Low Cost, High Density, High Voltage Silicon Driver for Low- to Mid-Power GaN FET Applications

Contents

Introduction

Many Transphorm FET datasheets recommend the Skyworks Si823x/Si827x drivers. These high performance drivers feature high isolation voltage rating (control-to-output drive signals), short propagation delay time, fast turn on/off time, and programmable deadtime among other advantages. However, they come at a relatively high cost—suggesting they may be better suited for higher power applications where the end product's customer pricing would likely better absorb the driver cost.

Lower power applications (power adapters and chargers), however, do not require safety isolation (control-to-output drive). In which case, the high performance features of the Skyworks drivers can be unnecessary. In such lower power application scenarios, control to a half-bridge can instead be issued by a microprocessor. Between the microprocessor and the half-bridge FETs, a cost-effective half-bridge gate driver is needed. This application note will introduce the Diodes Inc. DGD2304 high voltage / high speed half-bridge gate driver as that low-cost driver solution.

DGD2304 Half-Bridge Gate Driver IC

The DGD2304 [1] is a high voltage / high speed gate driver built by Diodes Inc. used to drive N-channel MOSFETs and IGBTs in a half-bridge configuration. High voltage manufacturing process techniques enable the DGD2304's high side to switch to 600 V in a bootstrap operation.

The DGD2304 logic inputs are compatible with standard TTL and CMOS levels (down to 2.3 V (min)) to interface easily with controlling devices. The driver outputs feature high pulse current buffers designed for minimum driver cross conduction. An internal deadtime of 100 ns[1] protects high-voltage MOSFETs from shoot-through.

The DGD2304 is offered in the SO-8 package and operates over an extended -40°C to +125°C temperature range, with an online price of 1/6 the Skyworks Si8274.

Evaluation of the DGD2304 Gate Driver IC

We understand that applications for the DGD2304 will be mostly in the mid to low power range. For this reason, we chose the Transphorm evaluation kit TDHBG1200DC100 1200 W Buck/Boost evaluation kit for this demonstration. The TDHBG1200DC100 kit consists of a motherboard printed circuit board assembly (PCBA) and a daughter card PCBA. The motherboard has a power inductor, accepts gate power supply (typical 12 V), and receives logic gate signals, and has mating holes to accept the daughter card. The schematic of the mother PCB is shown below.

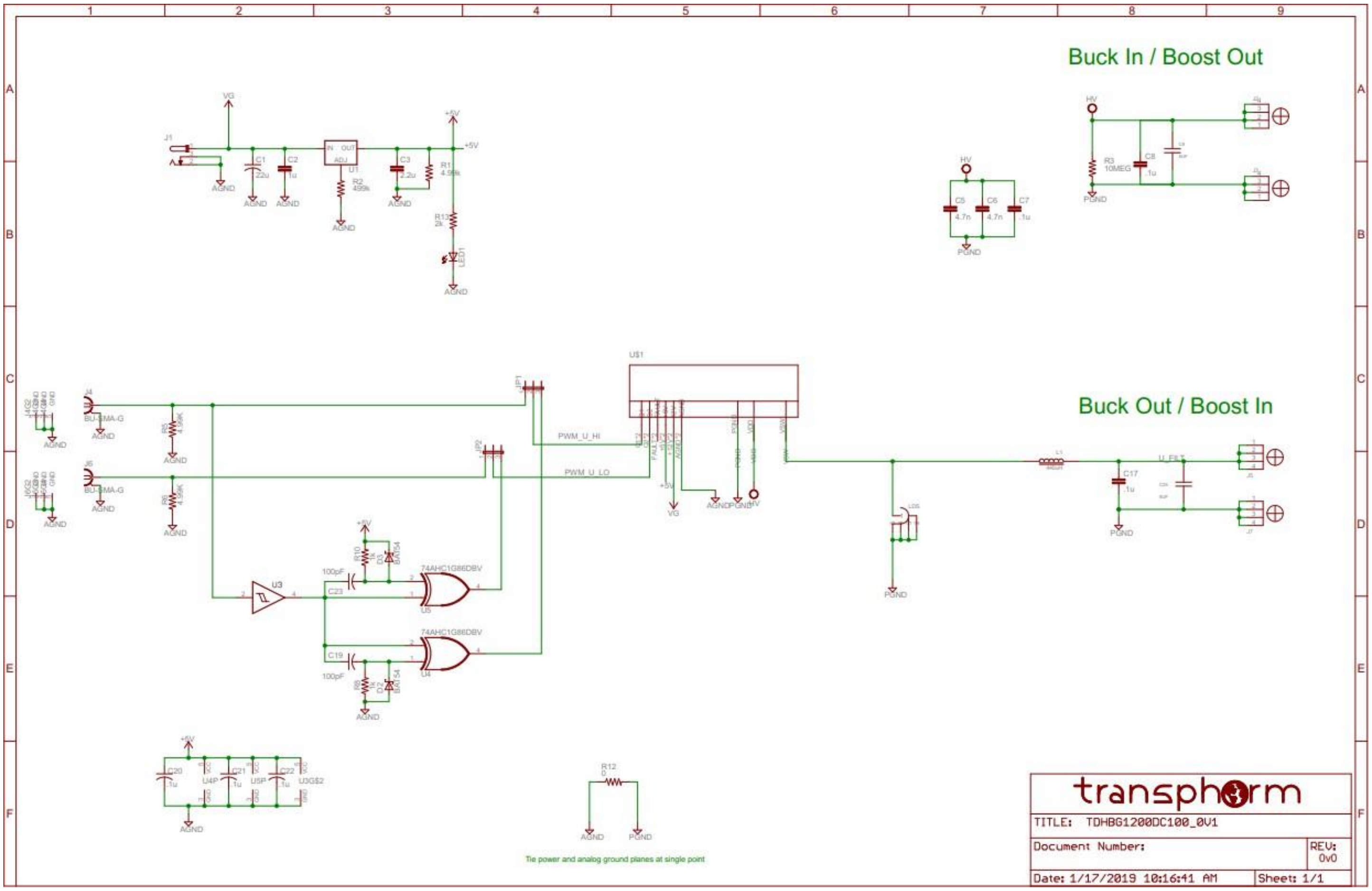

Figure 1: TDNBG1200DC100 half-bridge motherboard schematic

The motherboard accepts various daughter cards that use Transphorm SuperGaN® FETs with different footprints. One such daughter card is the TDHB-65H070L-DC (Figure 2), which was used here to compare the Si8230 to the DGD2304. The TDHB- 65H070L-DC has a half-bridge circuit with:

- TP65H070LDG (Q1) as the high side FET
- TP65H070LSG (Q2) as the low side FET
- Si8230 (U1) as the gate driver
- Isolated DC-to-DC power supply (U2) used to provide power to the output side of the Si8230 such that fully isolated functionality can be evaluated.

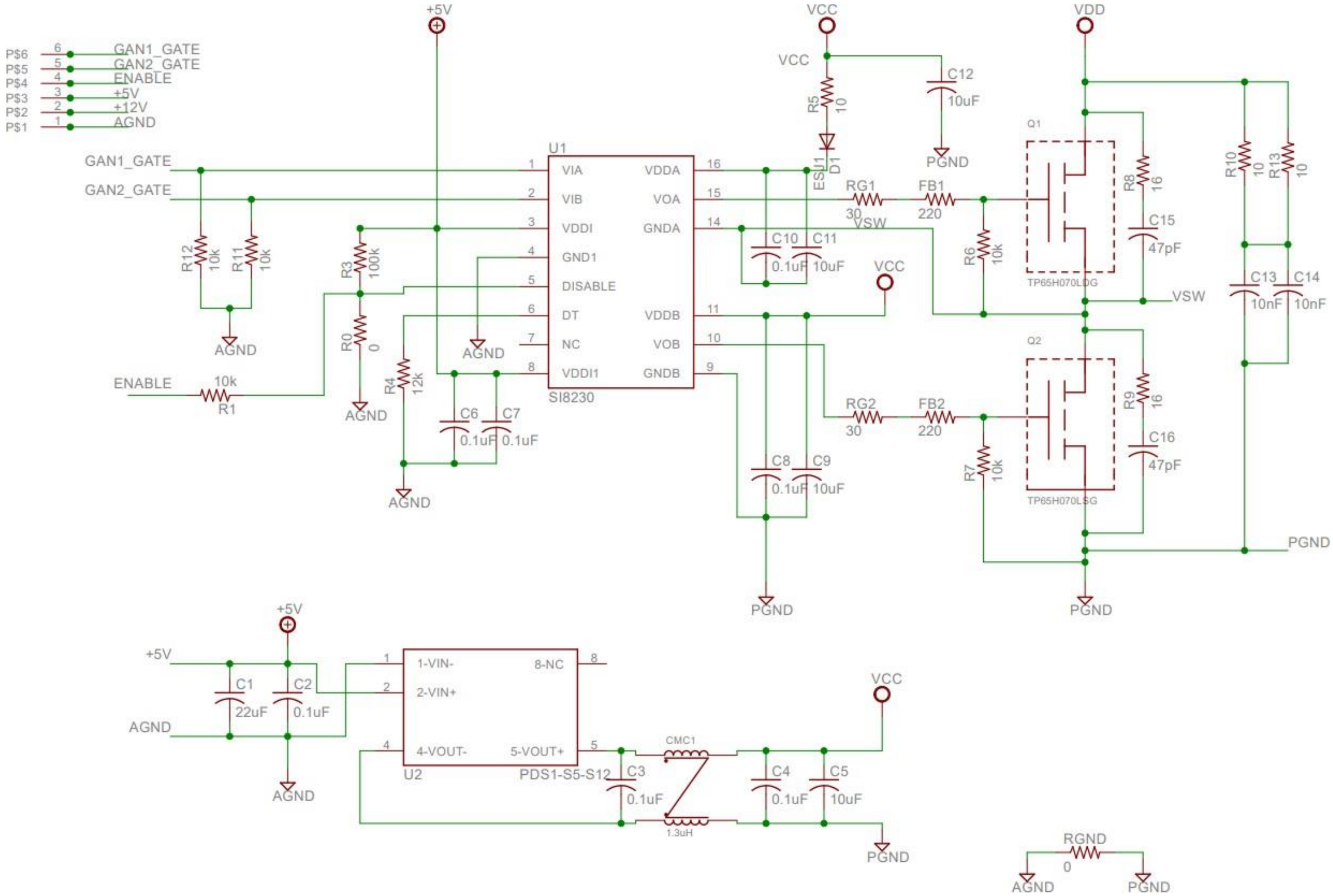

Figure 2: TDHB-65H070L-DC daughter card with half-bridge circuit

For evaluation of the DGD2304, a new daughter PCB is built with the schematic below (Figure 3).

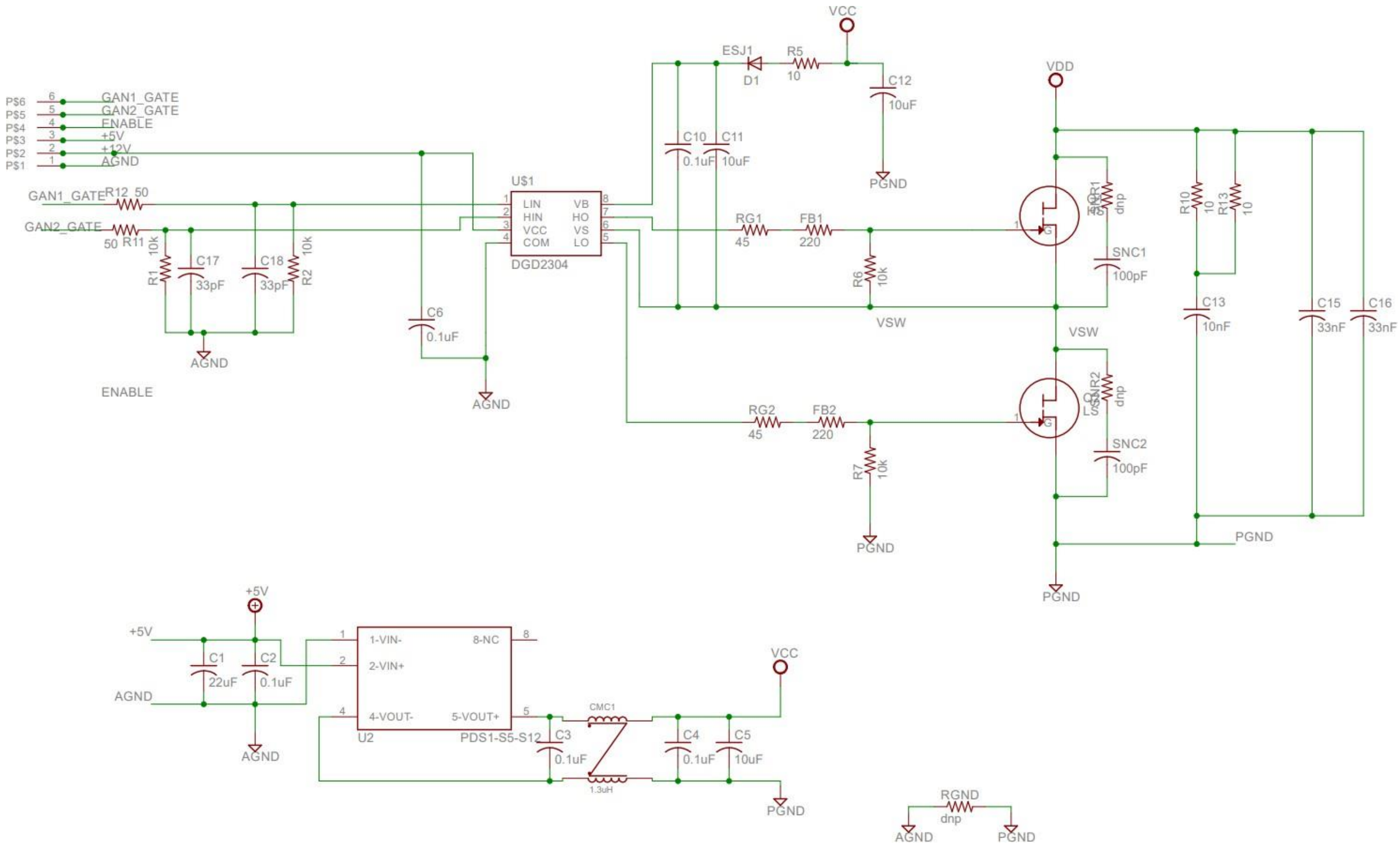

Figure 3: Half-bridge daughter card using the DGD2304 non-isolated 600 V high voltage gate driver

Below (Figure 4) shows the DGD2304 daughter PCB mounted on the TDHBG1200DC100 mother PCB in its actual test environment.

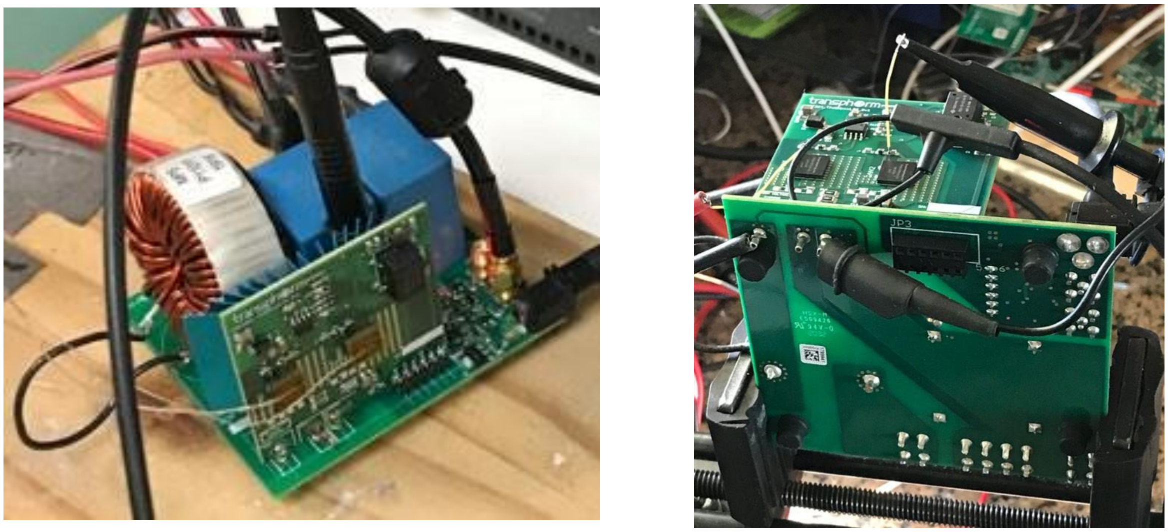

Figure 4: The updated daughter card using the DGD2305 gate drivers

Comparison Tests with the Si8230

For evaluation, we mainly run the evaluation kit in boost mode with Vin = 200 V and Vout = 400 V. Various loads are applied to obtain data for power levels from 200 W to 1200 W.

Comparison tests are run with TP65H070LxG FETs on both daughter PCBs with identical gate resistor values. Detail switching behaviors are characterized with switching frequencies at 50 kHz and 100 kHz. Switching node DV/DT, efficiency and driver propagation delays are measured as below (Table 1). Even though the DGD2304 driver has an approximate 120 to 160 nanosecond longer propagation delay, the efficiency results versus the Si8230 are comparable at both 50 kHz and 100 kHz.

Gate Driver Technical Specification Comparison		
Design Parameters	Skyworks Si8230	Diodes Inc. DGD2304
Turn on propagation delay	100 ns	190 ns
Turn off propagation delay	220 ns	350 ns
Deadtime	120 ns (set by external resistor value)	100 ns (fixed by internal gate driver IC)
Pin (W) @ 50 kHz	213	213
Efficiency (%) @ 50 kHz	97.4	97.5
DV/DT at turn off @ 50 kHz	18.4 V/ns	17.9 V/ns
DV/DT turn on @ 50 kHz	7.1 V/ns	7 V/ns
Pin (W) @ 100 kHz	215	215
Efficiency (%) at 100 kHz	96.2	96.2
DV/DT turn off @ 100 kHz	22.2V/ns	22 V/ns
DV/DT turn on @ 100 kHz	5.2V/ns	5.1 V/ns
Package	S08	SOIC-16
Package size	5 x 6: 30 mm^2	6 x 9: 54 mm^2

Table 1: Gate driver comparison

Tables 2 and 3 show efficiency comparisons at higher power levels of 50 kHz and 100 kHZ. Both gate drivers achieve similar efficiency performance with Si8230 slightly better numbers.

Output Power @ 50 kHz	Efficiency With Si8230	Efficiency With DGD2304
800 W	98.84%	98.82%
1.2 kW	98.99%	98.98%

Table 2: Test at 50 kHz at 800 and 1200 W

Output Power @ 50 kHz	Efficiency With Si8230	Efficiency With DGD2304
800 W	98.84%	98.82%
1.2 kW	98.99%	98.98%
Output Power @ 50 kHz	Efficiency With Si8230	Efficiency With DGD2304
800 W	98.84%	98.82%
1.2 kW	98.99%	98.98%

Table 3: Tests at 100 kHz at 400, 600, 800, 1000, and 1200 W power levels

We also investigated the dependency of the system efficiency to switching frequency (Figure 5). The efficiency is roughly the same at low switching frequencies of 50 kHz and 100 kHz and only slightly widens when the switching frequency increases, indicating the difference in the propagation delay.

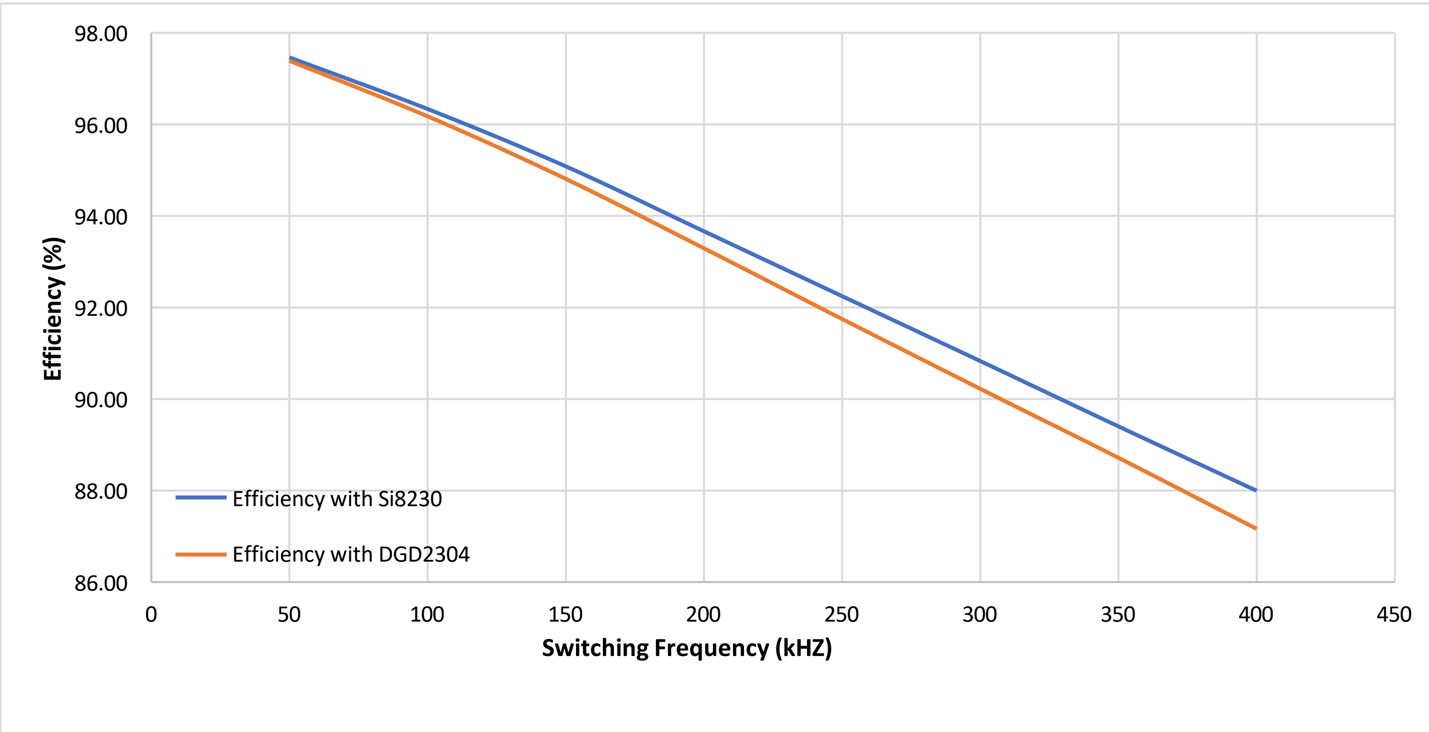

Figure 5: Efficiency versus switching frequency between the Si8230 and DGD2304 at 200 W

Tests with Various Transphorm Products

We mounted different Transphorm GaN FETs onto the new DGD2304 daughter card. Below (Tables 4, 5, 6, and 7; Figures 6, 7, 8, and 9) are the test results with temperatures for Q1 and Q2. The data shows that the DGD2304 works well with switching frequencies <= 150kHz without a heatsink or forced air used to cool the Transphorm FETs.

TP65H070LSG GaN FET Using Forced Air with Heatsink							
Switching Frequency (kHz)	L	Vin	Vout	Pout	Efficiency (%)	T_Q1 (°C)	T_Q2 (°C)
50	490u	200	400	200	97.66	25.5	26.4
50	490u	200	400	400	98.32	26.2	33.1
50	490u	200	400	600	98.73	27.7	36.2
50	490u	200	400	800	98.9	28.7	38.8
50	490u	200	400	1000	98.96	30.1	41.7
50	490u	200	400	1200	99.01	31.9	46.1
100	490u	200	400	200	96.67	26.8	39.9
100	490u	200	400	400	98.03	28.3	43.8
100	490u	200	400	600	98.47	29.3	47.3
100	490u	200	400	800	98.65	30.7	52
100	490u	200	400	1000	98.71	32.2	56.7
100	490u	200	400	1200	98.75	35	63.4

Table 4: Results with the TP65H070LSG

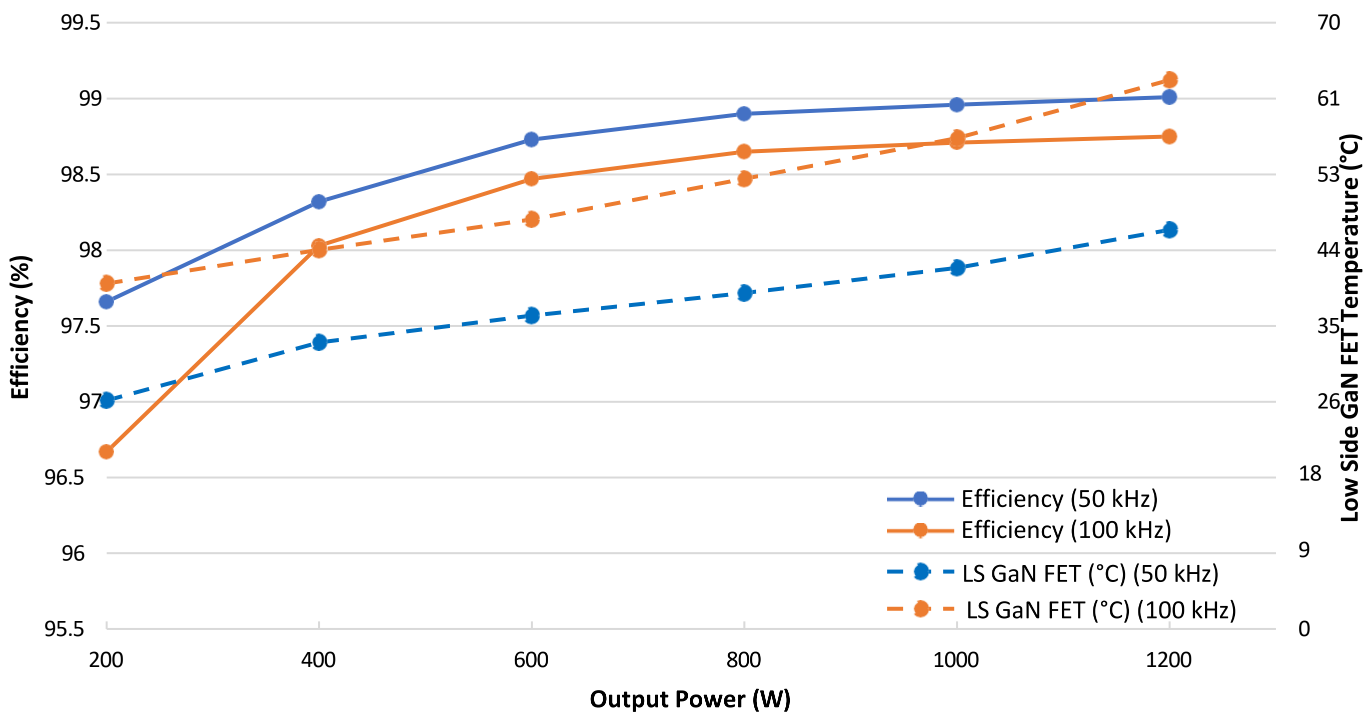

Figure 6: Efficiency and Device Temperature: DGD2340 with the TP65H070LSG at 50 and 100 kHz (forced air with heatsink)

We experimented with two inductor values. The results are summarized in Tables 5 and 6 and Figures 7, 8, and 9. With lower inductor value (490uH), inductor current has more ripple and can run negative at low switching frequencies (Figure 9a). When inductor current runs negatively, power is processed one time from input to output and then returned from output to input. This double processing reflects as lower system efficiency for the 490uH inductor value in Tables 5 and 6 and Figures 7 and 8.

TP65H150G4LSG GaN FET Using No Heatsink, No Forced Air									
Switching Frequency (kHz)	L	IL	Vin	Vout	Pin	Pout	Efficiency (%)	T_Q1 (°C)	T_Q2 (°C)
50	490u	Figure 9a	199.7	385.6	371.11	365.38	98.5	54.8	60.8
100	490u	Figure 9a	199.71	392.96	357.4	351.81	98.4	62	75.5
150	490u	Figure 9b	199.77	390.71	349.59	342.88	98.1	69.3	93
50	880u	Figure 9c	199.79	395.56	369.3	365.57	99	49.2	56.8
100	880u	Figure 9c	199.71	392.7	359.18	354.44	98.7	58	75
150	880u	Figure 9c	199.78	390.29	350.39	344.13	98.2	67	97

Table 5: Tests using TP65H150G4LSG

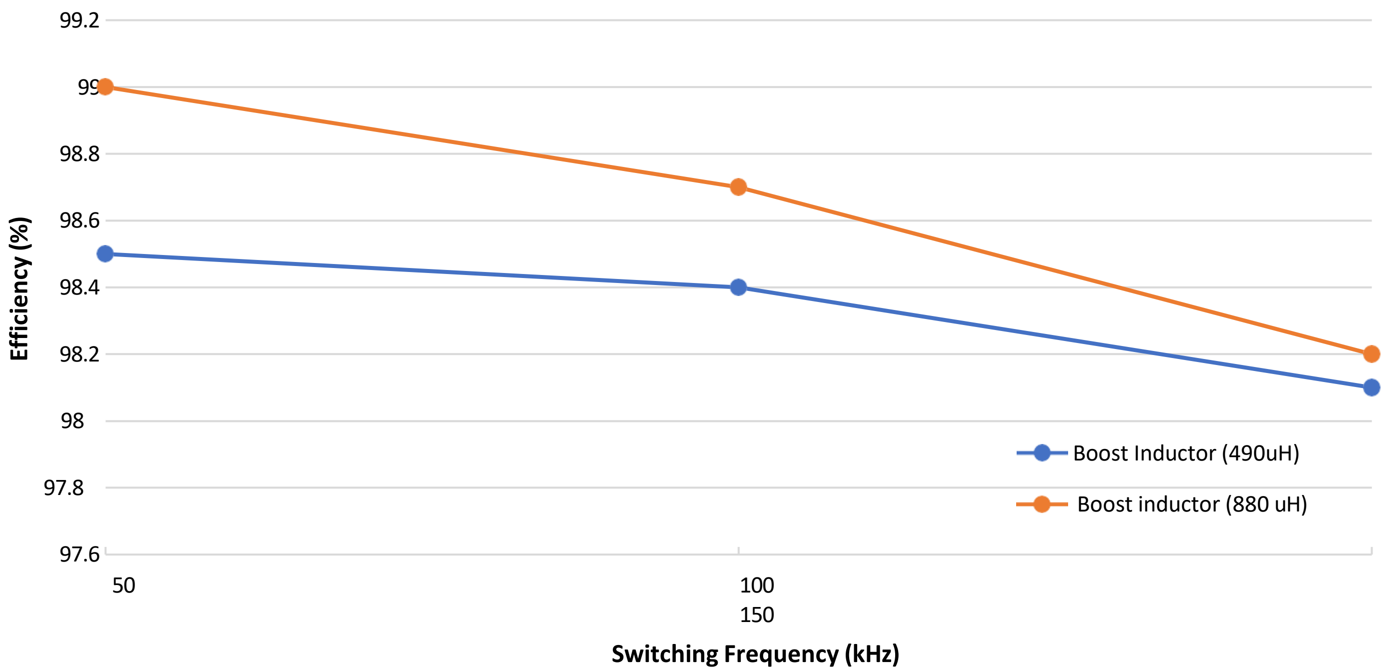

Figure 7: DGD2340 with the TP65H150G4LSG at 50, 100, and 150 kHz (no heatsink, no forced air)

TP65H300G4LSG GaN FET Using No Heatsink, No Forced Air									
Switching Frequency (kHz)	L	IL	Vin	Vout	Pin	Pout	Efficiency (%)	T_Q1 (°C)	T_Q2 (°C)
50K	490u	Figure 9a	199.74	397.1	370.72	364.14	98.2	58	65.5
100K	490u	Figure 9a	199.8	396.92	358.77	352.92	98.4	63	84
150K	490u	Figure 9b	199.86	397.04	340.08	333.29	98	72.5	104.4
50K	880u	Figure 9c	199.64	397.1	370.23	366.25	98.9	53	62
100K	880u	Figure 9c	199.78	396.91	359.53	354.92	98.7	61.8	80.5
150K	880u	Figure 9c	199.85	396.79	350.44	344.45	98.3	68.7	101.4

Table 6: Tests using TP65H300G4LSG

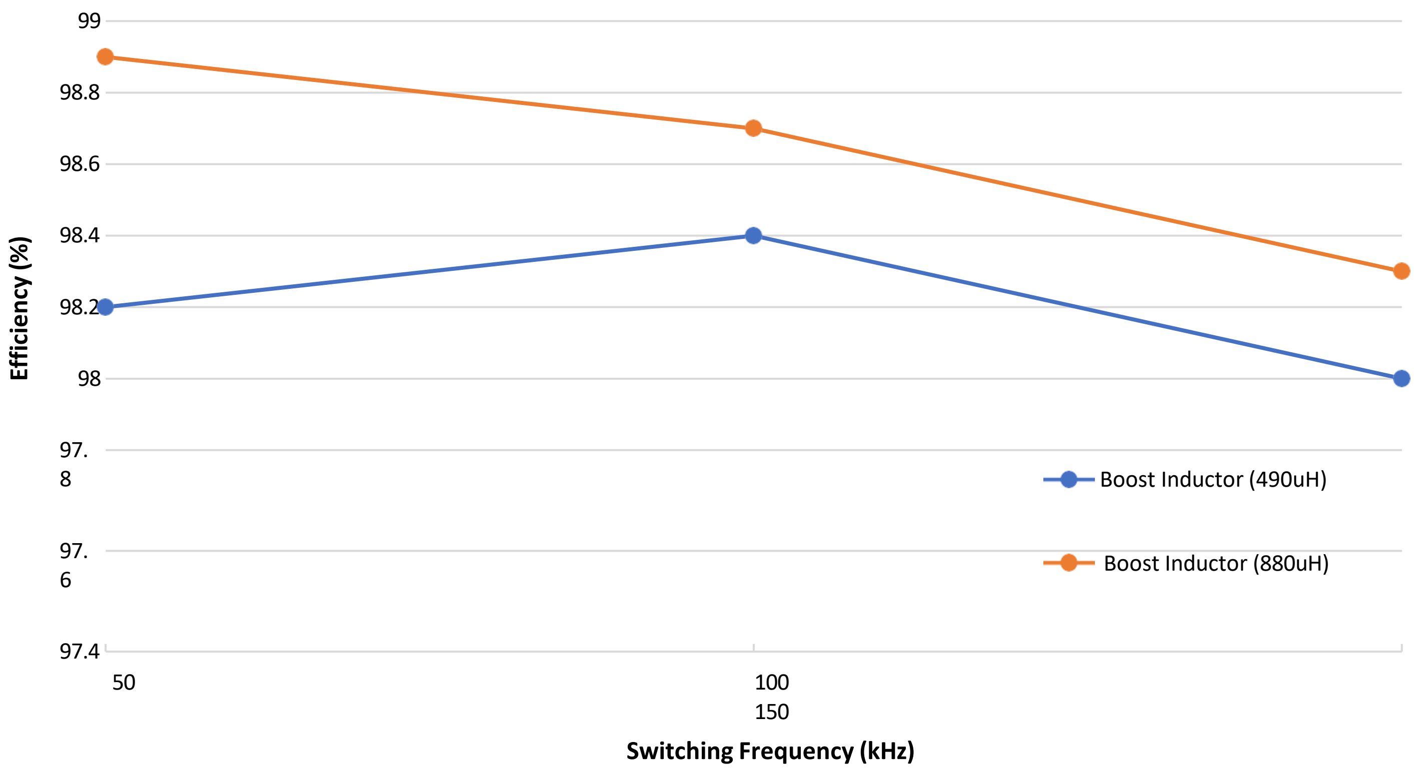

Figure 8: DGD2340 with the TP65H300G4LSG at 50, 100, and 150 kHz (no heatsink, no forced air)

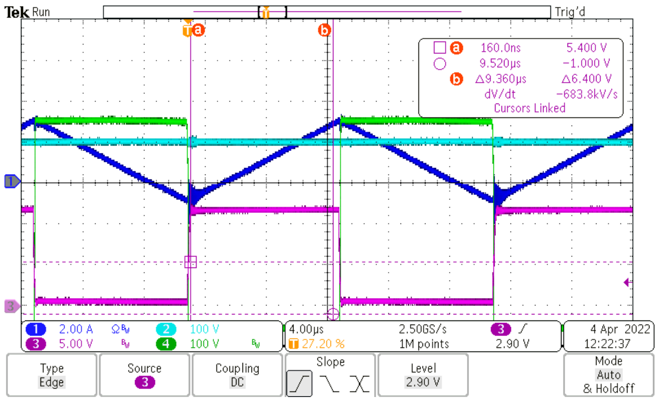

Figure 9a: Valley of IL is negative

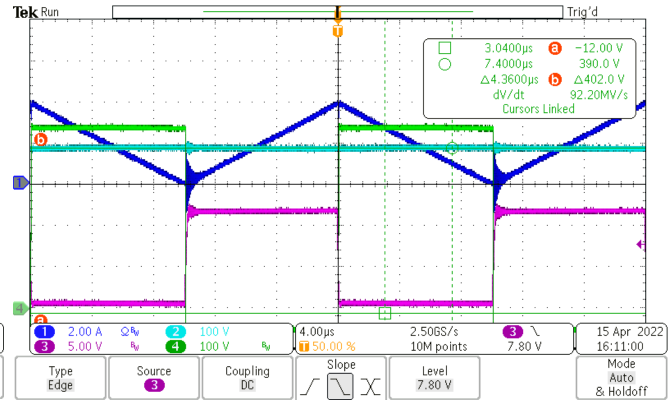

Figure 9b: Valley of IL touches zero

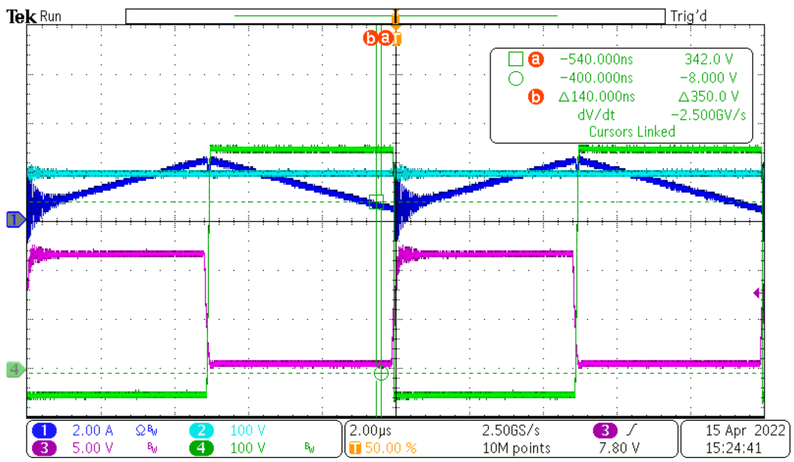

Figure 9c: Valley of IL is positive

Conclusion

The DGD2304 was tested using different on resistance GaN FETs, power levels, and operating frequencies. Though this was not an exhaustive analysis, it gives a good picture of the driver's use and performance. We know that the following specifications effect performance and reliability of the GaN FET when using any gate driver:

1) Turn on/turn off propagation delay
2) Frequency of operation
3) Source and sink current rating of the driver
4) On resistance/operating temperature of the GaN FET

These factors all need to be considered when selecting a gate driver. In comparison with the Si8230, we recommend using the DGD2304 at frequencies of < 250 kHz due to higher propagation delays. If power levels above 1200 W are required, we also recommend that tests are done to make sure that there is sufficient gate charge (turn on sourcing current) to fully turn the FET on during every cycle.

Ultimately, the DGD2304 is suitable as a low-cost, high density gate driver solution for Transphorm SuperGaN FET products.

Reference

[1] DGD2304 datasheet, half-bridge gate driver in SO-8, Diodes Inc.,
https://www.diodes.com/assets/Datasheets/DGD2304.pdf.