Low Voltage 0.5x Regulated Step Down Charge Pump

Product Datasheet

VPA1000

Features

- Low cost alternative to buck regulator
- Saves up to ~500mW compared to standard LDO
- Small PCB footprint
- 1.2V, 1.5V, or 1.8V fixed output voltages
- 300mA maximum output current
- 3.3V to 1.2V with 72% efficiency
- High frequency (2.4MHz) reduces size of external components
- Short-circuit current protection
- Over-temperature protection
- Soft start
- TSOT-6 package

Applications

- Notebook computers
- Handsets
- Battery powered equipment

Description

The VPA1000 is a low voltage 0.5x regulated step-down charge pump. It is designed as a low cost replacement for inductor-based step-down switching regulators (buck), or a high efficiency replacement for linear regulators (LDO). At full load, it can save nearly 500mW of power compared to a standard LDO, making it ideal for low cost battery powered applications. The VPA1000 can also be put in a micro-power shutdown mode with 1µA nominal input current to extend battery life when not in use.

The VPA1000 is available in a TSOT-6 package and characterized over the industrial temperature range of -40°C to +85°C.

Typical Application Circuit

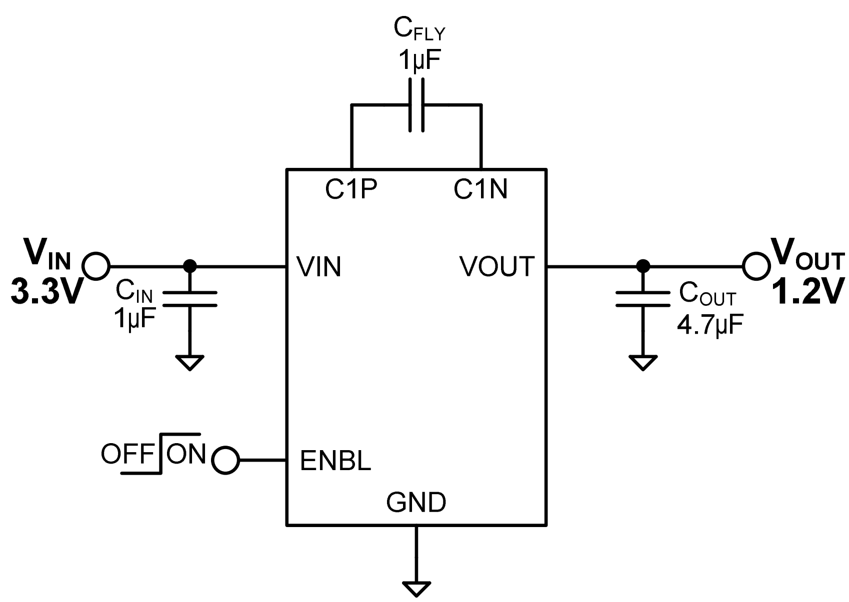

Figure 1. VPA1000DYGI-12 Typical Application Circuit

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Revision History

January 2010 – Rev 1.0: Initial Version

ABSOLUTE MAXIMUM RATINGS

Table 1. Absolute Maximum Ratings Summary

PIN	**MAXIMUM RATING** [NOTE 1]
VIN, VOUT, ENBL, C1N, C1P to GND	-0.3V to +6V
Operating Ambient Temperature Range	-40°C to +85°C
Storage Temperature	-55°C to +150°C
Junction Temperature	-40°C to +125°C
Lead Temperature (10 seconds)	+260°C
Maximum Power Dissipation	Internally limited [Note 2]

[Note 1] Stresses greater than those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect reliability.

[Note 2] The maximum power dissipation is $P_{D(MAX)} = (T_{J(MAX)} - T_A) / \theta_{JA}$ where $T_{J(MAX)}$ is 125°C. Exceeding the maximum allowable power dissipation will result in excessive die temperature, and the device will enter thermal shutdown.

Table 2. Package Thermal Resistivity

PACKAGE	**THERMAL RESISTIVITY (Θ_{JA})** [NOTE 3]
TSOT-6	118 °C/W

[Note 3] This thermal rating was calculated based on JEDEC standard conditions (EIA-JESD 51-2 for natural convection & JESD 51 6 for forced convection). The board type is 2S2P recommended by JEDEC (4-layers: 2 oz copper surface traces/ 1 oz copper buried planes, 4" x 4.5" board size). Actual thermal resistivity will be affected by PCB size, solder joint quality, PCB layer count, copper thickness, air flow, altitude, and other unlisted variables.

SPECIFICATION TABLE

V_{IN} = 2.7V to 5V; ENBL = HIGH; C_{IN} = 2.2µF, C_{FLY} = 1µF, C_{OUT} = 4.7µF. Unless otherwise specified, all specifications are tested under T_A = 25°C. The ◙ denotes specifications that apply for T_A = -40°C to +85°C. [Note 4]

Table 3. Input Specification

SYMBOL	PARAMETER	CONDITIONS	◙	MIN	TYP	MAX	UNITS
V_{IN}	Operating input voltage range		◙	2.7		5	V
I_{OUT}	Maximum output current	3V < V_{IN} < 5V		300			mA
		2.7V < V_{IN} ≤ 3V		150			mA
UVLO	Under voltage lockout	V_{IN} rising			2.1	2.4	V
	Under voltage lockout hysteresis				0.1		V
I_Q	V_{IN} quiescent current	V_{IN} = 3.3V			1.65		mA
I_{SD}	V_{IN} shutdown current	V_{IN} = 3.3V, V_{OUT} = 0V, ENBL = 0V			1	2	µA
	Output voltage accuracy under all conditions		◙	-3		3	%
	Output voltage load regulation	I_{OUT} = 30mA to 300mA			0.5		%
	Output voltage line regulation	Over full input range, I_{OUT} = 30mA				0.4	%
	Output voltage temperature regulation	Over full input range, I_{OUT} = 30mA			0.004		%/°C
f_{OSC}	Charge pump switching frequency	I_{OUT} = 30mA	◙	2.0	2.4	2.8	MHz
I_{SC}	Short circuit current (folded back current)	V_{OUT} = 0V, V_{IN} = 3.3V			120		mA
V_{DO}	Charge pump dropout voltage	I_{OUT} = 300mA, [Note 5]	◙		200	300	mV
R_{eq}	Equivalent series resistance	V_{IN} = 3V, I_{OUT} = 300mA, [Note 6]			0.6	1	Ω
T_{SD}	Over-temperature protection trip point	[Note 6]			133		°C
	Over-temperature protection hysteresis	[Note 6]			15		°C
t_{SS}	Soft start time				75		µs
V_{ENBL_l}	ENBL pin low level		◙			0.4	V
V_{ENBL_h}	ENBL pin high level		◙	1.6			V

[Note 4] Specifications over the -40°C to +85°C operation ambient temperature are guaranteed by design, characterization and statistical correlation.

[Note 5] Minimum input voltage is measured when output voltage is reduced by 2% as compared to the nominal condition under full load. Dropout is calculated as $V_{IN(MIN)}/2 - V_{OUT}$.

[Note 6] Guaranteed by design, not 100% production tested.

TYPICAL PERFORMANCE CHARACTERISTICS

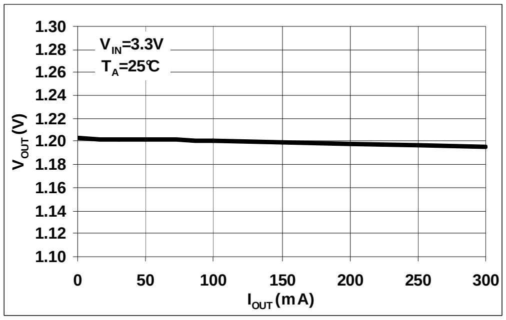


Figure 2. Output Voltage vs. Output Current

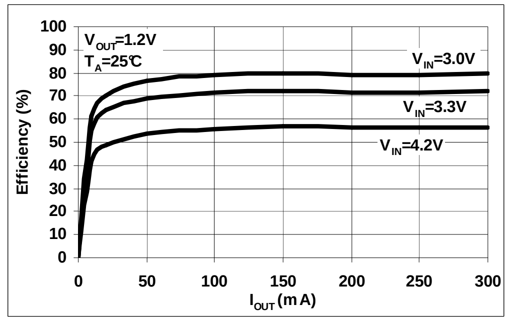


Figure 3. Efficiency vs. Output Current

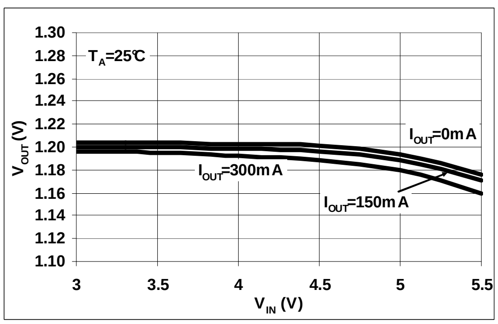


Figure 4. Output Voltage vs. Input Voltage

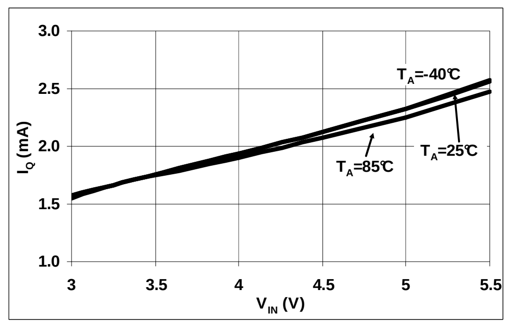


Figure 5. Quiescent Current vs. Input Voltage

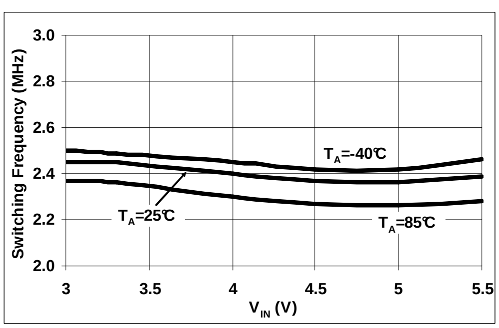


Figure 6. Charge Pump Switching Frequency vs. Input Voltage

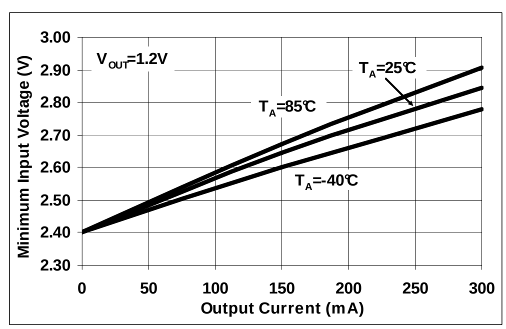


Figure 7. Minimum Input Voltage vs. Output Current

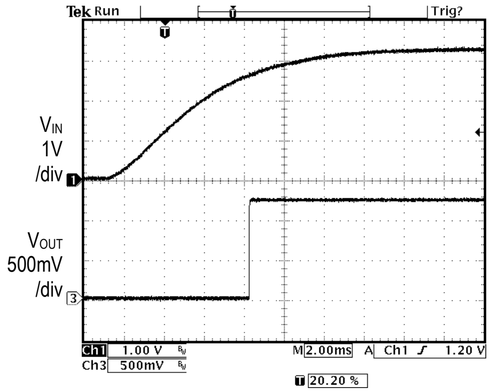


Figure 8. Power Up with No Load and V_{IN} = 3.3V

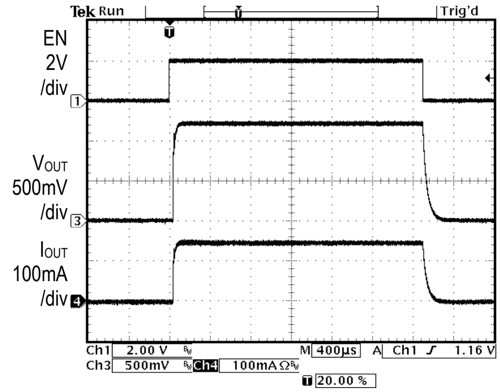


Figure 9. Enable/Disable with I_{OUT} = 150mA and V_{IN} = 3.3V

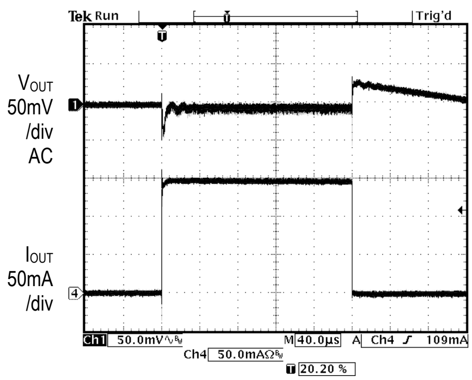


Figure 10. Load Transient Response for I_{OUT} = 0mA to 150mA

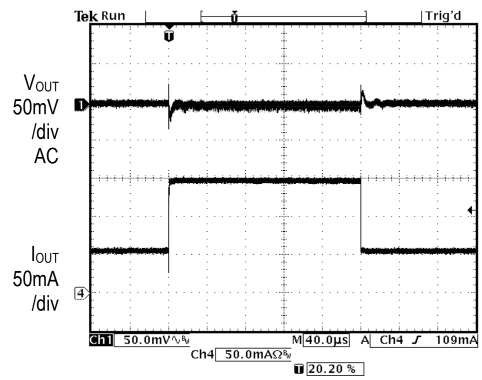


Figure 11. Load Transient Response for I_{OUT} = 50mA to 150mA and V_{IN} = 3.3V

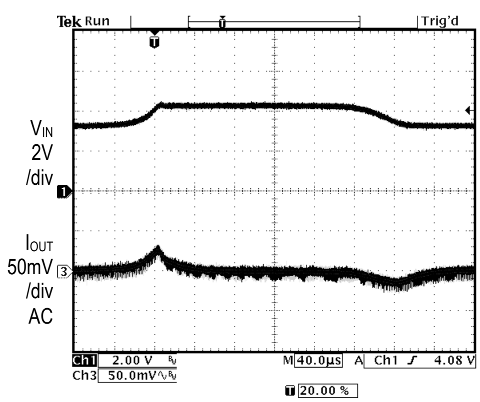


Figure 12. Line Transient Response from V_{IN} = 3.3V to 4.3V for I_{OUT} = 200mA

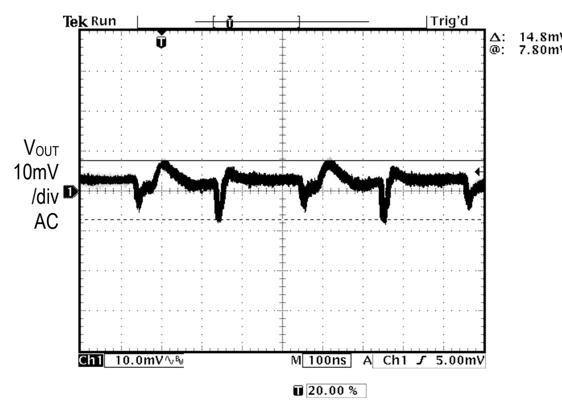


Figure 13. Output Voltage Ripple for I_{OUT} = 150mA and V_{IN} = 3.3V

PIN CONFIGURATION & DESCRIPTION

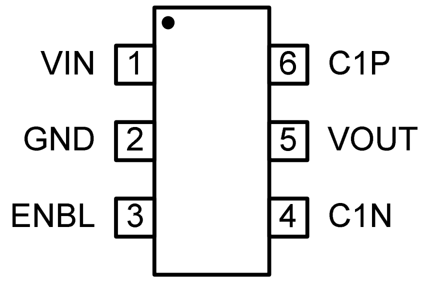


Figure 14. VPA1000 Pin Assignment (Top View)

Table 4. Pin Descriptions

NUMBER	LABEL	I/O	DESCRIPTION
1	VIN	Input	Power supply input voltage. Place a decoupling 1µF capacitor next to this pin.
2	GND		Ground connection for the IC.
3	ENBL	Input	Enable input. Apply logic high for normal operation. When logic low is applied, the charge pump enters a micro-power shutdown mode.
4	C1N		Negative terminal of the flying capacitor.
5	VOUT	Output	Output voltage of the regulated charge pump. Connect a 4.7µF ceramic capacitor from this pin to ground.
6	C1P		Positive terminal of the flying capacitor.

FUNCTIONAL DIAGRAM

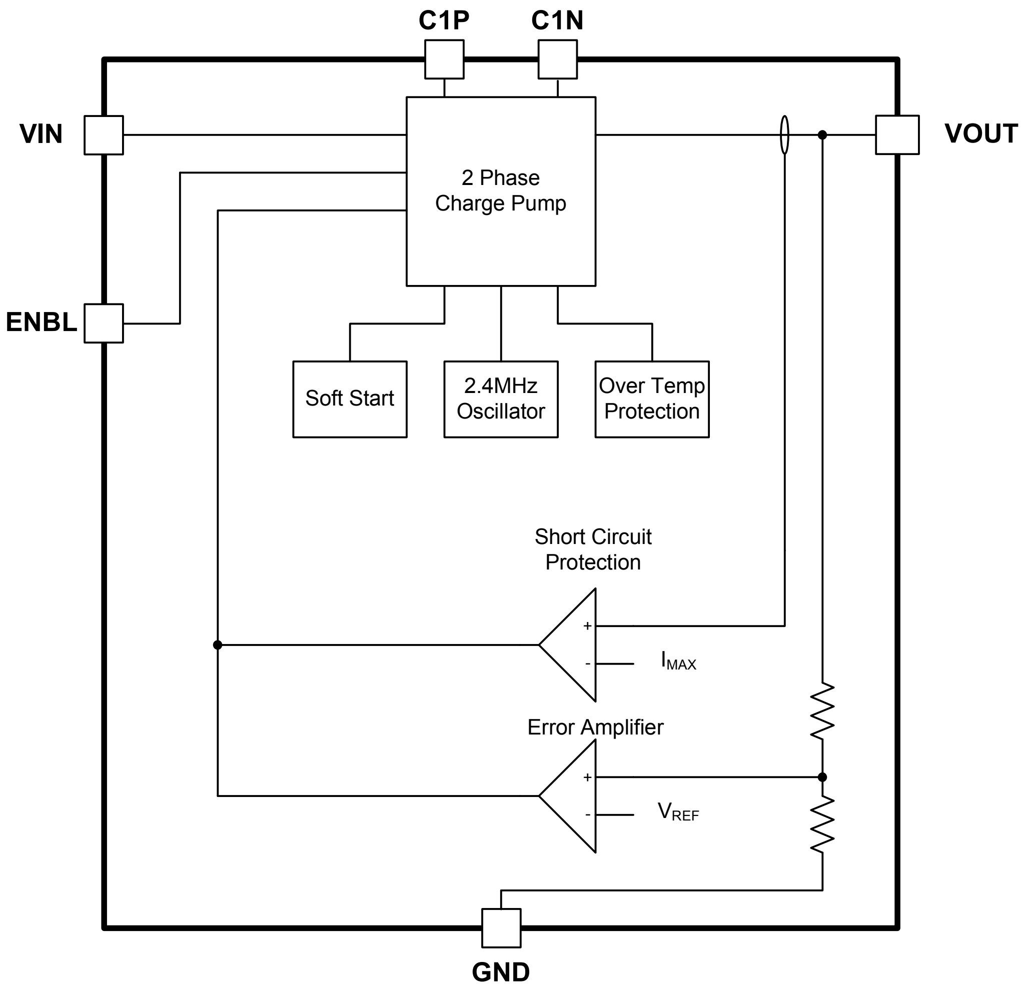


Figure 15. VPA1000 Functional Diagram

THEORY OF OPERATION

Description

The VPA1000 is a 0.5x regulated charge pump operating at constant frequency with 50% duty cycle. During the first phase, flying capacitor C_{FLY} is placed in series with output capacitor C_{OUT}. The input current charges both the flying capacitor and output capacitor, and supplies the output load. During the second phase, the output capacitor and the flying capacitor are placed in parallel, and both capacitors are discharged to supply the output load. Since V_{IN} conducts to V_{OUT} with 50% duty cycle, the average input current is equal to 50% of the output current. Thus, the efficiency is approximately double than that of a standard LDO.

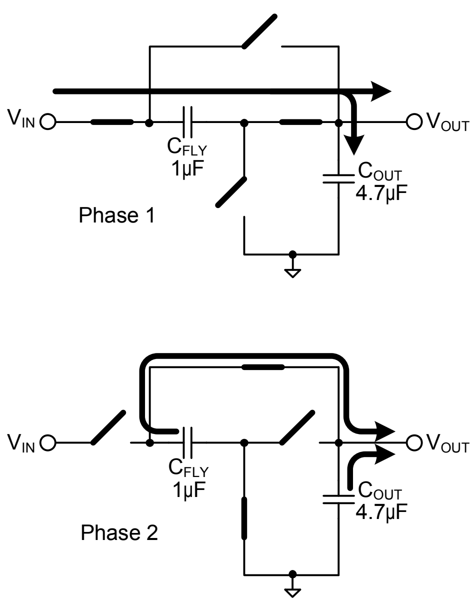


Figure 16. 0.5x Charge Pump Two Phase Operation

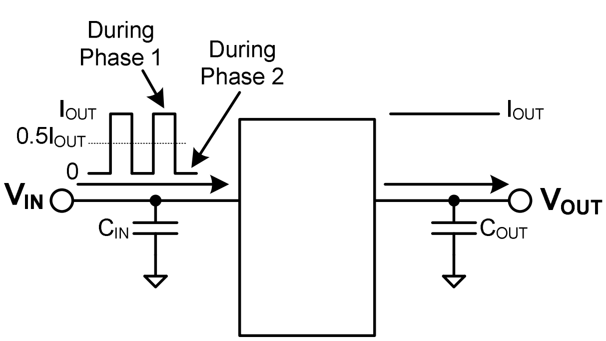


Figure 17. Input Current Flowing Diagram

To regulate the output voltage, the error amplifier controls the input P-channel MOSFET gate driver voltage, which controls the amount of current flowing into the flying capacitor during the charging phase. Thus, the flying capacitor's differential voltage is charged up to be equal to the output voltage.

Minimum Input Voltage

For different output voltage options and output current loads, the minimum input voltage requirement is different in order to keep the output voltage regulation within 2% of its nominal level. For the 1.2V output, the minimum input voltage for a 300mA load is 2.85V. For a 150mA load, the minimum input voltage is 2.65V (refer to Figure 7). The VPA1000 guarantees the maximum dropout voltage for a 300mA load at 300mV over full temperature range. Thus, the minimum input voltage is calculated as:

$$V_{IN(MIN)} = 2 \times (300\text{mV} + V_{OUT} \times 0.98) \quad [1]$$

Soft Start

The VPA1000 has a built-in soft start circuitry to limit inrush current during start up. The soft start time is fixed with a nominal value of 75µs.

Short-circuit and Over-temperature Protection

The short-circuit protection ensures the maximum output current is limited to 120mA during short-circuit conditions. When the junction temperature of the VPA1000 reaches thermal shutdown threshold, the over-temperature protection will activate and shut down the charge pump and the gate driver. The device will resume to its previous operating condition when the junction temperature drops by 15°C.

Power Efficiency

Since the input current is about half of the output current, the VPA1000 efficiency is much better than a conventional LDO. The efficiency can be calculated with the following equation:

$$\text{Efficiency } (\%) = 2 \times \frac{V_{OUT}}{V_{IN}} \times 100\% \quad [2]$$

For example, with V_{IN} = 3.3V, V_{OUT} = 1.2V, and I_{OUT} = 150mA, the VPA1000 efficiency is 72.7% while a conventional LDO efficiency is 36.4% under the same conditions.

APPLICATION

The VPA1000 is designed as a low cost replacement for a switching buck regulator, or a high efficiency replacement for a standard linear regulator (LDO). With a simple application circuit and small PCB footprint, the VPA1000 is an ideal component for low power, low cost systems.

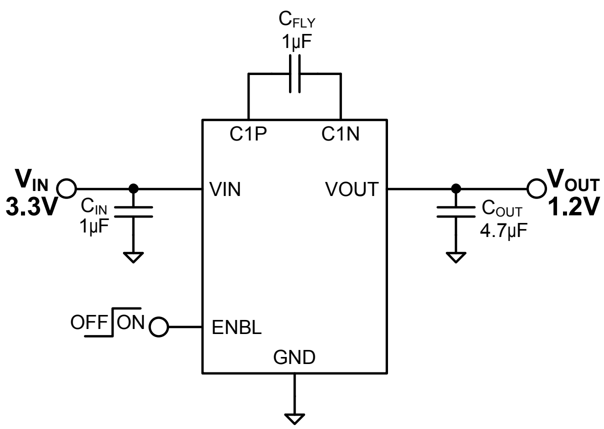


Figure 18. VPA1000DYGI-12 Typical Application Circuit

Enable/Shutdown

The VPA1000 is enabled and shut down by applying a logic high or logic low to the ENBL pin. When the device is in shut down mode, the supply current will drop to 1µA. If this feature is not used, the ENBL pin should be tied to V_{IN} to permanently enable the device.

Capacitor Selection

The VPA1000 requires one input capacitor, one flying capacitor, and one output capacitor. Low ESR ceramic capacitors should be chosen, and X5R and X7R are recommended for their better performance over the -40°C to 85°C and -40°C to 125°C temperature ranges, respectively. A minimum 1µF input capacitor should be used to bypass the input voltage. The flying capacitor value should be between 0.1µF and 1µF.

Smaller flying capacitor will reduce the output overshoot during startup while larger flying capacitor will reduce the output ripple. To ensure stability over its operating current range, at least a 4.7µF output capacitor is required. Higher output capacitance will help to reduce the output ripple and will have better transient response performance.

Thermal Considerations

To prevent the device from exceeding its maximum power handling capability, it is important to keep the device junction temperature below 125°C. Use the following equations to calculate the maximum allowable power dissipation.

$$P_{D(MAX)} = \frac{(T_{J(MAX)} - T_A)}{\theta_{JA}} \quad [3]$$

where T_A is the ambient temperature, and θ_{JA} is the package thermal resistance from junction to ambient, which is 118°C/W for TSOT-6 with JESD51 standards.

Thus, the power dissipation for the charge pump can be calculated as:

$$P_D = I_{OUT}(0.5V_{IN} - V_{OUT}) \quad [4]$$

For example, with V_{IN} = 3.3V, V_{OUT} = 1.2V, I_{OUT} = 150mA, and T_A = 25°C and using the above equations, the maximum allowable power dissipation is:

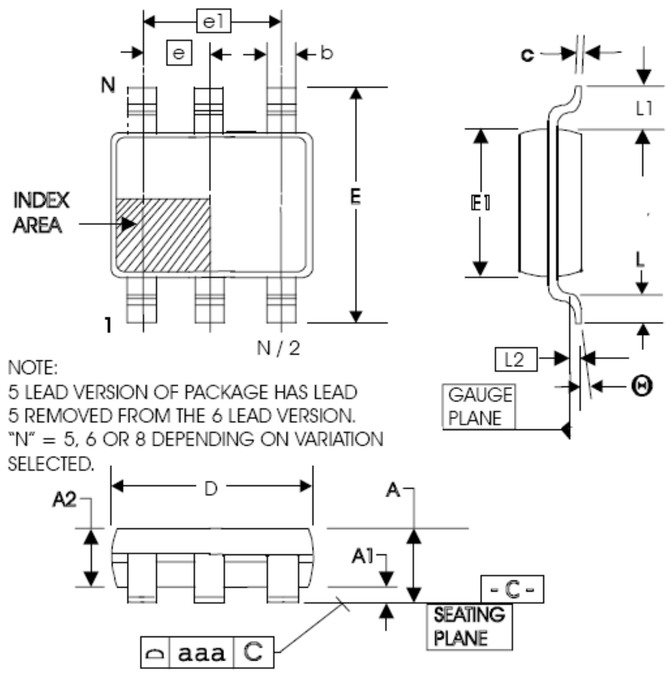
$$P_{D(MAX)} = \frac{(125°C - 25°C)}{118°C/W} = 0.85W \quad [5]$$

and the power dissipated by the charge pump is 0.0675W with the above conditions. If power dissipation exceeds the maximum allowable power dissipation, a larger copper area or extra heat sink may be required.

Layout Considerations

To optimize the device performance, keep all capacitors close to the device pins, and connect all ground connections to a ground plane.

PACKAGE OUTLINE DRAWING



TSOT PACKAGE 5, 6 or 8 Lead

SYMBOL	DIMENSIONS IN MILLIMETERS			
	N = 5 or 6		N = 8	
	MIN	MAX	MIN	MAX
A	--	1.00	--	1.00
A1	0.01	0.10	0.01	0.10
A2	0.84	0.90	0.84	0.90
b	0.30	0.45	0.22	0.36
c	0.12	0.20	0.12	0.20
D	2.90 BASIC		2.90 BASIC	
E	2.80 BASIC		2.80 BASIC	
E1	1.60 BASIC		1.60 BASIC	
e	0.95 BASIC		0.65 BASIC	
e1	1.90 BASIC		1.95 BASIC	
L	0.30	0.50	0.30	0.50
L1	0.60 REF.		0.60 REF.	
L2	0.25 BASIC		0.25 BASIC	
θ	0º	8º	0º	8º
aaa	--	0.10	--	0.10

Figure 19. Package Outline Drawing

ORDERING GUIDE

Table 5. Ordering Summary

PART NUMBER	MARKING	VOLTAGE OPTION	PACKAGE	AMBIENT TEMP. RANGE	SHIPPING CARRIER	QUANTITY
VPA1000DYGI-12	00A0I	1.2V	TSOT-6	-40°C to +85°C	Tape or Canister	25
VPA1000DYGI-128	00A0I	1.2V	TSOT-6	-40°C to +85°C	Tape and Reel	2,500

→ **OTHER VOLTAGE OPTIONS ARE AVAILABLE UPON REQUEST.**

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