

5V 3A 1MHz Synchronous Step-Down DC/DC Converter

DESCRIPTION

The MT3013 is a 3A high frequency synchronous Step Down DC/DC converter using constant frequency, current mode architecture. The device integrates main switch and synchronous rectifier switch for high efficiency without an external schottky diode. To maximize light load efficiency, The MT3013 draws only 40µA quiescent current to improve light load efficiency. In shutdown, The MT3013 reduces supply current less than 1µA. The MT3013 can supply 3A of load current from 2.5V to 6.0V input voltage. The output voltage can be regulated as low as 0.6V. The switching frequency is internally set at 1MHz. The MT3013 automatically operates PSM or PWM mode depending on the external load. The MT3013 has built-in internal Soft Start, Short Circuit Protection and OTP functions, allowing the use of small surface mount inductors and capacitor. The MT3013 is available in a low profile DFN2x2mm_8L package.

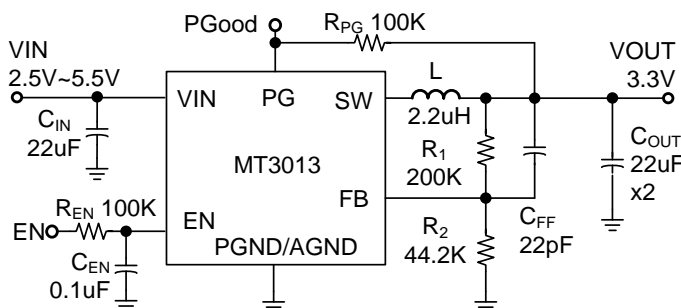
FEATURES

- Input Voltage Range from 2.5V to 6.0V
- +/- 2% 0.6V Feedback Voltage Accuracy
- 1MHz Switching Frequency
- Continuous Output Current up to 3A
- Low Quiescent Current of 40µA
- 0.1µA Shutdown Current
- 100% Duty Cycle Operation
- Built-in 110/80mΩ Power Switch
- Internal Soft-Start
- Cycle-by-Cycle Current Limit Protection
- Over-Load and Hiccup Mode Short Circuit
- Thermal Shutdown Protection
- PWM with Power Saving Mode
- Available in a Small DFN2x2mm_8L Package
- Pb-Free RoHS Compliant

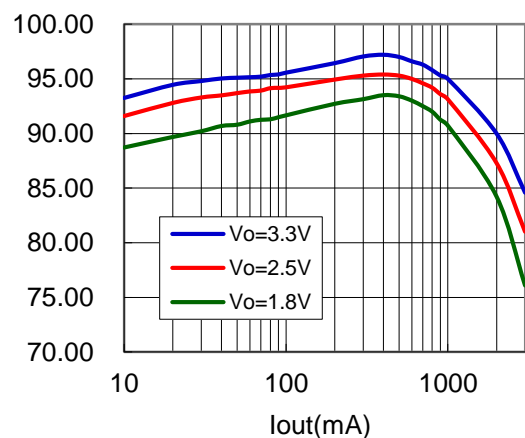
APPLICATIONS

- Solid-State and Hard Disk Drives
- Wireless and DSL Card
- Portable/Handheld Device
- STB, TV, Sound Bar, MP3 Player
- Microprocessor and DSP Core Supply

Typical Applications



Efficiency VIN=5V



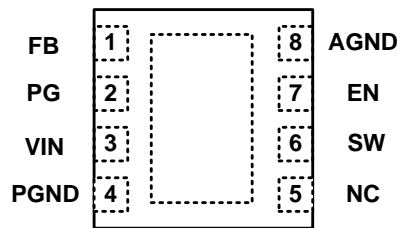
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Ordering Information

Part No.	Marking	Temp. Range	Package	MOQ
MT3013NDAR	3013 YWxx	-40°C ~+85°C	DFN2x2_8L	3000/Tape & Reel

Note: Y:Year, WW:Week

Pin Configuration



EXPOSED PAD ON BACKSIDE

Top View

Pin Description

Pin No.	Symbol	Description
1	FB	Voltage Feedback
2	PG	Power Good Indicator
3	VIN	Main Input Supply Voltage
4	PGND	Power Ground
5	NC	Not Connected
6	SW	Power Switches Node
7	EN	Regulator Enable Control Input, Don't float this PIN <ul style="list-style-type: none"> • Drive EN above 1.2V to turn on the converter • Drive EN below 0.3V to turn off the converter
8	AGND	Analog Ground

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Absolute Maximum Rating (Reference to GND) (Note1)

Input Supply Voltage	GND-0.3V to +6.5V	Junction Temperature Range	-40°C to 150°C
EN, FB Voltage	-0.3V to V_{IN}	Storage Temperature Range	-65°C to 150°C
ESD Classification	Class 2	Lead Temperature (Soldering 10s)	260°C

Recommend Operating Conditions (Note2)

Input Voltage (V_{IN})	+2.5V to +6V	Operating Temperature Range	-40°C to +85°C
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Thermal information (Note3)

Maximum Power Dissipation($T_A=+25^\circ\text{C}$)	1.3W	Thermal Resistance (θ_{JA})	75°C/W
		Thermal Resistance (θ_{JC})	20°C/W

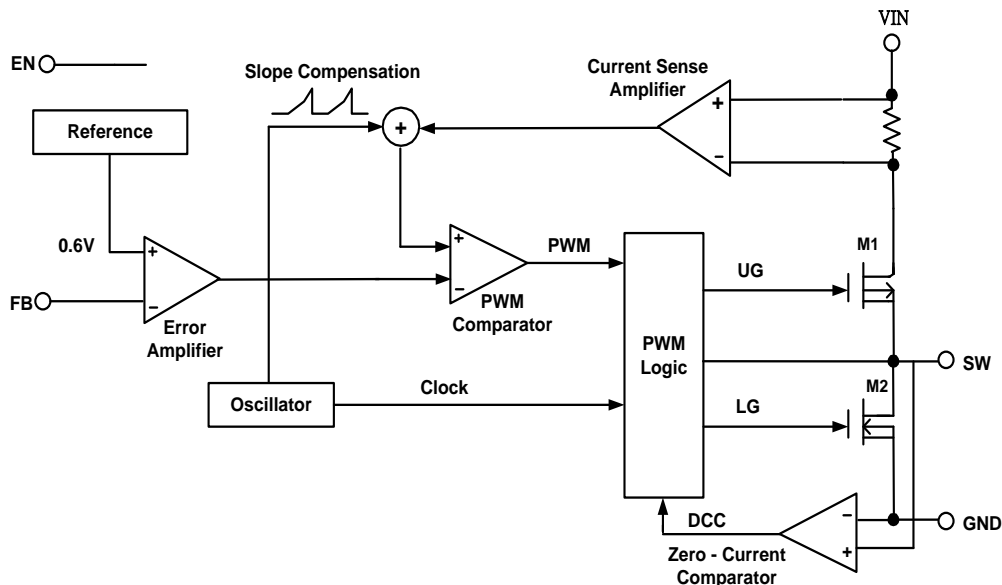
Note (1): Stress exceeding those listed "Absolute Maximum Ratings" may damage the device.

Note (2): The device is not guaranteed to function outside of the recommended operating conditions.

Note (3): Measured on JESD51-7, 4-Layer PCB.

Note (4): 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 $P_{D_MAX} = (T_{J_MAX} - T_A) / \theta_{JA}$. 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.

Functional Block Diagram



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Electrical Characteristics
 $T_A = 25^\circ\text{C}$, $V_{IN}=5\text{V}$, unless otherwise noted.

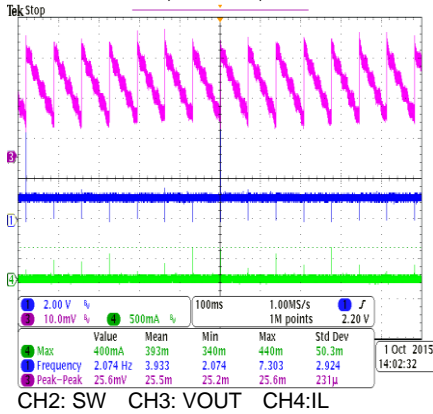
PARAMETER	TEST CONTITIONS	MIN	TYP	MAX	UNIT
Input Supply Voltage		2.5		6.0	V
Quiescent Current	$V_{EN} = V_{IN}$, $V_{FB} = 0.65\text{V}$, $I_{OUT}=0\text{A}$, No switching		40	60	μA
Shutdown Current	$V_{EN} = 0\text{V}$		0.1	1.2	μA
Regulated Feedback Voltage V_{REF}	$T_A = 25^\circ\text{C}$	0.588	0.6	0.612	V
Feedback Current		-30		30	nA
VIN Under voltage Lockout Threshold	VIN rising		2.2		V
	VIN falling		1.9		
PMOSFET On Resistance	$I_{SW} = 100\text{mA}$, $V_{IN}=5\text{V}$		110		$\text{m}\Omega$
NMOSFET On Resistance	$I_{SW} = -100\text{mA}$, $V_{IN}=5\text{V}$		80		$\text{m}\Omega$
PMOSFET Current Limit	$V_{IN}=3.3\text{V}$		5		A
SW Leakage Current	$V_{EN} = 0\text{V}$, $V_{IN} = 6.0\text{V}$ $V_{SW} = 0\text{V}$ or 6.0V	-1		1	μA
Oscillator Frequency	$I_{OUT}=1\text{A}$		1		MHz
Min. On-Time for HS Switch			100		ns
Maximum Duty	$V_{FB} < 0.6\text{V}$			100	%
EN On Threshold		1.5			V
EN Off Threshold				0.4	V
EN Input Current	$V_{EN} = 0\text{V}$ to V_{IN}	-1		1	μA
Power Good Indication	Rise Threshold		90		%
Soft Start Time			0.65		ms
Thermal Shutdown Threshold			160		$^\circ\text{C}$

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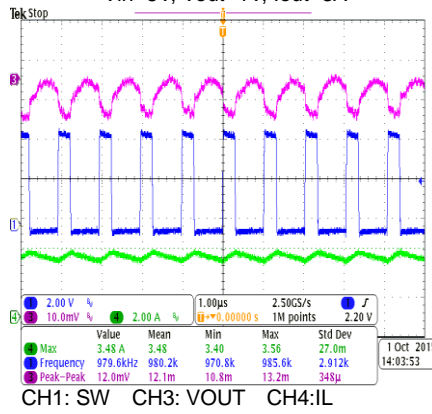
TYPICAL PERFORMANCE CHARACTERISTICS

(C_{IN}=22uF, C_{OUT} = 44uF, L=2.2uH, T_A=25 °C)

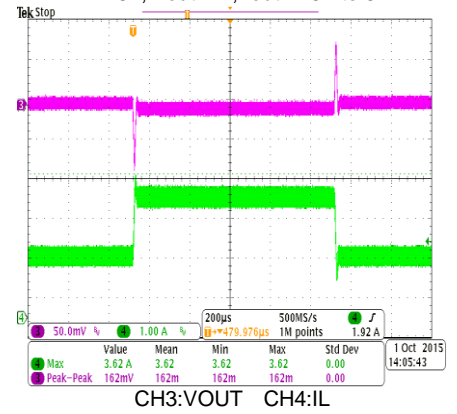
Steady State Test
Vin=5V, Vout=1V, Iout=0A



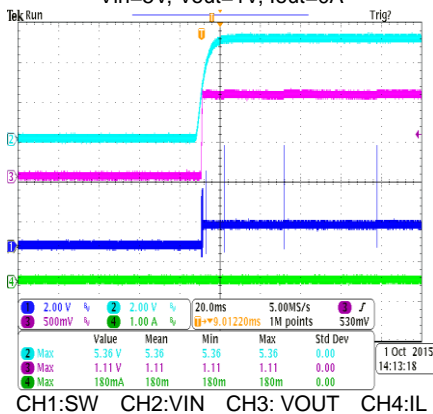
Steady State Test
Vin=5V, Vout=1V, Iout=3A



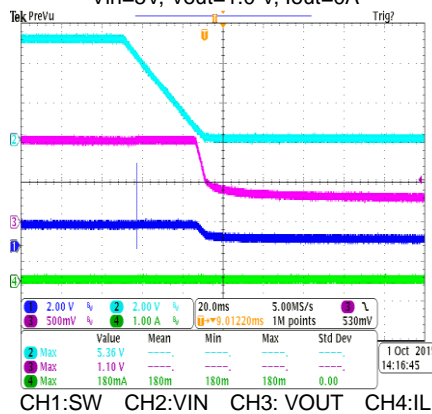
Load Transient Response
Vin=5V, Vout=1V, Iout=1.5A to 3A



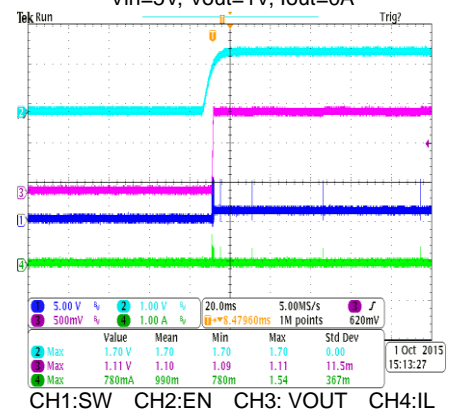
Vin Power On
Vin=5V, Vout=1V, Iout=0A



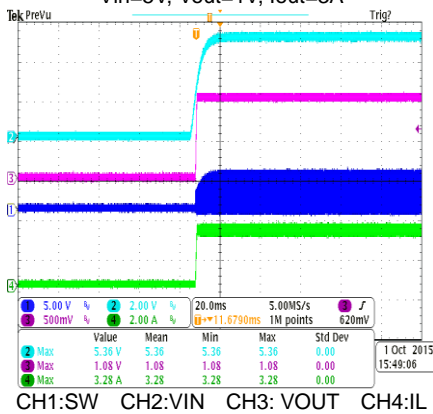
Vin Power Off
Vin=5V, Vout=1.0 V, Iout=0A



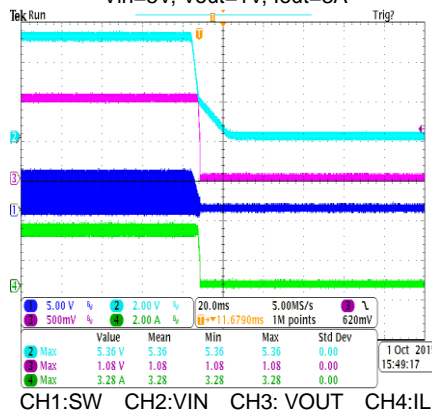
EN On
Vin=5V, Vout=1V, Iout=0A



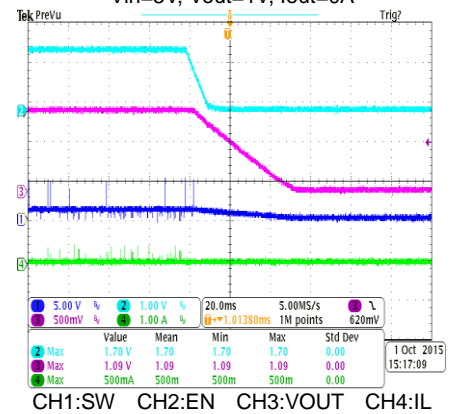
Vin Power On
Vin=5V, Vout=1V, Iout=3A



Vin Power On
Vin=5V, Vout=1V, Iout=3A



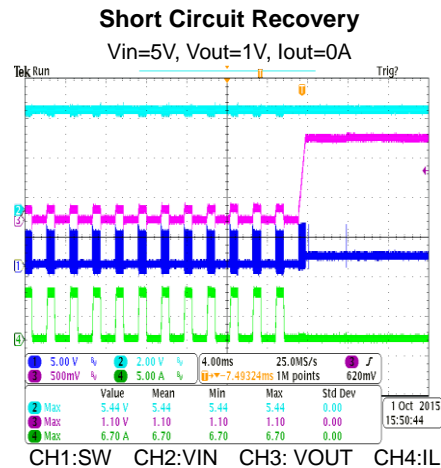
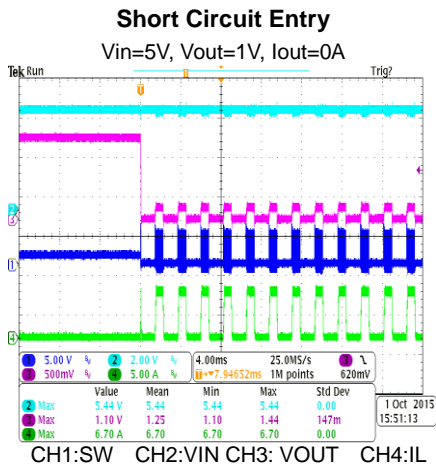
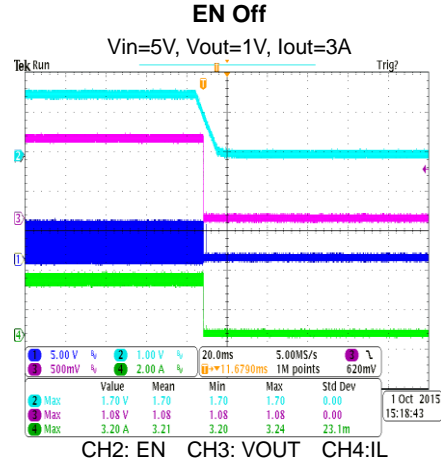
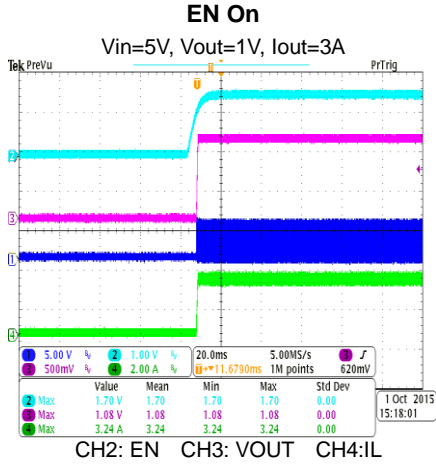
EN Off
Vin=5V, Vout=1V, Iout=0A



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TYPICAL PERFORMANCE CHARACTERISTICS

($C_{IN}=10\mu F$, $C_{OUT} = 22$, $L=2.2\mu H$, $T_A=25^\circ C$)



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Detailed Description

The MT3013, a current mode PWM step-down converter with a constant frequency, is optimized for low voltage, Li-Ion battery powered applications for which the high efficiency and small size are critical. It uses an external resistor divider to set the output voltage from 0.6V to V_{in} and integrates both a main switch and a synchronous rectifier, which provides the high efficiency and eliminates an external Schottky diode. MT3013 has power saving mode to provide high efficiency at light load.

Current Mode PWM Control

Current mode PWM control provides stable switching and cycle-by-cycle current limit for superior load and line response and protection of the internal main switch and synchronous rectifier. The MT3013 switches at a constant frequency (1MHz) and regulates the output voltage.

During normal operation, the hidden side is turned on at the beginning of a clock cycle when the VFB voltage is below the V_{ref} (0.6V). The current flows into the inductor and the load increases until the current limit is reached. The switch is turned off and energy stored in the inductor flows through the low side switch into the load until the next clock cycle.

Power Saving Mode

The power saving mode at light load can minimize the switching loss by reducing the switching frequency. Therefore, the MT3013 is designed as the power saving mode for high efficiency at light load.

Under Voltage Lockout

The MT3013 features an Under-Voltage Lockout circuit, which provides the function to shut down the part when the input voltage drops below about 2.10V to prevent unstable operation.

Internal Soft-start

The MT3013 features an internal soft-start function, which reduces inrush current and overshoot of the output voltage. Soft-start is achieved by ramping up the reference voltage (V_{ref}) which is applied to the input of the error amplifier. The typical soft-start time, depending on the component's values on AP circuit, is about 650 μ sec.

Short Circuit Protection

The MT3013 has short circuit protection. When the output is shorted to ground, the oscillator's frequency is reduced to prevent the inductor's current from increasing beyond the P MOSFET current limit. The frequency will return to the normal values once the short circuit condition is removed and the feedback voltage $> 0.3V$.

Maximum Load Current

The MT3013 can operate down to 2.5V input voltage; however the maximum load current decreases at lower input due to large IR drop on the main switch and synchronous rectifier. The slope compensation signal reduces the inductor's peak current as a function of the duty cycle to prevent sub-harmonic oscillations at duty cycles greater than 50%. Conversely the current limit increases as the decrease of the duty cycle matches other diagrams in this datasheet.

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Application Information**Input Capacitor Selection**

It is necessary for the input capacitor to sustain the ripple current produced during the period of "ON" state of the upper MOSFET, so a low ESR is required to minimize the loss. The RMS value of this ripple can be obtained by the following:

$$I_{INRMS} = I_{OUT} \sqrt{D \times (1-D)}$$

Where D is the duty cycle, I_{INRMS} is the input RMS current, and I_{OUT} is the load current. The equation reaches its maximum value with $D = 0.5$. The loss of the input capacitor can be calculated by the following equation:

$$P_{CIN} = ESR_{CIN} \times I_{INRMS}^2$$

Where P_{CIN} is the power loss of the input capacitor and ESR_{CIN} is the effective series resistance of the input capacitance. Due to large di/dt through the input capacitor, electrolytic or ceramics should be used. If a tantalum must be used, it must be surge-protected. Otherwise, capacitor failure could occur.

Output Inductor Selection

The output inductor selection is to meet the requirements of the output voltage ripple and affects the load transient response. The higher inductance can reduce the inductor's ripple current and induce the lower output ripple voltage. The ripple voltage and current are approximated by the following equations:

$$\Delta I = \frac{V_{IN} - V_{OUT}}{F_S \times L} \cdot \frac{V_{OUT}}{V_{IN}}$$

$$\Delta V_{OUT} = \Delta I \times ESR$$

Although the increase of the inductance reduces the ripple current and voltage, it contributes to the decrease of the response time for the regulator to load transient. The way to set a proper inductor value is to have the ripple current (ΔI) be approximately 20%~50% of the maximum output current. Once the value has been determined, select an inductor capable of carrying the required peak current without going into saturation. It is also important to have the inductance tolerance specified to keep the accuracy of the system controlled. 20% tolerance (at room temperature) is reasonable for the most inductor manufacturers. For some types of inductors, especially those with ferrite core, the ripple current will increase abruptly when it saturates, which will result in a larger output ripple voltage.

Output Capacitor Selection

An output capacitor is required to filter the output and supply the load transient current. The high capacitor value and low ESR will reduce the output ripple and the load transient drop. In typical switching regulator design, the ESR of the output capacitor bank dominates the transient response. The number of output capacitors can be determined by the following equations:

$$ESR_{MAX} = \frac{\Delta V_{ESR}}{\Delta I_{OUT}}$$

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$$\text{Number of capacitors} = \frac{\text{ESR}_{\text{CAP}}}{\text{ESR}_{\text{MAX}}}$$

ΔV_{ESR} = change in output voltage due to ESR

ΔI_{OUT} = load transient

ESR_{CAP} = maximum ESR per capacitor (specified in manufacturer's data sheet)

ESR_{MAX} = maximum allowable ESR

High frequency decoupling capacitors should be placed as closely to the power pins of the load as physically possible. For the decoupling requirements, please consult the capacitor manufacturers for confirmation.

Output Voltage

The output voltage is set using the FB pin and a resistor divider connected to the output as shown in AP Circuit below. The output voltage (V_{OUT}) can be calculated according to the voltage of the FB pin (V_{FB}) and ratio of the feedback resistors by the following equation, where (V_{FB}) is 0.6V:

$$V_{\text{FB}} = V_{\text{OUT}} \times \frac{R_2}{(R_1 + R_2)}$$

Thus the output voltage is:

$$V_{\text{OUT}} = 0.6 \times \frac{(R_1 + R_2)}{R_2}$$

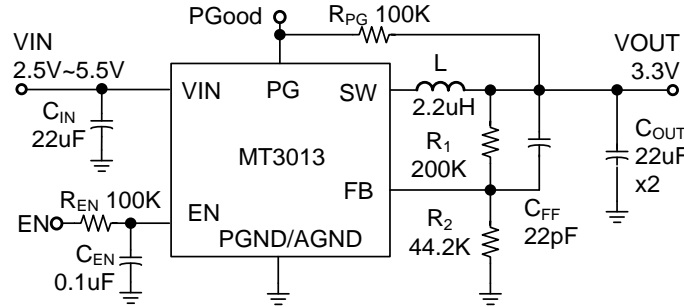
Choose $R_1=100\text{k}\Omega\sim 200\text{k}\Omega$ to ensure feedback loop noise immunity. It is optional to add a feed-forward capacitor $C_{\text{FF}}=22\sim 33\text{pF}$ in parallel with R_1 to achieve better transient response performance.

Layout Consideration

The physical design of the PCB is the final stage in the design of power converter. If designed improperly, the PCB could radiate excessive EMI and contribute instability to the power converter. Therefore, following the PCB layout guidelines below can ensure better performance of MT3013.

- (1). The loop (Vin-SW-L-Cout-GND) indicates a high current path. The traces within the loop should be kept as wide and short as possible to reduce parasitic inductance and high-frequency loop area. It is also good for efficiency improvement.
- (2). Input capacitor as close as possible to the IC Pins (Vin and GND) and the input loop area should be as small as possible to reduce parasitic inductance, input voltage spike and noise emission.
- (3). Feedback components (R_1 , R_2 and C_{FF}) should be routed as far away from the inductor and the SW Pin as possible to minimize noise and EMI issue.
- (4). For a typical 2-layer PCB layout, please refer to EVB Top Layer and EVB Bottom Layer below.

MT3013 Application Schematic



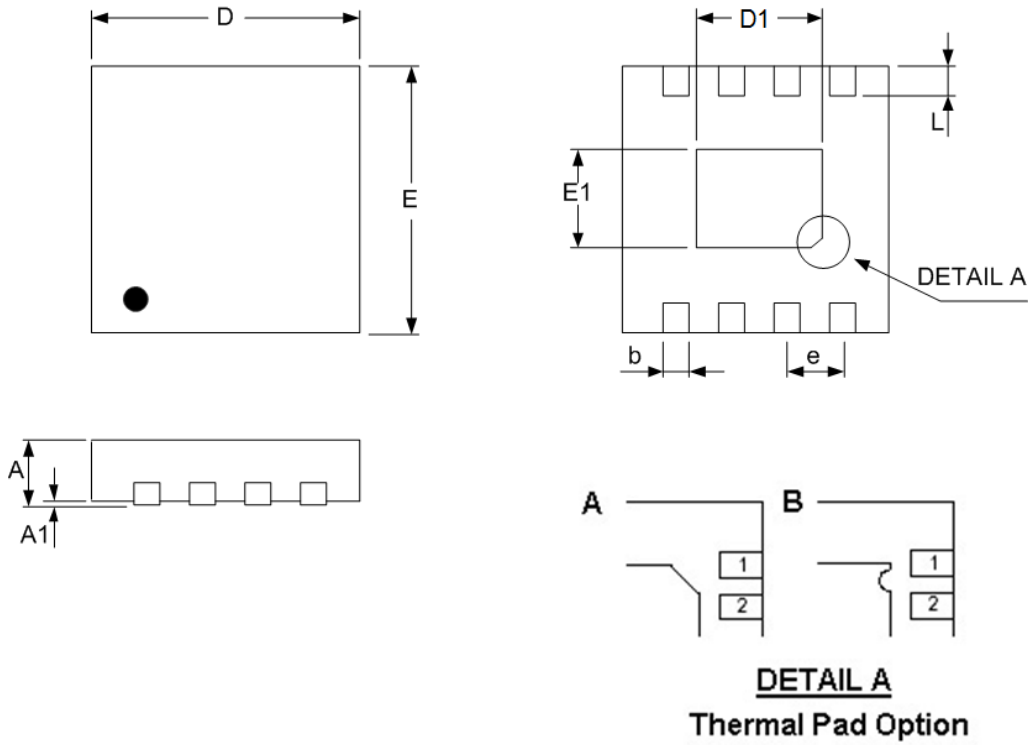
EVB BOM List

Qty	Ref	Value	Description	Package	
1	C _{IN}	22μF	Ceramic Capacitor, 10V, X5R	0805	
2	C _{OUT}	22μF	Ceramic Capacitor, 10V, X5R	0805	
1	C _{FF}	22p	Ceramic Capacitor, 10V, X5R	0603	
1	C _{EN}	0.1μF	Ceramic Capacitor, 10V, X5R	0603	
1	L1	2.2μH	Inductor, 5A	SMD	
1	R1	Vout=3.3V	200KΩ	Resistor, ±1%	0603
		Vout=2.5V	187KΩ		
		Vout=1.8V	200KΩ		
		Vout=1.2V	100KΩ		
		Vout=1V	66.5KΩ		
1	R2	Vout=3.3V	44.2KΩ	Resistor, ±1%	0603
		Vout=2.5V	59KΩ		
		Vout=1.8V	100KΩ		
		Vout=1.2V	100KΩ		
		Vout=1V	100KΩ		
2	R _{PG} , R _{EN}	100 KΩ	Resistor, ±1%	0603	
1	U1	MT3013	Step-Down DC/DC Converter	DFN2x2_8L	

Package Information

DFN 8L 2x2mm Outline Dimensions

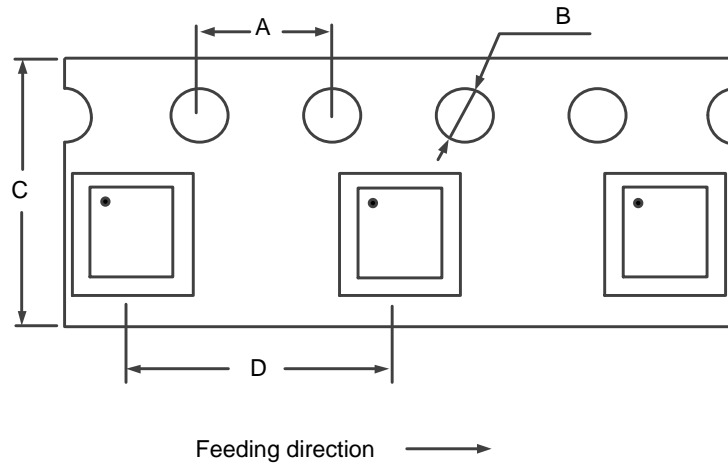
Unit: inches/mm



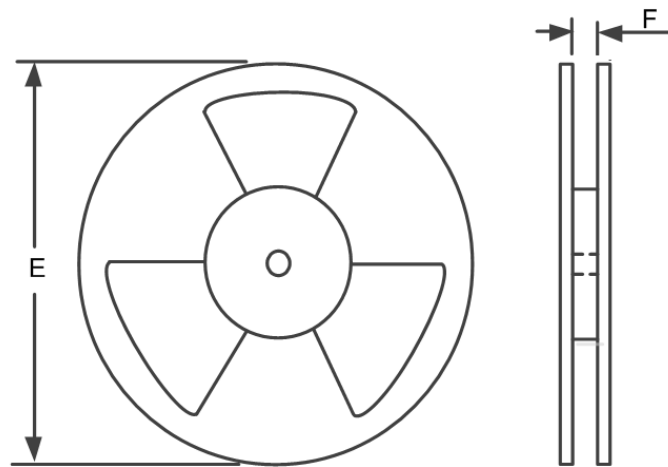
SYMBOLS	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A	0.70	0.80	0.028	0.031
A1	0.00	0.05	0.000	0.002
b	0.18	0.30	0.007	0.012
D	1.90	2.10	0.075	0.083
D1	1.20		0.047	
E	1.90	2.10	0.075	0.083
E1	0.60		0.024	
e	0.50		0.020	
L	0.25	0.45	0.010	0.018

Carrier Tape & Reel Dimensions

1. Orientation / Carrier Tape Information :



2. Rokreel Information :



3. Dimension Details :

PKG Type	A	B	C	D	E	F	Q'ty/Reel
Q(D)FN 2x2	4.0 mm	1.5 mm	8.0 mm	4.0 mm	7 inches	9.0 mm	3,000

Reflow Profile

Classification Of IR Reflow Profile

Reflow Profile	Green Assembly
Average Ramp-Up Rate ($T_{s_{min}}$ to T_p)	1~2°C/second, 3°C/second max.
Preheat & Soak	
-Temperature Min($T_{s_{min}}$)	150°C
-Temperature Max($T_{s_{max}}$)	200°C
-Time($t_{s_{min}}$ to $t_{s_{max}}$)	60~120 seconds
Time maintained above:	
-Temperature(T_L)	217°C
-Time(t_L)	60~150 seconds
Peak Temperature(T_p)	See Classification Temp in table 1
Time within 5°C of actual Peak Temperature(t_p)	30 seconds max.
Ramp-Down Rate	6°C/second max.
Time 25°C to Peak Temperature	8 minutes max.

* Tolerance for peak profile Temperature (T_p) is defined as a supplier minimum and a user maximum.
 ** Tolerance for time at peak profile temperature (t_p) is defined as a supplier minimum and a user maximum.

Table 1. Pb-free Process – Classification Temperatures (T_c)

Package Thickness	Volume mm^3 <350	Volume mm^3 350-2000	Volume mm^3 >2000
<1.6 mm	260 °C	260 °C	260 °C
1.6 mm – 2.5 mm	260 °C	250 °C	245 °C
2.5 mm	250 °C	245 °C	245 °C

Note: For all temperature information, please refer to topside of the package, measured on the package body surface.

