

## Integrated DrMOS Power Stage

### DESCRIPTION

The SiC780 is an integrated power stage solution optimized for synchronous buck applications offering high current, high efficiency and high power density. Packaged in Vishay's proprietary 6 mm x 6 mm MLP package, SiC780 enables voltage regulator designs to deliver in excess of 50 A per phase current with 93 % peak efficiency.

The internal Power MOSFETs utilize Vishay's state-of-the-art TrenchFET Gen III Technology that delivers industry benchmark performance by significantly reducing switching and conduction losses.

The SiC780 incorporates an advanced MOSFET gate driver IC that features high current driving capability, adaptive dead-time control, and integrated bootstrap Schottky diode, and a thermal warning (THDN) that alerts the system of excessive junction temperature. The driver is also compatible with a wide range of PWM controllers and supports Tri-state PWM, 3.3 V (SiC780ACD)/5 V (SiC780CD) PWM Logic, and skip mode (SMOD) to improve light load efficiency.

### FEATURES

- Thermally enhanced PowerPAK MLP6x6-40L package
- Industry benchmark MOSFET with integrated schottky diode
- Delivers in excess of 50 A continuous current
- 93 % peak efficiency
- High frequency operation up to 1 MHz
- Power MOSFETs optimized for 12 V input stage
- 3.3 V (SiC780ACD)/5 V (SiC780CD) PWM logic with Tri-state and hold-off
- SMOD logic for light load efficiency boost
- Low PWM propagation delay (< 20 ns)
- Thermal monitor flag
- Enable feature
- V<sub>CIN</sub> UVLO
- Compliant with Intel DrMOS 4.0 specification
- Material categorization: For definitions of compliance please see [www.vishay.com/doc?99912](http://www.vishay.com/doc?99912)



### APPLICATIONS

- Synchronous buck converters
- Multi-phase VRDs for CPU, GPU and memory
- DC/DC POL modules

### TYPICAL APPLICATION DIAGRAM

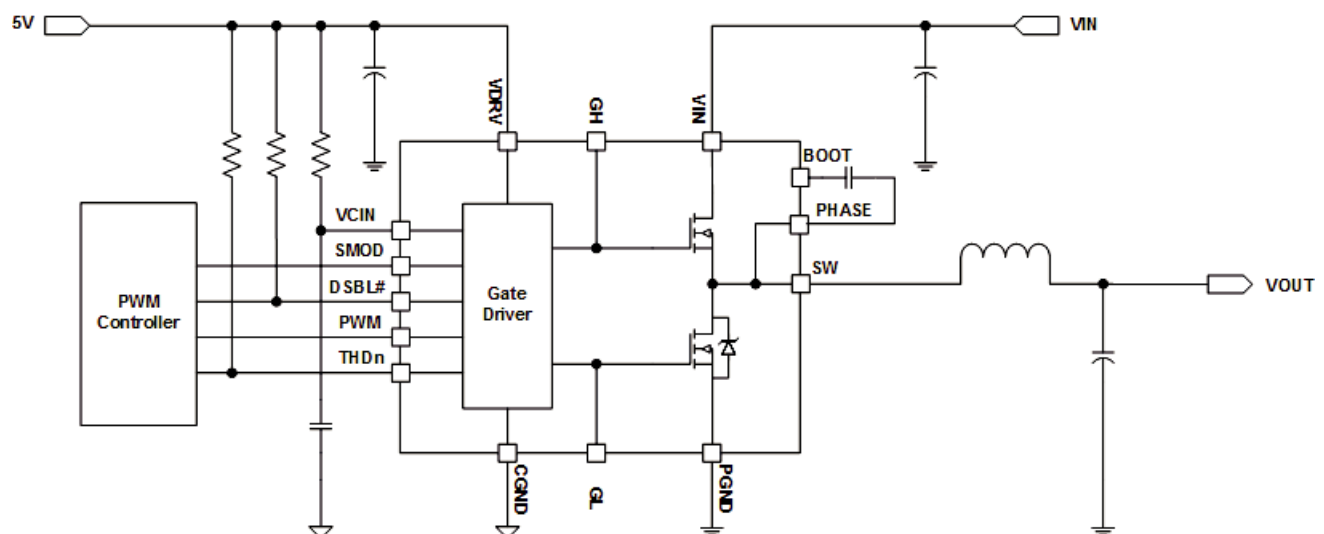


Figure 1: SiC780 Typical Application Diagram

## PIN CONFIGURATION - Bottom View

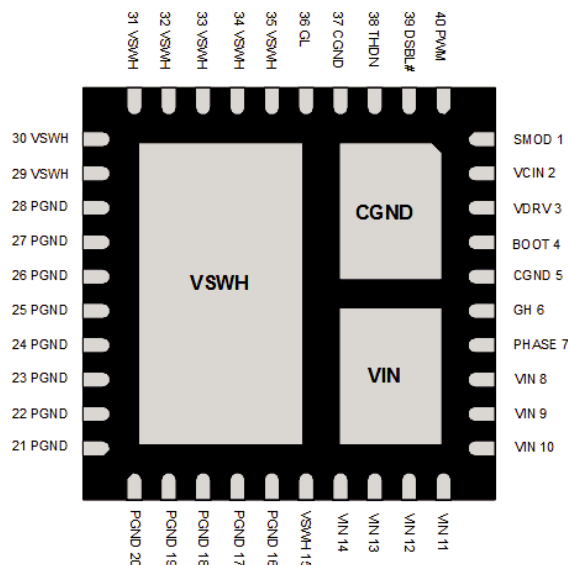


Figure 2 - SiC780 Pin Configuration

PIN DESCRIPTION		
Pin Number	Symbol	Description
1	SMOD#	LS FET turn-off logic. Active low
2	V <sub>CIN</sub>	Supply voltage for internal logic circuitry
3	V <sub>DRV</sub>	Supply voltage for internal gate driver
4	BOOT	High side driver bootstrap voltage
5, 37, P1	C <sub>GND</sub>	Analog ground for the driver IC
6	GH	High side gate signal
7	PHASE	Return path of HS Gate driver
8 to 14, P2	V <sub>IN</sub>	Power stage input voltage. Drain of high side MOSFET
15, 29 to 35, P3	V <sub>SWH</sub>	Phase node of the power stage
16 to 28	P <sub>GND</sub>	Power ground
36	GL	Low side gate signal
38	THDN	Thermal shutdown open drain output
39	DSBL#	Disable pin. Active low
40	PWM	PWM input logic



<b>ORDERING INFORMATION</b>		
Part Number	Package	Marking Code
SiC780CD-T1-GE3	PowerPAK MLP66-40L	SiC780CD
SiC780ACD-T1-GE3	PowerPAK MLP66-40L	SiC780A
SiC780DB	Reference Board	

<b>ABSOLUTE MAXIMUM RATINGS <sup>(1)</sup></b>			
Electrical Parameter	Symbol	Limits	Unit
Input Voltage	$V_{IN}$	- 0.3 to 22	V
Control Input Voltage	$V_{CIN}$	- 0.3 to 7	
Drive Input Voltage	$V_{DRV}$	- 0.3 to 7	
Switch Node (DC)	$V_{SW}$	- 0.3 to 22	
Switch Node (AC) <sup>(2)</sup>	$V_{SW}$	- 0.3 to 27	
Boot Voltage (DC Voltage)	$V_{BS}$	- 0.3 to 29	
Boot to Switching Node (DC Voltage)	$V_{BS\_SW}$	- 0.3 to 7	
All Logic Inputs and Outputs (PWM, DSBL, SMOD and THDN)		- 0.3 to $V_{CIN} + 0.3$	
Max. Operating Junction Temperature	$T_J$	150	°C
Ambient Temperature	$T_A$	- 40 to 125	
Storage Temperature		- 65 to 150	

Notes:

- 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.
- The specification values indicated "AC" is  $V_{SW}$  to  $P_{GND}$  27 V (< 50 ns), max.

<b>RECOMMENDED OPERATING CONDITIONS</b>				
Parameter	Min.	Typ.	Max.	Unit
Input Voltage ( $V_{IN}$ )	4.5		18	V
Drive Input Voltage ( $V_{DRV}$ )	4.5	5	5.5	
Control Input Voltage ( $V_{CIN}$ )	4.5	5	5.5	
Switching Node (LX, DC Voltage)			19	
BOOT-SW	4	4.5	5.5	

<b>THERMAL RESISTANCE RATINGS</b>				
Parameter	Min.	Typ.	Max.	Unit
Thermal Resistance from Junction to Case (to P3 PAD ( $V_{SHW}$ ))		2.5		°C/W
Thermal Resistance from Junction to PCB		5		

ELECTRICAL SPECIFICATIONS						
Parameter	Symbol	Test Conditions Unless Specified $V_{DSBL\#} = 5\text{ V}$ , $V_{SMOD} = 5\text{ V}$ , $V_{IN} = 12\text{ V}$ , $V_{DRV} = V_{CIN} = 5\text{ V}$ , $T_A = 25\text{ }^\circ\text{C}$	Min. <sup>(3)</sup>	Typ. <sup>(1)</sup>	Max. <sup>(3)</sup>	Unit
<b>Power Supplies</b>						
$V_{CIN}$ Control Logic Input Current	$I_{VCIN}$	$V_{DSBL\#} = 0\text{ V}$ , no switching		100		$\mu\text{A}$
		$V_{DSBL\#} = 5\text{ V}$ , no switching		300		
		$V_{DSBL\#} = 5\text{ V}$ , $f_s = 300\text{ kHz}$ , $D = 0.1$		300		
Drive Input Current (Dynamic)	$I_{VDRV}$	$f_s = 300\text{ kHz}$ , $D = 0.1$		16	25	$\text{mA}$
		$f_s = 1\text{ MHz}$ , $D = 0.1$		60		
Drive Input Current (No Switching)	$I_{VDRV}$	$V_{DSBL\#} = 0\text{ V}$ , no switching		30		$\mu\text{A}$
		$V_{DSBL\#} = 5\text{ V}$ , no switching		60		
<b>Bootstrap Supply</b>						
Bootstrap Switch Forward Voltage	$V_F$	$V_{CIN} = 5\text{ V}$ , forward bias current 2 mA			0.4	V
<b>PWM Control Input (SiC780CD)</b>						
Rising Threshold	$V_{th\_pwm\_r}$		3.4	3.7	4.2	V
Falling Threshold	$V_{th\_pwm\_f}$		0.7	0.9	1.2	
Tri-state Voltage	$V_{tri}$	PWM pin floating		2.3		
Tri-state Rising Threshold	$V_{th\_tri\_r}$		0.9		1.5	
Tri-state Falling Threshold	$V_{th\_tri\_f}$		3	3.4	3.7	
Tri-state Rising Threshold Hysteresis	$V_{hys\_tri\_r}$			225		mV
Tri-state Falling Threshold Hysteresis	$V_{hys\_tri\_f}$			325		
PWM Input Current	$I_{PWM}$	$V_{PWM} = 5\text{ V}$			500	$\mu\text{A}$
		$V_{PWM} = 0\text{ V}$			- 500	
<b>PWM Control Input (SiC780ACD)</b>						
Rising Threshold	$V_{th\_pwm\_r}$		2.1	2.4	2.8	V
Falling Threshold	$V_{th\_pwm\_f}$		0.7	0.9	1.2	
Tri-state Voltage	$V_{tri}$	PWM pin floating		1.8		
Tri-state Rising Threshold	$V_{th\_tri\_r}$		0.9		1.5	
Tri-state Falling Threshold	$V_{th\_tri\_f}$		1.9	2.2	2.6	
Tri-state Rising Threshold Hysteresis	$V_{hys\_tri\_r}$			225		mV
Tri-state Falling Threshold Hysteresis	$V_{hys\_tri\_f}$			275		
PWM Input Current	$I_{PWM}$	$V_{PWM} = 3.3\text{ V}$			300	$\mu\text{A}$
		$V_{PWM} = 0\text{ V}$			- 300	

## Notes:

1. Typical limits are established by characterization and are not production tested.
2. Guaranteed by design.
3. Min. and max. parameters are not 100 % production tested.



<b>ELECTRICAL SPECIFICATIONS</b>						
Parameter	Symbol	Test Conditions Unless Specified $V_{DSBL\#} = V_{SMOD} = 5\text{ V}$ , $V_{IN} = 12\text{ V}$ , $V_{VDRV} = V_{VCIN} = 5\text{ V}$ , $T_A = 25\text{ }^\circ\text{C}$	Min. <sup>(3)</sup>	Typ. <sup>(1)</sup>	Max. <sup>(3)</sup>	Unit
<b>Timing Specifications</b>						
Tri-State to GH/GL Rising Propagation Delay	$T_{PD\_R\_Tri}$	No load, see fig. 4.		20		ns
Tri-state Hold-Off Time	$T_{TSHO}$			150		
GH - Turn Off Propagation Delay	$T_{PD\_OFF\_GH}$			20		
GH - Turn ON Propagation Delay (Dead Time Rising)	$T_{PD\_ON\_GH}$			10		
GL - Turn Off Propagation Delay	$T_{PD\_OFF\_GL}$			20		
GL - Turn On Propagation Delay (Dead Time Falling)	$T_{PD\_ON\_GL}$			10		
DSBL# Hi to GH/GL Rising Propagation Delay	$T_{PD\_R\_DSBL}$				22	
DSBL# Lo to GH/GL Falling Propagation Delay	$T_{PD\_F\_DSBL}$			10		
<b>DSBL#, SMOD INPUT</b>						
DSBL# Logic Input Voltage	$V_{DSBL}$	Enable	2			V
		Disenable			0.8	
SMOD Logic Input Voltage	$V_{SMOD}$	High State	2			
		Low State			0.8	
<b>Protection</b>						
Under Voltage Lockout	$V_{UVLO}$	Rising, On Threshold		3.7	4.3	V
		Falling, Off Threshold	2.7	3.2		
Under Voltage Lockout Hysteresis		Note 2		550		mV
THDn Flag Set				160		°C
THDn Flag Clear				135		
THDn Flag Hysteresis				25		
THDn Output Low					0.02	

Notes:

1. Typical limits are established by characterization and are not production tested.
2. Guaranteed by design.
3. Min. and max. parameters are not 100 % production tested.

## DETAILED OPERATIONAL DESCRIPTION

### PWM Input with Tri-state Function

The PWM input receives the PWM control signal from the VR controller IC. The PWM input is designed to be compatible with standard controllers using two state logic (H and L) and advanced controllers that incorporate Tri-state logic (H, L and Tri-state) on the PWM output. For two state logic, the PWM input operates as follows. When PWM is driven above  $V_{th\_pwm\_r}$  the low side is turned OFF and the high side is turned ON. When PWM input is driven below  $V_{th\_pwm\_f}$  the high side turns off and the Low side turns on. For Tri-state logic, the PWM input operates as above for driving the MOSFETs. However, there is an third state that is entered into as the PWM output of Tri-state compatible controller enters its high impedance state during shut-down. The high impedance state of the controller's PWM output allows the SiC780A to pull the PWM input into the Tri-state region (see the Tri-state Voltage Threshold Diagram below). If the PWM input stays in this region for the Tri-state Hold-Off Period,  $t_{TSHO}$ , both high side and low side MOSFETs are turned off. This function allows the VR phase to be disabled without negative output voltage swing caused by inductor ringing and saves a schottky diode clamp. The PWM and Tri-state regions are separated by hysteresis to prevent false triggering. The SiC780ACD incorporates PWM voltage thresholds that are compatible with 3.3 V logic, and SiC780CD is 5 V logic.

### Disable (DSBL#)

In the low state, the DSBL# pin shuts down the driver IC and disables both high-side and low-side MOSFET. In this state, the standby current is minimized. If DSBL# is left unconnected an internal pull-down resistor will pull the pin down to  $C_{GND}$  and shut down the IC.

### Diode Emulation Mode (SMOD) Skip

When SMOD pin is low the diode emulation mode is enabled and GL is turned off. This is a non-synchronous conversion mode that improves light load efficiency by reducing switching losses. Conducted losses that occur in synchronous buck regulators when inductor current is negative can also be reduced. Circuitry in the external controller IC detects when inductor current crosses zero and drive SMOD Lo turning the low side MOSFET off. See SMOD Operation diagram for additional details. This function can be also be used for a pre-biased output voltage. If SMOD is left unconnected, an internal pull up resistor will pull the pin up to  $V_{CIN}$  (Logic High) to disable the SMOD function.

### Thermal Shutdown Warning (THDN)

The THDN pin is an open drain signal that flags the presence of excessive junction temperature. Connect a maximum of 20 k $\Omega$  to pull this pin up to  $V_{CIN}$ . An internal temperature sensor detects the junction temperature. The temperature threshold is 160 °C. When this junction temperature is exceeded the THDN flag is set. When the junction temperature drops below 135 °C the device will clear the THDN signal. The SiC780 does not stop

operation when the flag is set. The decision to shutdown must be made by an external thermal control function.

### Voltage Input ( $V_{IN}$ )

This is the power input to the drain of the high-side Power MOSFET. This pin is connected to the high power intermediate BUS rail.

### Switch Node ( $V_{SWH}$ and PHASE)

The Switch node  $V_{SWH}$  is the circuit PWM regulated output. This is the output applied to the filter circuit to deliver the regulated high output for the buck converter. The PHASE pin is internally connected to the switch node  $V_{SWH}$ . This pin is to be used exclusively as the return pin for the BOOT capacitor. A 20.2 k $\Omega$  resistor is connected between GH and PHASE to provide a discharge path for the HS MOSFET in the event that  $V_{CIN}$  goes to zero while  $V_{IN}$  is still applied.

### Ground connections ( $C_{GND}$ and $P_{GND}$ )

$P_{GND}$  (power ground) should be externally connected to  $C_{GND}$  (control signal ground). The layout of the Printed Circuit Board should be such that the inductance separating the  $C_{GND}$  and  $P_{GND}$  should be a minimum. Transient differences due to inductance effects between these two pins should not exceed 0.5 V.

### Control and Drive Supply Voltage Input ( $V_{DRV}$ , $V_{CIN}$ )

$V_{CIN}$  is the bias supply for the gate drive control IC.  $V_{DRV}$  is the bias supply for the gate drivers. It is recommended to separate these pins through a resistor. This creates a low pass filtering effect to avoid coupling of high frequency gate drive noise into the IC.

### Bootstrap Circuit (BOOT)

The internal bootstrap switch and an external bootstrap capacitor form a charge pump that supplies voltage to the BOOT pin. An integrated bootstrap diode is incorporated so that only an external capacitor is necessary to complete the bootstrap circuit. Connect a boot strap capacitor with one leg tied to BOOT pin and the other tied to PHASE pin. Shoot-Through Protection and Adaptive Dead Time

### Shoot-Through Protection and Adaptive Dead Time (AST)

The SiC780A has an internal adaptive logic to avoid shoot through and optimize dead time. The shoot through protection ensures that both high-side and low-side MOSFET are not turned on the same time. The adaptive dead time control operates as follows. The HS and LS gate voltages are monitored to prevent the one turning on until the other's gate voltage is sufficiently low (1 V), that and built in delays ensure the one Power MOS is completely off, before the other can be turned on. This feature helps to adjust dead time as gate transitions change with respect to output current and temperature.

### Under Voltage Lockout (UVLO)

During the start up cycle, the UVLO disables the gate drive holding high-side and low-side MOSFET gate low until the input voltage rail has reached a point at which the logic circuitry can be safely activated. The SiC780A also

incorporates logic to clamp the gate drive signals to zero when the UVLO falling edge triggers the shutdown of the device. As an added precaution, a 20.2 kΩ resistor is connected between GH and PHASE to provide a discharge path for the HS MOSFET.

### FUNCTIONAL BLOCK DIAGRAM

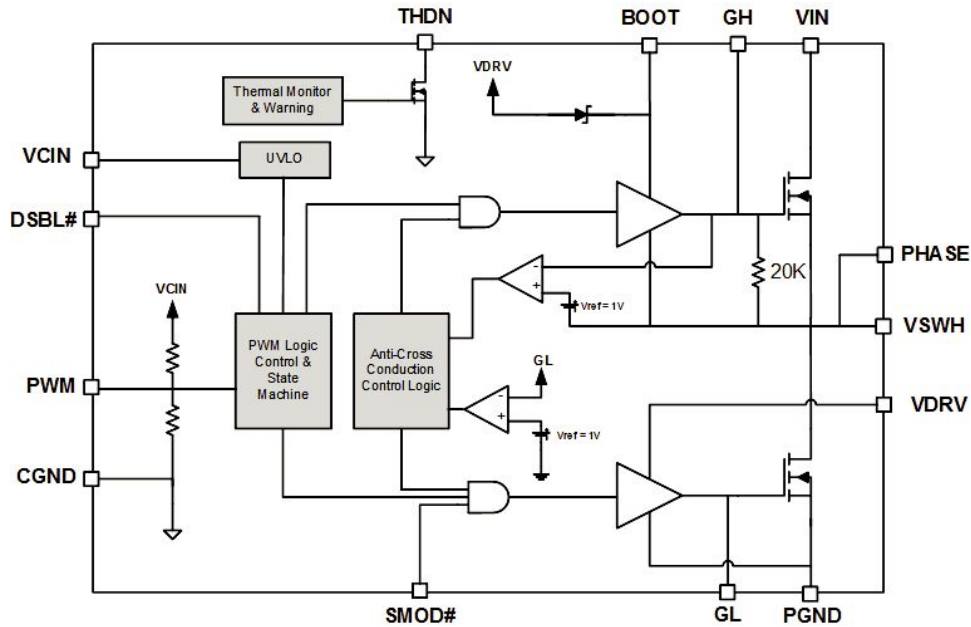


Figure 3: SiC780 Functional Block Diagram

DEVICE TRUTH TABLE				
DSBL#	SMOD	PWM	GH	GL
Open	X	X	L	L
L	X	X	L	L
H	L	L	L	L
H	L	H	H	L
H	H	H	H	L
H	H	L	L	H
H	L	Tri-state	L	L
H	H	Tri-state	L	L

## PWM TIMING DIAGRAM

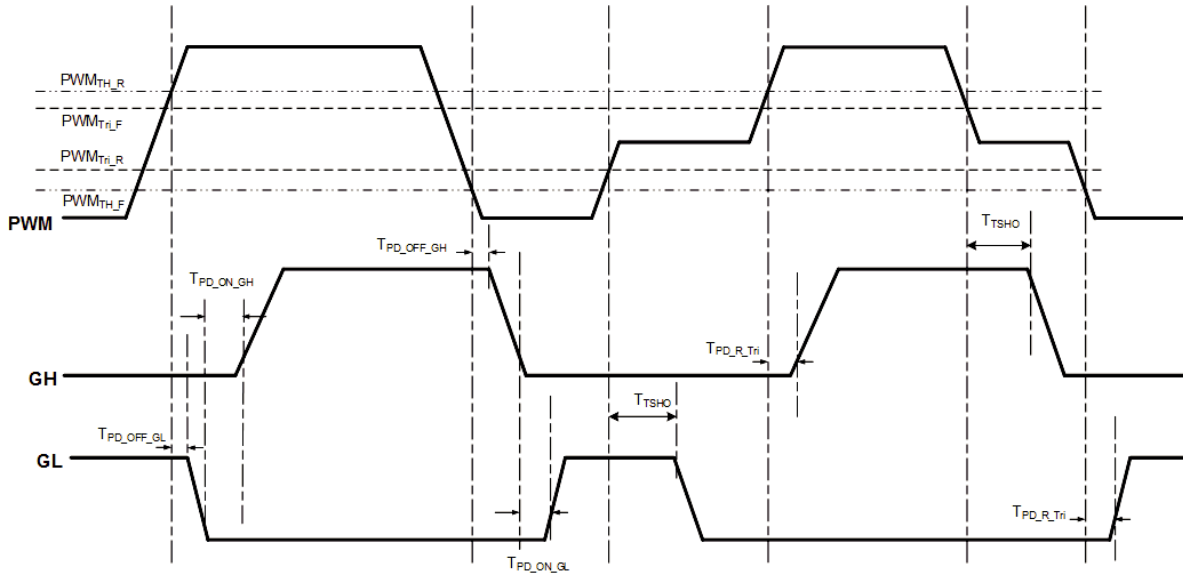


Figure 4: Definition of PWM Logic and Tri-state

## SMOD OPERATION DIAGRAM

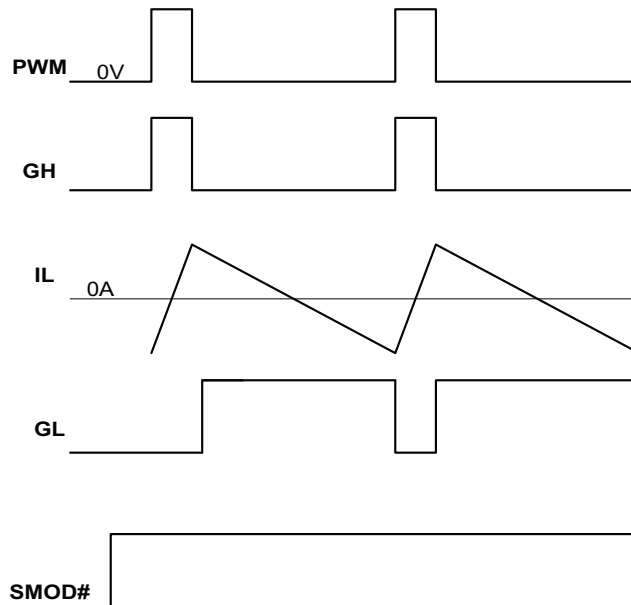
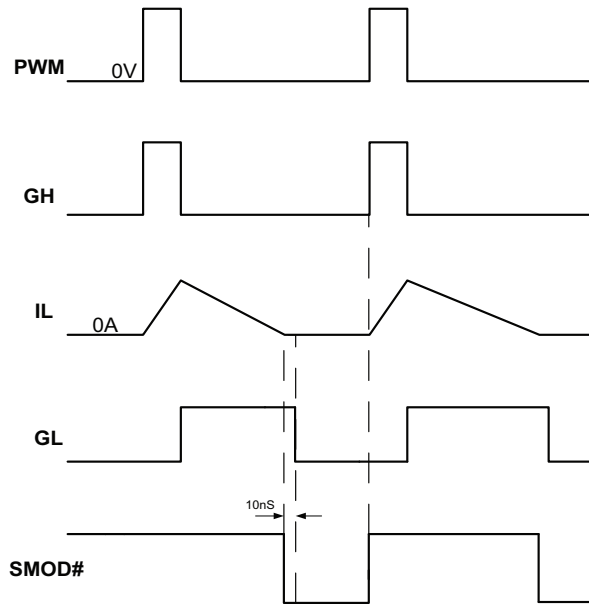


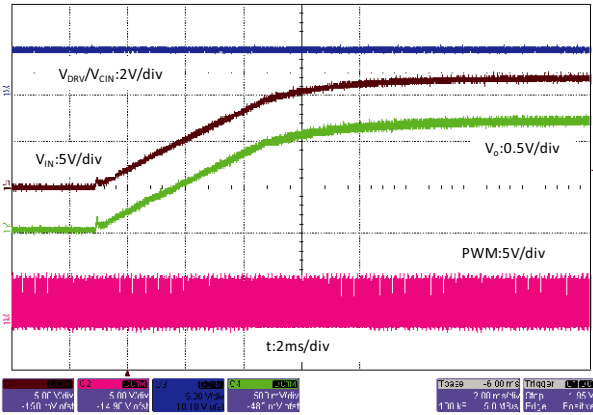
Figure 5: CCM Operation with SMOD# = HIGH



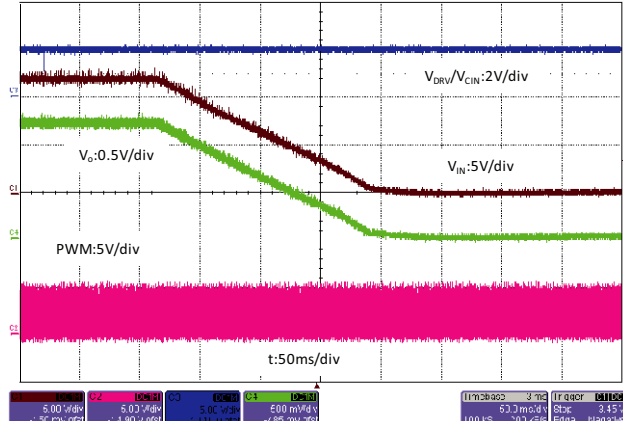


**Figure 6: DCM Operation with SMOD# = Active Toggle**

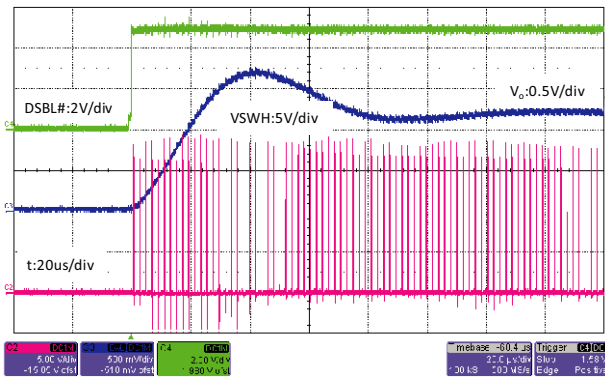
## ELECTRICAL CHARACTERISTICS



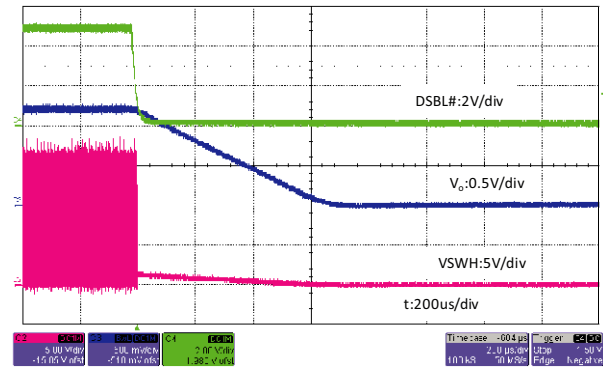
**Startup with  $V_{IN}$  Ramping Up**  
 $V_{IN} = 12\text{ V}$ ,  $V_{OUT} = 1.2\text{ V}$ ,  $F_{SW} = 500\text{ kHz}$ ,  $I_{OUT} = 0\text{ A}$



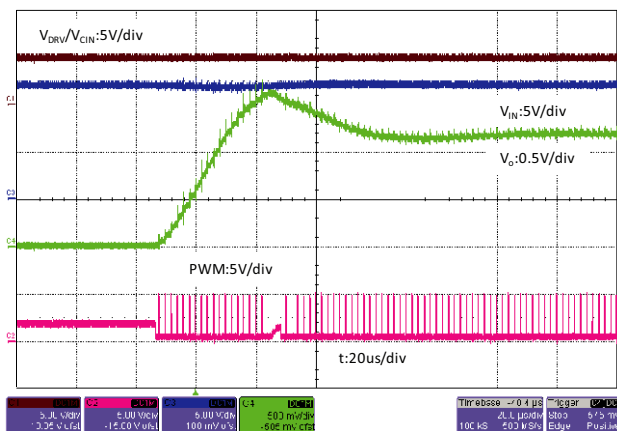
**Power Off with  $V_{IN}$  Ramping Down**  
 $V_{IN} = 12\text{ V}$ ,  $V_{OUT} = 1.2\text{ V}$ ,  $F_{SW} = 500\text{ kHz}$ ,  $I_{OUT} = 1.2\text{ A}$



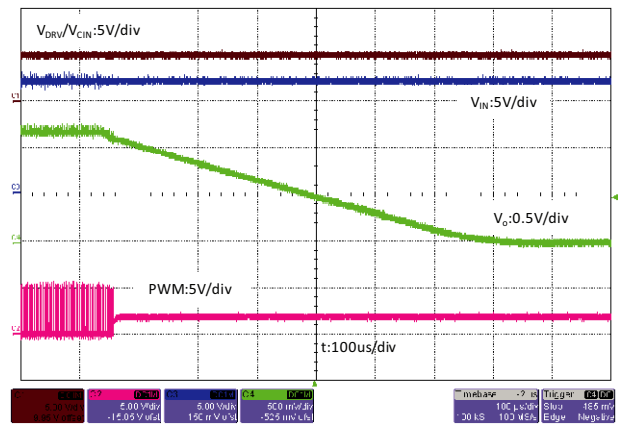
**Enable with  $V_{IN} = 12\text{ V}$ ,**  
 $V_{OUT} = 1.2\text{ V}$ ,  $F_{SW} = 500\text{ kHz}$ ,  $I_{OUT} = 1.2\text{ A}$



**Disable with  $V_{IN} = 12\text{ V}$ ,**  
 $V_{OUT} = 1.2\text{ V}$ ,  $F_{SW} = 500\text{ kHz}$ ,  $I_{OUT} = 1.2\text{ A}$

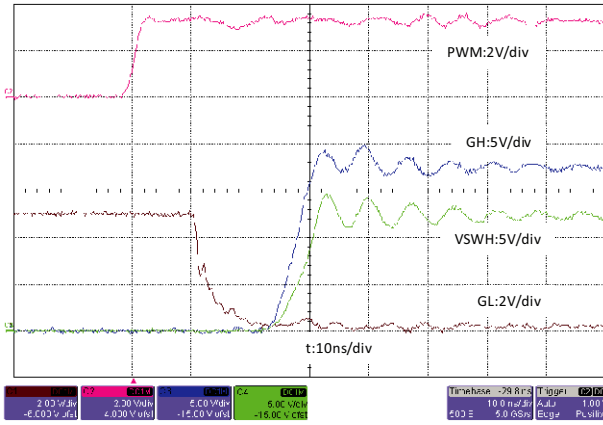


**PWM Start with  $V_{IN} = 12\text{ V}$ ,**  
 $V_{OUT} = 1.2\text{ V}$ ,  $F_{SW} = 500\text{ kHz}$ ,  $I_{OUT} = 1.2\text{ A}$

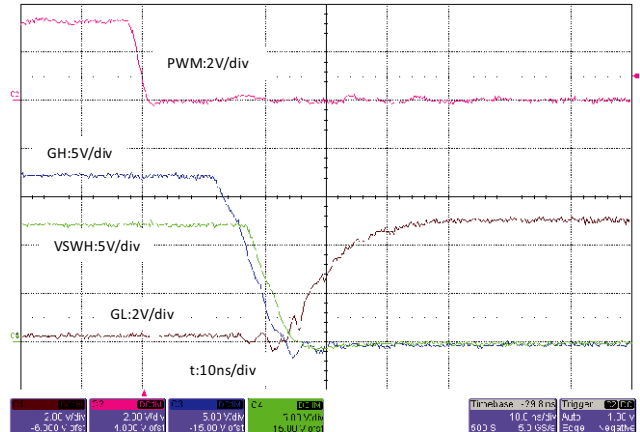


**PWM Turn-off with  $V_{IN} = 12\text{ V}$ ,**  
 $V_{OUT} = 1.2\text{ V}$ ,  $F_{SW} = 500\text{ kHz}$ ,  $I_{OUT} = 1.2\text{ A}$

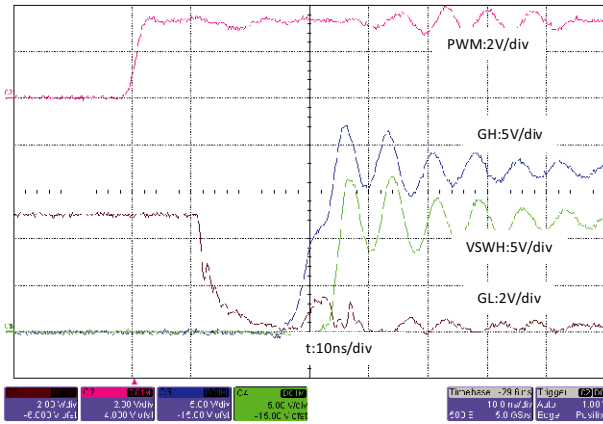
## ELECTRICAL CHARACTERISTICS



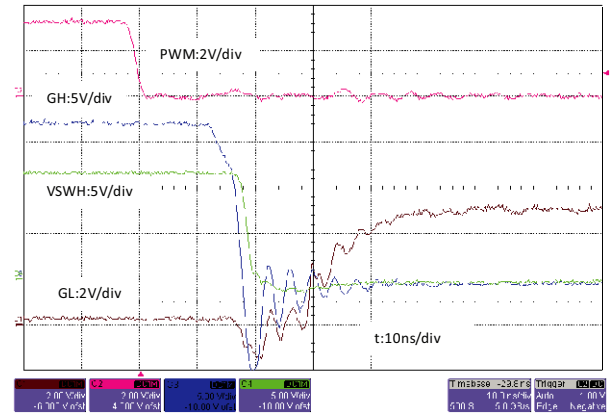
**Switching Waveform at PWM Rising Edge**  
 $V_{IN} = 12\text{ V}$ ,  $V_{OUT} = 1.2\text{ V}$ ,  $F_{SW} = 500\text{ kHz}$ ,  $I_{OUT} = 0\text{ A}$



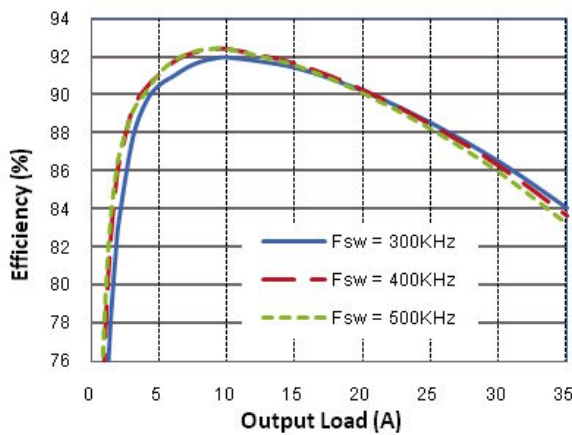
**Switching Waveform at PWM Falling Edge**  
 $V_{IN} = 12\text{ V}$ ,  $V_{OUT} = 1.2\text{ V}$ ,  $F_{SW} = 500\text{ kHz}$ ,  $I_{OUT} = 0\text{ A}$



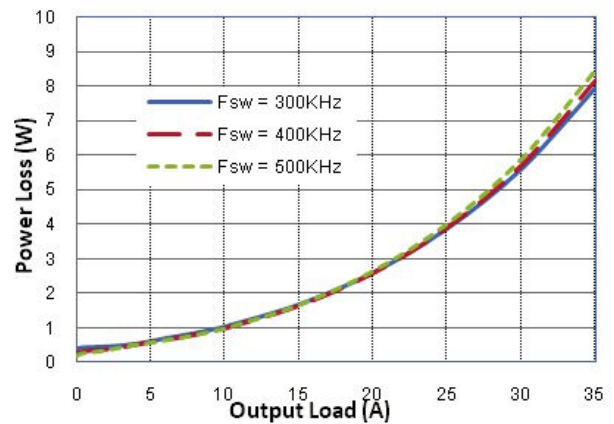
**Switching Waveform at PWM Rising Edge**  
 $V_{IN} = 12\text{ V}$ ,  $V_{OUT} = 1.2\text{ V}$ ,  $F_{SW} = 500\text{ kHz}$ ,  $I_{OUT} = 30\text{ A}$



**Switching Waveform at PWM Falling Edge**  
 $V_{IN} = 12\text{ V}$ ,  $V_{OUT} = 1.2\text{ V}$ ,  $F_{SW} = 500\text{ kHz}$ ,  $I_{OUT} = 30\text{ A}$

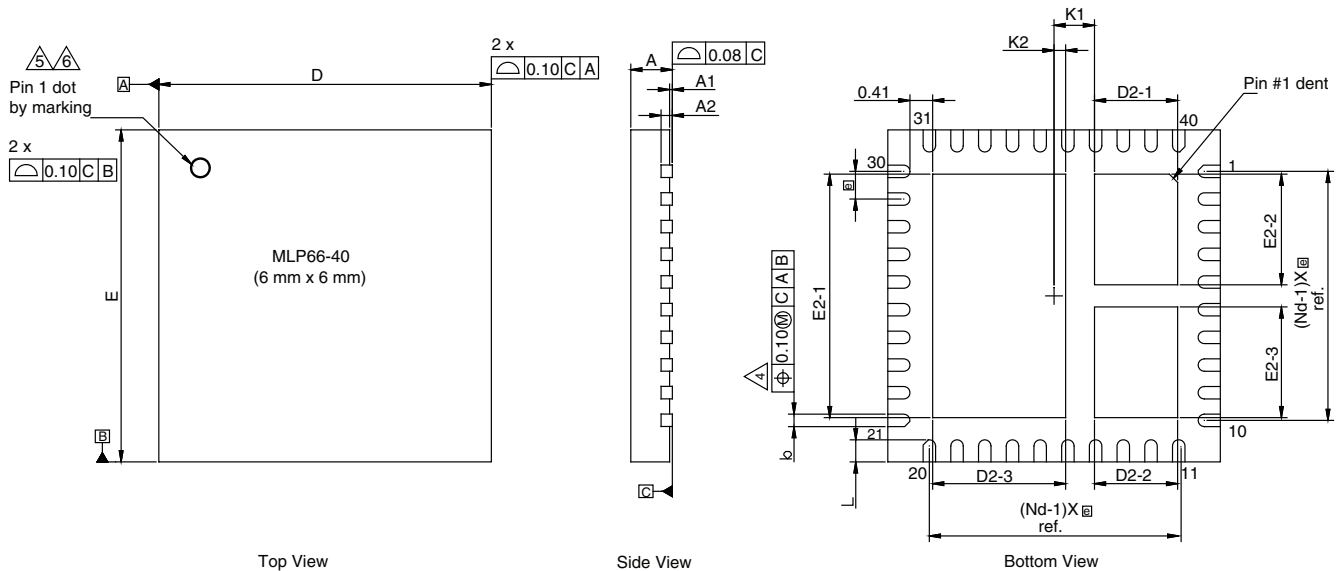


**Typical Efficiency**  
 $V_{IN} = 12\text{ V}$ ,  $V_{OUT} = 1.2\text{ V}$ ,  $V_{DRV} = V_{CIN}$ ; NO AIR FLOW,  
 O/P Inductance = 0.33  $\mu\text{H}$



**Typical Power Loss**  
 $V_{IN} = 12\text{ V}$ ,  $V_{OUT} = 1.2\text{ V}$ ,  $V_{DRV} = V_{CIN}$ ; NO AIR FLOW,  
 O/P Inductance = 0.33  $\mu\text{H}$

### PACKAGE DIMENSIONS



DIM	MILLIMETERS			INCHES		
	Min.	Nom.	Max.	Min.	Nom.	Max.
A <sup>(8)</sup>	0.70	0.75	0.80	0.027	0.029	0.031
A1	0	-	0.05	0	-	0.002
A2	0.20 ref.			0.008 ref.		
b <sup>(4)</sup>	0.20	0.25	0.30	0.078	0.098	0.111
D	6.00 BSC			0.236 BSC		
e	0.50 BSC			0.019 BSC		
E	6.00 BSC			0.236 BSC		
L	0.35	0.40	0.45	0.013	0.015	0.017
N <sup>(3)</sup>	40			40		
Nd <sup>(3)</sup>	10			10		
Ne <sup>(3)</sup>	10			10		
D2-1	1.45	1.50	1.55	0.057	0.059	0.061
D2-2	1.45	1.50	1.55	0.057	0.059	0.061
D2-3	2.35	2.40	2.45	0.095	0.094	0.096
E2-1	4.35	4.40	4.45	0.171	0.173	0.175
E2-2	1.95	2.00	2.05	0.076	0.078	0.080
E2-3	1.95	2.00	2.05	0.076	0.078	0.080
K1	0.73 BSC			0.028 BSC		
K2	0.21 BSC			0.008 BSC		

**Notes:**

1. Use millimeters as the primary measurement.
2. Dimensioning and tolerances conform to ASME Y14.5M-1994.
3. N is the number of terminals.  
Nd is the number of terminals in X-direction and Ne is the number of terminals in Y-direction.
4. Dimension b applies to plated terminal and is measured between 0.20 mm and 0.25 mm from terminal tip.
5. The pin #1 identifier must be existed on the top surface of the package by using indentation mark or other feature of package body.
6. Exact shape and size of this feature is optional.
7. Package warpage max. 0.08 mm.
8. Applied only for terminals.

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