MP2013A

40V, 150mA, Low-Quiescent Current Linear Regulator

DESCRIPTION

The MP2013A is a low-power, linear regulator that supplies power to systems with high-voltage batteries. It includes a wide 2.5V to 40V input range, low-dropout voltage and low-quiescent-supply current. The low-quiescent current and low-dropout voltage allow operation at extremely low-power levels. The MP2013A is ideal for low-power microcontrollers and battery-powered equipment.

The MP2013A provides a wide variety of fixed, output-voltage options: 1.8V, 1.9V, 2.3V, 2.5V, 3.0V, 3.3V, 3.45V, and 5.0V, and it provides an adjustable output option (from 1.215V to 15V).

The regulator output current is internally limited; the device is protected against over-load and over-temperature conditions.

The MP2013A includes thermal shutdown (TSD) and current-limiting fault protection. It is available in QFN6 (2x2mm), and QFN8 (3x3mm) packages.

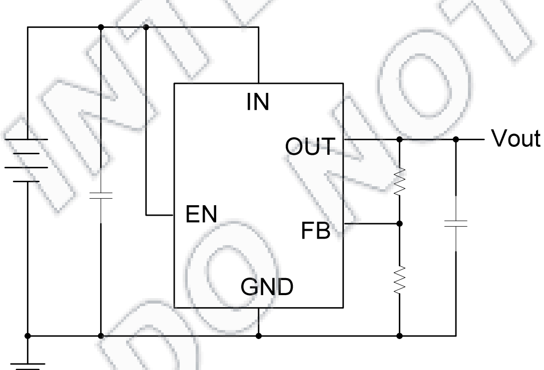
FEATURES

- 2.5V to 40V Input Range
- 3.2μA Quiescent-Supply Current
- Stable with Low-Value Output Ceramic Capacitor (> 0.47 μF)
- 150mA Specified Current
- 620mV Dropout at 150mA Load
- Available in Fixed and Adjustable Output (1.215 V to 15 V) Versions
- ±2% Output Accuracy
- Specified Current Limit
- Thermal Shutdown
- -40°C to +125°C Specified Junction-Temperature Range
- Available in QFN6 (2x2mm), and QFN8 (3x3mm) Packages

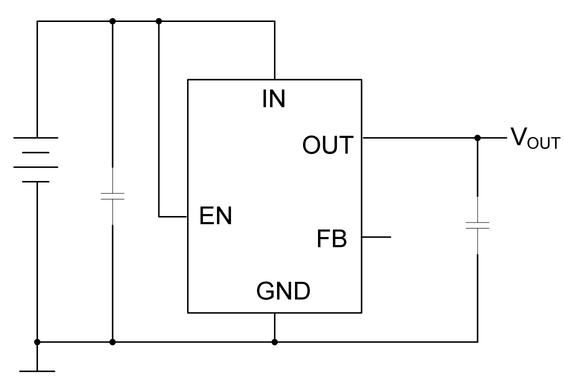
APPLICATIONS

- Industrial/Automotive Applications
- Portable/Battery-Powered Equipment
- Ultra Low-Power Microcontrollers
- Cellular Handsets
- Medical Imaging

TYPICAL APPLICATION



Output Adjustable Version



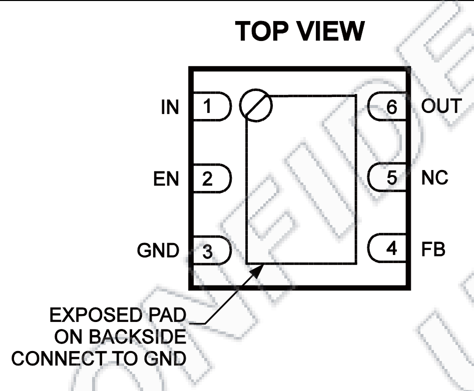
Output Fixed Version

ORDERING INFORMATION

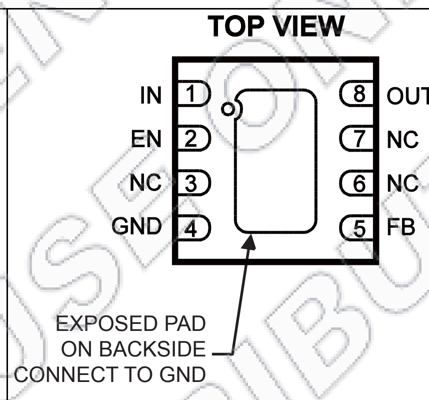
Part Number*	Package	Top Marking
MP2013AGQ	QFN8(3x3mm)	AJD
MP2013AGG**	QFN6(2x2mm)	CD
MP2013AGQ-33	QFN8(3x3mm)	AJZ
MP2013AGG-33**	QFN6(2x2mm)	CP
MP2013AGQ-5	QFN8(3x3mm)	ALJ

* For Tape & Reel, add suffix –Z (e.g. MP2013AGQ-33–Z)

** Pre-release



QFN6(2x2mm)



QFN8(3x3mm)

PACKAGE REFERENCE

ABSOLUTE MAXIMUM RATINGS (1)

IN, EN ....-0.3V to +42V
OUT ....-0.3V to +17V
FB ....-0.3V to +6V
Lead Temperature ....260°C
Storage Temperature............... -65°C to +150°C
Continuous Power Dissipation (T_A = +25°C) (2)
QFN8(3x3mm)... 2.08W
QFN6(2x2mm)... 1.25W

ESD SUSCEPTIBILITY (3)

HBM (Human Body Mode) 2kV
MM (Machine Mode)................................ 200V

Recommended Operating Conditions (4)

Supply Voltage V_{IN} ....2.5V to 40V
Output Voltage V_{OUT} ....1.215V to 15V
Operating Junction Temp. (T_J). -40°C to +125°C

Thermal Resistance (5)	θ_{JA}	θ_{JC}	
QFN6(2x2mm)........................	80	16...	°C/W
QFN8(3x3mm)........................	48	11...	°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) Devices are ESD sensitive. Handling precaution recommended.
4) The device is not guaranteed to function outside of its operating conditions.
5) Measured on JESD51-7, 4-layer PCB.

ELECTRICAL CHARACTERISTICS

T_J = +25°C, V_{EN}=V_{IN}, I_{OUT} = 1mA, C_{OUT} = 1µF, unless otherwise noted.

Parameter	Symbol	Condition	Min	Typ	Max	Units
Input Voltage	V_{IN}		2.5		40	V
Output-Voltage Range	V_{OUT}		1.215		15	V
GND Current	I_{GND}	MP2013AGQ-33, 0<I_{OUT}<1mA, V_{IN}=4.3V to 40V		4.4	8	µA
		MP2013AGQ-33, 1mA<I_{OUT}<30mA, V_{IN}=4.3V to 15V		15	20	
		MP2013AGQ-33, 30mA<I_{OUT}<150mA, V_{IN}=4.3V		35	48	
		MP2013AGQ-5, 0<I_{OUT}<1mA, V_{IN}=6V to 40V		4.4	8	µA
		MP2013AGQ-5, 1mA<I_{OUT}<30mA, V_{IN}=6V to 15V		15	20	
		MP2013AGQ-5, 30mA<I_{OUT}<150mA, V_{IN}=6V		35	48	
		MP2013AGQ, 0<I_{OUT}<1mA, V_{IN}=2.5V to 40V, V_{OUT}=5V(V_{IN}≥6V) or FB(V_{IN}<6V)		3.3	7	µA
		MP2013AGQ, 1mA<I_{OUT}<30mA, V_{IN}=2.5V to 15V, V_{OUT}=5V (V_{IN}≥6V) or FB (V_{IN}<6V)		11	19	
		MP2013AGQ, 30mA<I_{OUT}<150mA,V_{IN}=6V,V_{OUT}=5V		32	47	
		MP2013AGG, 0<I_{OUT}<1mA, V_{IN}=2.5V to 40V, V_{OUT}=5V (V_{IN}≥6V) or FB (V_{IN}<6V)		3.3	7	µA
		MP2013AGG, 1mA<I_{OUT}<30mA, V_{IN}=2.5V to 15V, V_{OUT}=5V (V_{IN}≥6V) or FB (V_{IN}<6V)		11	19	
		MP2013AGG, 30mA<I_{OUT}<150mA,V_{IN}=6V,V_{OUT}=5V		32	47	
Shutdown Supply Current	I_{SHDN}	V_{EN}=0, V_{IN}=2.5 to 40V		3	6	µA
Load Current Limit	I_{LIMIT}	MP2013AGQ, MP2013AGQ-5, V_{OUT} = 0V, V_{IN}=6V to 15V	180	270	390	mA
		MP2013AGQ-33,V_{OUT} = 0V, V_{IN}=4.3V to 15V				
Output-Voltage Accuracy		MP2013AGQ-33, V_{IN}=4.3V,I_{OUT}=0	3.234	3.3	3.366	V
		MP2013AGQ-5, V_{IN}=6V, I_{OUT}=0	4.9	5	5.1	
FB Voltage	V_{FB}	FB = OUT, V_{IN}=5V, I_{OUT}=0	1.191	1.215	1.239	V
Dropout Voltage V_{IN}=$V_{OUT(NOM)}$-0.1V	$V_{DROPOUT}$	MP2013AGQ-33, I_{OUT} = 150mA, $V_{OUT(NOM)}$ =3.3V		700	850	mV
		MP2013AGQ-5, MP2013AGQ and MP2013AGG, I_{OUT} = 150mA, $V_{OUT(NOM)}$ =5V		600	850	

ELECTRICAL CHARACTERISTICS *(continued)*

T_J = +25°C, V_{EN}=V_{IN}, I_{OUT} = 1mA, C_{OUT} = 1µF, unless otherwise noted.

Parameter	Symbol	Condition	Min	Typ	Max	Units
FB Input Current	I_{FB}	MP2013A-33 and MP2013A-5, V_{FB} = 1.3V, V_{IN}=6V,OUT floating	1.05	1.3	1.55	µA
		MP2013A, V_{FB} = 1.3V, V_{IN}=6V,OUT floating	-50	0	50	nA
Line Regulation(6)		V_{IN} = 2.5 to 40V, I_{OUT} = 1mA, OUT = FB		0.01	0.05	%/V
Load Regulation(7)		MP2013AGQ-33, I_{OUT} = 100µA to 150mA, V_{IN}=4.3V to 6V		0.005	0.01	%/mA
		MP2013AGQ,MP2013AGQ-5, MP2013AGG, I_{OUT} = 100µA to 150mA, V_{IN}= 6V				
Output Voltage PSRR(8)		100Hz, C_{IN} = 100pF, C_{OUT} = 4.7µF I_{OUT}=10mA, V_{IN}=6V		58		dB
		1kHz, C_{IN} = 100pF, C_{OUT} = 4.7µF I_{OUT}=10mA, V_{IN}=6V		41		dB
		100kHz,C_{IN} = 100pF, C_{OUT} = 4.7µF I_{OUT}=10mA, V_{IN}=6V		55		dB
Startup Response Time		MP2013AGQ, I_{OUT}= 100mA, C_{OUT}=6.8µF, V_{OUT}= 5V			3	ms
		MP2013AGQ-33, I_{OUT}= 10mA, C_{OUT}=6.8µF, V_{OUT}= 3.3V			1.8	
		MP2013AGQ-5, I_{OUT}= 10mA, C_{OUT}=6.8µF, V_{OUT}= 5V			3	
EN Rising Threshold	EN_{TH_R}	V_{IN}=2.5V to 40V	1.38	1.48	1.58	V
EN Falling Threshold	EN_{TH_F}	V_{IN}=2.5V to 40V	1.18	1.26	1.38	V
EN Input Current	I_{EN}	V_{EN} = 0V or 15V, V_{IN}=2.5V to 40V			0.1	µA
Thermal Shutdown(8)	T_{SD}		150	165		°C
Thermal Shutdown Hysteresis(8)	ΔT_{SD}			20		°C

Notes:

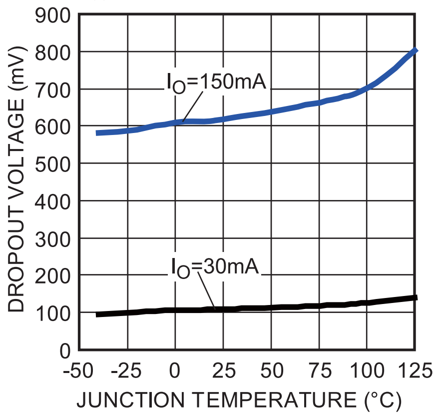
6) Line Regulation= $\frac{|V_{OUT[V_{IN(MAX)}]} - V_{OUT[V_{IN(MIN)}]}|}{(V_{IN(MAX)} - V_{IN(MIN)}) \times V_{OUT(NOM)}} \times (\%/V)$

7) Load Regulation= $\frac{|V_{OUT[I_{OUT(MAX)}]} - V_{OUT[I_{OUT(MIN)}]}|}{(I_{OUT(MAX)} - I_{OUT(MIN)}) \times V_{OUT(NOM)}} \times (\%/mA)$

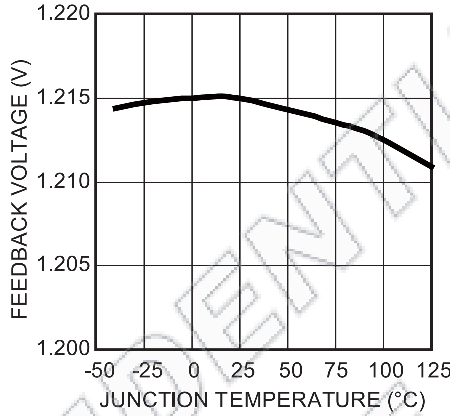
8) Derived from bench characterization. Not tested in production.

TYPICAL CHARACTERISTICS

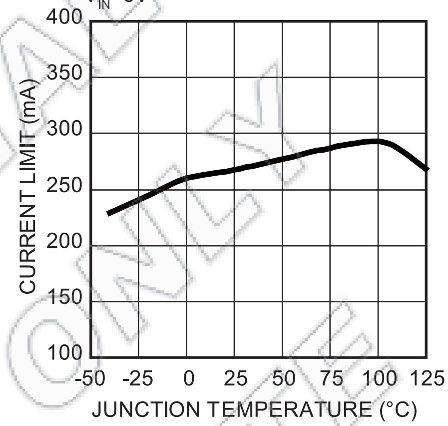
Dropout Voltage vs. Junction Temperature
V_{OUT}=5V



Feedback Voltage vs. Junction Temperature
V_{IN}=6V



Current Limit vs. Junction Temperature
V_{IN}=6V

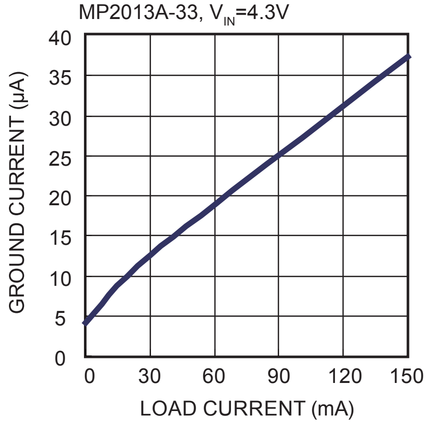


TYPICAL PERFORMANCE CHARACTERISTICS

C_{IN} = 1µF, C_{OUT} = 4.7µF, V_{OUT}=5V, T_A = +25ºC, unless otherwise noted

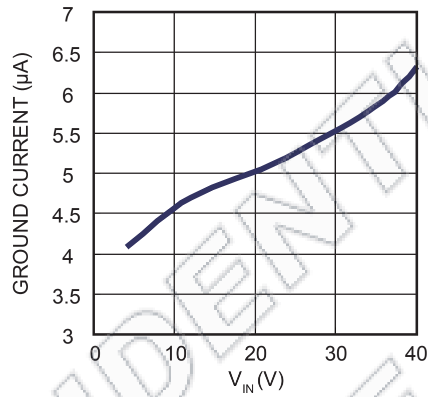
Ground Current vs. Load Current

MP2013A-33, V_{IN}=4.3V



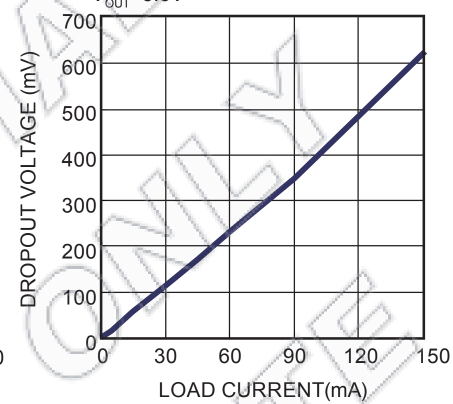
Ground Current vs. V_{IN}

MP2013A-33, I_{OUT}=0mA

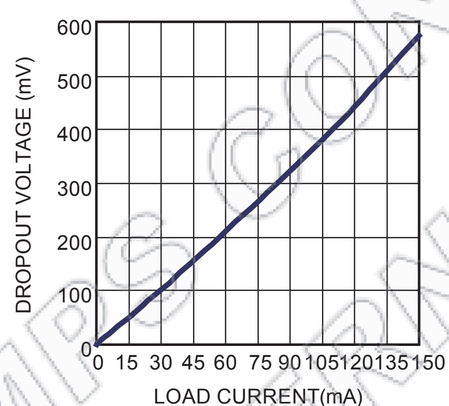


Dropout Voltage vs. Load Current

V_{OUT}=3.3V

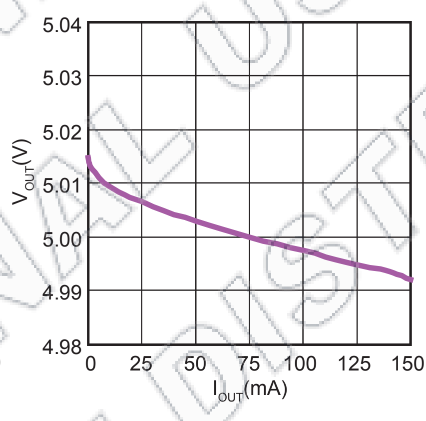


Dropout Voltage vs. Load Current



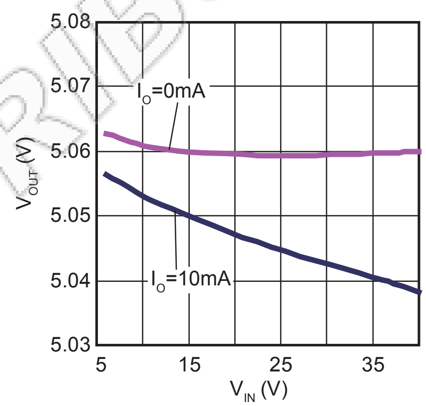
V_{OUT} vs. I_{OUT}

V_{IN}=6V



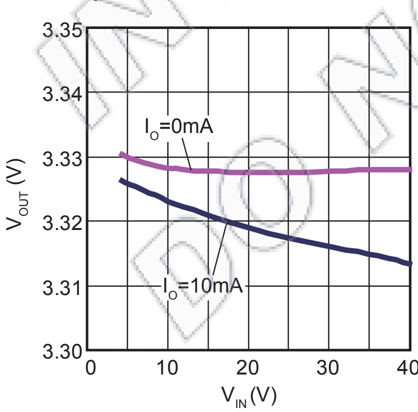
V_{OUT} vs. V_{IN}

V_O=5V



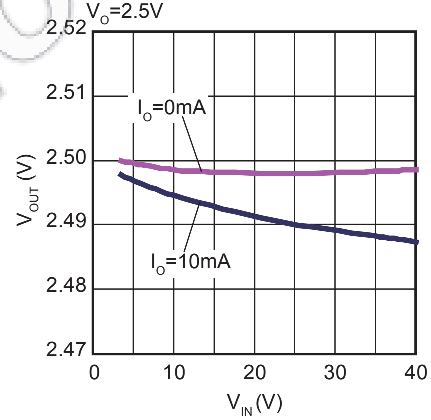
V_{OUT} vs. V_{IN}

V_O=3.3V



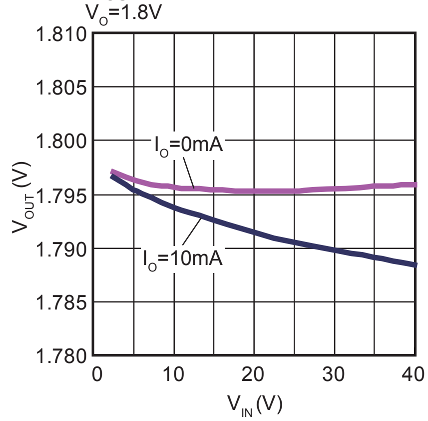
V_{OUT} vs. V_{IN}

V_O=2.5V



V_{OUT} vs. V_{IN}

V_O=1.8V

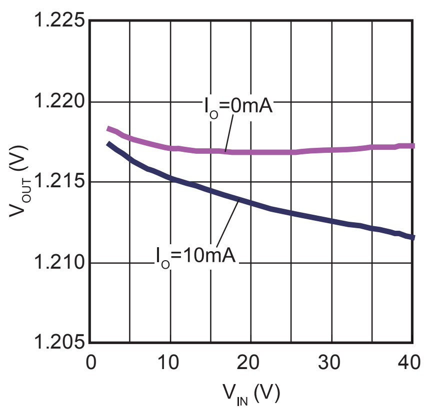


TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

C_{IN} = 1µF, C_{OUT} = 4.7µF, V_{OUT}=5V, T_A = +25ºC, unless otherwise noted

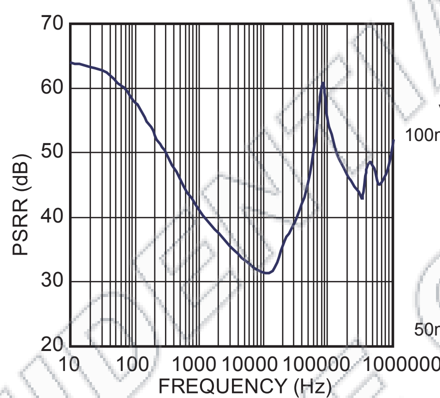
V_{OUT} vs. V_{IN}

V_O=1.215V



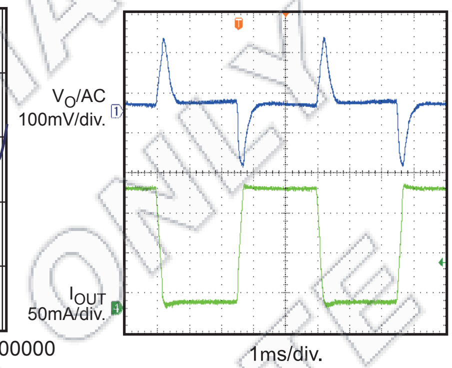
PSRR vs. Frequency

V_{IN1}=V_{IN2}=6V, I_O=10mA, C_{IN}=100pF



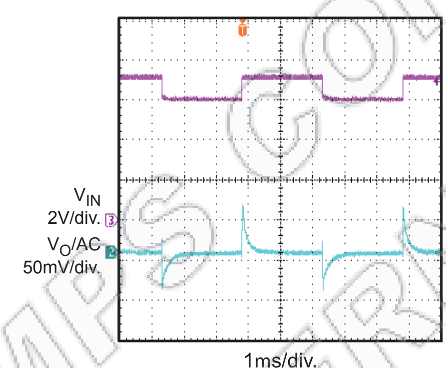
Load Transient

V_{IN} = 12V, I_{OUT} = 8mA-150mA



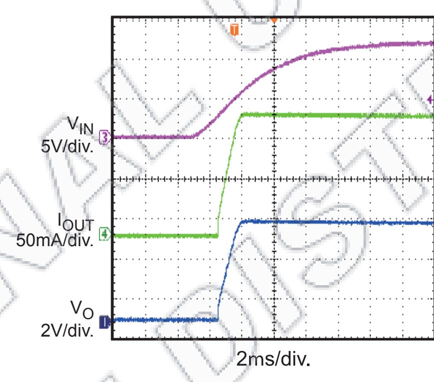
Line Transient

V_{IN} = 6V-7V, I_{OUT} = 150mA



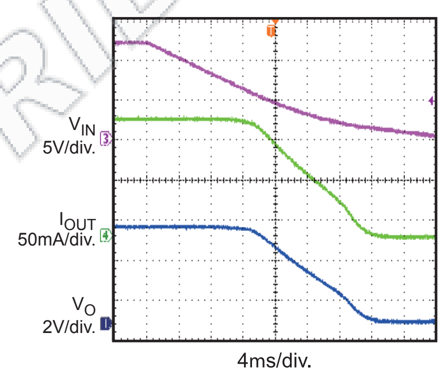
Startup Through V_{IN}

V_{IN} = 12V, I_{OUT} = 150mA



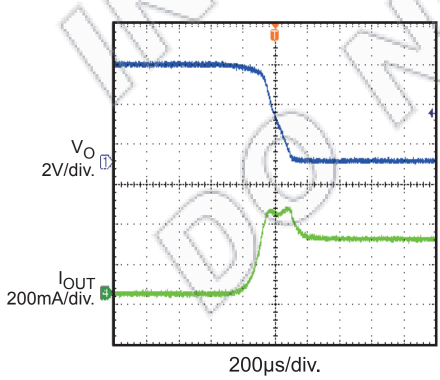
Shutdown Through V_{IN}

V_{IN} = 12V, I_{OUT} = 150mA



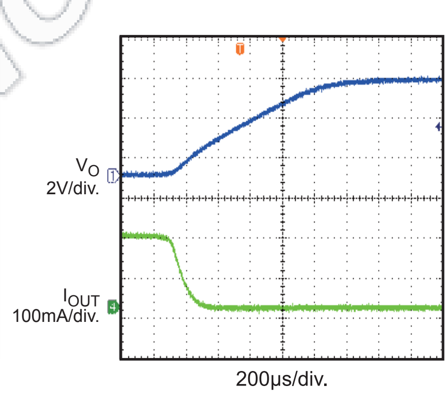
Short-Circuit Entry

V_{IN} = 12V, I_{OUT} = 0mA to short circuit



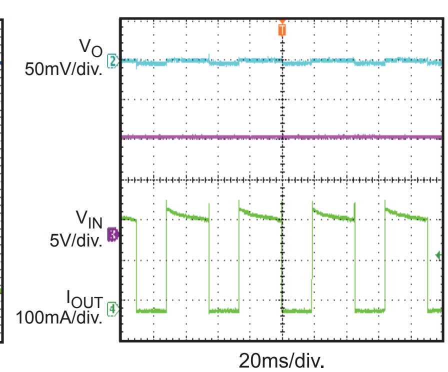
Short-Circuit Recovery

V_{IN} = 12V, short circuit to I_{OUT} = 0mA



Short-Circuit Steady State

V_{IN} = 12V



PIN FUNCTIONS

Pin # QFN6 (2x2mm)	Pin # QFN8 (3x3mm)	Name	Description
1	1	IN	Input Voltage. Connect IN to a 2.5V to 40V supply.
2	2	EN	Enable. A logic low on EN shuts down the IC; logic high starts it up. Connect EN to IN for automatic startup.
3, exposed pad	4, exposed pad	GND	Ground. The exposed pad and GND must be connected to the same ground plane.
4	5	FB	Feedback Input. FB is regulated to 1.215V nominally. Connect to an external resistive divider between OUT and GND to set output voltage. For a fixed-output version, FB can float.
6	8	OUT	Regulated Output Voltage. Only a low-value ceramic capacitor (≥ 0.47µF) on output is required for stability.
5	3, 6, 7	NC	No Connection. May be left open or tied to ground for improved thermal performance.

OPERATION

The MP2013A is a linear regulator that supplies power to systems with high-voltage batteries. It includes a wide 2.5V to 40V input range, low-dropout voltage and low-quiescent-supply current.

The MP2013A provides a wide variety of fixed, output-voltage options: 1.8V, 1.9V, 2.3V, 2.5V, 3.0V, 3.3V, 3.45V, and 5.0V; and it provides an adjustable output option (from 1.215V to 15V).

The adjustable output option delivers an output that is adjustable from 1.215V to 15V with a simple resistor divider. It uses external feedback, allowing the user to set the output voltage with an external resistor divider. The typical FB voltage is 1.215V.

The IC enters shutdown mode when EN is low. In shutdown mode, the pass transistor, control circuitry, reference, and all biases turn off, reducing the supply current to <0.15µA. Connect EN to IN for automatic startup.

The regulator output current is internally limited. The device is protected against over-load and over-temperature conditions.

The peak-output current is limited to around 270mA, which exceeds the 150mA recommended continuous-output current.

When the junction temperature is too high, the thermal sensor sends a signal to the control logic that shuts down the IC. The IC restarts when the temperature has cooled sufficiently.

The maximum power-output current is a function of the package's maximum power dissipation for a given temperature.

The maximum power dissipation is dependent on the thermal resistance of the case and the circuit board, the temperature difference between the die junction and the ambient air, and the rate of air flow. The GND and exposed pad must be connected to the ground plane for proper dissipation.

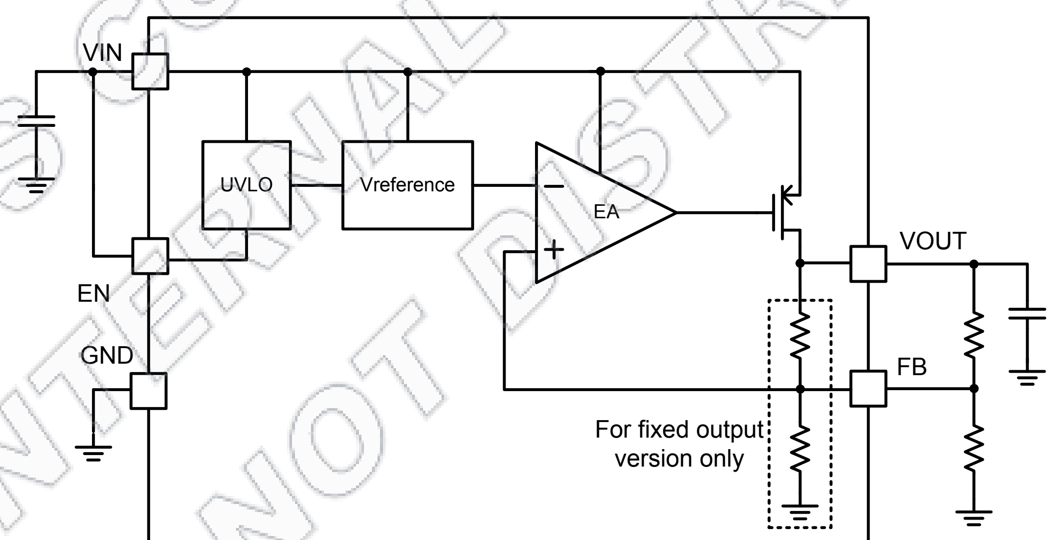


Figure 1: Functional Block Diagram

APPLICATION INFORMATION

COMPONENT SELECTION

Setting the Output Voltage

Set the output voltage using a resistor divider (see Figure 2).

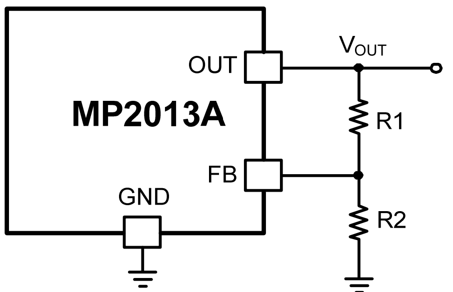


Figure 2: FB Resistor Divider to Set V_{OUT}

Choose R2=1MΩ to maintain a 1.215μA minimum load. Calculate the value for R1 using the following equation:

$$R1 = R2 \times \left(\frac{V_{OUT}}{1.215V} - 1 \right)$$

For fixed output, V_{OUT} is adjusted by adding an external resistor divider, take the internal FB resistor divider into consideration when choosing an external divider (see Figure 3).

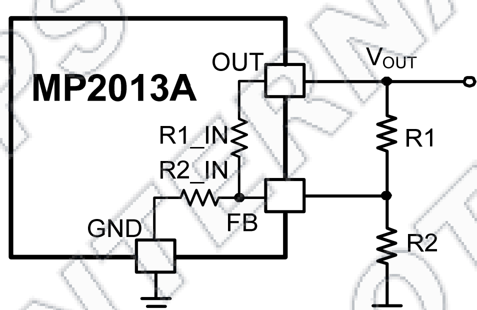


Figure 3: FB Divider of Fixed-Output Version

Table 1 lists the internal FB resistor dividers for different fixed-output versions.

Table 1: Internal FB Resistor Divider

Fixed Output Voltage	R1_IN	R2_IN
3.3V	1.72MΩ	1MΩ
5V	3.12MΩ	1MΩ

Setting VIN UVLO

To prevent the part from operating at an insufficient power-supply voltage, a resistor divider (see Figure 4) can be used to adjust the VIN UVLO point.

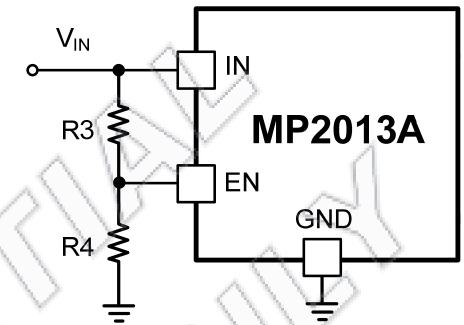


Figure 4: EN Resistor Divider to Set VIN UVLO

Choose R3 first, then calculate R4 using the following equation:

$$R4 = R3 \times \frac{EN_{TH\_L}}{V_{IN\_UVLO} - EN_{TH\_L}}$$

Where EN_{TH_L} is the EN falling threshold (1.26V). To limit the divider current, high-value resistors are recommended. For example, if V_{IN_UVLO} is set at 4.5V, R3=2MΩ and R4=778kΩ can be used.

Input Capacitor

For efficient operation, place a ceramic capacitor (C1) of dielectric type X5R or X7R (between 1μF and 10μF) between the input pin and ground. Larger values in this range improve line-transient response.

Output Capacitor

For efficient operation, use a ceramic capacitor (C2) of dielectric type X5R or X7R between 1μF and 10μF. Larger values in this range improve load-transient response and reduce noise. Output capacitors of other dielectric types may be used, but are not recommended as their capacitance deviates greatly from their rated value over temperature.

To improve load-transient response, add a small ceramic (X5R, X7R or Y5V dielectric) 22nF feedforward capacitor in parallel with R1. The feedforward capacitor is not required for efficient operation.

OUTPUT NOISE

During normal operation, the MP2013A exhibits noise on the output. This noise is negligible for most applications. However, in applications which include analog-to-digital converters (ADCs) of more than 12 bits, consider the ADC's power-supply rejection specifications. The feedforward capacitor C2 across R1 significantly reduces the output noise.

PCB LAYOUT GUIDE

Efficient PCB layout is critical in achieving good regulation, ripple rejection, transient response and thermal performance. It is highly recommended to duplicate EVB layout for optimum performance.

If changes are necessary, please follow the guidelines below using figure 5 as reference layout based on the circuit in figure 6.

1) Input and output bypass ceramic capacitors are recommended. Place as close to IN and OUT as possible.
2) Ensure all feedback connections are short and direct. Place the feedback resistors and compensation components as close to the chip as possible.
3) Connect IN, OUT and GND to a large copper area to cool the chip. This improves thermal performance and long-term reliability.

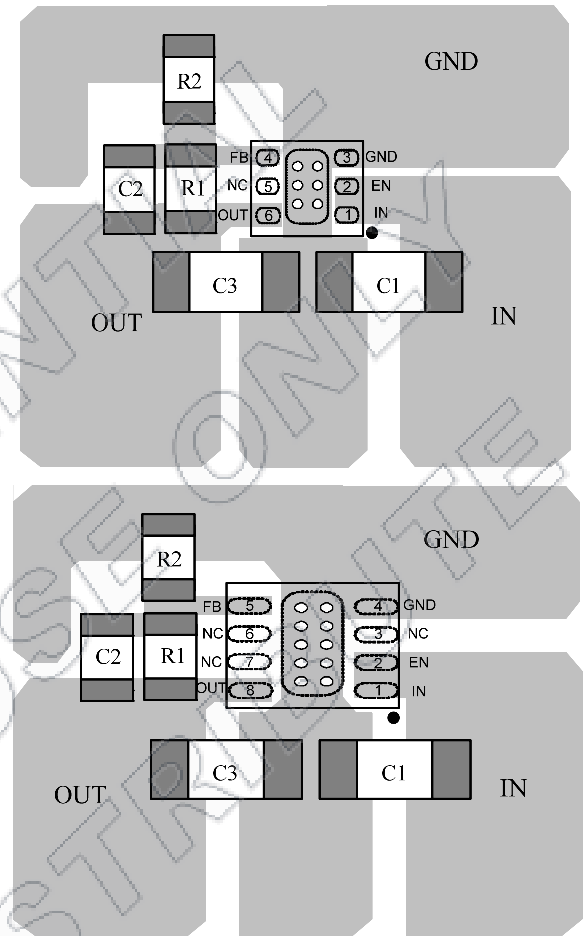


Figure 5: PCB Layout (Top Layer)

DESIGN EXAMPLE

See Figure 6 for a design example following the application guidelines for V_{OUT}=3.3V with feedforward cap.

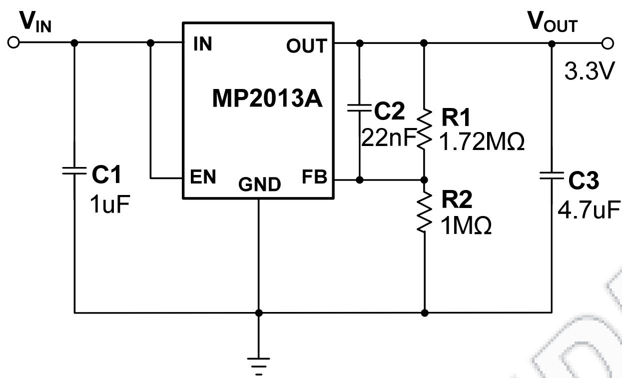


Figure 6: Design Example

TYPICAL APPLICATION CIRCUITS

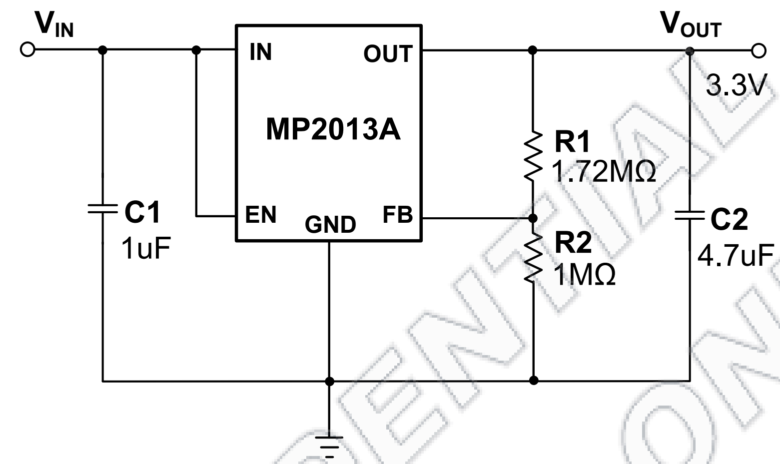


Figure 7: 3.3V Output Typical Application Circuit

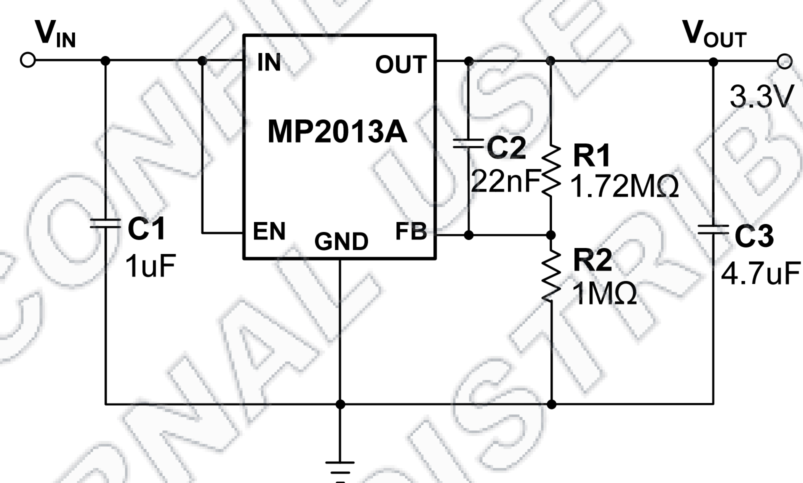


Figure 8: 3.3V Output with Feedforward Capacitor

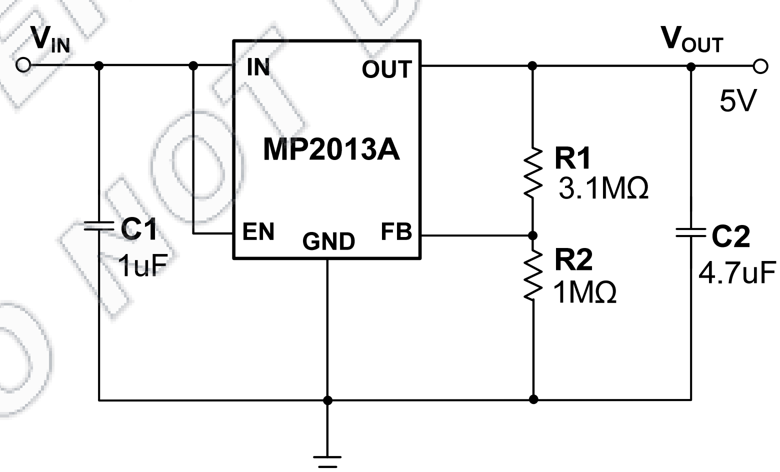
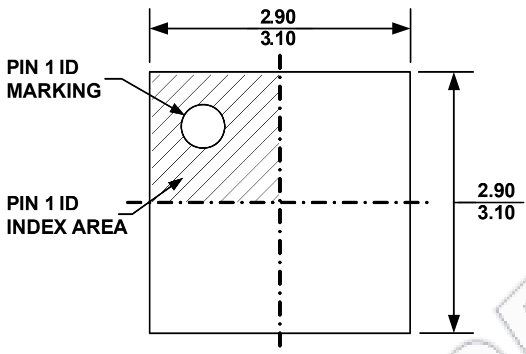


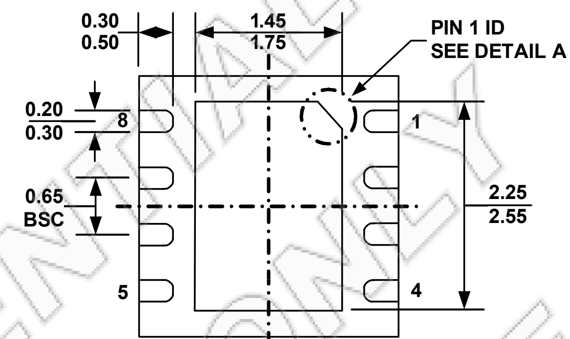
Figure 9: 5V Output Typical Application Circuit

PACKAGE INFORMATION

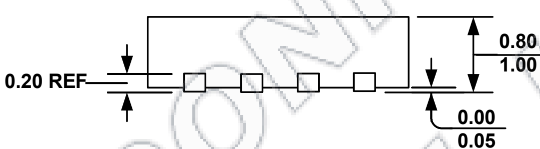
QFN8 (3x3mm)



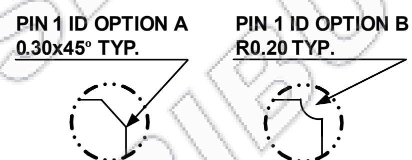
TOP VIEW



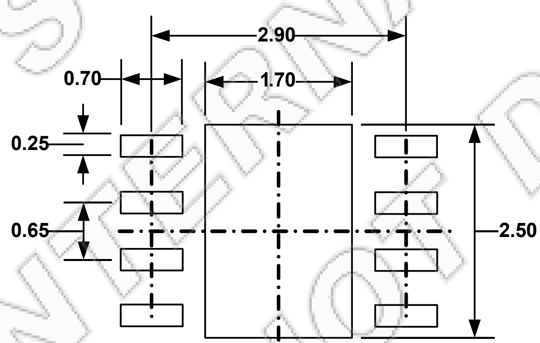
BOTTOM VIEW



SIDE VIEW



DETAIL A

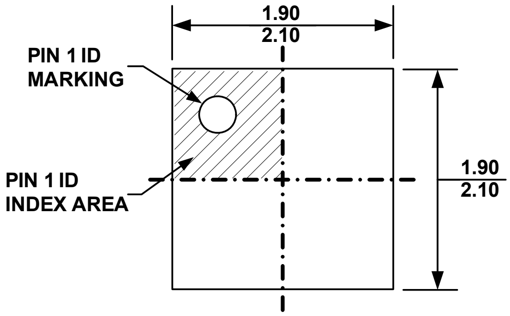


RECOMMENDED LAND PATTERN

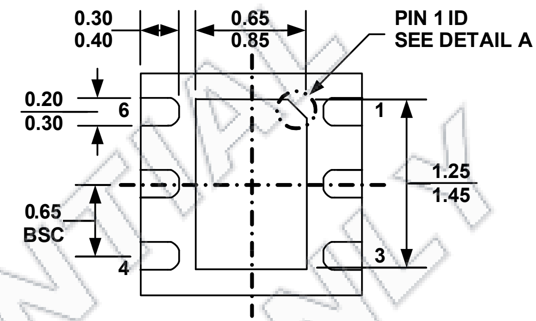
NOTE:

1) ALL DIMENSIONS ARE IN MILLIMETERS
2) EXPOSED PADDLE SIZE DOES NOT INCLUDE MOLD FLASH
3) LEAD COPLANARITY SHALL BE 0.10 MILLIMETER MAX
4) JEDEC REFERENCE IS MO-229, VARIATION VEEC-2.
5) DRAWING IS NOT TO SCALE

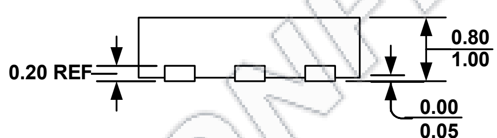
QFN6 (2x2mm)



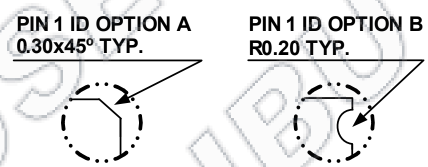
TOP VIEW



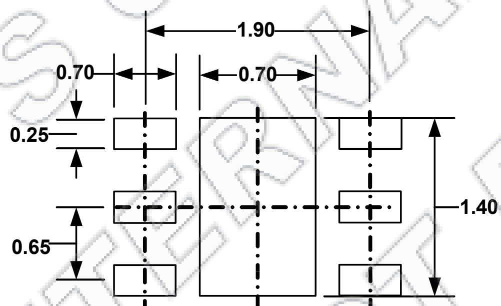
BOTTOM VIEW



SIDE VIEW



DETAIL A



RECOMMENDED LAND PATTERN

NOTE:

1) ALL DIMENSIONS ARE IN MILLIMETERS
2) EXPOSED PADDLE SIZE DOES NOT INCLUDE MOLD FLASH
3) LEAD COPLANARITY SHALL BE0.10 MILLIMETER MAX
4) JEDEC REFERENCE IS MO-229, VARIATION VCCC.
5) DRAWING IS NOT TO SCALE