AN-1602
APPLICATION NOTE

One Technology Way • P.O. Box 9106 • Norwood, MA 02062-9106, U.S.A. • Tel: 781.329.4700 • Fax: 781.461.3113 • www.analog.com

Using the ADuM4135 Gate Driver with the Microsemi APTGT75A120T1G 1200 V IGBT Module

by Martin Murnane

INTRODUCTION

Insulated gate bipolar transistors (IGBTs) are cost effective solutions for high voltage applications such as on-board chargers, off board chargers, dc-to-dc fast chargers, and switch mode power supplies (SMPS) applications. The switching frequency ranges from dc to 100 kHz. IGBTs can be single devices or even half bridge devices as selected for the design shown in Figure 1.

The APTGT75A120 IGBT in the design described in this application note is a fast trench device with field stop IGBT technology that is proprietary to Microsemi Corporation®. This IGBT device also has low tail current, a switching frequency to 20 kHz, and soft recovery parallel diodes with low stray inductance due to the symmetrical design. The high level of integration with the selected IGBT gives optimal performance at high frequency, with a low junction to case thermal resistance.

Gate drive technology from Analog Devices, Inc., drives the IGBT. The ADuM4135 gate driver is a single-channel device with a typical drive capability of 7 A source and sink at >25 V operating voltage (VDD to VSS). The device has a minimum common-mode transient immunity (CMTI) of 100 kV/µs. The ADuM4135 provides supplies up to 35 V. Therefore, a ±15 V supply is adequate for this application.

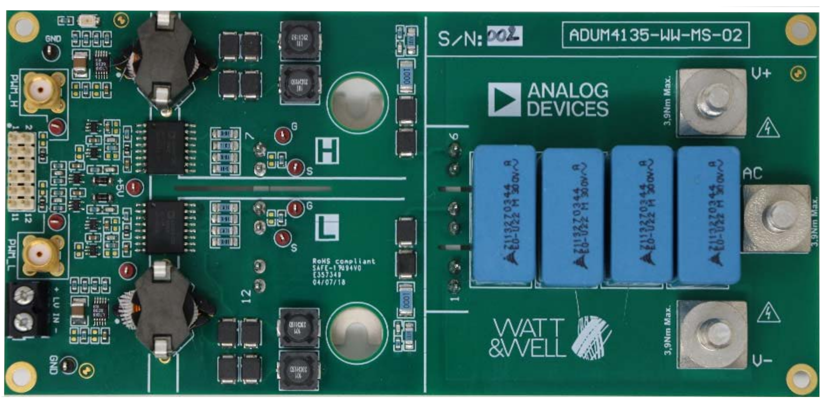

Figure 1. ADuM4135 Gate Driver Module

TABLE OF CONTENTS

REVISION HISTORY

5/2019—Revision 0: Initial Version

TEST SETUP

ELECTRICAL SETUP

The electrical setup of the system test circuit is shown in Figure 2. A dc voltage is applied to the inputs across the full half bridge where decoupling capacitors of 900 µF (C1) are added to the input stage. The output stage is an inductor capacitor (LC) filter stage of 200 µH (L1) and 50 µF (C2), filtering the output into the load (R1) of 2 Ω to 30 Ω. Table 1 details the test setup power components. U1 is the DC supply for HV+ and HV− and T1 and T2 are a single IGBT module.

A complete electrical setup is shown in Figure 3 and Table 2 gives the full list of equipment used in the test.

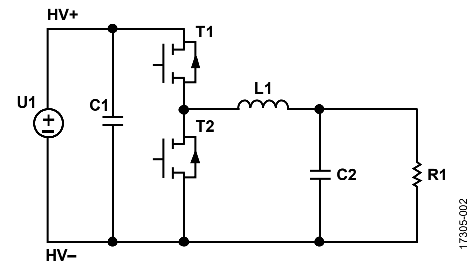

Figure 2. Electrical Setup of the System Test Circuit

Table 1. Test Setup Power Components

Equipment	Value
IGBT Module, T1, T2	APTGT75A120T1G1
U1	200 V to 900 V
Capacitor C1	900 µF
Inductor L1	200 µH
Capacitor C2	50 µF
Load Resistor R1	2 Ω to 30 Ω

Table 2. Complete Setup Equipment

Equipment	Manufacturer	Part Number
Oscilloscope	Agilent	DSO-X 3024A, 200 MHz
DC Supply	Delta Elektronika	SN660-AR-11 (two in serial)
Gate Driver Board	WATT&WELL	ADUM4135-WW-MS-02 SN001
Waveform Generator	Agilent	33522A
Current Probe	Hioki	3275
Current Probe	Hioki	3276
Passive Voltage Probe	Keysight	N2873A, 500 MHz
Passive High Voltage Probe	Elditest	GE3421, 100 MHz
High Voltage Differential Probe	Tektronix	P5200
High Voltage Differential Probe	Testec	TT-SI 9110
Thermal Camera	Optris	PI 160

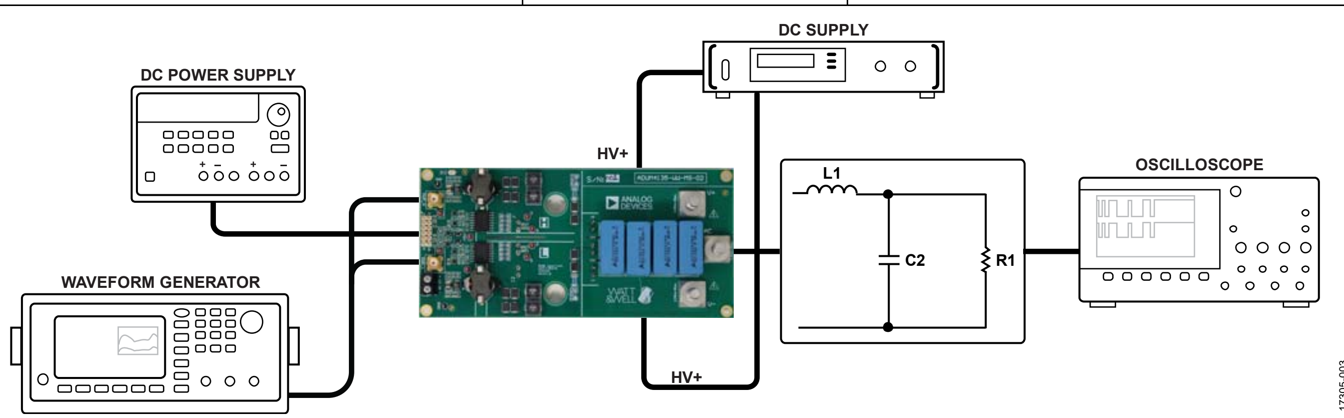

Figure 3. Connection Diagram for Gate Driver Power Board Testing

TEST RESULTS

NO LOAD TESTING

In a no load testing setup low output current is drawn at the output of the module. In this application, a 30 Ω resistor is used.

Table 3 shows important elements of the electrical test setup with no load along with the low current flowing within the load. Table 4 shows the temperature observed across the module. Table 3 and Table 4 contain summaries of the observed results. Figure 5 to Figure 10 show the test results of the switching waveforms across various voltages and switching frequencies.

As shown in Table 3, Test 1 and Test 2 are carried out at 600 V. Test 1 is carried out at a 10 kHz switching frequency, and Test 2 is carried out at a 20 kHz switching frequency. Test 3 is carried out at 900 V with a switching frequency of 10 kHz.

Figure 4 shows the electrical setup for no load testing.

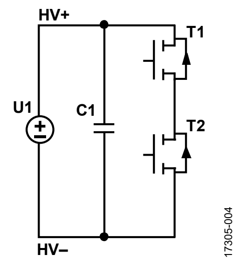

Figure 4. Electrical Setup for No Load Testing

Table 3. No Load Testing, Figure Assignments

Test	DC Voltage, V_{DC}[1], (V)	Switching Frequency, f_{SW}, (kHz)	Duty Cycle (%)	I_{IN}[2] (A)	Reference Figures
1	600	10	50	0.007	Figure 5 and Figure 6
2	600	20	50	0.013	Figure 7 and Figure 8
3	900	10	50	0.009	Figure 9 and Figure 10

[1] V_{DC} is the HV+ and HV– voltage.
[2] I_{IN} is the input current through U1.

Table 4. No Load Testing, Temperature Summary[1]

			Temperature		DC-to-DC Power Supply Temperature		Gate Driver Temperature	
Test	V_{DC} (V)	f_{SW} (kHz)	Ambient (°C)	Heat Sink (°C)	High-Side (°C)[2]	Low-Side (°C)[2]	High-Side (°C)	Low-Side (°C)
1	600	10	26	30.8	34	34	38.2	37.6
2	600	20	26	31	35	35	39.5	39.4
3	900	10	26	31	34.2	34.2	38.6	37.7

[1] All temperatures are recorded with a thermal camera.
[2] Measured from transformers.

PERFORMANCE GRAPHS FOR TURNING IGBT ON AND OFF

The test results in this section show the switching waveforms at various voltage of interest where f_{SW} = 10 kHz and 20 kHz. V_{DS} is the V_{DRAIN} source and V_{GS} is the V_{GATE} source

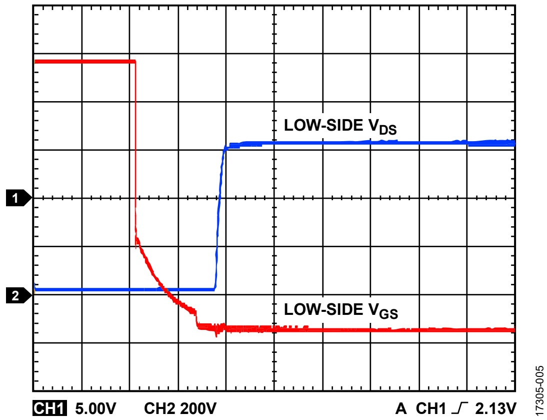

Figure 5. V_{DC} = 600 V, f_{SW} = 10 kHz, No Load

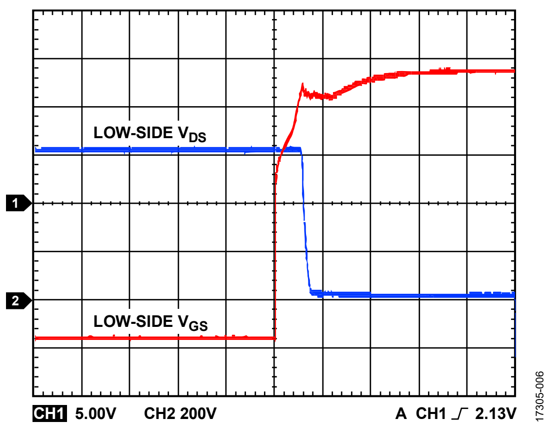

Figure 6. V_{DC} = 600 V, f_{SW} = 10 kHz, No Load

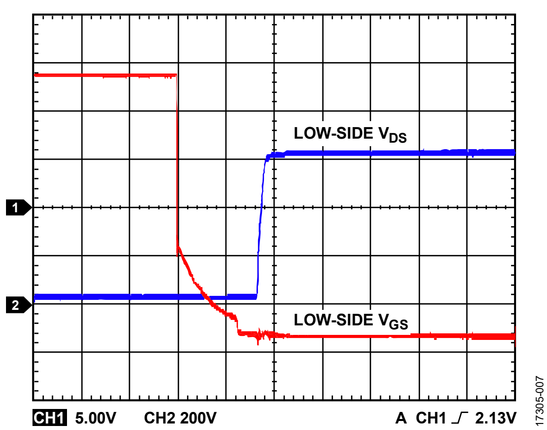

Figure 7. V_{DC} = 600 V, f_{SW} = 20 kHz, No Load

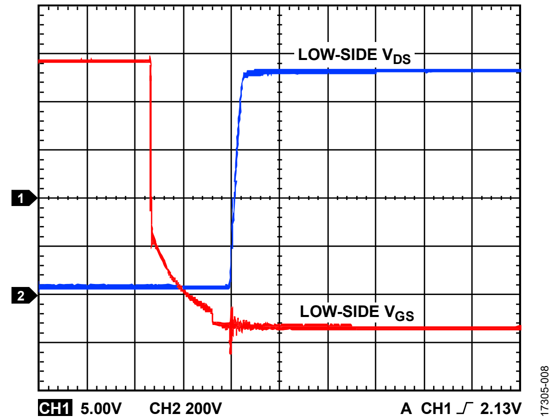

Figure 8. V_{DC} = 600 V, f_{SW} = 20 kHz, No Load

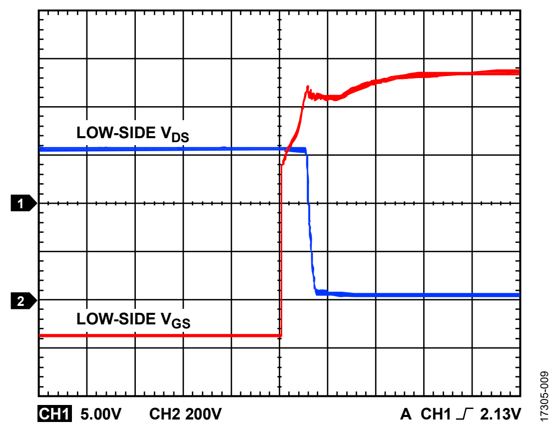

Figure 9. V_{DC} = 900 V, f_{SW} = 10 kHz, No Load

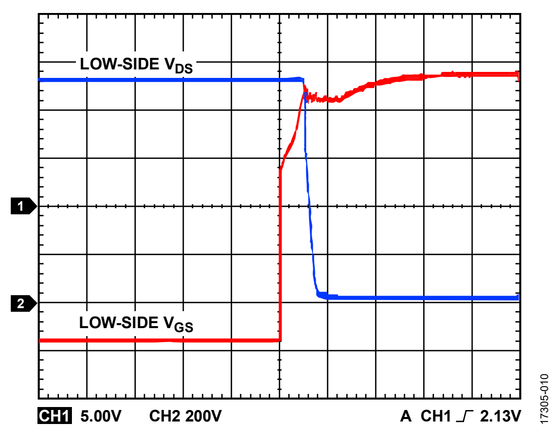

Figure 10. V_{DC} = 900 V, f_{SW} = 10 kHz, No Load

LOAD TESTING

The test configuration is similar to the test setup (see Figure 4) of the no load tests in the No Load Testing section. Table 5 summarizes the observed results, and Figure 11 to Figure 16 show the test performance and results across various voltages, frequencies, and loads.

Test 4 is carried out at 200 V at a 10 kHz switching frequency with a 25% duty cycle. Test 5 is carried out at 600 V at a 10 kHz switching frequency with a 25% duty cycle. Test 6 is carried out at 900 V at a 10 kHz switching frequency with a 25% duty cycle.

Table 5. Load Testing

Test	V_{DC} (V)	f_{SW} (kHz)	Duty Cycle (%)	I_{OUT}[1] (A)	V_{OUT}[2] (V)	P_{OUT}[3] (W)	I_{IN} (A)	Reference Figures
4	200	10	25	1.8	49.3	90.2	0.55	Figure 11 and Figure 13
5	600	10	25	5.4	146.5	791.1	1.62	Figure 12 and Figure 14
6	900	10	25	7.8	214	1669.2	2.5	Figure 15 and Figure 16

[1] I_{OUT} is the output current in Load Resistor R1.
[2] V_{OUT} is the output voltage across R1.
[3] P_{OUT} is the output power ($I_{OUT} \times V_{OUT}$).

PERFORMANCE GRAPHS FOR TURNING IGBT ON AND OFF AND NO LOAD TESTING

The test results in this section show switching waveforms at various voltage of interest across f_{SW} = 10 kHz and 20 kHz.

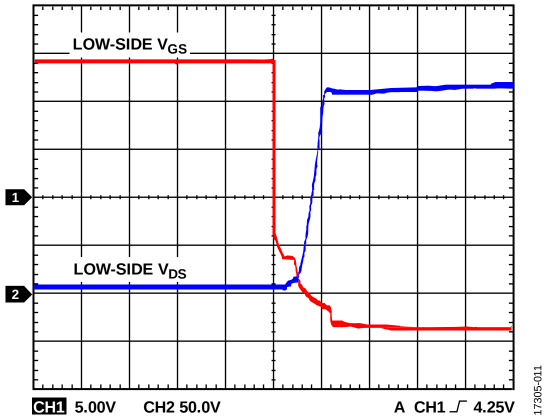

Figure 11. V_{DC} = 200 V, f_{SW} = 10 kHz, P_{OUT} = 90.2 W

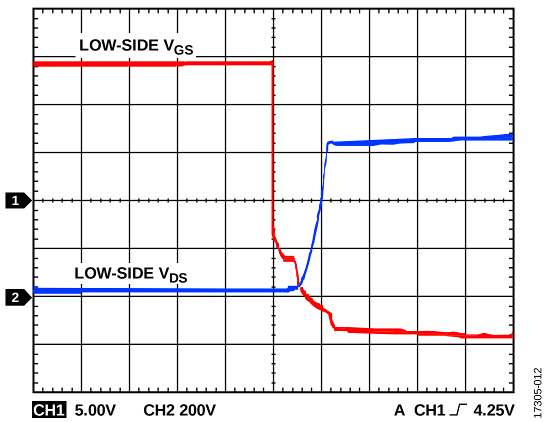

Figure 12. V_{DC} = 600 V, f_{SW} = 10 kHz, P_{OUT} = 791.1 W

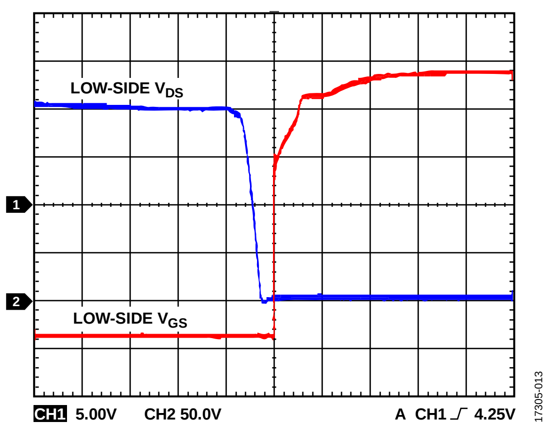

Figure 13. V_{DC} = 200 V, f_{SW} = 10 kHz, P_{OUT} = 90.2 W

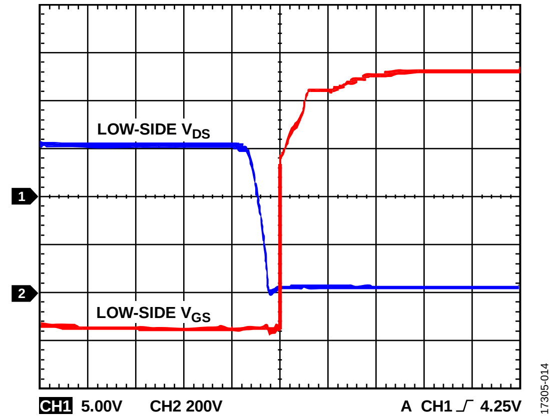

Figure 14. V_{DC} = 600 V, f_{SW} = 10 kHz, P_{OUT} = 791.1 W

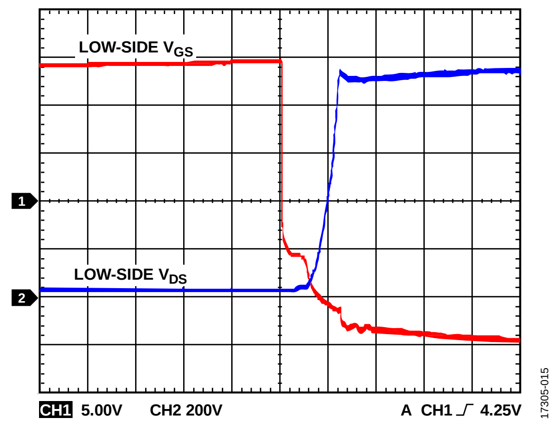

Figure 15. V_{DC} = 900 V, f_{SW} = 10 kHz, P_{OUT} 1669.2 W

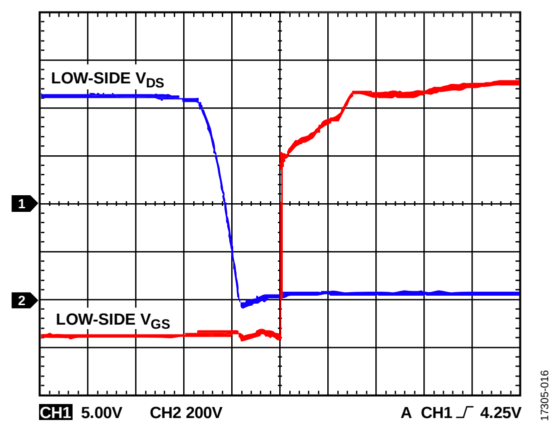

Figure 16. V_{DC} = 900 V, f_{SW} = 10 kHz, P_{OUT} 1669.2 W

HIGH CURRENT TESTING

The test configuration is similar to the physical setup shown in Figure 3. Table 6 summarizes the observed results, and Figure 17 to Figure 20 show the test performance and results across various voltages, frequencies, and loads.

The output load resistor is varied for individual tests, as shown in Table 1, where 2 Ω and 30 Ω loads are used to vary the current. V_{OUT} is measured as the voltage across R1.

Test 7 is carried out at 300 V at a 10 kHz switching frequency with a 25% duty cycle. Test 8 is carried out at 400 V at 10 kHz switching frequency with 25% duty cycle.

Table 6. High Current Testing

Test	V_{DC} (V)	f_{SW} (kHz)	Duty Cycle (%)	I_{OUT} (A)	V_{OUT} (V)	P_{IN}[1] (W)	I_{IN} (A)	Reference Figures
7	300	10	25	19.6	68.7	1346.3	5	Figure 17 and Figure 19
8	400	10	25	25.8	91.7	2365.9	6.6	Figure 18 and Figure 20

[1] P_{IN} is the input power ($I_{IN} \times V_{IN}$) where V_{IN} is the dc source power supply.

PERFORMANCE GRAPHS FOR TURNING IGBT ON AND OFF WITH LOAD TESTING

The test results in this section show switching waveforms at various voltage of interest across f_{SW} = 10 kHz and 20 kHz.

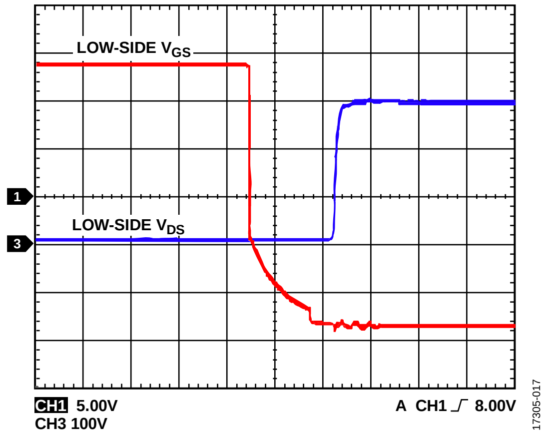

Figure 17. V_{DC} = 300 V, f_{SW} = 10 kHz, P_{OUT} = 1346.3 W

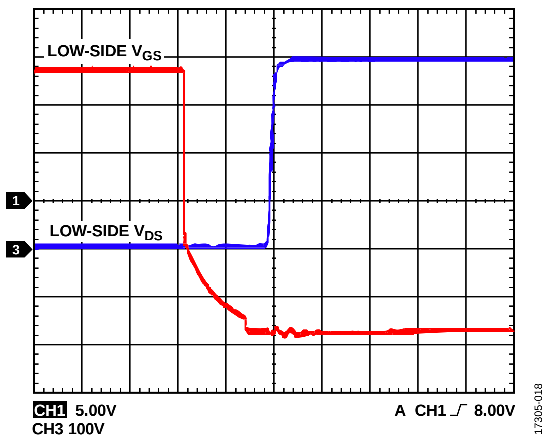

Figure 18. V_{DC} = 400 V, f_{SW} = 10 kHz, P_{OUT} = 2365.9 W

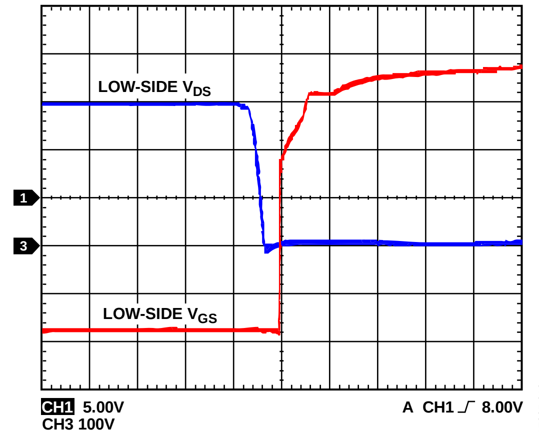

Figure 19. V_{DC} = 300 V, f_{SW} = 10 kHz, P_{OUT} = 1346.3 W

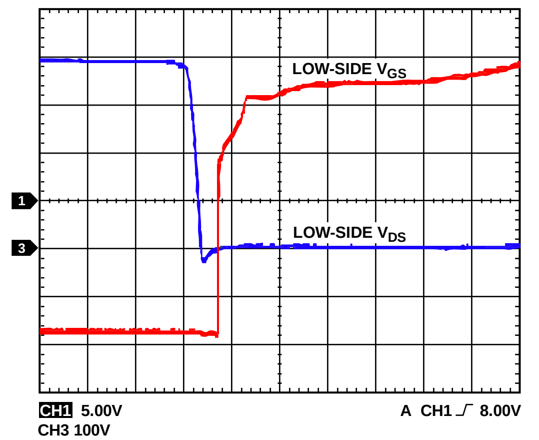

Figure 20. V_{DC} = 400 V, f_{SW} = 10 kHz, P_{OUT} = 2365.9 W

DESATURATION TESTING

The electrical setup of the system test circuit is shown in Figure 21. A dc voltage is applied to the inputs across the full half bridge, where decoupling capacitor of 900 µF are added to the input stage. This setup is used to test the desaturation detection. In this application, the maximum I_C = 150 A, where I_C is the current through T1 and T2.

The high-side switch of the IGBT (T1) is bypassed by an inductor of 83 µH, and the T1 switch must be off.

The low-side switch of the IGBT (T2) is driven for 50 µs every 500 ms.

Table 7 details a list of the power components of the desaturation testing setup.

Figure 22 shows a switching event at 135 A in the inductor L1, and Figure 23 shows a desaturation detection at 139 A in the inductor L1.

Table 7. Test Setup of the Power Components for Desaturation Testing

Equipment	Value
U1	0 V to 80 V
C1	900 µF
L1	83 µH

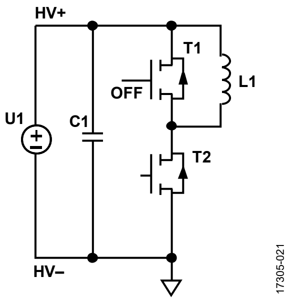

Figure 21. Electrical Setup of the System Test Circuit

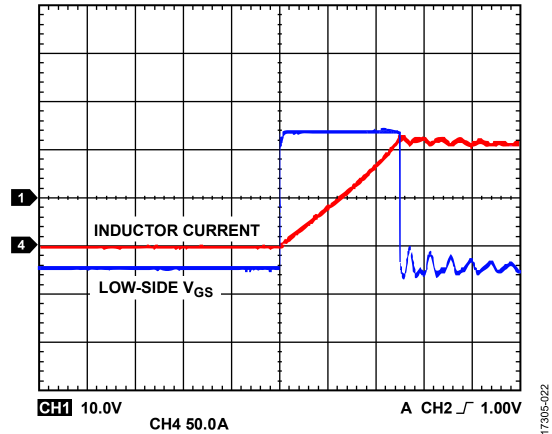

Figure 22. V_{DC} < 68 V, f_{SW} = 2 Hz, Duty Cycle = 0.01%

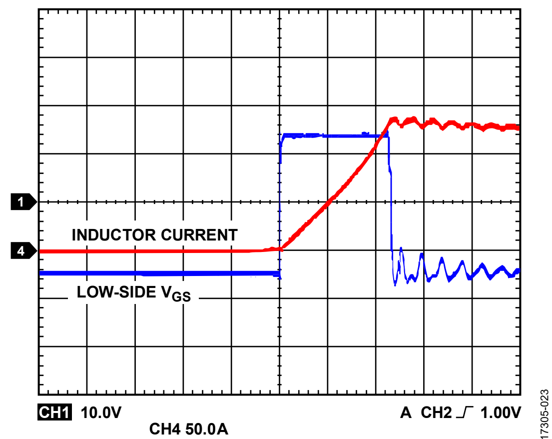

Figure 23. V_{DC} > 68 V, f_{SW} = 2 Hz, Duty Cycle = 0.01%

APPLICATION SCHEMATIC

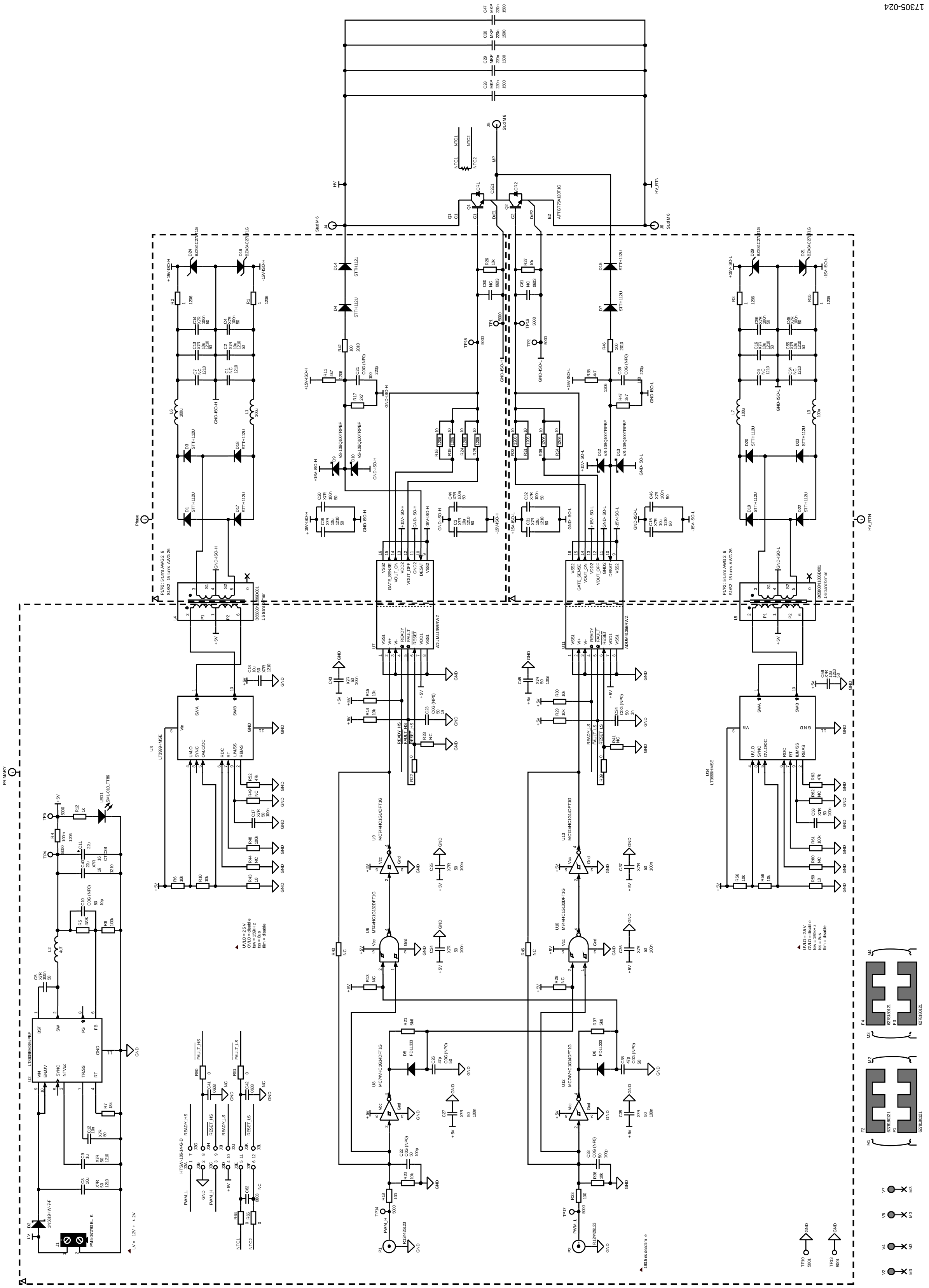

Figure 24. ADuM4135 Gate Driver Board Schematic

CONCLUSION

The ADuM4135 gate driver has the current drive capability, proper power supply range, and a strong CMTI capability of 100 kV/μs to deliver optimal performance when driving IGBTs.

The test results in this application note provide data that demonstrate that the ADuM4135 evaluation board is a solution for high voltage applications driving IGBTs.

AN17305-0-5/19(0)