

48 V GaN motor drive with diode-Less operation and short 30 ns dead time for 70A/100kHz systems

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Introduction

High-performance motor-control systems for applications such as robotics, power tools, e-mobility, and drones increasingly demand higher efficiency, reduced size, and improved thermal behavior. Gallium Nitride (GaN) power devices are attractive in 48 V systems because of their low switching losses, negligible reverse-recovery charge, and ability to operate at high switching frequencies and short dead times. The work presented here evaluates a 48 V GaN-based three-phase motor drive incorporating parallel e-mode GaN HEMTs with a dedicated controller, developed to demonstrate the advantages of GaN in real motor-control applications.

- The evaluation system is a 48 V GaN-based three-phase inverter board. It incorporates 12 eMode-GaN transistors (**GANE1R8-100QBA**) across three independently controlled half-bridges. Each half-bridge uses four devices per phase: two in parallel for the high-side switch and two for the low-side switch.
- This lowers conduction losses and equalizes thermal stress per FET, enhancing reliability under high-current operation. The system is shown in Figure 1 below reported and the basic switching behavior in Figure 2.

GaN HEMTs bring key advantages to motor-control systems:

- Very low $R_{DS(on)}$ and Q_g for fast, efficient switching
- Low Q_{OSS} , and negligible Q_{rr} basically just linked to Q_{OSS} and its capacitive peak current, (charging and discharging peaks) minimizing especially turn-on losses
- Low-inductance SMD packaging enabling clean switching without oscillations root of EMI/EMC.

These characteristics translate into clear system-level advantages:

- Lower switching losses and higher or faster frequency capability
- Shorter dead times and improved efficiency
- Reduced ripple, smoother and quieter motor operation
- Lower winding/core losses and smaller, denser power stage.

Figure 1. Basic schematic and PCB picture

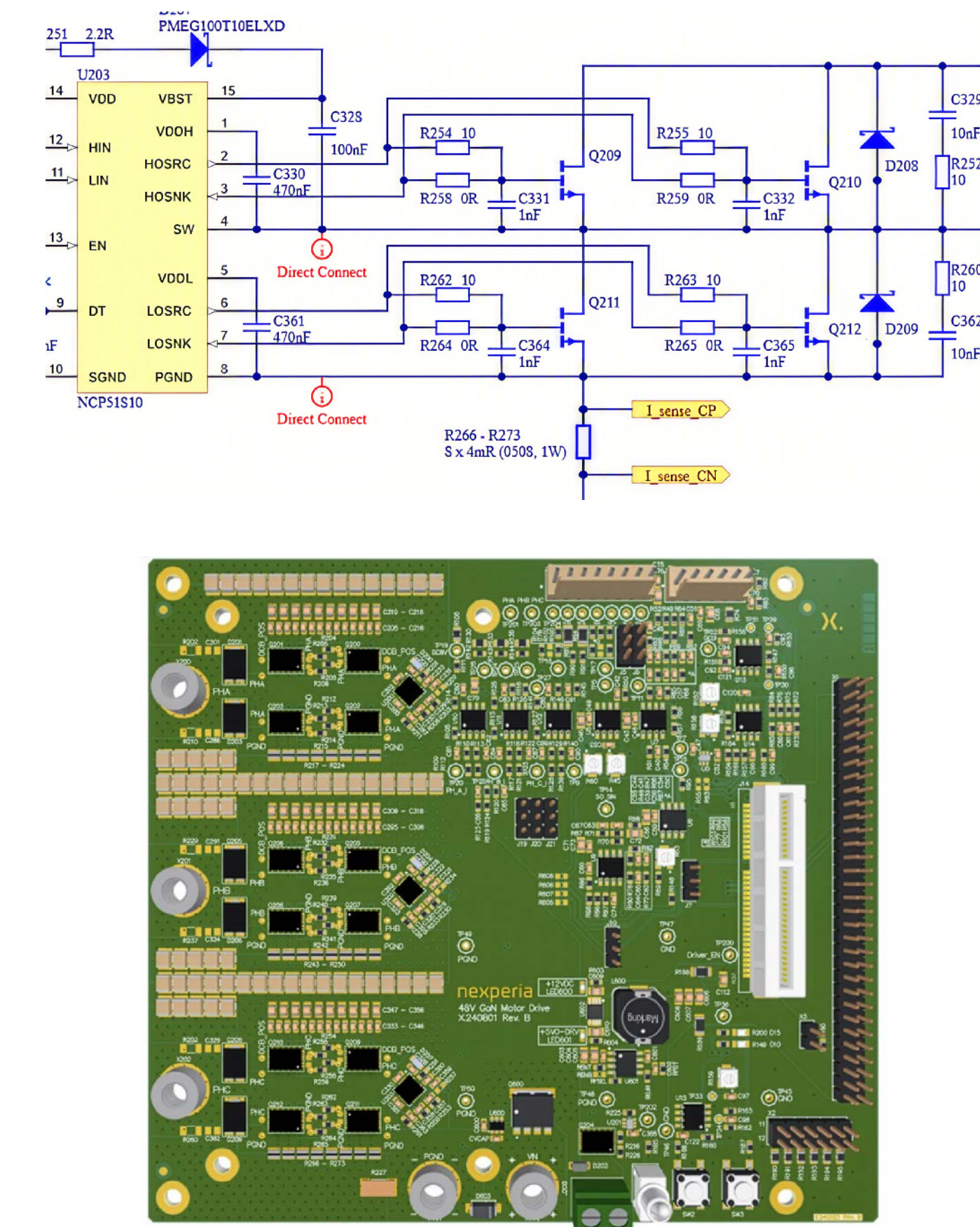
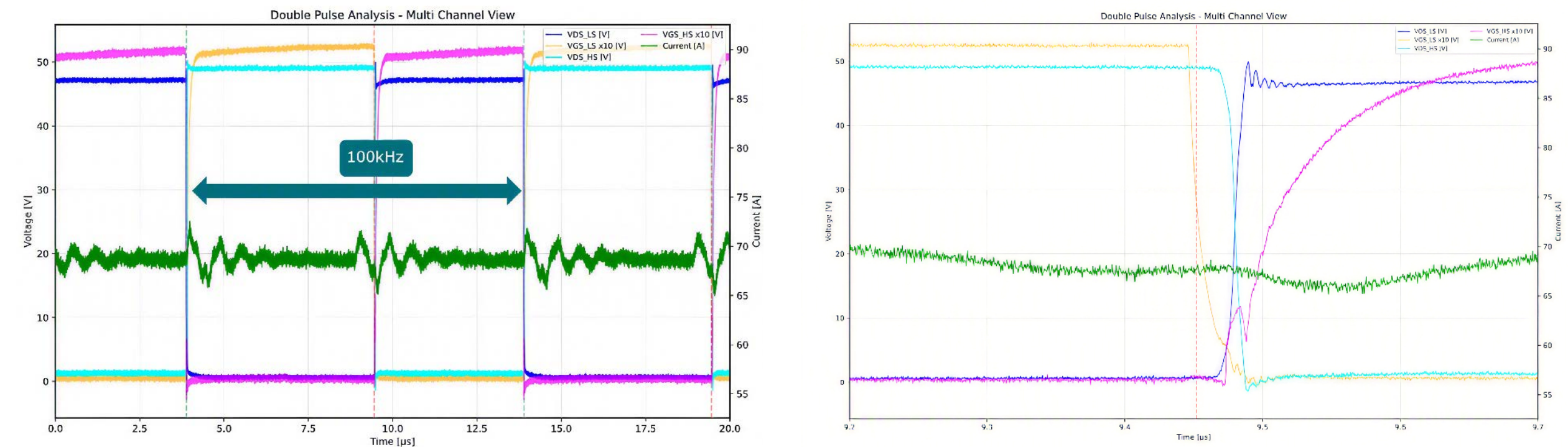


Figure 2. Switching at 100kHz (steady state and turn off zoom)



Thermal measurements were captured using IR imaging. At 75 A phase current (150 A peak-to-peak), the maximum measured FET temperature was 135 °C (Figure 3). Considering the extremely short dead time [3] and removal of diodes, this thermal performance demonstrates the robustness of GaN devices in high-current 48 V motor-control environments. Efficiency measurement were caught at 48V using a dynamometer bench at the conditions defined in the side table (Figure 4). The final peak achieves 96.2% as reported in Figure 4.

Figure 3. Thermal picture

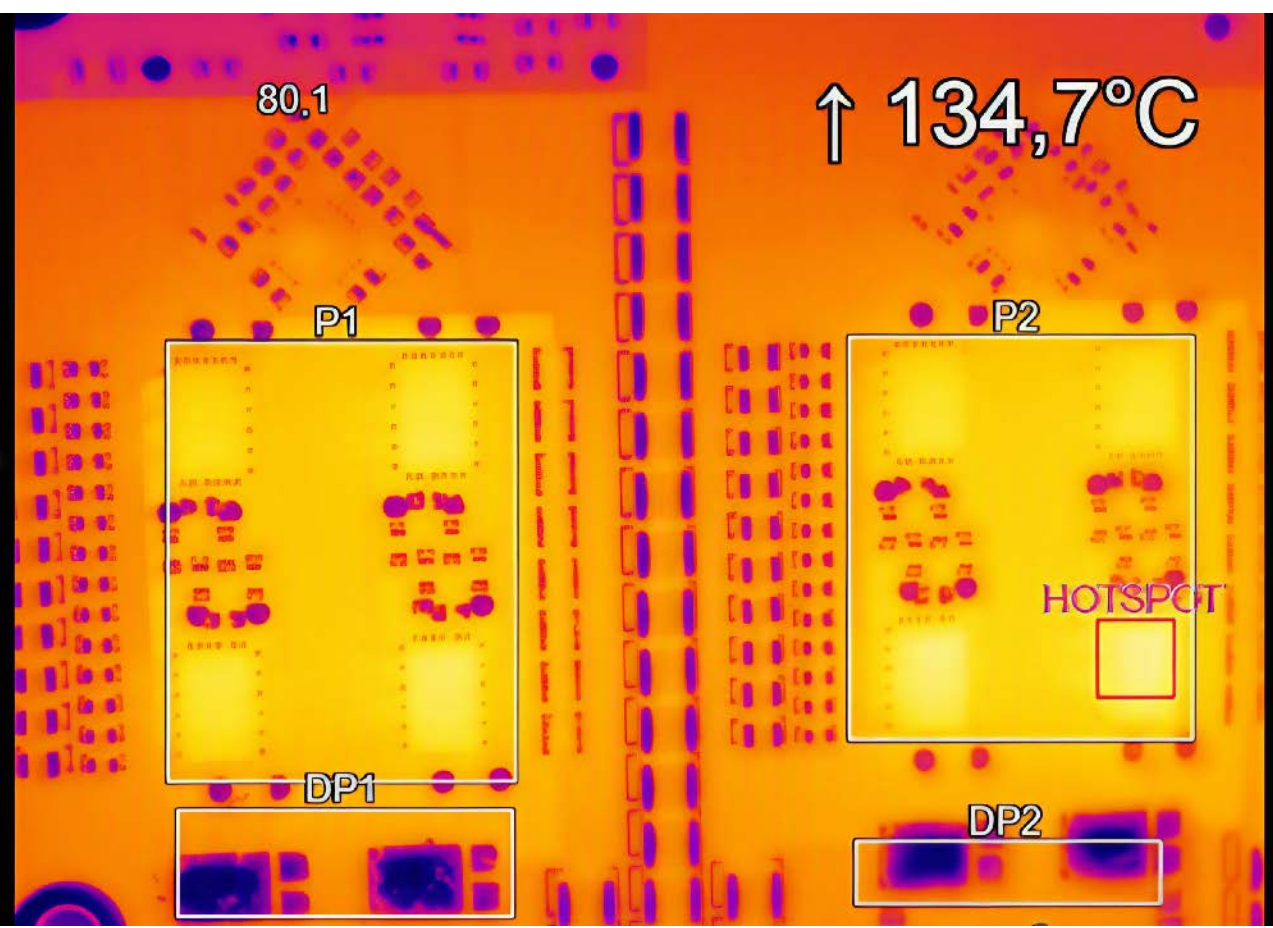


Figure 4. Testing conditions and efficiency results at Vin = 48V

Test conditions	
PWM sw frequency	100kHz
Max output power	1200W
Max phase current Irms	44A
DC BUS Voltage	24-60V
Dead Time	25ns

GaN Inverter Efficiency mapping 48V 100kHz 25ns DeadTime												
Phase Current Ia [A]	I _{peak} (A)	I _{arms} (A)										
			100 rpm	200 rpm	300 rpm	400 rpm	500 rpm	600 rpm	700 rpm	800 rpm	900 rpm	1000rpm
62.2	44.0	81.60	87.50	90.20	92.00	93.20	94.00	94.90	95.40	95.80	95.60	
57.3	40.5	81.20	86.70	90.00	92.20	93.30	94.10	94.80	95.40	95.80	96.00	
54.0	38.2	81.10	87.30	90.10	92.00	93.10	94.10	94.90	95.60	95.90	96.20	
49.9	35.3	80.60	87.00	90.20	92.00	93.10	94.10	94.80	95.50	96.20	96.20	
45.3	32.0	80.00	86.70	89.80	92.20	93.40	94.20	94.80	95.80	95.90	96.20	
40.6	28.7	79.40	86.10	89.60	91.90	92.60	94.10	94.80	95.50	95.80	96.10	
36.9	26.1	78.30	85.60	89.70	91.90	93.00	94.00	94.90	95.40	95.90	96.20	
33.4	23.6	77.40	85.30	89.20	91.50	92.80	93.90	94.50	95.30	95.90	96.00	
29.1	20.6	75.80	84.50	88.90	91.10	92.30	93.60	94.50	95.10	95.60	96.00	
24.7	17.5	74.50	82.70	87.40	90.10	91.90	93.20	94.00	94.80	95.00	95.60	
21.2	15.0	70.00	81.30	86.80	89.10	90.00	92.40	93.50	94.00	94.50	95.70	
16.7	11.8	67.10	78.00	83.60	87.30	89.70	91.70	92.30	93.10	94.20	94.40	
13.0	9.2	61.00	74.50	80.90	84.40	86.90	89.30	90.80	91.60	92.30	93.40	
8.4	5.9	51.50	64.40	74.50	80.50	83.10	85.50	86.50	89.60	90.80	90.70	
4.6	3.3	34.60	49.90	61.60	69.50	72.40	78.20	80.50	82.10	82.50	84.60	