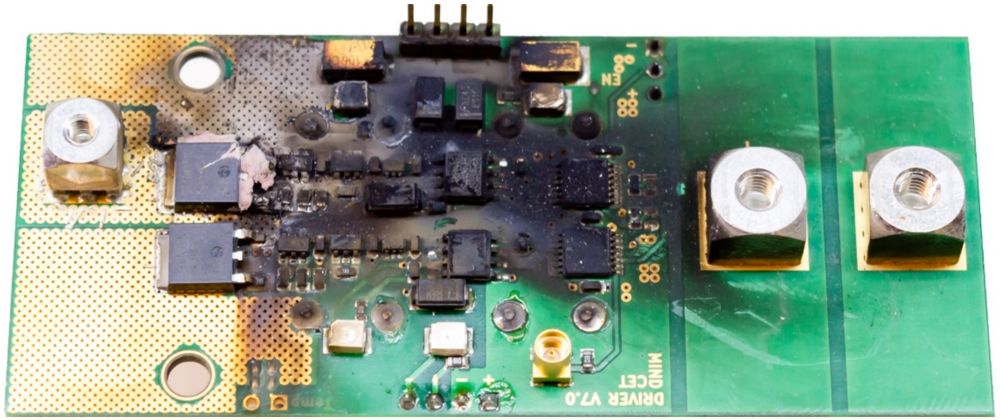
What not to do

A GaN HEMT is NO MOSFET:

- Lower and tighter controlled gate turn-on voltage
- Lower threshold voltage (V_{th})
- Significantly faster Turn On and Off times
- Lower $C_{gate\text{-}source}$ / $C_{drain\text{-}gate}$ ratio

⇒ An ideal recipe for expensive fireworks

⇒ Needs an optimized gate-drive approach

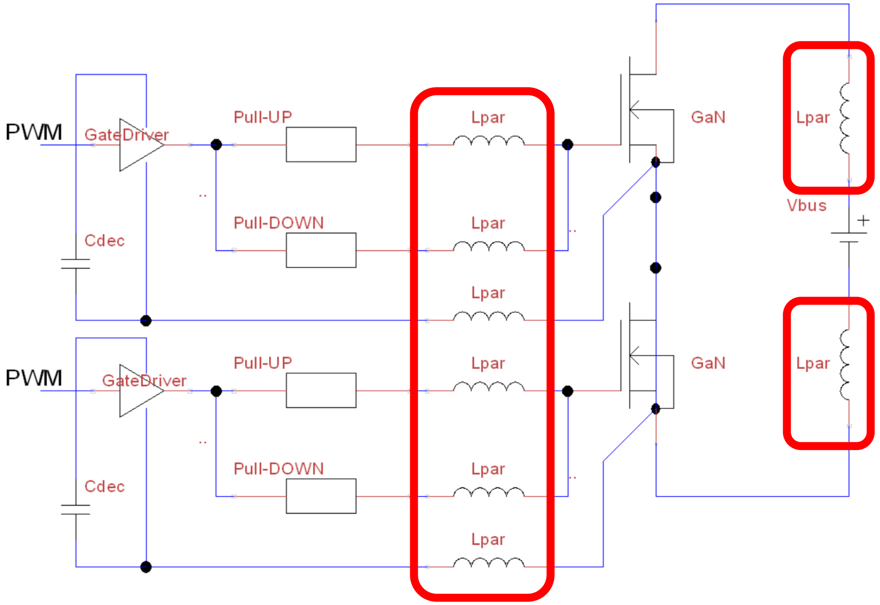


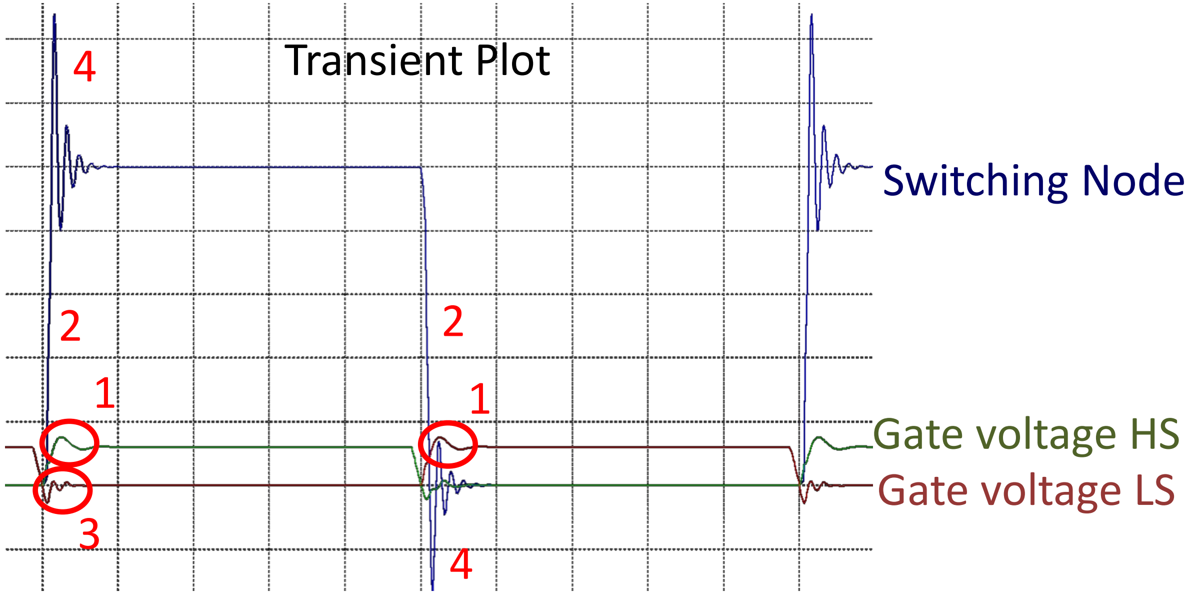
Challenges of Driving GaN

What to watch out for

On PCB level:

- **Gate-loop inductance**
  - Over-voltage stress on the gate 1
  - Limits transient speed 2
  - Parasitic turn-on 3
- **Supply inductance**
  - Ringing on switching node 4
  - Limits transient speed 2



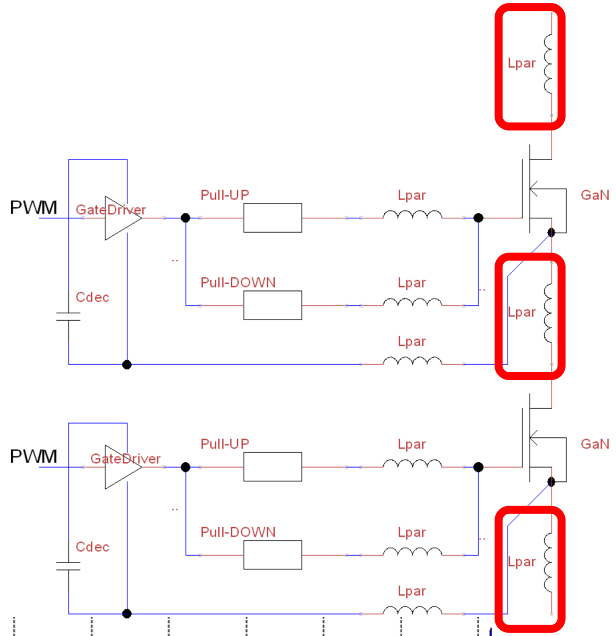


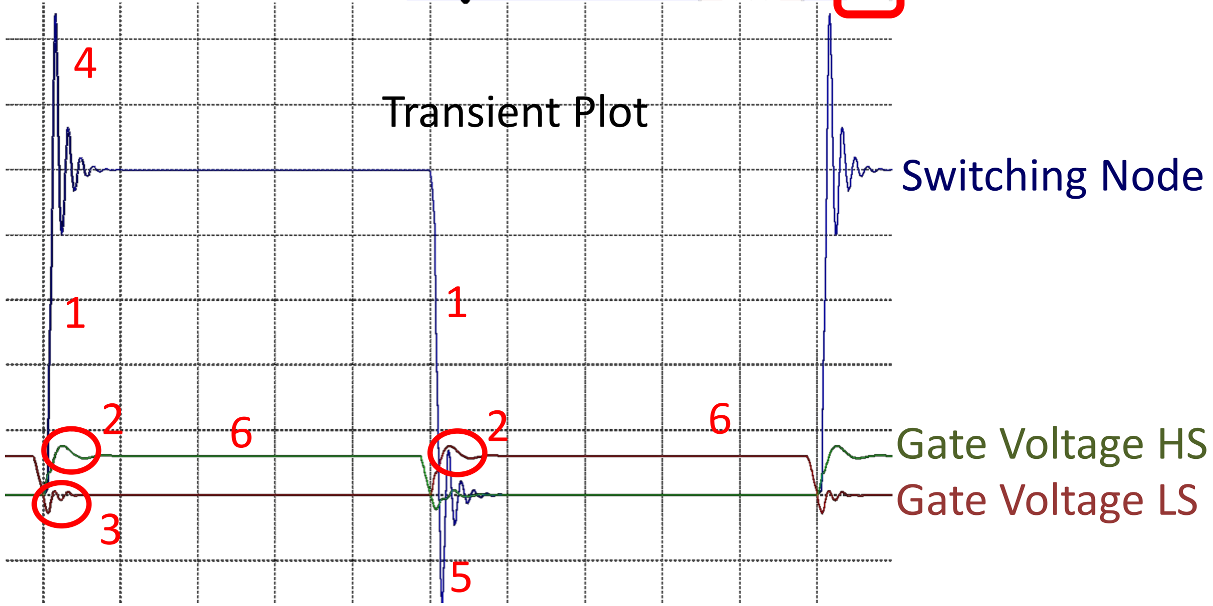
Challenges of Driving GaN

What we need to watch out for

On PCB level:

- **Gate resistors**
  - Regulates transient speed 1
  - Keeps dissipation from the driver
  - Dampens the gate LC 2
  - Prevents parasitic turn-on 3
- **Drain-source inductance**
  - Ringing on switching node 4
  - Negative voltage on driver 5
  - Over-charges bootstrap 6

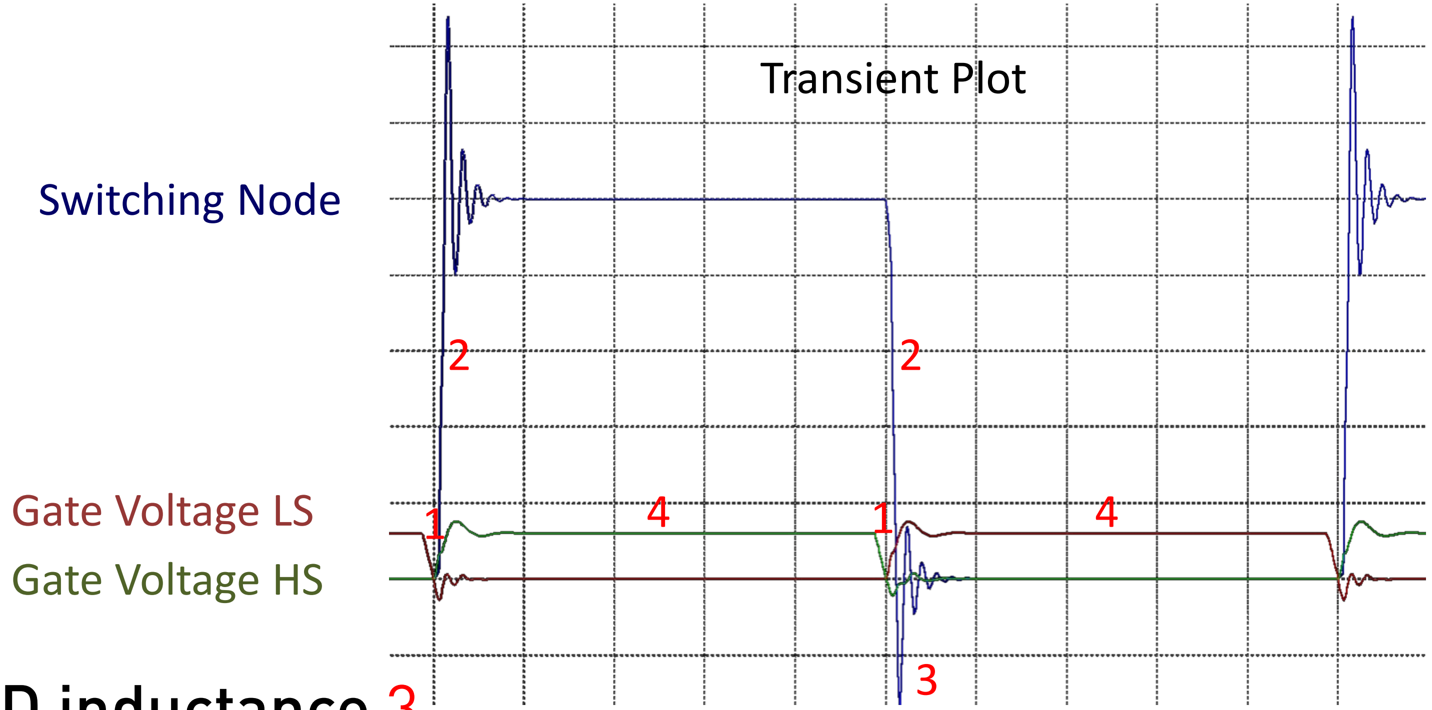




Challenges of Driving GaN

What the gate driver needs to overcome

- **Dead-time control** 1
  - Cross currents in GaN
  - Recirculation loss
- **LS/HS delay-matching** 1
  - Cross currents in GaN
- **dV/dt** 2
  - False gate commutation
  - Driver failure
- **Negative Source voltage = GND inductance** 3
  - False gate commutation
  - Driver failure
  - Bootstrap over-charging -> Gate-stress and breakdown 4



Our Answer: High-Speed GaN Gate-Driver

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Key specifications MDC901

- 200V High and Low side
- 30ns propagation delay **-> Control loop stability**
- 1ns delay matching **-> Optimized dead-time**
- Slew rate 100V/ns compatible

  -> High-speed switching
- 10-A peak source,17-A peak sink currents

  -> High-speed, no parasitic turn-on
- Up to -4V GaN source operation guaranteed

  -> No false-triggering of gate
- -40 to 125°C ambient operation (-55° to 175°C junction temp possible)

  -> High power density

QFN56 7x7mm²

Our Answer: High-Speed GaN Gate-Driver

Device Features MDC901

MIND CET. Custom Integrated Power Management Solutions

- Logic 5V as well as a floating & programmable HS/LS LDO for gate voltage 4-6.5V

  -> No gate-overcharge
- 100% duty cycle enabled by on-chip charge pump

  -> Low & high duty cycles
- Integrated Bootstrap diodes

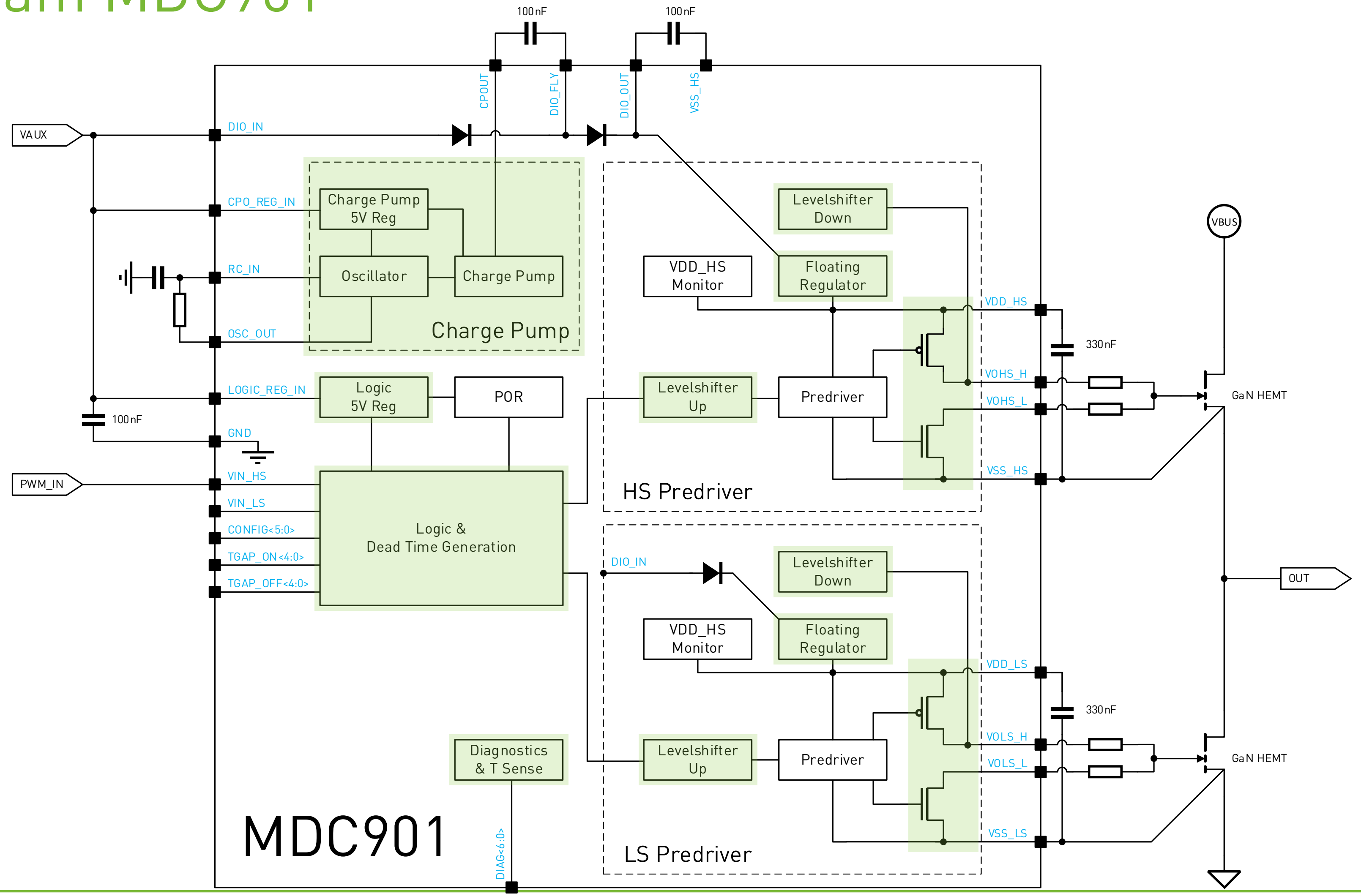
  -> Gate power @ higher frequencies
- Automatic dead-time or programmable dead-time

  -> Maximal flexibility and reliability
- Internal temp sensor -> System monitoring
- UVLO -> Avoid insufficient gate-overdrive

QFN56 $7x7mm^2$

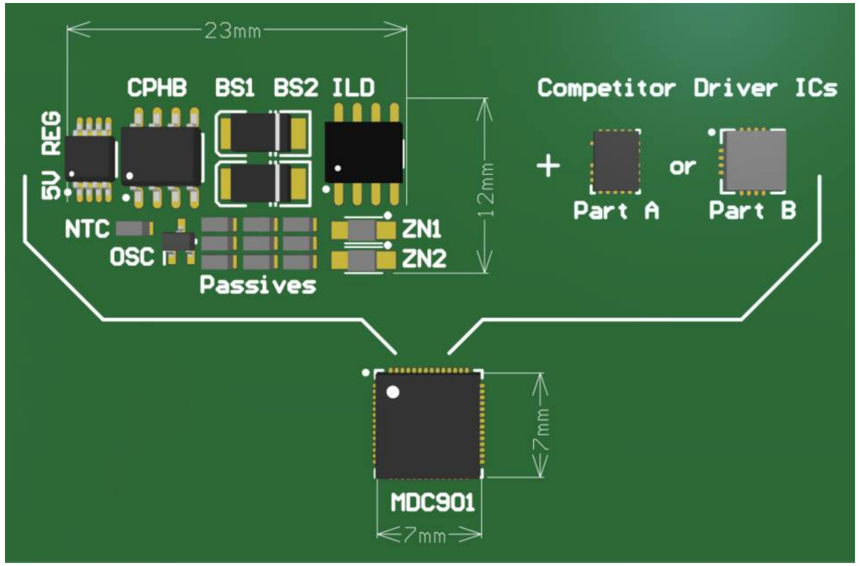
Our Answer: High-Speed GaN Gate-Driver

Block diagram MDC901

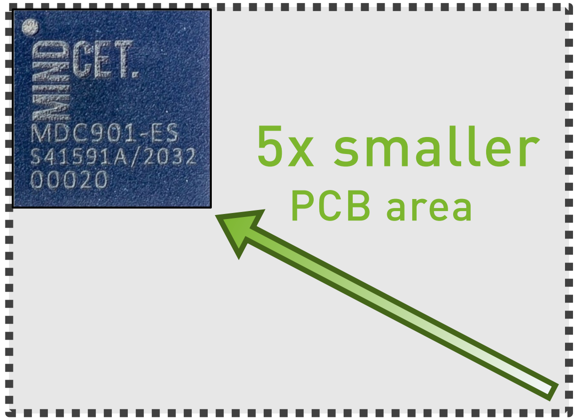


Our Answer: High-Speed GaN Gate-Driver

High level of integration for design ease & footprint reduction



Required external components for an equivalent competitor gate driver solution to the MDC901



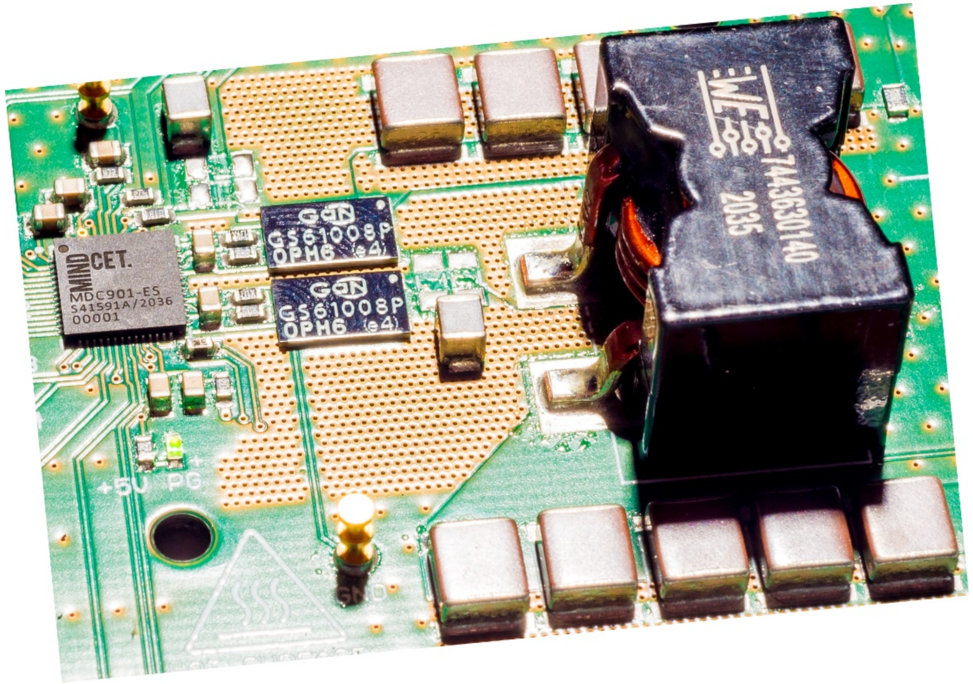
**shown to scale*

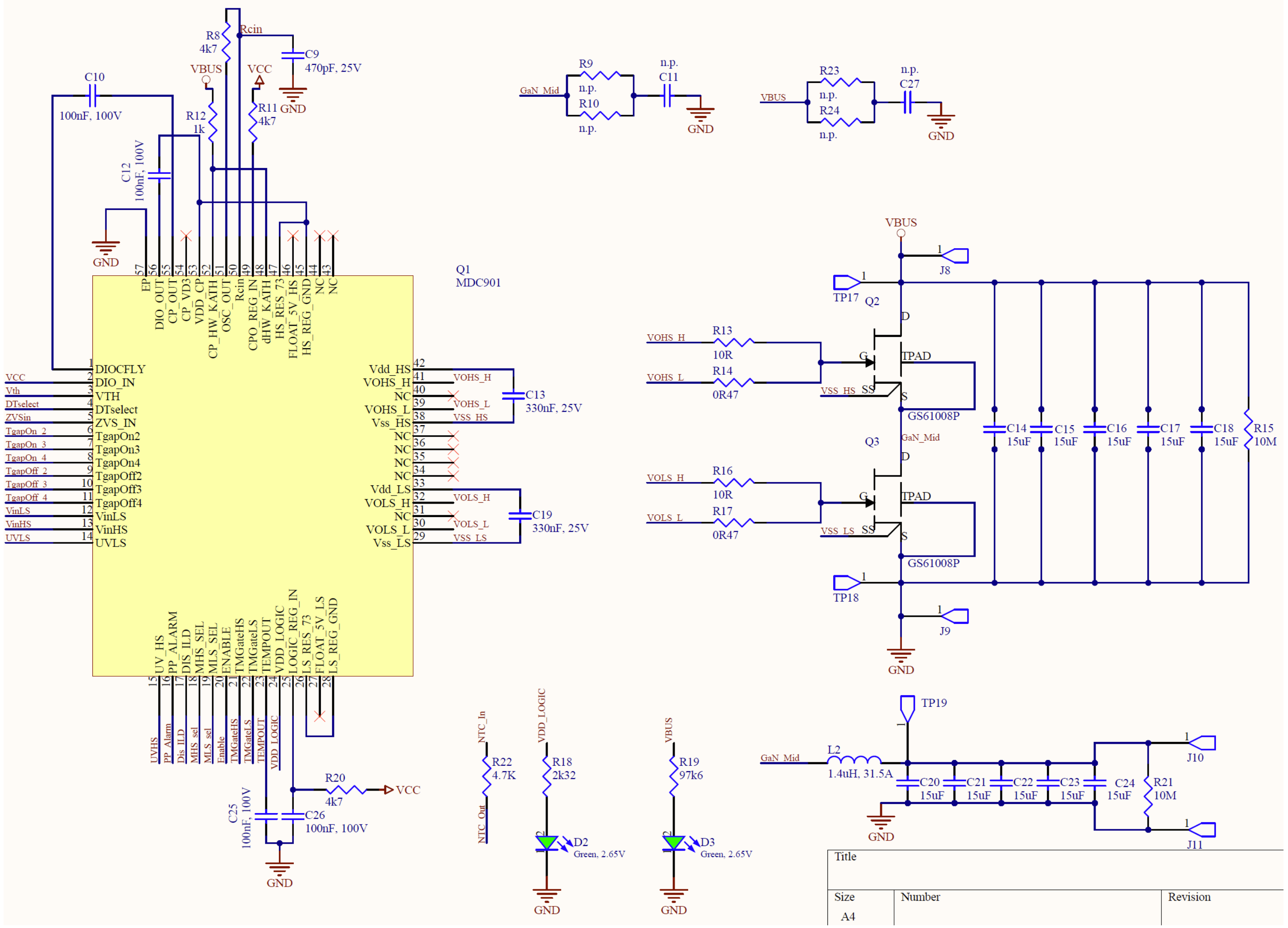
- Significant PCB footprint reduction → lowered costs
- Decreased design effort → faster time-to-market
- Increased system robustness through decreased part count

MDC901 provides decreased complexity with efficient & robust gate driving through a highly integrated gate drive IC

MDC901 Evaluation Kit

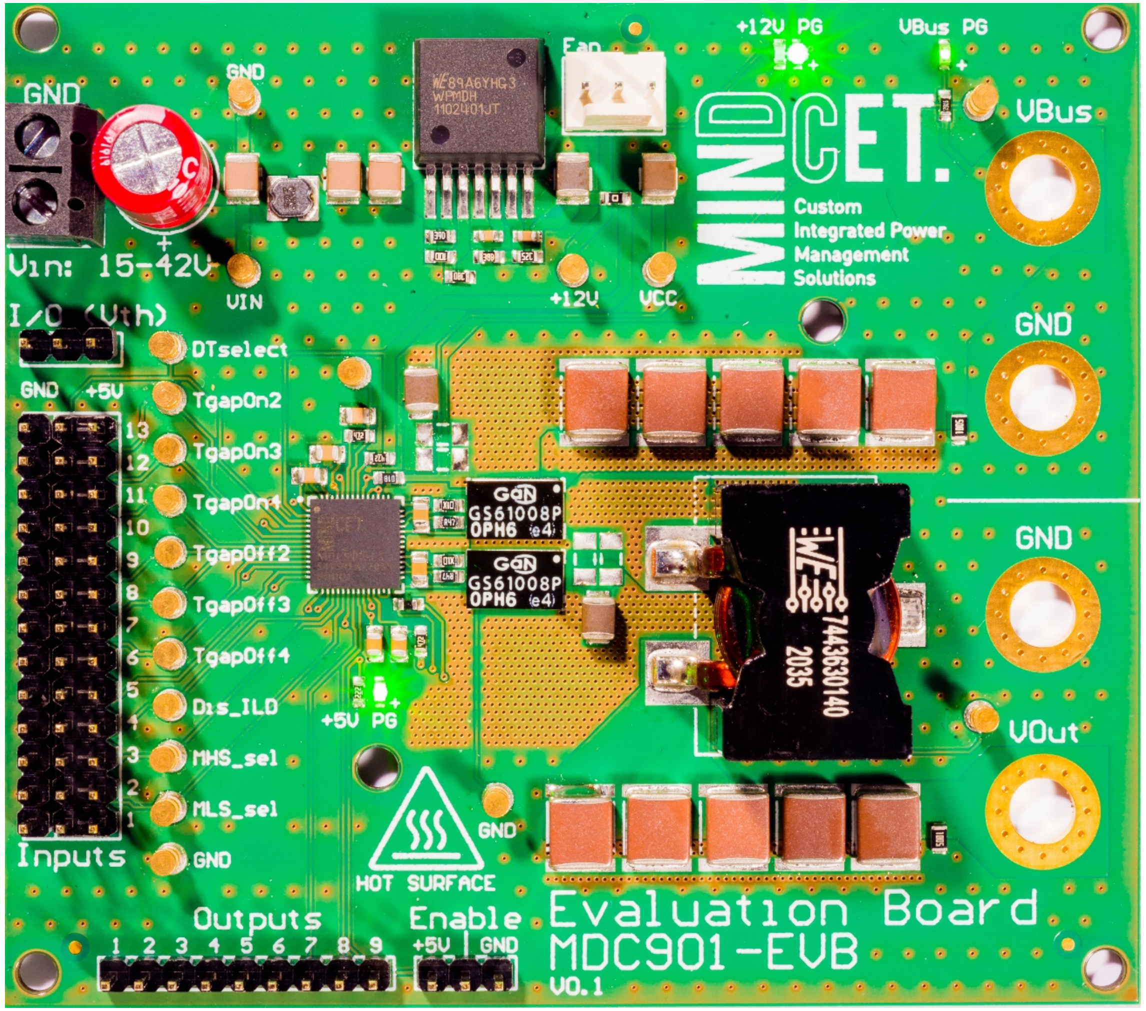
Main DC/DC circuit



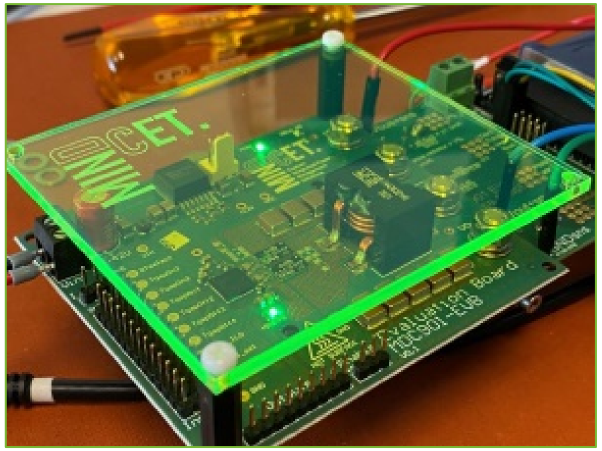


MDC901 Evaluation Kit

The hardware



- MDC901 200V GaN gate driver
- 100V HB HEMT featuring GaN GS61008P
- Featuring Würth Elektronik WE components
- 20A/50V operation, 100V / 40A possible (thermal limitation)
- Thermistor close to GaN for temp monitoring
- Regulated 12V Fan supply
- All components mounted and materials provided:
  - Active heatsink + TIM
  - Plexi cover
  - Cables
  - Screw and bolts
  - Manual
  - Re-useable box



Applications

A versatile driver

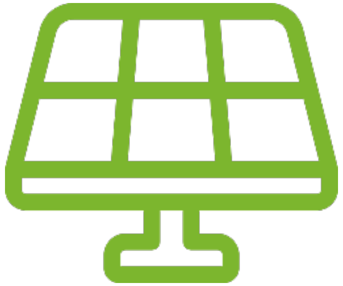
Audio class-D

Server & data
center PoL

High-end eBikes & lightweight
eMobility

High Perfomance
Consumer & Industrial
Applications

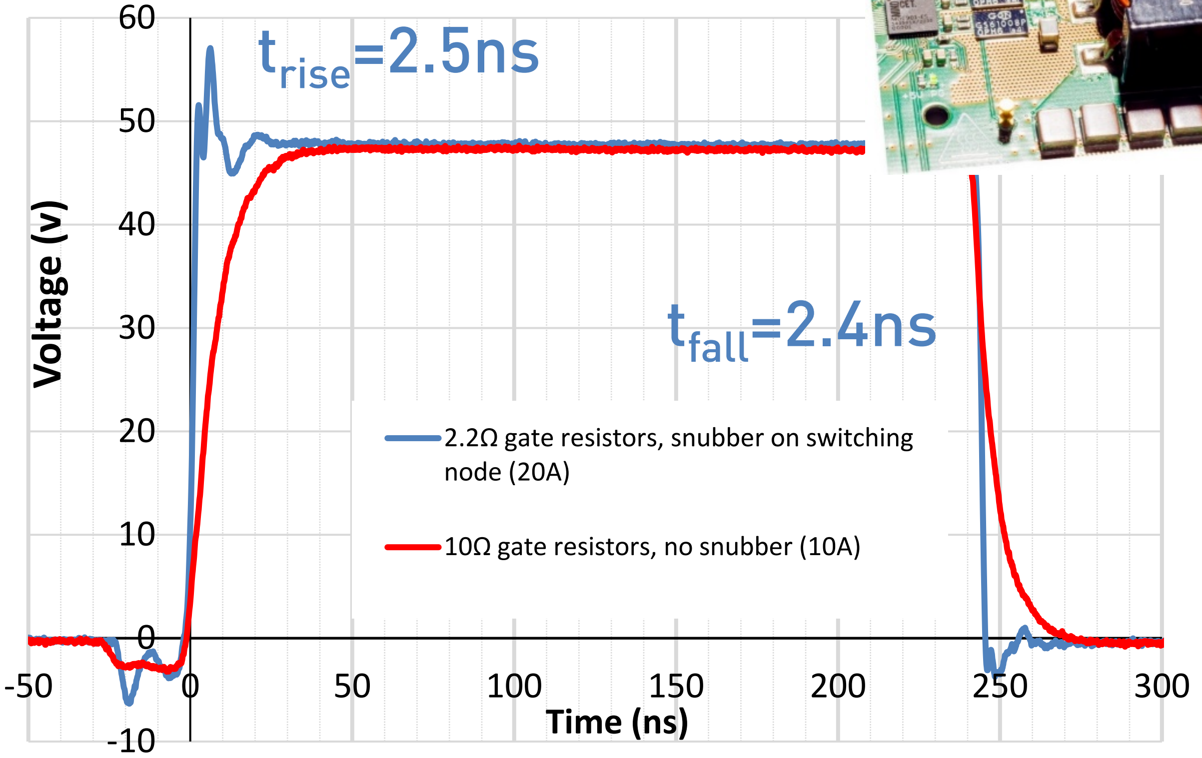
Battery-powered tools & devices
(e.g. power-tools, drones)

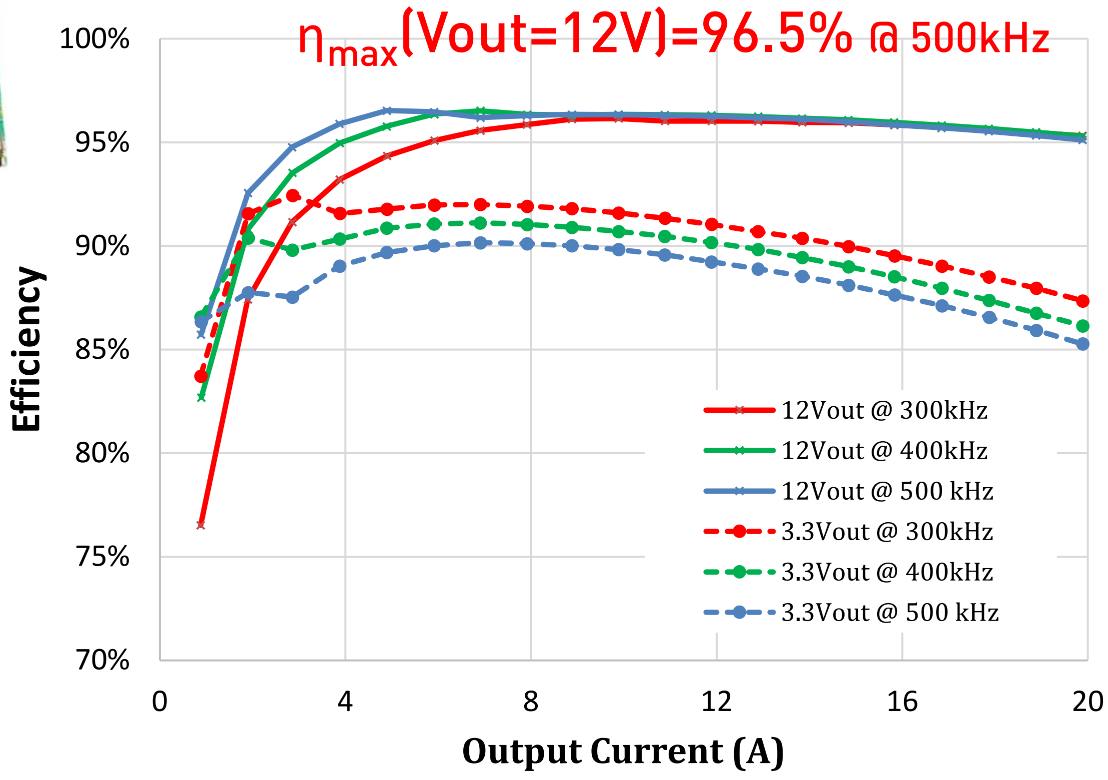


PV microinverter

Applications

Evaluation board performance in real-life: Buck DCDC





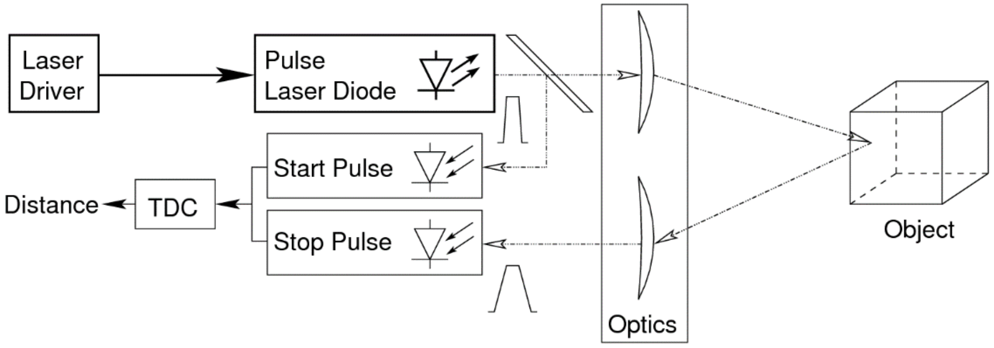
Tunable dv/dt

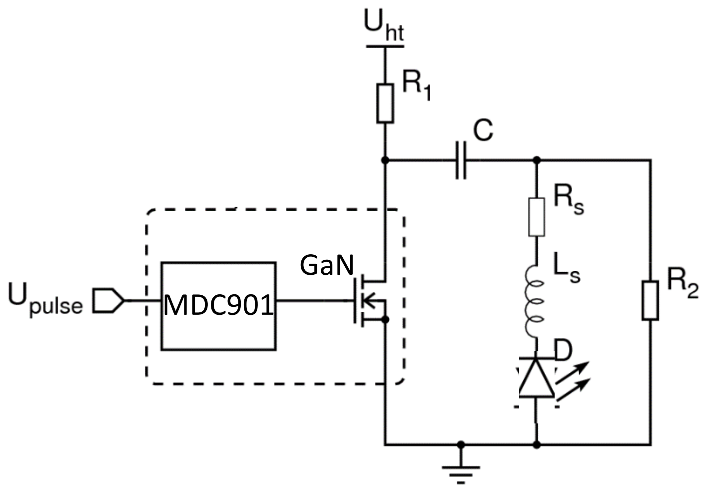
Efficiency curves for Vin=48 V to Vout=12 V or 3.3V

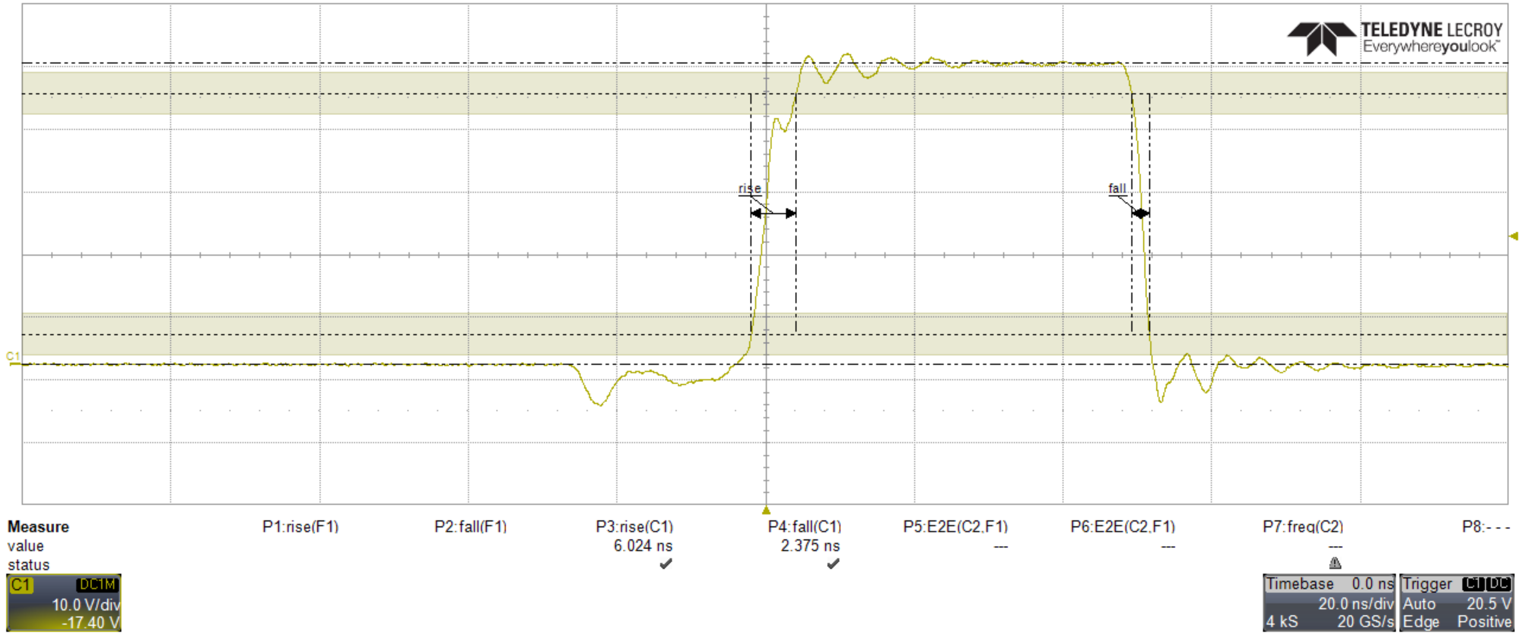
Applications

LIDAR Laser Driver

- Short pulses with high current amplitude





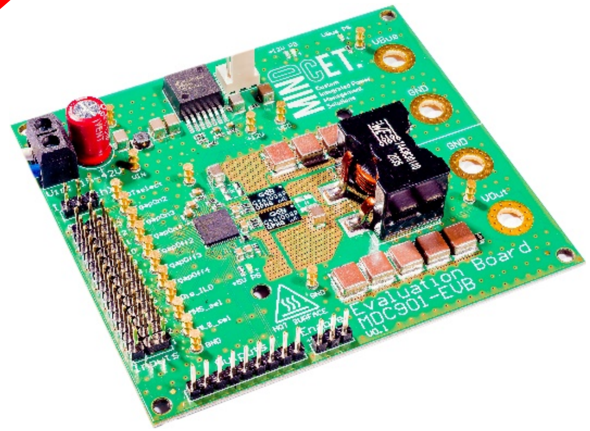


Applications

Class-D Audio Amplifier

- Low distortion:
  - Clean square-wave switching
  - Nano-second dead-time
- High efficiency
- High power density
- Deep modulation possible
  - Charge-pump

?

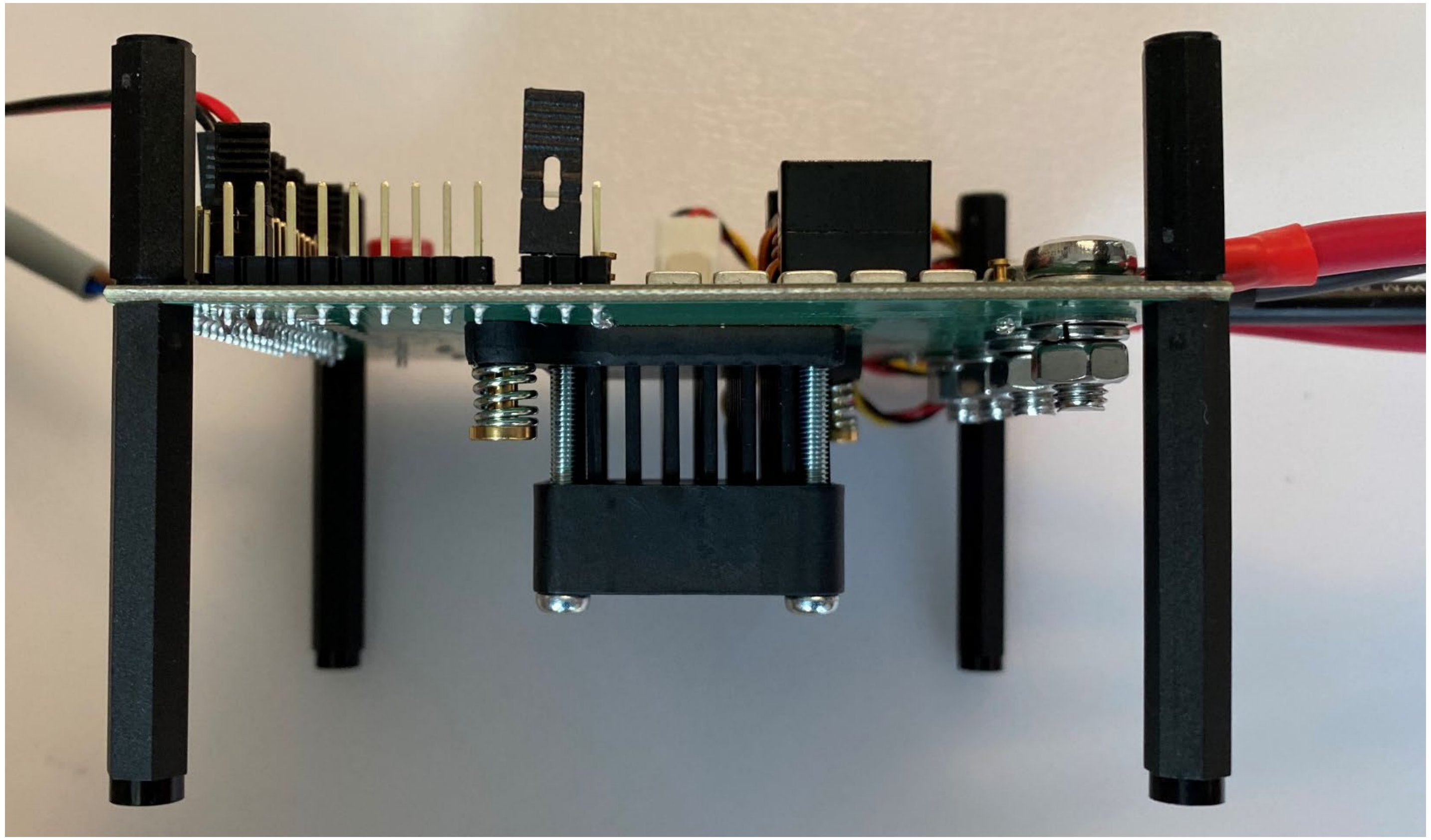


Thermal Performance

Strong thermal management at steady state (with heatsink & fan)

- GaN HEMT on PCB top-side
- Isolating Thermal Interface Material (TIM) on PCB bare copper (ENIG)
- Active pin grid array heatsink on bottom-side of PCB (spring-loaded)

⇒ About 4 K/W from GaN to ambient



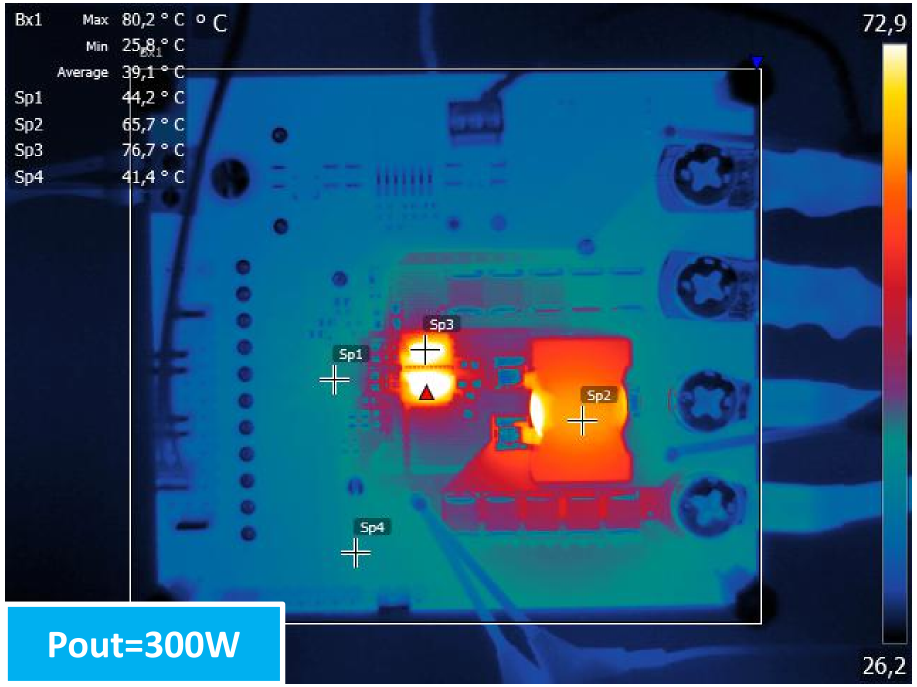
Thermal Performance

Strong thermal management at steady state (with heatsink & fan)

Vin=48V, Vout=3.3V, Iout= 20A, fsw=300kHz

Efficiency = 88.6% Ploss = 8.5W

Max Temp (LS HEMT) = 58.1°C



Vin=48V, Vout=12V, Iout= 25A, fsw=300kHz

Efficiency = 94.5% Ploss = 17.5W

Max temp (LS HEMT) = 80.2°C

Optimized deadtime and PCB layout with a heatsink & fan provides ideal performance

Conclusions

- Improper GaN gate-driving induces many problems, potentially off-setting the benefits of GaN
- Gate-drive can enable the true benefits of GaN:
  - transient speed
  - Low losses
  - High power density
- State-of-the-art solution presented as the MDC901 gate-driver
- Enables a range of enhanced applications:
  - DC/DC converters, LIDAR drivers, class-D audio, BLDC Motor drivers and more
- GaN HEMTs are not the cheapest components, in order to utilize the benefit to the maximal -> Get Your Gate DRIVE(R) Right!

What can we do for you?

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