LA8542

150KHz, 3A/40V Step-Down DC-DC Converter

General Description

LA8542 is a voltage mode, step-down DC-DC converter that is designed to meet 3A output current, and utilizes PWM control scheme that switches with 150KHz fixed frequency. The input voltage range is from 4.5V to 40V, and provides fixed 3.3V, 5V, or adjustable output voltage for customers in application.

This device provides shutdown function that can be controlled by external logic signal. It also provides excellent regulation during line or load transient. Other features of current limit and thermal shutdown protection are also included. It guarantees ±15% tolerance on internal oscillator frequency and ±4% tolerance on output voltage under specified input voltage and output current. The package is available in standard TO-252-5, TO-263-5, and TO-220-5.

Features

- 4.5V to 40V Input Voltage Range
- 1.23V to 37V Adjustable Output Voltage
- 3.3V and 5V Fixed Output Voltage
- Continuous 3A Output Capability
- 150KHz Oscillation Frequency
- Built-in NPN transistor
- No External Compensation Required
- Current Limit
- Thermal Shutdown Protection
- Standard 5 Pin TO-252/263/220 Packages
- Meet RoHS Standard

Applications

- Broadband Communication Device
- LCD TV / Monitor
- Storage Device
- Wireless Application

Ordering Information

LA8542 1 2 3 4

1 : Package Type

G: TO-252 **H**: TO-263 **I**: TO-220

2 : Number of Pins

D: 5 pin

3 : Output Voltage

33: 3.3V **50**: 5.0V

Blank: Adjustable Version

4 : Special Feature

Blank: N/A

Available Part Number

LA8542GD	LA8542HD	LA8542ID
LA8542GD33	LA8542HD33	LA8542ID33
LA8542GD50	LA8542HD50	LA8542ID50

Marking Information

1 2 : Package Code

TO-252-5 : **GD** TO-263-5 : **HD** TO-220-5 : **ID**

3 4 : Voltage Code

3.3V : **33** 5.0V : **50** ADJ : **Blank**

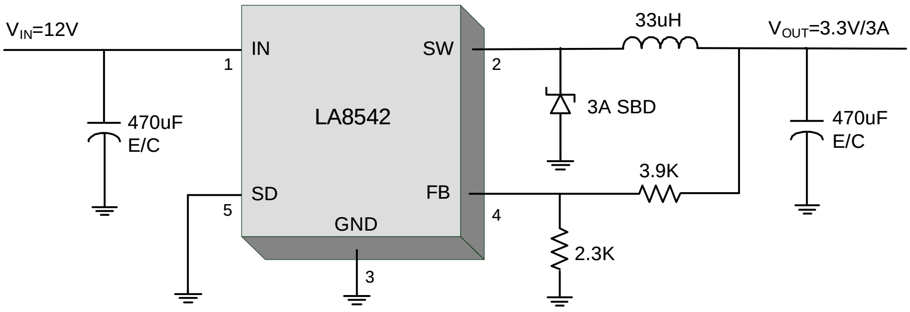
5 6 : Date Code

For date code rule, please contact our sales representative directly.

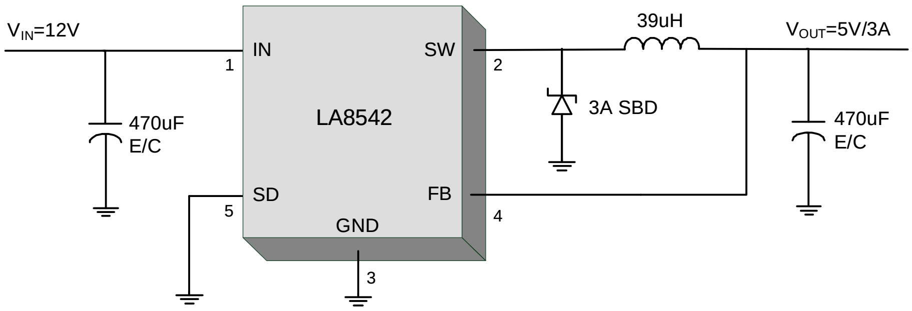
7 8 : Internal Code

Typical Application

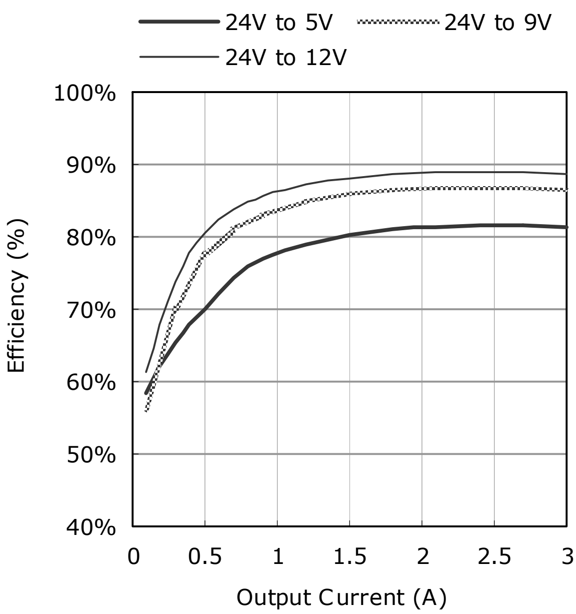
- *12V to 3.3V, I_{OUT}=3A, Adjustable Version*

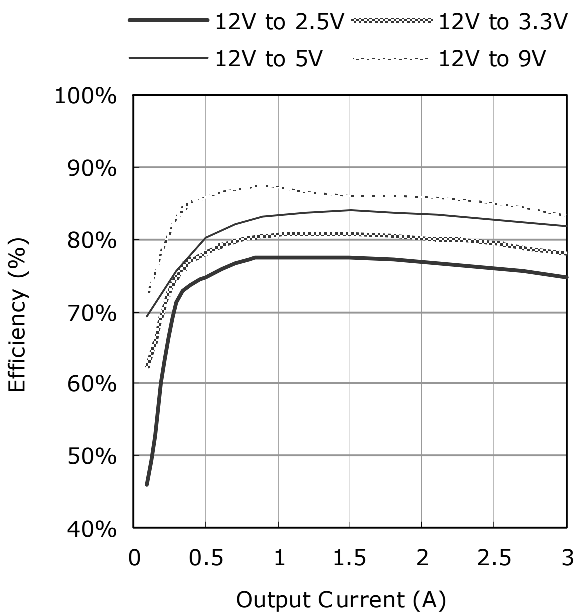


- *12V to 5V, I_{OUT}=3A, Fixed 5V Version*



- *Efficiency Curve*





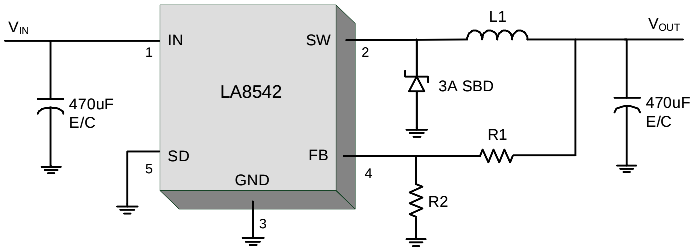
Quick Design Table

For 3A output current, $\triangle I_L$ = 0.6A, continuous current mode operation.

L1: Recommended Inductor

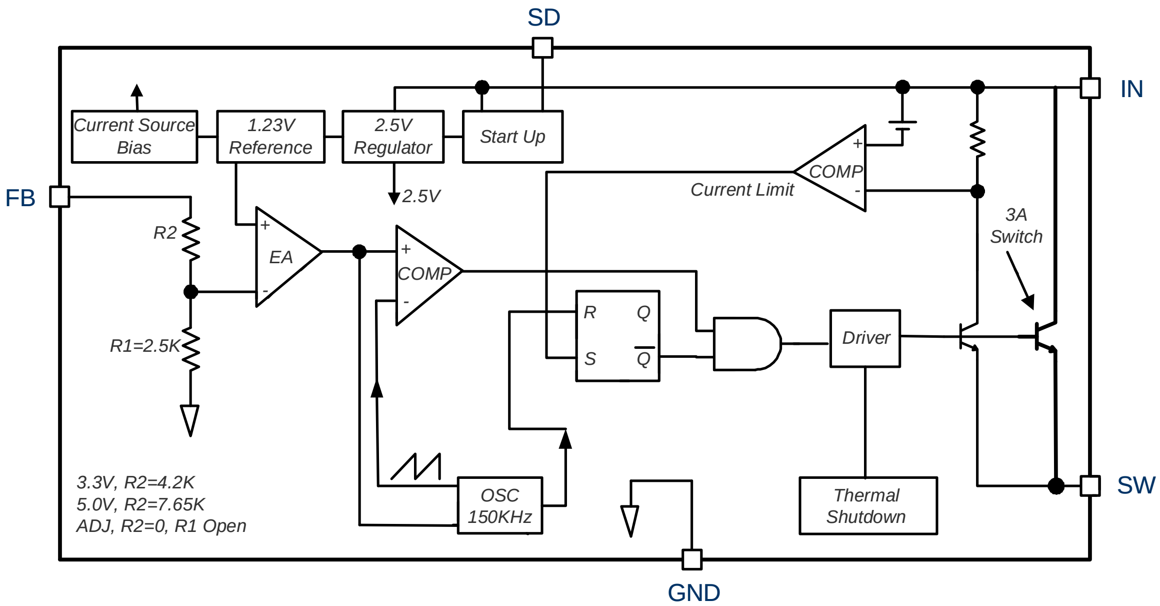
R1: Output Voltage Divider

R2: Output Voltage Divider

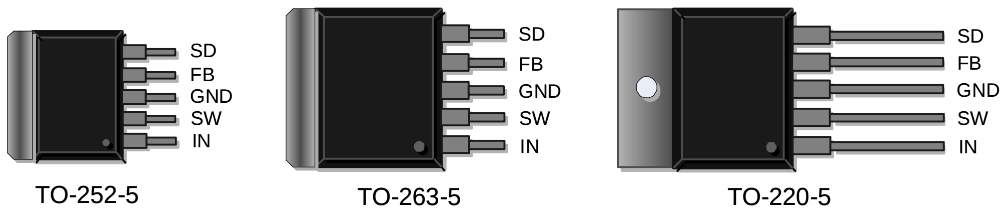


VIN / VOUT	5V	9V	12V	18V	24V
1.5V	L1 : 15uH R1 : 1.5KOhm R2 : 6.8KOhm	L1 : 18uH R1 : 1.5KOhm R2 : 6.8KOhm	L1 : 18uH R1 : 1.5KOhm R2 : 6.8KOhm	L1 : 18uH R1 : 1.5KOhm R2 : 6.8KOhm	L1 : 18uH R1 : 1.5KOhm R2 : 6.8KOhm
1.8V	L1 : 15uH R1 : 1.8KOhm R2 : 3.9KOhm	L1 : 22uH R1 : 1.8KOhm R2 : 3.9KOhm	L1 : 22uH R1 : 1.8KOhm R2 : 3.9KOhm	L1 : 22uH R1 : 1.8KOhm R2 : 3.9KOhm	L1 : 18uH R1 : 1.8KOhm R2 : 3.9KOhm
2.5V	L1 : 18uH R1 : 2.3KOhm R2 : 2.2KOhm	L1 : 27uH R1 : 2.3KOhm R2 : 2.2KOhm	L1 : 27uH R1 : 2.3KOhm R2 : 2.2KOhm	L1 : 33uH R1 : 2.3KOhm R2 : 2.2KOhm	L1 : 27uH R1 : 2.3KOhm R2 : 2.2KOhm
3.3V	L1 : 15uH R1 : 3.9KOhm R2 : 2.3KOhm	L1 : 27uH R1 : 3.9KOhm R2 : 2.3KOhm	L1 : 33uH R1 : 3.9KOhm R2 : 2.3KOhm	L1 : 39uH R1 : 3.9KOhm R2 : 2.3KOhm	L1 : 33uH R1 : 3.9KOhm R2 : 2.3KOhm
5V		L1 : 33uH R1 : 3.1KOhm R2 : 1KOhm	L1 : 39uH R1 : 3.1KOhm R2 : 1KOhm	L1 : 47uH R1 : 3.1KOhm R2 : 1KOhm	L1 : 47uH R1 : 3.1KOhm R2 : 1KOhm
9V			L1 : 33uH R1 : 8.2KOhm R2 : 1.3KOhm	L1 : 56uH R1 : 8.2KOhm R2 : 1.3KOhm	L1 : 68uH R1 : 8.2KOhm R2 : 1.3KOhm
12V				L1 : 56uH R1 : 20KOhm R2 : 2.3KOhm	L1 : 68uH R1 : 20KOhm R2 : 2.3KOhm

Functional Block Diagram



Pin Configurations



Pin No.	Name	Description
1	IN	The input pin of the step-down converter. A suitably large capacitor must be connected from this pin to ground to bypass noise on the input of the IC.
2	SW	The output pin of the step-down converter. This pin is the switching node that supplies power to the output. Connect a LC filter from this pin to the output load and a rectifier diode to the ground.
3	GND	The ground pin of the step-down converter. Connect this pin to the circuit ground.
4	FB	This pin senses the feedback voltage to regulate the output voltage. Connect this pin to a resistor divider to set the output voltage for adjustable version or connect to the positive side of load directly for fixed version.
5	SD	This pin allows an external control signal to turn-on/off this device. Float this pin or force it above 2V to turn-off this device, force it below 0.6V to turn-on this device. If this feature is not needed, connect this pin to GND directly.

Absolute Maximum Ratings

Parameter	Rating
Input Voltage	45V
SW Pin Voltage Range	-1V ~ V_{IN}+0.5V
FB Pin Voltage Range	-0.3V ~ 25V
SD Pin Voltage Range	-0.3V ~ 25V
Storage Temperature Range	-65°C ~ 150°C
Junction Temperature	150°C
Lead Soldering Temperature (10 sec)	300°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.

Recommended Operating Conditions

Parameter	Rating
Input Voltage Range	4.5V ~ 40V
Output Voltage Range	1.23V ~ 37V
Ambient Temperature Range	-40°C ~ 85°C
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***.

Package Information

Parameter	Package	Symbol	Rating
Thermal Resistance (Junction to Case)	TO-252	θ_{JC}	10 °C/W
	TO-263		4 °C/W
	TO-220		3 °C/W
Thermal Resistance (Junction to Ambient)	TO-252	θ_{JA}	50 °C/W
	TO-263		30 °C/W
	TO-220		25 °C/W

Electrical Specifications

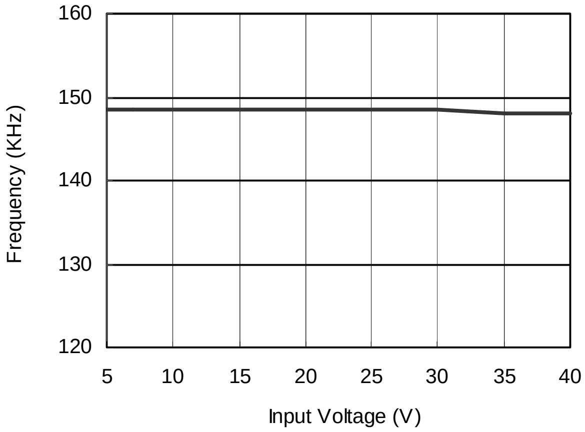
I_{LOAD}=500mA, V_{IN}=12V for the 3.3V, 5V, and adjustable version, unless otherwise noted. The **boldface type** denotes specifications which apply over the full operating temperature range, otherwise specifications are T_A=25ºC.

Parameter	Test Condition		Min.	Typ.	Max.	Units
Feedback Voltage	ADJ. Version	V_{OUT}+3V ≦ V_{IN} ≦ 40V I_{LOAD} = 0.2A ~ 3A For Adjustable version, V_{OUT} set to 3V	1.193	1.23	1.267	V
			1.18		**1.28**	
Output Voltage	Fixed 3.3V		3.168	3.3	3.432	
			3.135		**3.465**	
	Fixed 5.0V		4.8	5	5.2	
			4.75		**5.25**	
Efficiency	ADJ. Version	I_{LOAD}=3A For Adjustable version, V_{OUT} set to 3V		76		%
	Fixed 3.3V			78		
	Fixed 5.0V			81		
Oscillation Frequency			127	150	173	KHz
			110		**173**	
Duty Cycle	V_{FB}=0V			100		%
	V_{FB}=12V			0		
Switch Saturation Voltage	I_{OUT}=3A, V_{FB}=0V without external circuit			1.16	1.4	V
					1.5	
Current Limit	V_{FB}=0V without external circuit			5		A
SW Pin Leakage Current	V_{SW}=0V	V_{IN}=40V, V_{FB}=12V without external circuit			50	uA
	V_{SW}=-1V				30	mA
Quiescent Current	V_{FB}=12V			5	10	mA
Shutdown Current	V_{SD}=5V, V_{IN}=40V			85	200	uA
					250	
SD Pin Input Threshold Voltage	Regulator ON			1.3	0.6	V
	Regulator OFF		2.0			
SD Pin Bias Current	Regulator ON				5	uA
	Regulator OFF				15	
FB Pin Bias Current	ADJ. Version	V_{FB}=1.3V		40	100	nA
Over Temperature Shutdown				140		℃
Over Temperature Shutdown Hysteresis				15		℃

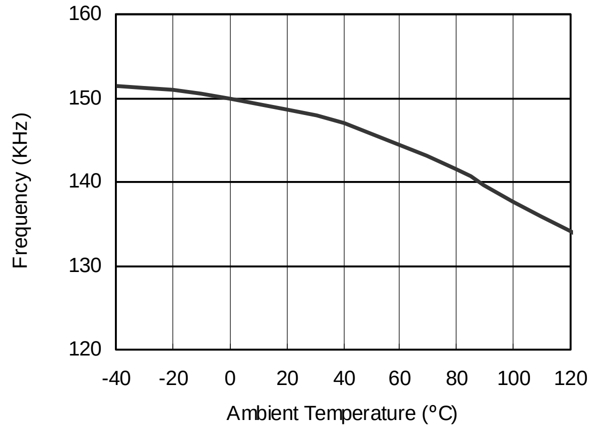
Typical Performance Characteristics

V_{IN}=12V, T_A=25ºC, unless otherwise noted.

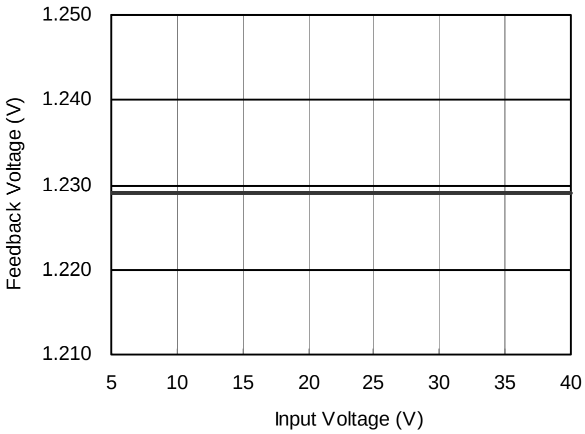
Frequency vs. Input Voltage



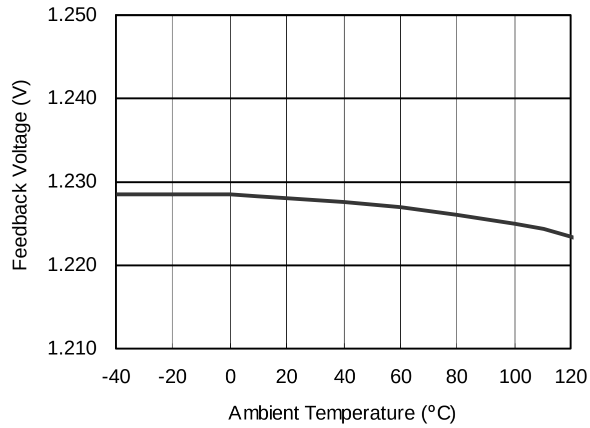
Frequency vs. Temperature



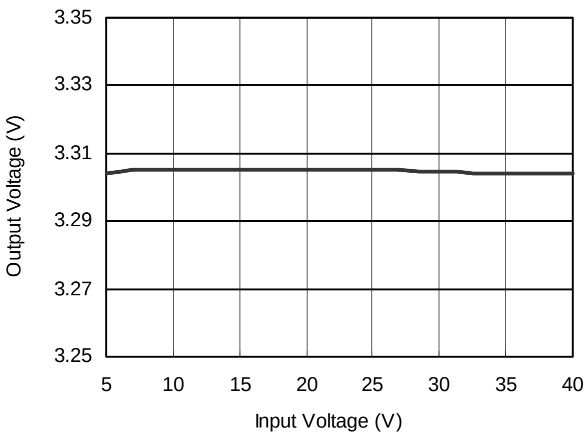
Feedback Voltage vs. Input Voltage



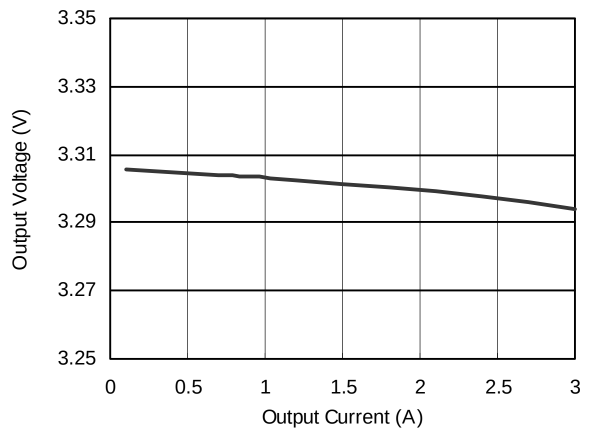
Feedback Voltage vs. Temperature



Line Regulation

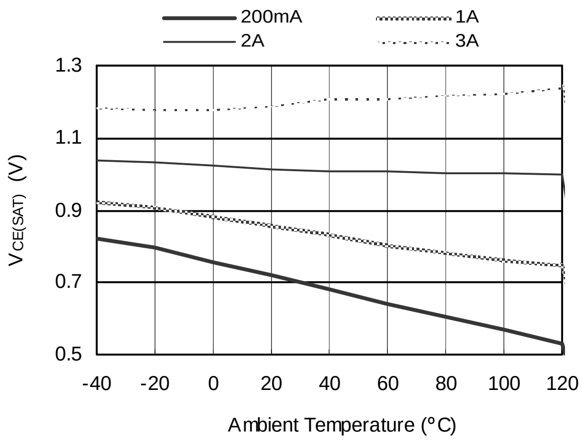


Load Regulation

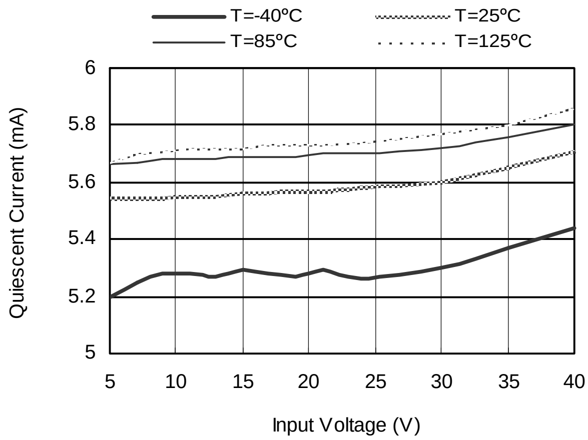


Typical Performance Characteristics (Contd.)

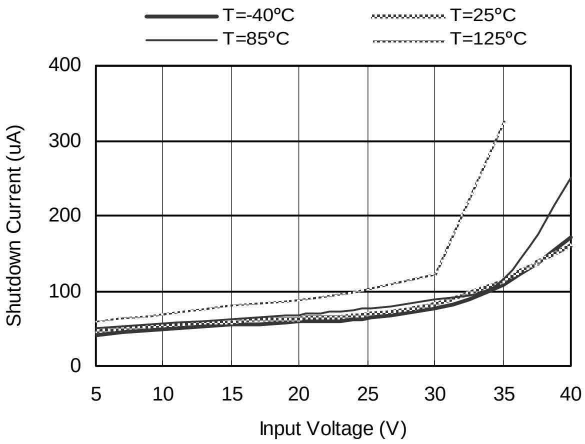
Saturation Voltage vs. Temperature



Quiescent Current vs. Input Voltage



Shutdown Current vs. Input Voltage



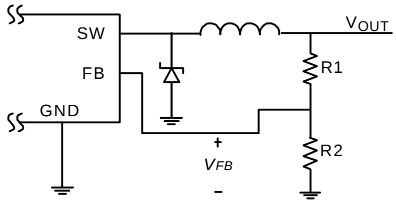
Application Information

Output Voltage Programming

LA8542 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 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:

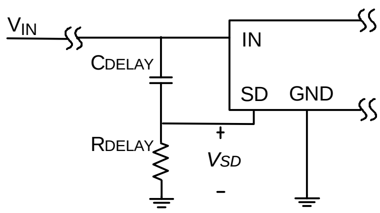
$$V_{OUT} = V_{FB} \times (1 + R1 / R2) \quad \text{where } V_{FB} = 1.23V$$



For the fixed version, R1 and R2 are integrated into the device.

Delay Start-up

The following circuit uses the SD 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 SD pin high, keeping the device off. Once the capacitor voltage rises and the voltage of R_{DELAY} below the SD pin threshold voltage, the device will start to operate. The start-up delay time can be calculated by the following formula:



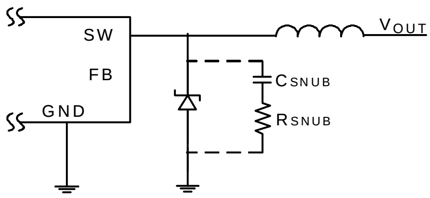
$$V_{IN} \times (e^{-T/(RxC)}) < V_{SD}$$

Where T is the start-up delay time, R is R_{DELAY}, C is C_{DELAY}, and the typical V_{SD} is 1.3V.

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

Thermal protection limits total power dissipation in this device. When the junction temperature reaches approximately 140°C, the thermal sensor signals the shutdown logic turning off this device. The thermal sensor will turn this device on again after the IC's junction temperature cools by approximately 15°C. 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:

$$P_D = I_{LOAD} \times V_{SAT} \times \frac{V_{OUT}}{V_{IN}} + \frac{1}{2} \times V_{IN} \times I_{OUT} \times (t_r + t_f) \times f_S + V_{IN} \times I_Q$$

Where fs is the 150KHz switching frequency, (tr+tf) is the switching time, and I_Q is the 5mA supply current.

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 that consists of the IN trace, the SW trace, the external inductor and the GND trace should be kept wide and as short as possible.
(2) The power discharge path that consists of the SW trace, the external inductor, the rectifier diode and the GND trace should be kept wide and as short as possible.
(3) The feedback path of voltage divider should be close to the FB pin and keep noisy traces away; also keep them separate using grounded copper.
(4) The input capacitors should be close to the regulator and rectifier diode.
(5) The output capacitors should be close to the load.

Component Selection

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:

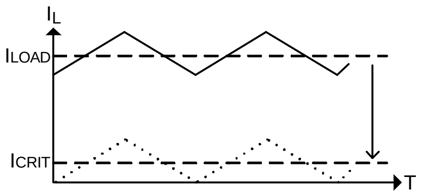
$$D_{(MIN)} = \frac{V_{OUT} + I_{LOAD} \times DCR + V_F}{V_{IN(MAX)} - V_{SAT} + V_F} = \frac{T_{ON}}{T_S}$$

Where DCR is the DC resistance of the inductor, V_F is the forward voltage of the rectifier diode, and Ts is the switching period.

This formula can be simplified as below:

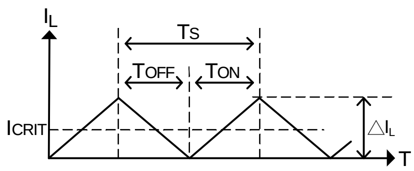
$$D_{(MIN)} = \frac{V_{OUT}}{V_{IN(MAX)}} = \frac{T_{ON}}{T_S} \quad ; \quad 0 \leq D \leq 1$$

(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}).



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

(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 $\triangle I_L$.

$$L \geq \frac{[V_{IN(MAX)} - I_{LOAD} \times DCR - V_{SAT} - V_{OUT}] \times D_{(MIN)}}{\Delta I_L \times fs}$$

This formula can be simplified to

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

The higher inductance results in lower output ripple current and ripple voltage. But it 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:

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

Rectifier Diode Selection

The rectifier diode provides a current path for the inductor current when the internal power MOSFET turns off. The best solution is Schottky diode, and some parameters about the diode must be take care as below:

(1) The forward current rating must be higher than the continuous output current.

(2) The reverse voltage rating must be higher than the maximum input voltage.

(3) The lower forward voltage will reduce the conduction loss.

(4) The faster reverse recovery time will reduce the switching loss, but it is very small compared to conduction loss.

(5) The power dissipation can be calculated by the forward voltage and output current for the time that the diode is conducting.

$$P_{D\_DIODE} = I_{LOAD} \times V_F \times (1 - D)$$

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.

The ESR of the aluminum electrolytic or the tantalum capacitor is an important parameter to determine the output ripple voltage. But the manufacturers usually do not specify ESR in the specifications. Assuming the capacitance is enough results in the output ripple voltage that due to the capacitance can be ignored, the ESR should be limited to achieve the expectative output ripple voltage. The maximum ESR can be calculated as below:

$$ESR\_COUT \le \frac{\Delta V_{OUT}}{\Delta I_L}$$

Choose the output capacitance by the average value of the RC product as below:

$$C_{OUT} \approx \frac{50 \sim 80 \times 10^{-6}}{ESR\_COUT}$$

The capacitors' ESR and ripple current result in power dissipation that will increase the internal temperature. Usually, the capacitors' manufacturers specify ripple current ratings and should not be exceeded to prevent excessive temperature shorten the life time. Choose a smaller inductor causes higher ripple current which maybe result in the capacitor overstress. The RMS ripple current flowing through the output capacitor and power dissipation can be calculated as below:

$$I_{RMS}\_COUT = \frac{\Delta I_L}{\sqrt{12}} = \Delta I_L \times 0.289$$

$$P_D\_COUT = (I_{RMS}\_COUT)^2 \times ESR\_COUT$$

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.

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:

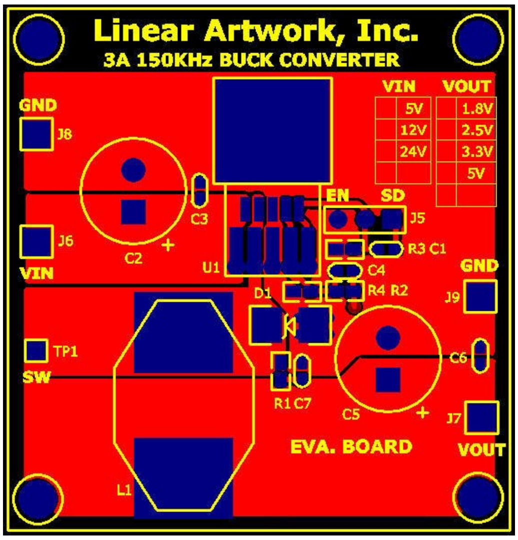
$$C_{IN} = \frac{I_{LOAD(MAX)} \times D \times (1 - D)}{fs \times (\Delta V_{IN} - I_{LOAD(MAX)} \times ESR\_{CIN})}$$

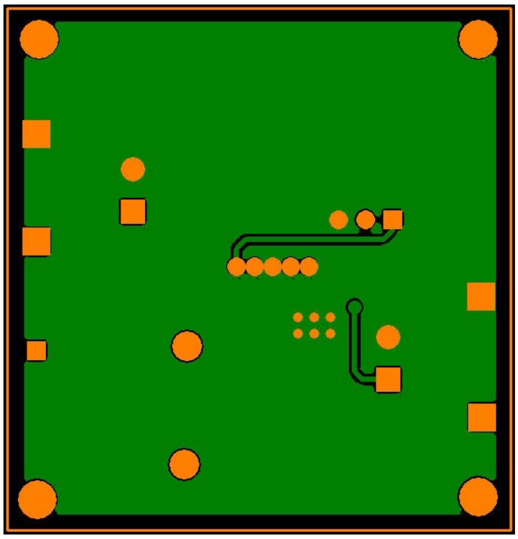
If using aluminum electrolytic or tantalum input capacitors, parallel connecting 0.1uF bypass capacitor as close to the regulator as possible. If using ceramic capacitor, make sure the capacitance is enough to prevent the excessive input ripple current.

The power dissipation of input capacitor causes a small conduction loss can be calculated as below:

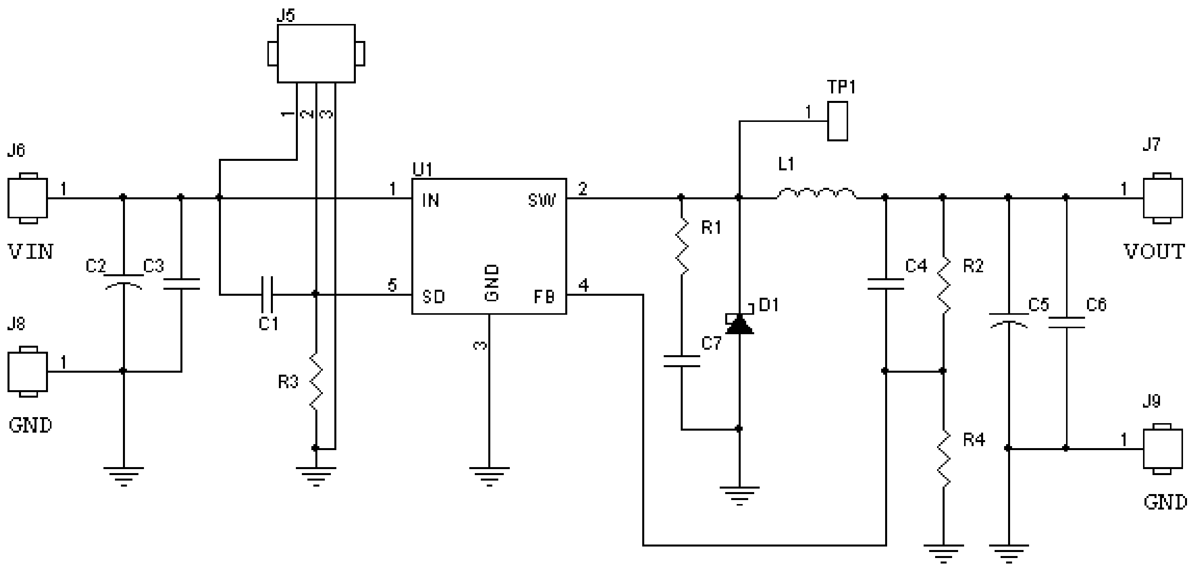
$$P_{D\_CIN} = (I_{RMS\_CIN})^2 \times ESR_{\_CIN}$$

Evaluation Board Layout





Evaluation Board Schematic



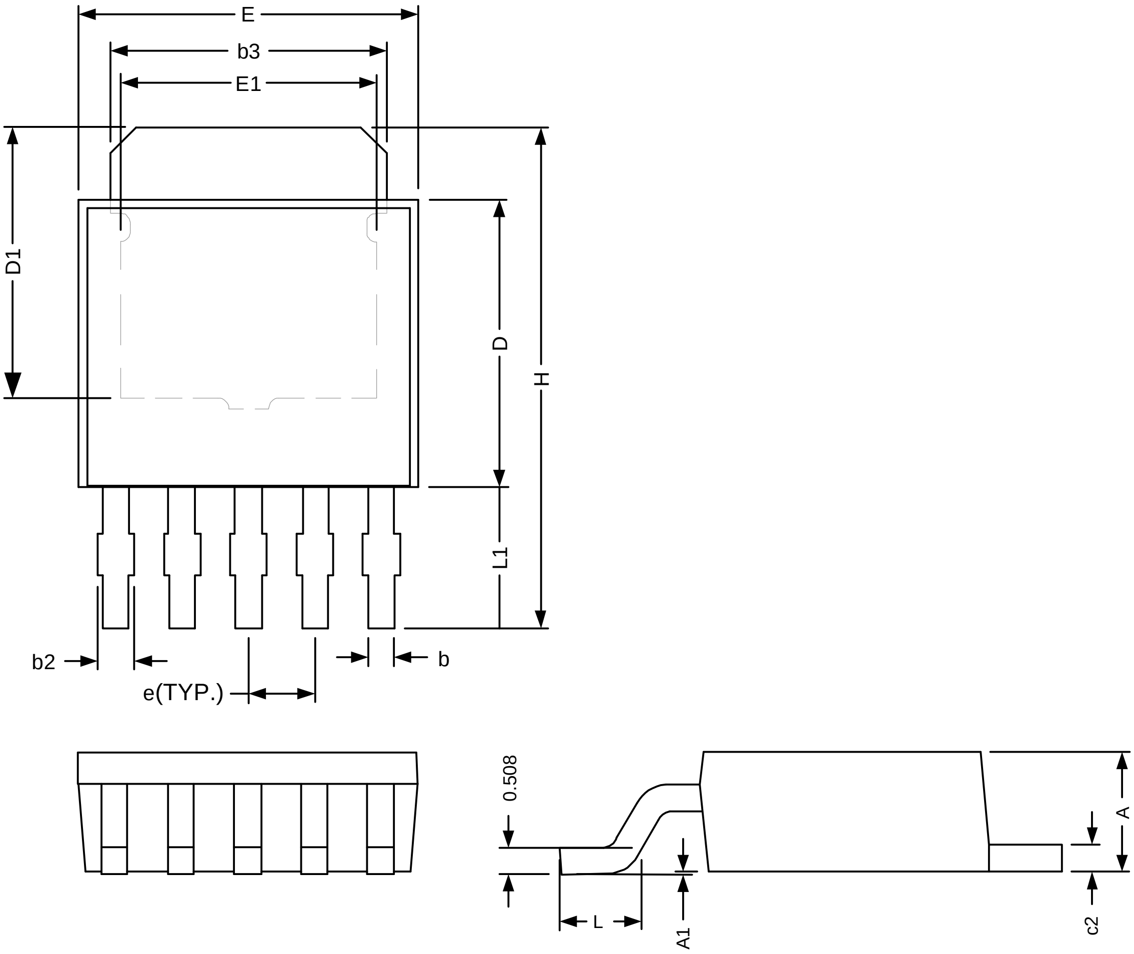
Bill of Materials

Fixed Output Version; V_{IN}=12V, V_{OUT}=3.3V, I_{OUT}=3A

Designation	Descriptions	Manufacturer Part #	Manufacturer	Manufacturer Website
U1	150KHz, 3A Step-Down DC-DC Converter TO-263-5 Package	LA8542HD33	Linear Artwork	www.linear-artwork.com
L1	Choke 33uH, 5A, 0.025Ohm	744151	WE	www.we-online.com
	Choke 33uH, 5.5A, 0.029Ohm	TDH1920T-330K-N	Chilisin	www.chilisin.com.tw
D1	Schottky 40V, 3A, 0.5V_F, SMB Package	SS34B	Tiptek	www.tip-tek.com.tw
C2,C5	Low ESR E/C 470uF, 25V, 10x16mm	EKY-250EXX471MJ16S	NCC	www.chemi-con.co.jp
	Low ESR E/C 470uF, 25V, 10x16mm	WLR471M1EG16	Jamicon	www.jamicon.com.tw
C3,C6	MLCC 0.1uF, 0805, X7R, 50V	UMK212BJ104KG	Taiyo Yuden	www.yuden.co.jp
	MLCC 0.1uF, 0603, B, 50V	C1608JB1H104K	TDK	www.tdk.com
C1,C7,R1,R3	Optional Parts			
C4,R4	No Connection			
R2	Short			
J5	Male Header 180° 3*1P 2.54mm			
J6,J7,J8,J9	Terminal Binding Post 1.6mm			
TP1	Male Header 180° 1P 2.54mm			

Package Outline

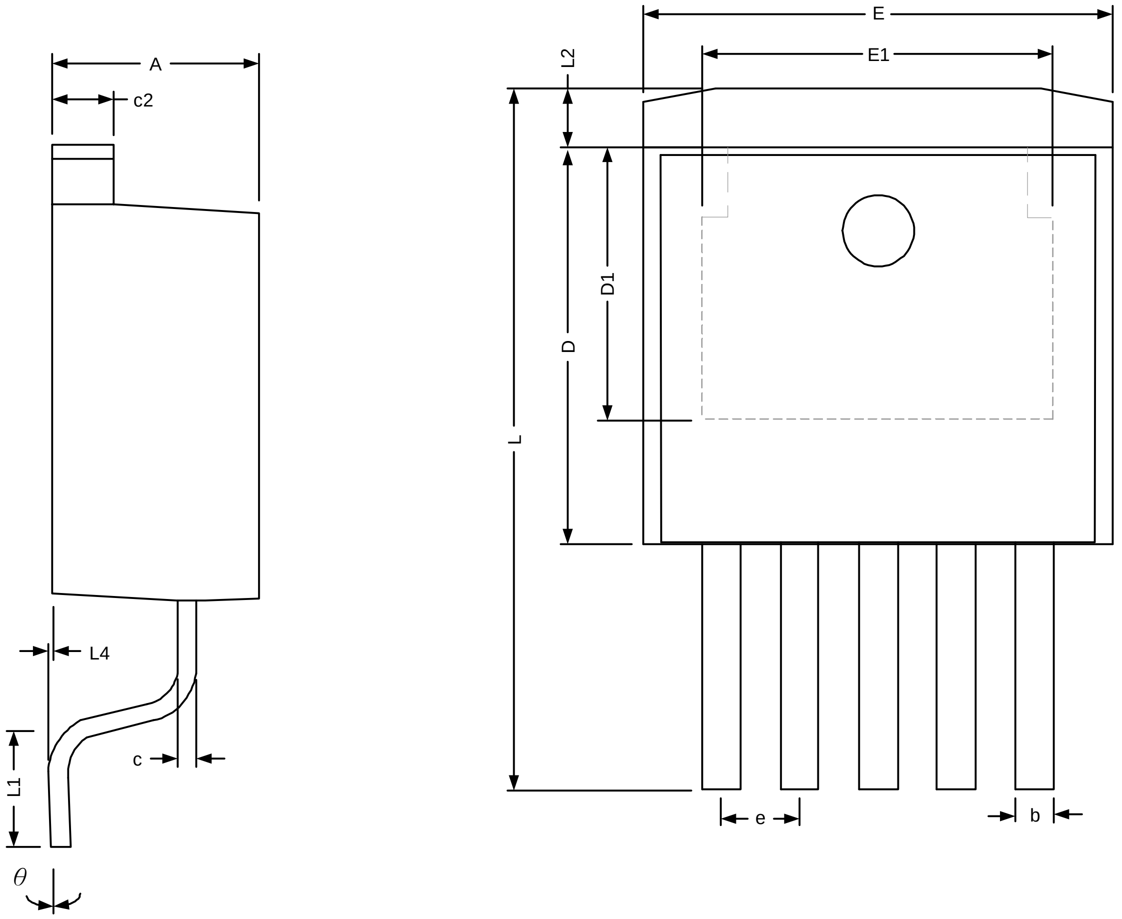
TO-252-5



DIMENSIONS					
REF.	Millimeter		REF.	Millimeter	
	Min.	Max.		Min.	Max.
A	2.20	2.40	D1	4.57	…
A1	0.00	0.15	E	6.35	6.73
b	0.45	0.60	E1	3.81	…
b2	0.50	0.80	e	1.27 REF.	
b3	5.21	5.46	H	9.40	10.20
c2	0.46	0.58	L	1.40	1.77
D	5.40	5.59	L1	2.40	3.00

Package Outline (Contd.)

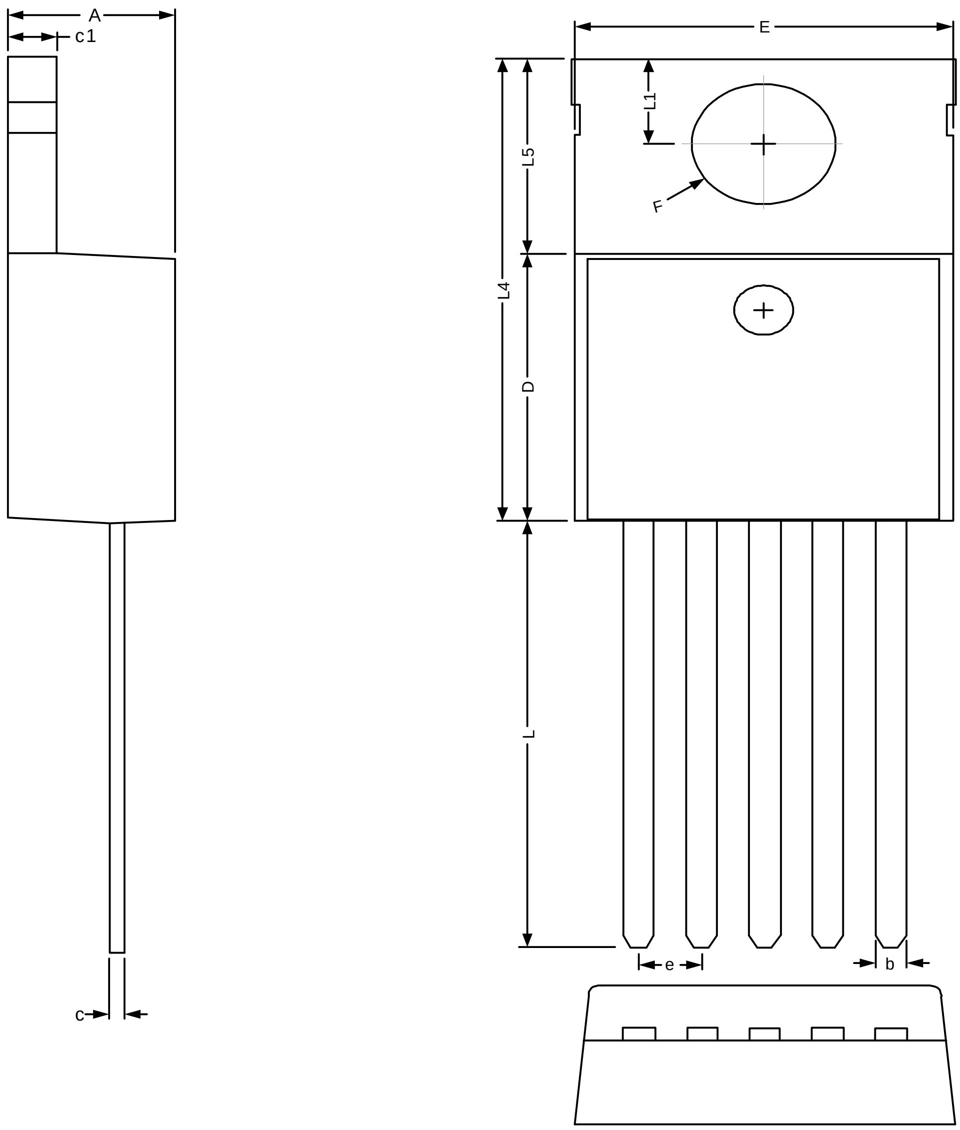
TO-263-5



DIMENSIONS					
REF.	Millimeter		REF.	Millimeter	
	Min.	Max.		Min.	Max.
A	4.40	4.80	c2	1.25	1.45
b	0.66	0.91	L2	1.27 REF.	
L4	0.00	0.30	D	8.60	9.00
c	0.36	0.50	D1	5.90 REF.	
L1	2.29	2.79	e	1.70 REF.	
E	9.80	10.40	L2	14.60	15.80
E1	7.60 REF.		θ	0°	8°

Package Outline (Contd.)

TO-220-5



DIMENSIONS					
REF.	Millimeter		REF.	Millimeter	
	Min.	Max.		Min.	Max.
A	4.40	4.80	c1	1.25	1.45
b	0.76	1.00	L5	6.20	6.60
D	8.60	9.00	L	13.25	14.25
c	0.36	0.50	e	1.70 REF.	
E	9.80	10.40	L1	2.60	2.89
L4	14.70	15.30	F	3.71	3.96

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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.

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