High Efficiency Synchronous Rectifier Boost Converter with PWM Output Current Control

General Description

The uP6013 is an electronic cigarette solution for products powered by a single-cell Li-Ion or Li-Polymer battery. The uP6013 is a high efficiency synchronous step-up converter which integrates power MOSFETs, includes the output true shutdown function and adjustable output current limit with thermal fold back. The uP6013 uses a fixed-frequency PWM current mode control at 500kHz for fast transient response with internal compensation. Protect function includes cycle-by-cycle current limit, short-circuit protection, thermal fold back and over temperature protection. The uP6013 is suitable for applications in electronic cigarettes, tablet computers, smart phones, and portable devices.

The uP6013 is available in a VQFN4x4 - 24L package.

Ordering Information

Order Number	Package Type	Remark
uP6013PQAG	VQFN4x4 - 24L	

Note:
(1) Please check the sample/production availability with uPI representatives.
(2) uPI products are compatible with the current IPC/JEDEC J-STD-020 requirement. They are halogen-free, RoHS compliant and 100% matte tin (Sn) plating that are suitable for use in SnPb or Pb-free soldering processes.

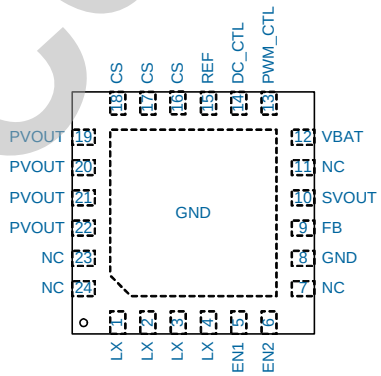
Features

- Hight Efficiency Synchronous Boost Converter with 9A Typical Switch Current Limit
- Quiescent Current <400uA
- Shutdown Current <1uA
- 500kHz PWM Switching Frequency
- Integrated Power MOSFET
- Internal Soft-Start to Limit Inrush Current
- Adjustable Output Voltage
- Output Current Control through DC or PWM Input
- Protection:
  - Output Turn Off True Shutdown Function
  - Overload/Short-Circuit Protection
  - Input Under Voltage Lockout Protection
  - Current Limit Protection for Current Source
- VQFN4x4 - 24L Package
- RoHS Compliant and Halogen Free

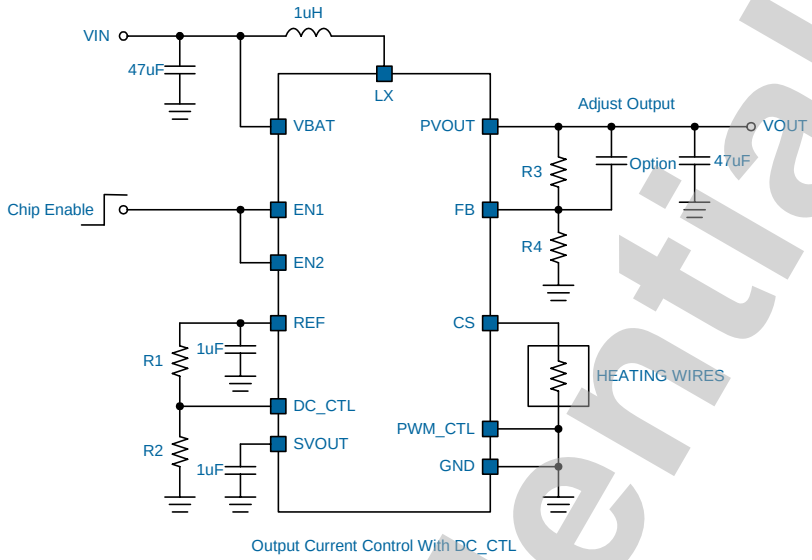
Applications

- Electronic Cigarette
- Battery-Powered Products
- Portable Devices

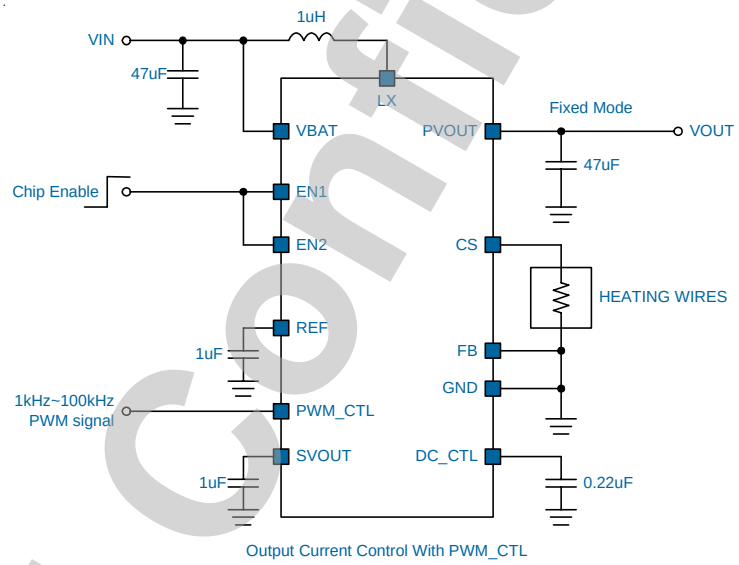
Pin Configuration



Typical Application Circuit

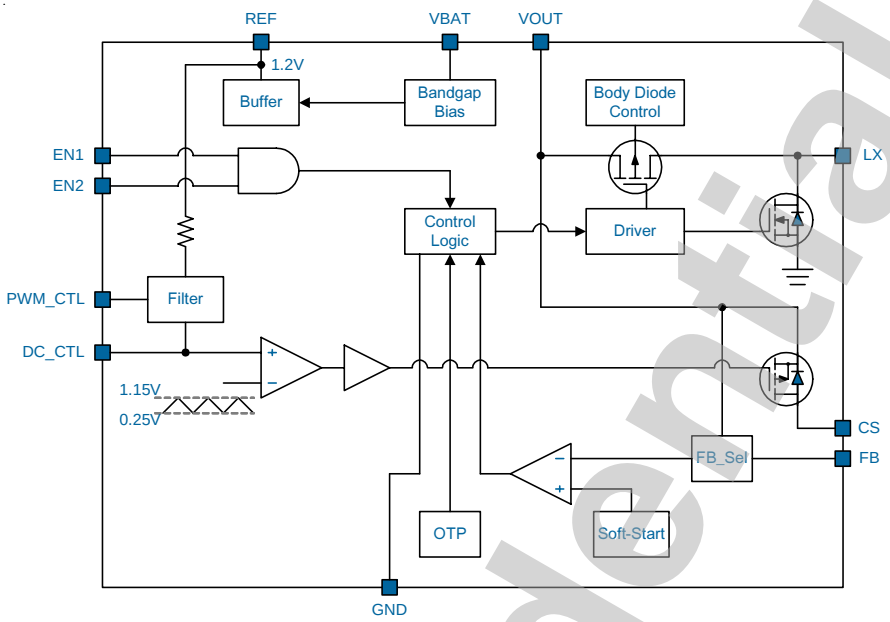


Adjustable Output Voltage by R3 and R4



5V Output Voltage by Fixed Mode

Functional Block Diagram



Functional Pin Description

Pin No.	Pin Name	Pin Function
1, 2, 3, 4	LX	**Switch Nodes.** Connect these pins to the inductor.
5	EN1	**Chip Enable Control 1.** Chip Enable Control pin 1. Pull the pin and EN2 pin high to turn on chip.
6	EN2	**Chip Enable Control 2.** Chip Enable Control pin 2. Pull the pin and EN1 pin high to turn on chip.
7, 11, 23, 24	NC	**Not Internally Connected.**
8	GND	**Ground.** Ties this pin directly to the cathode terminal of CIN and COUT and ground plane with the lowest impedance. All small-signal, compensation and feedback components should connect to this pin.
9	FB	**Feedback Voltage.** This pin is the inverting input of the error amplifier.
10	SVOUT	**Signal Output Pins.** Decouple this pin to ground with a 1uF capacitor for noise immunity consideration.
12	VBAT	**Supply Input.** Input voltage that supplies current to the output voltage and powers the internal control circuit.
13	PWM_CTL	**PWM Input For Output Current Control.** This pin can be used to adjust the output current by 1kHz~100kHz PWM input. Connect the pin to ground if not used.
14	DC_CTL	**DC Input For Output Current Control.** This pin can be used to adjust the output current by connecting resistors to the pin between the REF and ground. Connect a 0.1uF capacitor to ground if not used.
15	REF	**Reference Output (1.2V).** Connect a 1uF capacitor with this pin to ground.
16, 17, 18	CS	**Current Source Output.** Voltage output pin of current source.
19, 20, 21, 22	PVOUT	**Power Output Pins.**
Exposed Pad		**Power Ground.** The exposed pad should be well soldered to ground plane with multiple vias for effective thermal conduction.

Functional Description

The uP6013 integrates an N-channel and P-channel MOSFETs to realize a synchronous rectifier with a current source of P-MOSFETs for output current regulation. The power conversion efficiency is up to 90%. Since a typical step-up converter has a conduction path from the input to the output via the body diode of the P-channel MOSFET, a specific circuit is used to reverse the polarity of the P-channel body diode when the part is shutdown. It certainly protects battery from being completely depleted during shutdown.

Input Supply Voltage, V_{IN}

V_{IN} supplies current to internal control circuits and output voltages. The supply voltage range is from 2.7V to 5V. A power-on reset (POR) continuously monitors the input supply voltage. The POR level is typically 2.5V at V_{IN} rising. A minimum 47uF ceramic capacitor with shortest PCB traces is highly recommended for bypassing the supply input.

Current Limit Function

When the inductor current is higher than current limit threshold, the current limit function activates and forces the N-channel MOSFET to turn off the limit inductor current cycle-by-cycle. If output voltage drops under 73% (Typ) of setting, the short circuit protection (SCP) will be activated and latch off the output of boost converter. To restart the output after latch-off, please input enable signal again.

Output Voltage Setting and Feedback Network

The output voltage can be set from VFB to VOUT by a voltage divider as:

$$V_{OUT} = V_{FB} \times \left(1 + \frac{R3}{R4}\right)$$

The internal VREF is 1.227V with 1.5% accuracy. In real applications, a 22pF feedforward ceramic capacitor is recommended in parallel with R3 for better transient responses.

Output Current Control

The uP6013 is built-in with a current source of P-MOSFETs for output current control. The P-MOSFETs can be turned on or turned off to regulate output current through a PWM input (PWM_CTL) or DC input (DC_CTL). It supports external PWM input frequency from 1kHz to 100kHz, the relationship between PWM_CTL with CS Duty can be shown as Figure 1.

When using DC input control, the output current duty corresponds to DC_CTL is 0.25~1.15V and the DC control input voltage can be achieved by setting the ratio of R1 and R2 resistors.

$$V_{DC\_CTL} = 1.2 \times \left(\frac{R2}{R1+R2}\right)$$

Then the DC control input voltage corresponds to output current duty can be shown as:

$$\frac{V_{DC\_CTL-MAX} - V_{DC\_CTL-MIN}}{0.9} = \textit{Output Current Duty}$$

Where

Input range of V_{DC_CTL} = 0.25V ~ 1.15 V

Keep V_{DC_CTL} between 0.25V and 1.15V, if V_{DC_CTL} falls under 0.25V, the current source output will keep in minimum on duty.

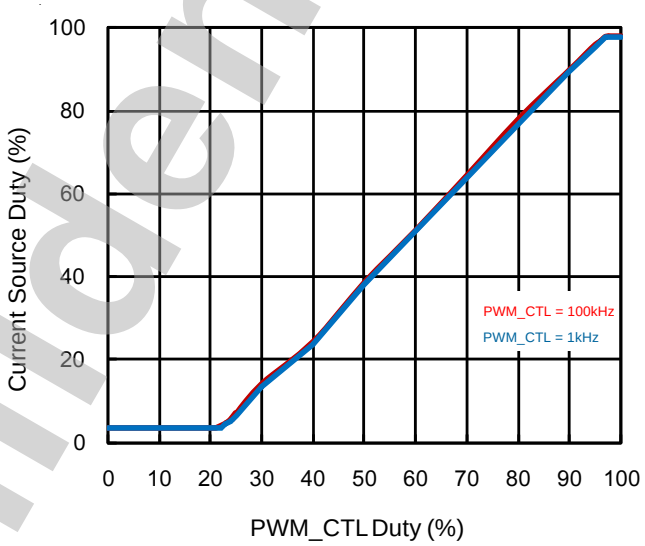


Figure 1. PWM_Duty vs. CS Duty

Fixed Mode

The uP6013 is implemented with a fixed 5V output voltage function without the need of an external feedback voltage divider. If the FB pin is shorted to GND during device start-up, the uP6013 will automatically activate its internal feedback network and regulate its output at 5V.

Over Temperature Protection (OTP)

The OTP is triggered and shuts down the uP6013 if the junction temperature reaches higher than 160°C. The OTP is a non-latch type of protection. The uP6013 automatically initiates another soft start cycle if the junction temperature drops below 140°C.

Thermal Fold Back

The thermal fold back function can monitor IC temperature to keep heating wires continuously working. When the junction temperature exceeds 120°C, the uP6013 will switch into thermal fold back mode and current source duty cycle will be set to 50% of normal operation to decrease output current. The uP6013 will return to normal operation once the junction temperature drops down to 80°C.

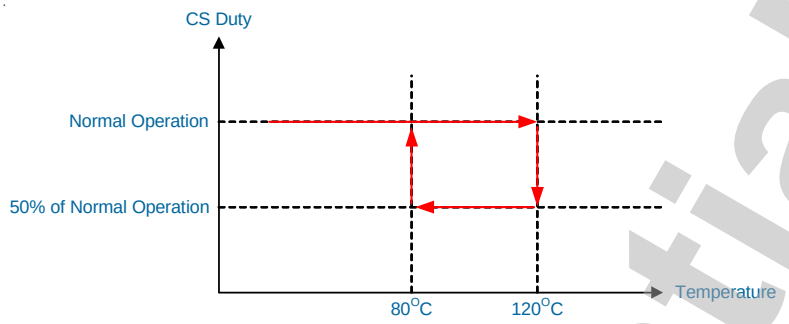


Figure 2. Thermal Fold Back Curve

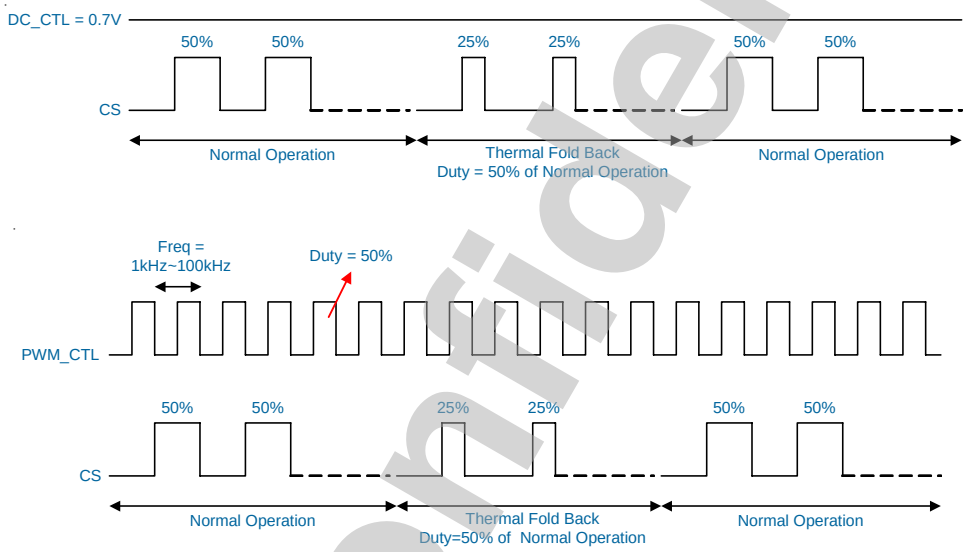


Figure 3. Thermal Fold Back Control Timing

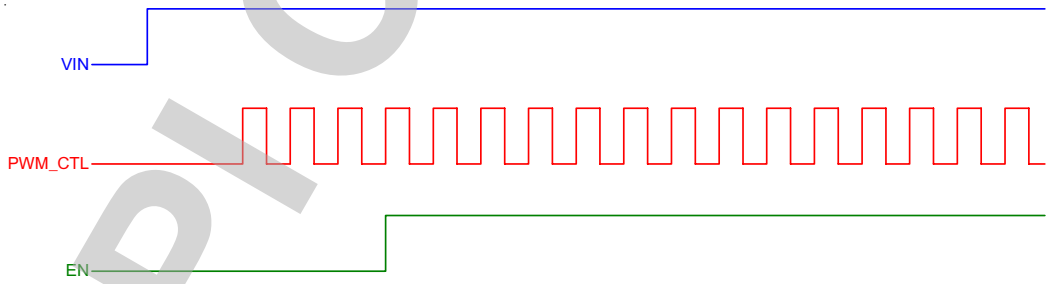


Figure 4. EN Sequence

Absolute Maximum Rating

(Note 1)

VBAT, PVOUT, SVOUT, LX, FB, CS, EN1, EN2, REF, PWM_CTL, DC_CTL to GND ---------- -0.3V to +7V
Storage Temperature Range ---------- -65°C to +150°C
Junction Temperature ---------- 150°C
Lead Temperature (Soldering, 10 sec) ---------- 260°C
ESD Rating (Note 2)
HBM (Human Body Mode) ---------- 2kV
MM (Machine Mode) ---------- 200V

Thermal Information

Package Thermal Resistance (Note 3)
VQFN4x4 - 24L θ_{JA} ---------- 40°C/W
VQFN4x4 - 24L θ_{JC} ---------- 4°C/W
Power Dissipation, P_D @ T_A = 25°C
VQFN4x4 - 24L ---------- 2.50W

Recommended Operation Conditions

(Note 4)

Operating Junction Temperature Range ---------- -40°C to +125°C
Operating Ambient Temperature Range ---------- -40°C to +85°C
Supply Input Voltage, V_{IN} ---------- +2.7V to +5V

Note 1. Stresses listed as the above *Absolute Maximum Ratings* may cause permanent damage to the device. These are for stress ratings. Functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may remain possibility to affect device reliability.

Note 2. Devices are ESD sensitive. Handling precaution recommended.

Note 3. θ_{JA} is measured in the natural convection at T_A = 25°C on a low effective thermal conductivity test board of JEDEC 51-3 thermal measurement standard.

Note 4. The device is not guaranteed to function outside its operating conditions.

Electrical Characteristics

(V_{IN} = 3.6V, V_{OUT} = 5V, L = 1uH, C_{IN} = 47uF, C_{OUT} = 47uF, T_A=25°C, unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Supplies						
Supply Voltage Range	V_{IN}		2.7	--	5	V
Quiescent Current	I_{IN}	DC_CTL = PWM_CTL = GND VFB > 1.5V, No Switching	--	300	400	uA
Shutdown Current	I_{SHT}	EN1 = EN2 = GND	--	0.1	1	uA
Under Voltage Lockout	V_{UVLO}	VIN Falling Edge	--	2.3	2.4	V
		VIN Rising Edge	--	2.5	2.6	
REF Output Voltage	V_{REF}		1.164	1.2	1.236	V
REF Output Current Capability	I_{REF}		--	--	0.2	mA
Oscillator & Driver						
Switching Frequency	F_{OSC}		350	500	650	kHz
Maximum Duty Cycle	D_{MAX}		86	91	96	%
LX Leakage Current	I_{LX_LK}		--	1	5	uA
Soft Start Time	T_{SS}		--	2	--	ms
Switch On Resistance	R_{DS-P}		--	30	39	mΩ
	R_{DS-N}		--	20	26	mΩ
Current Source						
CS Switching Frequency	F_{CS}		20	25	30	kHz
CS Leakage Current	I_{CS_LK}		--	--	1	uA
CS MOS Resistance(P-MOS)	R_{DS-OC}		--	50	65	mΩ
CS MOS Current Limit	I_{CS_CL}		4.25	5	5.75	A
CS Minimum On Duty	D_{MIN-ON}	F_{CS} = 20kHz~30kHz	--	5	--	%
CS Duty Control Accuracy	D_{CS_ACC}	CS Duty = 5%~100% at PWM_CTL or DC_CTL Input	--	--	+/-5	%
Reference						
FB Reference Voltage	V_{FB}		1.208	1.227	1.246	V
FB Sink Current	I_{FB}		--	--	0.1	uA
Output Voltage	V_{OUT}	I_{OUT} > 100mA at CCM	4.925	5	5.075	V
		I_{OUT} > 100mA at CCM (Fixed Mode)	--	5	--	

Electrical Characteristics

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Logic Input						
EN1 Logic Low	V_{EN1_L}	Disable	--	--	0.5	V
EN1 Logic High	V_{EN1_H}	Enable	1.5	--	--	V
EN2 Logic Low	V_{EN2_L}	Disable	--	--	0.5	V
EN2 Logic High	V_{EN2_H}	Enable	1.5	--	--	V
PWM_CTL Logic Low	V_{PWM_L}		--	--	0.5	V
PWM_CTL Logic High	V_{PWM_H}		1.5	--	--	V
PWM_CTL Input Frequency	F_{PWM}		1	--	100	kHz
DC_CTL Input Voltage	V_{DC_IN}		0.25	--	1.15	V
Protection						
Thermal Shutdown Temperature	T_{SHDN}		--	160	--	°C
Thermal Shutdown Hysteresis	ΔT_{SHDN}		--	20	--	°C
Thermal Fold Back Temperature	T_{T_FOLD}		--	120	--	°C
Thermal Fold Back Hysteresis	ΔT_{T_FOLD}		--	40	--	°C
Current Limit	I_{LX_CL}		--	9	--	A
VOUT Short-Circuit Threshold	V_{SCP}	Falling	--	V_{OUT}* 73%	--	V

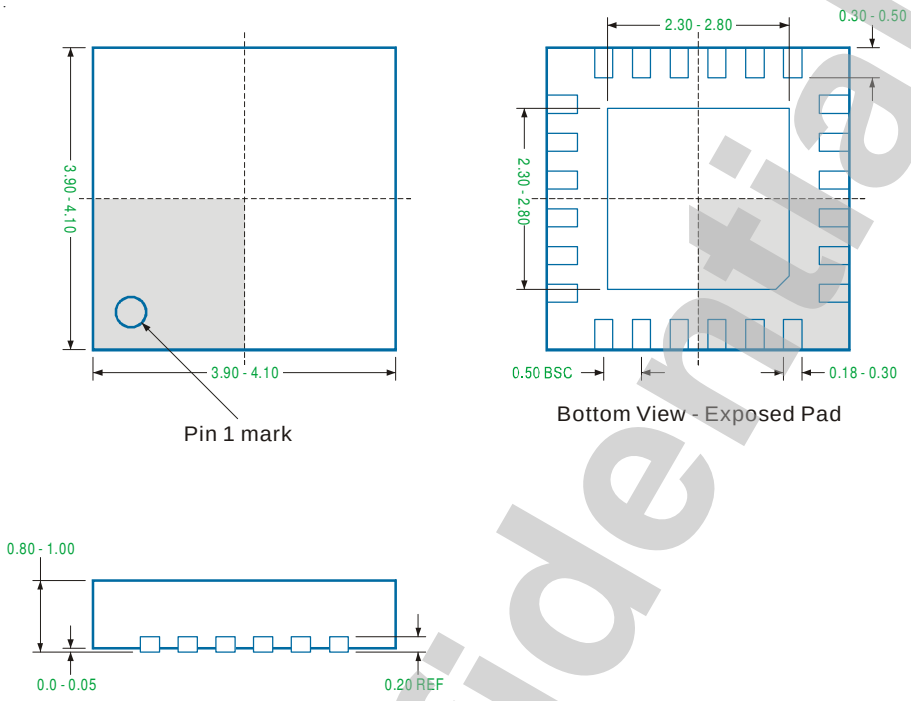
Typical Operation Characteristics

This page is intentionally left blank and will be updated when silicon data is available.

This page is intentionally left blank and will be updated when silicon data is available.

Package Information

VQFN4x4 - 24L



Note

1. Package Outline Unit Description:
   BSC: Basic. Represents theoretical exact dimension or dimension target
   MIN: Minimum dimension specified.
   MAX: Maximum dimension specified.
   REF: Reference. Represents dimension for reference use only. This value is not a device specification.
   TYP. Typical. Provided as a general value. This value is not a device specification.
2. Dimensions in Millimeters.
3. Drawing not to scale.
4. These dimensions do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.15mm.

Important Notice

uPI and its subsidiaries reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete.

uPI products are sold subject to the taerms and conditions of sale supplied at the time of order acknowledgment. However, no responsibility is assumed by uPI or its subsidiaries for its use or application of any product or circuit; nor for any infringements of patents or other rights of third parties which may result from its use or application, including but not limited to any consequential or incidental damages. No uPI components are designed, intended or authorized for use in military, aerospace, automotive applications nor in systems for surgical implantation or life-sustaining. No license is granted by implication or otherwise under any patent or patent rights of uPI or its subsidiaries.

uPI Semiconductor Corp.
Headquarter
9F.,No.5, Taiyuan 1st St. Zhubei City,
Hsinchu Taiwan, R.O.C.
TEL : 886.3.560.1666 FAX : 886.3.560.1888

Sales Branch Office
12F-5, No. 408, Ruiguang Rd. Neihu District,
Taipei Taiwan, R.O.C.
TEL : 886.2.8751.2062 FAX : 886.2.8751.5064