Driving Electric Motors with GaN Power ICs

Alfred Hesener, Senior Director Industrial & Consumer,
Navitas Semiconductor

Bodo's Wide Bandgap Event 2024

Making WBG Designs Happen

GaN

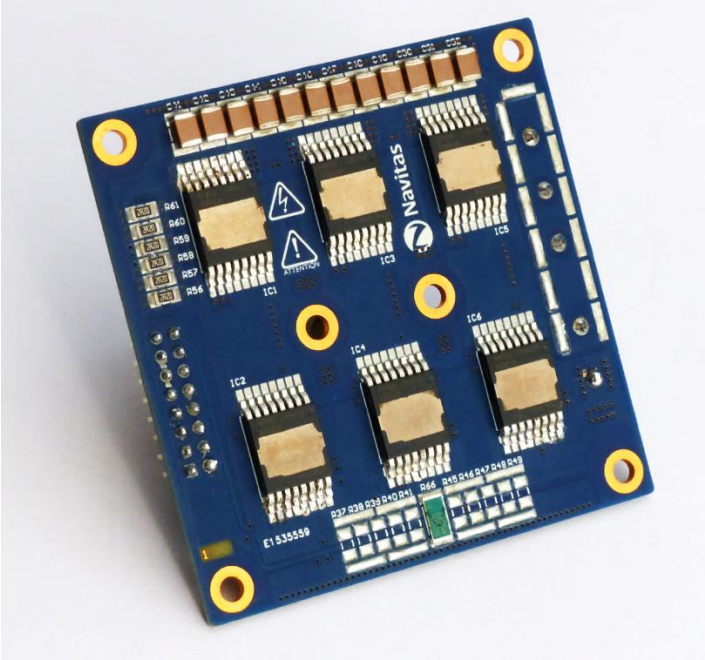
Key challenges and changes

- Using GaN power ICs in motor inverters can reduce system cost
  - Removal of heatsink, higher integration, automated assembly
- Higher efficiency reduces energy cost, improves ratings / labeling
- Legacy solutions using silicon switches are well-known in the industry, and perceived to be more robust
  - Not every application requires higher power density

Key Benefits in Motor Inverters

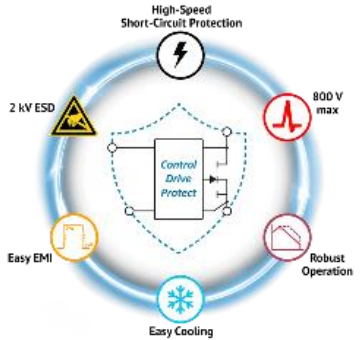
Feature	Impact	Benefit
Very low switching losses	Reduce losses by >20% over SiC, >50% over Si	Small or no heatsink, easier thermal design, higher reliability
Very high switching frequency possible (50 kHz+)	Sinusoidal modulation Lower motor inductance	2% better efficiency, less harmonics; smaller , up to 30% lower cost motor, 20% smaller EMI filter
Precise switch timing with low latency and dead time	Improved control loop performance, low EMI	Smaller EMI filter , better dynamic performance under load steps
High voltage ratings (650V DC / 800V transient)	High robustness against transient overvoltage peaks	10x lower field failure rate
Integrated gate driver and voltage regulator	Excellent reliability through precise gate drive conditions	Improved lifetime and low field failure rate
Integrated lossless current sensing and temperature sensor	Excellent robustness through very fast and precise action	Robust, protected application and low failure rate; 1% better efficiency
High level of integration – less components on PCB	Very compact size and higher reliability	10% smaller system size and cost, and very easy to use

High Power Motor Inverter with GaNSafe™



- Supply voltage: 400V DC
- Input current: 16A RMS
- Motor power: 4kW+ (depending on heatsink and ambient temp.)
- Switching frequency: 100kHz+

GaNSafe™

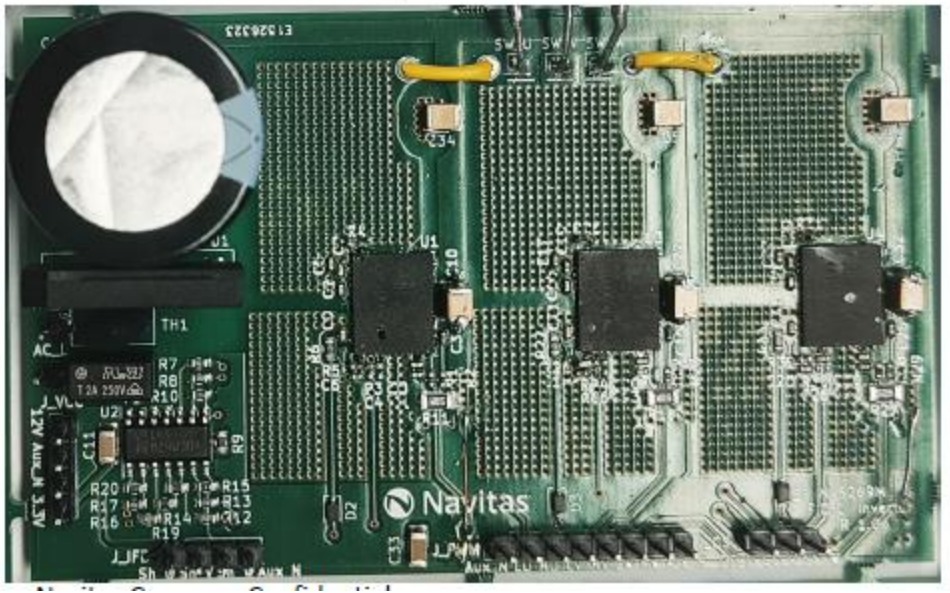


GaNSense plus:

- ✓ **Desat detect Short Circuit Protection with ultra-fast 300ns latency**
- ✓ **Robust, thermally enhanced packaging: ultra-low $R_{\Theta\_JUNC-AMB}$ and BLTC Reliability**
- ✓ **4th Gen integrated GaN gate drive with positive TempCo V_{GS} regulation**
- ✓ **Integrated Miller Clamp (no negative gate bias, higher 3rd quadrant efficiency)**
- ✓ **Programmable dV/dt Turn-ON/OFF slew rate control for ease of design**

GaN-based Motor Inverter

- No heatsink – cooling is done via copper areas on the board
- Very small number of external components
- Most SMD components
- Contains only power stage (rectifier, DC link capacitor 82µF, 3x GaN power IC in half-bridge configuration, current sense)



GaNFast™ Half-Bridge IC with GaNSense™

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Complete Integration

- Full integration of Half-bridge circuit (Control, Drive, Power, Protection)
- Integrated level-shifter & Bootstrap
- 2MHz switching frequency
- 2kV ESD protection

GaNSense Technology

- Integrated loss-less current sensing
- Over-current protection / Short circuit protection
- Over-temperature protection
- Autonomous low-current standby mode
- Auto-standby enable input

Small, low profile SMT QFN

- 6x8 mm (8x10 mm footprint, 0.85 mm profile
- Minimized package inductance
- Enlarged cooling pads

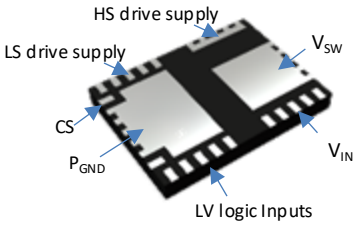
Sustainability

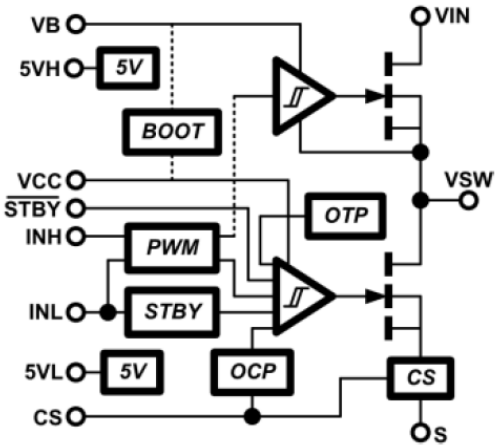
- RoHS, Pb-free, REACH-compliant
- Up to 40% energy savings vs Si solutions
- System level 4 kg CO_2 Carbon Footprint reduction

Product Reliability

- 20-year limited product warranty

PQFN 6x8





Part #	Type	$V_{DS(CONT)}$ (V)	$R_{DS(ON)}$ (mΩ, typ)	Package	Status	Motor power*
NV6245C	Half-Bridge	650	275/275	PQFN 6x8	Production	200
NV6247C	Half-Bridge		160/160	PQFN 6x8	Production	400
NV6269C	Half-Bridge		70/70	PQFN 8x10	Production	600
NV6245M	Half-Bridge		275/275	PQFN 6x8	Samples	200
NV6247M	Half-Bridge		160/160	PQFN 6x8	Production	400
NV6269M	Half-Bridge		70/70	PQFN 8x10	Samples	600

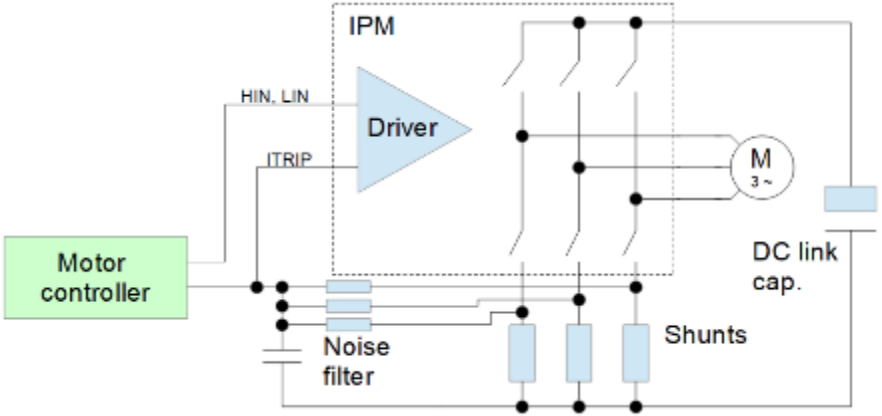
(* Motor power estimated and depending on application conditions, in particular thermal design)

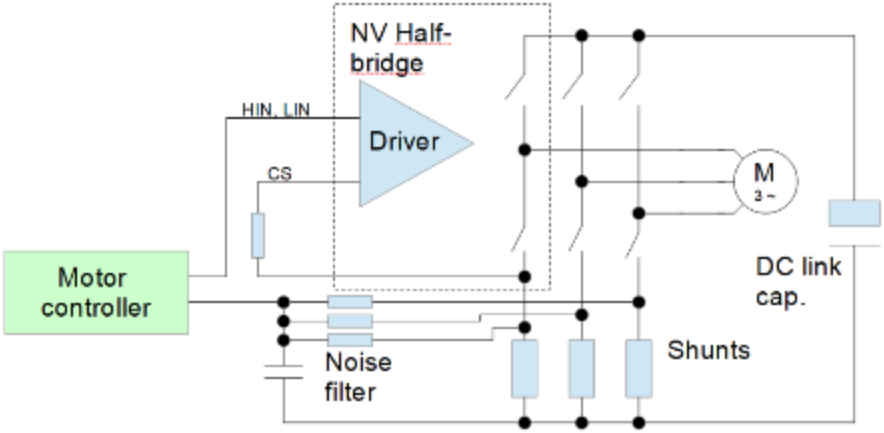
"C" = fast switching, "M" = slow switching

Thermal design - Considerations

- Heatsink represents large thermal “capacitance” and can store a lot of transient energy (abnormal operation, e.g. rotor blocking)
- PCB layout cooling does not have high storage → are higher peak temperatures to be expected?
  - Heatsink is selected for thermal resistance, not thermal impedance, and is typically oversized for the energy of abnormal events
  - Lower heat generation reduces the problem to begin with
  - Overcurrent protection will turn off the power switches very fast
  - Thermal throttling should be implemented (depending on application conditions)

Implementation Considerations – Current Sense and OCP





- Signal latency through the noise filter, comparator and gate driver easily adds up to 1…2µs
- Using the CS signal from GaNSense™ for overcurrent protection reliably turns off the power switch in < 100ns

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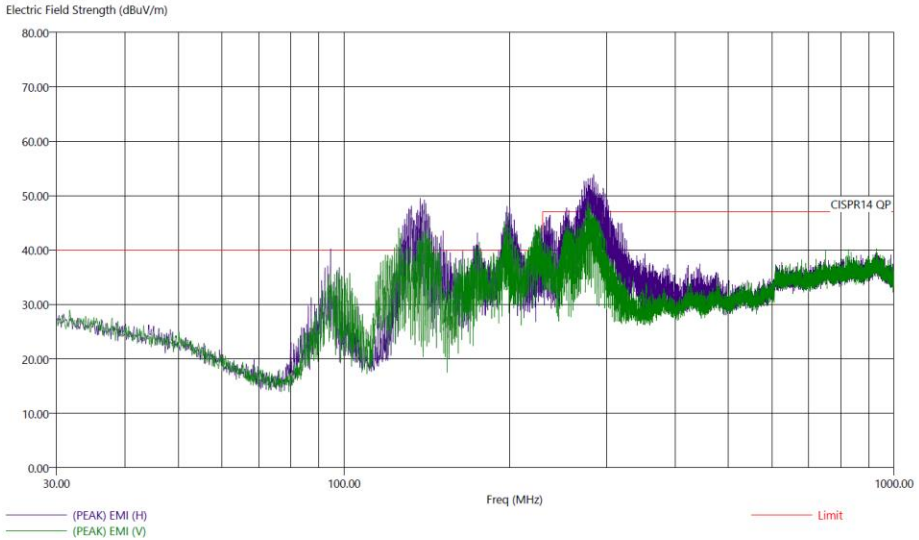
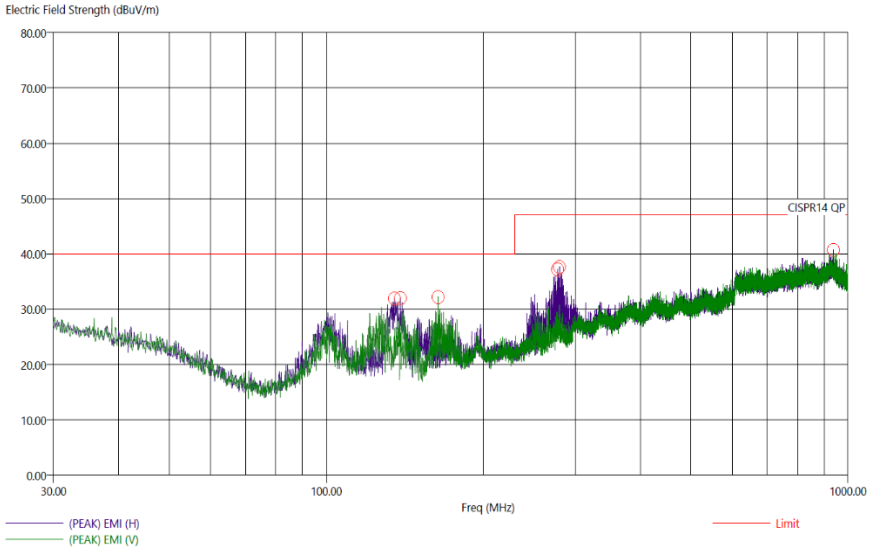
Implementation Considerations – EMI





- NV GaNSense offers adjustable dV/dt
- Radiated emissions spectrum for identical operating conditions for NV6245C (fast, left picture) and NV6245M (slow, right picture)
- Diagrams are showing a clear improvement of more than 10dBµV/m

Conclusion

- Motor inverters using GaN power ICs can enable significant system cost savings:
  - Minimal or no heatsink
  - Better robustness through built-in protections
  - Reliable and repeatable operation with high performance
- Still, the thermal design needs consideration, especially for abnormal operating conditions
- Large portfolio of GaN power ICs (half-bridge and single switches) can address a large power range in many consumer and industrial applications

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