

55 A VRPower® Integrated Power Stage

DESCRIPTION

The SiC674A is a high frequency integrated power stage optimized for synchronous buck applications to offer high current, high efficiency, and high power density performance with very low shutdown current. Packaged in Vishay's 5 mm x 5 mm MLP package, SiC674A enable voltage regulator designs to deliver up to 55 A continuous current per phase.

The internal power MOSFETs utilize Vishay's latest TrenchFET® technology that delivers industry benchmark performance to significantly reduce switching and conduction losses.

The SiC674A incorporate an advanced MOSFET gate driver IC that features high current driving capability, adaptive dead-time control, an integrated bootstrap switch, and user selectable zero current detection to improve light load efficiency. The driver is also compatible with a wide range of PWM controllers, supports tri-state PWM, and 3.3 V PWM logic.

The device also supports PS4 mode to reduce power consumption when the system is in standby state, and warning flags that improve the reliability.

APPLICATIONS

- Multi-phase VRDs for computing, graphics card and memory
- Intel core processor power delivery
 - V_{CORE} , $V_{GRAPHICS}$, $V_{SYSTEM\ AGENT}$
 - V_{CCGI}
- Up to 24 V rail input DC/DC VR modules

FEATURES

- Highly efficient
 - Thermally enhanced PowerPAK® MLP55-31L package
 - Vishay's latest TrenchFET technology and low side MOSFET with integrated Schottky diode
 - Integrated, low impedance, bootstrap switch
 - Power MOSFETs optimized for 19 V input stage
 - Supports PS4 mode light load requirement with low shutdown supply current (5 V, 3 μ A)
 - Zero current detection for improved light load efficiency
- Highly versatile
 - 3.3 V PWM logic with tri-state and hold-off timer
 - 5 V DSBL#, ZCD_EN# logic with PS4 state support
 - High frequency operation up to 2 MHz
- Robust and reliable
 - Delivers in excess of 55 A continuous current, 70 A, peak (10 ms) and 100 A, peak (10 μ s)
 - Over temperature flag
 - Over temperature protection
 - Under-voltage lockout protection
- Effective monitoring and reporting
 - Warnings and faults reporting flag
- Material categorization: for definitions of compliance please see www.vishay.com/doc?99912



RoHS
COMPLIANT
HALOGEN
FREE

TYPICAL APPLICATION DIAGRAM

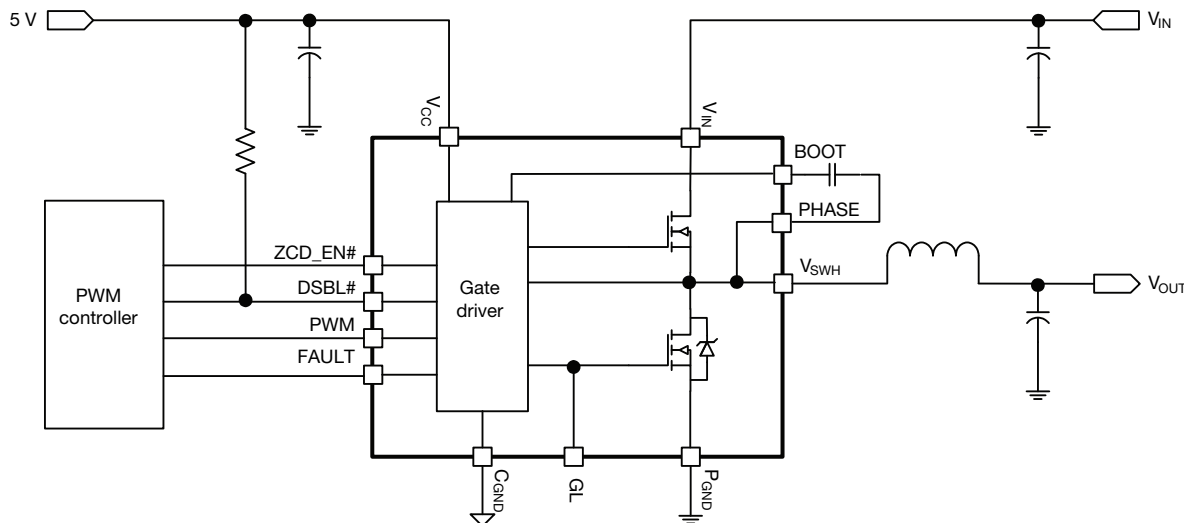
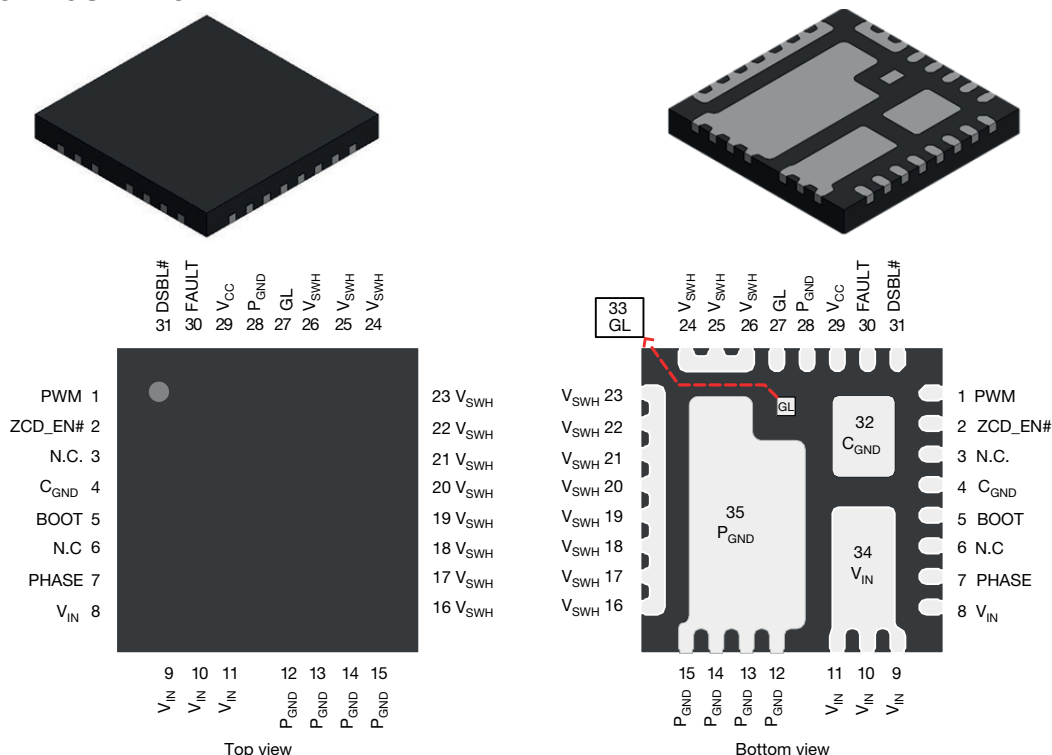
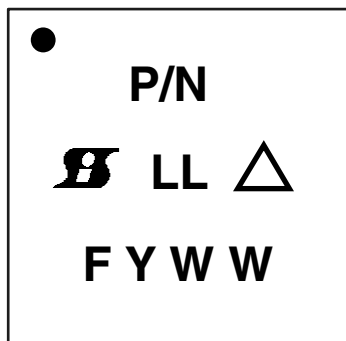




Fig. 1 - Typical Application Diagram

PINOUT CONFIGURATION

Fig. 2 - Pin Configuration

PIN CONFIGURATION		
PIN NUMBER	NAME	FUNCTION
1	PWM	PWM input
2	ZCD_EN#	The ZCD_EN# pin enables or disables diode emulation. When ZCD_EN# is LOW, diode emulation is allowed. When ZCD_EN# is HIGH, continuous conduction mode is forced. ZCD_EN# can also be put in a high impedance mode by floating the pin. If ZCD_EN# is floating, the device shuts down and consumes typically 3 μ A (10 μ A max.) current.
3	N.C.	Not connected
5	BOOT	High side driver bootstrap voltage
4, 32	C _{GND}	Analog ground
6	N.C.	Not connected
7	PHASE	Return path of high side gate driver
8 to 11, 34	V _{IN}	Power stage input voltage. Drain of high side MOSFET
12 to 15, 28, 35	P _{GND}	Power ground
16 to 26	V _{SWH}	Phase node of the power stage
27, 33	GL	Low side MOSFET gate signal
29	V _{CC}	Supply voltage
30	FAULT#	FAULT flag output
31	DSBL#	Disable input, active low

ORDERING INFORMATION			
PART NUMBER	PACKAGE	MARKING CODE	OPTION
SiC674ACD-T1-GE3	PowerPAK MLP55-31L	SiC674A	3.3 V PWM optimized
SiC674ADB		Reference board	

PART MARKING INFORMATION


- = Pin 1 Indicator
- P/N = Part Number Code
-  = Siliconix Logo
-  = ESD Symbol
- F = Assembly Factory Code
- Y = Year Code
- WW = Week Code
- LL = Lot Code

ABSOLUTE MAXIMUM RATINGS			
ELECTRICAL PARAMETER	SYMBOL	LIMIT	UNIT
Input voltage	V_{IN}	-0.3 to +28	V
Control logic supply voltage	V_{CC}	-0.3 to +7	
Switch node (DC voltage)	V_{SWH}	-0.3 to +28	
Switch node (AC voltage) ⁽¹⁾		-7 to +35	
BOOT voltage (DC voltage)	V_{BOOT}	33	
BOOT voltage (AC voltage) ⁽²⁾		40	
BOOT to PHASE (DC voltage)	$V_{BOOT-PHASE}$	-0.3 to +7	
BOOT to PHASE (AC voltage) ⁽³⁾		-0.3 to +8	
All logic inputs and outputs	PWM, ZCD_EN#, DSBL#, FAULT	-0.3 to $V_{CC} + 0.3$	
Max. operating junction temperature	T_J	150	°C
Ambient temperature	T_A	-40 to +125	
Storage temperature	T_{stg}	-65 to +150	
Electrostatic discharge protection	Human body model, JESD22-A114	2000	V
	Charged device model, JESD22-C101	1000	

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
- ⁽¹⁾ The specification values indicated “AC” is V_{SWH} to P_{GND} -7 V (< 20 ns, 10 μ J), min. and 35 V (< 50 ns), max.
- ⁽²⁾ The specification value indicates “AC voltage” is V_{BOOT} to P_{GND} , 40 V (< 50 ns) max.
- ⁽³⁾ The specification value indicates “AC voltage” is V_{BOOT} to V_{PHASE} , 8 V (< 50 ns) max.

RECOMMENDED OPERATING RANGE				
ELECTRICAL PARAMETER	MINIMUM	TYPICAL	MAXIMUM	UNIT
Input voltage (V_{IN})	2.5	-	24	V
Control logic supply voltage (V_{CC})	4.5	5	5.5	
BOOT to PHASE ($V_{BOOT-PHASE}$, DC voltage)	4	4.5	5.5	
Thermal resistance from junction to ambient	-	10.6	-	°C/W
Thermal resistance from junction to case	-	1.6	-	

**ELECTRICAL SPECIFICATIONS**(ZCD_EN# = 5 V, V_{IN} = 12 V, V_{CC} = 5 V, DSBL# = 5 V, T_A = 25 °C, unless otherwise stated)

PARAMETER	SYMBOL	TEST CONDITION	LIMITS			UNIT
			MIN.	TYP.	MAX.	
POWER SUPPLY						
Control logic supply current	I _{VCC}	V _{PWM} = FLOAT	-	80	-	μA
		V _{PWM} = FLOAT, V _{ZCD_EN#} = 0 V	-	120	-	
Drive supply current		f _S = 300 kHz, D = 0.1	-	10.3	20	mA
		f _S = 1 MHz, D = 0.1	-	30	-	
PS4 mode supply current	I _{VCC}	V _{PWM} = V _{ZCD_EN#} = FLOAT, T _A = -10 °C to +100 °C	-	3	9	μA
		DSBL# = 0 V	-	3	9	
BOOTSTRAP SUPPLY						
Bootstrap switch R _{DS(on)}	R _{BS}	V _{CC} = 5 V	-	3	-	Ω
DSBL# CONTROL INPUT						
DSBL# logic input voltage	V _{IH_DSBL#}	Input logic high	2	-	-	V
	V _{IL_DSBL#}	Input logic low	-	-	0.8	
DSBL# input current	I _{DSBL#}	V _{DSBL#} = 5 V	-	0.25	1	μA
PWM CONTROL INPUT						
Rising threshold	V _{TH_PWM_R}		2.2	2.45	2.7	V
Falling threshold	V _{TH_PWM_F}		0.72	0.9	1.1	
Tri-state voltage	V _{TRI}	V _{PWM} = FLOAT	-	1.8	-	
Tri-state rising threshold	V _{TRI_TH_R}		0.9	1.15	1.38	
Tri-state falling threshold	V _{TRI_TH_F}		1.95	2.2	2.45	
Tri-state rising threshold hysteresis	V _{HYS_TRI_R}		-	325	-	mV
Tri-state falling threshold hysteresis	V _{HYS_TRI_F}		-	225	-	
PWM input current	I _{PWM}	V _{PWM} = 3.3 V	-	-	225	μA
		V _{PWM} = 0 V	-	-	-225	
ZCD_EN# CONTROL INPUT						
Rising threshold	V _{TH_ZCD_EN#_R}		2.1	2.4	2.8	V
Falling threshold	V _{TH_ZCD_EN#_F}		0.7	0.9	1.2	
Tri-state voltage	V _{TRI_ZCD_EN#}	V _{ZCD_EN#} = FLOAT	-	1.8	-	
Tri-state rising threshold	V _{TRI_ZCD_EN#_R}		0.9	1.3	1.5	
Tri-state falling threshold	V _{TRI_ZCD_EN#_F}		1.9	2.1	2.6	
Tri-state rising threshold hysteresis	V _{HYS_TRI_ZCD#_R}		-	325	-	mV
Tri-state falling threshold hysteresis	V _{HYS_TRI_ZCD#_F}		-	250	-	
ZCD_EN# input current	I _{ZCD_EN#}	V _{ZCD_EN#} = 3.3 V	-	-	100	μA
		V _{ZCD_EN#} = 0 V	-	-	-100	

**ELECTRICAL SPECIFICATIONS**(ZCD_EN# = 5 V, V_{IN} = 12 V, V_{CC} = 5 V, DSBL# = 5 V, T_A = 25 °C, unless otherwise stated)

PARAMETER	SYMBOL	TEST CONDITION	LIMITS			UNIT
			MIN.	TYP.	MAX.	
TIMING SPECIFICATIONS						
Tri-state to GH/GL rising propagation delay	t _{PD_TRI_R}	No load, see fig. 4	-	35	-	ns
Tri-state hold-off time	t _{TSHO}		-	30	-	
GH - turn off propagation delay	t _{PD_OFF_GH}		-	15	-	
GH - turn on propagation delay (dead time rising)	t _{PD_ON_GH}		-	30	-	
GL - turn off propagation delay	t _{PD_OFF_GL}		-	25	-	
GL - turn on propagation delay (dead time falling)	t _{PD_ON_GL}		-	25	-	
PWM minimum on-time	t _{PWM_ON_MIN.}		-	30	-	
PS4 exit latency	t _{PS4EXIT}		-	-	5.5	μs
UNDER VOLTAGE LOCKOUT						
V _{CC} under voltage lockout	V _{UVLO}	V _{CC} rising, on threshold	-	3.8	4	V
		V _{CC} falling, off threshold	3.4	3.6	-	
V _{CC} under voltage lockout hysteresis	V _{UVLO_HYST}		-	200	-	mV
V _{BOOT} under voltage lockout	V _{BOOT_UVLO}	V _{BOOT} rising, on threshold	-	3.6	3.8	V
		V _{BOOT} falling, off threshold	3.2	3.4	-	
V _{BOOT} under voltage lockout hysteresis	V _{BOOT_UVLO_HYS T}		-	200	-	mV
THERMAL FAULT FLAG						
Thermal flag	T _{THDN}		-	140	-	°C
Thermal flag hysteresis	T _{THDN_HYS}		-	25	-	

Notes

- (1) Typical limits are established by characterization and are not production tested
 (2) Guaranteed by design

**DETAILED OPERATIONAL DESCRIPTION****DSBL# Input, Enable Function**

The DSBL# pin shuts down the driver and disables both high side and low side MOSFETs. In this state, standby current is minimized. When DSBL# is low, both PWM and ZCD_EN# internal dividers are disconnected to reduce current consumption. If DSBL# is left unconnected, an internal pull-up resistor enables the SiC674A.

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 $V_{PWM_TH_R}$ the low side is turned OFF and the high side is turned ON. When PWM input is driven below $V_{PWM_TH_F}$ the high side is turned OFF and the low side is turned ON. For tri-state logic, the PWM input operates as previously stated for driving the MOSFETs when PWM is logic high and logic low. However, there is a third state that is entered as the PWM output of a tri-state compatible controller enters its high impedance state. The high impedance state of the controller's PWM output allows the SiC674A to pull the PWM input into the tri-state region (see definition of PWM logic and tri-state, fig. 4). 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. The 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 SiC674A incorporates PWM voltage thresholds that are compatible with 5 V logic.

Diode Emulation Mode and PS4 Mode (ZCD_EN#)

The ZCD_EN# pin enables or disables diode emulation mode. When ZCD_EN# is driven below $V_{TH_ZCD_EN\#_F}$, diode emulation is allowed. When ZCD_EN# is driven above $V_{TH_ZCD_EN\#_R}$, continuous conduction mode is forced. Diode emulation mode allows for higher converter efficiency under light load situations. With diode emulation active, the SiC674A will detect the zero current crossing of the output inductor and turn off the low side MOSFET. This ensures that discontinuous conduction mode (DCM) is achieved. Diode emulation is asynchronous to the PWM signal, therefore, the SiC674A will respond to the ZCD_EN# input immediately after it changes state.

The ZCD_EN# pin can be floated resulting in a high impedance state. The SiC674A will pull a floated ZCD_EN# to the internally set tri-state level. A tri-state ZCD_EN# combined with a tri-stated PWM output will shut down the SiC674A, reducing current consumption to typically 3 μ A. This is an important feature in achieving the low standby current required in the PS4 state in ultrabooks and notebooks.

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 power stage output. This is the output applied to the power inductor and output filter to deliver the 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.

Ground Connections (C_{GND} and P_{GND})

P_{GND} (power ground) should be externally connected to C_{GND} (control analog ground). The layout of the printed circuit board should be such that the inductance separating C_{GND} and P_{GND} is minimized. Transient differences due to inductance effects between these two pins should not exceed 0.5 V.

Control and Drive Supply Voltage Input (V_{CC})

V_{CC} is the bias supply for the control IC and for the gate drivers.

Bootstrap Circuit (BOOT)

A bootstrap switch and an external bootstrap capacitor form a charge pump that supplies voltage to the BOOT pin. An integrated bootstrap switch is incorporated so that only an external capacitor is necessary to complete the bootstrap circuit. Connect a bootstrap capacitor with one leg tied to BOOT pin and the other tied to PHASE pin.

Shoot-Through Protection and Adaptive Dead Time

The SiC674A 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 MOSFETs are not turned ON at the same time. The adaptive dead time control operates as follows. The high side and low side gate voltages are monitored to prevent one from turning ON until the other gate voltage is sufficiently low (< 1 V). Built-in delays also ensure that 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 gates low until the supply voltage has reached a point at which the logic circuitry can be safely activated. The SiC674A also incorporates logic to clamp the gate drive signals to zero when the UVLO falling edge triggers the shutdown of the device.

FAULT Fault Flag Functions

The FAULT output is used to report operating conditions detected by the logic of the driver that require attention.

A fault is reported by the FAULT output going low.

The reported condition is high temperature.

In a multi-phase topology, all FAULT signals are connected to the PWM controller and will indicate the temp. of the warmest device.

If the operating temperature exceeds 140 °C the FAULT output will signal a fault condition. The fault is reset when the temperature is below the temperature hysteresis threshold.

FUNCTIONAL BLOCK DIAGRAM

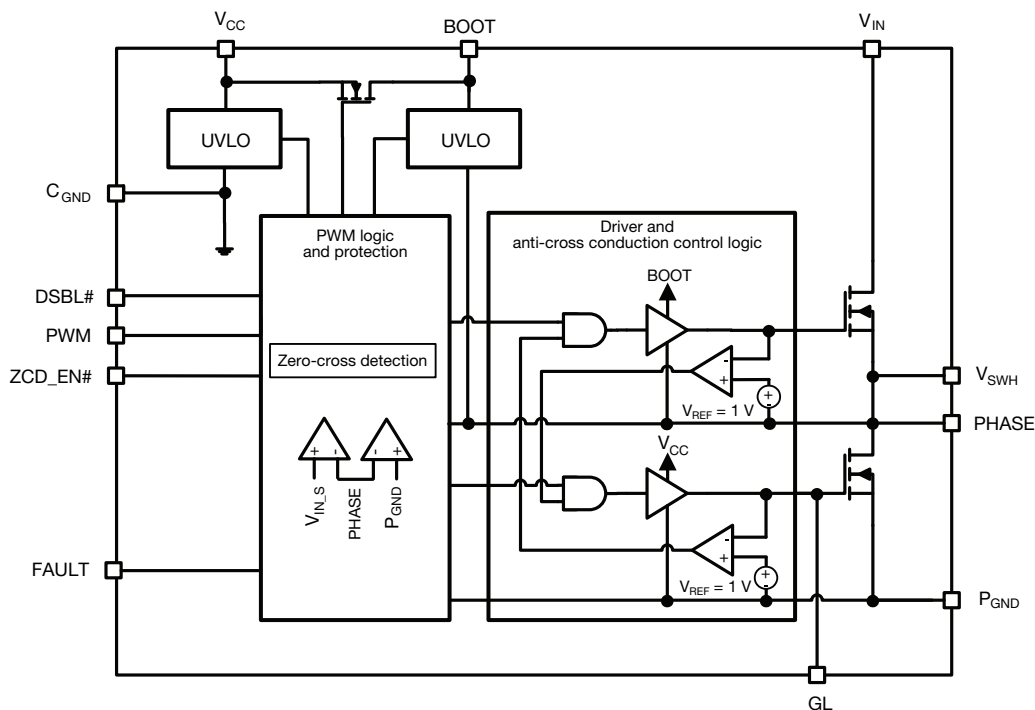
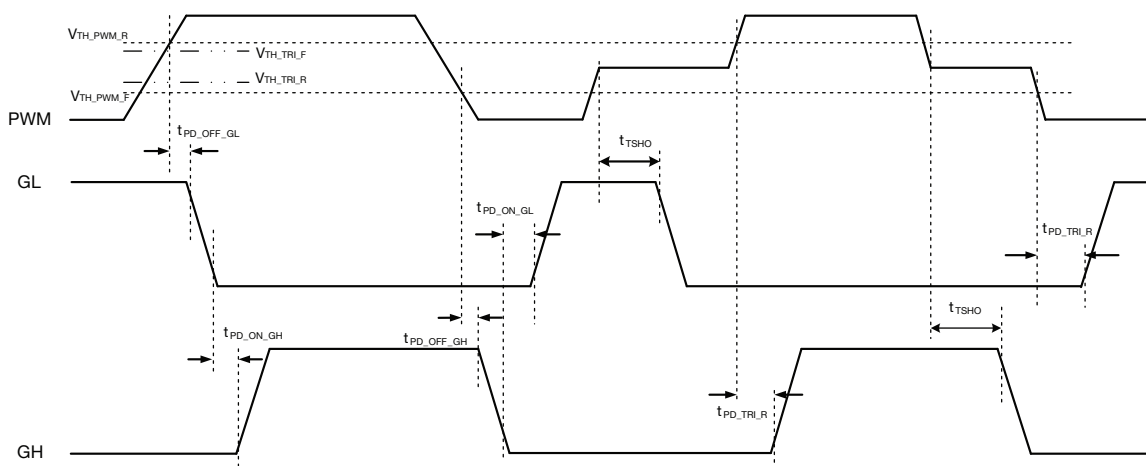
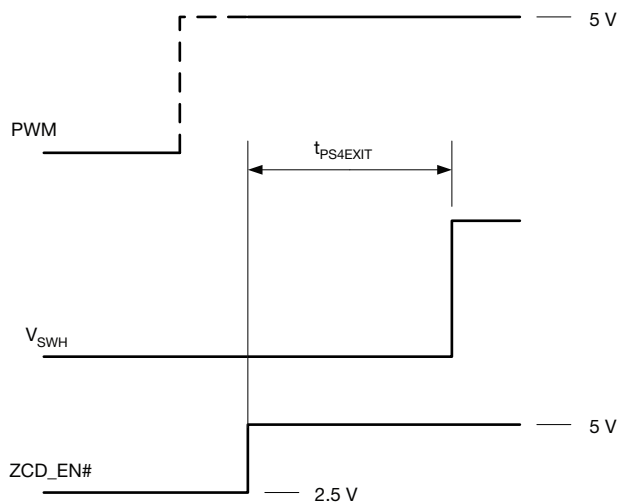


Fig. 3 - Functional Block Diagram

**DEVICE TRUTH TABLE**

DSBL#	ZCD_EN#	PWM	GH	GL
L	X	X	L	L
H	Tri-state	X	L	L
H	L	L	L	H, $I_L > 0$ A L, $I_L < 0$ A
H	L	H	H	L
H	L	Tri-state	L	L
H	H	L	L	H
H	H	H	H	L
H	H	Tri-state	L	L

PWM TIMING DIAGRAM**Fig. 4 - Definition of PWM Logic and Tri-state****ZCD_EN# - PS4 EXIT TIMING****Fig. 5 - ZCD_EN# - PS4 Exit Timing**

ELECTRICAL CHARACTERISTICS

Test condition: $V_{IN} = 12\text{ V}$ (unless otherwise stated), $V_{CC} = 5\text{ V}$, $ZCD_EN\# = 5\text{ V}$, $DSBL\# = 5\text{ V}$, $V_{OUT} = 1.05\text{ V}$, $L_{OUT} = 220\text{ nH}$ ($DCR = 0.29\text{ m}\Omega$), $T_A = 25\text{ }^\circ\text{C}$, natural convection cooling (all power loss and normalized power loss curves show SiC674A losses only unless otherwise stated)

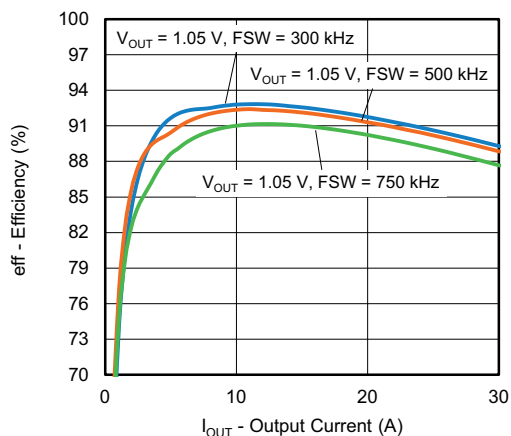


Fig. 6 - Efficiency vs. Output Current ($V_{IN} = 12\text{ V}$)

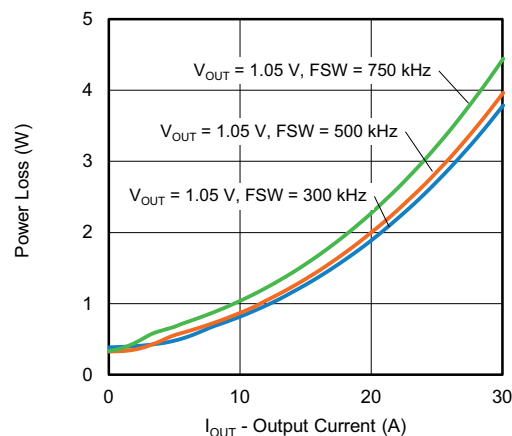


Fig. 9 - Power Loss vs. Output Current ($V_{IN} = 12\text{ V}$)

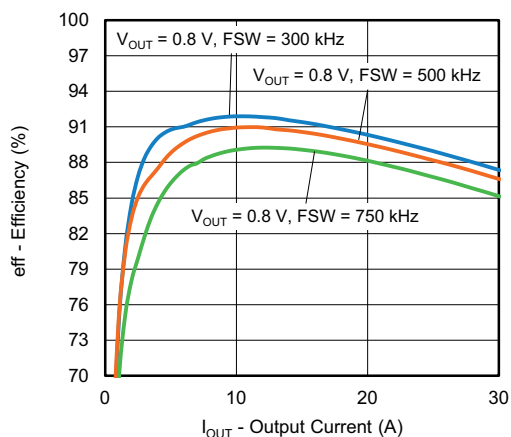


Fig. 7 - Efficiency vs. Output Current ($V_{IN} = 12\text{ V}$)

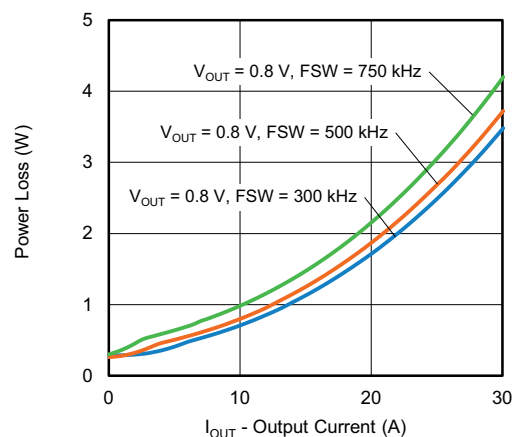


Fig. 10 - Power Loss vs. Output Current ($V_{IN} = 12\text{ V}$)

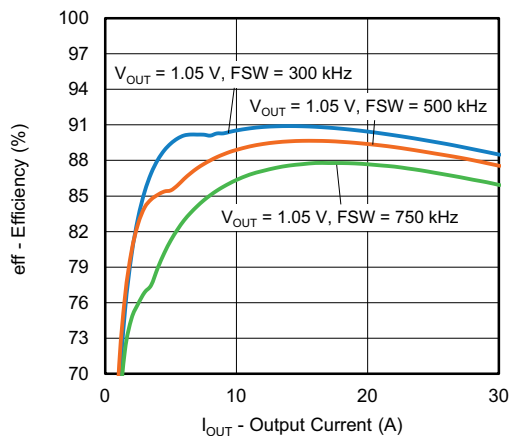


Fig. 8 - Efficiency vs. Output Current ($V_{IN} = 19\text{ V}$)

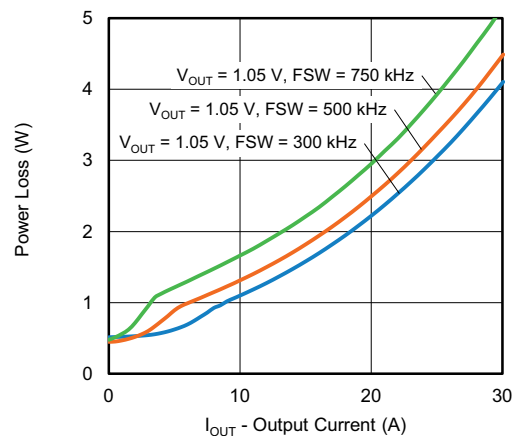


Fig. 11 - Power Loss vs. Output Current ($V_{IN} = 19\text{ V}$)

ELECTRICAL CHARACTERISTICS

Test condition: $V_{IN} = 13\text{ V}$ (unless otherwise stated), $V_{CC} = 5\text{ V}$, $ZCD_EN\# = 5\text{ V}$, $DSBL\# = 5\text{ V}$, $V_{OUT} = 1.05\text{ V}$, $L_{OUT} = 220\text{ nH}$ ($DCR = 0.29\text{ m}\Omega$), $T_A = 25\text{ }^\circ\text{C}$, natural convection cooling (all power loss and normalized power loss curves show SiC674A losses only unless otherwise stated)

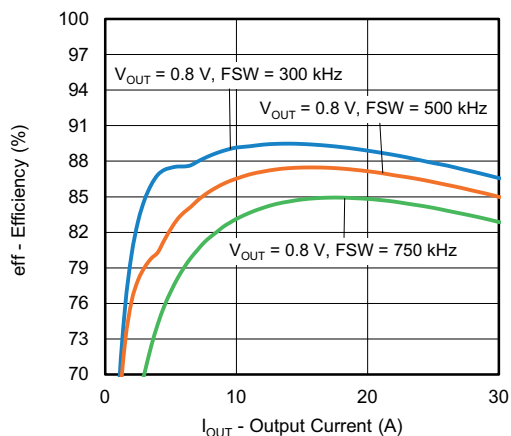


Fig. 12 - Efficiency vs. Output Current ($V_{IN} = 19\text{ V}$)

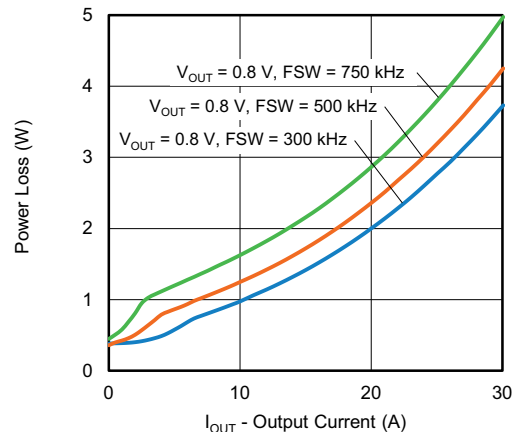


Fig. 15 - Power Loss vs. Output Current ($V_{IN} = 19\text{ V}$)

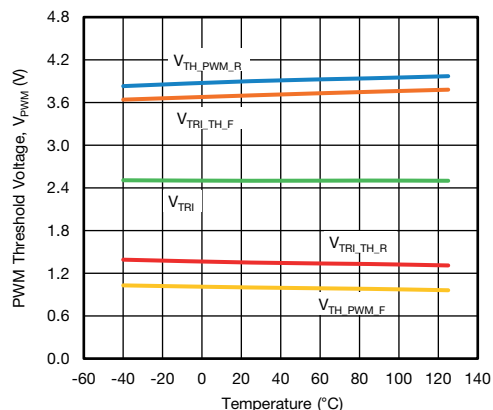


Fig. 13 - PWM Threshold vs. Temperature

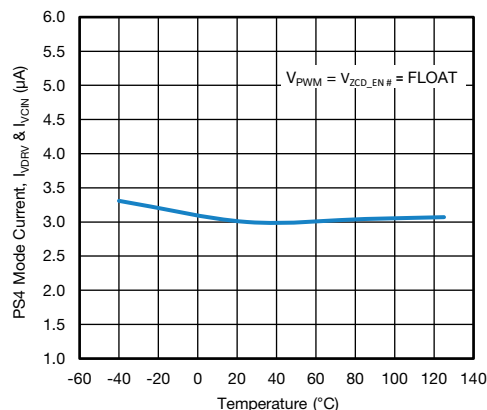


Fig. 16 - PS4 Mode Current vs. Temperature

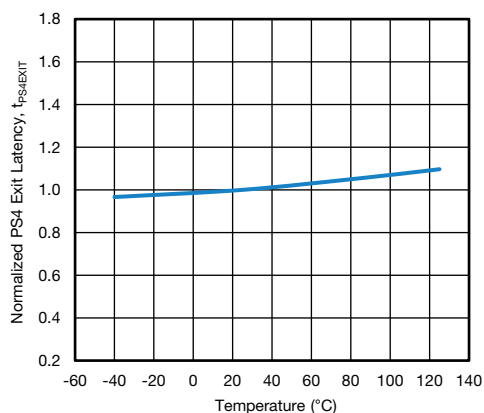
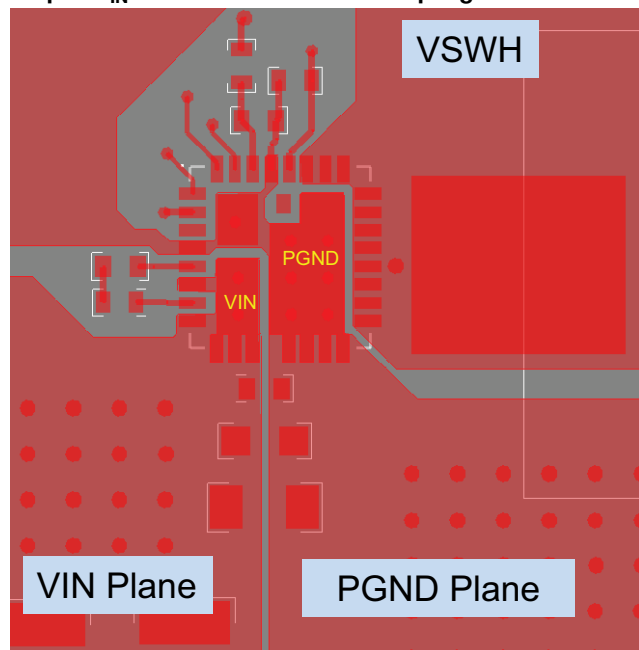


Fig. 14 - PS4 Exit Latency vs. Temperature

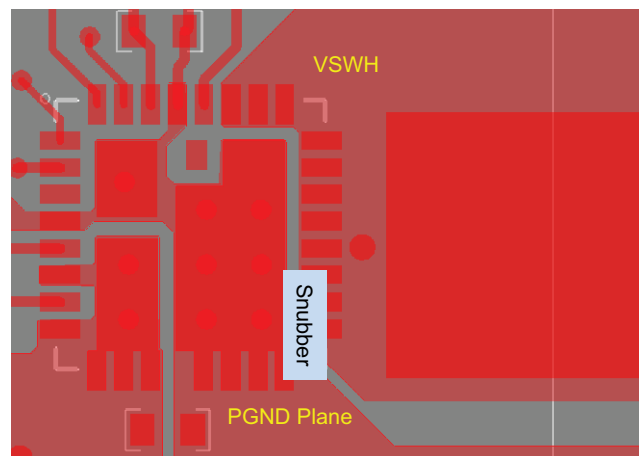
PCB LAYOUT RECOMMENDATIONS

Step 1: V_{IN} / GND Planes and Decoupling



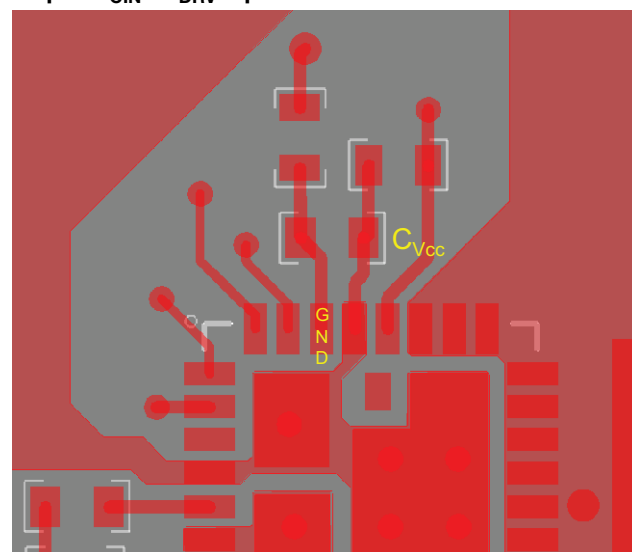
1. Layout V_{IN} and P_{GND} planes as shown above
2. Ceramic capacitors should be placed right between V_{IN} and P_{GND} , and very close to the device for best decoupling effect
3. Different values / packages of ceramic capacitors should be used to cover entire decoupling spectrum e.g. 1210, 0805, 0603 and 0402
4. Smaller capacitance value, closer to device V_{IN} pin(s) - better high frequency noise absorbing

Step 2: V_{SWH} Plane



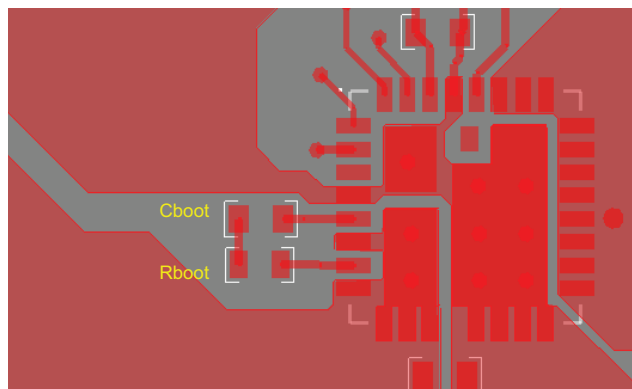
1. Connect output inductor to DrMOS with large plane to lower the resistance
2. If any snubber network is required, place the components as shown above and the network can be placed at bottom

Step 3: V_{CC} / V_{DRV} Input Filter

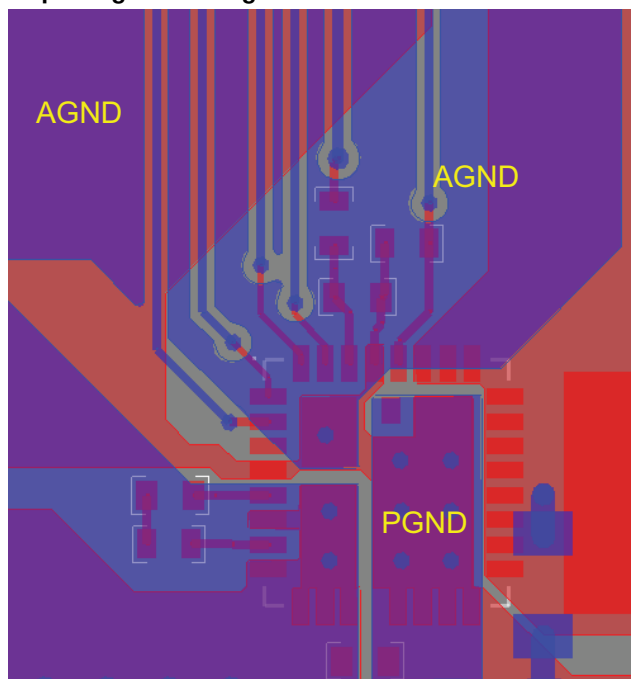


1. The V_{CC} input filter ceramic cap should be placed very close to DrMOS
2. C_{VCC} cap should be placed between pin 28 (P_{GND} of driver IC) and pin 29 to provide maximum instantaneous driver current for low side MOSFET during switching cycle

Step 4: BOOT Resistor and Capacitor Placement



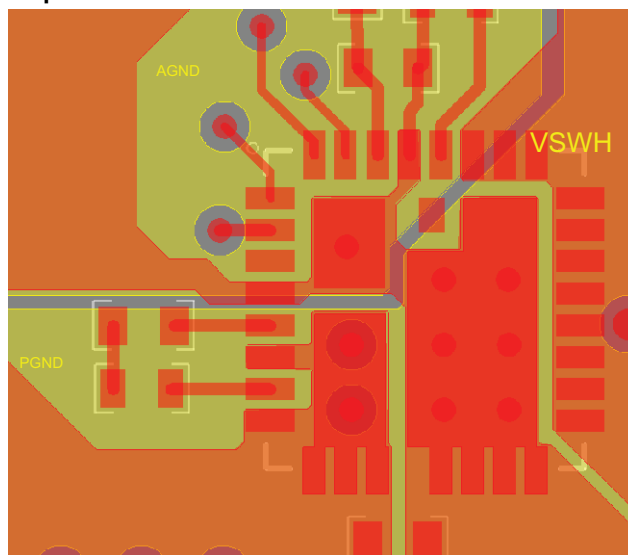
1. These components need to be placed very close to DrMOS, right between PHASE (pin 7) and BOOT (pin 5)
2. To reduce parasitic inductance, chip size 0402 can be used

Step 5: Signal Routing


1. Route the PWM / SMOD / DSBL / THDN signal traces out of the top left corner next DrMOS pin1
2. PWM signal is very important signal, both signal and return traces need to pay special attention of not letting this trace cross any power nodes on any layer
3. It is best to “shield” them with GND island form power switching nodes, e.g. V_{SWH} , to improve signal integrity
4. GL (pin27) has been connected with GL pad internally and does not to connect externally

Step 6: Adding Thermal Relief Vias


1. Thermal relief Vias can be added on the V_{IN} and GND pads to utilize inner layers for high current and thermal dissipation
2. To achieve better thermal performance, additional Vias can be put on V_{IN} plane and P_{GND} plane
3. V_{SWH} pad is a noise source and not recommended to put Vias on this plane
4. 8 mil drill for pads and 10 mils drill for plane can be the optional Via size with 40 mils pitch. The Vias on pad may drain solder during assembly and cause assembly issue. Please consult with the assembly house for guideline

Step 7: Ground Connection


1. It is recommended to make single connection between A_{GND} and P_{GND} and this connection can be done on top layer
2. It is recommended to make the whole inner 1 layer (next to top layer) ground plane and separate them into A_{GND} and P_{GND} plane
3. These ground planes provide shielding between noise source on top layer and signal trace on bottom layer

Multi-Phases VRPower PCB Layout

The following is an example of 6 phase layout. As can be seen, all the VRPower stages are lined in X-direction compactly with decoupling capacitors next to them. The inductors are placed as close as possible to the SiC674A to minimize the PCB copper loss. Vias are applied on all PADS (V_{IN} , P_{GND} , C_{GND}) of the SiC674A to ensure that both electrical and thermal performance are optimized. Large copper planes are used for all high current loops, such as V_{IN} , V_{SWH} , V_{OUT} and P_{GND} . These copper planes are duplicated in other layers to minimize the inductance and resistance. All the control signals are routed from the SiC674A to a controller placed to the north of the power stage through inner layers to avoid the overlap of high current loops. This achieves a compact design with the output from the inductors feeding a load located to the south of the design as shown in the figure.

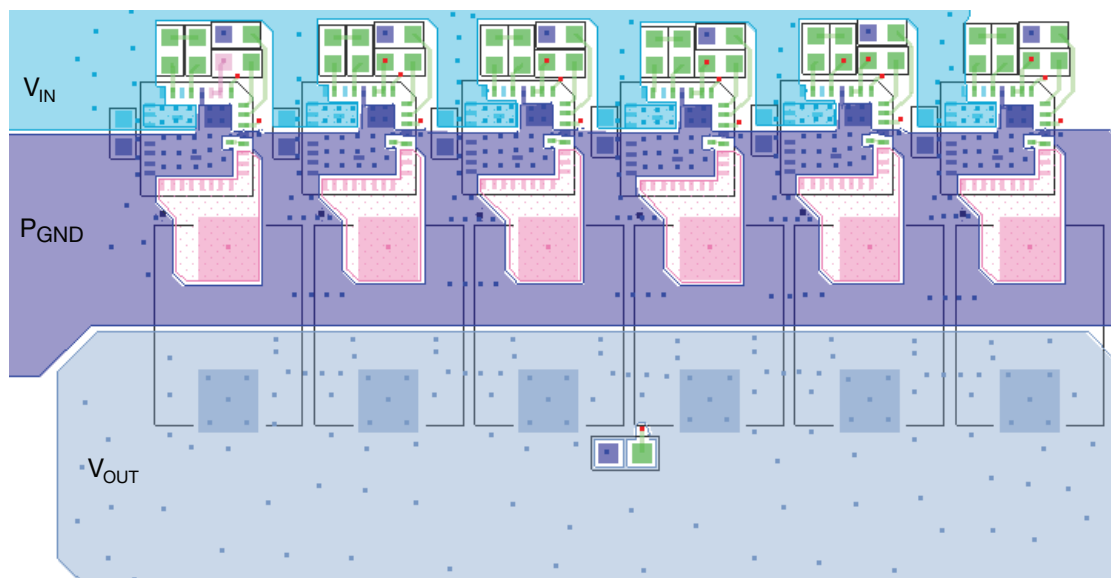


Fig. 17 - Multi-Phase VRPower Layout Top View

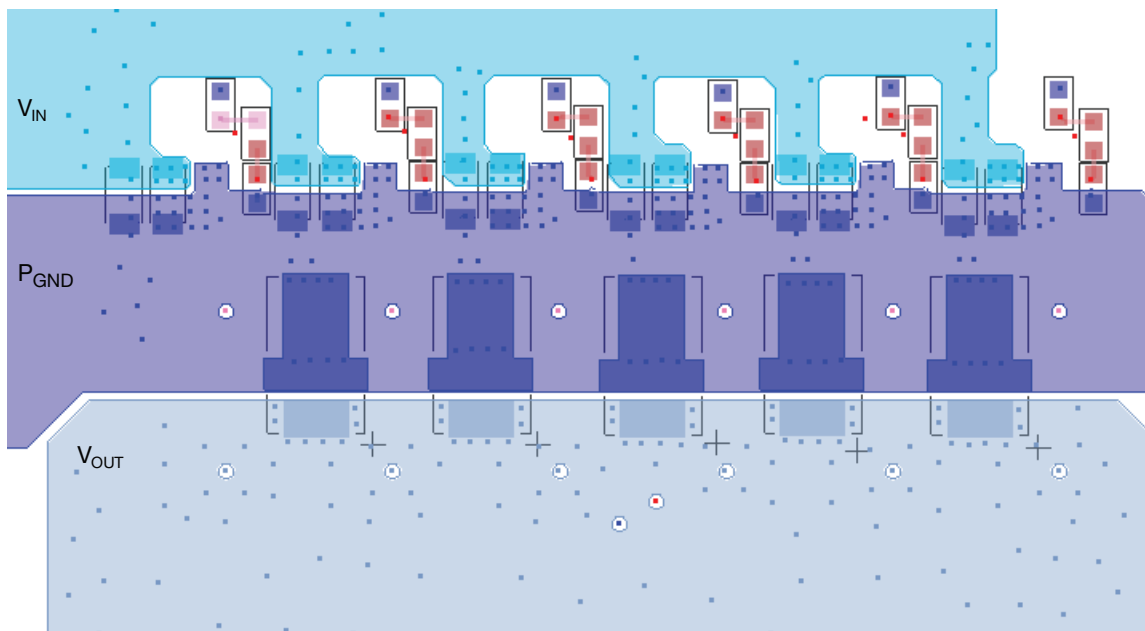


Fig. 18 - Multi-Phase VRPower Layout Bottom View

**PRODUCT SUMMARY**

Part number	SiC674A
Description	55 A power stage, 2.5 V to 24 V _{IN} , 3.3 V PWM with ZCD, PS4 mode
Input voltage min. (V)	2.5
Input voltage max. (V)	24
Current rating (A)	55
Switch frequency max. (kHz)	2000
Enable (yes / no)	Yes
Monitoring features	FAULT Monitor
Protection	UVLO
Light load mode	ZCD
Pulse-width modulation (V)	3.3
Package type	PowerPAK® MLP55-31L
Package size (W, L, H) (mm)	5 x 5 x 0.75
Status code	1
Product type	VRPower (DrMOS)
Applications	Computer, networking

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