Unlocking the Power of GaN

PSMA Semiconductor Committee Industry Session

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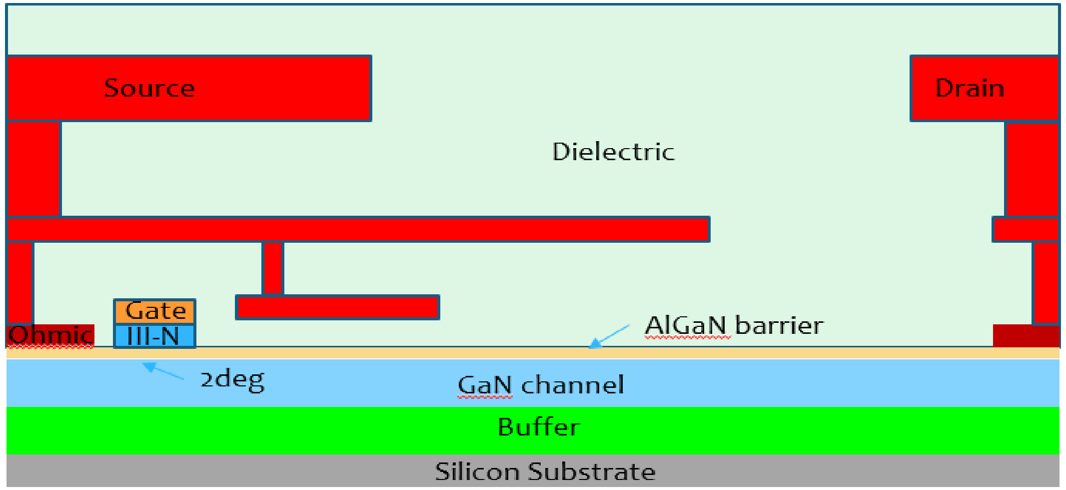
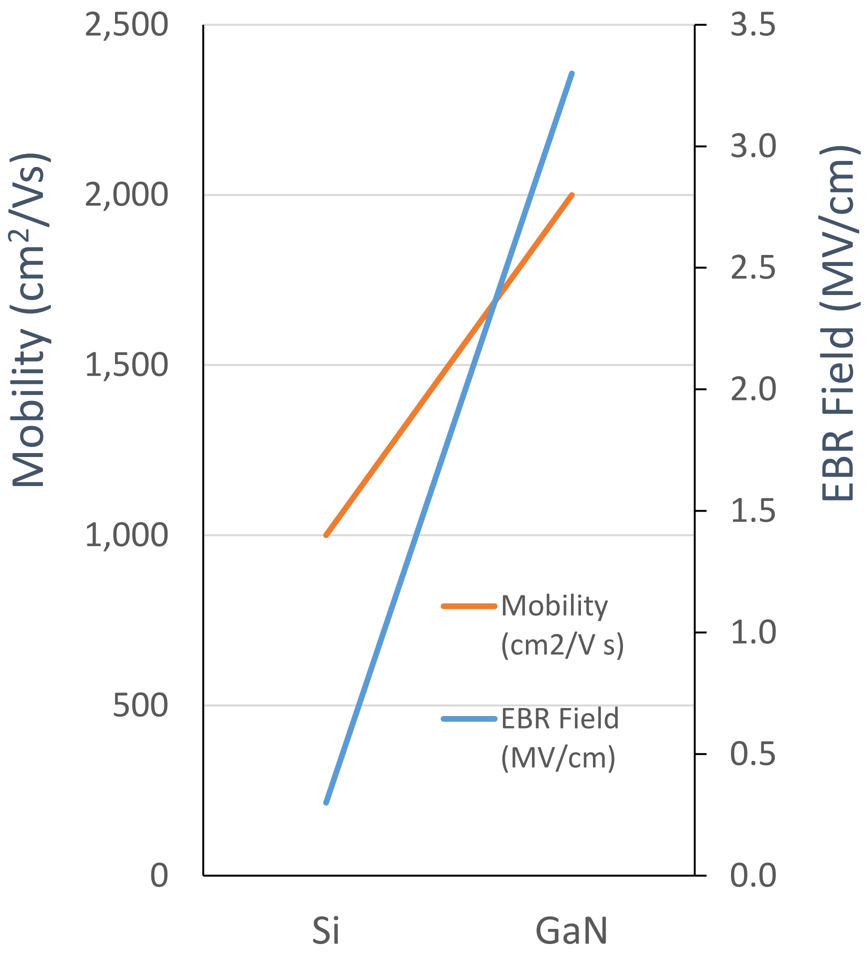
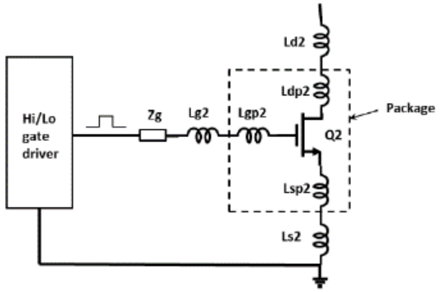
GaN vs. Si

- WBG GaN material allows high electric fields so high carrier density can be achieved
- Two dimensional electron gas with AlGaN/GaN heteroepitaxy structure gives very high mobility in the channel and drain drift region
- Lateral device structure achieves extremely low Q_g and Q_{OSS} and allows integration
- Large diameter GaN-on-Si, low cost Si-compatible processing

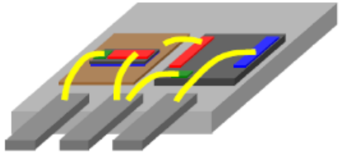




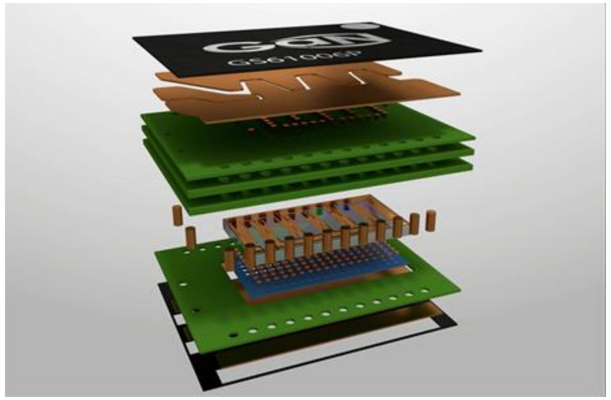
Existing GaN Packages



- Through-hole
  - High inductance, limits switching frequency



- Cascode (co-pack and/or stacking)
  - Multi-die, additional components
  - Higher cost for dice and assembly

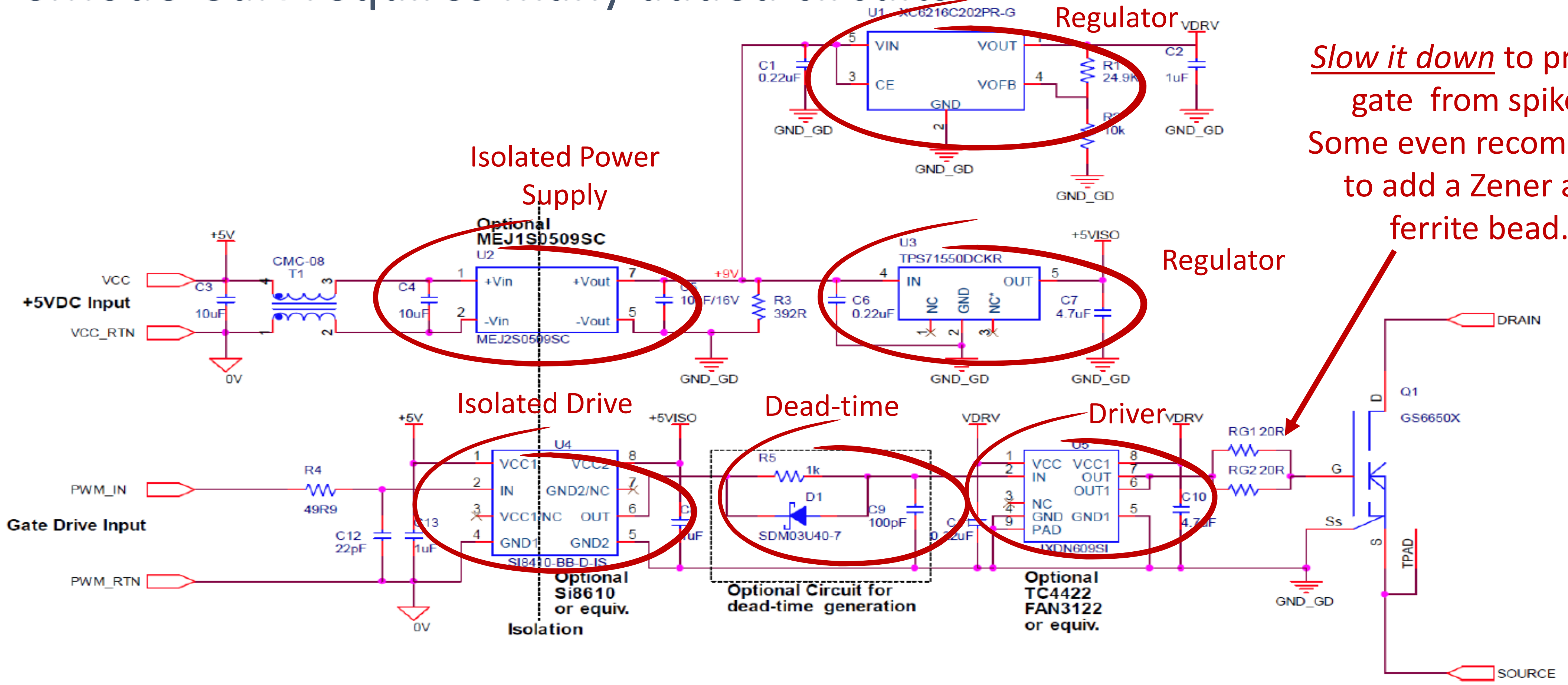


- PCB-embedded
  - Non-standard, high cost

Speed Limit:

Complex Drive

- dMode GaN needs extra FET, extra passives, isolation, complex packaging
- Early eMode GaN requires many added circuits:



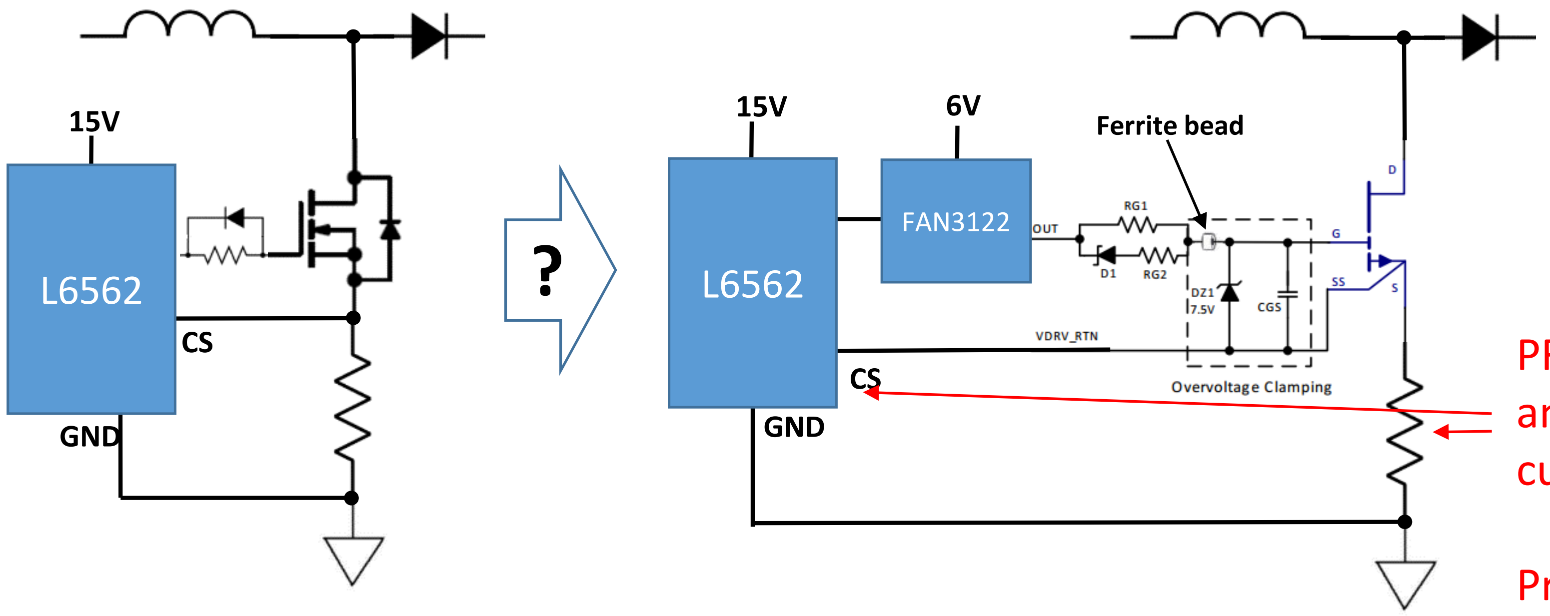
Slow it down to protect gate from spikes! Some even recommend to add a Zener and ferrite bead.

Ref: GaN Systems Application note GN001 Rev 2014-10-21

Package Parasitics Impede GaN Performance

Discrete Si
Limit 200kHz

Discrete GaN
500kHz+



PFC IC needs sense resistor and source connection for current sensing

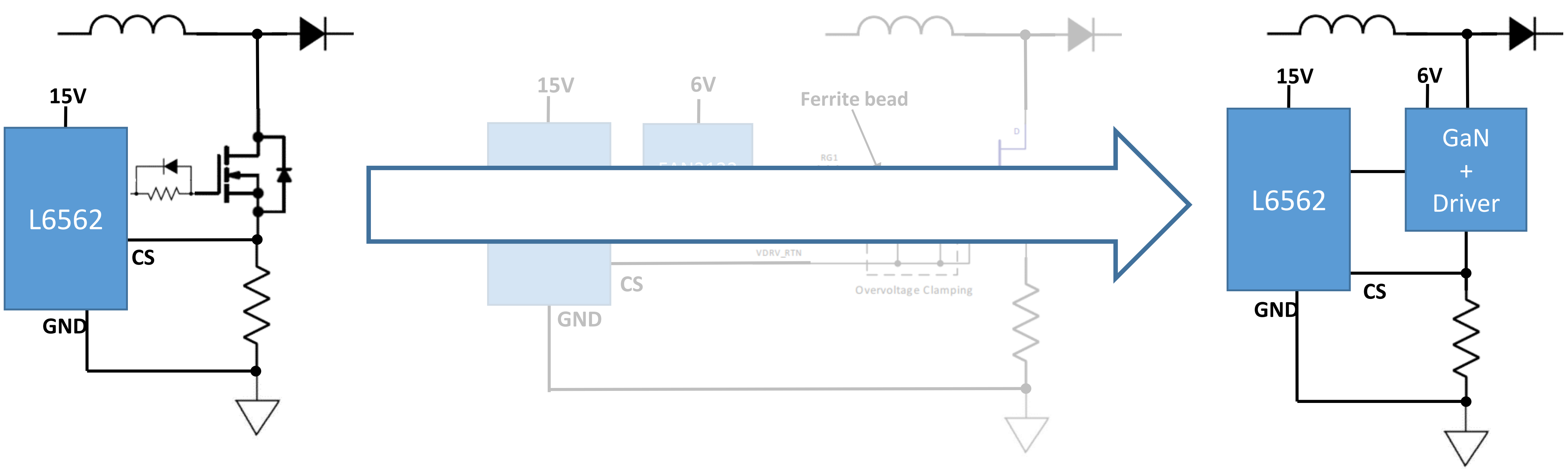
Problems with gate drive ringing and clamping

GaN with Integrated Driver: Simple, Fast

Discrete Si
Limit 200kHz

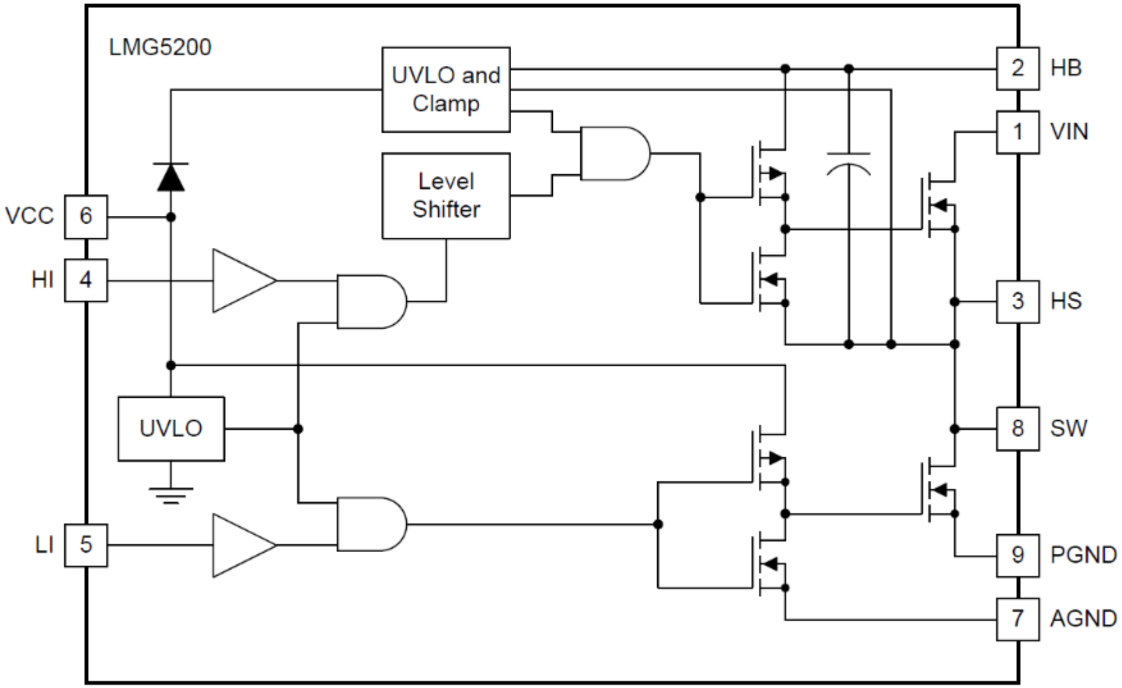
Discrete GaN
500kHz+

Integrated GaN
2MHz+

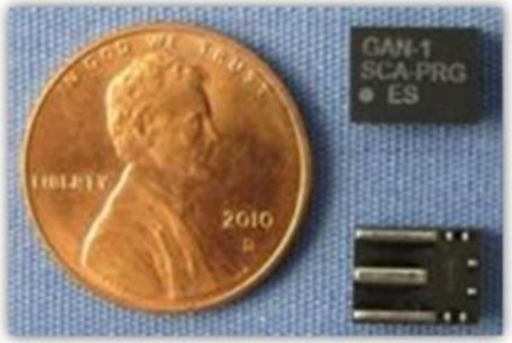


Multichip Si / GaN Integration

- Multi-chip module integrates Si driver and GaN transistor(s)
  - 80V product example



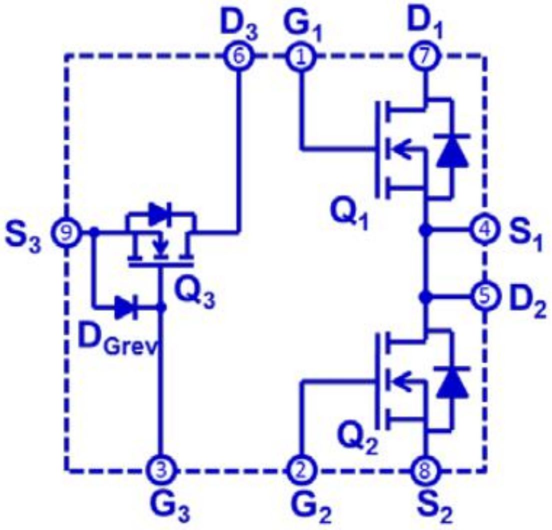
TI LMG200 integrated driver + half-bridge

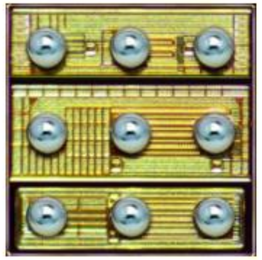


6 mm x 8 mm

Simple Integration of 2 Power FETs & Bootstrap

- Monolithic GaN transistor integration
- Gate drive still external / complex
- 100V example

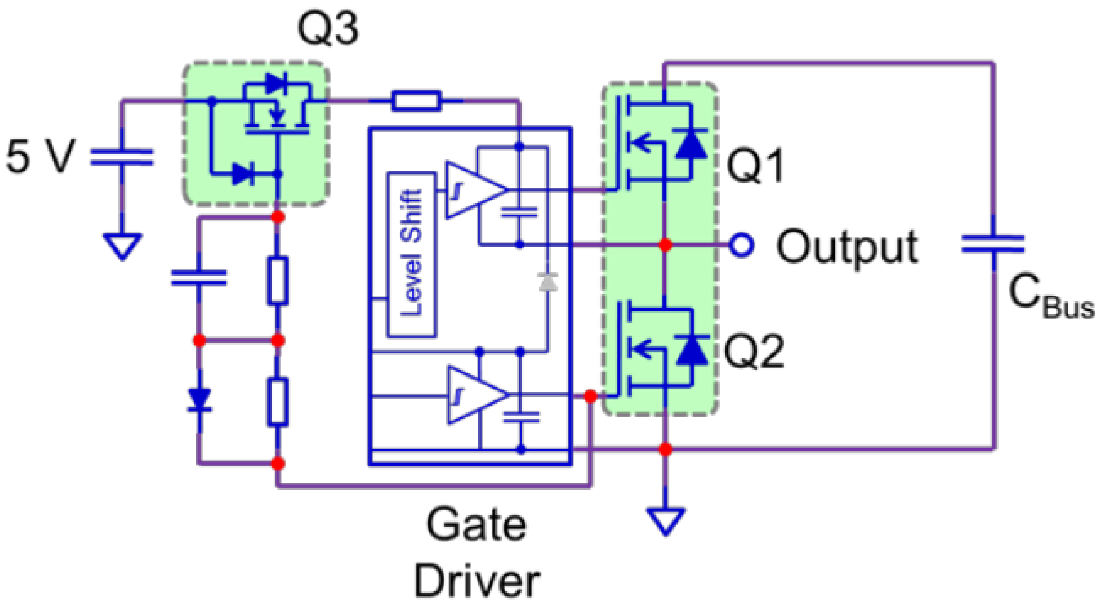




EPC2107 devices are supplied only in passivated die form with solder balls

Die Size: 1.35 mm x 1.35 mm

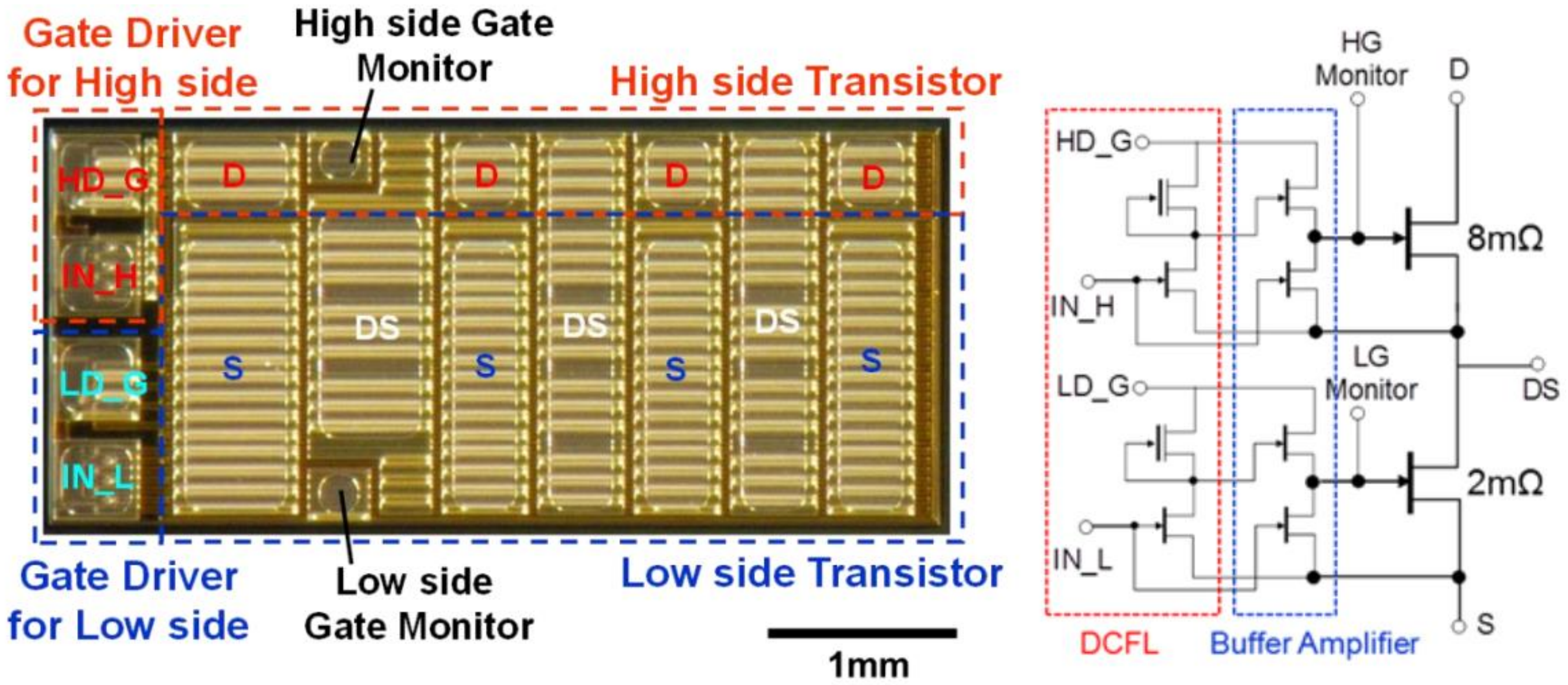
Typical Circuit



EPC2107 – Enhancement-Mode GaN Power Transistor Half Bridge With Integrated Synchronous Bootstrap Preliminary Specification Sheet

Monolithic GaN Integration with Buffer

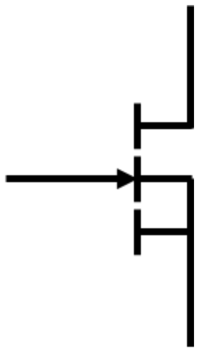
- Monolithic GaN Half-Bridge including input buffer stage
  - Example uses low voltage process, requires eMode and dMode devices
  - Low voltage DC/DC application



Panasonic research APEC 2015

Creating the World's First AllGaN™ Power ICs

Fastest, most efficient GaN Power FETs



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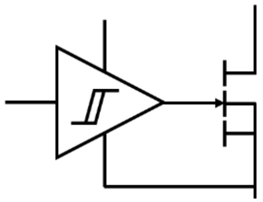
First & Fastest Integrated GaN Gate Driver



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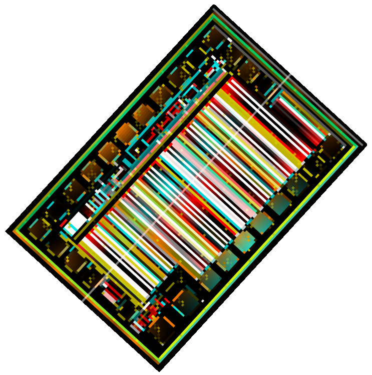
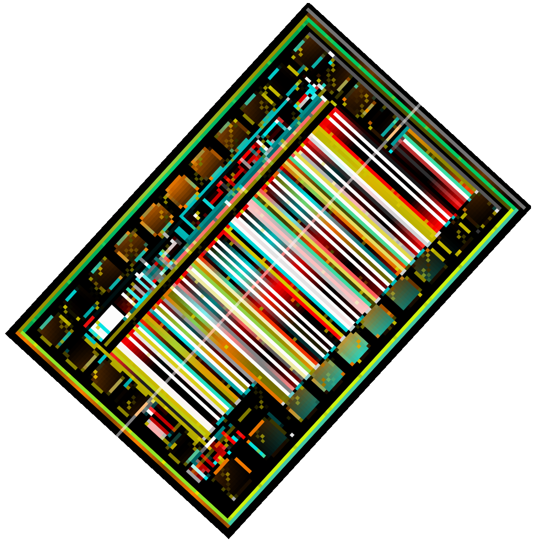
World's First AllGaN™ Power IC



Up to 40MHz switching, 4x higher density & 20% lower system cost

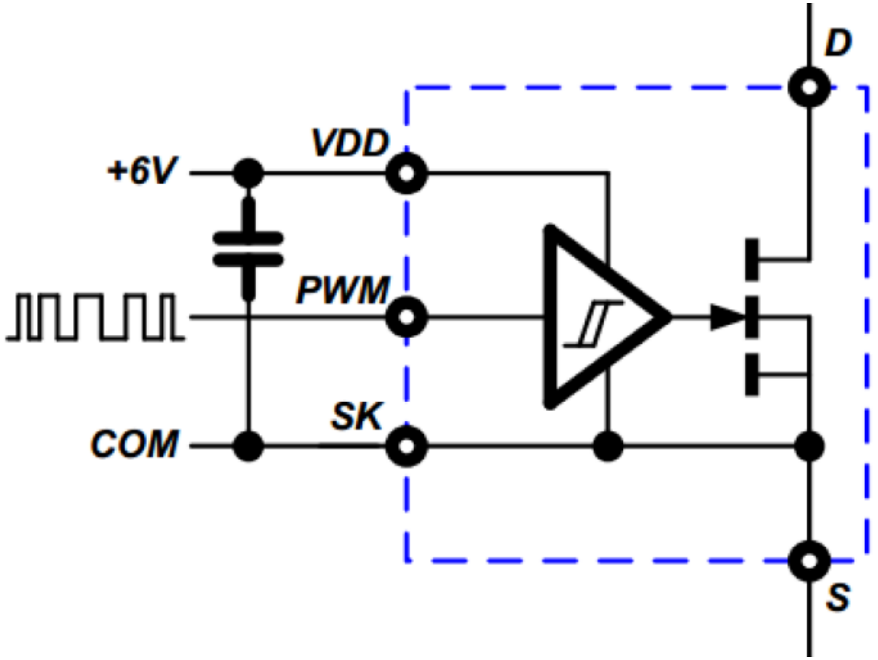
AllGaN™

- Proprietary core technology platform
- Industry’s first GaN Power IC Process Design Kit (PDK)
- Monolithic integration of GaN IC circuits (drive, logic) up to 650V with GaN FET(s)
- Other functions can also be included, such as
  - Hysteretic digital inputs, voltage regulation, ESD protection
- High-volume production capability
- World-class partners for wafers, assembly & test



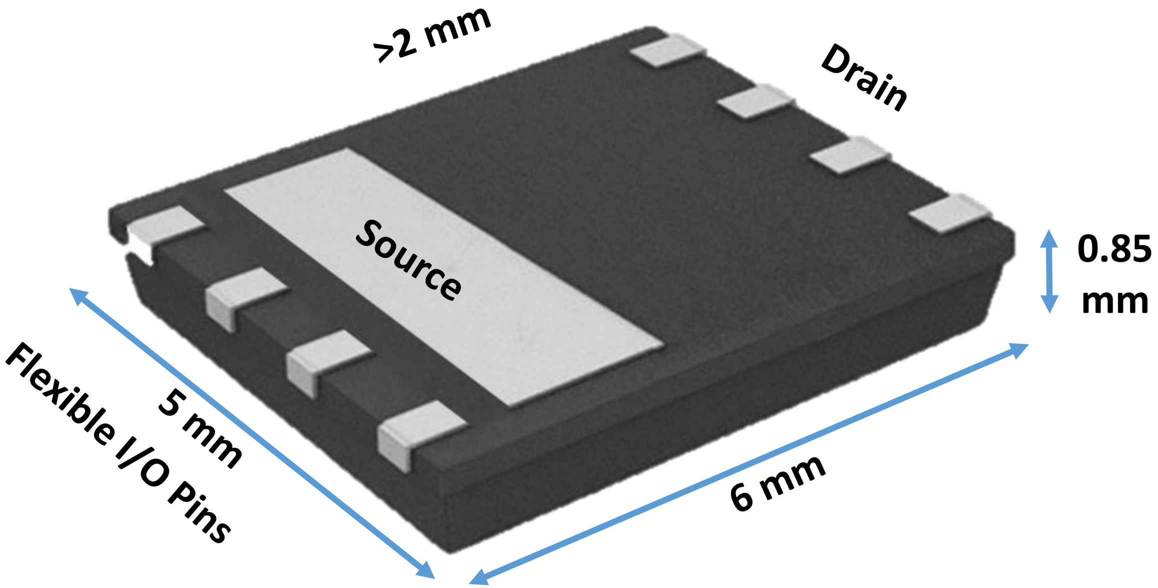
Navitas GaN Power IC

- **Monolithic** integration
- 20X lower drive loss than silicon
- Driver impedance matched to power device
- Shorter prop delay than silicon (10ns)
- Zero inductance turn-off loop
- Digital input (hysteretic)
- Rail-rail drive output
- Layout insensitive



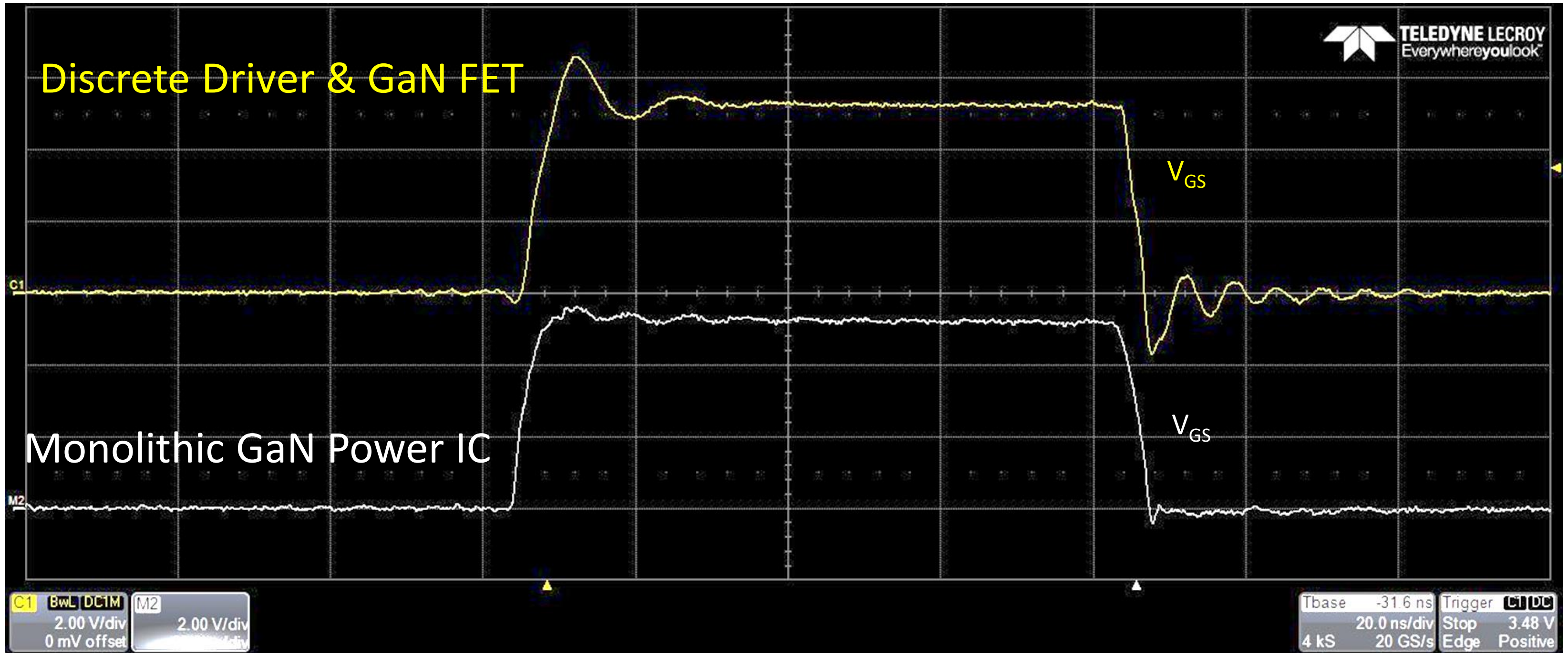
Power QFN Packaging

- Attractive attributes
  - Leadframe package outline
  - Industry-standard
  - Low-cost
  - Small (5 x 6 mm)
  - High voltage clearance (>2 mm)
  - Low thermal resistance (<2°C/W)
  - Kelvin gate driver connection
  - Low inductance power connections (~0.2nH)
  - Supports multi-chip co-packaging
  - Low profile (0.85 mm)



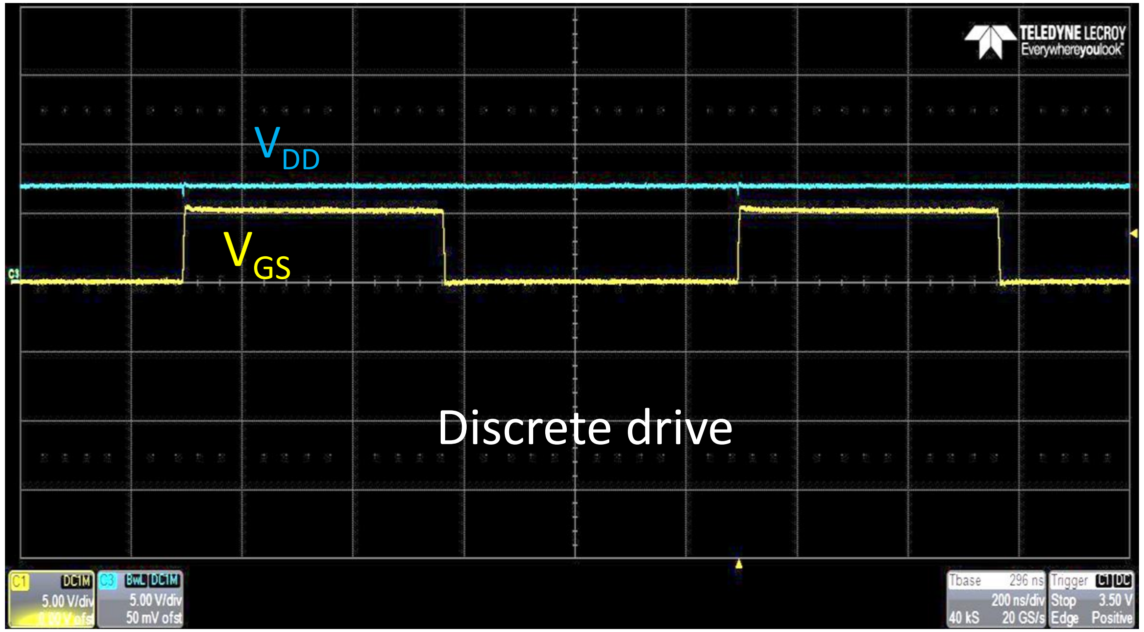
Clean Gate Waveforms

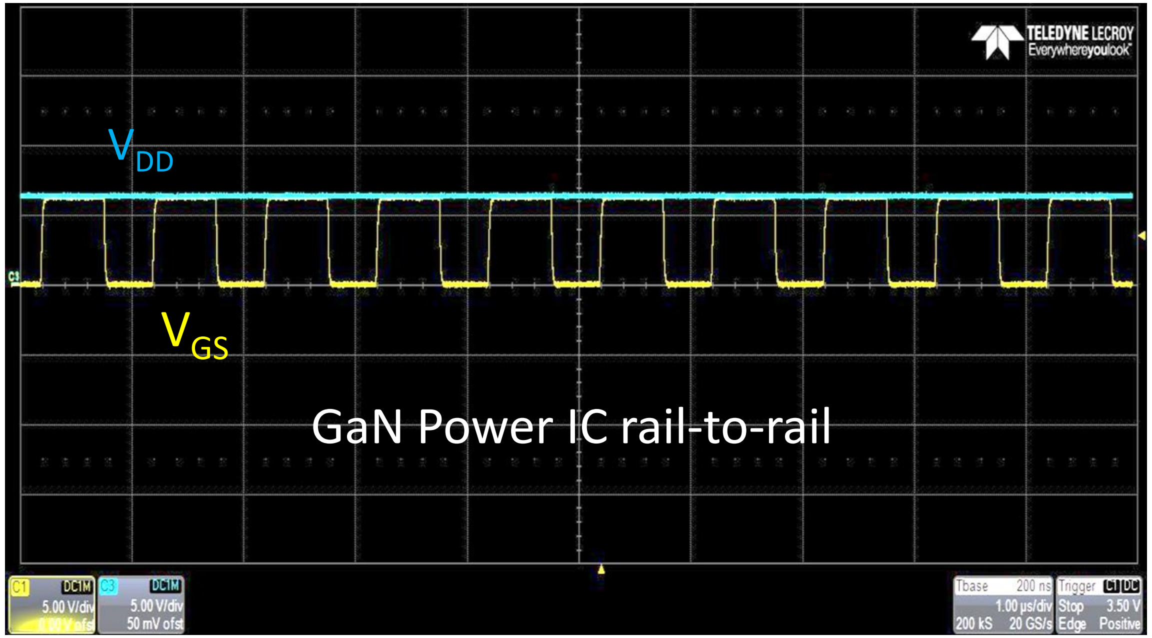
- Discrete driver:
  - Gate loop inductance creates overshoot (even with good layout)
  - Reliability concern
- GaN Power IC:
  - No gate loop parasitic
  - Clean and fast gate signal



Rail-to-Rail Gate Signal

- Other GaN integrations offer simple buffer stages
  - Cannot efficiently deliver V_{DD} voltage to the gate due to lack of PMOS transistor
  - Gate droop creates performance and variability issues
- GaN Power IC delivers rail-to-rail gate signal

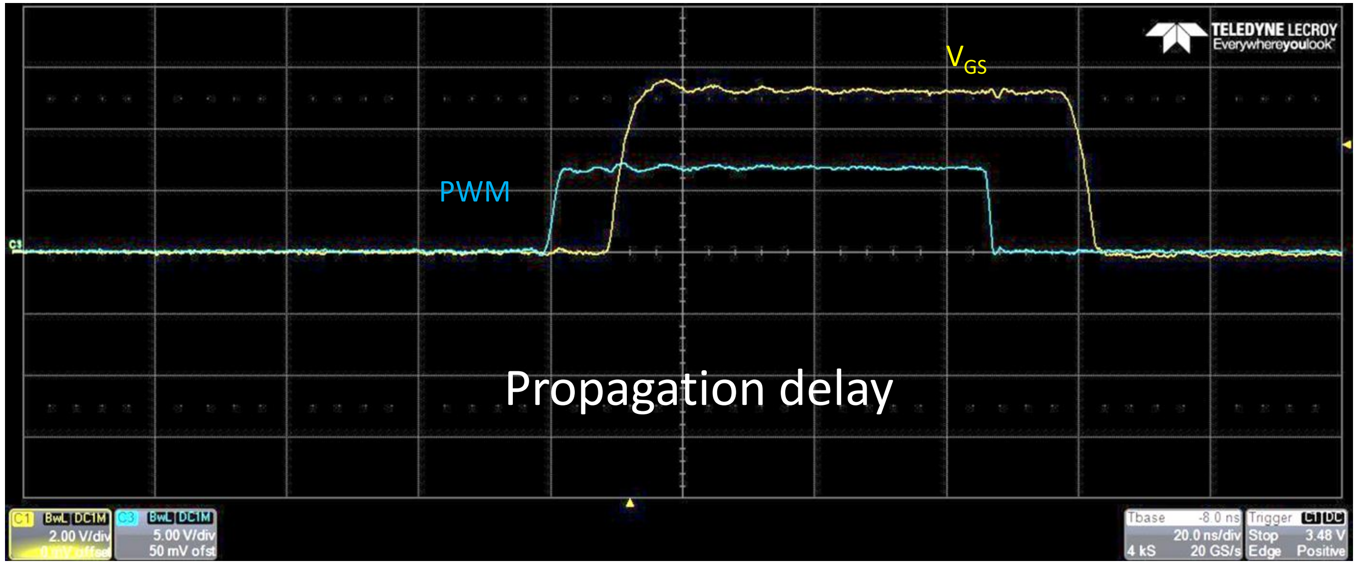




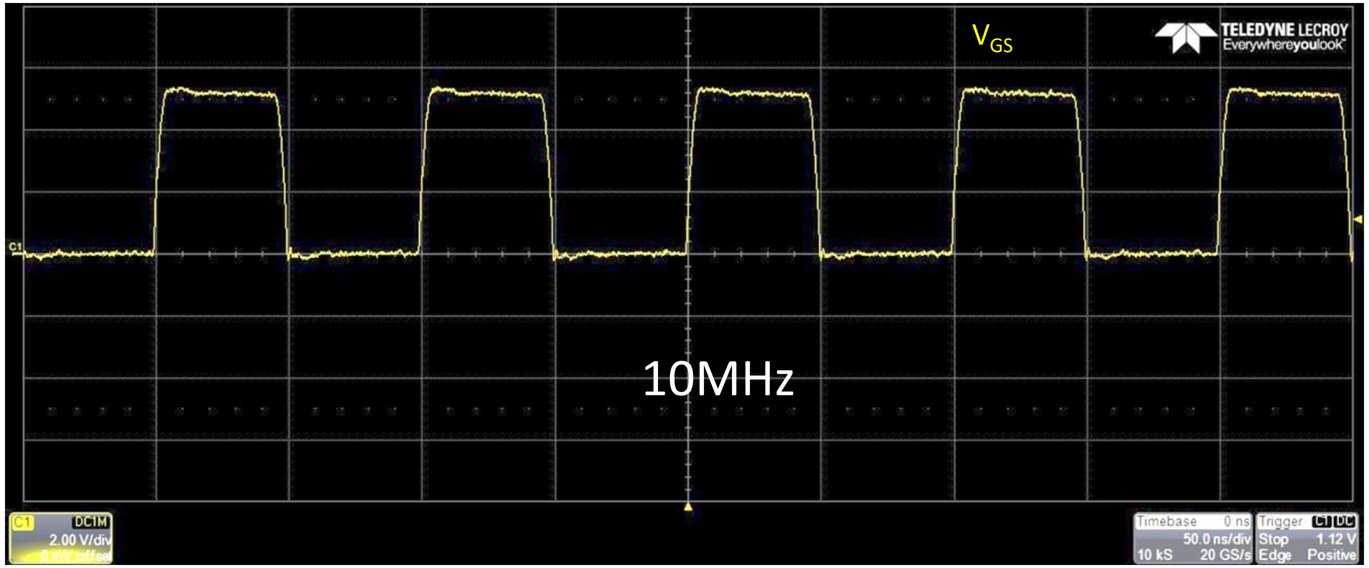
High Frequency Drive with Minimal Delay

- 10-20ns propagation delay (can be further reduced)
- Switches at 10MHz effortlessly
- Smooth, clean gate drive waveform

20ns/div



50ns/div

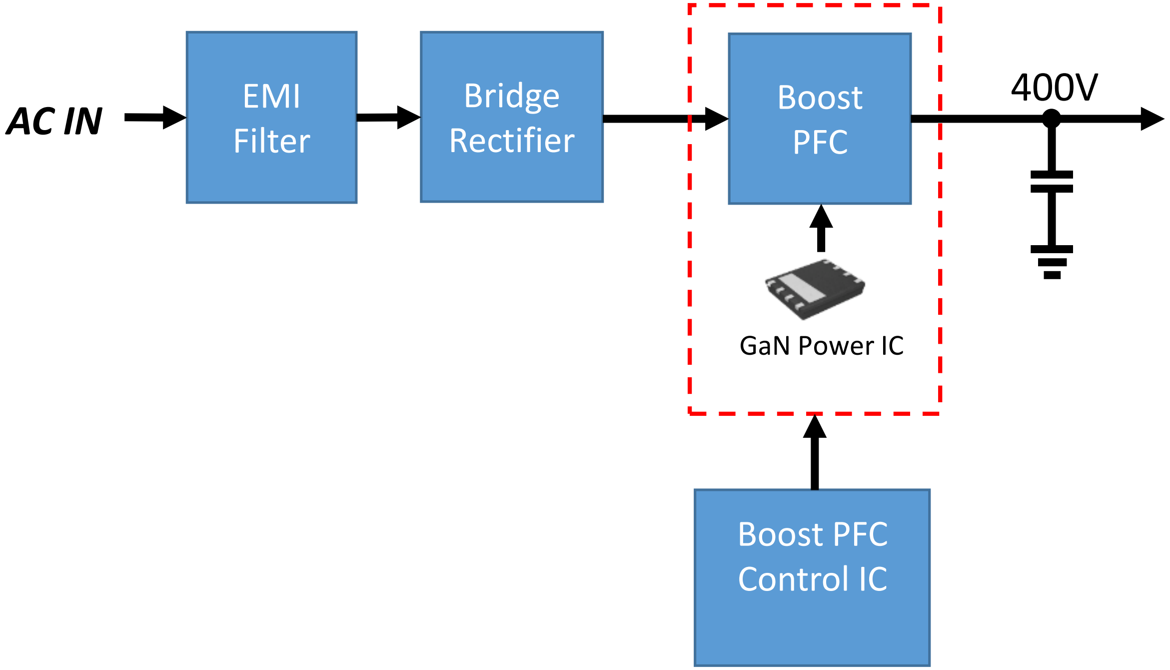


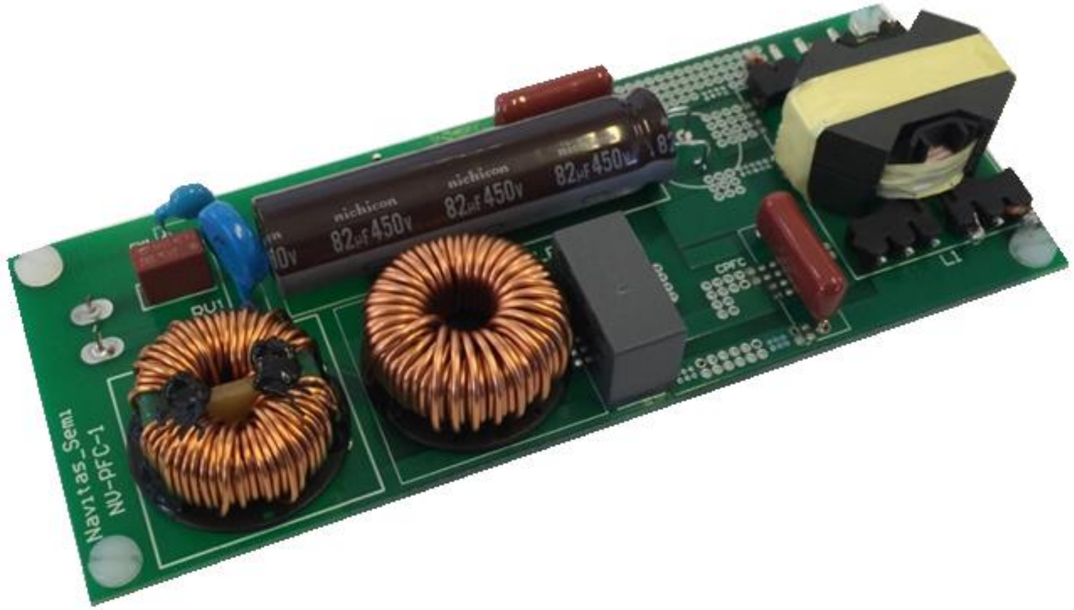
Application example #1:

150W Boost PFC

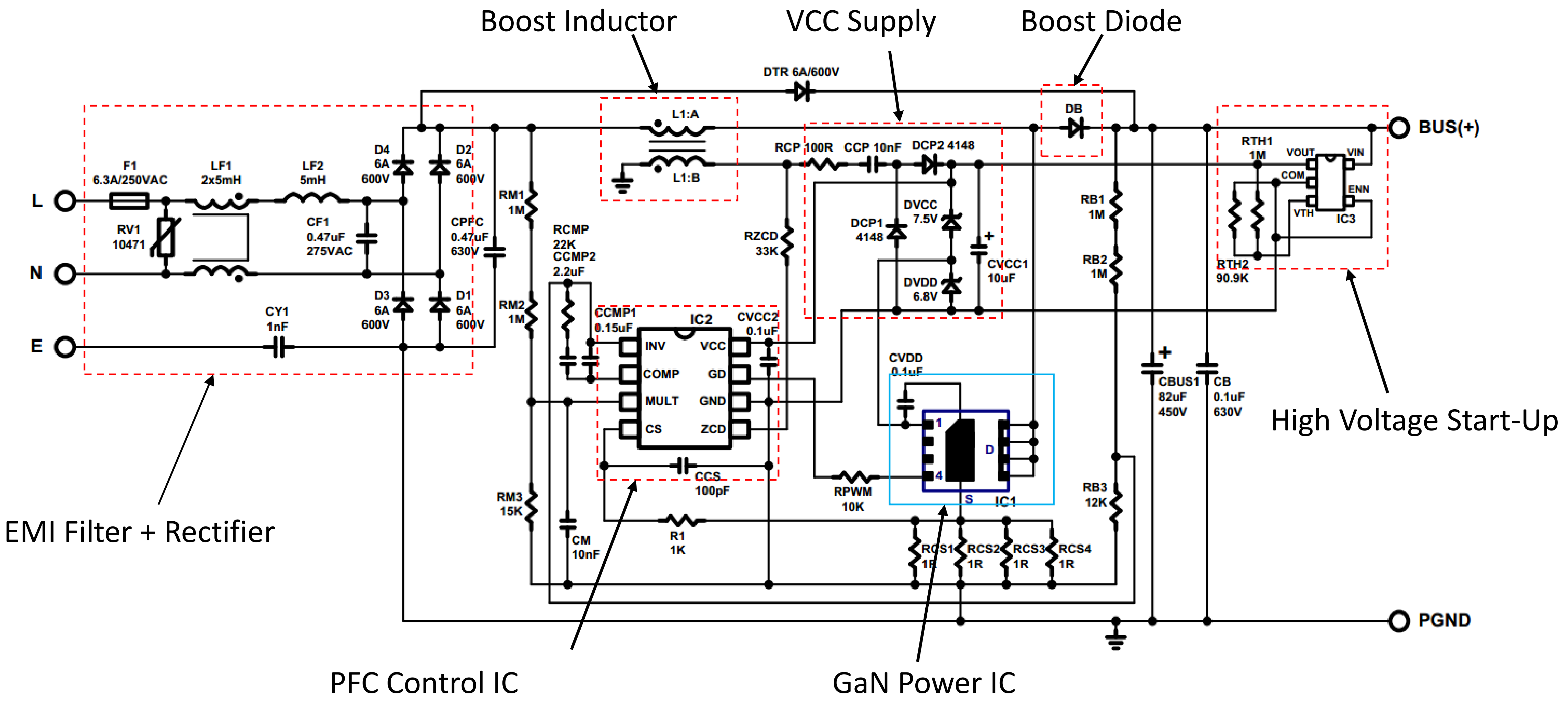
- Input : Universal AC (85-265V_{AC}, 47-63Hz)
- Output : 400V, 0.27A (150W)
- Frequency* : PFC= >500kHz (*limited by control IC)

- Size : 100 x 50 x 20mm *"No heatsink" design*
- Construction : 2-layer PCB, SMT powertrain on bottom side
- Power Factor : >0.995 at 150W
- Efficiency : 98.1% (220V_{AC}) / 97% (120V_{AC})



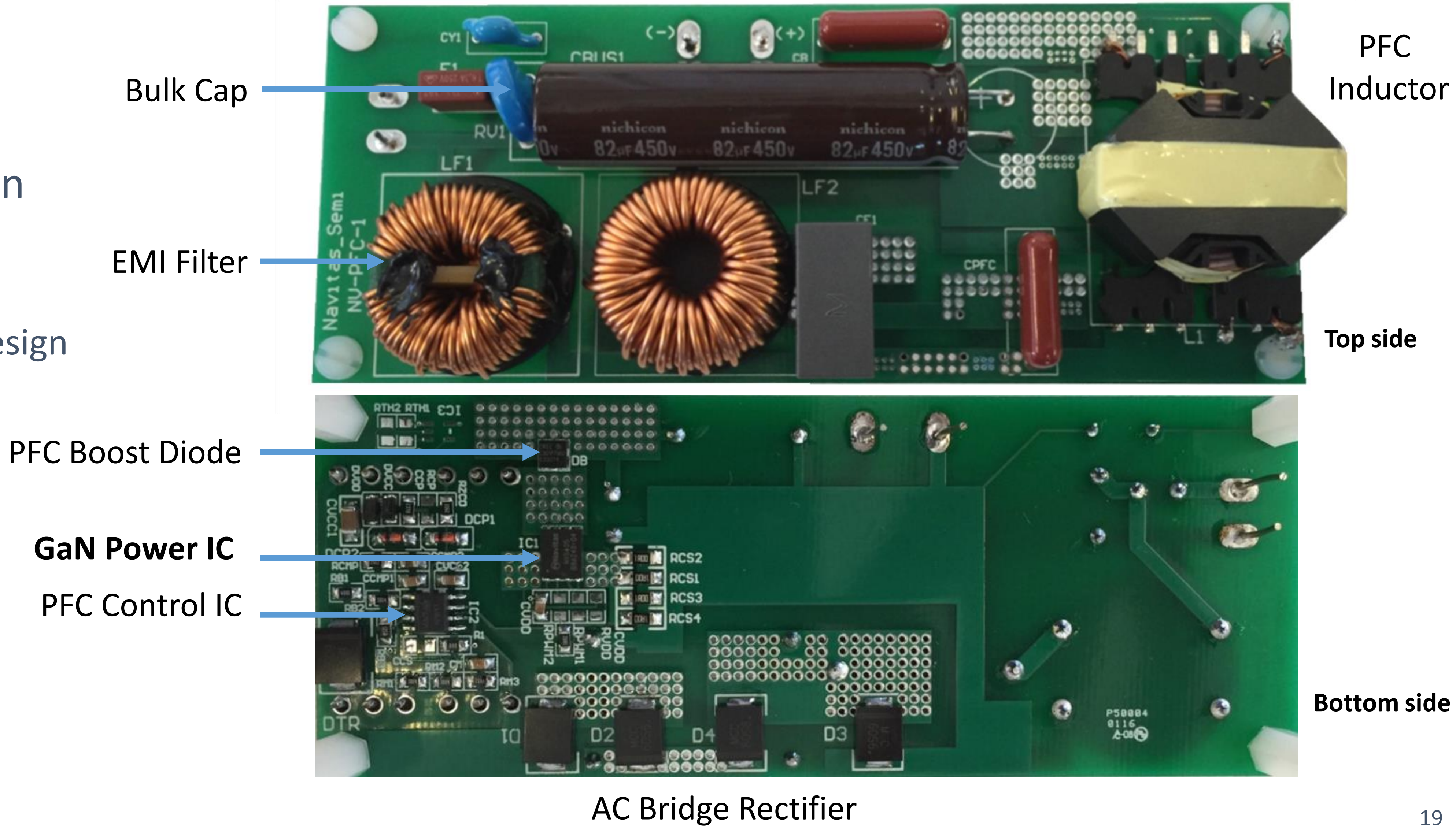


Simple Circuit Design



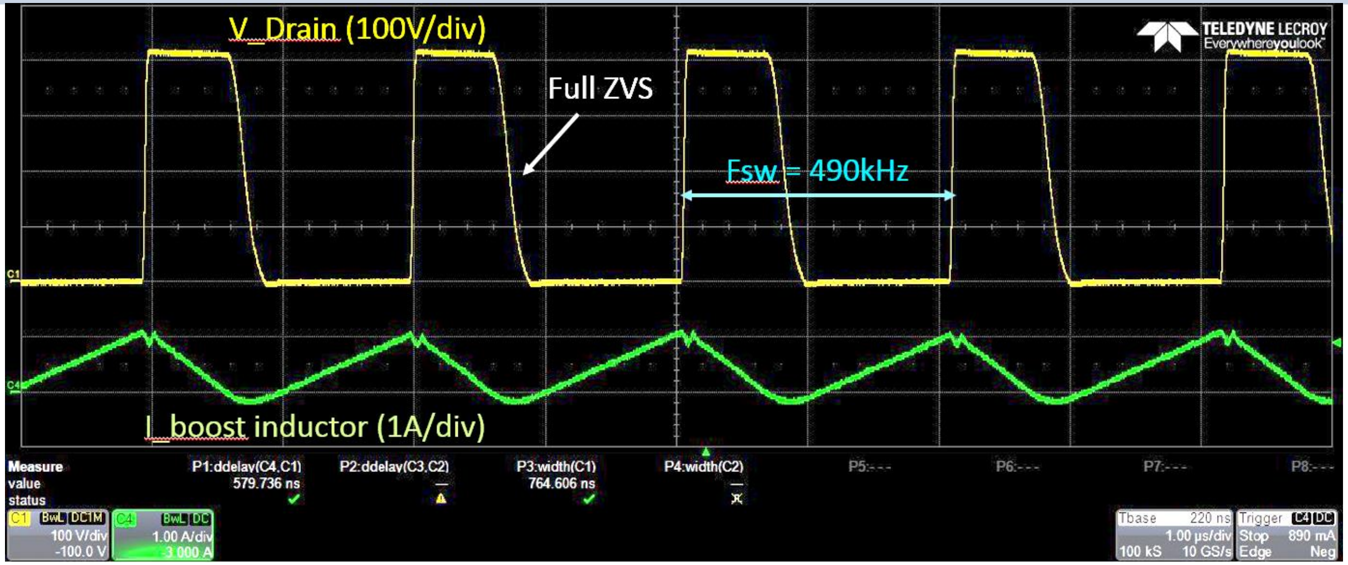
Easy, Flexible Layout

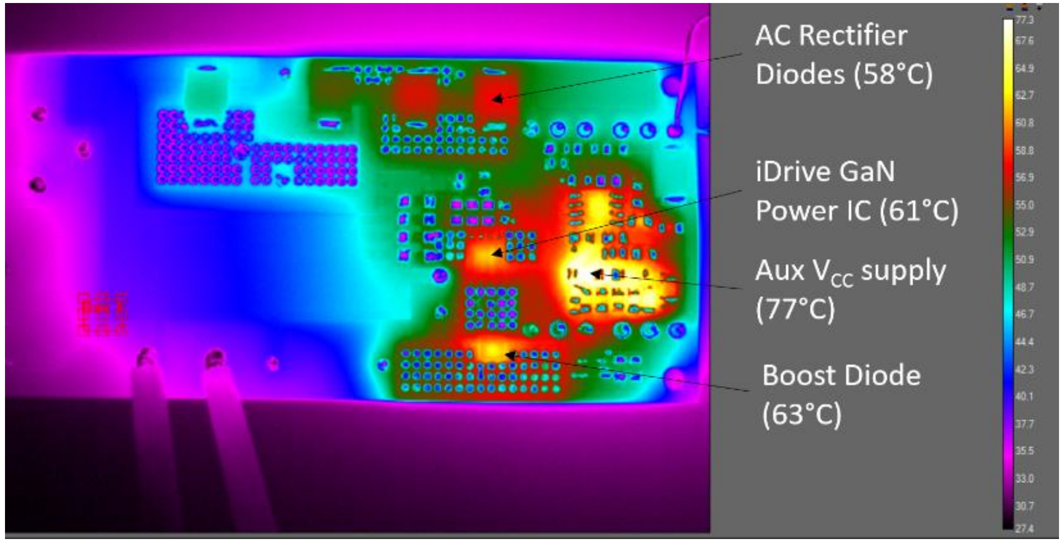
- 100 x 50 x 20mm
- All active semis on bottom-side
  - Low profile
  - ‘No-heatsink’ design
  - 2-layer
  - 2 oz Cu
  - Standard vias

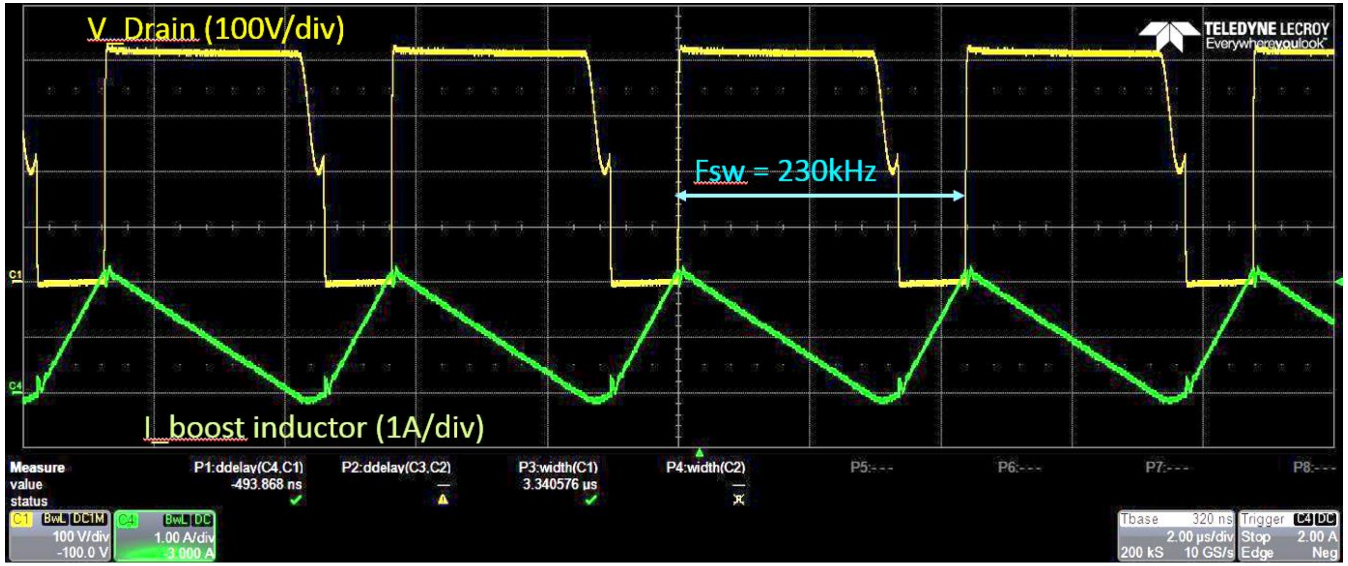


Fast, Clean, and Cool with Integrated Drive

- Fast, clean PFC operation
  - At $220V_{AC}$, 50% and 100% of peak line
- Cool GaN Power IC
  - Only $61^{o}C$ at $220V_{AC}$ and 150W (full load)

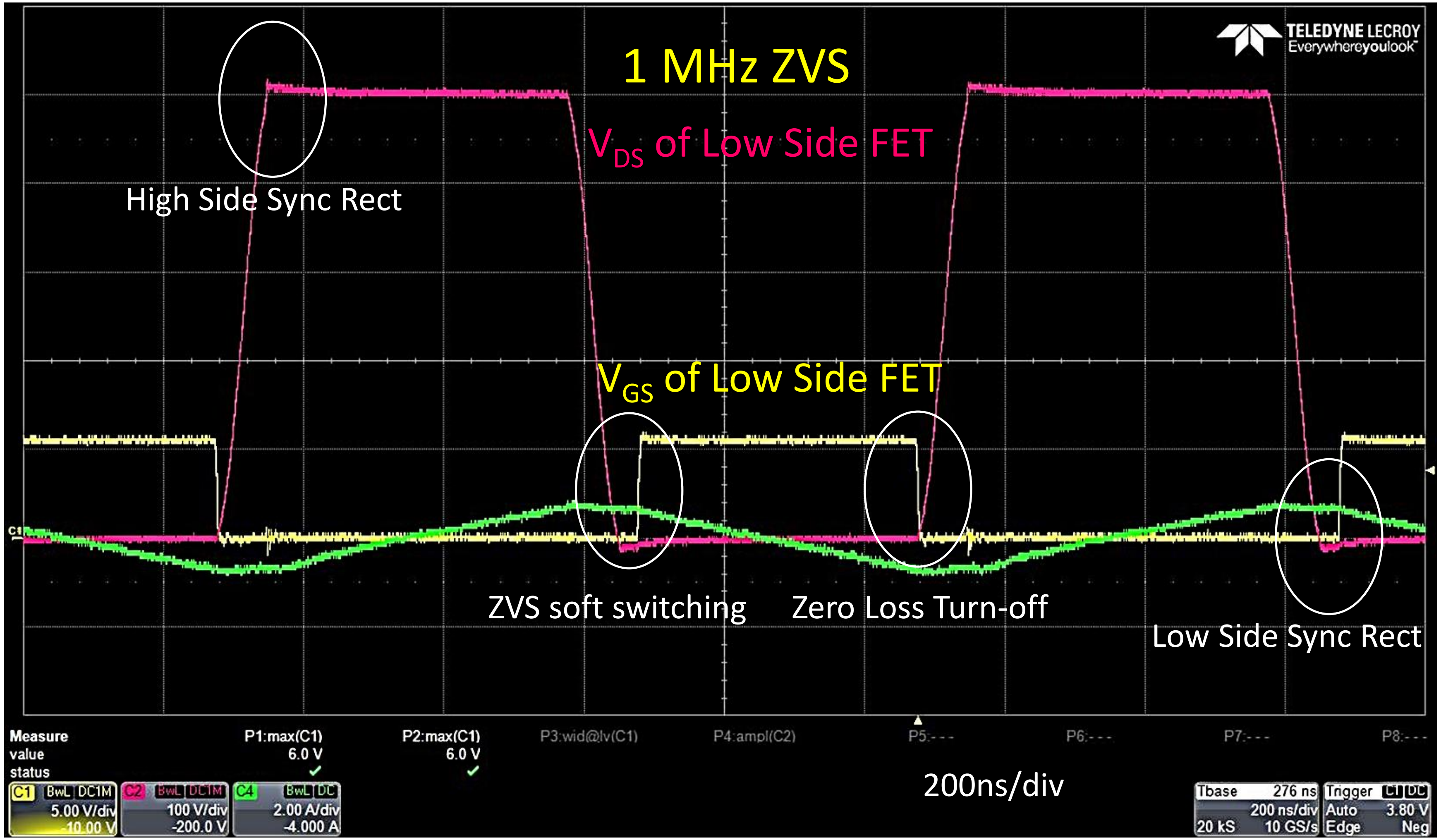






Application Example #2:
150W Half-Bridge

- 500V Switching
- No overshoot / spike
- No oscillations
- ‘S-curve’ transitions
- ZVS Turn-on
- Zero Loss Turn-off
- Sync Rectification
- High frequency
- Small, low cost filter



Conclusion

- GaN offers superior switching performance vs. Silicon
  - Extremely low input, output, and Miller capacitance
- Speed and performance inhibited by discrete drive and packaging
  - Very difficult to have clean gate waveforms that reliably stay within safe operating range
  - eMode GaN is substantially easier to package and enables monolithic drive
- Monolithic GaN Power ICs:
  - Eliminate gate loop parasitics for a fast, clean gate with no overshoot
  - Unlock the power of GaN, enabling significant increase in frequencies and power density
  - Offer best performance and cost potential
- High levels of integration are possible: power, drive, protection, regulation
  - Enables fast adoption of high frequency circuit topologies