MPM3805

6V Input, 0.6A Module Synchronous Step-Down Converter with Integrated Inductor

DESCRIPTION

The MPM3805 is a module with monolithic step-down switch mode converter with built-in internal power MOSFETs and inductor. It's designed to simplify power system design and provide ease of use. The DC-DC module has a small surface-mount QFN-12 (2.5mmX3.0mmX0.9mm) package. It achieves 0.6A continuous output current from a 2.5V to 6V input voltage with excellent load and line regulation. The output voltage can be regulated as low as 0.6V. For adjustable output, only input, output capacitors and FB resistors are needed to complete the design.

The Constant-On-time control scheme provides fast transient response and eases loop stabilization. Fault condition protection includes cycle-by-cycle current limiting and thermal shutdown.

The MPM3805 is ideal for a wide range of applications including high performance DSPs, FPGAs, PDAs, portable instruments and storage.

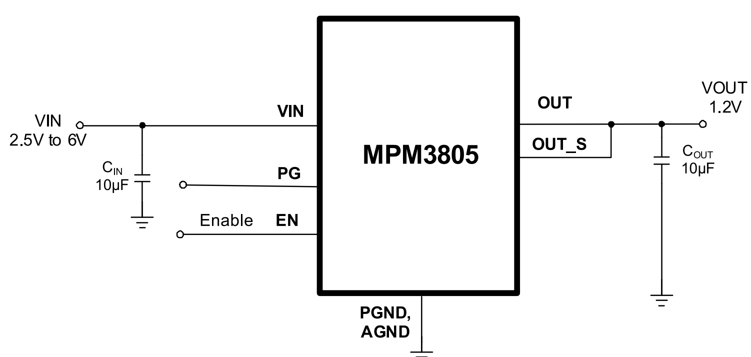
FEATURES

- Wide 2.5V to 6V Operating Input Range
- Fixed and Adjustable output from 0.6V
- QFN-12 (2.5mmX3.0mmX0.9mm) Package
- Total Solution Size 6mm x 3.8mm
- Up to 0.6A Output Current
- 100% Duty Cycle in Dropout
- Ultra Low IQ: 17μA
- EN and Power Good for Power Sequencing
- Cycle-by-Cycle Over-Current Protection
- Short Circuit Protection with Hiccup Mode
- Adjustable Output Only Needs 4 External Components - 2 Ceramic Capacitors and FB Divider Resistors
- Fixed Output only Needs Input and Output Capacitors

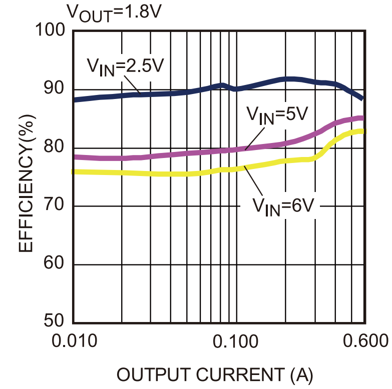
APPLICATIONS

- Low Voltage I/O System Power
- LDO Replacement
- Power for Portable Products
- Storage (SSD/HDD)
- Space-limited Applications

TYPICAL APPLICATION (Fixed Output)



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

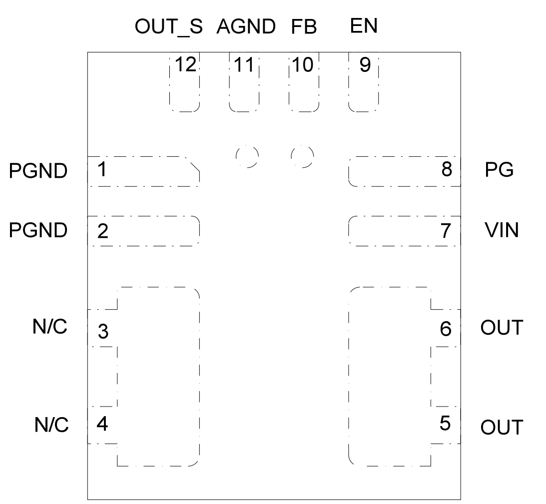


ORDERING INFORMATION

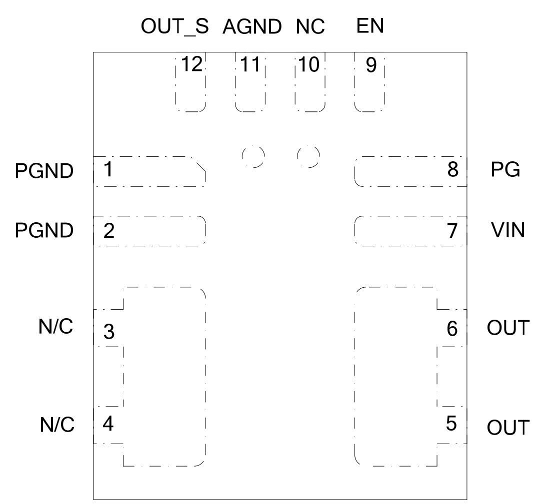
Part Number	Package	Top Marking	Vo Range
MPM3805GQB*	QFN-12 (2.5mmX3.0mmX0.9mm)	AGR	Adjustable
MPM3805GQB-12	QFN-12 (2.5mmX3.0mmX0.9mm)	AHE	Fixed 1.2V
MPM3805GQB-18	QFN-12 (2.5mmX3.0mmX0.9mm)	AHD	Fixed 1.8V
MPM3805GQB-25	QFN-12 (2.5mmX3.0mmX0.9mm)	AJK	Fixed 2.5V
MPM3805GQB-33	QFN-12 (2.5mmX3.0mmX0.9mm)	AJJ	Fixed 3.3V

* For Tape & Reel, add suffix –Z (e.g. MPM3805GQB–Z);

PACKAGE REFERENCE



MPM3805GQB



MPM3805GQB-12 MPM3805GQB-18
MPM3805GQB-25 MPM3805GQB-33

QFN-12 (2.5mmX3.0mmX0.9mm)

ABSOLUTE MAXIMUM RATINGS (1)

Supply Voltage V_{IN} 6.5V
V_{SW} ....
-0.3V (-5V for <10ns) to 6.5V (7V for <10ns)
All Other Pins ....-0.3V to 6.5 V
Junction Temperature ....150°C
Lead Temperature ....260°C
Continuous Power Dissipation (T_A = +25°C) (2)
……………. 1.9W
Storage Temperature............... -65°C to +150°C

Recommended Operating Conditions (3)

Supply Voltage V_{IN} ....2.5V to 6V
Output Voltage V_{OUT}.................. 12% x V_{IN} to V_{IN}
Operating Junction Temp. (T_J). -40°C to +125°C

Thermal Resistance (4)

	θ_{JA}	θ_{JC}	
QFN-12 (2.5mmX3.0mm)……	65	13	°C/W

Notes:
1) Exceeding these ratings may damage the device.
2) The maximum allowable power dissipation is a function of the maximum junction temperature T_J (MAX), the junction-to-ambient thermal resistance θ_{JA}, and the ambient temperature T_A. The maximum allowable continuous power dissipation at any ambient temperature is calculated by P_D (MAX) = (T_J (MAX)-T_A)/θ_{JA}. Exceeding the maximum allowable power dissipation will cause excessive die temperature, and the regulator will go into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage.
3) The device is not guaranteed to function outside of its operating conditions.
4) Measured on JESD51-7, 4-layer PCB.

ELECTRICAL CHARACTERISTICS

V_{IN} = 5V, T_J = -40°C to +125°C, Typical value is tested at T_J = +25°C. The limit over temperature is guaranteed by characterization, unless otherwise noted.

Parameter	Symbol	Condition	Min	Typ	Max	Units
Feedback Voltage (MPM3805GQB Only)	V_{FB}	2.5V ≤ V_{IN} ≤ 6V, T_J=+25°C	-2%	0.600	+2%	V/%
Fixed Output Voltage		Only for MPM3805GQB-12, I_{OUT}=10mA, T_J=+25°C	-2.5%	1.2	+2.5%	V/%
		Only for MPM3805GQB-18, I_{OUT}=10mA, T_J=+25°C	-2.5%	1.8	+2.5%	
		Only for MPM3805GQB-25, I_{OUT}=10mA, T_J=+25°C	-2.5%	2.5	+2.5%	
		Only for MPM3805GQB-33, I_{OUT}=10mA, T_J=+25°C	-2.5%	3.3	+2.5%	
Feedback Current	I_{FB}	V_{FB} = 0.63V, Only for MPM3805GQB		10		nA
PFET Switch On Resistance	R_{DSON_P}			110		mΩ
NFET Switch On Resistance	R_{DSON_N}			70		mΩ
Dropout Resistance	R_{DR}	100% on duty		235		mΩ
Switch Leakage		V_{EN} = 0V, V_{IN} = 6V V_{SW} = 0V and 6V, T_J=+25°C		0	1	μA
PFET Current Limit			1.0	1.4	1.8	A
ON Time	T_{ON}	V_{IN}=5V, V_{OUT}=1.2V		70		ns
		V_{IN}=3.6V, V_{OUT}=1.2V		100		
Switching Frequency	F_s	V_{OUT}=1.2V	-20%	3500	+20%	kHz/%
Minimum Off Time	$T_{MIN\text{-}OFF}$			60		ns
Soft-Start Time	$T_{SS\text{-}ON}$			1.5		ms
Power Good Upper Trip Threshold	PG_H	FB voltage respect to the regulation		+10		%
Power Good Lower Trip Threshold	PG_L			-10		%
Power Good Delay	PG_D			50		μs
Power Good Sink Current Capability	$V_{PG\text{-}L}$	Sink 1mA			0.4	V
Power Good Logic High Voltage	$V_{PG\text{-}H}$	V_{IN}=5V, V_{FB}=0.6V	4.9			V
Power Good Internal Pull Up Resistor	R_{PG}			550		kΩ
Under Voltage Lockout Threshold Rising			2.15	2.3	2.48	V
Under Voltage Lockout Threshold Hysteresis				300		mV
EN Input Logic Low Voltage					0.4	V
EN Input Logic High Voltage			1.2			V

ELECTRICAL CHARACTERISTICS *(continued)*

V_{IN} = 5V, T_J = -40°C to +125°C, Typical value is tested at T_J = +25°C. The limit over temperature is guaranteed by characterization, unless otherwise noted.

Parameter	Symbol	Condition	Min	Typ	Max	Units
EN Input Current		V_{EN}=2V		1.5		μA
		V_{EN}=0V		0.1	1	μA
Supply Current (Shutdown)		V_{EN}=0V, T_J=+25°C			1	μA
Supply Current (Quiescent)		V_{EN}=2V,V_{FB}=0.63V,V_{IN}=5V, , T_J=+25°C		17	21	μA
Thermal Shutdown(5)				150		°C
Thermal Hysteresis(5)				30		°C

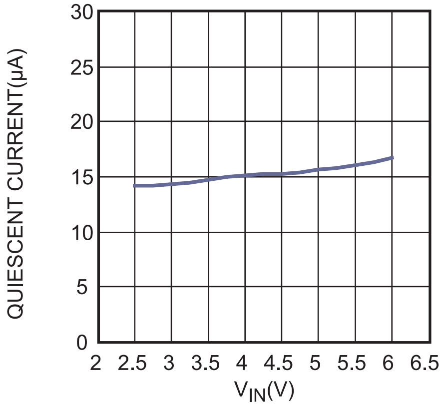
Notes:

5) Not production test, guaranteed by design.

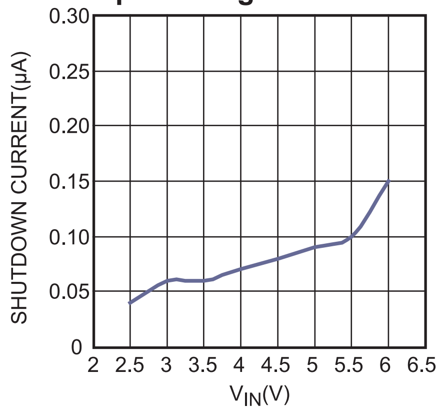
TYPICAL CHARACTERISTICS

V_{IN} = 5V, V_{OUT} = 1.2V, C_{IN}=10µF, C_{OUT}=20µF, T_A = +25ºC, unless otherwise noted.

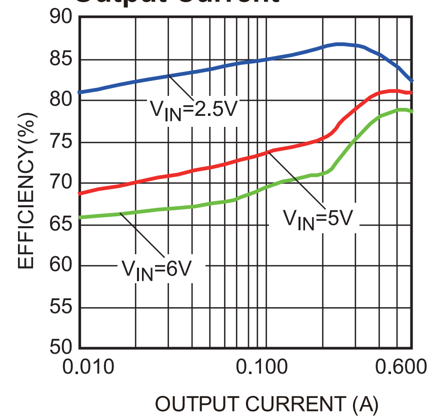
Quiescent Current vs. Input Voltage



Shutdown Current vs. Input Voltage

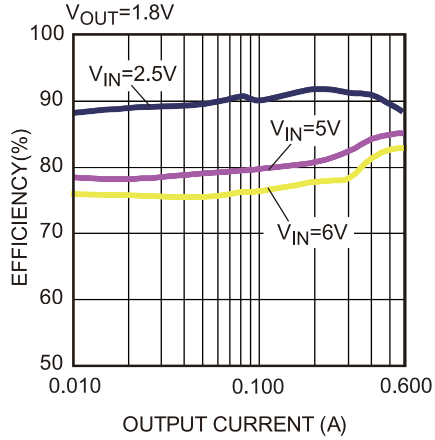


Efficiency vs. Output Current

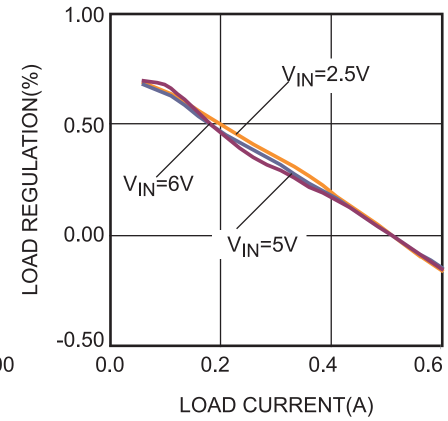


Efficiency vs. Output Current

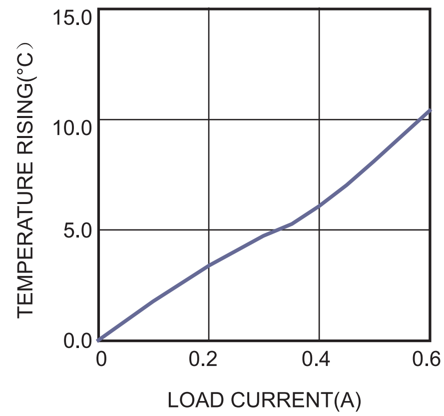
V_{OUT}=1.8V



Load regulation

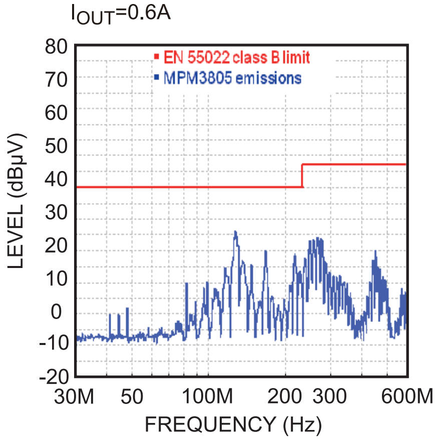


Thermal rising Vs. Load current



Radiated Emission

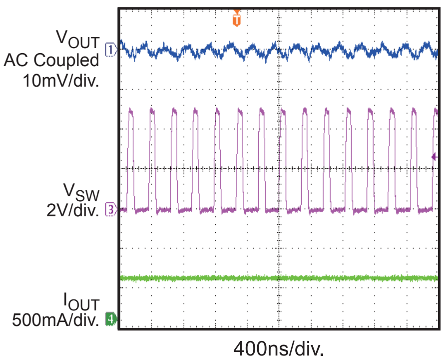
I_{OUT}=0.6A



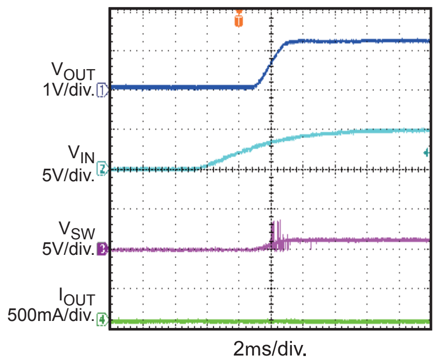
TYPICAL PERFORMANCE CHARACTERISTICS

V_{IN} = 5V, V_{OUT} = 1.2V, C_{IN}=10µF, C_{OUT}=20µF, T_A = +25ºC, unless otherwise noted.

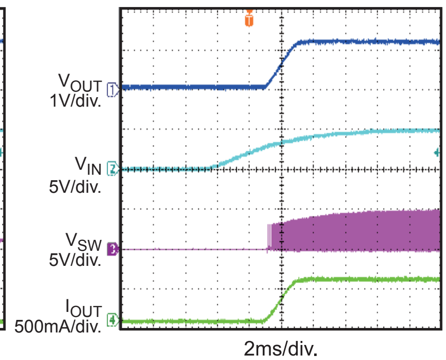
Output Ripple
I_{OUT}=0.5A



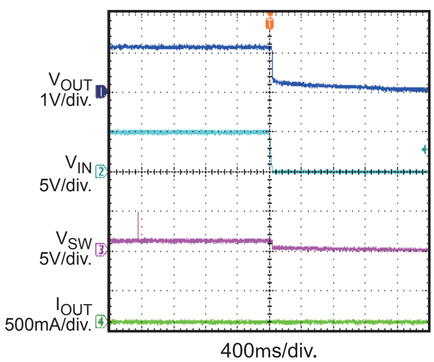
VIN Power Up without Load



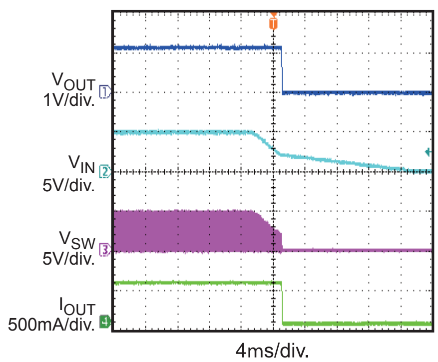
VIN Power Up with 0.5A Load



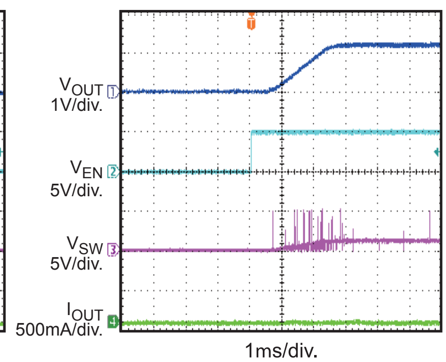
VIN Shut Down without Load



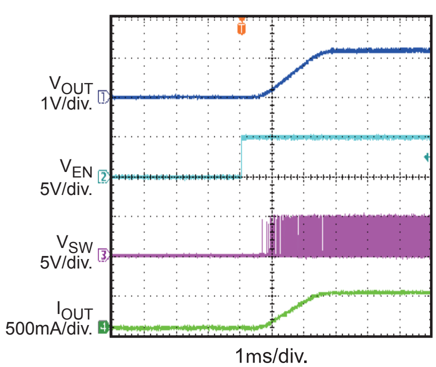
VIN Shut Down with 0.5A Load



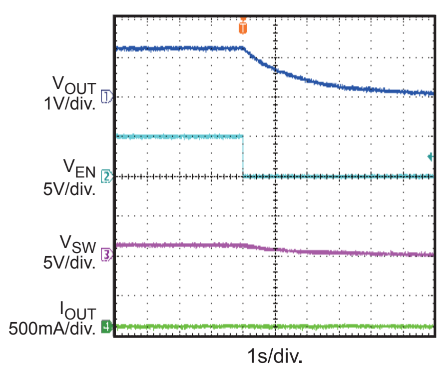
EN Start Up without Load



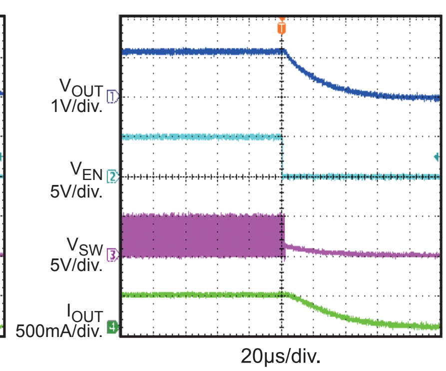
EN Start Up with 0.5A Load



EN Shut Down without Load



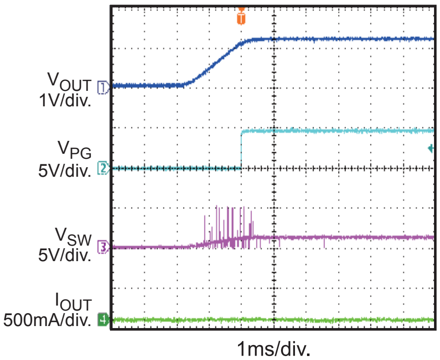
EN Shut Down with 0.5A Load



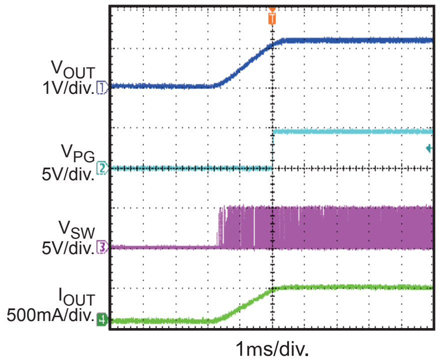
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 5V, V_{OUT} = 1.2V, C_{IN}=10µF, C_{OUT}=20µF, T_A = +25ºC, unless otherwise noted.

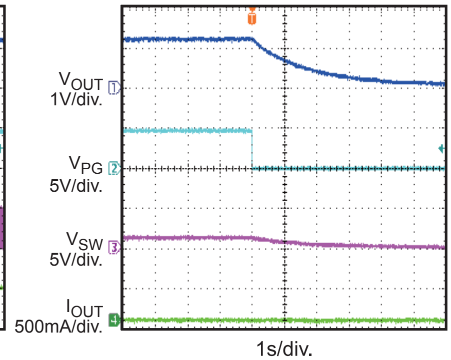
Power Good On without Load



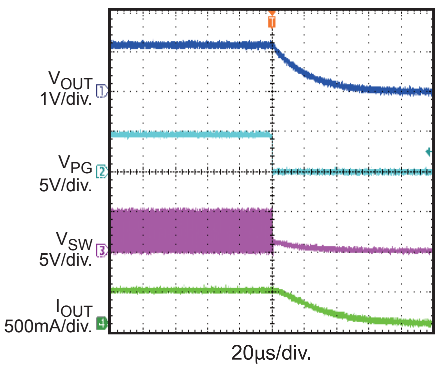
Power Good On with 0.5A Load



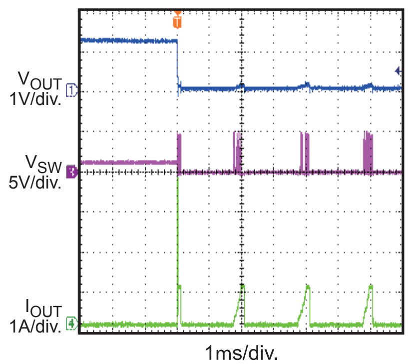
Power Good Off without Load



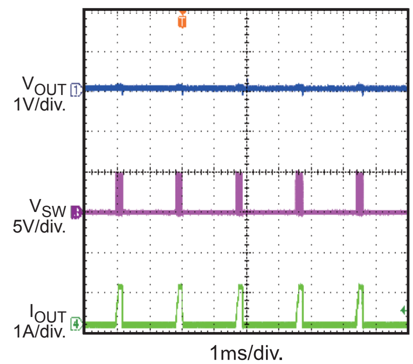
Power Good Off with 0.5A Load



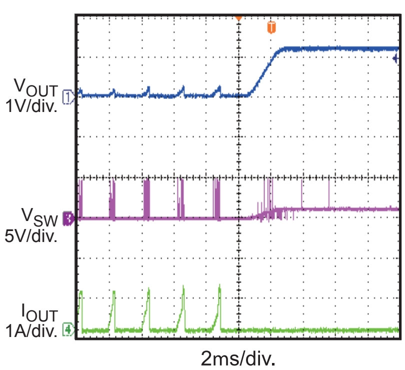
Short Circuit Entry



Short Circuit



Short Circuit Recovery



PIN FUNCTIONS

Pin #	Name	Description
1, 2	PGND	Power ground.
3, 4	NC	Internal SW pad. Connected with copper pad for thermal sink.
5, 6	OUT	Output Voltage power rail. Connect load to this pin. Output capacitor is needed.
7	VIN	Supply Voltage. The MPM3805 operates from a +2.5V to +6V unregulated input. Decouple capacitor is needed to prevent large voltage spikes from appearing at the input. Place the decoupling capacitor as close to the VIN pin as possible.
8	PG	Power Good Indicator. The output of this pin is an open drain with internal pull up resistor to VIN. PG is pulled up to VIN when the FB voltage is within 10% of the regulation level. If FB voltage is out of that regulation range, it is LOW.
9	EN	On/Off Control.
10	FB (MPM3805GQB only)	Feedback pin. An external resistor divider from the output to GND, tapped to the FB pin, sets the output voltage.
	NC	Internal test pad. Do Not Connect.
11	AGND	Analogy ground for internal control circuit.
12	OUT_S	Input sense pin for output voltage.

OPERATION

The DC-DC module has a small surface-mount QFN-12 (2.5mmX3.0mmX0.9mm) package. The module integrated inductor make the schematic and layout design very simple. Only input, output capacitors and FB resistors are needed to complete the design. MPM3805 uses constant on-time control with input voltage feed forward to stabilize the switching frequency over full input range. At light load, MPM3805 employs a proprietary control of low side switch and inductor current to improve efficiency.

Constant On-time Control

Compare to fixed frequency PWM control, constant on-time control offers the advantage of simpler control loop and faster transient response. By using input voltage feed forward, MPM3805 maintains a nearly constant switching frequency across input and output voltage range. The on-time of the switching pulse can be estimated as:

$$T_{ON} = \frac{V_{OUT}}{V_{IN}} \cdot 0.28\mu s$$

To prevent inductor current run away during load transient, MPM3805 fixes the minimum off time to be 60ns. However, this minimum off time limit will not affect operation of MPM3805 in steady state in any way.

Light Load Operation

In light load condition, MPM3805 uses a proprietary control scheme to save power and improve efficiency. The MPM3805 will turn off the low side switch when inductor current starts to reverse. Then MPM3805 works in discontinuous conduction mode (DCM) operation.

There is a zero current cross circuit to detect if the inductor current starts to reverse. Considering the internal circuit propagation time, the typical delay is 30ns. It means the inductor current still fall after the ZCD is trigger in this delay. If the inductor current falling slew rate is fast (Vo voltage is high or close to Vin), the low side MOSFET is turned off and inductor current may be negative. This phenomena will cause MPM3805 can not enter DCM operation. If the DCM mode is required, the off time of low side MOSFET in CCM should be longer than 60ns. For example, Vin is 3.6V and Vo is 3.3V, the off time in CCM is 24ns. It is difficult to enter DCM at light load. And using smaller inductor can improve it and make it enter DCM easily.

Enable

When input voltage is greater than the under-voltage lockout threshold (UVLO), typically 2.3V, MPM3805 can be enabled by pulling EN pin to higher than 1.2V. Leaving EN pin float or pull down to ground will disable MPM3805. There is an internal 1Meg Ohm resistor from EN pin to ground.

Soft Start

MPM3805 has built-in soft start that ramps up the output voltage in a controlled slew rate, avoiding overshoot at startup. The soft start time is about 1.5ms typical.

Power GOOD Indictor

MPM3805 has an open drain with 550kΩ pull-up resistor pin for power good indicator PGOOD. When FB pin is within +/-10% of regulation voltage, i.e. 0.6V, PGOOD pin is pulled up to IN by the internal resistor. If FB pin voltage is out of the +/-10% window, PGOOD pin is pulled down to ground by an internal MOS FET. The MOS FET has a maximum R_{dson} of less than 400 Ohm.

Current limit

MPM3805 has a typical 1.4A current limit for the high side switch. When the high side switch hits current limit, MPM3805 will touch the hiccup threshold until the current lower down. This will prevent inductor current from continuing to build up which will result in damage of the components.

Short Circuit and Recovery

MPM3805 enters short circuit protection mode also when the current limit is hit, and tries to recover from short circuit with hiccup mode. In short circuit protection, MPM3805 will disable output power stage, discharge soft-start cap and then automatically try to soft-start again. If the short circuit condition still holds after soft-start ends, MPM3805 repeats this operation cycle till short circuit disappears and output rises back to regulation level.

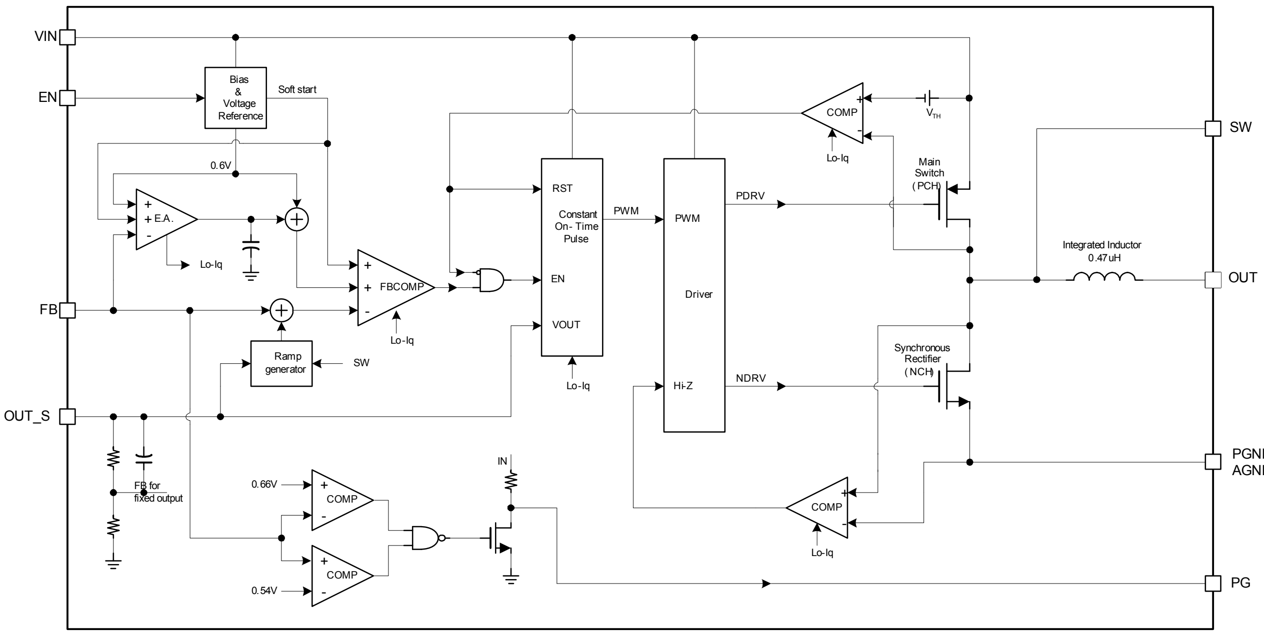


Figure 1: Functional Block Diagram

APPLICATION INFORMATION

COMPONENT SELECTION

Setting the Output Voltage

The external resistor divider is used to set the output voltage (see Typical Application on page 1). The feedback resistor R1 can not be too large neither too small considering the trade-off for stability and dynamic. Choose R1 to be around 40kΩ to 80kΩ. R2 is then given by:

$$R2 = \frac{R1}{\frac{V_{out}}{0.6} - 1}$$

The feedback circuit is shown as Figure 2.

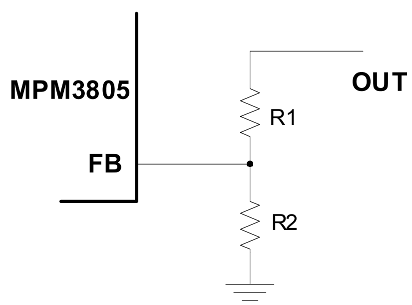


Figure 2: Feedback Network

Table 1 lists the recommended resistors value for common output voltages.

Table 1: Resistor Selection for Common Output Voltages

V_{OUT} (V)	R1 (kΩ)	R2 (kΩ)
1.0	40(1%)	60(1%)
1.2	40(1%)	40(1%)
1.8	60(1%)	30(1%)
2.5	80(1%)	25(1%)
3.3	80(1%)	17.7(1%)

Selecting the Input Capacitor

The input current to the step-down converter is discontinuous, therefore a capacitor is required to supply the AC current to the step-down converter while maintaining the DC input voltage. Use low ESR capacitors for the best performance. Ceramic capacitors with X5R or X7R dielectrics are highly recommended because of their low ESR and small temperature coefficients. For most applications, a 10μF capacitor is sufficient. For higher output voltage, 22μF may be needed for more stable system.

Since the input capacitor absorbs the input switching current it requires an adequate ripple current rating. The RMS current in the input capacitor can be estimated by:

$$I_{C1} = I_{LOAD} \times \sqrt{\frac{V_{OUT}}{V_{IN}} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)}$$

The worse case condition occurs at $V_{IN} = 2V_{OUT}$, where:

$$I_{C1} = \frac{I_{LOAD}}{2}$$

For simplification, choose the input capacitor whose RMS current rating greater than half of the maximum load current.

The input capacitor can be electrolytic, tantalum or ceramic. When using electrolytic or tantalum capacitors, a small and high quality ceramic capacitor, i.e. 0.1μF, should be placed as close to the IC as possible. When using ceramic capacitors, make sure that they have enough capacitance to provide sufficient charge to prevent excessive voltage ripple at input. The input voltage ripple caused by capacitance can be estimated by:

$$\Delta V_{IN} = \frac{I_{LOAD}}{f_S \times C1} \times \frac{V_{OUT}}{V_{IN}} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

Selecting the Output Capacitor

The output capacitor (C_{OUT}) is required to maintain the DC output voltage. Ceramic capacitors are recommended. Low ESR capacitors are preferred to keep the output voltage ripple low. The output voltage ripple can be estimated by:

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_S \times L_1} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \times \left(R_{ESR} + \frac{1}{8 \times f_S \times C2}\right)$$

Where L_1 is the inductor value and R_{ESR} is the equivalent series resistance (ESR) value of the output capacitor. L_1 is 0.47μH here.

Using ceramic capacitors, the impedance at the switching frequency is dominated by the capacitance. The output voltage ripple is mainly caused by the capacitance. For simplification, the output voltage ripple can be estimated by:

$$\Delta V_{OUT} = \frac{V_{OUT}}{8 \times f_S^{\,2} \times L_1 \times C2} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

In the case of tantalum or electrolytic capacitors, the ESR dominates the impedance at the switching frequency. For simplification, the output ripple can be approximated to:

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_S \times L_1} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \times R_{ESR}$$

The characteristics of the output capacitor also affect the stability of the regulation system.

PCB Layout

The module integrated inductor make the schematic and layout design very simple. Only input, output capacitors and FB resistors are needed to complete the design. The high current paths (PGND, IN and OUT) should be placed very close to the device with short, direct and wide traces. The input capacitor needs to be as close as possible to the IN and PGND pins. The external feedback resistors should be placed next to the FB pin. Keep the switching node away from the feedback network.

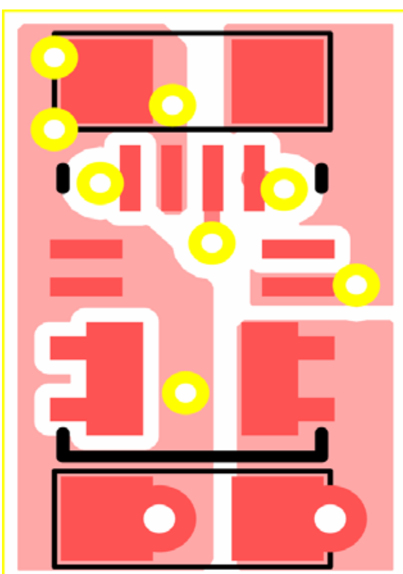


Figure 3: Top View of Layout Guide

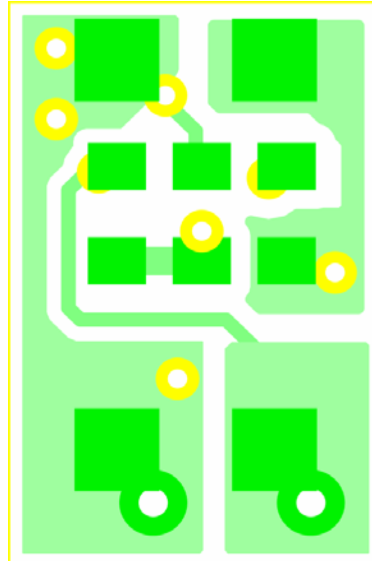


Figure 4: Bottom View of Layout Guide

TYPICAL APPLICATION CIRCUITS (Adjustable Output)

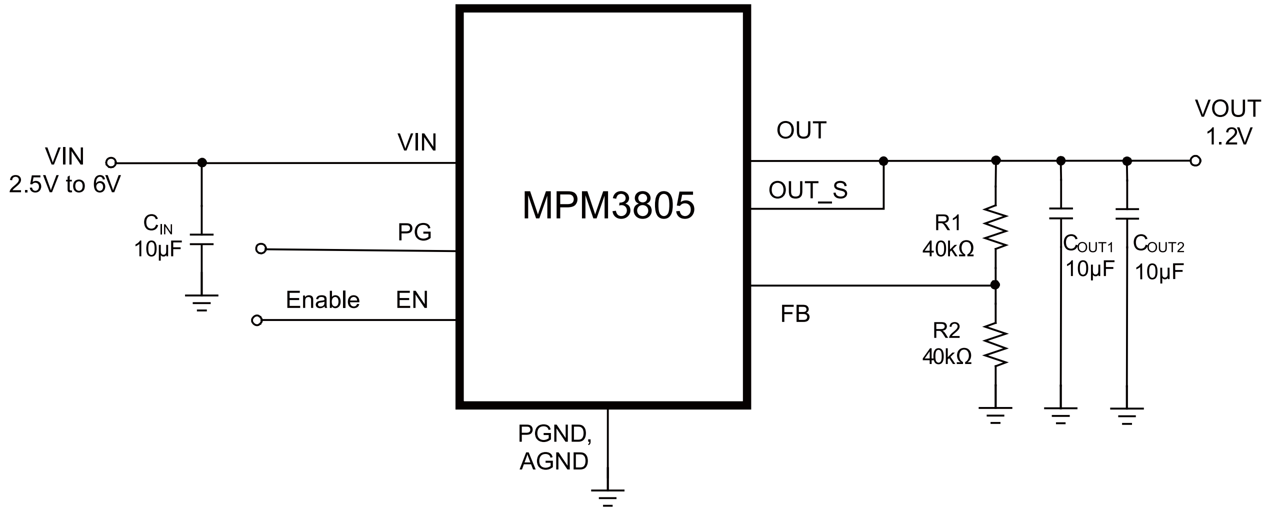
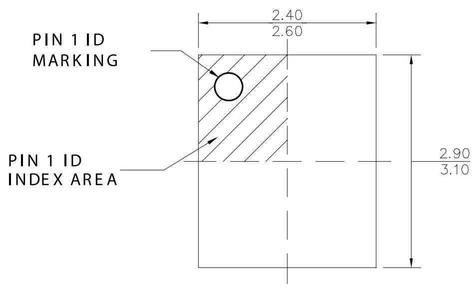


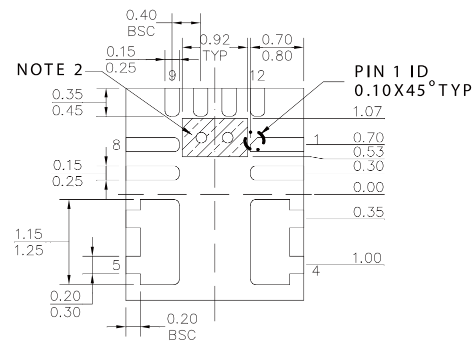
Figure 5: Typical Application Circuit

PACKAGE INFORMATION

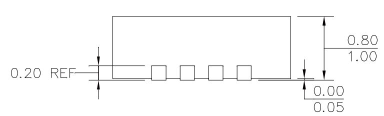
QFN-12 (2.5mmX3.0mmX0.9mm)



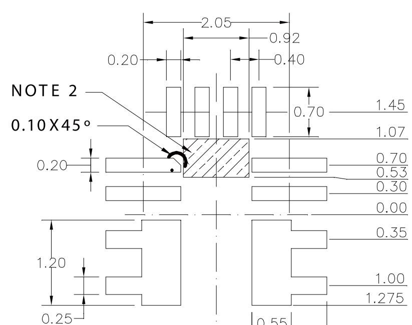
TOP VIEW



BOTTOM VIEW



SIDE VIEW



RECOMMENDED LAND PATTERN

NOTE:

1) ALL DIMENSIONS ARE IN MILLIMETERS
2) SHADED AREA IS THE KEEP-OUT ZONE. THE EXPOSED BOTTOM METAL PADS ENCLOSED BY THIS ZONE IS NOT TO BE CONNECTED TO ANY PCB METAL TRACE& VIA ELECTRICALLY OR MECHANICALLY.
3) EXPOSED PADDLE SIZE DOES NOT INCLUDE MOLD FLASH.
4) LEAD COPLANARITY SHALL BE 0.10 MILLIMETERS MAX.
5) JEDEC REFERENCE IS MO-220.
6) DRAWING IS NOT TO SCALE.

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