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# LA5735MC

Monolithic Linear IC

## Separately-Excited Step-Down Switching Regulator (Variable Type)

### Overview

The LA5735MC is a separately-excited step-down switching regulator (variable type).

### Functions

- Time-base generator (300kHz) incorporated.
- Current limiter incorporated.
- Thermal shutdown circuit incorporated.

### Specifications

#### Absolute Maximum Ratings at $T_a = 25^\circ\text{C}$

Parameter	Symbol	Conditions	Ratings	Unit
Input voltage	$V_{IN}$		34	V
SW pin application reverse voltage	$V_{SW}$		-1	V
VOS pin application voltage	$V_{VOS}$		-0.2 to 7	V
Allowable power dissipation	$P_d \text{ max}$	Mounted on a circuit board.*	0.75	W
Operating temperature	$T_{opr}$		-30 to +125	$^\circ\text{C}$
Storage temperature	$T_{stg}$		-40 to +150	$^\circ\text{C}$
Junction temperature	$T_{jmax}$		150	$^\circ\text{C}$

\* Specified circuit board : 114.3×76.1×1.6mm<sup>3</sup>, glass epoxy board.

Caution 1) Absolute maximum ratings represent the value which cannot be exceeded for any length of time.

Caution 2) Even when the device is used within the range of absolute maximum ratings, as a result of continuous usage under high temperature, high current, high voltage, or drastic temperature change, the reliability of the IC may be degraded. Please contact us for the further details.

Stresses exceeding Maximum Ratings may damage the device. Maximum Ratings are stress ratings only. Functional operation above the Recommended Operating Conditions is not implied. Extended exposure to stresses above the Recommended Operating Conditions may affect device reliability.

#### Recommended Operating Conditions at $T_a = 25^\circ\text{C}$

Parameter	Symbol	Conditions	Ratings	Unit
Input voltage range	$V_{IN}$		4.5 to 32	V

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**Electrical Characteristics** at  $T_a = 25^\circ\text{C}$ ,  $V_{\text{IN}} = 15\text{V}$

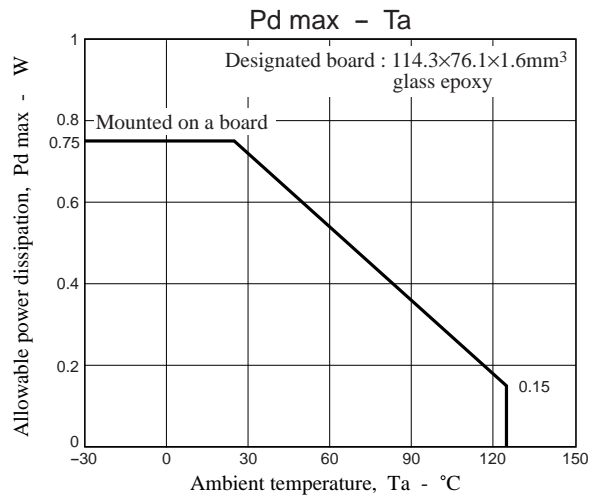
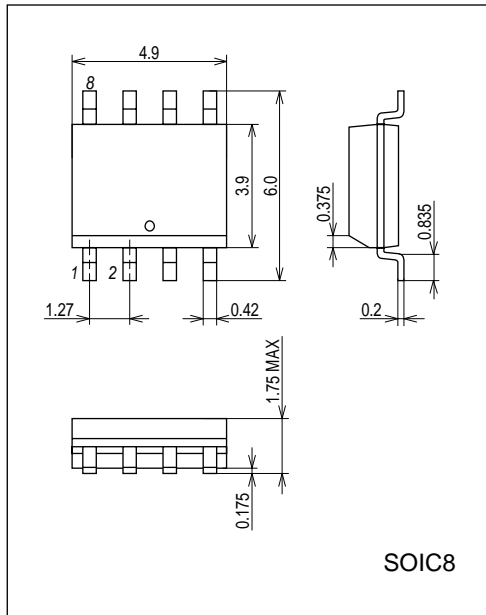
Parameter	Symbol	Conditions	Ratings			Unit
			min	typ	max	
Reference voltage	$V_{\text{OS}}$	$I_{\text{O}} = 0.3\text{A}$	1.20	1.23	1.26	V
Reference pin bias current	$I_{\text{FB}}$			1	2	$\mu\text{A}$
Switching frequency	$f_{\text{osc}}$		240	300	360	kHz
Short-circuit protection circuit operating switching frequency	$f_{\text{scp}}$			15		kHz
Saturation voltage	$V_{\text{sat}}$	$I_{\text{OUT}} = 0.3\text{A}$ , $V_{\text{OS}} = 0\text{V}$		1	1.15	V
Maximum on duty	D max	$V_{\text{OS}} = 0\text{V}$		100		%
Minimum on duty	D min	$V_{\text{OS}} = 5\text{V}$		0		%
Output leakage current	$I_{\text{lk}}$	$\text{SW}_{\text{OUT}} = -0.4\text{V}$			200	$\mu\text{A}$
Supply current	$I_{\text{in}}$	$V_{\text{OS}} = 2\text{V}$		5	10	mA
Current limiter operating current	$I_{\text{S}}$		0.7			A
Thermal shutdown operating temperature	TSD	Designed target value. *		165		$^\circ\text{C}$
Thermal shutdown Hysteresis width	$\Delta\text{TSD}$	Designed target value. *		15		$^\circ\text{C}$

\* Design target value : Design guarantee values are replaced with electrical measurements, and are not measured by temperature.

## Package Dimensions

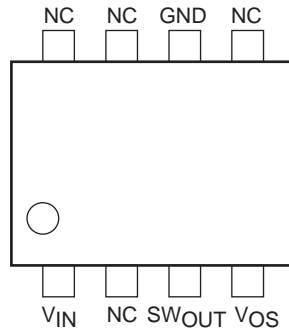
unit : mm (typ)

3424

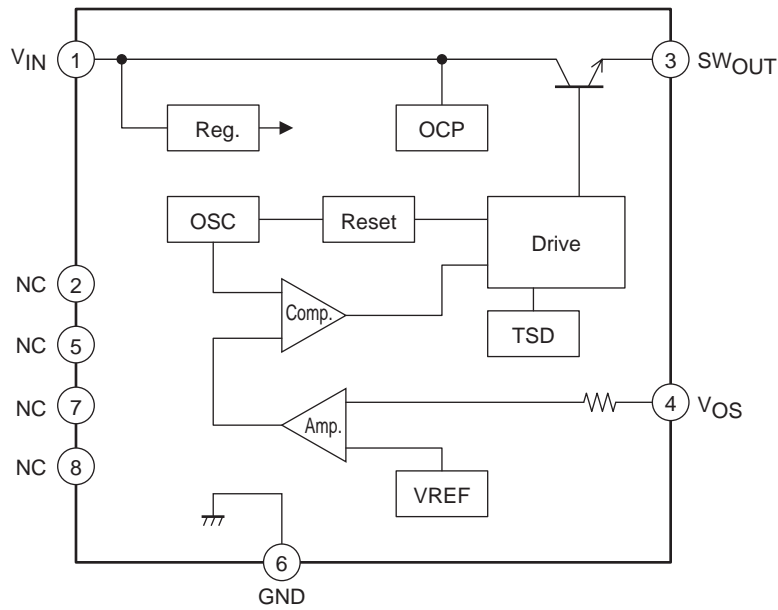


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## Pin Assignment

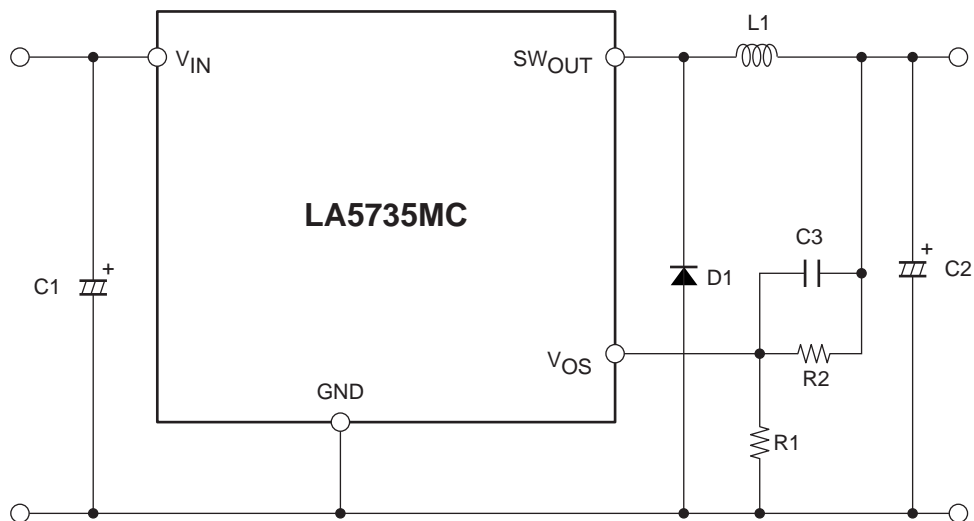


## Block Diagram



Note : Since the NC pins are not connected within the IC package, they can be used as connection points.

## Application Circuit Example

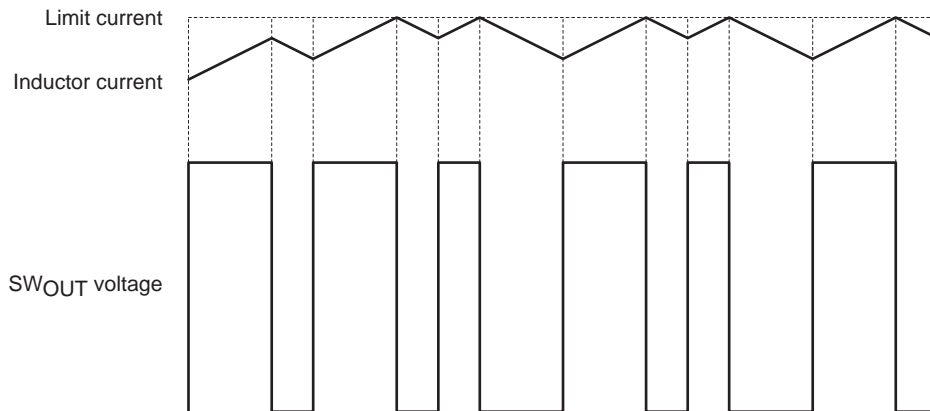


Note: In some cases, the output may not turn on if power is applied when a load is connected. If this is a problem, increase the value of the inductor.

**Protection Circuit Functional Descriptions**

1. Overcurrent protection function

The overcurrent protection function detects, on a pulse-by-pulse basis, the output transistor current and turns off that output transistor current if it exceeds 0.7A in a pulse-by-pulse manner.

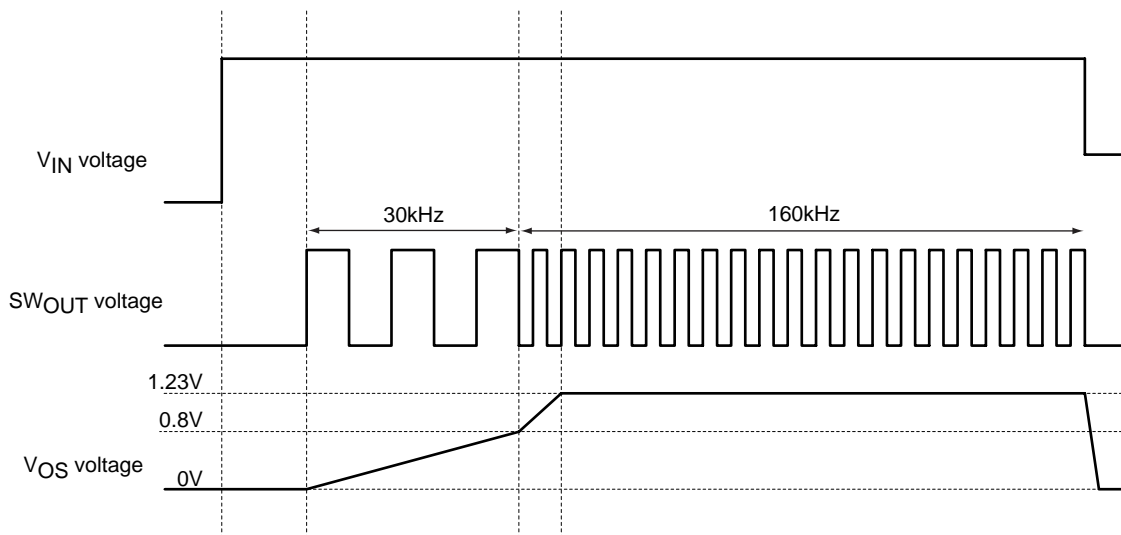


2. Short circuit protection function

This IC prevents the current from increasing when the outputs are shorted by setting the switching frequency to 15kHz if the V<sub>OS</sub> pin voltage falls below 0.8V.

Note : At startup, since the switching frequency will be 15kHz while the V<sub>OS</sub> pin voltage is 0.8V or lower, the current capacity is reduced. If the load is applied at startup and the applications has trouble starting, increase the value of the inductor to resolve this problem.

**Timing Chart**



**Part selection and set**

1. Resistors R1 and R2

R1 and R2 are resistors to set the output voltage. When the large resistance value is set, the error of set voltage increases due to the V<sub>OS</sub> pin current. The output voltage may also increase due to the leak current of switching transistor at light load. In consequence, it is essential to set R1 and R2 current to around 500μA.

$$R1 = \frac{1.23V}{500\mu A} \approx 2.4k\Omega \quad \text{We recommend values in the range 2.0 to 2.4k}\Omega$$

$$R2 = \frac{V_{OUT}}{1.23V} - 1 \times R1$$

The following equation gives the output voltage set by R1 and R2.

$$V_O = \left(1 + \frac{R2}{R1}\right) \times 1.23V \text{ (typ)}$$

2. Capacitor C1, C2 and C3

The large ripple current flows through C1 and C2, so that the high-frequency low-impedance product for switching power supply must be used. Do not use, for C2, a capacitor with extremely small equivalent series resistance (ESR), such as ceramic capacitor, tantalum capacitor. Otherwise, the output waveform may develop abnormal oscillation. The C2 capacitance and ESR value stabilization conditions are as follows:

$$\frac{1}{2 \times \pi \times C2 \times ESR} \leq 20kHz$$

C3 is a capacitor for phase compensation of the feedback loop. Abnormal oscillation may occur when the C2 capacitance value is small or the equivalent series resistance is small. In this case, addition of the capacitance of C3 enables phase compensation, contributing to stabilization of power supply.

3. Input capacitor: Effective-value current

The AC ripple currents flowing in the input capacitor is larger than that in the output capacitor. The equation expressing the effective-value current is as follows. Use the capacitor within the rated current range.

$$I_{C1} = \sqrt{\frac{V_{out}}{V_{in}} \left( I_{out}^2 \left( 1 - \frac{V_{out}}{V_{in}} \right) + \frac{1}{12} \times \Delta I_R^2 \right)} \quad [\text{Arms}]$$

4. Output capacitor: Effective-value current

The AC ripple current flowing in the output capacitor is the triangular wave. Therefore, its effective value is obtained from the following equation. Select the output capacitor so that it does not exceed the allowable ripple current value.

$$I_{C2} = \frac{1}{2\sqrt{3}} \times \frac{V_{OUT} (V_{IN} - V_{OUT})}{L \times f_{sw} \times V_{IN}} \quad [\text{Arms}]$$

$$f_{sw} = \text{Switching frequency} \quad 300kHz$$

5. Choke coil L1

Note that choke coil heating due to overload or load shorting may be a problem. The inductance value can be determined from the following equation once the input voltage, output voltage, and current ripple conditions are known. ΔIR indicates the ripple current value.

Reference example : V<sub>IN</sub> = 12V, V<sub>OUT</sub> = 5V, ΔIR = 150mA

$$L = \frac{V_{IN} - V_{OUT} - V_{sat}}{\Delta I_R} \times T_{on}$$

$$= \frac{12 - 5.0 - 1.0}{0.15} \times 1.58 \times 10^{-6}$$

$$\approx 68\mu H$$

$$\left. \begin{aligned} T_{on} &= \frac{T}{((V_{IN} - V_{OUT} - V_{sat}) / (V_{OUT} + V_F)) + 1} \\ T_{off} &= T - T_{on} \\ t &: \text{Switching repetition period} \quad \dots \quad 3.33\mu s \text{ is assumed for the calculation} \\ V_F &: \text{Schottky diode forward voltage} \quad 0.4V \text{ is assumed for the calculation} \end{aligned} \right\}$$

6. Inductance current : peak value

The ripple current peak value must be held within the rated current values for the inductor used. Here, IRP is the ripple current. IRP can be determined from the following equation.

Reference example :  $V_{IN} = 12V$ ,  $V_{OUT} = 5V$ ,  $I_{OUT} = 0.5A$ ,  $L = 68\mu H$

$$\begin{aligned} IRP &= I_{OUT} + \frac{V_{IN} - V_{OUT} - V_{sat}}{2L} \times Ton \\ &= 0.5 + \frac{12 - 5.0 - 1.0}{2 \times 68 \times 10^{-6}} \times 1.58 \times 10^{-6} \\ &\approx 0.57A \end{aligned}$$

7. Inductance current : ripple current value

Here  $\Delta IR$  is the ripple current.  $\Delta IR$  can be determined from the following equation. If the load current becomes less than one half the ripple current, the inductor current will become discontinuous.

$$\begin{aligned} \Delta IR &= \frac{V_{IN} - V_{OUT} - V_{sat}}{L} \times Ton \\ &= \frac{12 - 5.0 - 1.0}{68 \times 10^{-6}} \times 1.58 \times 10^{-6} \\ &\approx 0.15A \end{aligned}$$

8. Diode D1

A Schottky barrier diode must be used for this diode. If a fast recovery diode is used, it is possible that the IC could be destroyed by the applied reverse voltage due to the recovery and the on-state voltage.

9. Diode current: peak current

Applications must be designed so that the peak value of the diode current remains within the rated current of the diode. The peak value of the diode current will be the same current as the peak value of the inductor current.

10. Repetitive peak reverse voltage

Applications must be designed so that the repetitive peak reverse voltage remains within the voltage rating of the diode. Here,  $V_{RRM}$  is the repetitive peak reverse voltage.  $V_{RRM}$  can be determined from the following equation.

$$V_{RRM} \geq V_{CC}$$

Since noise voltage and other terms will be added in actual operation, the voltage handling capacity of the device should be about 1.5 times that given by the above calculation.

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