Half-Bridge N-Channel MOSFET Driver for DC/DC Conversion with Adjustable High-Side Propagation Delay

FEATURES

- 12-V Low-Side Gate Drive (SiP41106)
- 8-V Low-Side Gate Drive (SiP41107)
- Undervoltage Lockout
- Internal Bootstrap Diode
- Adaptive Shoot-Through Protection
- Synchronous MOSFET Disable
- Adjustable High-Side Propagation Delay
- PWM Inactivity Detection
- Switching Frequency Up to 1 MHz
- Drive MOSFETs In 5- to 48-V Systems

Pb-free

APPLICATIONS

- Multi-Phase DC/DC Conversion
- High Current Synchronous Buck Converters
- High Frequency Synchronous Buck Converters
- Asynchronous-to-Synchronous Adaptations
- Mobile Computer DC/DC Converters
- Desktop Computer DC/DC Converters

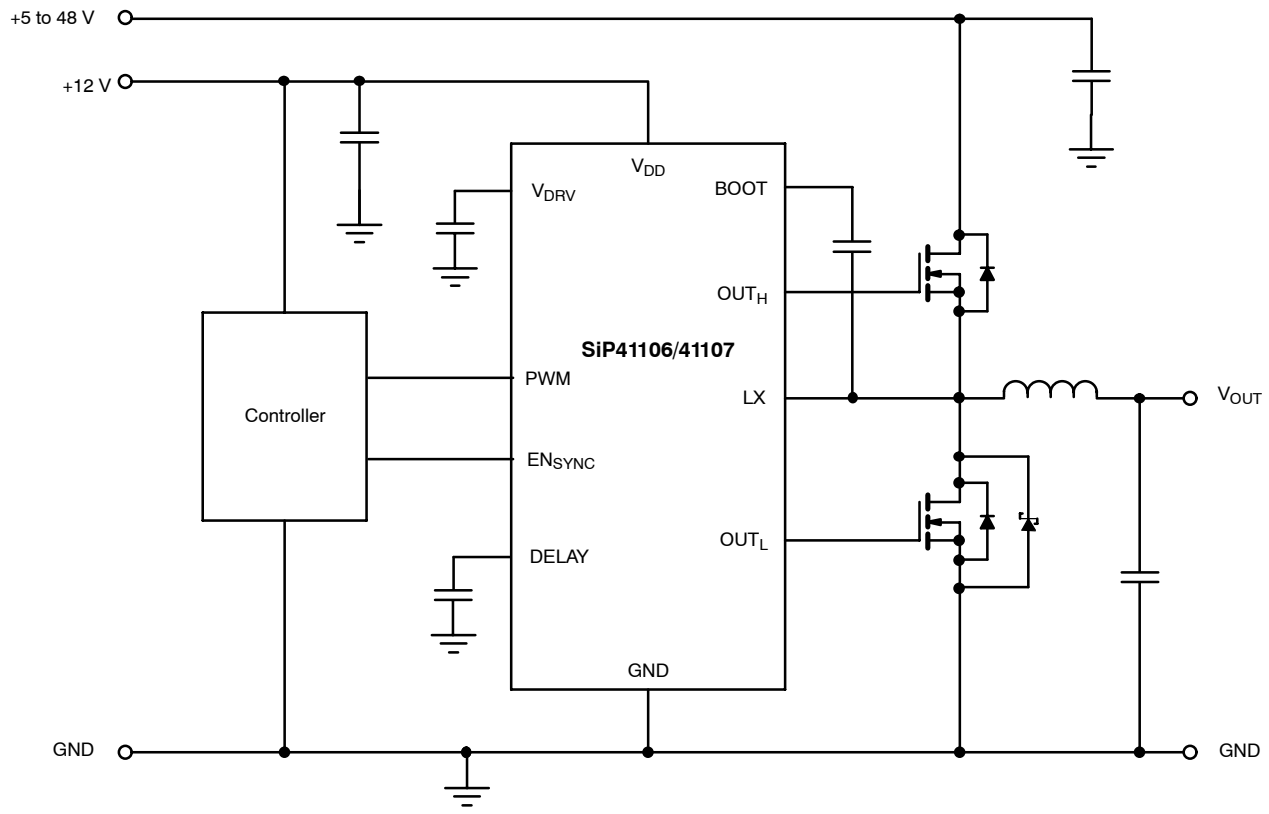
DESCRIPTION

SiP41106/7 is a high-speed half-bridge MOSFET driver with adaptive shoot-through protection for use in high frequency, high current, multiphase dc-dc synchronous rectifier buck power supplies. It is designed to operate at switching frequencies up to 1 MHz. The high-side driver is bootstrapped to allow driving n-channel MOSFETs. SiP41106/7 comes with adaptive shoot-through protection to prevent simultaneous conduction of the external MOSFETs.

There are two options available for the voltage of the low-side drivers. In the SiP41106, the regulator supplies gate drive voltage to the high-side driver and V_{CC} supplies the low-side driver. In the SiP41107, the regulator supplies the high-side and low-side gate drive voltage.

The SiP41106/7 are assembled in lead (Pb)-free 10-Pin MLP-33 packages and are specified to operate over the industrial operating range of –40°C to 85°C

FUNCTIONAL BLOCK DIAGRAM



ABSOLUTE MAXIMUM RATINGS (ALL VOLTAGES REFERENCED TO GND = 0 V)

V_{DD}, PWM, EN_{SYNC}, DELAY ..... –0.3 to 15 V
LX, BOOT ..... –0.3 to 55 V
BOOT to LX ..... –0.3 to 15 V
Storage Temperature ..... –40 to 150°C
Operating Junction Temperature ..... 125°C

Power Dissipation[a,b]
MLP-33 ..... 960 mW
Thermal Impedance (Θ_{JA})[a,b]
MLP-33 ..... 105°C/W
Notes
a. Device mounted with all leads soldered or welded to PC board.
b. Derate 9.6 mW/°C

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

RECOMMENDED OPERATING RANGE (ALL VOLTAGES REFERENCED TO GND = 0 V)

V_{DD} ..... 10.8 V to 13.2 V
V_{LX} ..... 48 V
C_{BOOT} ..... 100 nF to 1 µF
$V_{BOOT-LX}$ ..... 8 V
Operating Temperature Range ..... –40 to 85°C

SPECIFICATIONS[a]

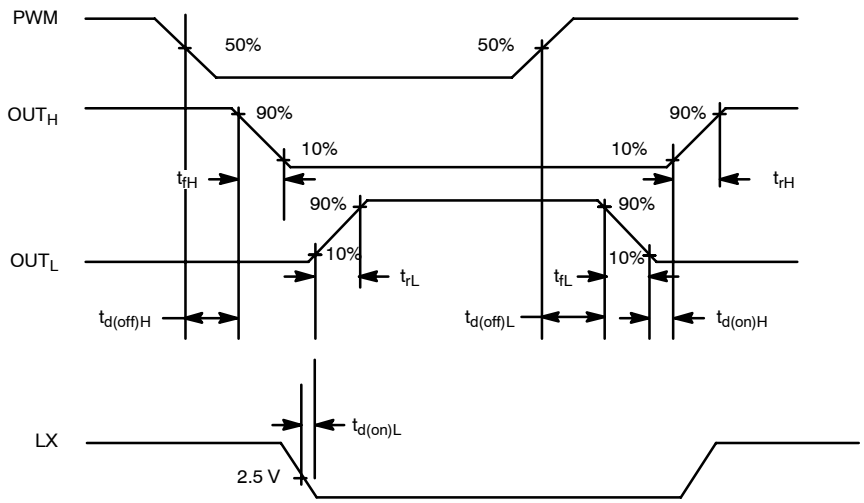
Parameter	Symbol	Test Conditions Unless Specified V_{DD} = 12 V, $V_{BOOT} - V_{LX}$ = 8 V, T_A = –40 to 85°C		Limits Min[a]	Limits Typ[b]	Limits Max[a]	Unit
Power Supplies							
Supply Voltage	V_{DD}			10.8		13.2	V
Quiescent Current	I_{DDQ}	PWM Non-Switching EN_{SYNC} = 14.2 V			5.0	8.5	mA
Supply Current	I_{DD}	f_{PWM} = 100 kHz, C_{LOAD} = 3 nF	SiP41106		11.5		mA
			SiP41107		10.0		
Standby Current	I_{DD1}	PWM = 0 V				1	µA
	I_{DD2}	PWM = 5 V				150	
Reference Voltage							
Break-Before-Make	V_{BBM}				2.5		V
PWM Input							
Input High	V_{IH}			4.0		V_{DD}	V
Input Low	V_{IL}					1.0	
Bias Current	I_B				±0.3	±1	µA
Inactivity Timeout	t_{INA}				80		µs
EN_{SYNC} Inputs							
Input High	V_{IH}			2.0		V_{DD}	V
Input Low	V_{IL}					1.0	
Bias Current	I_B					±1	µA
Bootstrap Diode							
Forward Voltage	V_F	I_F = 40 mA, T_A = 25°C		0.7	0.85	1.0	V
MOSFET Drivers							
High-Side Drive Current[c]	$I_{PKH(source)}$	$V_{BOOT} - V_{LX}$ = 8 V			0.8		A
	$I_{PKH(sink)}$				1.0		
Low-Side Drive Current[c]	$I_{PKL(source)}$	V_{DRV} = 8 V	SiP41107		0.9		
	$I_{PKL(sink)}$				1.2		
	$I_{PKL(source)}$	V_{DRV} = 12 V	SiP41106		1.4		
	$I_{PKL(sink)}$				1.8		

SPECIFICATIONS[a]

Parameter	Symbol	Test Conditions Unless Specified V_{DD} = 12 V, $V_{BOOT} - V_{LX}$ = 8 V, T_A = −40 to 85°C		Limits Min[a]	Limits Typ[b]	Limits Max[a]	Unit
MOSFET Drivers							
High-Side Driver Impedance	$R_{DH(source)}$	$V_{BOOT} - V_{LX}$ = 8 V, LX = GND			2.3	4.2	Ω
	$R_{DH(sink)}$				1.9	3.5	
Low-Side Driver Impedance	$R_{DL(source)}$	V_{DRV} = 8 V	SiP41107		2.9	5.2	
	$R_{DL(sink)}$				1.3	2.4	
	$R_{DL(source)}$	V_{DRV} = 12 V	SiP41106		2.4	4.3	
	$R_{DL(sink)}$				1.2	2.2	
High-Side Rise Time	t_{rH}	10% – 90%, $V_{BOOT} - V_{LX}$ = 8 V C_{LOAD} = 3 nF			40		ns
High-Side Fall Time	t_{fH}				30		
High-Side Rise Time Bypass		10% – 90%, $V_{BOOT} - V_{LX}$ = 12 V C_{LOAD} = 3 nF			40		
High-Side Fall Time Bypass					30		
High-Side Propagation Delay	$t_{d(off)H}$	See Timing Waveforms			20		
	$t_{d(on)H}$				25		
Low-Side Rise Time	t_{rL}	10% – 90%, $V_{BOOT} - V_{LX}$ = 8 V C_{LOAD} = 3 nF	SiP41107		35		
		10% – 90%, $V_{BOOT} - V_{LX}$ = 12 V C_{LOAD} = 3 nF	SiP41106		30		
Low-Side Fall Time	t_{fL}	10% – 90%, $V_{BOOT} - V_{LX}$ = 8 V C_{LOAD} = 3 nF	SiP41107		30		
		10% – 90%, $V_{BOOT} - V_{LX}$ = 12 V C_{LOAD} = 3 nF	SiP41106		25		
Low-Side Propagation Delay[c]	$t_{d(off)L}$	See Timing Waveforms			20		
	$t_{d(on)L}$				25		
LX Timer							
LX Falling Timeout[c]	t_{LX}				380		ns
V_{DRV} Regulator							
Output Voltage	V_{DRV}			7.6	8	8.4	V
Output Current	I_{DRV}				80	100	mA
Current Limit	I_{LIM}	V_{DRV} = 0 V		120	200	280	
Line Regulation	LNR	V_{CC} = 10.8 V to 13.2 V			0.05	0.5	%/V
Load Regulation	LDR	5 mA to 80 mA			0.1	1.0	%
V_{DRV} Regulator UVLO							
V_{DRV} Rising	V_{UVLO2}				6.7	7.2	V
V_{DRV} Falling					6.4	6.9	
Hysteresis	Hyst			100	300	500	mV
High-Side Undervoltage Lockout							
Threshold	V_{UVHS}	Rising or Falling		2.5	3.35	4.0	V
V_{DD} Undervoltage Lockout							
Threshold	V_{UVLO1}			5.0	5.3	5.6	V
Power on Reset Time	POR				2.5		ms
Thermal Shutdown							
Temperature	T_{SD}	Temperature Rising			165		°C
Hysteresis	T_H	Temperature Falling			25		

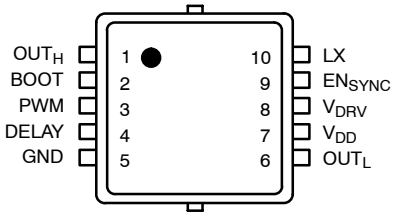
Notes
a. The algebraic convention whereby the most negative value is a minimum and the most positive a maximum (−40° to 85°C).
b. Typical values are for DESIGN AID ONLY, not guaranteed nor subject to production testing and are measured at V_{DD} = 12 V unless otherwise noted.

TIMING WAVEFORMS



PIN CONFIGURATION AND TRUTH TABLE

MLP33



Top View

TRUTH TABLE			
PWM	EN_{SYNC}	OUT_H	OUT_L
H	L	H	L
L	L	L	L
H	H	H	L
L	H	L	H

ORDERING INFORMATION		
Part Number	Temperature Range	Marking
SiP41106DM-T1—E3	–40 to 85°C	41A6
SiP41107DM-T1—E3		41A7

Eval Kit	Temperature Range
SiP41106/7DB	–40 to 85°C

PIN DESCRIPTION

Pin Number	Name	Function
1	OUT_H	8-V high-side MOSFET gate drive
2	BOOT	Bootstrap supply for high-side driver. A capacitor connects between BOOT and LX.
3	PWM	Input signal for the MOSFET drivers
4	DELAY	Connection for the high-side delay adjustment capacitor.
5	GND	Ground
6	OUT_L	Synchronous or low-side MOSFET gate drive
7	V_{DD}	12-V supply. Connect a bypass capacitor ≥ 1 μF from here to ground
8	V_{DRV}	8-V Voltage Regulator Output. Connect a bypass capacitor ≥ 1 μF from here to ground
9	EN_{SYNC}	Enables OUT_L, the driver for the synchronus MOSFET
10	LX	Connection to source of high-side MOSFET, drain of the low-side MOSFET, and the inductor

FUNCTIONAL BLOCK DIAGRAM

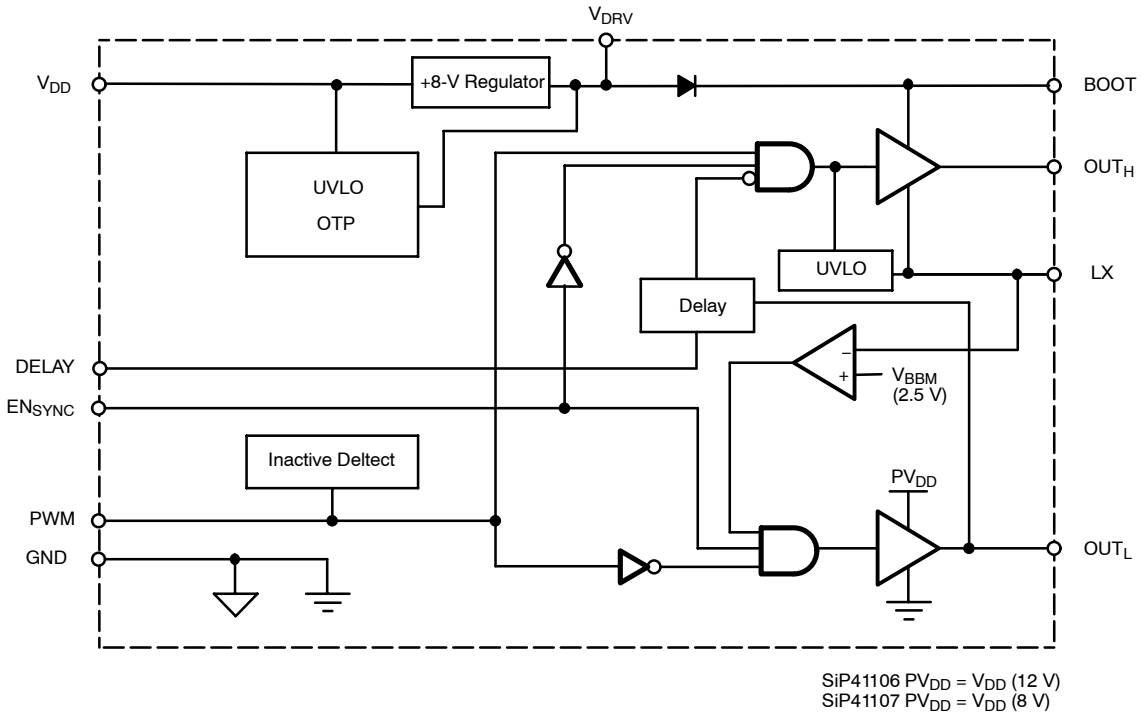


Figure 1.

DETAILED OPERATION

PWM

The PWM pin controls the switching of the external MOSFETs. The driver logic operates in a noninverting configuration. The PWM input stage should be driven by a signal with fast transition times, like those provided by a PWM controller or logic gate, (<200 ns). The PWM input functions as a logic input and is not intended for applications where a slow changing input voltage is used to generate a switching output when the input switching threshold voltage is reached.

If the PWM pin does not detect an input transition within 80 µs or frequency faster than 12 kHz, both OUTL and OUTH will be forced into the low state. In this standby mode, the part typically draws <1.5 mA from V_{DD}.

Low-Side Driver

In the SiP41106, the low-side driver voltage is supplied by V_{DD}. In the SiP41107, the low-side dirver voltage is supplied by V_{DRV}. During shutdown, OUT_L is held low.

High-Side Driver

The high-side driver is isolated from the substrate to create a floating high-side driver so that an n-channel MOSFET can be used for the high-side switch. The supplies for the high-side driver are BOOT and LX. The voltage is supplied by a floating bootstrap capacitor, which is continually recharged by the switching action of the output. During shutdown OUT_H is held low.

Gate Drive Voltage (V_{DRV}) Regulator

An integrated 80-mA, 8-V regulator supplies voltage to the V_{DRV} pin and it current limits at 200 mA typical when the output is shorted to ground. A capacitor (1 µF minimum) must be connected to the V_{DRV} pin to stabilize the regulator output. The voltage on V_{DRV} is supplied to the integrated bootstrap diode. V_{DRV} is used to recharge the bootstrap capacitor and powers the SiP41107 low-side driver. V_{DRV} pin can be externally connected to V_{DD} to bypass the 8-V regulator and increase high-side gate drive to 12 V. If the V_{DRV} is connected to V_{DD} the system voltage should not exceed 43 V.

Bootstrap Circuit

The internal bootstrap diode and an external bootstrap capacitor form a charge pump that supplies voltage to the BOOT pin. An integrated bootstrap diode replaces the external Schottky diode needed for the bootstrap circuit; only a capacitor is necessary to complete the bootstrap circuit. The bootstrap capacitor is sized according to,

$$C_{BOOT} = (Q_{GATE}/\Delta V_{BOOT-LX}) \times 10$$

where Q_{GATE} is the gate charge needed to turn on the high-side MOSFET and $\Delta V_{BOOT-LX}$ is the amount of droop allowed in the bootstrapped supply voltage when the high-side MOSFET is driven high. The bootstrap capacitor value is typically 0.1 μF to 1 μF. The bootstrap capacitor voltage rating must be greater than V_{DD} + 12 V to withstand transient spikes and ringing.

Shoot-Through Protection

The external MOSFETs are prevented from conducting at the same time during transitions. Break-before-make circuits monitor the voltages on the LX pin and the OUT_L pin and control the switching as follows: When the signal on PWM goes low, OUT_H will go low after an internal propagation delay. After the voltage on LX falls below 2.5 V by the inductor action, the low-side driver is enabled and OUT_L goes high after some delay. When the signal on PWM goes high, OUT_L will go low after an internal propagation delay. After the voltage on OUT_L drops below 2.5 V the high-side driver is enabled and OUT_H will go high after an internal propagation delay. If LX does not drop below 2.5 V within 380 ns after OUT_H goes low, OUT_L is forced high until the next PWM transition.

Delay

The addition of a capacitor between DELAY and GND will increase the propagation delay time for OUT_H going high. Delay capacitance may be added to prevent shoot through current in the low-side MOSFET due to the finite time between OUT_L going low and the continuing conduction of the low-side MOSFET. Choose a MOSFET with lower gate resistance to reduce this effect. If necessary, choose a capacitor value that prevents MOSFET conduction under worst-case temperature and manufacturing conditions. Propagation delay is increased according to the ratio of 1 ns/pF.

Synchronous MOSFET Enable

Under light load conditions, efficiency can be increased by disabling the synchronous MOSFET, thus avoiding the gate charge losses of the synchronous MOSFET. When EN_{SYNC} is low, OUT_L is forced low. When high, the low-side driver operates normally. EN_{SYNC} should be driven by a 5-V signal.

V_{DD} Bypass Capacitor

MOSFET drivers draw large peak currents from the supplies when they switch. A local bypass capacitor is required to supply this current and reduce power supply noise. Connect a 1-μF ceramic capacitor as close as practical between the V_{DD} and GND pins.

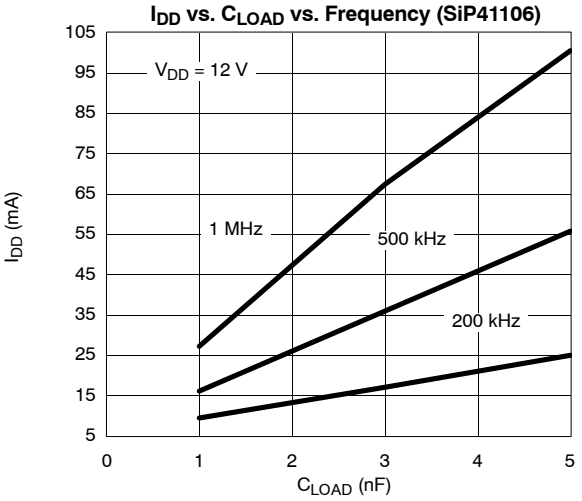
Undervoltage Lockout

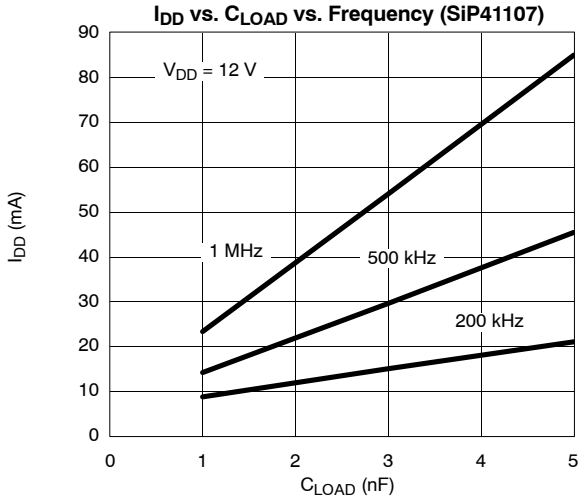
Undervoltage lockout prevents control of the circuit until the supply voltages reach valid operating levels. The UVLO circuit forces OUT_L and OUT_H to low when V_{DD} is below its specified voltage. A separate UVLO forces OUT_H low when the voltage between BOOT and LX is below the specified voltage.

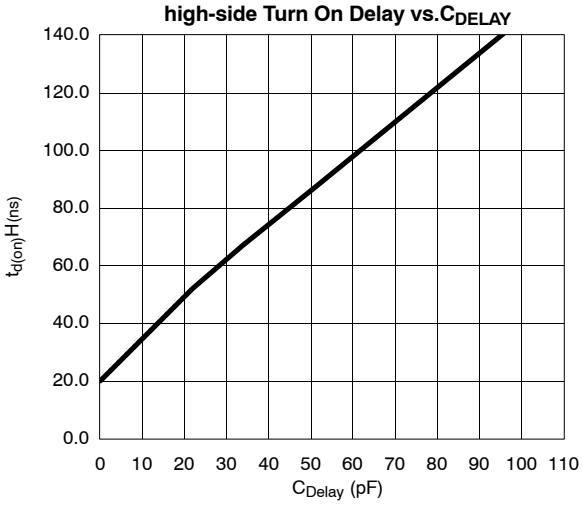
Thermal Protection

If the die temperature rises above 165°C, the thermal protection disables the drivers. The drivers are re-enabled after the die temperature has decreased below 140°C.

TYPICAL CHARACTERISTICS







TYPICAL WAVEFORMS

Figure 2. PWM Signal vs. HS Gate, LS Gate and LX (Rising)

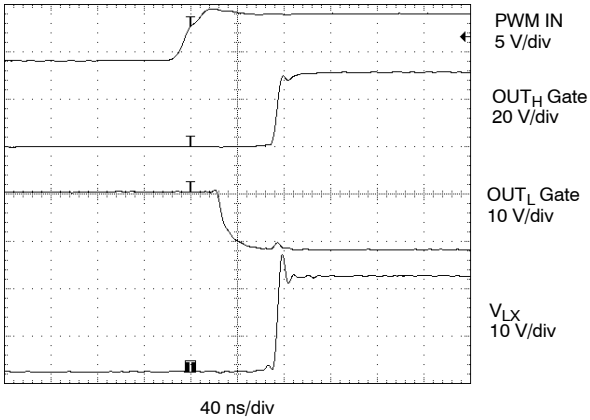
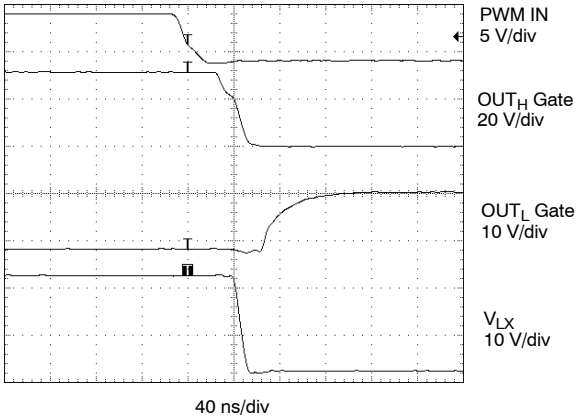


Figure 3. PWM Signal vs. HS Gate, LS Gate and LX (Falling)



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