48V Input, Positive/Negative Output, 0.7A Step-down DC-DC Power SoC with Integrated Inductor

FEATURES

- Wide Input Voltage from 4.5V to 48V
  - ✧ Positive Output: Input Voltage from 4.5V to 48V
  - ✧ Negative Output: VIN ≥ 4.5V; VIN+|VOUT| ≤48V
- Output Voltage
  - ✧ Positive Output: Adjustable Output Voltage from 0.8V to 98%VIN
  - ✧ Negative Output: Adjustable Output Voltage from−0.8V to −15V
- 700mA Continuous, 1A Peak Output Current
  - ✧ Positive Output:700mA Continuous, 1A Peak Output Current
  - ✧ Negative Output:400mA Continuous
- Peak Current Control Mode
- 1.6MHz Switching Frequency
- Pulse Frequency modulation (PFM) mode for Light Load
- High Duty Cycle Operation for Low Dropout
- Internal Soft-Start
- Junction Temperature Range from −40°C to 125°C
- Cycle-by-Cycle Output Current Limit Protection
- Short Circuit and Over-Load Hiccup Protection
- Thermal Shutdown Protection
- LGA-8 (4.0mm×4.5mm×1.68mm) Package
- Pb-Free RoHS Compliant

DESCRIPTION

The M4001 is a 700mA fully integrated power module in LGA-8 (4.0mm×4.5mm×1.68mm) package with step-down switching mode Power SoC (System on a Chip) with integrated power MOSFETs, inductor and input decoupling capacitor inside. The input voltage is from 4.5V to 48V and the switching frequency is fixed at 1.6MHz.

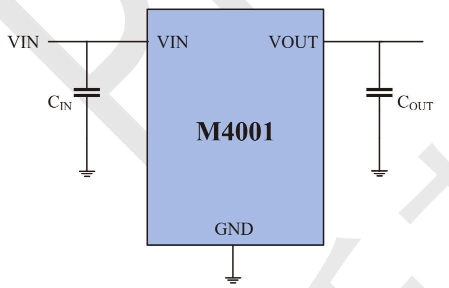
The M4001 provides highly efficient output with Peak Current Control Mode. It works on PFM mode for light load and supports high duty cycle for low dropout. Also, M4001 is suitable for negative output.

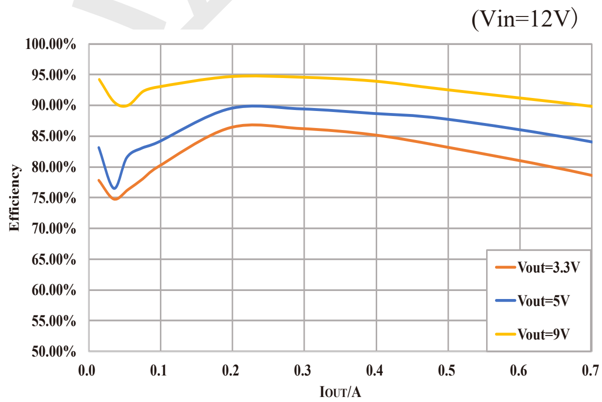
The M4001 has built in full protection features, over-load hiccup protection and over temperature shutdown protection.

APPLICATIONS

- Power Meter
- Industrial & Medical System
- Electrical Tools

TYPICAL APPLICATION&EFFICIENCY





PART NUMBER	Default VOUT
M4001DLCC-5V	5V
M4001DLCC-3V3	3.3V

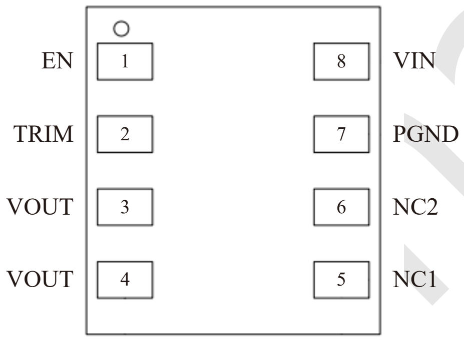
ORDERING INFORMATION

PART NUMBER	TOP MARKING	PACKAGE	MOQ	MSL LEVEL
M4001DLCC-5V	M4001-5V YWWLLL	LGA-8 (4.0mm×4.5mm×1.68mm)	3000/ Tape & Reel	3
M4001DLCC-3V3	M4001-3V3 YWWLLL	LGA-8 (4.0mm×4.5mm×1.68mm)	3000/ Tape & Reel	3

NOTES: Y: Year, WW: Week, LLL: Lot Number.

PACKAGE REFERENCE

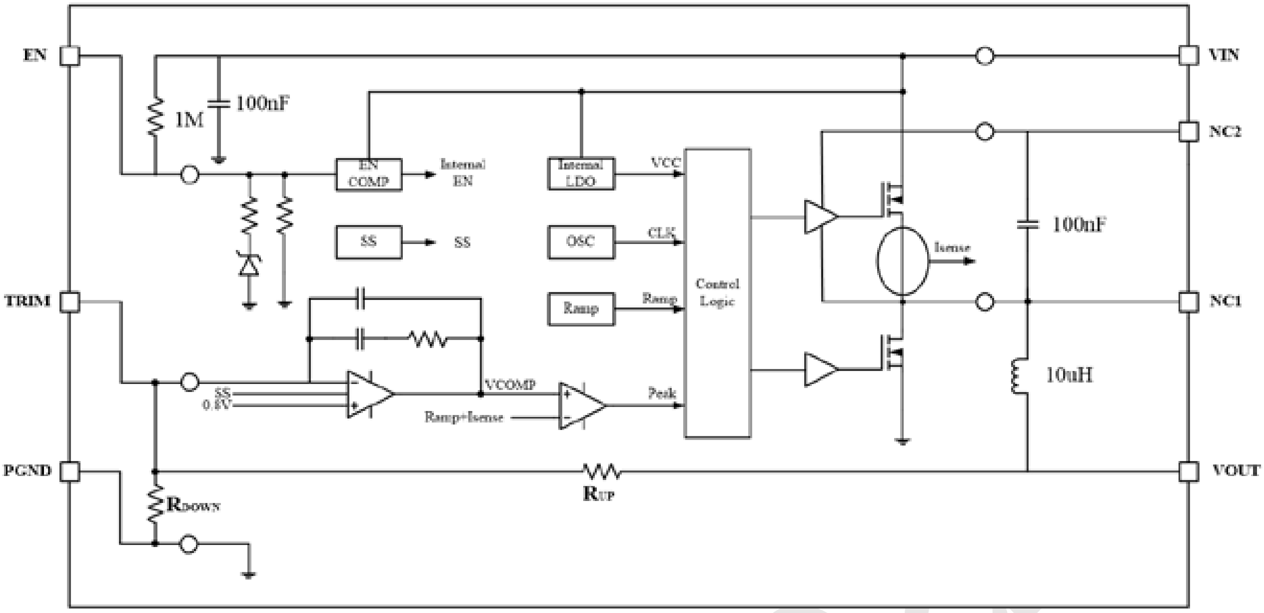
TOP VIEW



PIN FUNCTIONS

PIN #	NAME	DESCRIPTION
1	EN	**Enable Control.** This pin has been pulled up internally. Pulling this pin low shuts the chip down.
2	TRIM	**Trim.** The resistor divider from the VOUT to PGND has been placed internally to set the output voltage. The default output voltage is 3.3V or 5V. An external resistor divider can also be placed to change the output voltage.
3,4	VOUT	**Output Voltage Power Rail.** Connect this pin with the load. Output capacitor is recommended to be placed between VOUT and PGND.
5	NC1	**NC1 Pad Design for Test.** Connect with copper pad for thermal dissipation.
6	NC2	**NC2 Pad Design for Test.** Connect with copper pad for thermal dissipation.
7	PGND	**Power Ground.**
8	VIN	**Input Voltage Power Rail.** VIN supplies power to all the internal control circuitry and the power switch.

FUNCTIONAL BLOCK DIAGRAM



PART NUMBER	Default VOUT	R_{UP}	R_{DOWN}
M4001DLCC-5V	5V	604 kΩ	115kΩ
M4001DLCC-3V3	3.3V	604 kΩ	191kΩ

ABSOLUTE MAXIMUM RATINGS

	SYMBOL	MIN	MAX	UNIT
Voltage at Pins	V_{IN}	−0.3	50	V
Voltage at Other Pins		−0.3	6	V
Junction Temperature Range	T_J	−40	125	°C
Storage Temperature Range	T_S	−55	150	°C
Power Dissipation (T_A=+25°C)	P_D Note 1)		1.05	W

RECOMMANDED OPERATING CONDITIONS

	SYMBOL	MIN	MAX	UNIT
Input Voltage Range	V_{IN}	4.5	48	V
Output Voltage Range	V_{OUT}	0.8	$0.98\times V_{IN}$	V
Output Current Range	I_{OUT}		0.7	A
Junction Temperature Range	T_J	−40	125	°C

THERMAL RESISTANCE

	SYMBOL	MIN	MAX	UNIT
Junction to Ambient	θ_{JA} Note 2)		93	°C/W
Junction to Case	θ_{JC} Note 2)		21	°C/W

NOTES:

1) The maximum allowable continuous power dissipation at any ambient temperature (T_A) is calculated by $P_D(max)=(T_J(max)-T_A)/\theta_{JA}$. Exceeding the maximum allowable power dissipation will cause excessive die temperature, and the power module will go into thermal shutdown.
2) Measured on EVB, 2-layer PCB 1oZ.

ELECTRICAL CHARACTERISTICS

V_{IN}=12V, T_A=25°C, unless otherwise noted. Typical values are at V_{IN}=12V and V_{EN}=2V

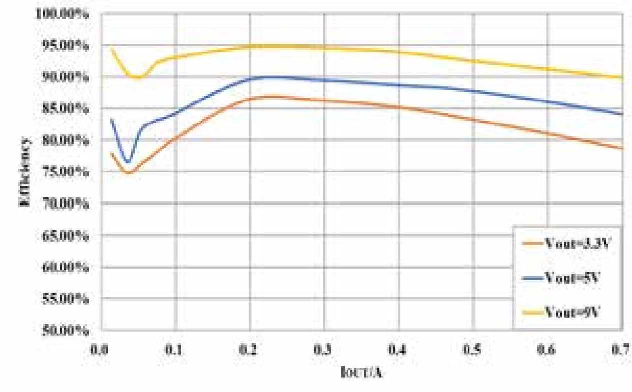
PARAMETERS	SYMBOL	CONDITION	MIN	TYP	MAX	UNIT
Input Voltage	V_{IN}		4.5		48	V
Input under Voltage Lockout Threshold	V_{UVLO}	V_{IN} Increasing	4.15	4.3	4.45	V
Input under Voltage Lockout Hysteresis				300		mV
Shutdown Current	I_{SD}	V_{EN}=0V, V_{IN}=15V		1	2	µA
Quiescent Current	I_Q	V_{Trim}=0.83V, no switching		150	220	µA
EN On Threshold		V_{EN} Increasing	1.5	1.55	1.6	V
EN off Threshold		V_{EN} Decreasing	1.1	1.22	1.3	V
Trim Voltage	V_{Trim_REF}		785	797	809	mV
Trim Current	I_{Trim}	V_{EN}=1V, V_{Trim}= 2V			0.1	µA
LS Switch Current Limit			0.8	1	1.2	A
Switching Frequency	F_{SW}		1.4	1.6	1.9	MHz
Soft-Start Time	TSS	V_{Trim} from 10% to 90%	0.35	0.6	0.85	ms
Maximum Duty cycle	D			98		%
Thermal Shutdown				151		°C
Thermal Shutdown Hysteresis				21		°C

TYPICAL PERFORMANCE CHARACTERISTICS

V_{IN}=12V and T_A=25°C, unless otherwise noted.

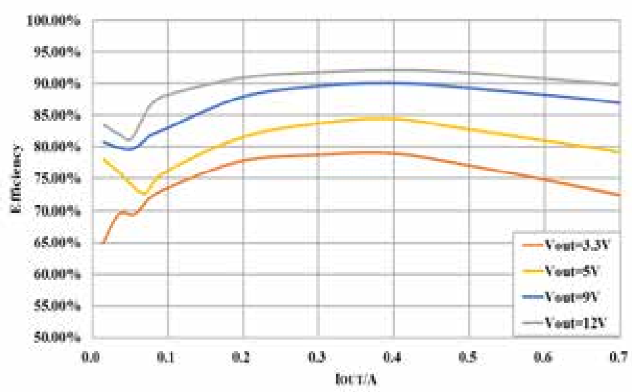
Efficiency

V_{IN}=12V, V_{OUT}=3.3V/5V/9V, I_{OUT}=0.02A~0.7A



Efficiency

V_{IN}=24V, V_{OUT}=3.3V/5V/9V/12V, I_{OUT}=0.02A~0.7A

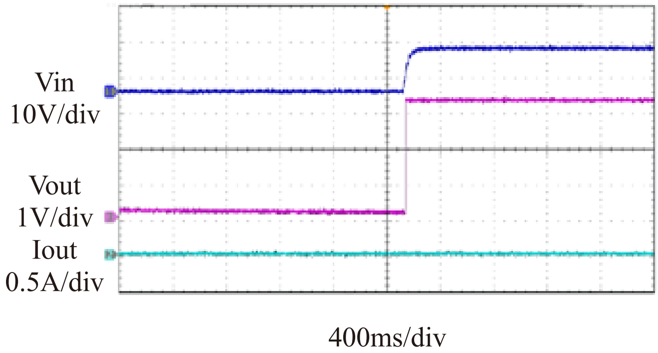


TYPICAL PERFORMANCE CHARACTERISTICS (continued)

V_{IN}=12V, V_{OUT}=3.3V, T_A=25°C, unless otherwise noted.

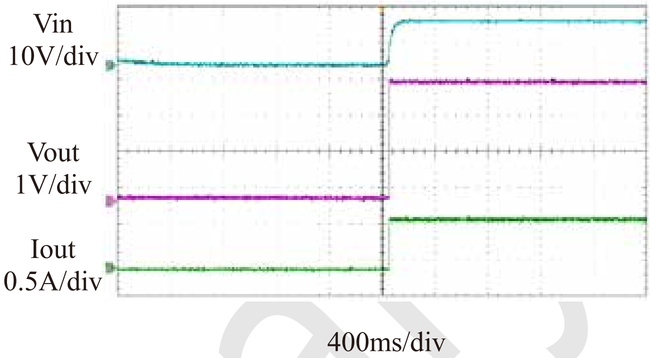
VIN Start up

I_{OUT}=0A



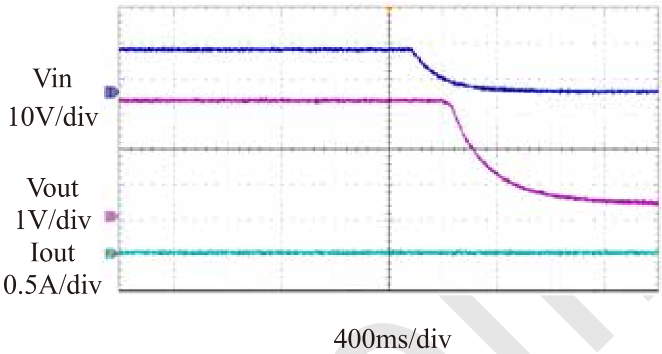
VIN Start up

I_{OUT}=0.7A



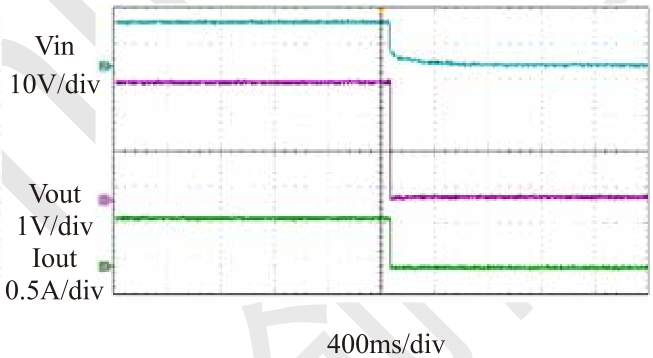
VIN Shut down

I_{OUT}=0A



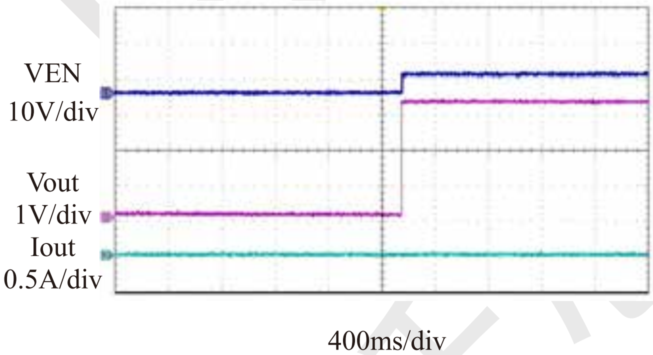
VIN Shut down

I_{OUT}=0.7A



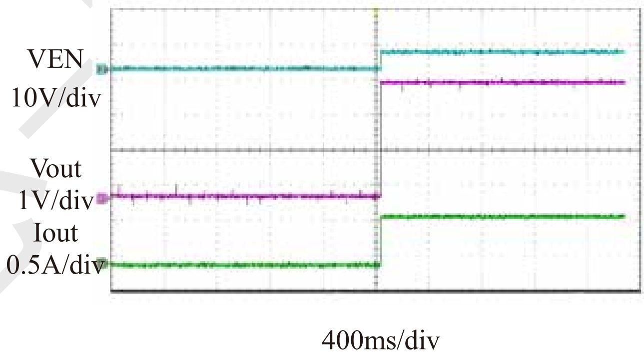
EN Start up

I_{OUT}=0A



EN Start up

I_{OUT}=0.7A

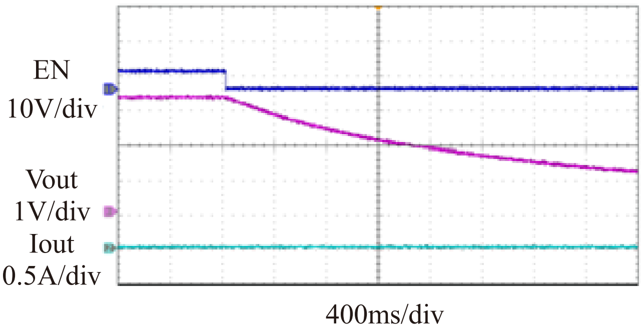


TYPICAL PERFORMANCE CHARACTERISTICS (continued)

V_{IN}=12V, V_{OUT}=3.3V, T_A=25°C, unless otherwise noted.

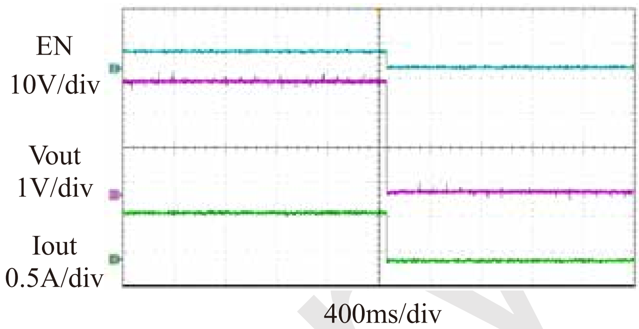
EN Shut down

I_{OUT}=0A



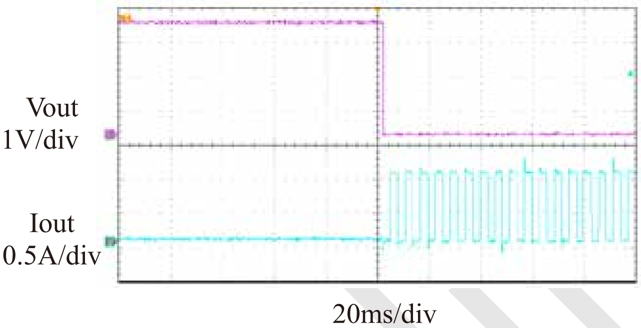
EN Shut down

I_{OUT}=0.7A



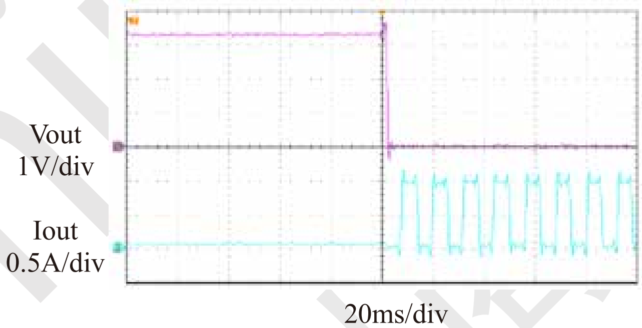
SCP Enter

I_{OUT}=0A



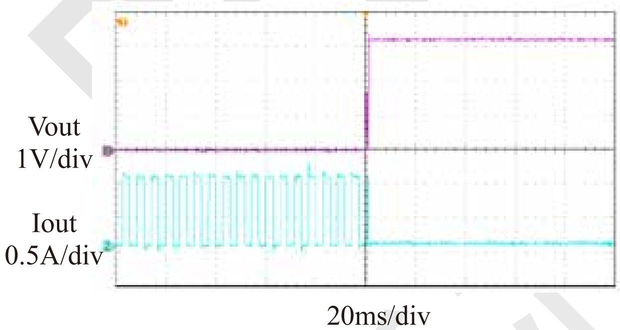
SCP Enter

I_{OUT}=0.7A



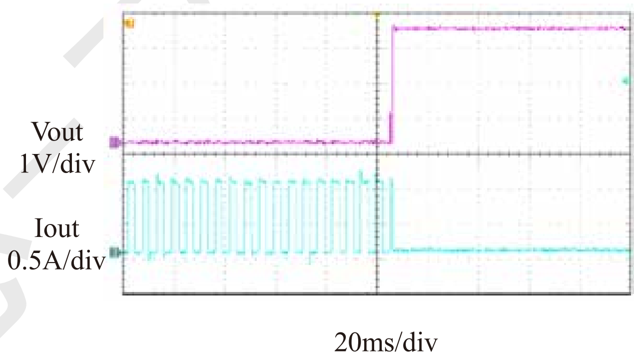
SCP Recover

I_{OUT}=0A



SCP Recover

I_{OUT}=0.7A

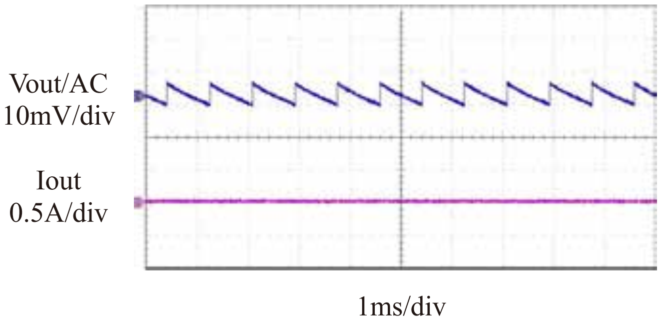


TYPICAL PERFORMANCE CHARACTERISTICS (continued)

V_{IN}=12V, T_A=25°C, unless otherwise noted. Typical values are at V_{IN}=12V and V_{OUT}=3.3V.

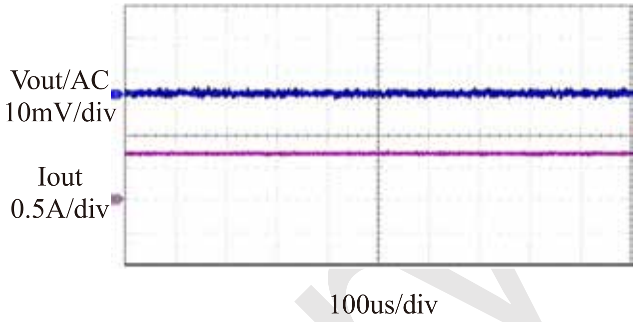
VOUT Ripple

Iout=0A



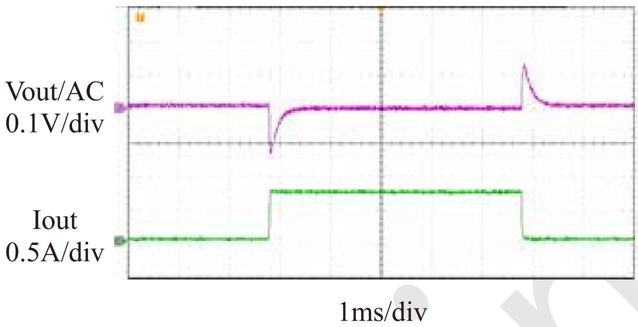
VOUT Ripple

Iout=0.7A



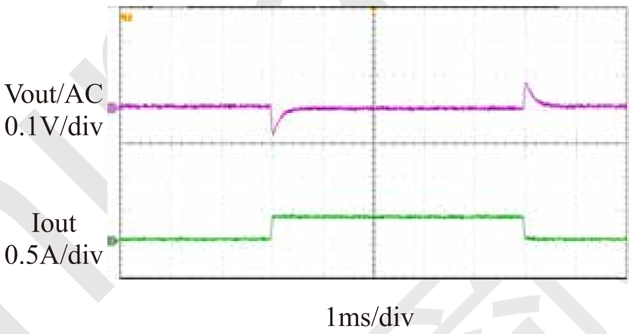
Load Transient

I_{OUT}=0A to 0.7A, 1A/µs



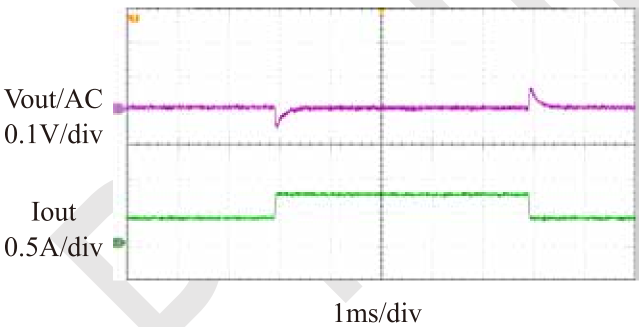
Load Transient

I_{OUT}=0A to 0.35A, 1A/µs



Load Transient

I_{OUT}=0.35A to 0.7A, 1A/µs



OPERATION

The M4001 is a 700mA synchronous step-down switching mode Power SoC with integrated high-side and low-side power MOSFETs, inductor and input capacitors in LGA-8 (4.0mm × 4.5mm × 1.68mm) package. M4001 works on peak current control mode to regulate the output voltage with the fixed switching frequency of 1.6MHz. M4001 operates in pulse frequency modulation (PFM) mode at light load condition to achieve excellent efficiency. M4001 can support up to 98% maximum duty cycle and has 0.6ms soft-start timer internally.

Only input and output capacitors are needed to complete the design over 4.5V to 48V input voltage range with the default 3.3V or 5V output. External Trim resistor divider can be used to change the output voltage. And the integrated input coupling capacitor can minimize the parasitic inductance of input circuit and reduce the voltage spike on switching pin which simplify the PCB layout.

Fully integrated protection features including OCP and OTP are shown below.

OVER CURRENT PROTECTION (OCP)

M4001 has a typical 1A cycle-by-cycle Low-Side current limit protection to prevent inductor current from running away. When the Low-Side switch reaches the current limit, M4001 will enter hiccup mode. It will stop switching for a pre-determined period of time and automatically start up again. It always starts up with soft-start to limit inrush current and avoid output overshoot.

OVER TEMPERATURE PROTECTION (OTP)

M4001 will stop switching when the junction temperature exceeds 150 °C. The device will power up again when the junction temperature drops below 130°C.

APPLICATION INFORMATION（Positive output）

Setting the Output Voltage

The output voltage of M4001 can be set by the external feedback resistor divider as Figure 1. Do consider the internal pull-up resistor R_{UP} and pull-down resistor R_{DOWN}. The output voltage can be set as:

$$|V_{OUT}|=V_{trim}\frac{R_1//R_{UP}+R_2//R_{DOWN}}{R_2//R_{DOWN}}$$

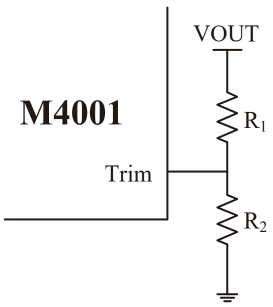


Figure 1: Typical Trim Connection of M4001

Table 1 lists the recommended feedback resistor values for common output voltages.

Table 1: Trim Resistor Values for Common Output Voltages

P/N	V_{OUT} (V)	R_1 (kΩ)	R_2 (kΩ)	R_{UP} (kΩ)	R_{DOWN} (kΩ)
M4001-3V3	±3.3	Float	Float	604	191
	±5	Float	287		
	±9	Float	84.5		
	±12	324	16.2		
M4001-5V	±3.3	100	36	604	115
	±5	Float	Float		
	±9	150	13		
	±12	270	15		

Input Capacitor Selection

The input current of the step-down converter is discontinuous with sharp edges, therefore input filter capacitors are necessary. For better performance, low ESR ceramic capacitors with X5R or X7R dielectrics are highly recommended because of their lowest temperature variations. The RMS current of the input capacitors is calculated:

$$I_{CIN\_RMS}=I_{OUT}\sqrt{D(1-D)}$$

in which D is the Duty Cycle and when the current is continuous, $D = V_{OUT}/V_{IN}$; I_{OUT} is the output load current. As the equation above, when D is 0.5, the highest RMS current is approximately:

$$I_{CIN\_RMS}=\frac{1}{2}\times I_{OUT}$$

So, it is recommended to choose the capacitor with the RMS current rating higher than 1/2 I_{OUT}.

The power dissipation on the input capacitor can be estimated with the RMS current and the ESR resistor.

Electrolytic or tantalum capacitors can also be used as there has been a small size 0.1µF ceramic capacitor placed closed to VIN and PGND in M4001 already. The input voltage ripple caused by the capacitor can be calculated as:

$$\Delta V_{CIN}=\frac{I_{OUT}}{F_{SW}\cdot C_{IN}}\cdot\frac{V_{OUT}}{V_{IN}}\cdot\left(1-\frac{V_{OUT}}{V_{IN}}\right)$$

in which, F_{SW} is switching frequency of 1.6MHz.

Output Capacitor Selection

An output capacitor is required to keep stable output voltage. To minimize the output voltage ripple, low ESR ceramic capacitors should be used. The output voltage ripple can be estimate as:

$$\Delta V_{OUT}=\frac{V_{OUT}}{8F_{SW}{}^2C_{OUT}L}\cdot\left(1-\frac{V_{OUT}}{V_{IN}}\right)$$

In which, L is the inductor, which value is fixed at 10µH internally.

If electrolytic or tantalum capacitor are used, the ESR will dominate the output voltage ripple as:

$$\Delta V_{OUT}=R_{ESR}\cdot\frac{V_{OUT}}{F_{SW}L}\cdot\left(1-\frac{V_{OUT}}{V_{IN}}\right)$$

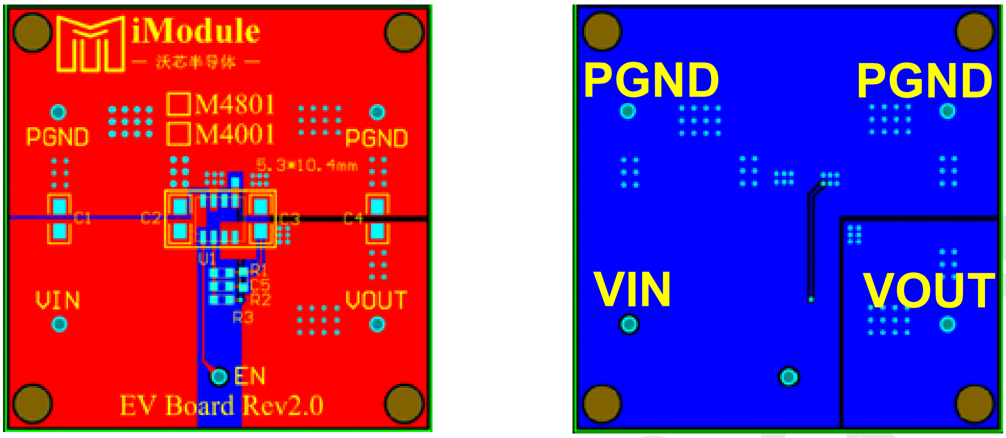
PCB Layout Guide

To optimize the electrical and thermal performance, some PCB layout guidelines should be considered as below:

1. Use wide trace for the high current paths and keep it as short as possible. It helps to minimize the PCB conduction loss and thermal stress.
2. The M4001 integrates the input decoupling capacitor, and it is also better to place other input capacitors close to VIN and PGND.

3. Connect all feedback network to TRIM shortly and directly and keep it as close to the Power Module as possible.
4. The PGND should be connected to a strong ground plane for better heat dissipation and noise protection.

Figure 2 gives a good example of the recommended layout.



(a) Top Layer (b)Bottom Layer

Figure 2: Recommended Layout

APPLICATION INFORMATION（Negative output）

Capacitor Selection for Negative Output Buck Boost Converter

For negative input, new input capacitor is added from V_{IN} to PGND. The input voltage ripple caused by the capacitor can be calculated as:

$$\Delta V_{CIN}=\frac{I_{OUT}}{F_{SW}\cdot C_{IN}}\cdot\frac{|V_{OUT}|}{V_{IN}+|V_{OUT}|}\cdot\left(1-\frac{|V_{OUT}|}{V_{IN}+|V_{OUT}|}\right)$$

in which, F_{SW} is switching frequency of 1.6MHz.

For negative output, the input capacitors of buck become C_{IO} (V_{IN} to V_{OUT} Capacitor) of the negative output buck boost converter. So C_{IO} can be typically one or two ceramic capacitors in parallel with a small size high frequency by-pass capacitor as ordinary buck. They can also be increased if desired.

For output capacitors, they must supply the current when low side MOSFET is off. Therefor, use the minimum voltage to calculate the output capacitance needed, and peak-to-peak current should be also maximum.

Output voltage ripple is

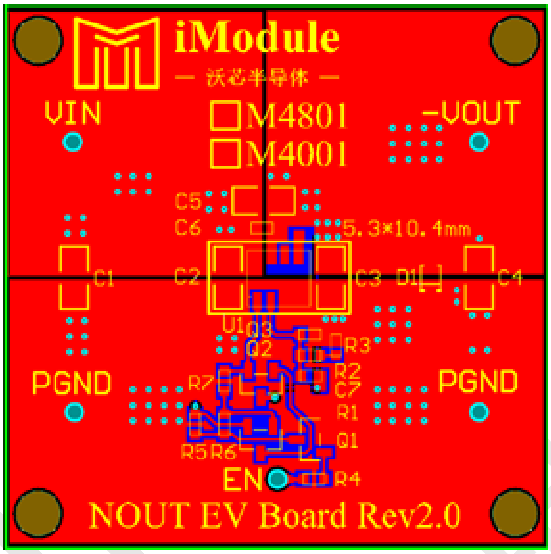
$$\Delta V_{OUT}=\frac{I_{OUTMAX}}{F_{SW}C_{OUT}}\cdot\frac{|V_{OUT}|}{V_{INMIN}+|V_{OUT}|}$$

PCB Layout Guide

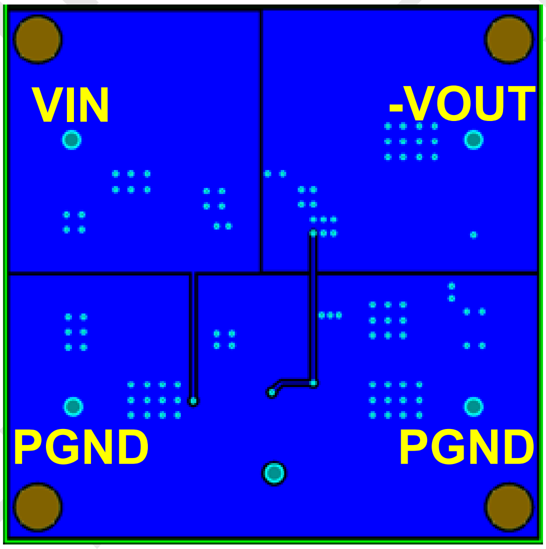
To optimize the electrical and thermal performance, PCB layout guidelines should be considered as below:

1. Use wide trace for the high current paths and keep it as short as possible. It helps to minimize the PCB conduction loss and thermal stress.
2. The M4001 integrated the input decoupling capacitor, and it is also better to place other input capacitors close to VIN and PGND.
3. Connect all feedback network to TRIM shortly and directly and keep it as close to the Power Module as possible.
4. The PGND should be connected to a strong ground plane for better heat dissipation and noise protection.

Figure 3 gives a good example of the recommended layout.



(a)Top Layer



(b) Bottom Layer

Figure 3: Recommended Layout

TYPICAL APPLICATION

Positive Output

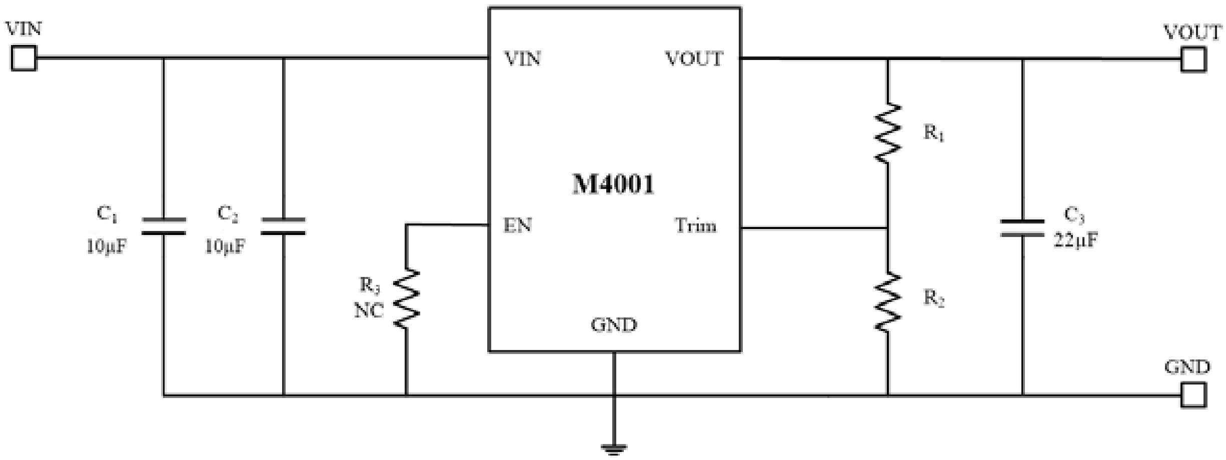


Figure 4: Typical Application Circuits of M4001 for Positive Output

Table 3: Reference Design for Positive Output

P/N	VOUT	CIN	COUT	R_1	R_2	R_{UP}	R_{DOWN}	I_{LIM}
M4001-3V3	3.3V	10μF	22μF	Float	Float	604 kΩ	191 kΩ	1A
	5V	10μF	22μF	Float	287 kΩ			1A
	9V	10μF	22μF	Float	84.5 kΩ			1A
	12V	10μF	22μF	324 kΩ	16.2 kΩ			1A
M4001-5V	3.3V	10μF	22μF	100 kΩ	36 kΩ	604 kΩ	115kΩ	1A
	5V	10μF	22μF	Float	Float			1A
	9V	10μF	22μF	150 kΩ	13kΩ			1A
	12V	10μF	22μF	270 kΩ	15 kΩ			1A

NOTES:

CIN is the sum of the input capacitors, COUT is the sum of the output capacitors, please refer to Figure 4 for parameters of other components.

Negative Output

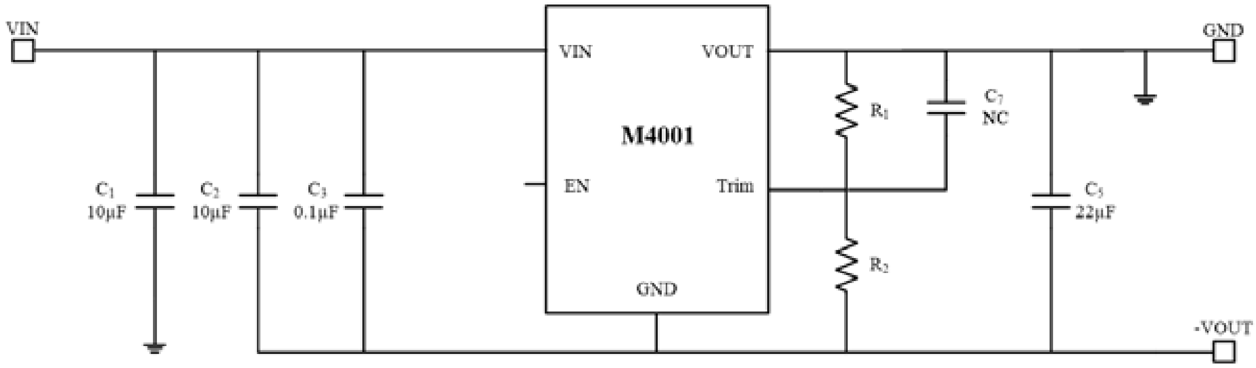


Figure 5: Typical Application Circuits of M4001 for Negative Output

Table 4: Reference Design for Negative Output

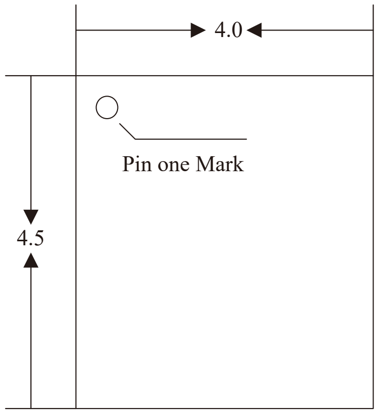
PN	VOUT	CIN	COUT	CIO	R1	R2	R_{UP}	R_{DOWN}	I_{LIM}
M4001-3V3	−3.3V	10μF	22μF	10μF	Float	Float	604 kΩ	191 kΩ	−0.4A
	−5V	10μF	22μF	10μF	Float	287 kΩ			−0.4A
	−9V	10μF	22μF	10μF	Float	84.5 kΩ			−0.4A
	−12V	10μF	22μF	10μF	324 kΩ	16.2 kΩ			−0.4A
M4001-5V	−3.3V	10μF	22μF	10μF	100 kΩ	36 kΩ	604 kΩ	115 kΩ	−0.4A
	−5V	10μF	22μF	10μF	Float	Float			−0.4A
	−9V	10μF	22μF	10μF	150 kΩ	13kΩ			−0.4A
	−12V	10μF	22μF	10μF	270 kΩ	15 kΩ			−0.4A

NOTES:

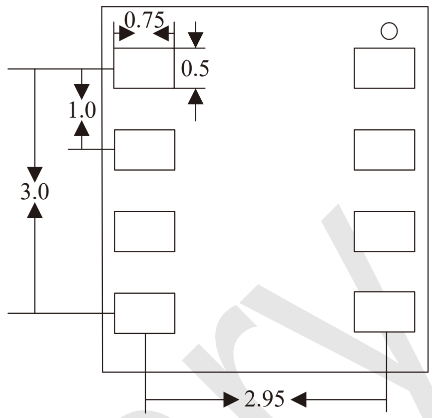
CIN is the sum of the input capacitors to PGND, COUT is the sum of the output capacitors, CIO is the sum of input capacitor to VOUT, please refer to Figure 5 for parameters of other components.

PACKAGE INFORMATION

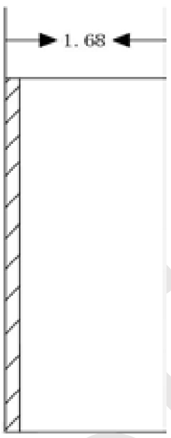
TOP VIEW



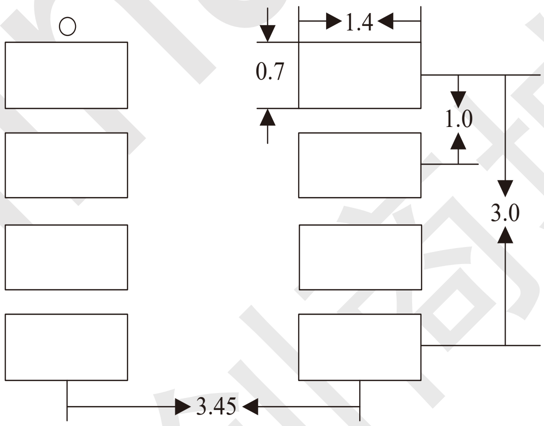
BOTTOM VIEW



SIDE VIEW



RECOMMENDED LAND PATTERN



LGA-8 (4.0mm×4.5mm×1.68mm) Package

NOTES:

All dimensions are in MM.

- Note: Peak Solder Reflow Body Temperature 245°C