MIC24085

18V, 3A, 1MHz, High-Performance, Integrated FET Buck Regulator in Tiny 3mm × 3mm QFN

General Description

Micrel's MIC24085 is a constant-frequency, current-mode PWM buck regulator with integrated switchers. The MIC24085 is targeted for cost-sensitive and high-performance applications.

The MIC24085 operates over a supply range of 4.5V to 18V at a fixed 1MHz switching frequency and can be used to provide up to 3A of output current. The output voltage is adjustable down to 0.9V.

The MIC24085 provides the features of low standby current at 10µA, device enable, input undervoltage lockout, and output voltage monitoring. The part also provides fault protections of overcurrent and overtemperature.

The MIC24085 is available in a 16-pin 3mm × 3mm QFN package with a junction operating range from –40°C to +125°C.

Datasheets and support documentation are available on Micrel's web site at: www.micrel.com.

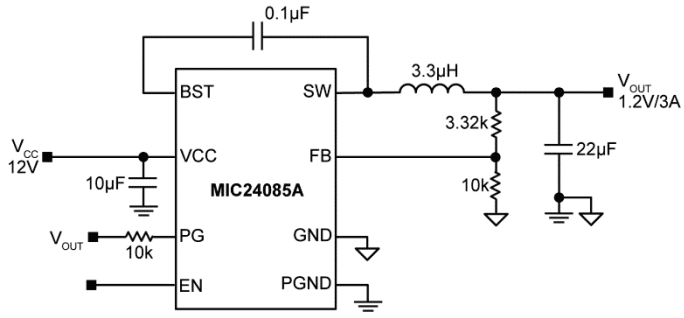
Features

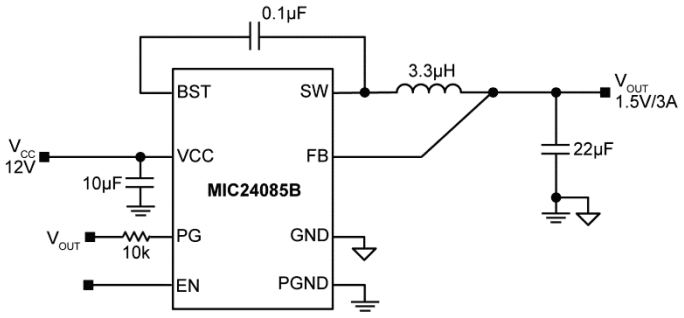
- Input voltage range 4.5V to 18V
- 3A output current
- 1MHz switching frequency
- 0.9V reference voltage with ±1.5% accuracy
- Fixed output voltages are available at: 1.5V/1.8V/2.5V/3.3V/5V
- Peak current-mode PWM with internal compensation
- PFM mode for light load efficiency
- 10µA typical shutdown current
- 4ms internal soft start
- Cycle-by-cycle current limit with frequency foldback
- Output overvoltage protection
- Enable input/power-good (PG) output
- Thermal-shutdown protection
- –40°C to +125°C junction temperature range
- Available in 16-pin 3mm × 3mm QFN package

Applications

- Camera, set-top box, gateways, and routers
- Networking/telecom infrastructure
- Printers, scanners, graphic cards, and video cards

Typical Applications

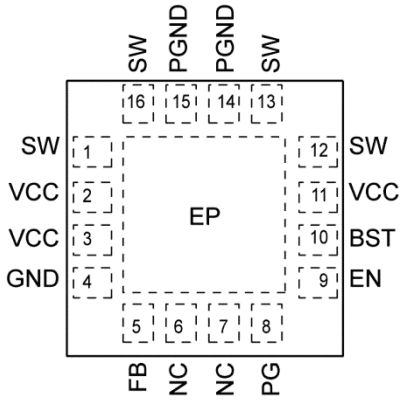




Ordering Information

Part Number	Output Voltage	Junction Temperature Range	Package	Lead Finish
MIC24085AYML	ADJ	–40°C to +125°C	16-Pin 3mm x 3mm QFN	Pb-Free
MIC24085BYML	1.5V			
MIC24085CYML	1.8V			
MIC24085DYML	2.5V			
MIC24085EYML	3.3V			
MIC24085FYML	5V			

Pin Configuration



16-Pin 3mm × 3mm QFN (ML)
(Top View)

Pin Description

Pin Number	Pin Name	Pin Function
1, 12, 13, 16	SW	Switch Node (Output): Power stage output. Connect an inductor to this pin.
2, 3, 11	VCC	Supply Voltage (for control circuit and power stage): A ceramic input capacitor between VCC and the power ground (PGND) is required.
4	GND	Analog Ground: GND is the ground path of the control circuitry.
5	FB	Feedback (Input): Input to the error amplifier of the PWM controller. The FB pin is regulated to 0.9V. A resistor divider connecting the feedback to the output is used to adjust the desired output voltage.
6, 7	NC	No connection.
8	PG	Power Good (Output): Open drain output, which needs a pull-up. The PG pin turns logic high when the converter output voltage is regulated in the range from 93% to 103% of the setting.
9	EN	Enable (Input): An accurate Enable with hysteresis is provided. High = enable, Low = shutdown. Enable has an internal pull-up to ensure a stable state if this pin is not connected.
10	BST	Boost (Output): Bootstrapped voltage to the high-side N-channel MOSFET. A boost capacitor of 0.1µF is connected between the BST pin and the SW pin.
14,15	PGND	Power Ground: PGND is the ground path for the power stage.
EP	ePAD	Exposed Pad. It must be connected to PGND on the PCB.

Absolute Maximum Ratings[1]

V_{VCC} to PGND ..... –0.3V to +20V
V_{SW} to PGND ..... –0.3V to +20V
V_{EN}, V_{FB}, $V_{PG,}$ to GND ..... –0.3V to + 6V
V_{BST} to V_{SW} ..... –0.3V to + 6V
V_{BST} to PGND ..... –0.3V to +26V
PGND to GND ..... –0.3V to + 0.3V
Junction Temperature ..... +150°C
Storage Temperature (T_S) ..... –65°C to +150°C
Lead Temperature (soldering, 10sec) ..... 260°C
ESD Rating[3] 2kV

Operating Ratings[2]

Supply Voltage (V_{VCC}) ..... 4.5V to 18V
Output Current 3A
Junction Temperature (T_J) ..... –40°C to +125°C
Junction Thermal Resistance
MLF-16 (θ_{JA}) ..... 68°C/W
MLF-16 (θ_{JC}) ..... 7.5°C/W

Electrical Characteristics[4]

V_{VCC} = 12V; T_A = 25°C, unless noted. **Bold** values indicate –40°C ≤ T_J ≤ +125°C.

Parameter	Condition	Min.	Typ.	Max.	Units
Power Supply Input					
V_{CC} Input Voltage Range		**4.5**		**18**	V
Quiescent Supply Current	No Switching, V_{FB} = 1.5V		2.3		mA
Shutdown Supply Current	V_{EN} = 0V		5	**10**	µA
V_{CC} UVLO Threshold			4.3	**4.5**	V
V_{CC} UVLO Hysteresis			650		mV
Reference (MIC24085AYML)					
Feedback Reference Voltage	-40°C ≤ T_J ≤ +125°C (±1.5%)	**0.886**	0.9	**0.914**	V
FB Bias Current	V_{FB} = 0.6V		50	**500**	nA
Soft-Start Time			4		ms
Load Regulation	I_{OUT} = 100mA to 3A		0.5		%
Line Regulation	V_{VCC} = 4.5V to 18V		0.5		%
Enable Control					
EN Logic Level High		**2.2**			V
EN Logic Level Low				**0.8**	V
EN Hysteresis			480		mV
EN Bias Current	V_{EN} = 5V		3.5		µA
	V_{EN} = 0V		-1.5		
PWM					
Switching Frequency	V_{FB} = 0.9V	**0.9**	1.0	**1.1**	MHz
Foldback Switching Frequency	V_{FB} < 60% × 0.9V		250		kHz
Maximum Duty Cycle	V_{FB} = 0V, 1MHz		97		%
Minimum Duty Cycle	V_{FB} = 1V		0		%

Notes:

1. Exceeding the absolute maximum ratings may damage the device.
2. The device is not guaranteed to function outside its operating ratings.
3. Devices are ESD sensitive. Handling precautions are recommended. Human body model, 1.5kΩ in series with 100pF.
4. Specification for packaged product only.

Electrical Characteristics[4] (Continued)

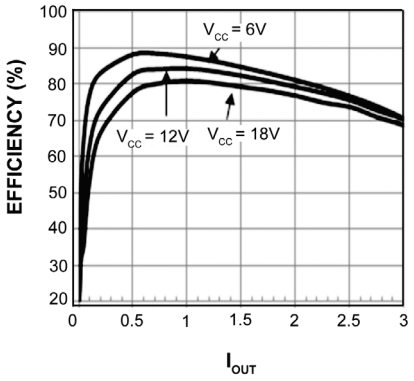
V_{VCC} = 12V; T_A = 25°C, unless noted. **Bold** values indicate –40°C ≤ T_J ≤ +125°C.

Parameter	Condition	Min.	Typ.	Max.	Units
Internal MOSFET					
High Side On-Resistance	I_{SW} = 1A		135		mΩ
Low Side On-Resistance	I_{SW} = 1A		90		mΩ
Overcurrent Protection					
Current-Limit Threshold	V_{FB} = 0.9V	**3.4**	3.8	**4.4**	A
Power Good					
Power Good Threshold Voltage	Sweep V_{FB} from Low-to-High	**91**	93	**95**	%V_{OUT}
Power Good Hysteresis	Sweep V_{FB} from High-to-Low		1.5		%V_{OUT}
Power Good Low Voltage	V_{FB} < 90% x V_{NOM}, I_{PG} = -0.3mA		50	**100**	mV
Power Good Recovery Hold Time	PG recovery after power restoration	9	11	**12**	ms
Thermal Protection					
Overtemperature Shutdown	T_J Rising		170		°C
Overtemperature Shutdown Hysteresis			10		°C

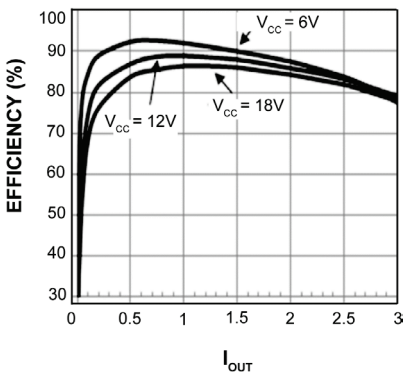
Typical Characteristics

T_J = –40°C to +125°C, V_{CC} = 12V (unless otherwise noted).

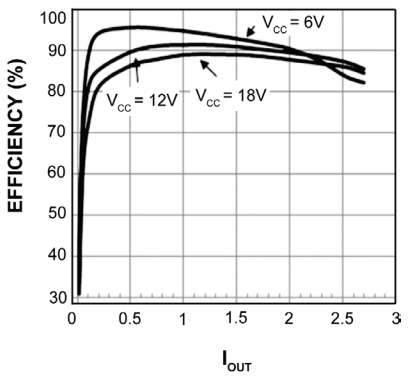
Efficiency vs. Output Current (V_{OUT} = 1.8V)



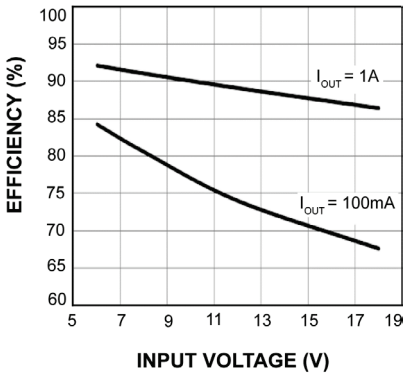
Efficiency vs. Output Current (V_{OUT} = 3.3V)



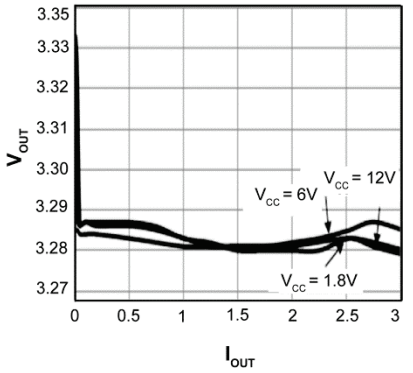
Efficiency vs. Output Current (V_{OUT} = 5V)



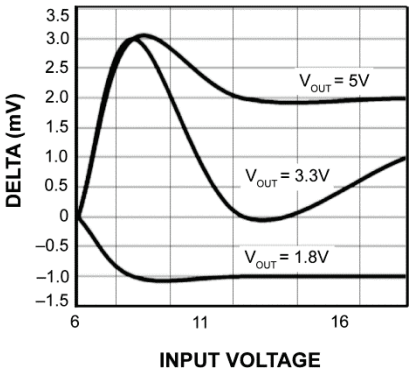
Efficiency vs. Input Voltage (V_{OUT} = 3.3V)



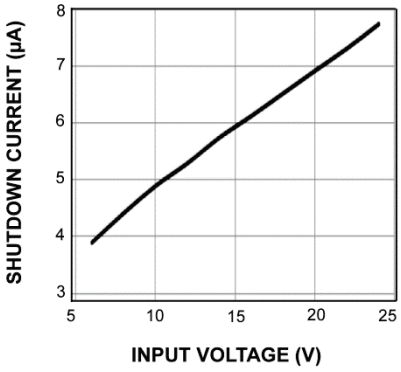
Load Regulation (V_{OUT} = 3.3V)



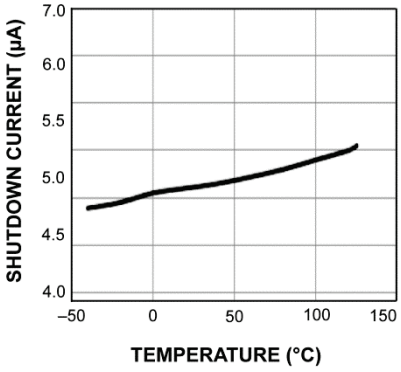
Line Regulation (I_{OUT} = 1A)



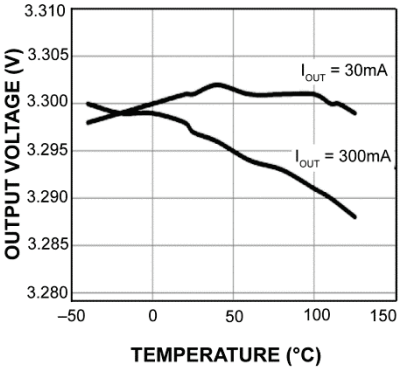
Shutdown Current vs. Input Voltage



Shutdown Current vs. Temperature



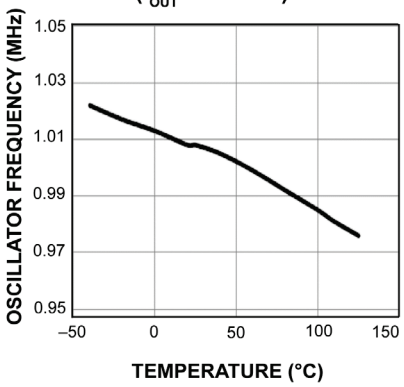
Output Voltage vs. Temperature



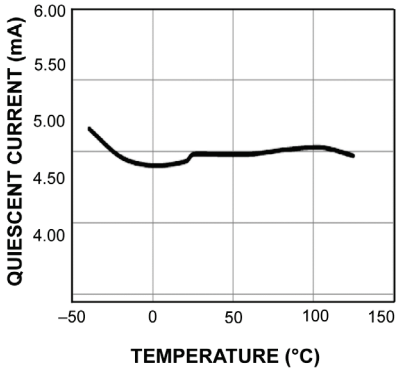
Typical Characteristics (Continued)

T_J = –40°C to +125°C, V_{CC} = 12V (unless otherwise noted).

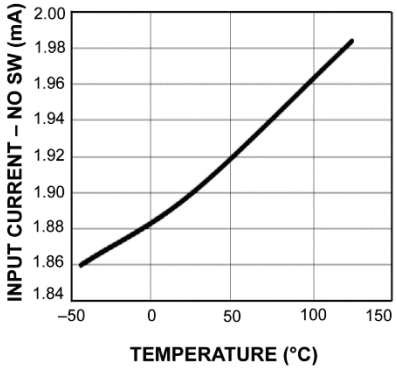
Oscillator Frequency vs. Temperature (I_{OUT} = 300mA)



Quiescent Current vs. Temperature (No Load)



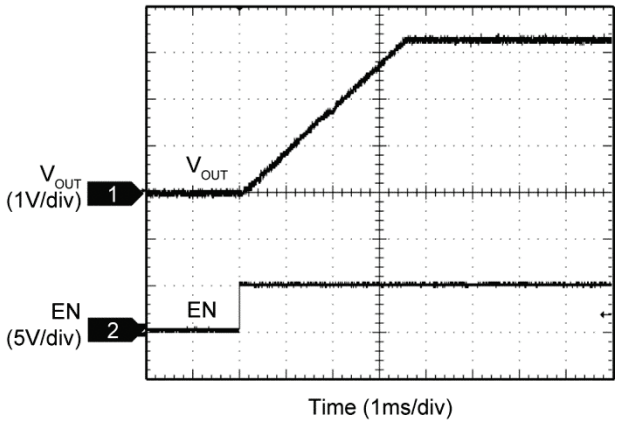
Input Current vs. Temperature (No Load/No Switching)



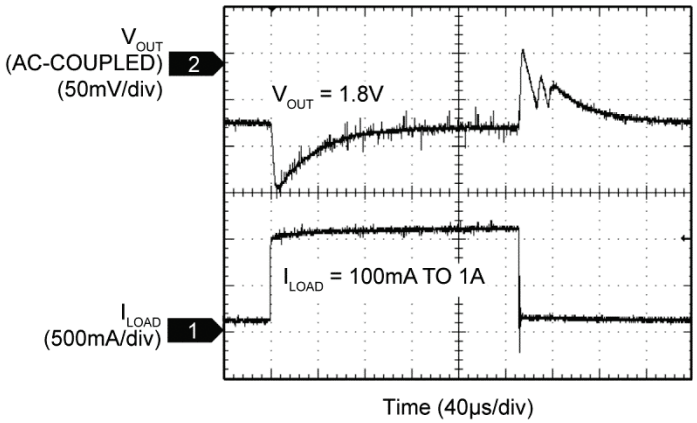
Functional Characteristics

T_J = –40°C to +125°C, V_{CC} = 12V (unless otherwise noted).

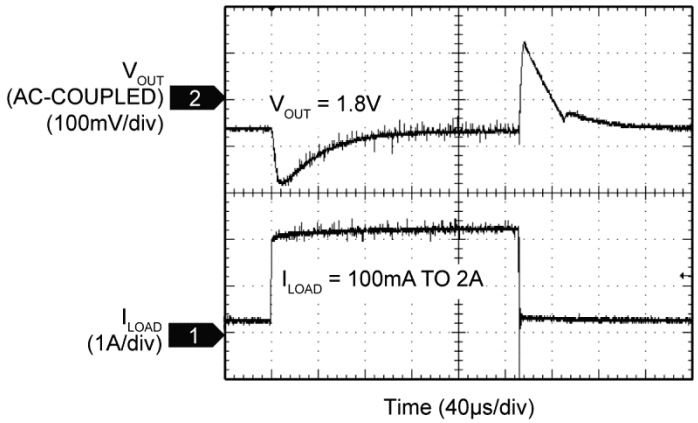
Start-Up Response



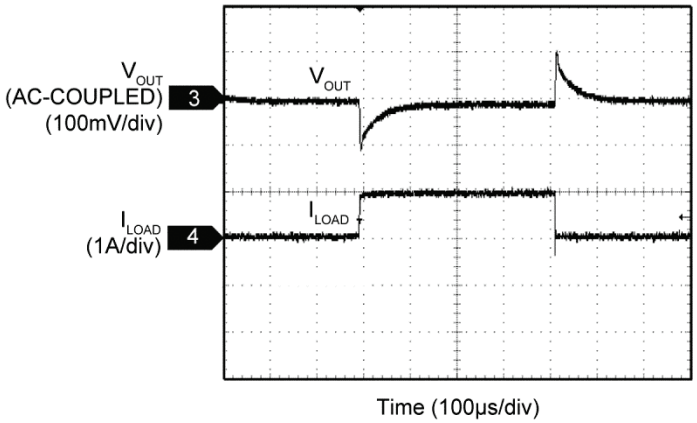
Load Step – 100mA to 1A
(V_{CC} = 12V, V_{OUT} = 1.8V)



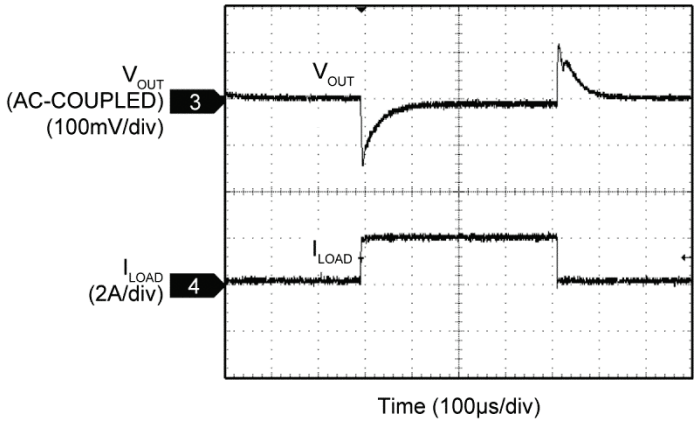
Load Step – 100mA to 2A
(V_{CC} = 12V, V_{OUT} = 1.8V)



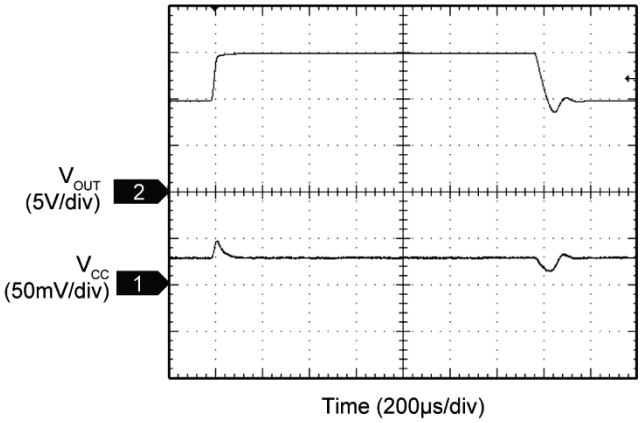
Load Step – 100mA to 1A
(V_{CC} = 12V, V_{OUT} = 3.3V)



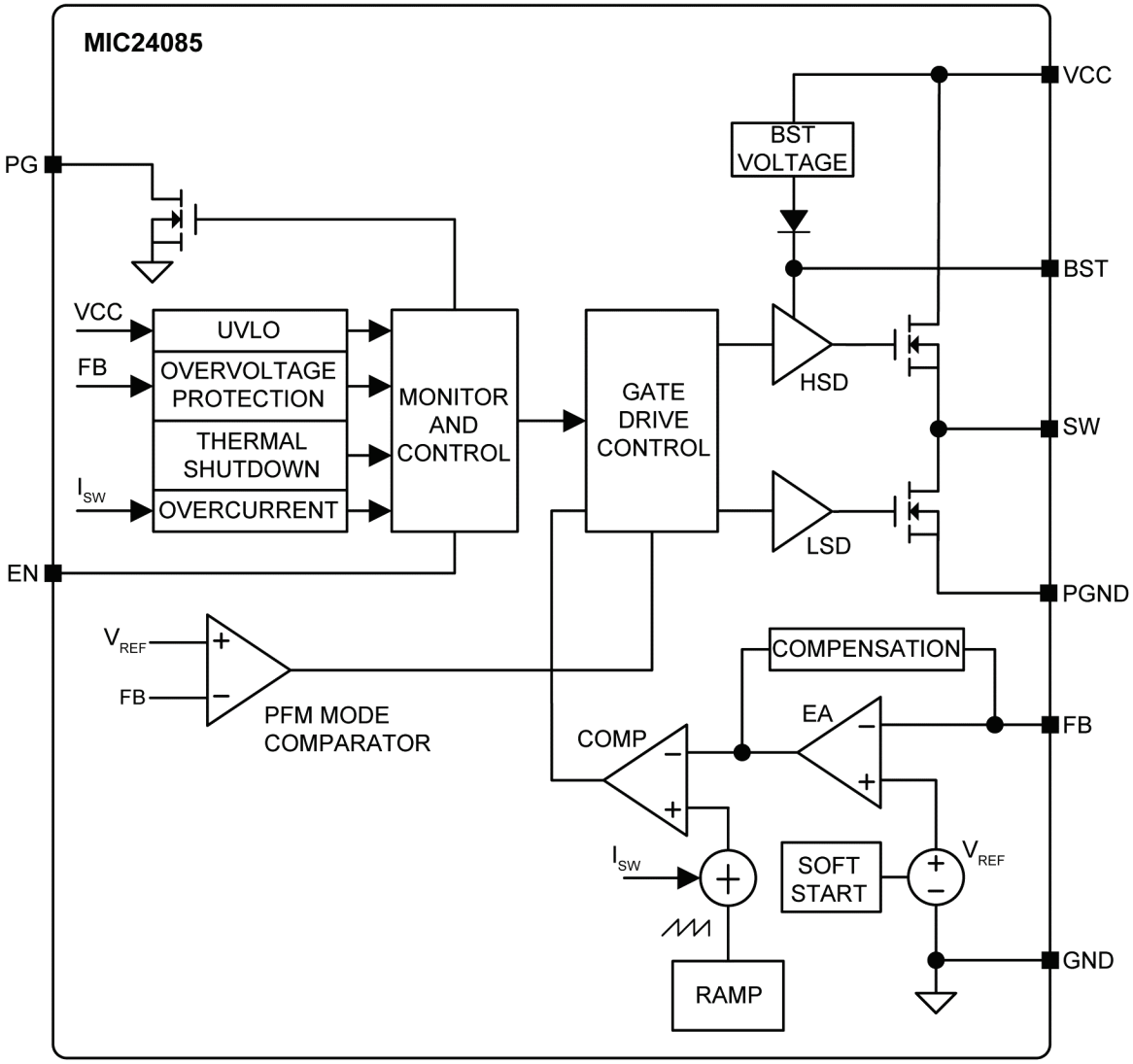
Load Step – 100mA to 2A
(V_{CC} = 12V, V_{OUT} = 3.3V)



Line Transient Response
(V_{CC} = 12V, V_{OUT} = 3.3V)



Functional Diagram



Functional Description

Micrel's MIC24085 is an 18V, 3A, 1MHz buck regulator with integrated MOSFETSs for low-cost high-performance applications. The MIC24085 provides basic features including enable, power good, internal soft-start, current-limit, and overtemperature protections.

VCC Supply Voltage and UVLO

The MIC24085 is held in the off state until VCC reaches the UVLO threshold, which has a 650mV hysteresis. A ceramic capacitor from VCC to PGND is recommended for clean operation.

Enable and Soft-Start

When the MIC24085 is enabled, the reference voltage is controlled to ramp-up from 0V to 0.9V in approximately 4ms. During the soft-start, the current limit is enabled to protect the device in case of a short circuit present at the output.

Peak Current-Mode PWM

To achieve fast transient response, the peak current-mode PWM control is employed in the MIC24085. As illustrated in the *Functional Diagram*, the high-side MOSFET current (ISW) is sensed and summed with a slope-compensating ramp. Then it is compared with the error amplifier output to generate a PWM signal.

The loop compensation is designed internally in the MIC24085 to ensure loop stability, even with a low-ESR capacitor at the output, such as a ceramic output capacitor.

PFM Mode at Light Load

The MIC24085 runs in asynchronous buck mode at light load, where the bottom MOSFET is turned off when the inductor current drops to zero. This scheme prevents the output energy from being pumped back to the input, and improves the over-all efficiency.

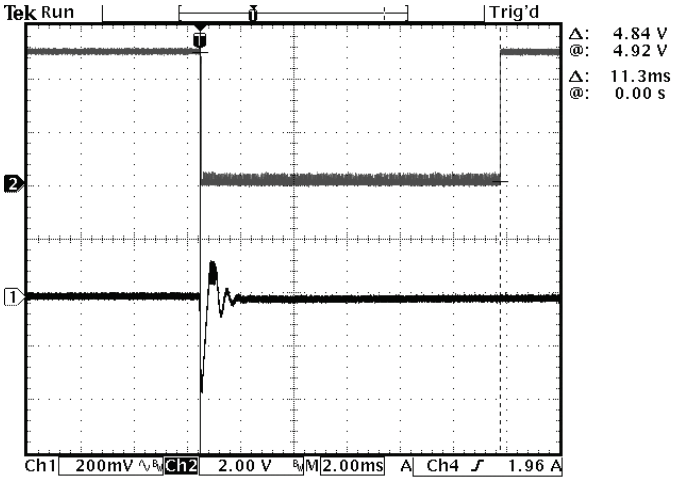
Current Limit and Frequency Foldback

In the MIC24085 ISW is also used to determine over-current conditions. As the peak inductor current is limited, the output voltage of the buck converter drops as the load current increases. When the output voltage reaches 60% of regulated voltage (or feedback voltage reaches 60% of 0.9V), the switching frequency is forced to fold back, from 1MHz to 250kHz. This current-limit scheme reduces the average inductor current (even with the same peak inductor current), and improves the power consumption at the overload conditions.

The current limit is always active when the regulator is enabled. Once the overcurrent condition is removed, the device runs to a soft-start and returns to a normal operation.

Power Good (PG)

Power good (PG) is an open drain output pin. A 10kΩ resistor to VOUT is required for pull-up. The PG pin turns low if the output voltage is below 93% of the reference voltage (0.9V). After VOUT fault and recovery, PG is held low for a typical duration of 11ms. See the Electrical Characteristics table for additional information.



Channel 1: VOUT, Channel 2: PG, Hold Time: 11ms

Output Voltage Protection

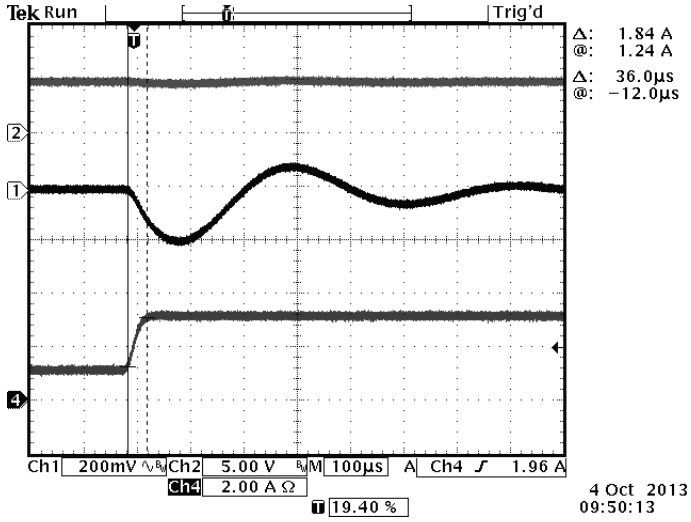
The MIC24085 turns both high-side and low-side MOSFETs off to shut down the buck regulator output voltage when the output voltage exceeds 103% of the regulated voltage. After the output voltage drops back below the threshold, the MIC24085 runs to a soft-start.

Thermal Shutdown

The MIC24085 turns both high-side and low-side MOSFETs off to shut down the buck regulator output voltage when the internal temperature is over the setting threshold at around 170°C. After the temperature drops back below the threshold, the MIC24085 runs to a soft-start.

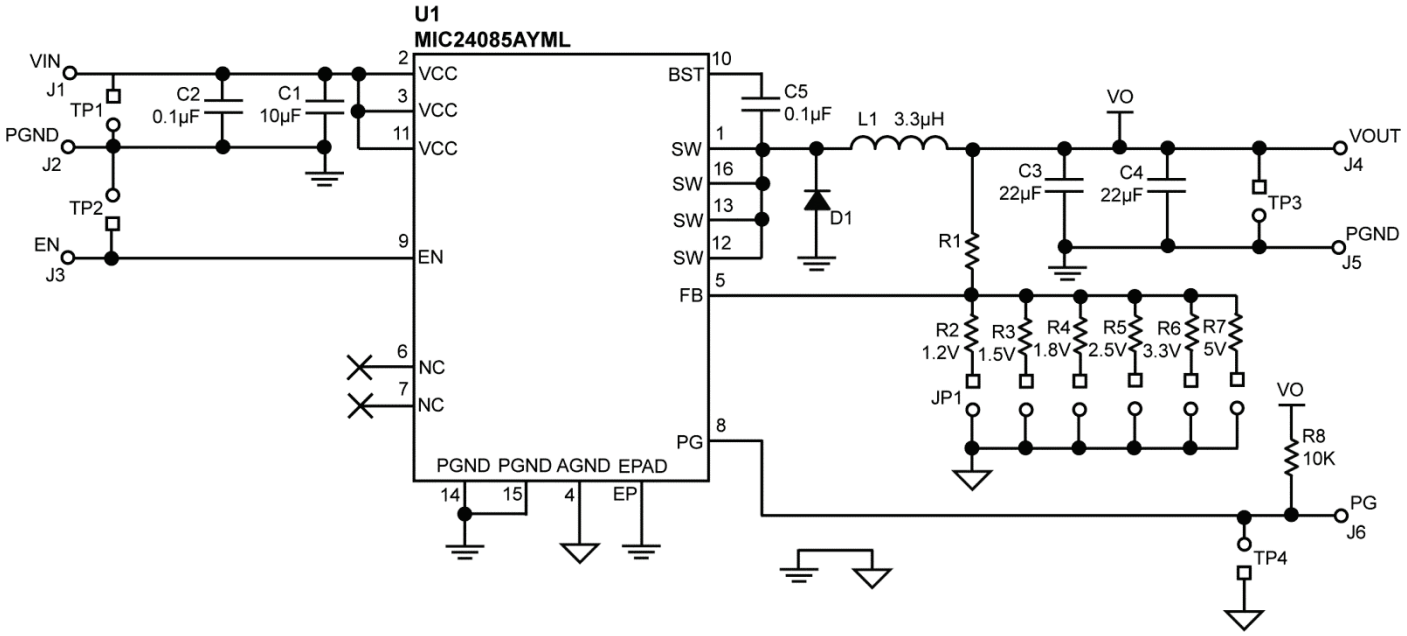
Transient Response and Control Loop Bandwidth

MIC24085 with adjustable output voltage has been designed to work under a wide range of input and output voltages, supporting different values and types of output capacitance. By design, the MIC24085 has a lower control loop bandwidth. For designs with aggressive load step response requirements, using a fixed-output voltage version with a larger output capacitance is recommended.



Adjustable Output Voltage: V_{IN} = 12V, V_{OUT} = 5V, Load Step = 0.5A to 2.5A at 50mA/µs with 1x470µF and 1x100µF output capacitance. Channel 1: VOUT, Channel 2: PG, Channel 3: Load Step

Evaluation Board Schematic



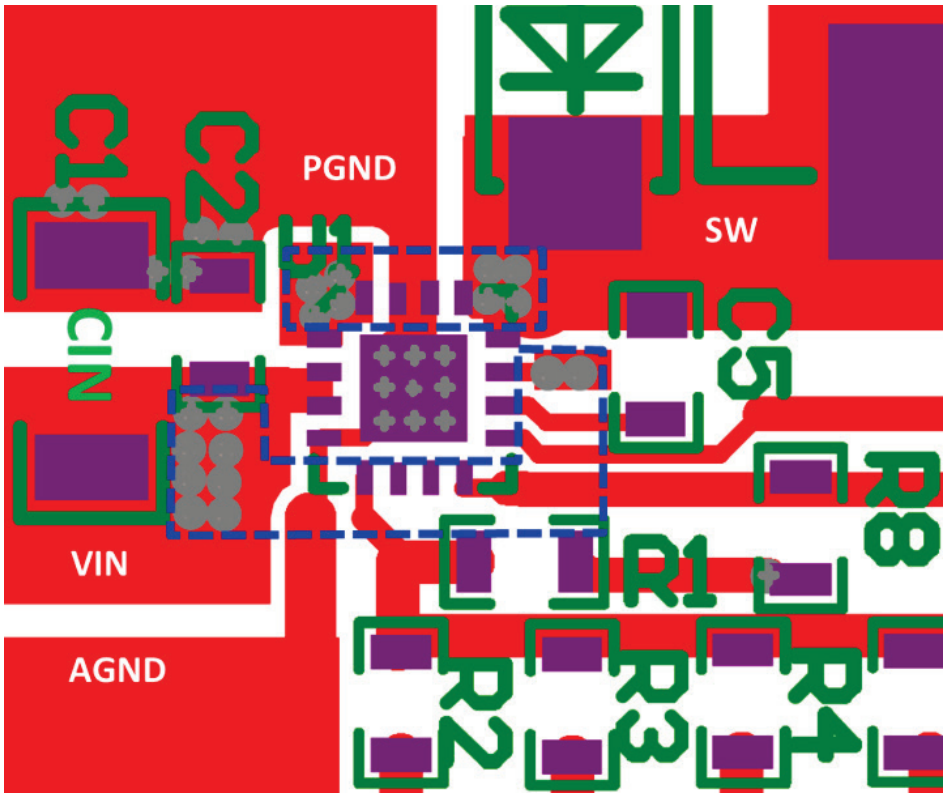
Bill of Materials

Item	Part Number	Manufacturer	Description	Qty.
C1	GRM31CR61E106KA12	Murata[5]	10µF/25V Ceramic Capacitor, X5R, Size 1206	1
C2, C5	GRM188R71H104KA93D	Murata	0.1µF/50V Ceramic Capacitor, X7R, Size 0603	2
C3	GRM31CF51A226ZE01L	Murata	22µF/10V Ceramic Capacitor, X5R, Size 1206	1
C4 (Open)		Murata	22µF/10V Ceramic Capacitor, X5R, Size 1206	1
D1 (Open)	SK33A	Diodes, Inc.[6]	40V Small Signal Schottky Diode, SOD123	1
L1	CIP0530LR3R3	ABC Taiwan Electronics Corporation[7]	3.3µH Inductor, 5A Sat. Current	1
R1, R4	CRCW06033K32FKEA	Vishay Dale[8]	3.32kΩ Resistor, Size 0603, 1%	1
R2, R8	CRCW060310K0FKEA	Vishay Dale	10kΩ Resistor, Size 0603, 1%	2
R3	CRCW06034K99FKEA	Vishay Dale	4.99kΩ Resistor, Size 0603, 1%	1
R5	CRCW06031K87FKEA	Vishay Dale	1.87kΩ Resistor, Size 0603, 1%	1
R6	CRCW06031K24FKEA	Vishay Dale	1.24kΩ Resistor, Size 0603, 1%	1
R7	CRCW0603732R0FKEA	Vishay Dale	732Ω Resistor, Size 0603, 1%	1
U1	MIC24085AYML	Micrel Inc.[9]	18V, 3A, 1MHz Tiny Buck Regulator	1

Notes:

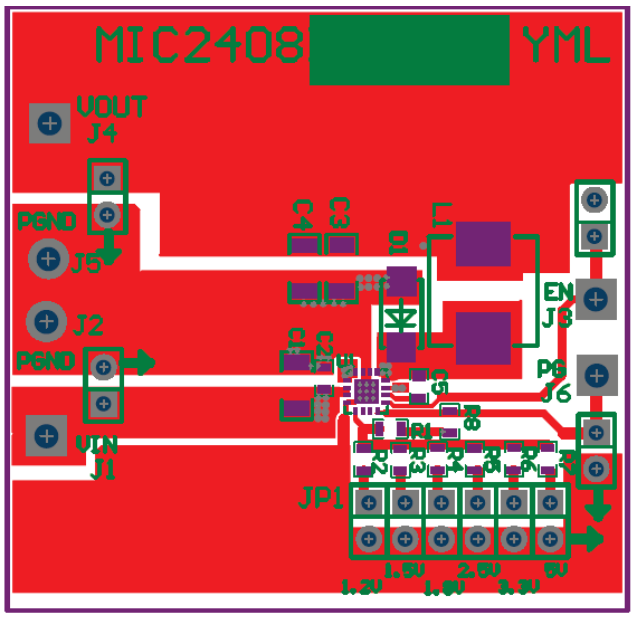
5. Murata: www.murata.com.
6. Diodes, Inc.: www.diodes.com.
7. ABC Taiwan Electronics Corporation: www.atec-group.com.
8. Vishay: www.vishay.com.
9. **Micrel, Inc.:** www.micrel.com.

PCB Layout Recommendations

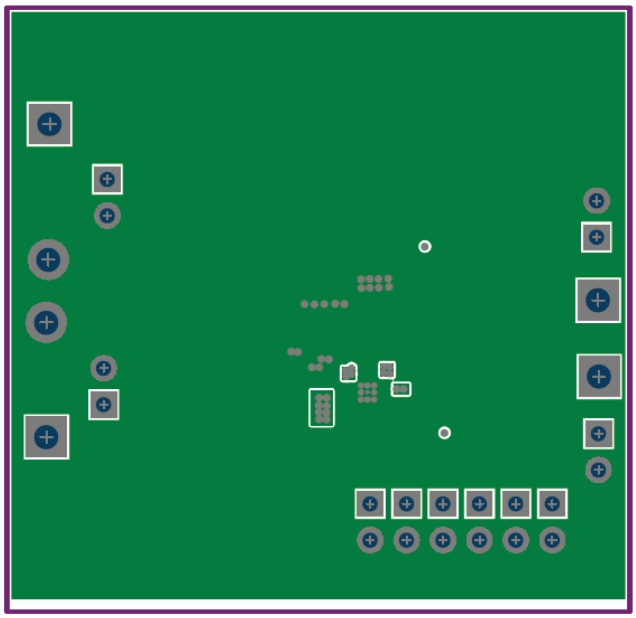


Recommended Component Placement at Top Layer

PCB Layout Recommendations (Continued)

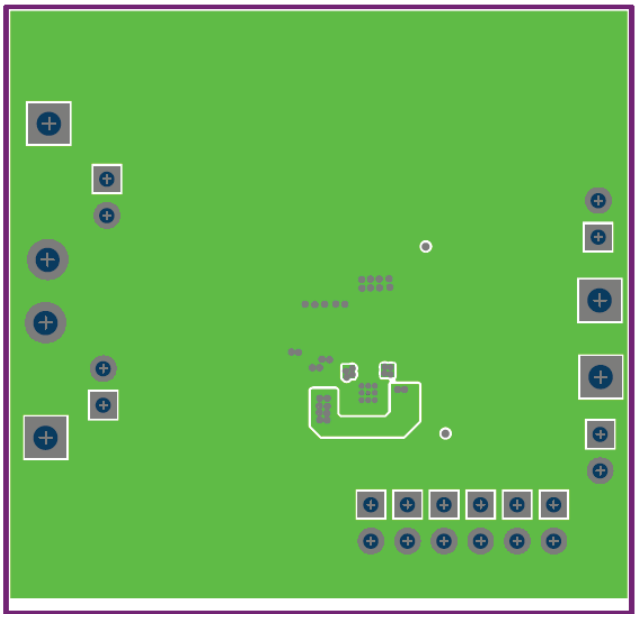


Top Layer

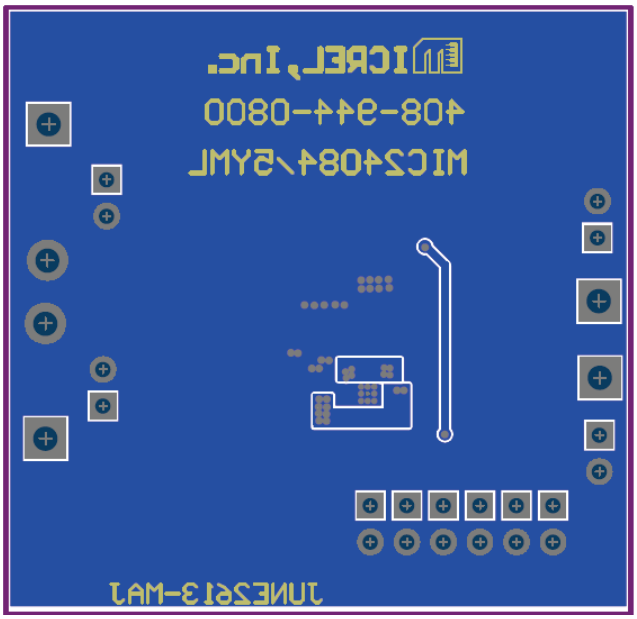


Mid-Layer 1 (Ground Plane)

PCB Layout Recommendations (Continued)

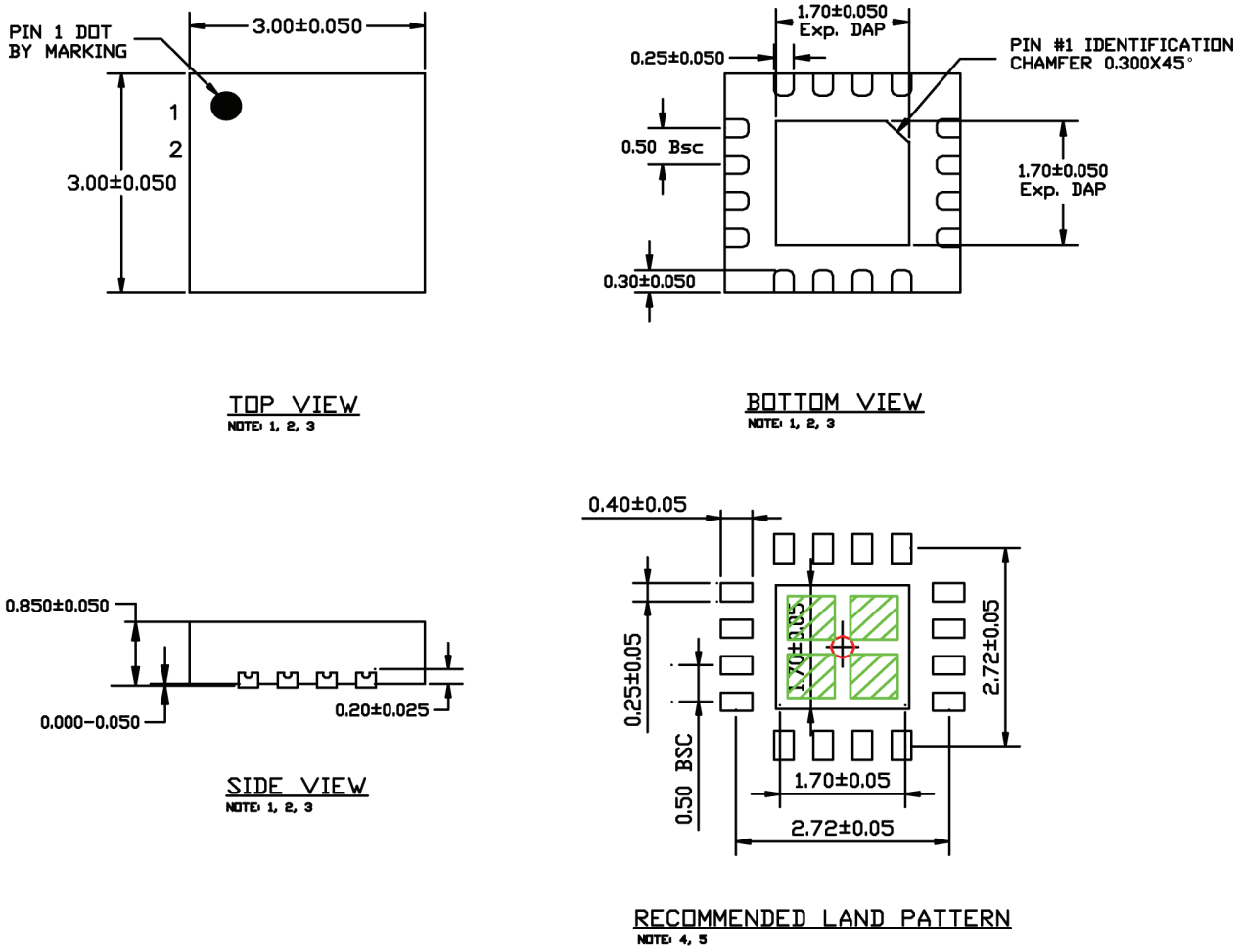


Mid-Layer 2 (Ground Plane)



Bottom Layer (Ground Plane)

Package Information[10] and Recommended Landing Pattern



NOTE:
1. MAX PACKAGE WARPAGE IS 0.05mm.
2. MAX ALLOWABLE BURR IS 0.076mm IN ALL DIRECTIONS
3. PIN #1 IS ON TOP WILL BE LASER MARKED.
4. RED CIRCLE IN LAND PATTERN INDICATES THERMAL VIA. SIZE SHOULD BE 0.30-0.35mm IN DIAMETER AND SHOULD BE CONNECTED TO GND FOR MAX THERMAL PERFORMANCE.
5. GREEN RECTANGLES (SHADED AREA) indicate SOLDER STENCIL OPENING ON EXPOSED PAD AREA. SIZE SHOULD BE 0.60x0.60mm IN SIZE, 0.20mm SPACING.

16-Pin 3mm × 3mm QFN (ML)

Note:

10. Package information is correct as of the publication date. For updates and most current information, go to www.micrel.com.

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