

## Description

The PAM2312 is a step-down current-mode, DC-DC converter. At heavy load, the constant frequency PWM control performs excellent stability and transient response. To ensure the longest battery life in portable applications, the PAM2312 provides a power-saving Pulse-Skipping Modulation (PSM) mode to reduce quiescent current under light load operation to save power.

The PAM2312 supports a range of input voltages from 2.5V to 5.5V, allowing the use of a single Li+/Li-polymer cell, multiple Alkaline/NiMH cell, USB, and other standard power sources. The output voltage is adjustable from 0.6V to the input voltage, while the part number suffix PAM2312-XX indicates pre-set output voltage of 3.3V, 2.8V, 2.5V, 1.8V, 1.5V, 1.2V or adjustable. All versions employ internal power switch and synchronous rectifier to minimize external part count and realize high efficiency. During shutdown, the input is disconnected from the output and the shutdown current is less than 1µA. Other key features include under-voltage lockout to prevent deep battery discharge.

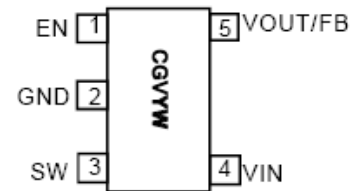
The PAM2312 is available in TSOT25 packages.

## Features

- Efficiency up to 96%
- Only 40µA (typ) Quiescent Current
- Output Current: Up to 1A
- Internal Synchronous Rectifier
- 1.5MHz Switching Frequency
- Soft Start
- Under-Voltage Lockout
- Short Circuit Protection
- Thermal Shutdown
- 5-pin Small TSOT25 Packages
- Pb-Free Package

## Pin Assignments

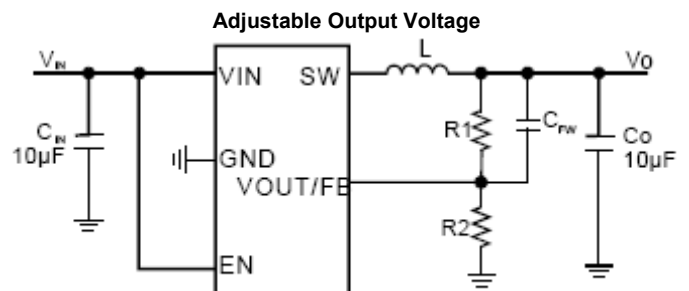
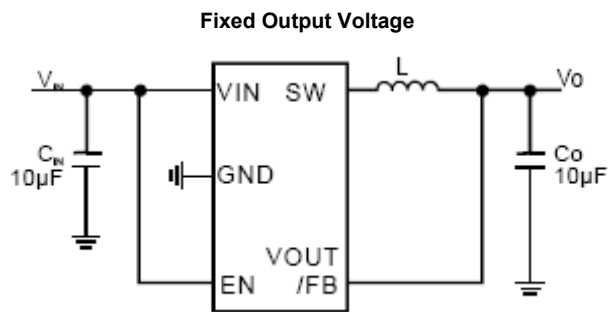
Top View  
TSOT25



## Applications

- Cellular Phone
- Portable Electronics
- Wireless Devices
- Cordless Phone
- Computer Peripherals
- Battery Powered Widgets
- Electronic Scales
- Digital Frame

## Typical Applications Circuit

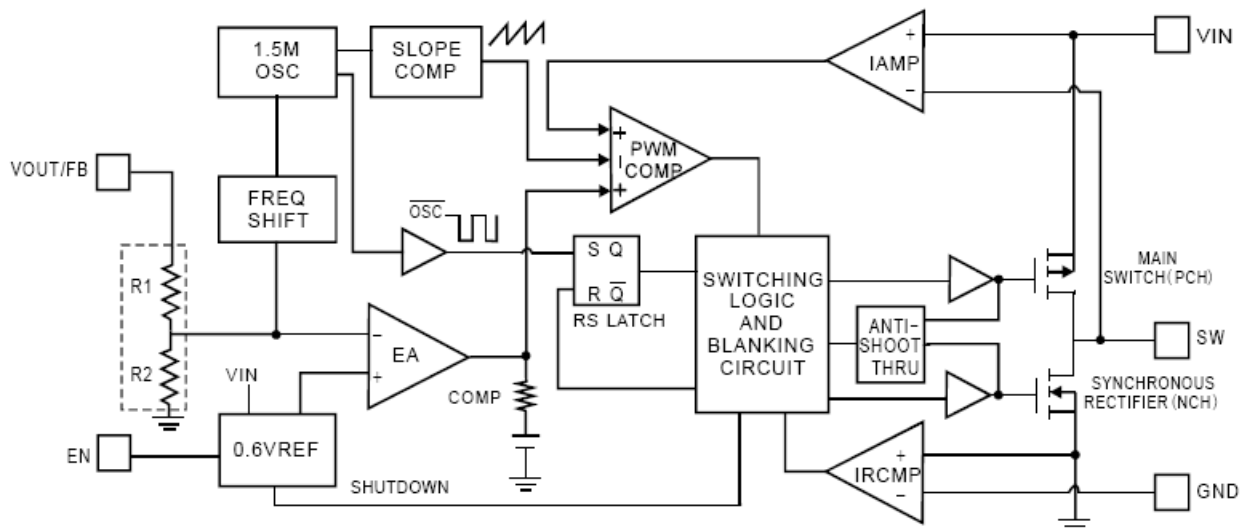


$$V_o = 0.6 \times \left( 1 + \frac{R_1}{R_2} \right)$$

### Pin Descriptions

Pin Name	TSOT25	Function
	Pin Name	
4	VIN	Chip main power supply pin.
2	GND	Ground
1	EN	Enable Control Input. Force this pin voltage above 1.5V, enables the chip, and below 0.3V shuts down the device.
5	VOUT/FB	VOUT: Output voltage feedback pin, an internal resistive divider divides the output voltage down for comparison to the internal reference voltage.
		FB: Feedback voltage to internal error amplifier, the threshold voltage is 0.6V.
3	SW	The drains of the internal main and synchronous power MOSFET.

### Functional Block Diagram



### Absolute Maximum Ratings (@T<sub>A</sub> = +25°C, unless otherwise specified.)

These are stress ratings only and functional operation is not implied. Exposure to absolute maximum ratings for prolonged time periods may affect device reliability. All voltages are with respect to ground.

Parameter	Rating	Unit
Inout Voltage	-0.3 to +6.0	V
EN, FB Pin Voltage	-0.3 to V <sub>IN</sub>	V
SW Pin Voltage	-0.3 to (V <sub>IN</sub> + 0.3)	V
Junction Temperature	150	°C
Storage Temperature Range	-65 to +150	°C
Soldering Temperature	300, 5sec	°C

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### Recommended Operating Conditions (@T<sub>A</sub> = +25°C, unless otherwise specified.)

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Parameter	Rating	Unit
Supply Voltage	2.5 to 5.5	V
Operation Temperature Range	-40 to +85	°C
Junction Temperature Range	-40 to +125	

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### Thermal Information

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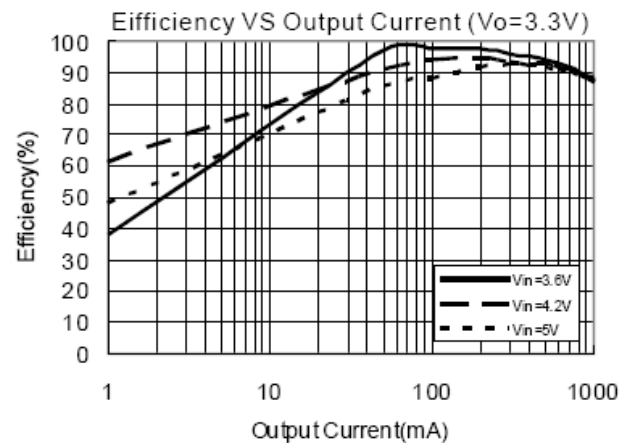
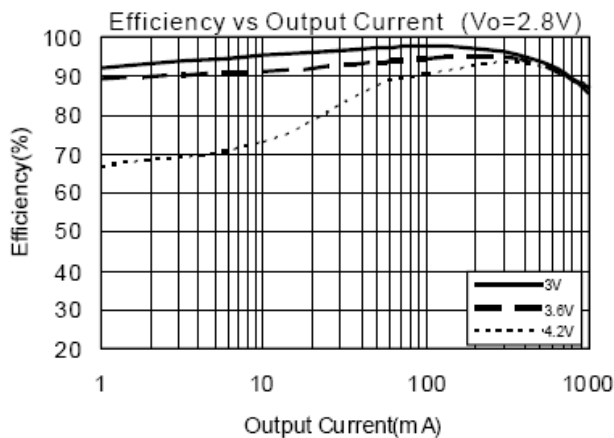
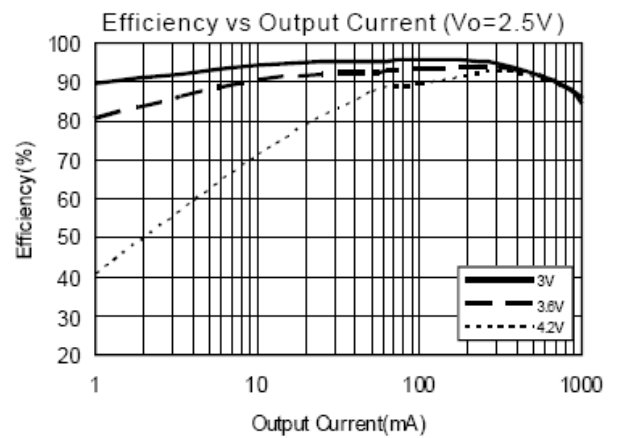
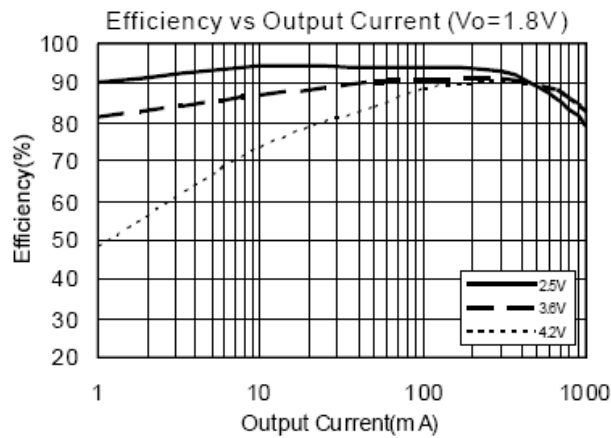
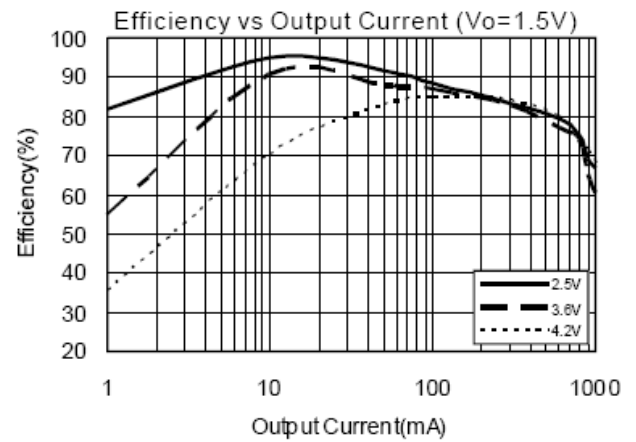
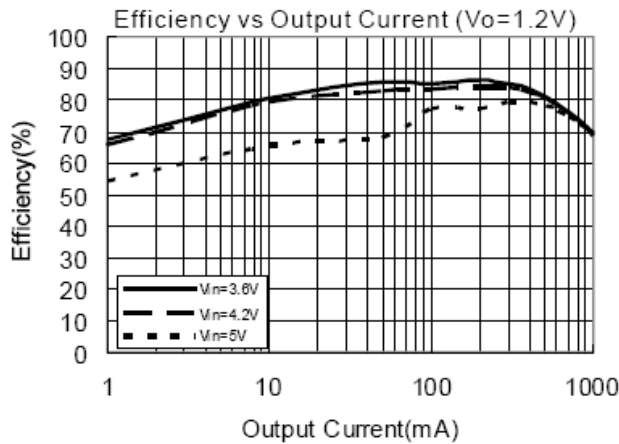
Parameter	Package	Symbol	Max	Unit
Thermal Resistance (Junction to Case)	TSOT25 (Note 1)	$\theta_{JC}$	130	°C/W
Thermal Resistance (Junction to Ambient)	TSOT25	$\theta_{JA}$	250	
Internal Power Dissipation	TSOT25	P <sub>D</sub>	400	mW

Note: 1. The maximum output current for TSOT25 package is limited by internal power dissipation capacity as described in Application Information hereinafter.

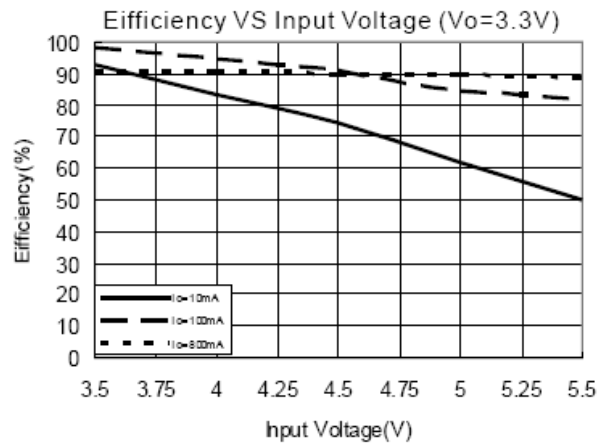
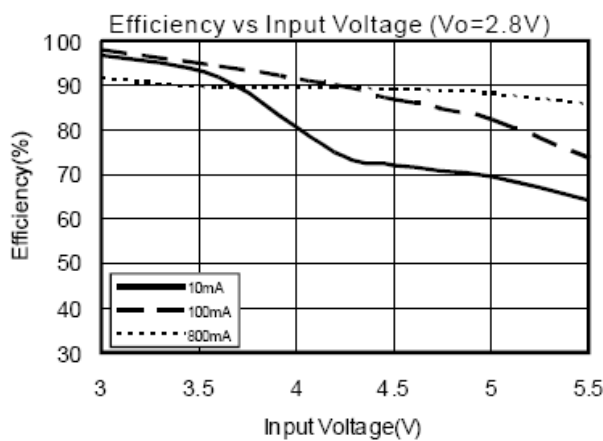
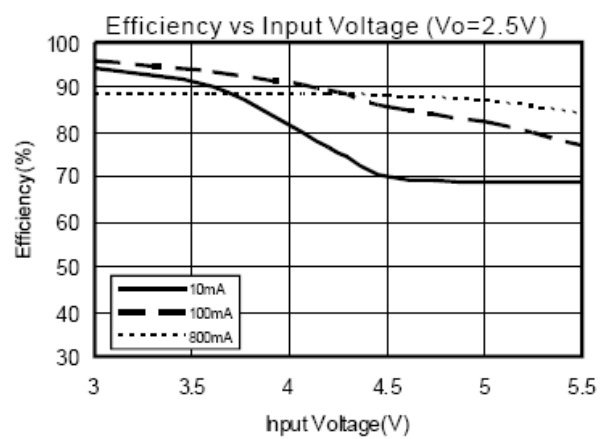
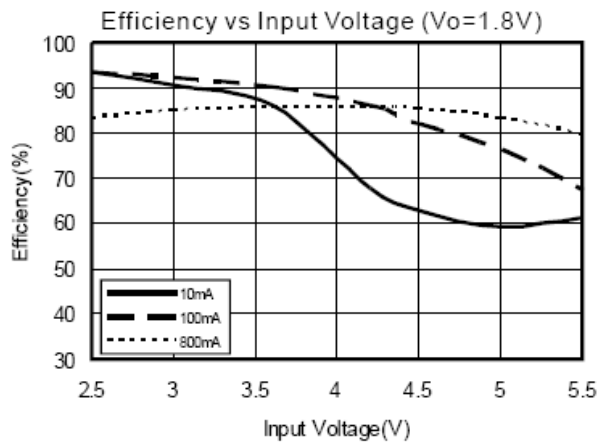
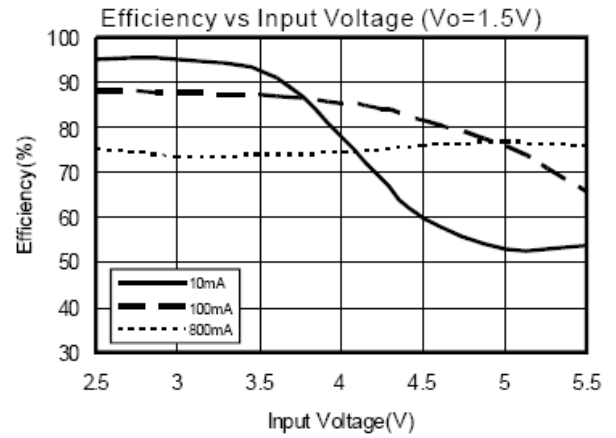
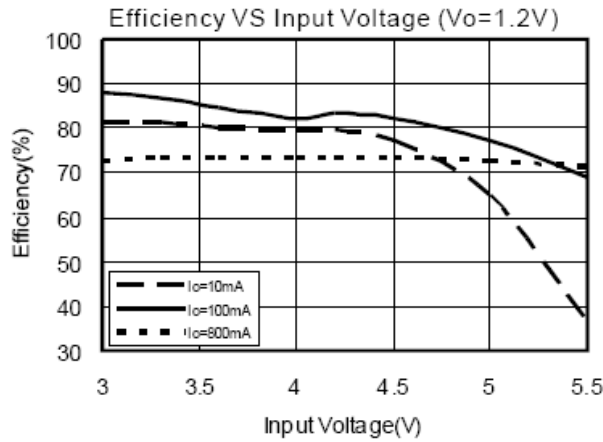
**Electrical Characteristics** (@ $T_A = +25^\circ\text{C}$ ,  $V_{IN} = 3.6\text{V}$ ,  $V_O = 1.8\text{V}$ ,  $C_{IN} = 10\mu\text{F}$ ,  $C_{OUT} = 10\mu\text{F}$ ,  $L = 4.7\mu\text{H}$ , unless otherwise specified.)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Input Voltage Range	$V_{IN}$		2.5		5.5	V
Regulated Feedback Voltage	$V_{FB}$		0.588	0.6	0.612	V
Reference Voltage Line Regulation	$\Delta V_{FB}$			0.3		%/V
Regulated Output Voltage Accuracy	$V_O$	$I_O = 100\text{mA}$	-3		+3	%
Peak Inductor Current	$I_{PK}$	$V_{IN} = 3\text{V}$ , $V_{FB} = 0.5\text{V}$ or $V_O = 90\%$		1.5		A
Putput Voltage Line Regulation	LNR	$V_{IN} = 2.5\text{V}$ to $5\text{V}$ , $I_O = 10\text{mA}$		0.2	0.5	%/V
Output Voltage Load Regulation	LDR	$I_O = 800\text{mA}$		0.5	1.5	%
Quiescent Current	$I_Q$	No Load		40	70	$\mu\text{A}$
Shutdown Current	$I_{SD}$	$V_{EN} = 0\text{V}$			1	$\mu\text{A}$
Oscillator Frequency	$f_{OSC}$	$V_O = 100\%$	1.2	1.5	1.8	MHz
		$V_{FB} = 0\text{V}$ or $V_O = 0\text{V}$		500		KHz
Drain-Source On-State Resistance	$R_{DS(ON)}$	$I_{DS} = 100\text{mA}$	P MOSFET	0.3	0.45	$\Omega$
			N MOSFET	0.35	0.5	$\Omega$
SW Leakage Current	$I_{LSW}$			$\pm 0.01$	1	$\mu\text{A}$
High Efficiency	$\eta$			96		%
EN Threshold High	$V_{EH}$		1.5			V
EN Threshold Low	$V_{EL}$				0.3	V
EN Leakage Current	$I_{EN}$			$\pm 0.01$		$\mu\text{A}$
Over Temperature Protection	OTP			150		$^\circ\text{C}$
OTP Hysteresis	OTH			30		$^\circ\text{C}$

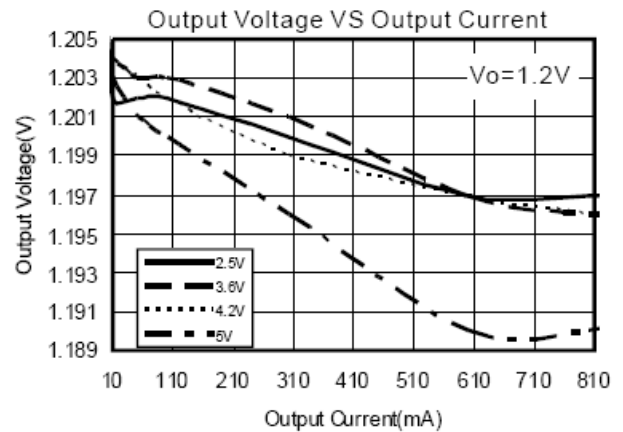
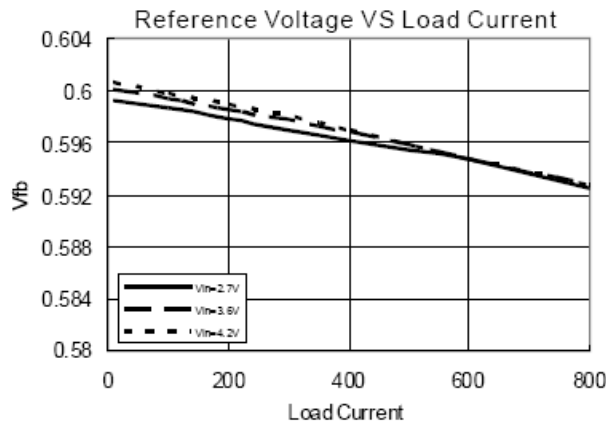
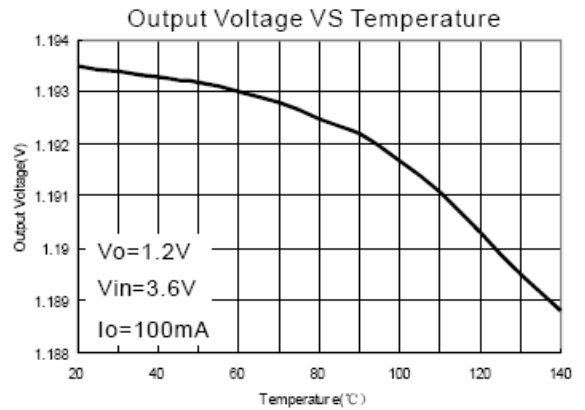
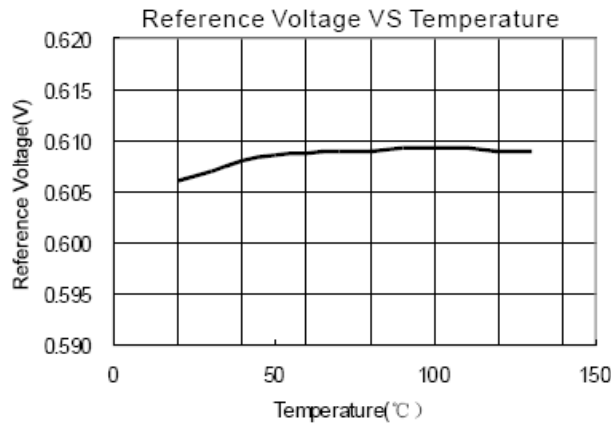
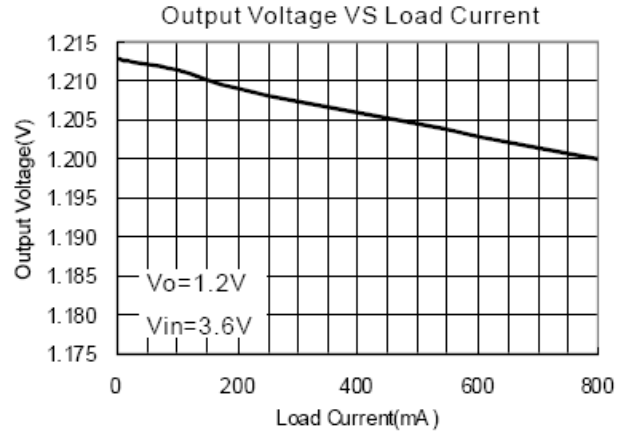
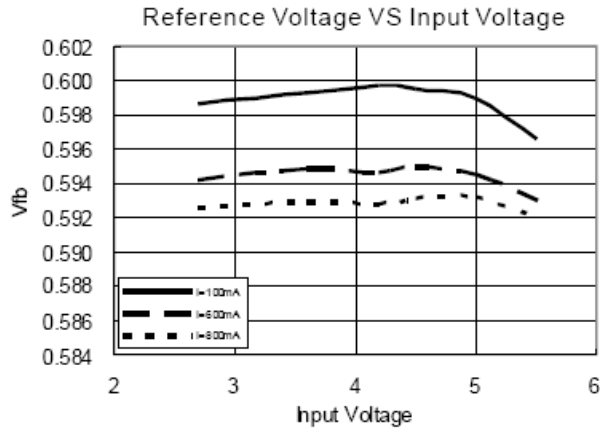
**Typical Performance Characteristics** (@ $T_A = +25^\circ\text{C}$ ,  $C_{IN} = 10\mu\text{F}$ ,  $C_O = 10\mu\text{F}$ ,  $L = 4.7\mu\text{H}$ , unless otherwise specified.)



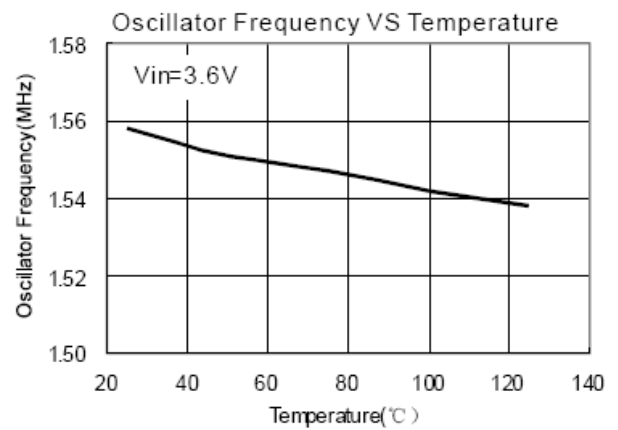
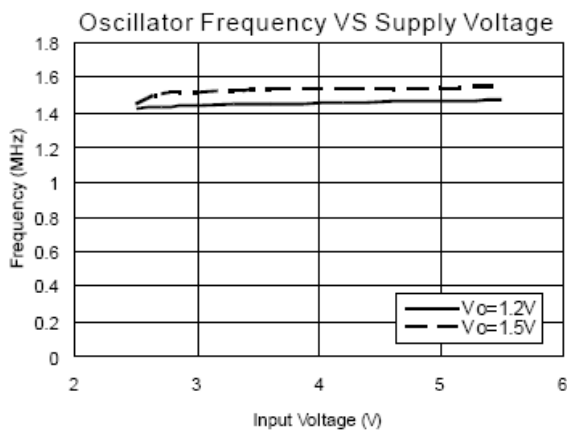
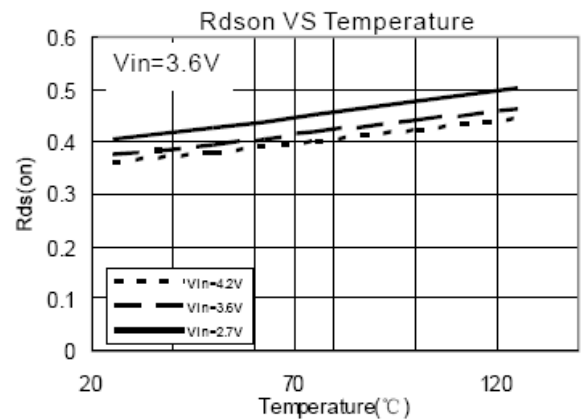
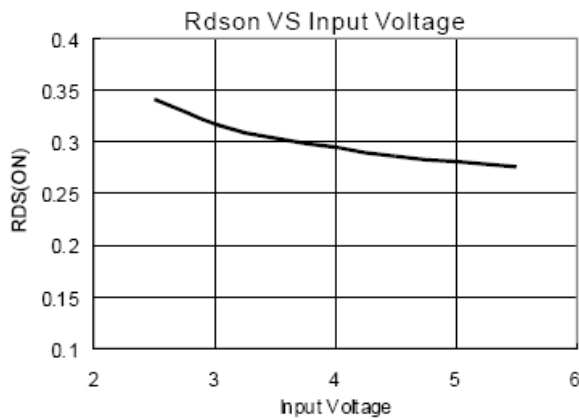
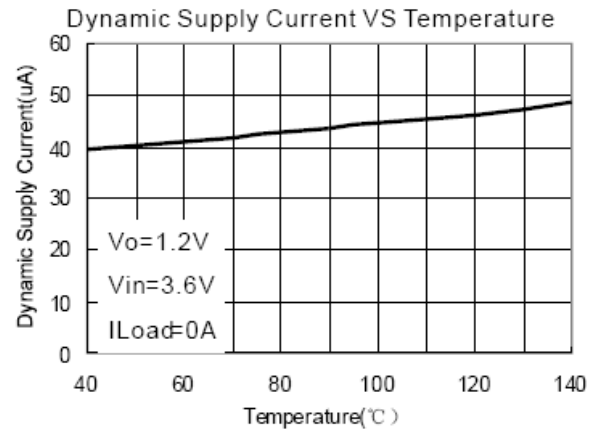
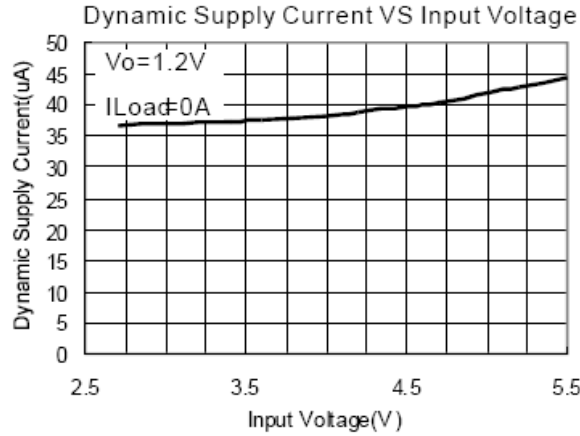
**Typical Performance Characteristics** (cont.) (@T<sub>A</sub> = +25°C, C<sub>IN</sub> = 10µF, C<sub>O</sub> = 10µF, L = 4.7µH, unless otherwise specified.)



**Typical Performance Characteristics** (cont.) (@ $T_A = +25^\circ\text{C}$ ,  $C_{IN} = 10\mu\text{F}$ ,  $C_O = 10\mu\text{F}$ ,  $L = 4.7\mu\text{H}$ , unless otherwise specified.)

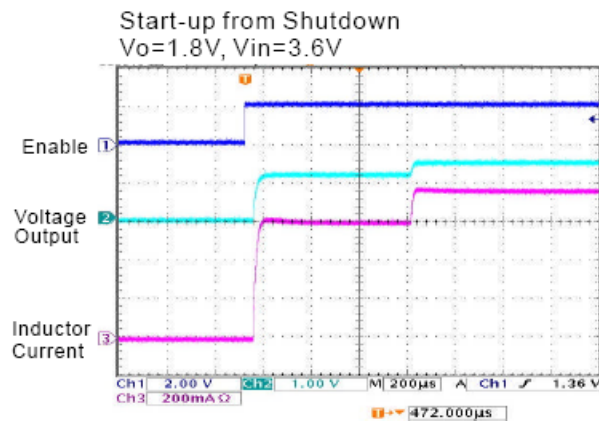
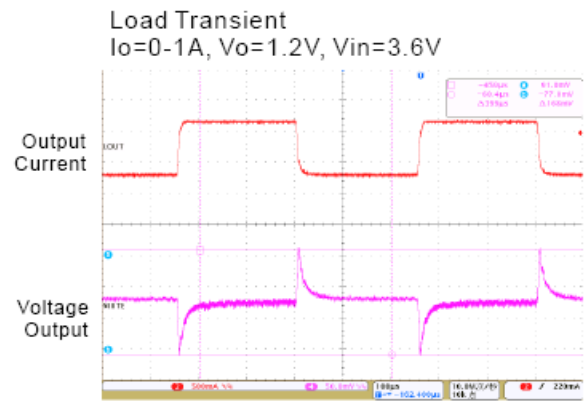
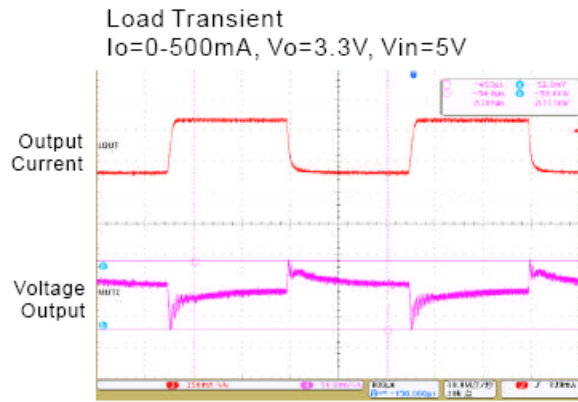


**Typical Performance Characteristics** (cont.) (@ $T_A = +25^\circ\text{C}$ ,  $C_{IN} = 10\mu\text{F}$ ,  $C_O = 10\mu\text{F}$ ,  $L = 4.7\mu\text{H}$ , unless otherwise specified.)





**Typical Performance Characteristics** (cont.) (@ $T_A = +25^\circ\text{C}$ ,  $C_{IN} = 10\mu\text{F}$ ,  $C_O = 10\mu\text{F}$ ,  $L = 4.7\mu\text{H}$ , unless otherwise specified.)



## Application Information

The basic PAM2312 application circuit is shown in Page 1. External component selection is determined by the load requirement, selecting L first and then C<sub>IN</sub> and C<sub>OUT</sub>.

### Inductor Selection

For most applications, the value of the inductor will fall in the range of 1μH to 4.7μH. Its value is chosen based on the desired ripple current. Large value inductors lower ripple current and small value inductors result in higher ripple currents. Higher V<sub>IN</sub> or V<sub>OUT</sub> also increases the ripple current as shown in Equation 1. A reasonable starting point for setting ripple current is ΔI<sub>L</sub> = 400mA (40% of 1A).

$$\Delta I_L = \frac{1}{fL} V_{OUT} \left( 1 - \frac{V_{OUT}}{V_{IN}} \right) \quad \text{Equation (1)}$$

The DC current rating of the inductor should be at least equal to the maximum load current plus half the ripple current to prevent core saturation. Thus, a 1.4A rated inductor should be enough for most applications (1A + 400mA). For better efficiency, choose a low DC-resistance inductor.

V <sub>O</sub>	1.2V	1.5V	1.8V	2.5V	3.3V
L	2.2μH	2.2μH	4.7μH	4.7μH	4.7μH

### C<sub>IN</sub> and C<sub>OUT</sub> Selection

In continuous mode, the source current of the top MOSFET is a square wave of duty cycle V<sub>OUT</sub>/V<sub>IN</sub>. To prevent large voltage transients, a low ESR input capacitor sized for the maximum RMS current must be used. The maximum RMS capacitor current is given by:

$$C_{IN \text{ required}} I_{RMS} \cong I_{OMAX} \frac{[V_{OUT}(V_{IN} - V_{OUT})]^{1/2}}{V_{IN}}$$

This formula has a maximum at V<sub>IN</sub> = 2V<sub>OUT</sub>, where I<sub>RMS</sub> = I<sub>OUT</sub>/2. This simple worst-case condition is commonly used for design because even significant deviations do not offer much relief. Note that the capacitor manufacturer's ripple current ratings are often based on 2000 hours of life. This makes it advisable to further derate the capacitor, or choose a capacitor rated at a higher temperature than required. Consult the manufacturer if there is any question.

The selection of C<sub>OUT</sub> is driven by the required effective series resistance (ESR).

Typically, once the ESR requirement for C<sub>OUT</sub> has been met, the RMS current rating generally far exceeds the I<sub>RIPPLE</sub> (P-P) requirement. The output ripple ΔV<sub>OUT</sub> is determined by:

$$\Delta V_{OUT} \approx \Delta I_L \left( ESR + \frac{1}{8fC_{OUT}} \right)$$

Where f = operating frequency, C<sub>OUT</sub> = output capacitance and ΔI<sub>L</sub> = ripple current in the inductor. For a fixed output voltage, the output ripple is highest at maximum input voltage since ΔI<sub>L</sub> increases with input voltage.

### Using Ceramic Input and Output Capacitors

Higher values, lower cost ceramic capacitors are now becoming available in smaller case sizes. Their high ripple current, high voltage rating and low ESR make them ideal for switching regulator applications. Using ceramic capacitors can achieve very low output ripple and small circuit size.

When choosing the input and output ceramic capacitors, choose the X5R or X7R dielectric formulations. These dielectrics have the best temperature and voltage characteristics of all the ceramics for a given value and size.

### Thermal Consideration

Thermal protection limits power dissipation in the PAM2312. When the junction temperature exceeds +150°C, the OTP (Over Temperature Protection) starts the thermal shutdown and turns the pass transistor off. The pass transistor resumes operation after the junction temperature drops below +120°C.

For continuous operation, the junction temperature should be maintained below +125°C. The power dissipation is defined as:

$$P_D = I_O^2 \frac{V_O R_{DS(ON)H} + (V_{IN} - V_O) R_{DS(ON)L}}{V_{IN}} + (t_{SW} F_S I_O + I_Q) V_{IN}$$

I<sub>Q</sub> is the step-down converter quiescent current. The term t<sub>sw</sub> is used to estimate the full load step-down converter switching losses.

## Application Information (cont.)

For the condition where the step-down converter is in dropout at 100% duty cycle, the total device dissipation reduces to:

$$P_D = I_O^2 R_{DS(ON)H} + I_Q V_{IN}$$

Since  $R_{DS(ON)}$ , quiescent current, and switching losses all vary with input voltage, the total losses should be investigated over the complete input voltage range. The maximum power dissipation depends on the thermal resistance of IC package, PCB layout, the rate of surrounding airflow and temperature difference between junction and ambient. The maximum power dissipation can be calculated by the following formula:

$$P_D = \frac{T_{J(MAX)} - T_A}{\theta_{JA}}$$

Where  $T_{J(MAX)}$  is the maximum allowable junction temperature +125°C.  $T_A$  is the ambient temperature and  $\theta_{JA}$  is the thermal resistance from the junction to the ambient. Based on the standard JEDEC for a two layers thermal test board, the thermal resistance  $\theta_{JA}$  of TSOT25 package is 250°C/W, DFN2X2 102°C/W, and QFN3X3 68°C/W, respectively. The maximum power dissipation at  $T_A = +25^\circ\text{C}$  can be calculated by following formula:

$$P_D = (125^\circ\text{C} - 25^\circ\text{C}) / 250^\circ\text{C/W} = 0.4\text{W}$$

### Setting the Output Voltage

The internal reference is 0.6V (Typical). The output voltage is calculated as below:

The output voltage is given by Table 1.

$$V_O = 0.6 \times \left( 1 + \frac{R_1}{R_2} \right)$$

**Table 1:** Resistor selection for output voltage setting.

$V_O$	R1	R2
1.2V	100k	100k
1.5V	150k	100k
1.8V	200k	100k
2.5V	380k	120k
3.3V	540k	120k

### 100% Duty Cycle Operation

As the input voltage approaches the output voltage, the converter turns the P-channel transistor continuously on. In this mode the output voltage is equal to the input voltage minus the voltage drop across the P-Channel transistor:

$$V_{OUT} = V_{IN} - I_{LOAD}(R_{DSON} + R_L)$$

where  $R_{DS(ON)}$  = P-Channel switch ON resistance,  $I_{LOAD}$  = Output Current,  $R_L$  = Inductor DC Resistance

### UVLO and Soft-Start

The reference and the circuit remain reset until the  $V_{IN}$  crosses its UVLO threshold. The PAM2312 has an internal soft-start circuit that limits the in-rush current during start-up. This prevents possible voltage drops of the input voltage and eliminates the output voltage overshoot. The soft-start acts as a digital circuit to increase the switch current in several steps to the P-channel current limit (1500mA).

### Short Circuit Protection

The switch peak current is limited cycle-by-cycle to a typical value of 1500mA. In the event of an output voltage short circuit, the device operates with a frequency of 500kHz and minimum duty cycle, therefore the average input current is typically 200mA.

### Thermal Shutdown

When the die temperature exceeds +150°C, a reset occurs and the reset remains until the temperature decrease to +120°C, at which time the circuit can be restarted.

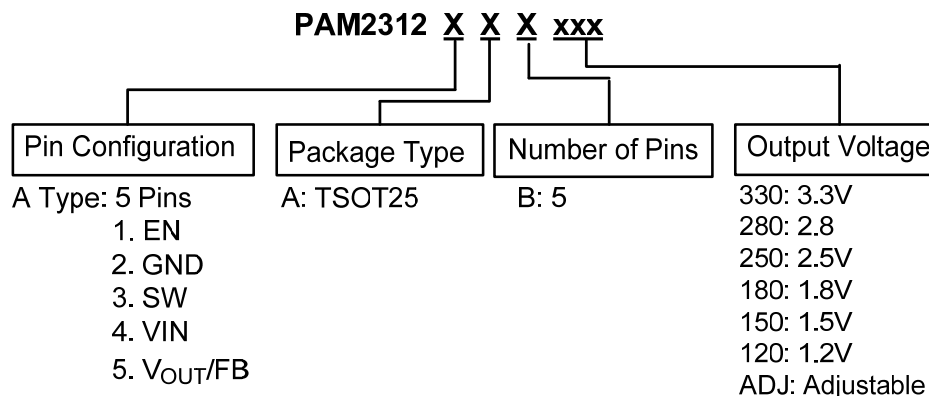
## Application Information (cont.)

### PCB Layout Check List

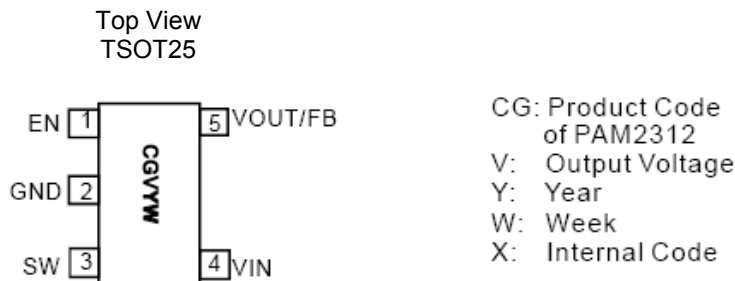
When laying out the printed circuit board, the following checklist should be used to ensure proper operation of the PAM2312. These items are also illustrated graphically in Figure 1. Check the following in your layout:

1. The power traces, consisting of the GND trace, the SW trace and the  $V_{IN}$  trace should be kept short, direct and wide.
2. Does the  $V_{FB}$  pin connect directly to the feedback resistors? The resistive divider R1/R2 must be connected between the (+) plate of  $C_{OUT}$  and ground.
3. Does the (+) plate of  $C_{IN}$  connect to  $V_{IN}$  as closely as possible? This capacitor provides the AC current to the internal power MOSFETs.
4. Keep the switching node, SW, away from the sensitive  $V_{FB}$  node.
5. Keep the (-) plates of  $C_{IN}$  and  $C_{OUT}$  as close as possible.

## Ordering Information

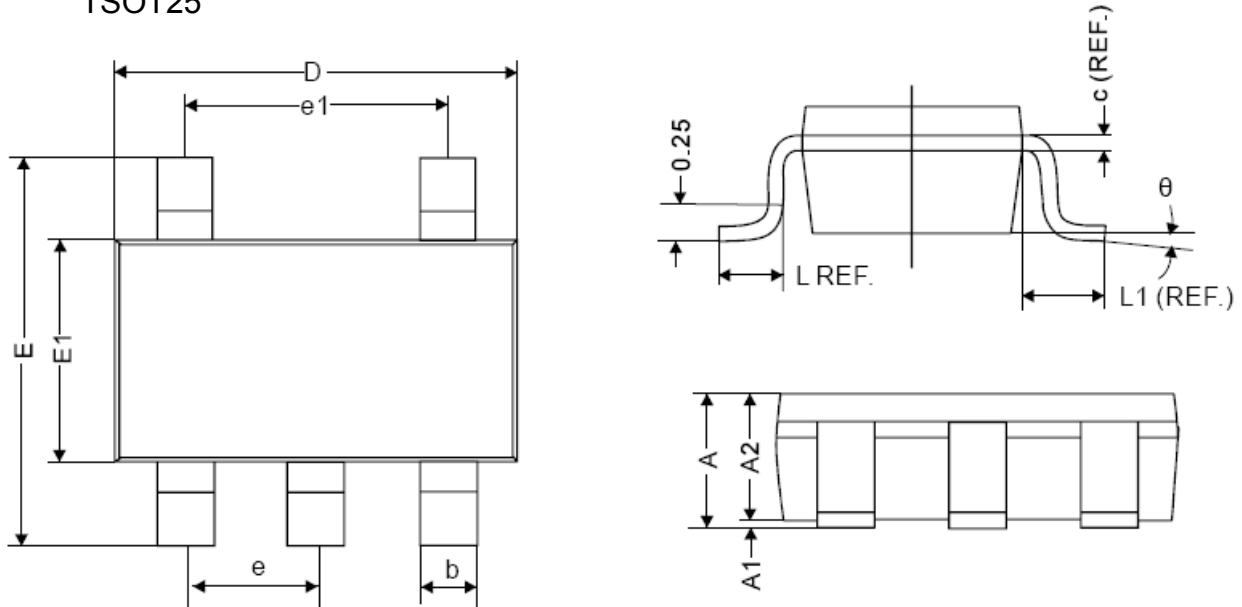


## Marking Information



**Package Outline Dimensions** (All dimensions in mm.)

TSOT25



REF.	Millimeter	
	Min	Max
A	1.10 MAX	
A1	0	0.10
A2	0.70	1
c	0.12 REF.	
D	2.70	3.10
E	2.60	3.00
E1	1.40	1.80
L	0.45 REF.	
L1	0.60 REF.	
theta	0°	10°
b	0.30	0.50
e	0.95 REF.	
e1	1.90 REF.	

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