MPM3820

6V Input, 2A Module Synchronous Step-Down Converter with Integrated Inductor

The Future of Analog IC Technology

DESCRIPTION

The MPM3820 is a monolithic step-down switch mode converter with built-in internal power MOSFETs and inductor. The DC-DC module has a small surface mount 3mm x 5mm x 1.6mm QFN package. It achieves 2A continuous output current from a 2.7V to 6V input voltage with excellent load and line regulation. The MPM3820 is ideal for powering portable equipment that runs from a single cell Lithium-Ion (Li+) Battery. The output voltage can be regulated as low as 0.6V. Only input, output capacitors and FB resistors are needed to complete the design.

The Constant-On-time (COT) control scheme provides fast transient response, high light-load efficiency and easy loop stabilization.

Fault condition protection includes cycle-by-cycle current limit and thermal shutdown.

The MPM3820 requires a minimum number of readily available standard external components and is available in an ultra-small QFN-20 (3mmx5mm) package.

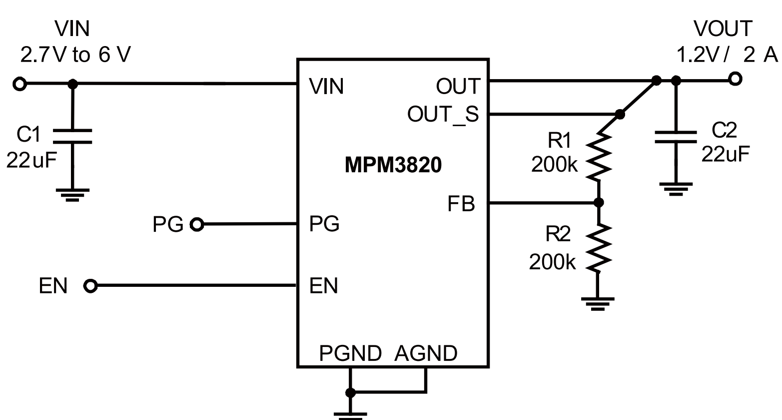
FEATURES

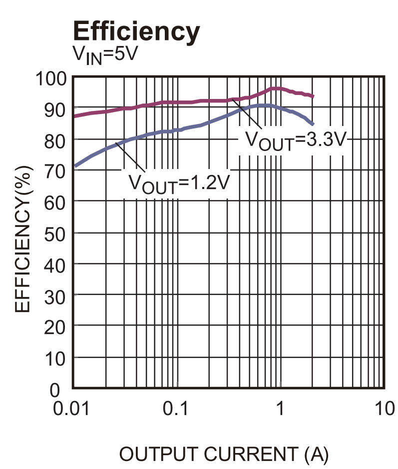
- Wide 2.7V to 6V Operating Input Range
- Adjustable output from 0.6V
- 3.0mm x 5.0mm x 1.6mm QFN Package
- Total Solution Size 8.5mm x 4.5 mm
- Low Radiated Emissions (EMI) Complies with EN55022 Class B Standard
- Up to 2A Continuous Output Current
- 100% Duty Cycle in Dropout
- Ultra Low IQ: 40µA
- 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

APPLICATIONS

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

TYPICAL APPLICATION



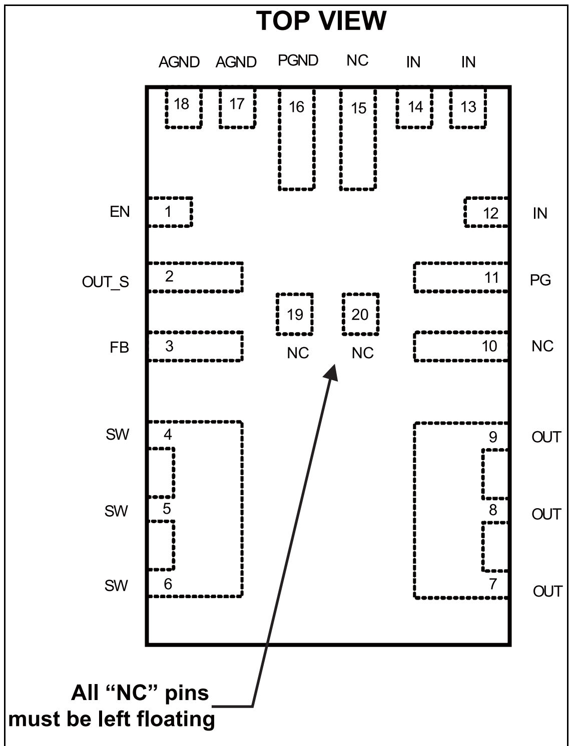


ORDERING INFORMATION

Part Number*	Package	Top Marking
MPM3820GQV	QFN-20 (3mmx5mm)	3820 M

* For Tape & Reel, add suffix –Z (e.g. MPM3820GQV–Z);

PACKAGE REFERENCE



QFN-20 (3mmx5mm)

ABSOLUTE MAXIMUM RATINGS (1)

Supply Voltage V_{IN} 6.5V
V_{SW} ....
-0.3V (-3V for <10ns) to 6.5V (7V for <10ns)
All Other Pins................................ -0.3V to 6.5V
Junction Temperature............................. 150°C
Lead Temperature .... 260°C
Continuous Power Dissipation (T_A = +25°C) (2)
…………….. ....2.8W
Storage Temperature............... -65°C to +150°C

Recommended Operating Conditions (3)

Supply Voltage V_{IN} .... 2.7V to 6V
Operating Junction Temp. (T_J). -40°C to +125°C

Thermal Resistance (4)	θ_{JA}	θ_{JC}	
QFN-20 (3mmx5mm)………….	46……	10	°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} = 3.6V, 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	V_{FB}	2.7V ≤ V_{IN} ≤ 6V	-1.5%	0.600	+1.5%	V/%
Feedback Current	I_{FB}	V_{FB} = 0.6V		10		nA
PFET Switch On Resistance	R_{DSON_P}			55		mΩ
NFET Switch On Resistance	R_{DSON_N}			45		mΩ
Dropout Resistance	R_{DR}	100% on duty		110		mΩ
Switch Leakage		V_{EN} = 0V, V_{IN} = 6V V_{SW} = 0V and 6V, T_J=25°C		0	2	μA
PFET Peak Current Limit			3.4	4.1		A
NFET Valley Current Limit				3.7		A
NFET Switch Sinking Current	I_{NSW}	V_{OUT}=1.2V, V_{FB}=0.7V		100		μA
ON Time	T_{ON}	V_{IN}=5V, V_{OUT}=1.2V		200		ns
		V_{IN}=3.6V, V_{OUT}=1.2V		280		
Switching Frequency	f_s	V_{OUT}=1.2V	-20%	1200	+20%	kHz/%
Minimum Off Time	$T_{MIN-OFF}$			30		ns
Minimum On Time[(5)]	T_{MIN-On}			50		ns
Soft-Start Time	T_{SS-ON}			1.5		ms
Soft-Stop Time	T_{SS-OFF}			1		ms
Power Good Upper Trip Threshold		FB with respect to the Regulation		+10		%
Power Good Lower Trip Threshold				-10		%
Power Good Delay				90		μs
Power Good Sink Current Capability	V_{PG_LO}	Sink 1mA			0.4	V
Power Good Logic High Voltage	V_{PG_HI}	V_{IN}=5V, V_{FB}=0.6V	4.9			V
Power Good Internal Pull Up Resistor	R_{PG}			500		kΩ
Under Voltage Lockout Threshold Rising			2.35	2.5	2.65	V
Under Voltage Lockout Threshold Hysteresis				400		mV
EN Input Logic Low Voltage					0.35	V
EN Input Logic High Voltage			1.2			V
EN Input Current		V_{EN}=2V		2		μA
		V_{EN}=0V		0		μA

ELECTRICAL CHARACTERISTICS *(continued)*

V_{IN} = 3.6V, 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
Supply Current (Shutdown)		V_{EN}=0V, **T_J=25°C**		0	1	μA
Supply Current (Quiescent)		V_{EN}=2V, V_{FB}=0.63V, V_{IN}=3.6V		40		μA
Thermal Shutdown(5)				160		°C
Thermal Hysteresis(5)				30		°C

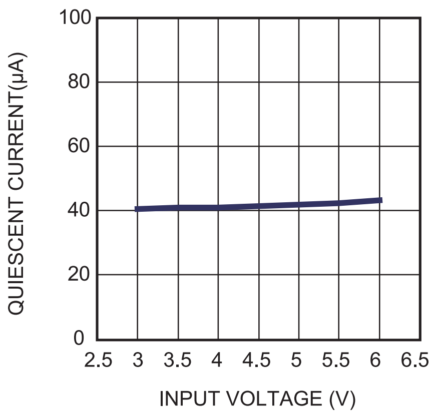
Notes:

5) Guaranteed by design.

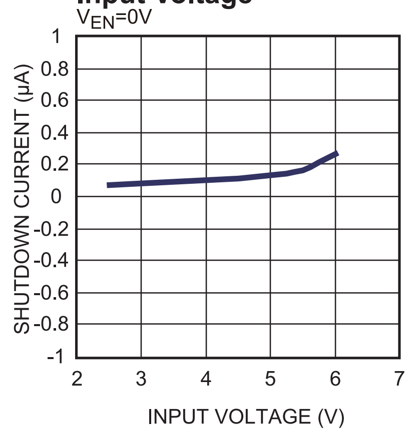
TYPICAL PERFORMANCE CHARACTERISTICS

V_{IN} = 5V, V_{OUT} = 1.2V, C_O=22uF, T_A = +25ºC, unless otherwise noted.

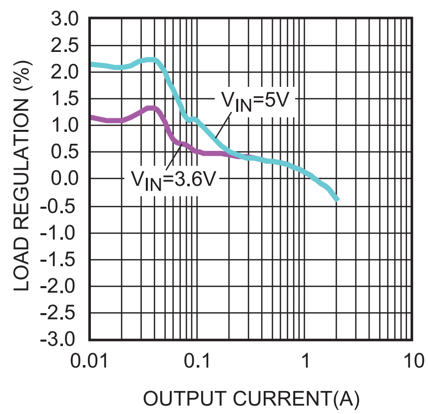
Quiescent Current vs. Input Voltage



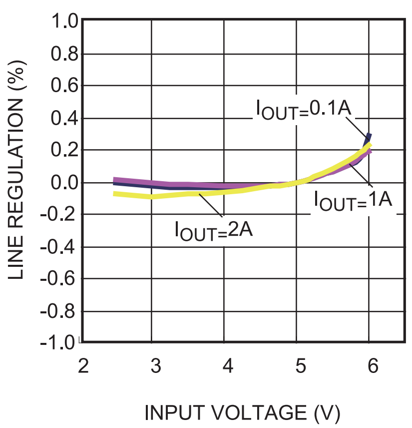
Shutdown Current vs. Input Voltage



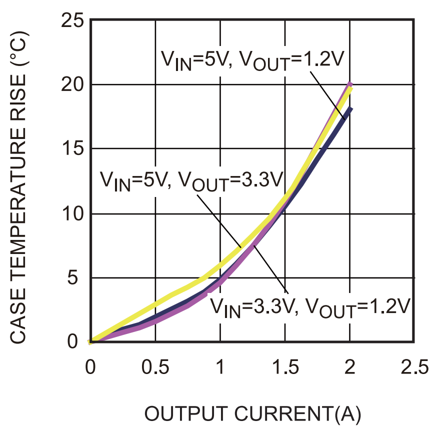
Load Regulation vs. Output Current



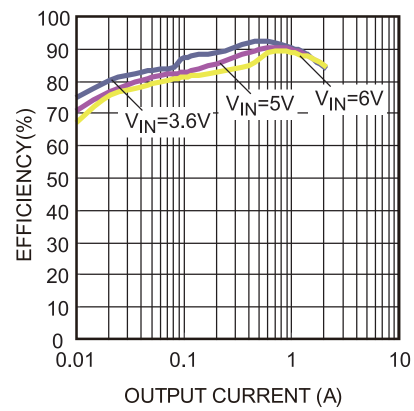
Line Regulation vs. Input Voltage



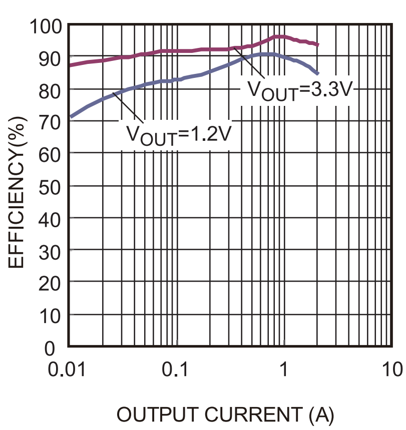
Case Temperature Rise



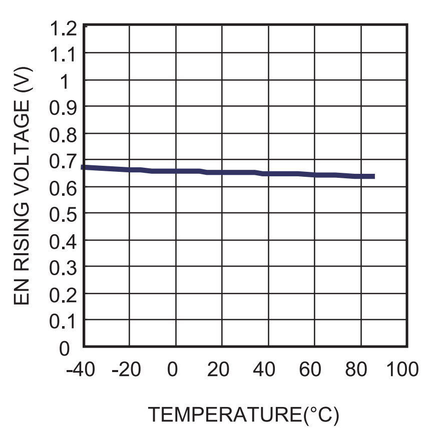
Efficiency



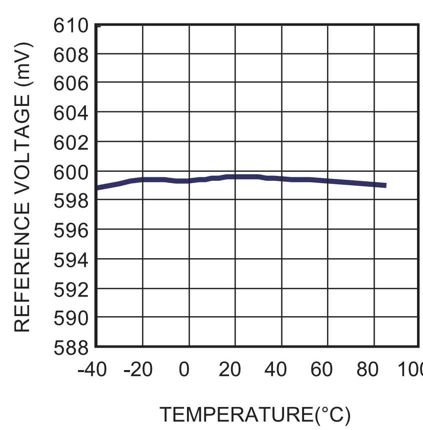
Efficiency



EN Rising vs. Temperature



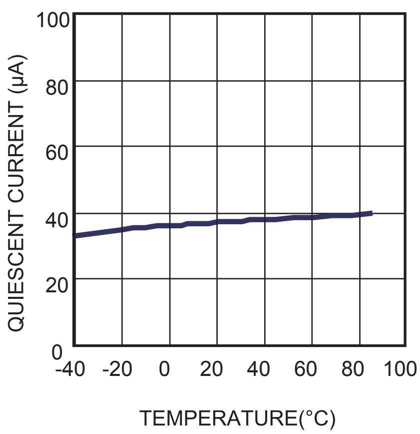
Reference Voltage vs. Temperature



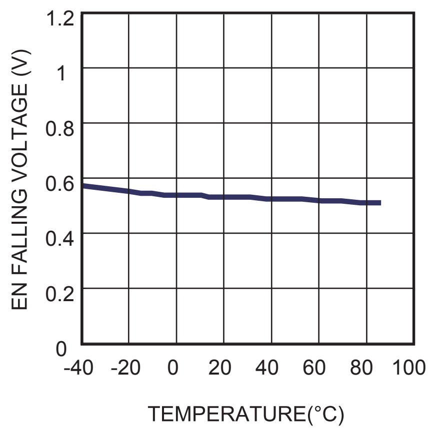
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 5V, V_{OUT} = 1.2V, C_O=22uF, T_A = +25ºC, unless otherwise noted.

Quiescent Current vs. Temperature

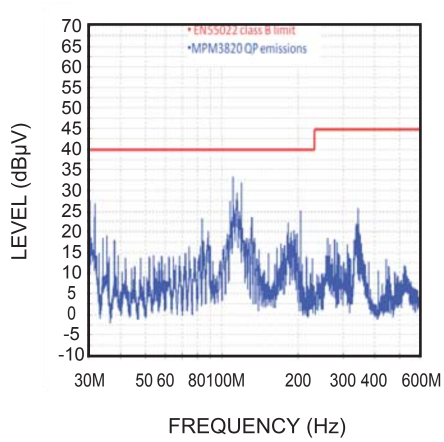


EN Falling vs. Temperature



Radiated Emission

I_{OUT}=2A, C_{OUT}=22µFx2

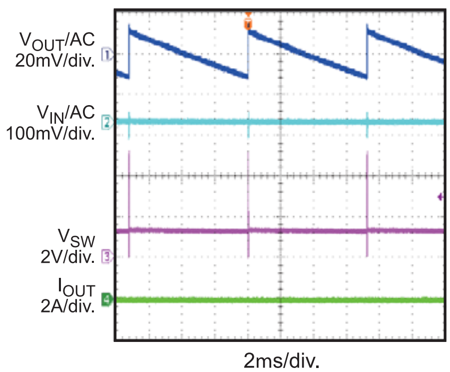


TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 5V, V_{OUT} = 1.2V, C_O=22uF, T_A = +25ºC, unless otherwise noted.

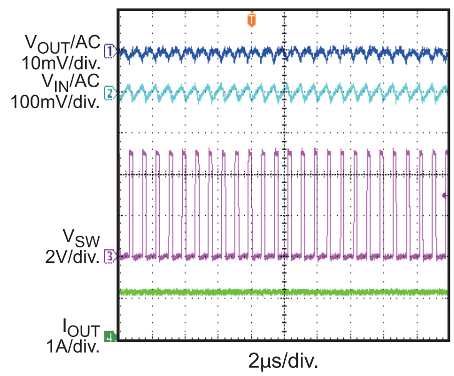
Input and Output Ripple

I_{OUT}=0A, C_{OUT}=22µFx2



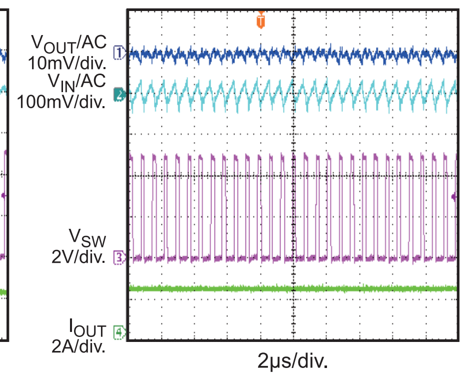
Input and Output Ripple

I_{OUT}=1A , C_{OUT}=22µFx2

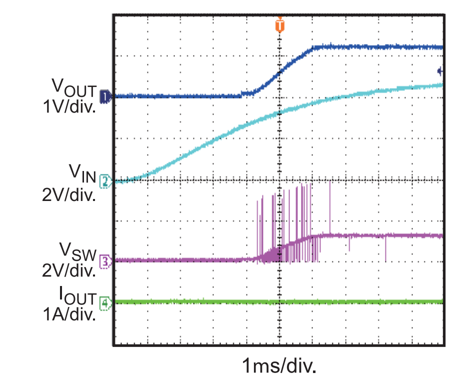


Input and Output Ripple

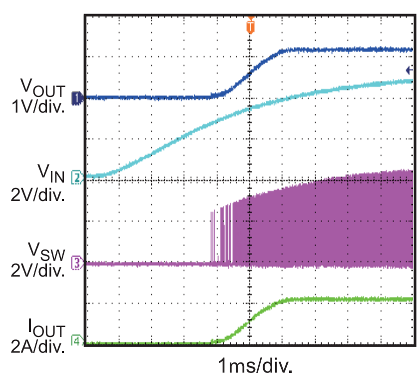
I_{OUT}=2A, C_{OUT}=22µFx2



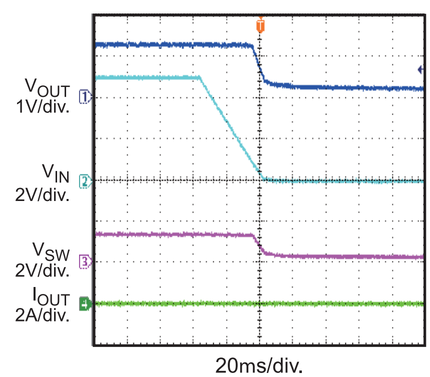
V_{IN} Power Up without Load



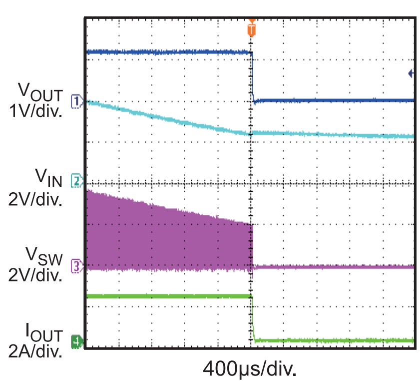
V_{IN} Power Up with 2A Load



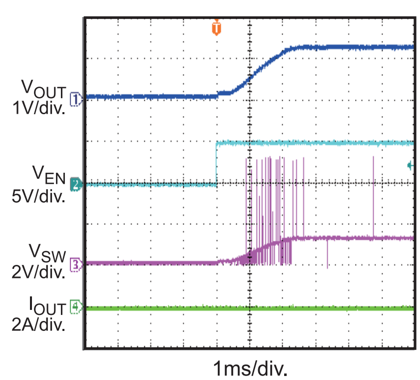
V_{IN} Shut down without Load



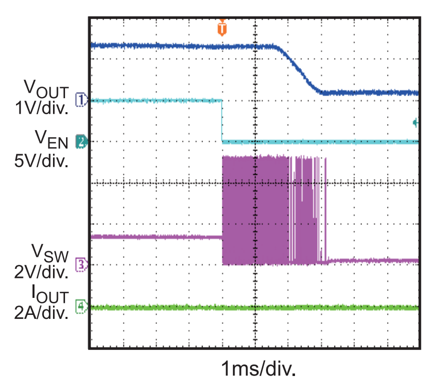
V_{IN} Shut down with 2A Load



EN Start Up without Load



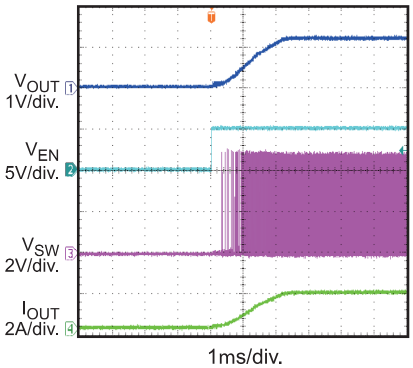
EN Shut Down without Load



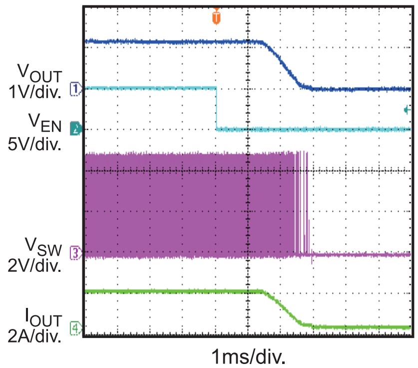
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 5V, V_{OUT} = 1.2V, C_O=22uF, T_A = +25ºC, unless otherwise noted.

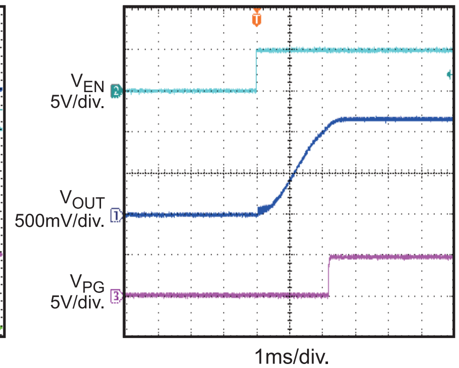
EN Start Up with 2A Load



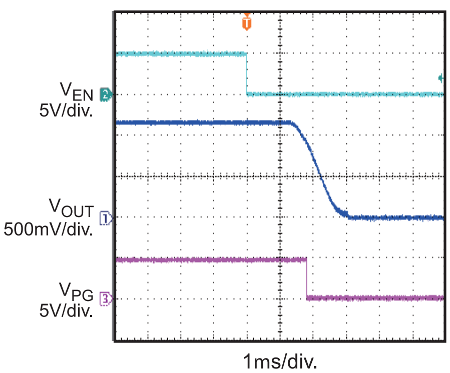
EN Shut Down with 2A Load



Power Good Through EN Start Up

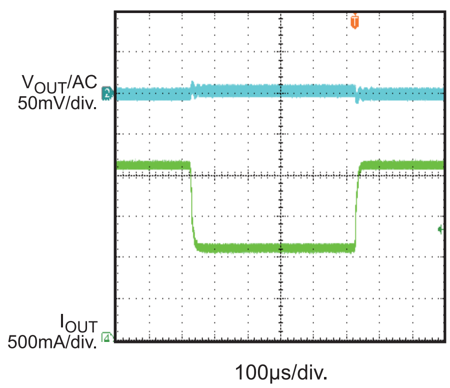


Power Good Through EN Shut Down

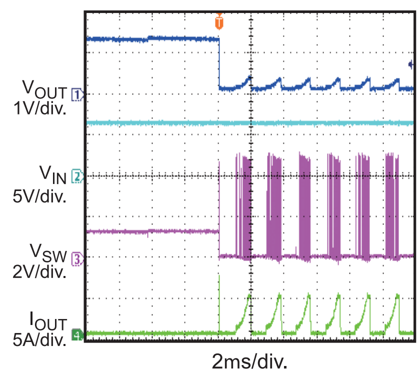


Load Transient Response

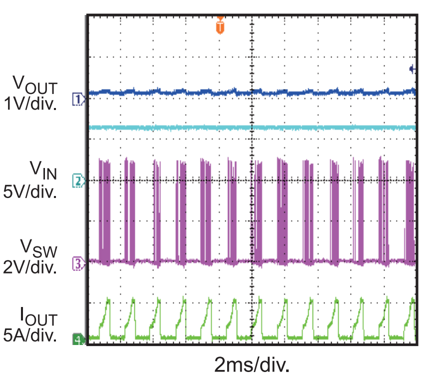
I_{OUT}=1A to 2A



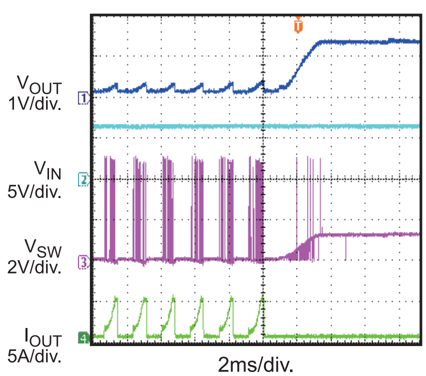
Short Circuit Entry



Short Circuit



Short Circuit Recovery



PIN FUNCTIONS

Pin #	Name	Description
1	EN	On/Off Control.
2	OUT_S	Input sense pin for output voltage.
3	FB	Feedback. An external resistor divider from the output to GND, tapped to the FB pin, sets the output voltage.
4,5,6	SW	Switch Output.
7,8,9	OUT	Power output pin.
11	PG	Power Good Indicator. The output of this pin is an open drain with internal pull up resistor to IN. PG is pulled up to IN when the FB voltage is within 10% of the regulation level, otherwise it is LOW.
12,13,14	IN	Supply Voltage to internal control circuitry. VIN is connected to PVIN internally.
16	PGND	Power Ground.
17, 18	AGND	Quiet ground for controller circuits.
10, 15, 19, 20	NC	DO NOT CONNECT. Pin must be left floating.

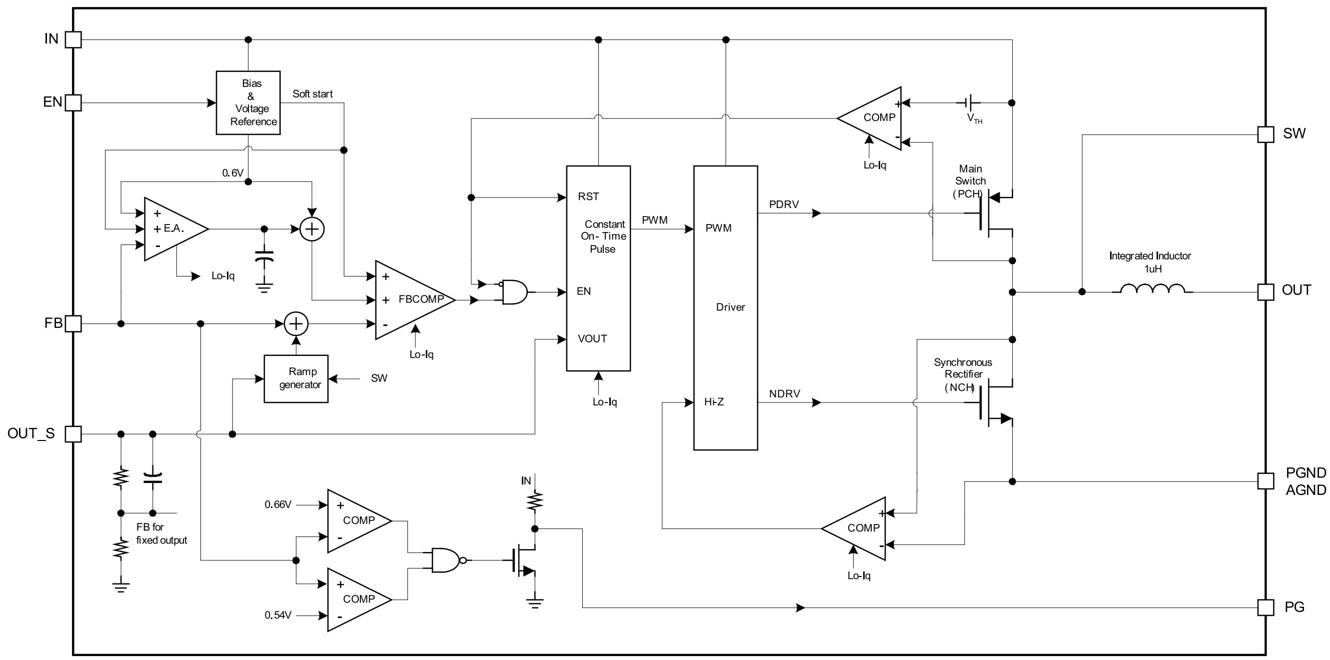


Figure 1: Functional Block Diagram

OPERATION

The DC-DC module has a small surface mount 3mm x 5mm x 1.6mm QFN 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. MPM3820 uses constant on-time control with input voltage feed forward to stabilize the switching frequency over full input range. At light load, MPM3820 employs a proprietary control of low side switch and inductor current on switching node and 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, MPM3820 maintains a nearly constant switching frequency across input and output voltage range. The on-time of the switching pulse can be estimated as:

$$T_{ON} = \frac{V_{OUT}}{V_{IN}} \times 0.833\mu s$$

To prevent inductor current run away during load transient, MPM3820 fixes the minimum off time to be 30ns. However, this minimum off time limit will not affect operation of MPM3820 in steady state in any way.

Light Load Operation

In light load condition, MPM3820 uses a proprietary control scheme to save power and improve efficiency. There is a zero current cross detect circuit (ZCD) to judge if the inductor current starts to reverse. When the inductor current touch ZCD threshold, the low side switch will start to be turned off.

The DCM mode happens only after low side switch turned off by ZCD circuit. Considering the ZCD circuit propagation time, the typical delay is 20ns. It means the inductor current still fall after the ZCD is trigger during 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 at the moment inductor current may be negative. This phenomena will cause MPM3820 can not enter DCM operation.

If the DCM mode is required, the off time of low side MOSFET in CCM should be longer than 40ns. It means the maximum duty is 95% to guarantee DCM mode at light load.

For example, Vin is 3.4V and Vo is 3.3V, the off time in CCM is 25ns. It is difficult to enter DCM at light load.

Enable

When input voltage is greater than the under-voltage lockout threshold (UVLO), typically 2.5V, MPM3820 can be enabled by pulling EN pin to higher than 1.2V. Leaving EN pin float or pull down to ground will disable MPM3820. There is an internal 1Meg Ohm resistor from EN pin to ground.

Soft Start/Stop

MPM3820 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. At disable, MPM3820 ramps down the internal reference thus allow the load to linearly discharge the output.

Power Good Indicator

MPM3820 has an open drain with 500kΩ pull-up resistor pin for power good indicator PG. When FB pin is within +/-10% of regulation voltage, i.e. 0.6V, PG pin is pulled up to IN by the internal resistor. If FB pin voltage is out of the +/-10% window, PG pin is pulled down to ground by an internal MOS FET. The MOS FET has a maximum R_{dson} of less than 100Ω.

Current limit

MPM3820 has a typical 4.1A current limit for the high side switch. When the high side switch hits current limit, MPM3820 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

MPM3820 enters short circuit protection mode when the inductor current hits the current limit, and tries to recover from short circuit with hiccup mode. In short circuit protection, MPM3820 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, MPM3820 repeats this operation cycle till short circuit disappears and output rises back to regulation level.

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 50kΩ to 200kΩ. R2 is then given by:

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

The feedback circuit is shown as Figure 2.

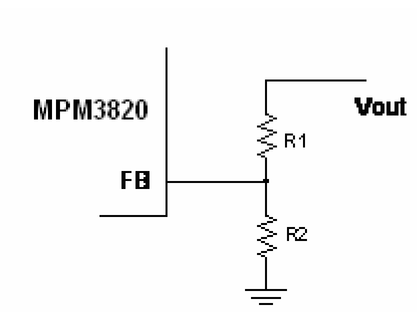


Figure 2— Feedback Network

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	200(1%)	300(1%)
1.2	200(1%)	200(1%)
1.8	200(1%)	100(1%)
2.5	200(1%)	63.2(1%)
3.3	200(1%)	44.2(1%)

Load Regulation Improvement

The load regulation of MPM3820 will be influenced by feedback resistor.

The relationship between Vo and feedback network can be estimated as:

$$V_O \approx V_{FB} \times \frac{R_1 + R_2}{R_2} - I_O \times DCR \frac{R_1}{R_C}$$

The integrated inductor DCR is typical 55mΩ. The R_C is internal compensation resistor, it's typical 1MΩ-1.2MΩ.

Base on the equation, to get better load regulation, decreasing the feedback resistor are the effective way. But too small feedback resistor will cause the steady problem.

For most applications, the 200kΩ R1 and 22uF output capacitor is sufficient, but for better load regulation, 100kΩ R1 and 2x22uF output capacitors are suggested.
Table 2 lists the recommended resistors and output capacitors value for better load regulation.

Table 2—Resistor and Capacitor Selection for Better Load Regulation

V_{OUT} (V)	R1 (kΩ)	R2 (kΩ)	Cout(uF)
1.0	100(1%)	150(1%)	44
1.2	100(1%)	100(1%)	44
1.8	150(1%)	75(1%)	44
2.5	200(1%)	63.2(1%)	44
3.3	200(1%)	44.2(1%)	44

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 22μF capacitor is sufficient

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 (C2) is required to maintain the DC output voltage.

Low ESR ceramic capacitors can be used with MPM3820 to keep the output ripple low. Generally, 22μF output ceramic capacitor is enough for most of the cases. In higher output voltage condition, 47μF might be needed for a stable system.

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 L1 is 1uH integrated inductor.

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

Layout Recommendation of MPM3820

Proper layout of the switching power supplies is very important, and sometimes critical to make it work properly. Especially, for the high switching converter, if the layout is not carefully done, the regulator could show poor line or load regulation, stability issues.

For MPM3820, the high speed step-down regulator, the input capacitor should be placed as close as possible to the IC pins. As shown in Figure 3, the 0805 size ceramic capacitor is used, please make sure the two ends of the ceramic capacitor be directly connected to PIN 12-14 (the Power Input Pin) and PIN 16 (the Power GND Pin).

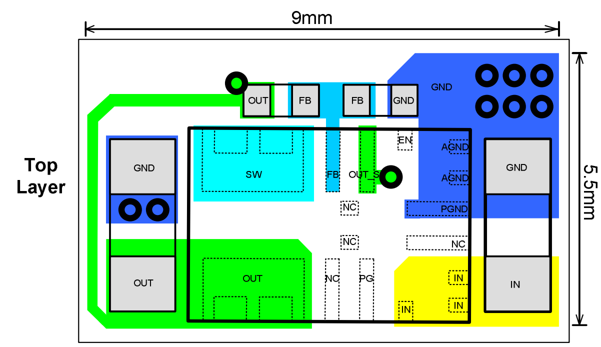


Figure 3— Top Layer

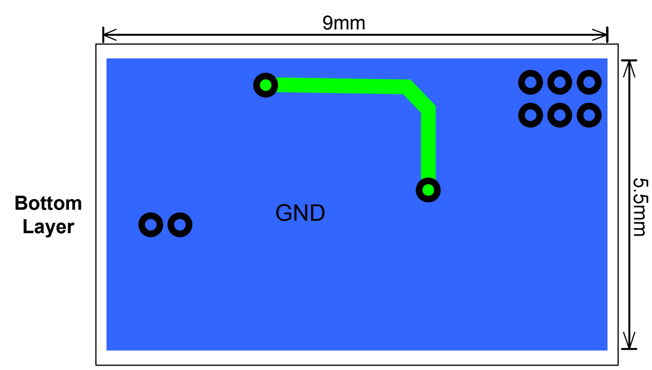


Figure 4— Bottom Layer

Power Dissipation

IC power dissipation plays an important role in circuit design—not only because of efficiency concerns, but also because of the chip's thermal requirements. Several parameters influence power dissipation, such as:

Conduction Loss (Cond)

Dead time (DT)

Switching Loss (SW)

MOSFET Driver Current (DR)

Supply Current (S)

Based on these parameters, we can estimate the power loss to equal:

$$P_{LOSS} = P_{Cond} + P_{DT} + P_{SW} + P_{DR} + P_{S}$$

Thermal Regulation

As previously discussed, changes in IC temperature change the electrical characteristics, especially when the temperature exceeds the IC's recommended operating range. Managing the IC's temperature requires additional considerations to ensure that the IC runs within the maximum allowable temperature junction. While operating the IC within recommended electrical limits is a major component to maintaining proper thermal regulation, specific layout designs can improve the thermal profile while limiting costs to either efficiency or operating range.

For the MPM3820, connect the exposed ground pad on the package to a GND plane on top of the PCB to use this plane as a heat sink. Connect this GND plane to GND planes beneath the IC using vias to further improve heat dissipation. However, given that these GND planes can introduce unwanted EMI noise and occupy valuable PCB space requires designing the size and shape of these planes to match the thermal resistance requirement:

$$\theta_{SA} = \theta_{JA} - \theta_{JC}$$

However, connecting the MPM3820 to a heat sink can not guarantee that the IC will not exceed its recommended temperature limits; for instance, if the ambient temperature exceeds the IC's temperature limits. If the ambient air temperature approaches the IC's temperature limit, options such as derating the IC so it operates using less power can help prevent thermal damage and unwanted electrical characteristics.

TYPICAL APPLICATION CIRCUITS

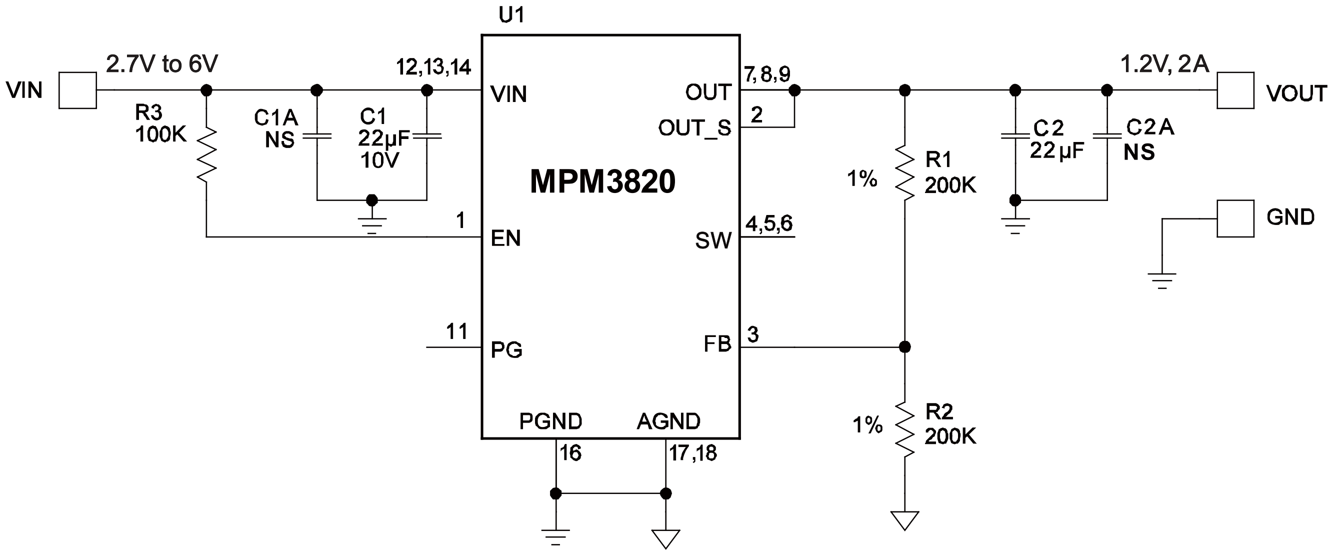


Figure 5— Typical Application Circuit

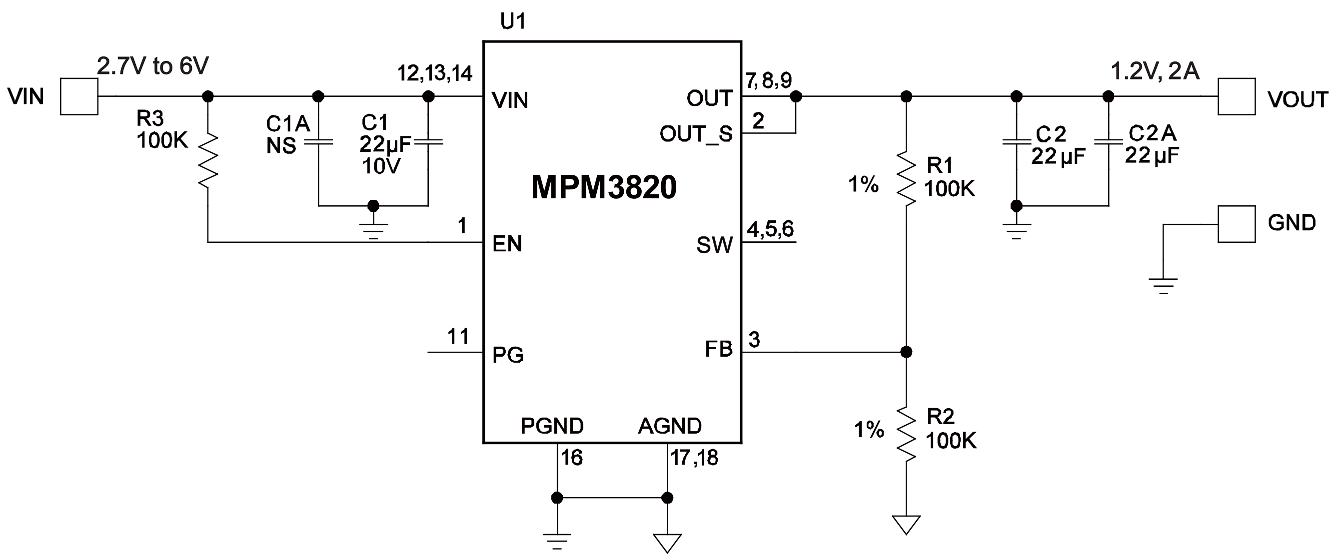
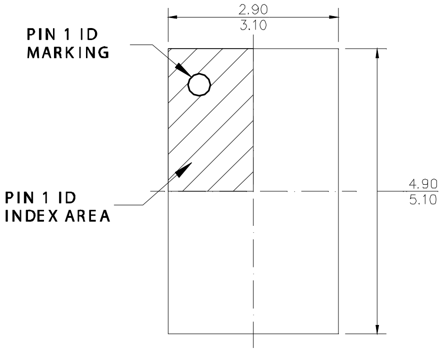


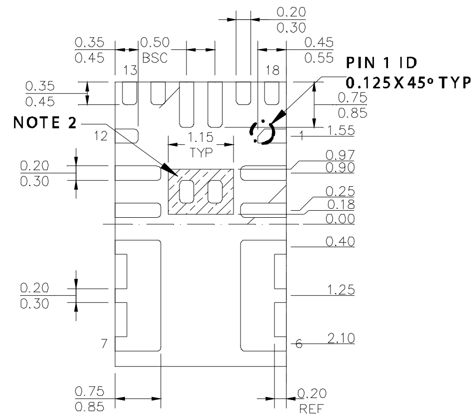
Figure 6— Better Load Regulation Circuit

PACKAGE INFORMATION

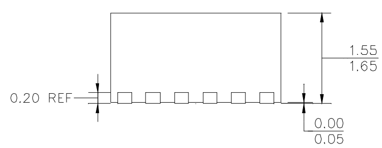
QFN-20 (3mmx5mm)



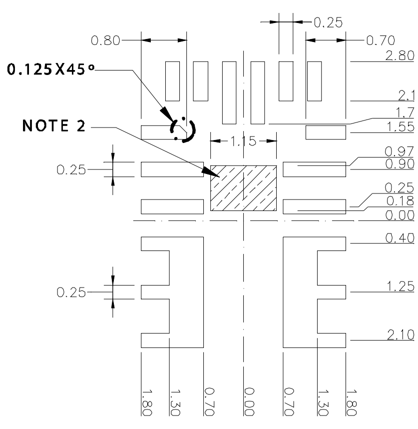
TOP VIEW



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.