LA8402

Dual 800mA, 1.5MHz, Synchronous Step-Down DC-DC Converter

v General Description

The LA8402 is a dual channel, current mode, step-down DC-DC converter that is designed to meet 800mA output current for each channel, and utilizes PWM control scheme that switches with 1.5MHz fixed frequency. This device includes a reference voltage source, error amplifier, oscillation circuit, MOSFETs, and etc.

The input voltage range of LA8402 is from 2.5V to 6.5V, and available in adjustable output voltage from 0.6V to V_{IN}. Supply current is only 250uA during operation and under 0.1uA in shutdown. Above mention makes LA8402 ideally suited for portable applications to extend battery life.

The LA8402 provides enable function that can be controlled by external logic signal. It also provides excellent regulation during line or load transient due to the internal compensation. Other features of current limit and short circuit protection are also included. Due to the low Drain-Source resistance of internal power MOSFETs, the LA8402 provides high efficiency step-down applications. It can also operate with a maximum duty cycle of 100% for use in low drop-out conditions.

The LA8402 is available in low profile (1mm) 10pin, TDFN package.

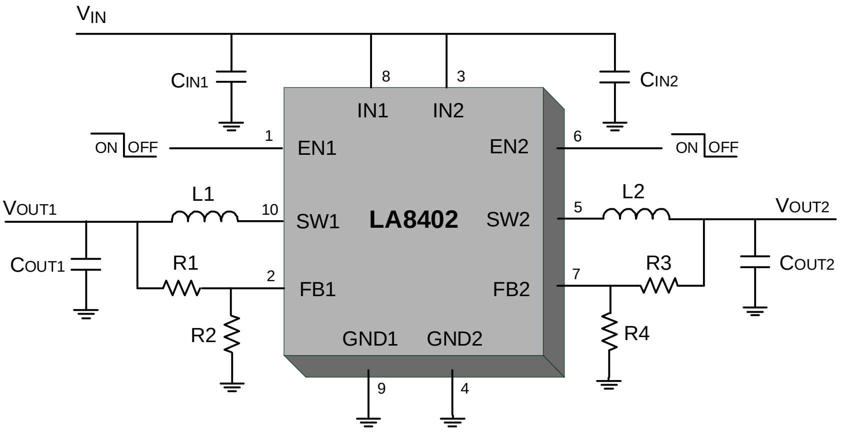
v Features

- Adjustable Output Voltage from 0.6V to V_{IN}
- 2.5V to 6.5V Input Voltage Range
- 800mA Output Capability
- 1.5MHz Oscillation Frequency
- 100% Duty Cycle
- Low Shutdown Current: 0.1uA
- Current Mode for Excellent Response
- No Schokkty Diode Required
- Current Limit
- Short Circuit Protection
- Space Saving TDFN-10 3x3mm Package
- All Products meet Rohs Standard

v Applications

- Digital Still and Video Cameras
- Mobile Phone
- PDA, PMP, MP3 Player
- Portable Instruments

v Typical Application



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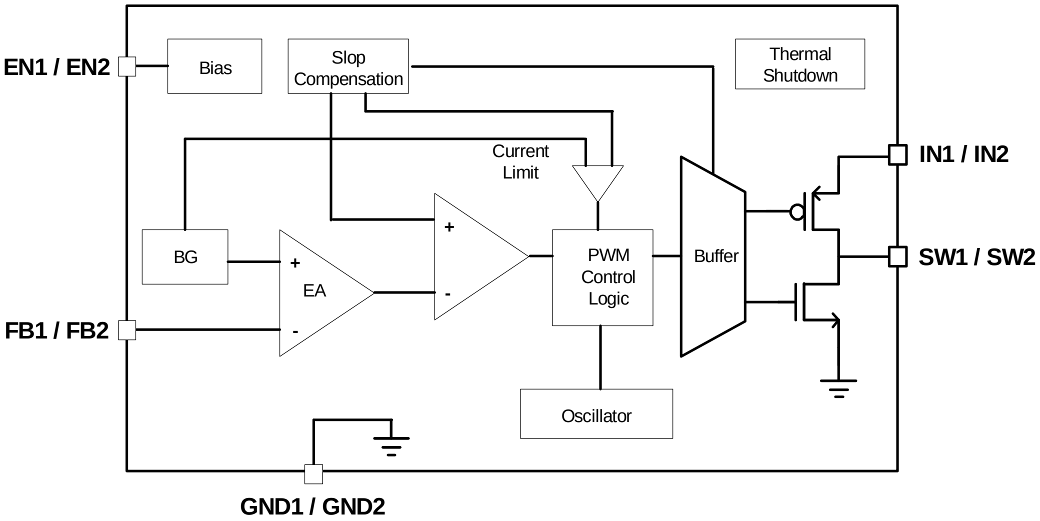
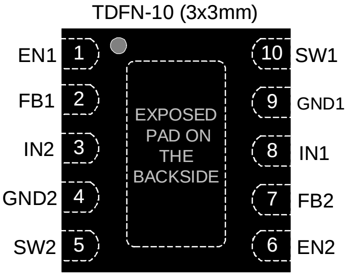
v Functional Block Diagram

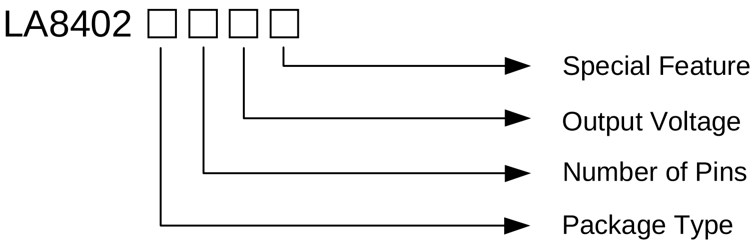


v Pin Configurations



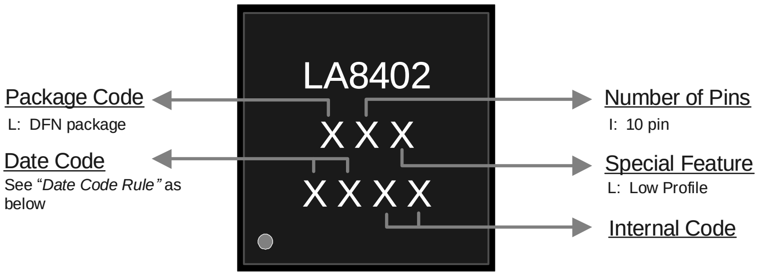
Pin No.	Name	Description
1	EN1	Channel 1 Enable Control Input. Floating this pin or drive it above 1.5V to turn on the channel 1, drive this pin below 0.3V to turn it off.
2	FB1	Channel 1 Feedback Input. It senses the feedback voltage to regulate the output voltage. Connect this pin to a resistor divider to set the output voltage.
3	IN2	Channel 2 Supply Input. Bypass to GND with a 2.2μF or greater ceramic capacitor.
4	GND2	Ground 2. Connect this pin to the circuit ground.
5	SW2	Channel 2 Power Switch Output. Connect a LC filter from this pin to the output load.
6	EN2	Channel 2 Enable Control Input. Floating this pin or drive it above 1.5V to turn on the channel 2, drive this pin below 0.3V to turn it off.
7	FB2	Channel 2 Feedback Input. It senses the feedback voltage to regulate the output voltage. Connect this pin to a resistor divider to set the output voltage.
8	IN1	Channel 1 Supply Input. Bypass to GND with a 2.2μF or greater ceramic capacitor.
9	GND1	Ground 1. Connect this pin to the circuit ground.
10	SW1	Channel 1 Power Switch Output. Connect a LC filter from this pin to the output load.

Ordering Information



Package Type	Number of Pins	Output Voltage	Special Feature
L: DFN	I: 10 pin	Blank: Adjustable	L: Low Profile

Marking Information



Data Code Rule

Year / Week	xxx0	xxx1	xxx2	xxx3	xxx4	xxx5	xxx6	xxx7	xxx8	xxx9
01	AA	CA	EA	GA	IA	KA	MA	OA	RA	TA
02	AB	CB	EB	GB	IB	KB	MB	OB	RB	TB
03	AC	CC	EC	GC	IC	KC	MC	OC	RC	TC
. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
25	AY	CY	EY	GY	IY	KY	MY	OY	RY	TY
26	AZ	CZ	EZ	GZ	IZ	KZ	MZ	OZ	RZ	TZ
27	BA	DA	FA	HA	JA	LA	NA	PA	SA	UA
28	BB	DB	FB	HB	JB	LB	NB	PB	SB	UB
. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
50	BX	DX	FX	HX	JX	LX	NX	PX	SX	UX
51	BY	DY	FY	HY	JY	LY	NY	PY	SY	UY
52	BZ	DZ	FZ	HZ	JZ	LZ	NZ	PZ	SZ	UZ

v Absolute Maximum Ratings

Parameter	Rating
Input Voltage	7V
SW Pin Voltage Range	-0.3V ~ V_{IN}+0.3V
FB Pin Voltage Range	-0.3V ~ V_{IN}+0.3V
EN Pin Voltage Range	-0.3V ~ V_{IN}+0.3V
Storage Temperature Range	-65°C ~ 150°C
Junction Temperature	150 °C
Lead Soldering Temperature (10 sec)	260 °C

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.

v Recommended Operating Conditions

Parameter	Rating
Input Voltage Range	2.5V ~ 6.5V
Junction Temperature Range	-40°C ~ 125°C

These are conditions under which the device functions but the specifications might not be guaranteed. For guaranteed specifications and test conditions, please see the *Electrical Specifications*.

v Package Information

Parameter	Package	Symbol	Maximum	Unit
Thermal Resistance (Junction to Case)	TDFN-10	θ_{JC}	8	°C / W
Thermal Resistance (Junction to Ambient)		θ_{JA}	50	°C / W

v Electrical Specifications

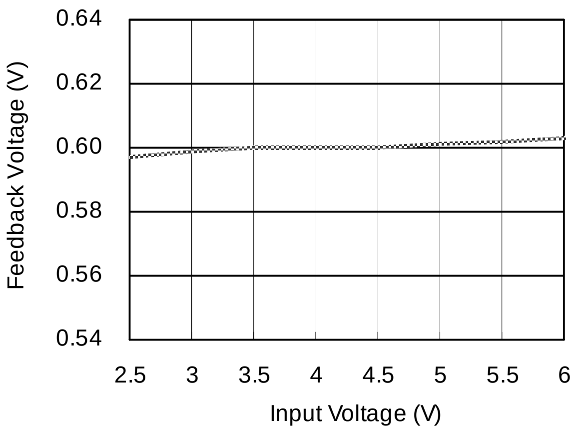
V_{IN}=V_{EN}=3.6V, T_A=25°C, unless otherwise noted.

Parameter	**Symbol**	**Test Condition**	**Min**	**Typ**	**Max**	**Units**
Feedback Voltage	V_{FB}		0.588	0.6	0.612	V
		-40°C≦T_A≦85°C	0.582	0.6	0.618	
Oscillation Frequency	F_{OSC}		1.2	1.5	1.8	MHz
Duty Cycle	DC	V_{FB}=GND		100		%
		V_{FB}=V_{IN}		0		
P-Channel MOSFET On Resistance	$R_{DS(ON)}$	I_{SW}=300mA		400	500	mΩ
N-Channel MOSFET On Resistance		I_{SW}=-300mA		350	450	
Output Current	I_{OUT}	Continuous output for each channel	800			mA
Current Limit	I_{LIM}	V_{IN}=3V, V_{OUT}=90%$V_{OUT(NORMAL)}$ DC<35%		1100		mA
Supply Current	I_{IN}	V_{FB}=GND		0.25	0.4	mA
Shutdown Current	I_S	V_{EN}=GND		0.1	1	uA
EN Pin Input Threshold Voltage	V_{EN}	Regulator OFF		1.0	0.3	V
		Regulator ON	1.3			
EN Pin Bias Current	I_{EN}	Regulator OFF		0.01	1	uA
		Regulator ON		0.01	1	
Switch Leakage Current	I_{SL}	V_{IN}=5V, V_{EN}=0V, V_{SW}=0V		0.01	1	uA
FB Pin Bias Current	I_{FB}				30	nA
Line Regulation	$\triangle V_{LINE}$	V_{IN}=2.5V~6.5V, I_{LOAD} =10mA		1		%
Load Regulation	$\triangle V_{LOAD}$	I_{LOAD}=50mA~800mA		1		%

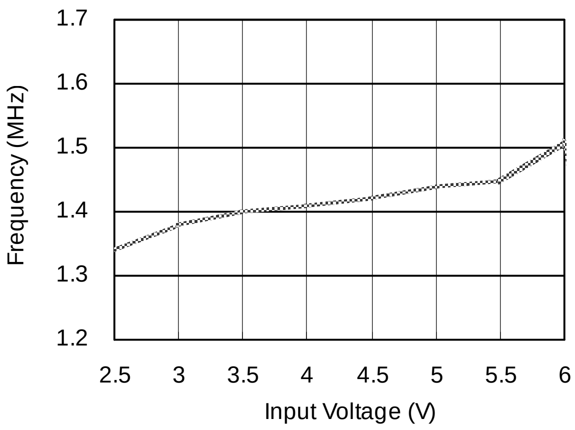
v Typical Performance Characteristics

V_{IN}=3.6V, T_A=25ºC, unless otherwise noted.

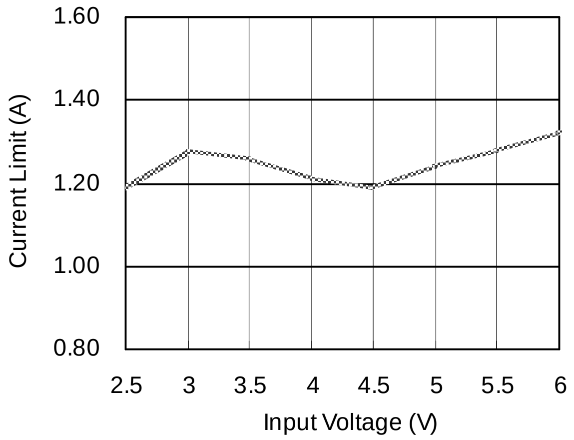
Feedback Voltage vs. Input Voltage



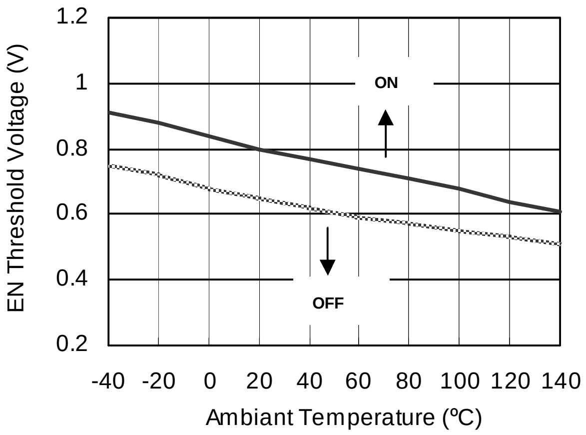
Frequency vs. Input Voltage



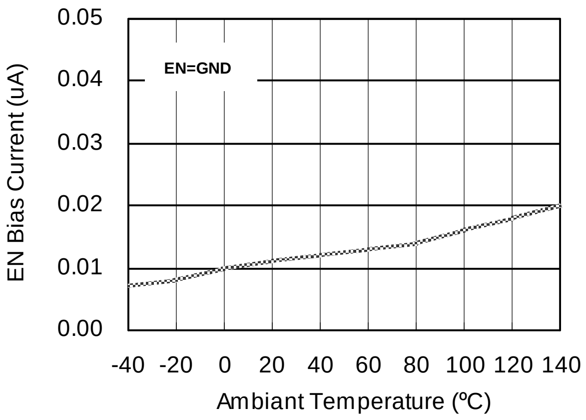
Current Limit vs. Input Voltage



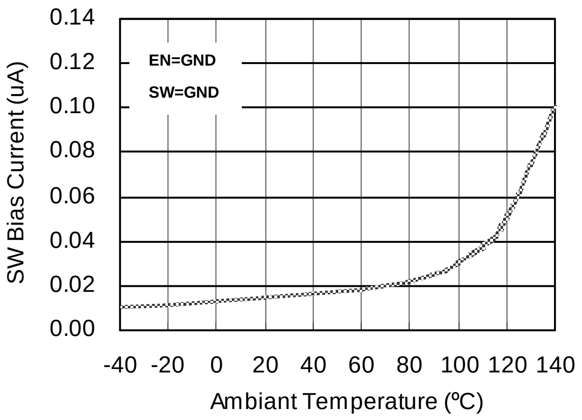
EN Threshold Voltage vs. Temperature



EN Bias Current vs. Temperature

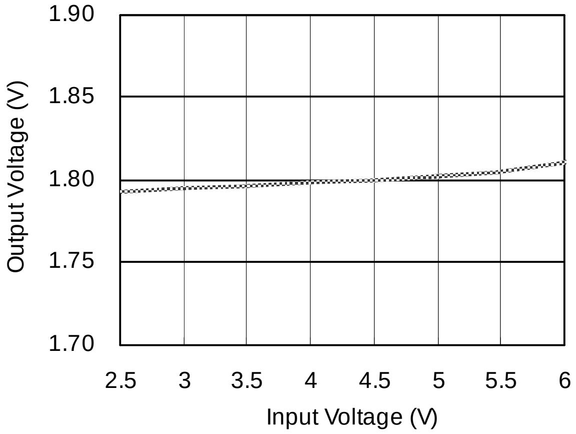


SW Bias Current vs. Temperature

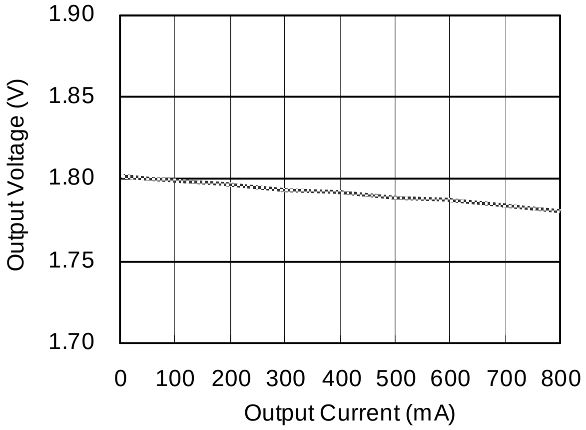


v Typical Performance Characteristics (Contd.)

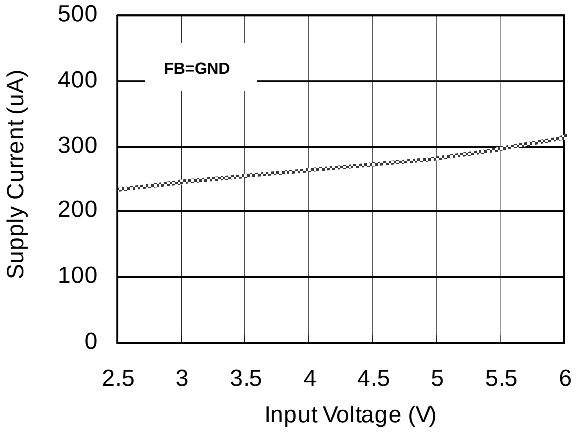
Line Regulation



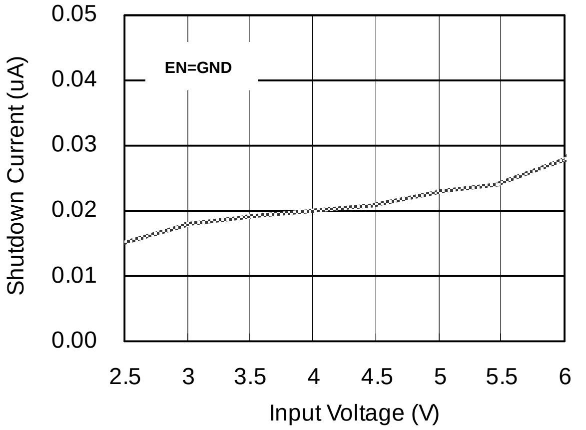
Load Regulation



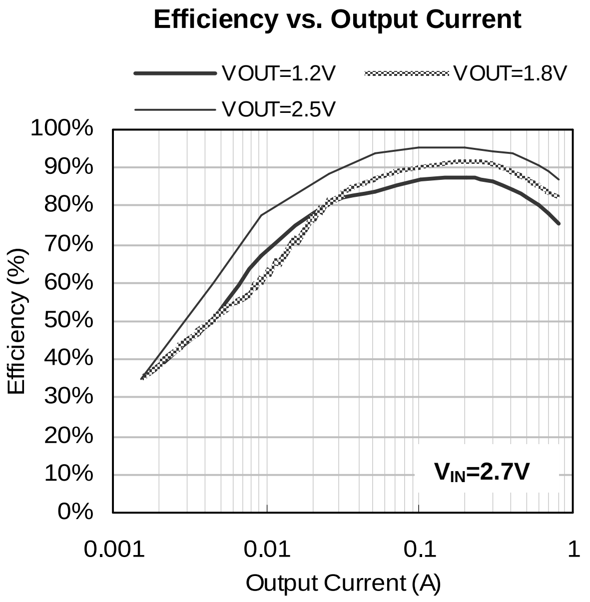
Supply Current vs. Input Voltage

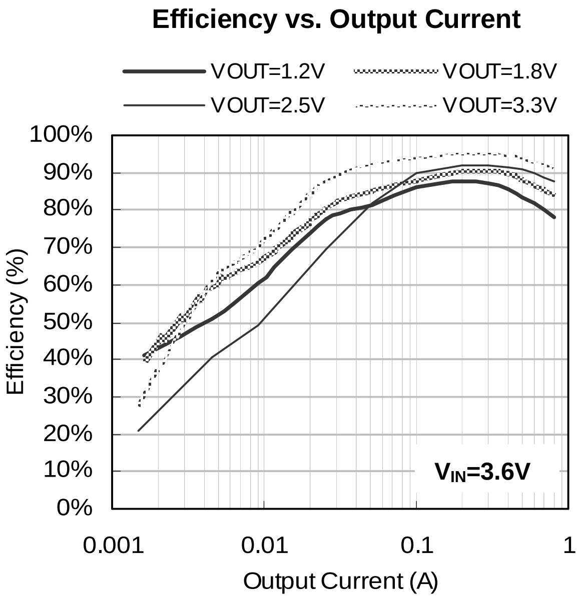


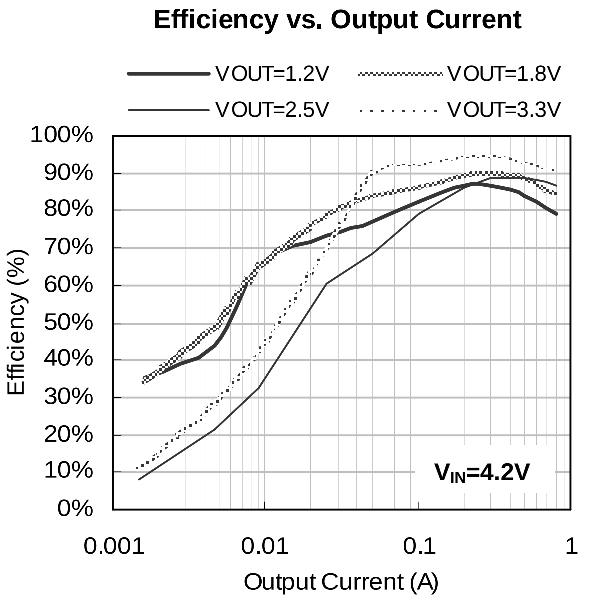
Shutdown Current vs. Input Voltage

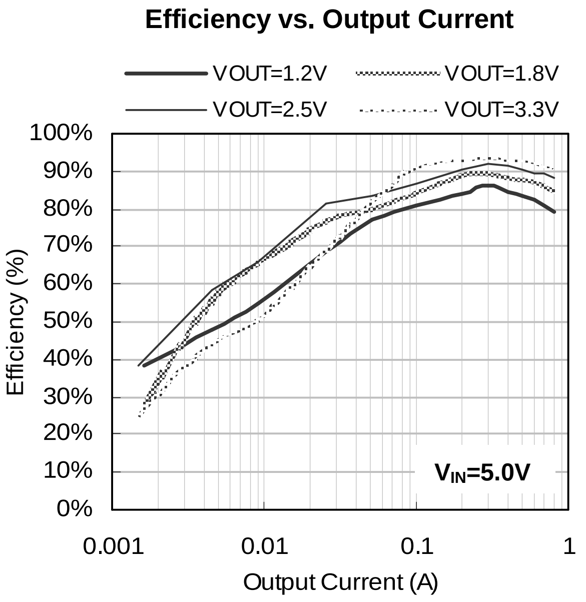


v Typical Performance Characteristics (Contd.)





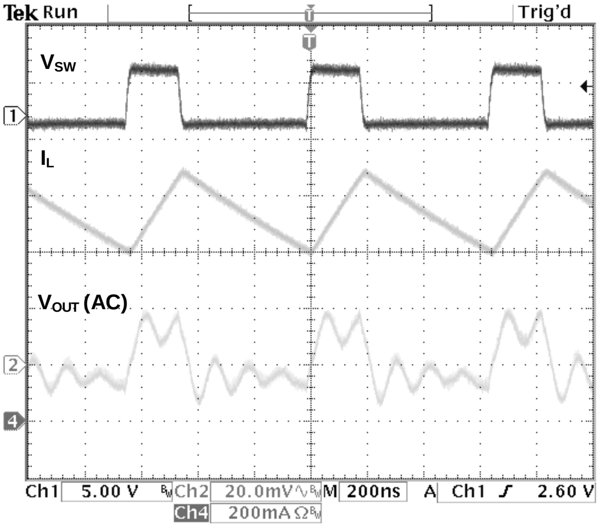




v Typical Performance Characteristics (Contd.)

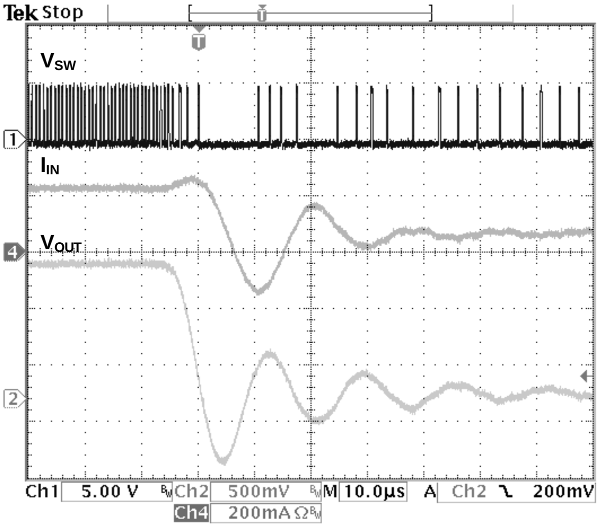
Output Voltage Ripple - CCM

V_{IN}=5V V_{OUT}=1.2V, I_{LOAD}=800mA



Short Circuit Protection

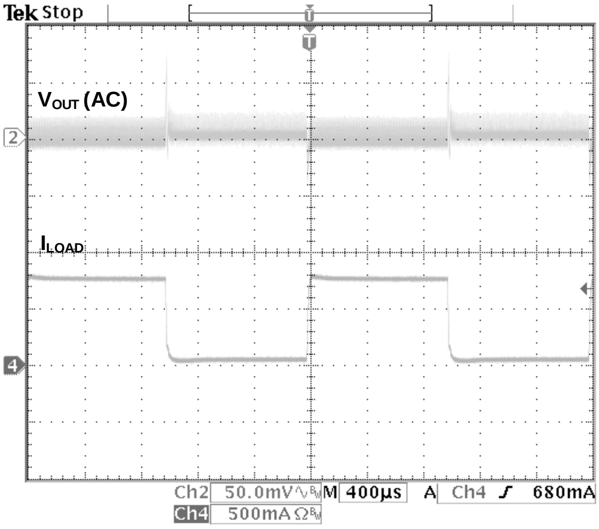
V_{IN}=5V V_{OUT}=1.2V, I_{LOAD}=800mA



Load Transient

V_{IN}=5V V_{OUT}=1.2V, I_{LOAD}=50mA~800mA

T_{ON}=T_{OFF}=1ms, T_r=T_f=1A/us



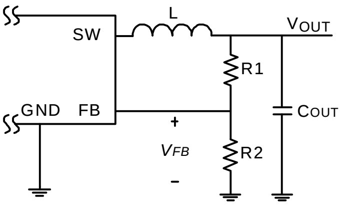
v Application Information

Output Voltage Programming

This LA8402 develops a band-gap between the feedback pin and ground pin. Therefore, the output voltage can be formed by R1 and R2. Use 1% metal film chip resistors for the lowest temperature coefficient and the best stability. Select lower resistor value to minimize noise pickup in the sensitive feedback pin, or higher resistor value to improve efficiency.

The output voltage is given by the following formula:

$V_{OUT} = V_{FB}$ x $(1 + R1 / R2)$ where $V_{FB} = 0.6V$

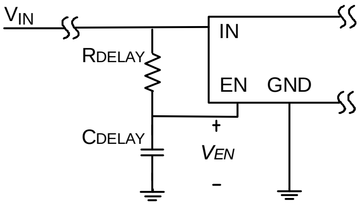


Short Circuit Protection

The LA8402 includes short circuit protection. When the output is shorted to ground, the protection circuit will be triggered and force the oscillation frequency down to several hundred KHz. The oscillation frequency will return to the normal value once the short circuit condition is removed or the feedback voltage reaches 0.6V.

Delay Start-up

The following circuit uses the EN pin to provide a time delay between the input voltage is applied and the output voltage comes up. As the instant of the input voltage rises, the charging of capacitor C_{DELAY} pulls the EN pin low, keeping the device off. Once the capacitor voltage rises above the EN pin threshold voltage, the device will start to operate.



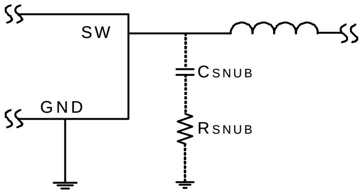
This feature is useful in situations where the input power source is limited in the amount of current it can deliver. It allows the input voltage to rise to a higher voltage before the device starts operating.

Snubber Circuit

The simple RC snubber is used for voltage transient and ringing suppression. The high frequency ringing and voltage overshooting at the SW pin is caused by fast switching transition and resonating circuit parasitical elements in the power circuit. It maybe generates EMI and interferes with circuit performance.

Reserve a snubber circuit in the PC board is preferred to damp the ringing due to the parasitical capacitors and inductors of layout.

The following circuit is a simple RC snubber:



Choose the value of RC network by the following procedure:

(1) Measure the voltage ringing frequency (f_R) of the SW pin.

(2) Find a small capacitor and place it across the SW pin and the GND pin to damp the ringing frequency by half.

(3) The parasitical capacitance (C_{PAR}) at the SW pin is 1/3 the value of the added capacitance above. The parasitical inductance (L_{PAR}) at the SW pin is:

$$L_{PAR} = \frac{1}{(2\pi f_R)^2 \times C_{PAR}}$$

(4) Select the value of C_{SNUB} that should be more than 2~4 times the value of C_{PAR} but must be small enough so that the power dissipation of R_{SNUB} is kept to a minimum. The power rating of R_{SNUB} can be calculated by following formula:

$$P\_{RSNUB} = C_{SNUB} \times V_{IN}^2 \times f_S$$

(5) Calculate the value of R_{SNUB} by the following formula and adjust the value to meet the expectative peak voltage.

$$R_{SNUB} = 2\pi \times f_R \times L_{PAR}$$

Thermal Considerations

For continuous operation, do not exceed the maximum operation junction temperature 125°C. The power dissipation across this device can be calculated by the following formula:

$$P_D = \left[R_{DS(ON)\_P} \times D + R_{DS(ON)\_N} \times (1-D)\right] \times (I_{LOAD})^2 + V_{IN} \times I_Q$$

Where D is the duty cycle of the internal P-MOSFET. The maximum power dissipation of this device depends on the thermal resistance of the IC package and PCB layout, the temperature difference between the die junction and ambient air, and the rate of airflow. The maximum power dissipation can be calculated by the following formula:

$$P_{D(MAX)} = \frac{(T_J - T_A)}{\theta_{JA}}$$

Where T_J -T_A is the temperature difference between the die junction and surrounding environment, θ_{JA} is the thermal resistance from the junction to the surrounding environment.

The value of junction to case thermal resistance θ_{JC} is also popular to users. This thermal parameter is convenient for users to estimate the internal junction operated temperature of packages while IC operating. The operated junction temperature can be calculated by the following formula:

$$T_J = T_C + P_D \times \theta_{JC}$$

T_C is the package case temperature measured by thermal sensor. Therefore it's easy to estimate the junction temperature by any condition.

There are many factors affect the thermal resistance. Some of these factors include trace width, copper thickness, total PCB copper area, and etc.

For the best thermal performance, wide copper traces and generous amounts of PCB copper should be used in the board layout. If further improve thermal characteristics are needed, double sided and multi-layer PCB with large copper areas and airflow will be recommended.

Layout Considerations

PC board layout is very important, especially for switching regulators of high frequencies and large peak currents. A good layout minimizes EMI on the feedback path and provides best efficiency. The following layout guides should be used to ensure proper operation of this device.

(1) The power charge path and discharge path those consist of the IN trace, the SW trace, external inductor and the GND trace should be kept wide and as short as possible.

(2) The feedback path of the voltage divider should be close to the FB pin and keep noisy traces away; also keep them separate using grounded copper.

(3) The (+) plates of input capacitors should be close to the regulator.

(4) Keep the (-) plates of input and output capacitors as close as possible.

v Component Selection

1. Inductor Selection

The conduction mode of power stage depends on input voltage, output voltage, output current, and the value of the inductor. Select an inductor to maintain this device operating in continuous conduction mode (CCM). The minimum value of inductor can be determined by the following procedure.

(1) Calculate the minimum duty ratio:

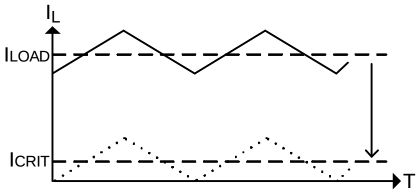
$$D_{(MIN)} = \frac{V_{OUT} + I_{LOAD} \times R_L + V_{DS\_NMOS}}{V_{IN(MAX)} - V_{DS\_PMOS} + V_{DS\_NMOS}} = \frac{T_{ON}}{T_S}$$

Where R_L is the DC resistance of the external inductor, V_{DS} is the turn-on voltage of the internal MOSFET, and Ts is the switching period.

This formula can be simplified to

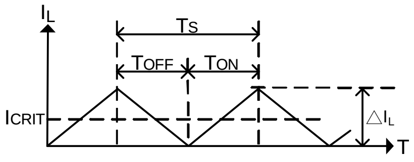
$$D_{(MIN)} = \frac{V_{OUT}}{V_{IN(MAX)}} = \frac{T_{ON}}{T_S} \quad ; \quad 0 \le D \le 1$$

(2) Define a value of minimum current that is approximately 10%~30% of full load current to maintain continuous conduction mode, usually referred to as the critical current (I_{CRIT}).



$$I_{CRIT} = \delta \times I_{LOAD} \quad ; \quad \delta = 0.1\text{~}0.3$$

(3) Calculate the inductor ripple current ($\triangle I_L$). In steady state conditions, the inductor ripple current increase, ($\triangle I_L+$), during the ON time and the current decrease, ($\triangle I_L-$), during the OFF time must be equal.



$$\Delta I_L = 2 \times I_{CRIT}$$

(4) Calculate the minimum value of inductor use maximum input voltage. That is the worst case condition because it gives the maximum $\triangle I_L$.

$$L \ge \frac{[V_{IN(MAX)} - I_{LOAD} \times (R_{DS(ON)} + R_L) - V_{OUT}] \times D_{(MIN)}}{\Delta I_L \times fs}$$

This formula can be simplified to

$$L \ge \frac{(V_{IN(MAX)} - V_{OUT}) \times D_{(MIN)}}{\Delta I_L \times fs}$$

The higher value inductor results in lower output ripple current and ripple voltage. It also reduces the conduction loss. But higher value inductor requires larger physical size and price.

(5) Calculate the inductor peak current and choose a suitable inductor to prevent saturation.

$$I_{L(PEAK)} = I_{LOAD} + \frac{\Delta I_L}{2}$$

Coil inductors and surface mount inductors are all available. The surface mount inductors can reduce the board size but they are more expensive and its larger DC resistance results in more conduction loss. The power dissipation is due to the DC resistance can be calculated as below:

$$P_{D\_INDUCTOR} = I_{LOAD}^2 \times R_L$$

2. Output Capacitor Selection

The functions of the output capacitor are to store energy and maintain the output voltage. The low ESR (Equivalent Series Resistance) capacitors are preferred to reduce the output ripple voltage ($\triangle V_{OUT}$) and conduction loss. The output ripple voltage can be calculated as below:

$$\Delta V_{OUT} = \Delta I_L \times (ESR\_{COUT} + \frac{1}{8 \times fs \times C_{OUT}})$$

Choose suitable capacitors must define the expectative value of output ripple voltage first. A 10uF ceramic capacitor with X7R or X5R for most applications is sufficient because of the lower ESR and physical size.

Besides, the capacitor's ESL (Equivalent Series Inductance) maybe causes ringing in the low MHz region. Choose low ESL capacitors, limiting lead length of PCB and capacitor, and parallel connecting several smaller capacitors to replace with a larger one will reduce the ringing phenomenon.

3. Input Capacitor Selection

The input capacitor is required to supply current to the regulator and maintain the DC input voltage. Low ESR capacitors are preferred those provide the better performance and the less ripple voltage.

The input capacitors need an adequate RMS current rating. It can be calculated by following formula and should not be exceeded.

$$I_{RMS\_CIN} = I_{LOAD(MAX)} \times \sqrt{D \times (1 - D)}$$

This formula has a maximum at $V_{IN}=2V_{OUT}$. That is the worst case and the above formula can be simplified to:

$$I_{RMS\_CIN} = \frac{I_{LOAD(MAX)}}{2}$$

Therefore, choose a suitable capacitor at input whose ripple current rating must greater than half of the maximum load current.

The input ripple voltage ($\triangle V_{IN}$) mainly depends on the input capacitor's ESR and its capacitance. Assuming the input current of the regulator is constant, the required input capacitance for a given input ripple voltage can be calculated as below:

$$C_{IN} = \frac{I_{LOAD(MAX)} \times D \times (1 - D)}{f_S \times (\Delta V_{IN} - I_{LOAD(MAX)} \times ESR\_{CIN})}$$

A 4.7uF ceramic capacitor with X7R or X5R for most applications is sufficient. If using aluminum electrolytic or tantalum input capacitors, parallel connecting a 0.1uF ceramic capacitor as close to the IN pin of regulator as possible. If using ceramic capacitor, make sure the capacitance is enough to prevent the excessive input ripple current.

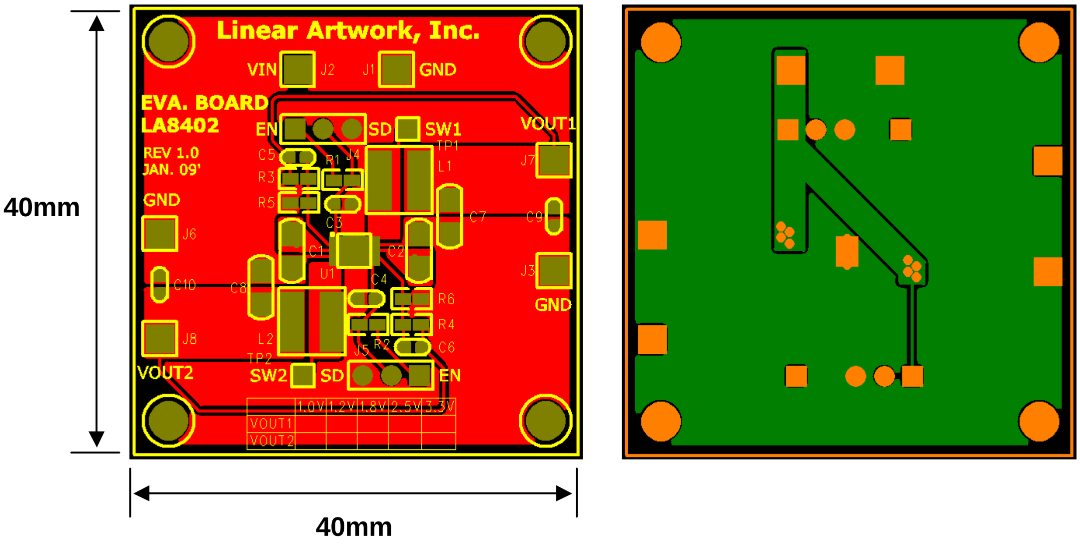
v Quick Design Table

For Adjustable version, I_{LOAD}=800mA, △I_L=240mA, C_{IN}=4.7uF, C_{OUT}=10uF, continuous mode operation

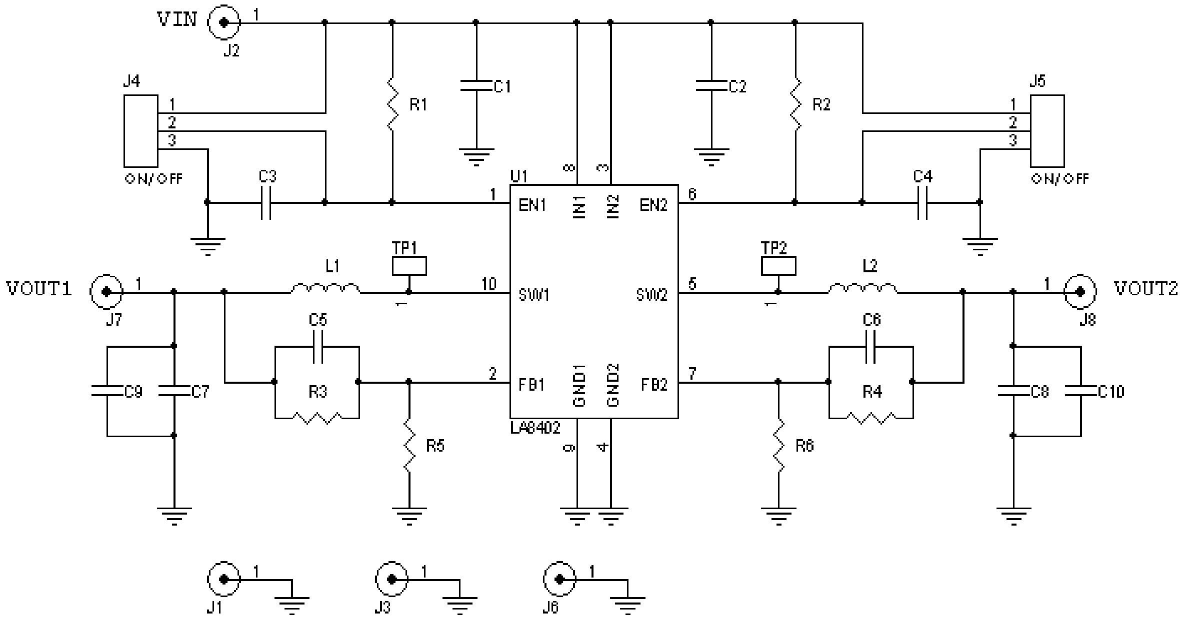
A: Minimum Inductor value
B: High side resistor of the output voltage divider
C: Low side resistor of the output voltage divider
D: Feedforward capacitor across the high side resistor of the voltage divider

V_{IN} / V_{OUT}	**Li-Ion Battery**	**3.3V**	**5V**
1.0V	A: 2.2uH B: 220KOhm C: 330KOhm D: 22pF	A: 2.2uH B: 220KOhm C: 330KOhm D: 22pF	A: 2.2uH B: 220KOhm C: 330KOhm D: 22pF
1.2V	A: 2.2uH B: 330KOhm C: 330KOhm D: 22pF	A: 2.2uH B: 330KOhm C: 330KOhm D: 22pF	A: 2.2uH B: 330KOhm C: 330KOhm D: 22pF
1.5V	A: 2.7uH B: 330KOhm C: 220KOhm D: 22pF	A: 2.2uH B: 330KOhm C: 220KOhm D: 22pF	A: 3.3uH B: 330KOhm C: 220KOhm D: 22pF
1.8V	A: 2.7uH B: 360KOhm C: 180KOhm D: 22pF	A: 2.2uH B: 360KOhm C: 180KOhm D: 22pF	A: 3.3uH B: 360KOhm C: 180KOhm D: 22pF
2.5V	A: 2.7uH B: 475KOhm C: 150KOhm D: 22pF	A: 2.2uH B: 475KOhm C: 150KOhm D: 22pF	A: 3.3uH B: 475KOhm C: 150KOhm D: 22pF
2.8V	A: 2.7uH B: 374KOhm C: 102KOhm D: 22pF	A: 2.2uH B: 374KOhm C: 102KOhm D: 22pF	A: 3.3uH B: 374KOhm C: 102KOhm D: 22pF
3.0V	A: 2.2uH B: 649KOhm C: 162KOhm D: 22pF	A: 2.2uH B: 649KOhm C: 162KOhm D: 22pF	A: 3.3uH B: 649KOhm C: 162KOhm D: 22pF
3.3V			A: 3.3uH B: 732KOhm C: 162KOhm D: 22pF

v Evaluation Board Layout



v Evaluation Board Schematic



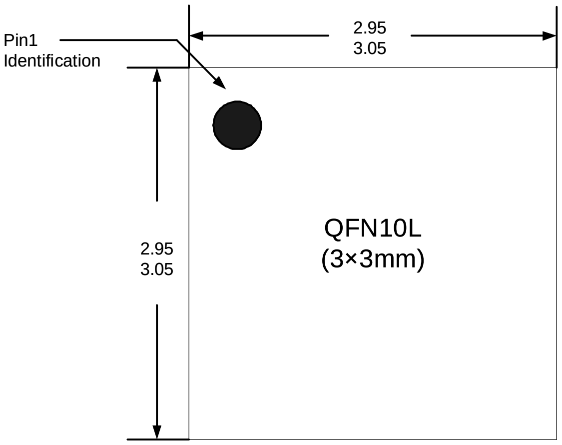
v Bill of Materials

V_{IN}=5V, V_{OUT1}=1.2V, V_{OUT2}=1.8V I_{OUT1}=I_{OUT2}=800mA

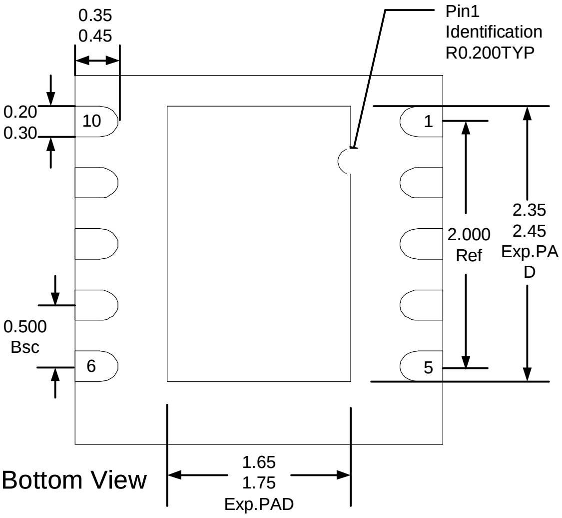
Designation	Descriptions	Manufacturer Part #	Manufacturer	Manufacturer Website
U1	Dual 800mA, 1.5MHz Step-Down Converter, TDFN-10 Package	LA8402LIL	Linear Artwork	www.linear-artwork.com
L1	SMD Shielded Inductor 2.2uH, 1.5A, 60mOhm, 3x3x1.5mm	NR3015T2R2M	Taiyo Yuden	www.yuden.co.jp
	SMD Shielded Inductor 2.2uH, 1.6A, 60mOhm, 3.2x3.2x2mm	SCDS2D18HP2R2	Chilisin	www.chilisin.com.tw
L2	SMD Shielded Inductor 3.3uH, 1.2A, 80mOhm, 3x3x1.5mm	NR3015T3R3M	Taiyo Yuden	www.yuden.co.jp
	SMD Shielded Inductor 3.3uH, 1.45A, 86mOhm, 3.2x3.2x2mm	SCDS2D18HP3R3	Chilisin	www.chilisin.com.tw
C1,C2	MLCC 4.7uF, 0805, X5R, 25V	TMK212BJ475KG-T	Taiyo Yuden	www.yuden.co.jp
C5,C6	MLCC 22pF, 0603, NPO, 50V	C1608CH1H220J	TDK	www.tdk.com
C7,C8	MLCC 10uF, 1206, X5R, 25V	TMK316BJ106KL-T	Taiyo Yuden	www.yuden.co.jp
C9,C10	MLCC 0.1uF, 0603, B, 50V	C1608JB1H104K	TDK	www.tdk.com
R1,R2,C3,C4	Optional Parts			
R3,R5	Chip Resistor, 330KOhm, 0603, ±1%	RC0603FR-07330KL	Yageo	www.yageo.com
R4	Chip Resistor, 360KOhm, 0603, ±1%	RC0603FR-07360KL	Yageo	www.yageo.com
R6	Chip Resistor, 180KOhm, 0603, ±1%	RC0603FR-07180KL	Yageo	www.yageo.com
J4,J5	Male Header 180° 3*1P 2.54mm			
J1,J2,J3,J6, J7,J8	Terminal Binding Post 1.6mm			
TP1,TP2	Male Header 180° 1P 2.54mm			

Package Outline

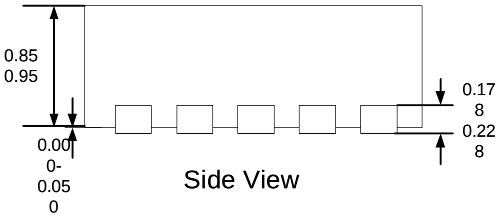
TDFN-10



Top View



Bottom View



Side View

NOTICE

The specifications and product information of Linear Artwork, Inc. are subject to change without any prior notice, and customer should contact Linear Artwork, Inc. to obtain the latest relevant information before placing orders and verify that such information is current and complete.

The information provided here is believed to be reliable and accurate; however Linear Artwork, Inc. makes no guarantee for any errors that appear in this document.

LIFE SUPPORT POLICY

Linear Artwork products are not designed or authorized for use as critical components in life support devices or systems without the express written approval of the president of Linear Artwork, Inc. As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and (c) whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury of the user.

2. A critical component in any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

Linear Artwork, Inc.

Headquarter

6F-1, No.293, Sec.1, Beisin Road, Sindian City, Taipei Country 231, Taiwan (R.O.C.)
TEL : +886-2-2912-5816
FAX : +886-2-2912-5826
Website : www.linear-artwork.com
E-mail : sales@linear-artwork.com