

Green-Mode PWM Controller with Frequency Swapping and Integrated Protections

Rev. 00

General Description

The LD7538R is built-in with several functions, protection and EMI-improved solution in a tiny package. It takes less components counts or circuit space, especially ideal for those total solutions of low cost.

The implemented functions include low startup current, green-mode power-saving operation, leading-edge blanking of the current sensing and internal slope compensation. It also features more protections like OLP (Over Load Protection) and OVP (Over Voltage Protection) to prevent circuit damage occurred under abnormal conditions.

Furthermore, the Frequency Swapping function is to reduce the noise level and thus helps the power circuit designers to easily deal with the EMI filter design by spending minimum amount of component cost and developing time.

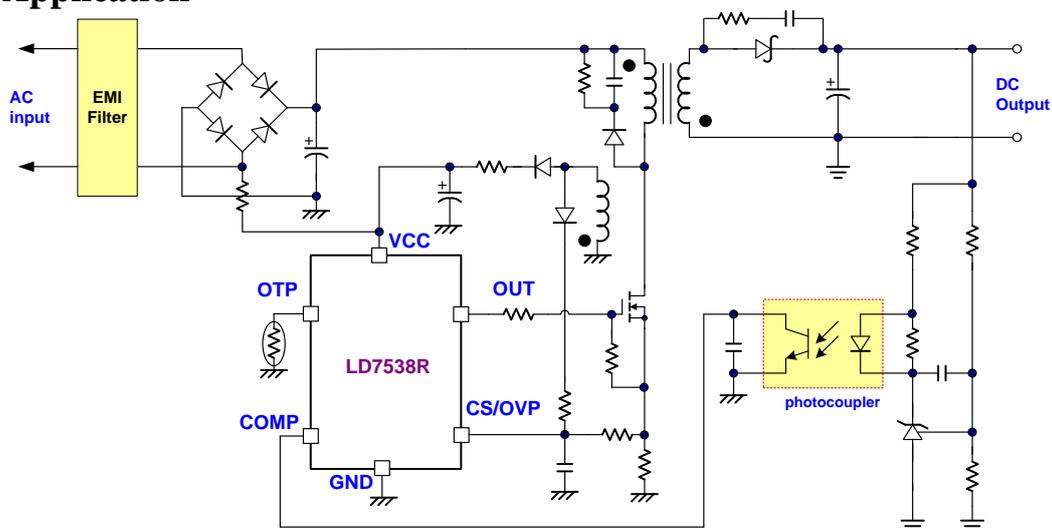
Features

- High-Voltage CMOS Process with Excellent ESD protection
- Very Low Startup Current (<14 μ A)
- Current Mode Control
- Green Mode Control
- UVLO (Under Voltage Lockout)
- LEB (Leading-Edge Blanking) on CS Pin
- Internal Frequency Swapping
- Internal Slope Compensation
- OVP (Over Voltage Protection) on Vcc Pin
- Adjustment OVP(Over Voltage Protection) on CS Pin
- Adjustment OCP(Over Current Protection) on CS Pin
- OTP (Over Temperature Protection) through a NTC
- OLP (Over Load Protection)
- 250/-500mA Driving Capability

Applications

- Switching AC/DC Adaptor and Battery Charger
- Open Frame Switching Power Supply

Typical Application

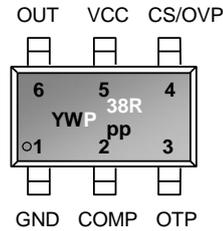


Pin Configuration

DIP-8 (TOP VIEW)



SOT-26 (TOP VIEW)



YY, Y : Year code (D: 2004, E: 2005.....)
 WW, W : Week code
 PP : Production code
 P38R : LD7538R

Ordering Information

Part number	Package	Top Mark	Shipping
LD7538R GL	SOT-26	YWP/38R	3000 /tape & reel
LD7538R GN	DIP-8	LD7538R GN	3600 /tube /Carton

The LD7538R is ROHS compliant/ Green packaged.

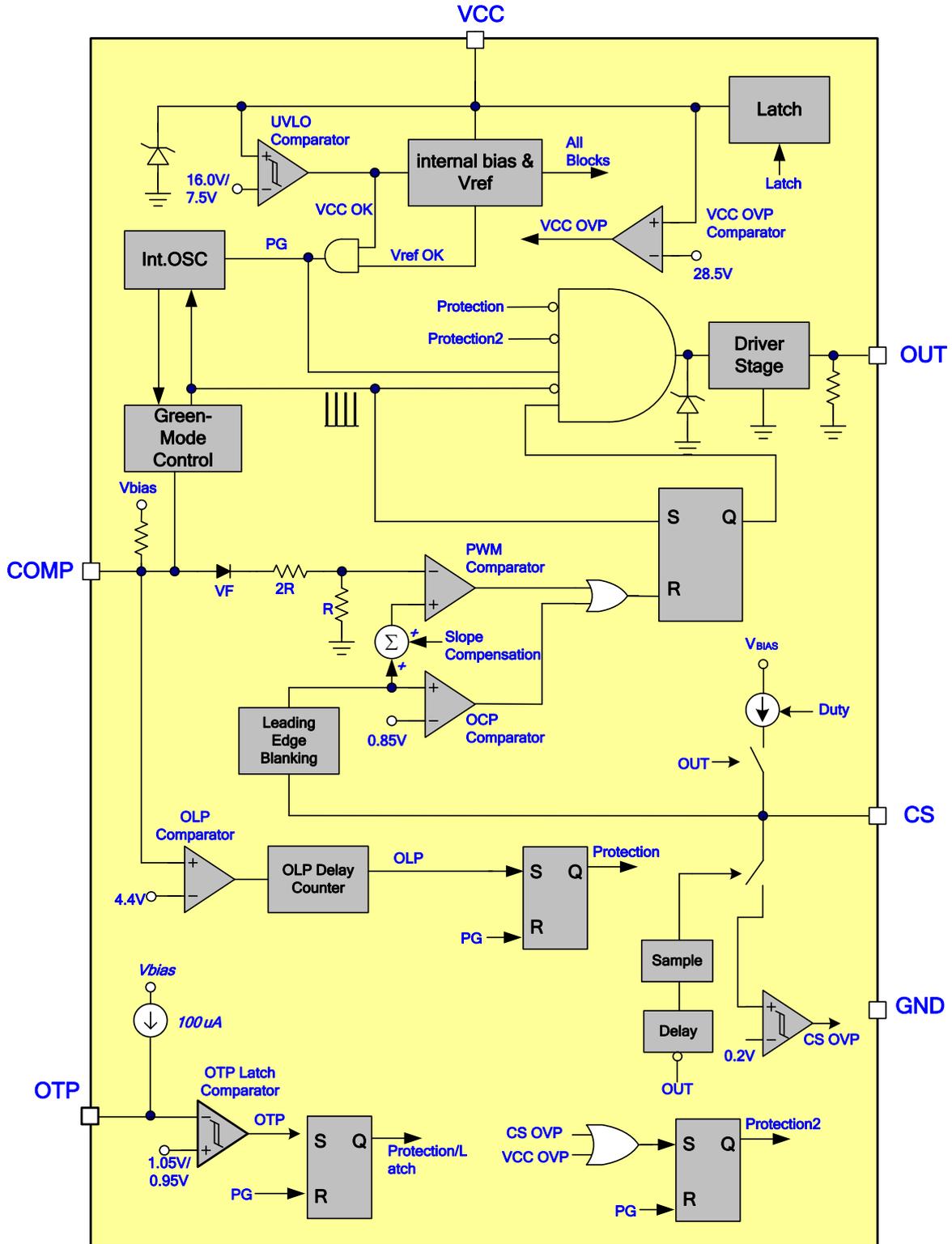
Protection Mode

Switching Freq.	VCC OVP	CS OVP	OLP	OTP Pin
65kHz	Auto recovery	Auto recovery	Auto recovery	Latch

Pin Descriptions

PIN SOT-26	PIN DIP-8	NAME	FUNCTION
1	8	GND	Ground
2	7	COMP	Voltage feedback pin (same as COMP pin of UC384X). Connect a photo-coupler with it to close the control loop and achieve the regulation.
3	5	OTP	Pull this pin below 0.95V to shutdown the controller into latch mode until AC power-on again. Connecting with NTC between this pin and ground will achieve OTP protection. Let this pin float or connect a 100kΩ resistor to disable the latch protection.
4	4	CS/OVP	Current sense pin. Connect it to sense the MOSFET current. This pin is also connected to an auxiliary winding of the PWM transformer through a resistor and a diode for output over-voltage protection.
5	2	VCC	Supply voltage pin
6	1	OUT	Gate drive output to drive the external MOSFET

Block Diagram



Absolute Maximum Ratings

Supply Voltage VCC.....	-0.3V ~29V
COMP, OTP, CS.....	-0.3V ~6V
OUT.....	-0.3V ~Vcc+0.3V
Maximum Junction Temperature.....	150°C
Storage Temperature Range.....	-65°C to 150°C
Package Thermal Resistance (SOT-26, θ_{JA}).....	250°C/W
Package Thermal Resistance (DIP-8, θ_{JA}).....	100°C/W
Power Dissipation (SOT-26, at Ambient Temperature = 85°C).....	160mW
Power Dissipation (DIP-8, at Ambient Temperature = 85°C).....	400mW
Lead temperature (Soldering, 10sec).....	260°C
ESD Voltage Protection, Human Body Model.....	2.5 KV
ESD Voltage Protection, Machine Model.....	250 V

Caution:

Stress 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 stress above Recommended Operating Conditions may affect device reliability.

Recommended Operating Conditions

Item	Min.	Max.	Unit
Operating Ambient Temperature	-40	85	°C
Operating Junction Temperature	-40	125	°C
Supply VCC Voltage	8.5	26.5	V
VCC Capacitor	3.3	10	μF
Start-up resistor Value (AC Side, Half Wave)	400K	1.8M	Ω
Comp Pin Capacitor	1	100	nF
CS Pin Capacitor Value	47	390	pF

Note:

1. It's essential to connect VCC pin with a SMD ceramic capacitor (0.1μF~0.47μF) to filter out the undesired switching noise for stable operation. This capacitor should be placed close to IC pin as possible
2. Connecting a capacitor to COMP pin is also essential to filter out the undesired switching noise for stable operation.
3. The small signal components should be placed to IC pin as possible.

Electrical Characteristics

($T_A = +25^\circ\text{C}$ unless otherwise stated, $V_{CC}=15.0\text{V}$)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Supply Voltage (Vcc Pin)					
Startup Current	$V_{CC} < UVLO$ (ON)		9	14	μA
Operating Current (with 1nF load on OUT pin)	$V_{COMP}=0\text{V}$	0.53	0.65	0.77	mA
	$V_{COMP}=3\text{V}$		1.85		mA
	OLP Tripped/ Auto, OTP=3V		0.52		mA
	OVP Tripped/ Auto, OTP=3V		0.52		mA
	OTP Pin Tripped/ Latch,			0.95	
Holding Current	$V_{CC}=6\text{V}$ (latched)	370	430	490	μA
UVLO (off)		7.0	7.5	8.0	V
UVLO (on)		15	16	17	V
VCC OVP Level		27.5	28.5	29.5	V
VCC OVP pin de-bounce time	*		8		cycle
Voltage Feedback (Comp Pin)					
Short Circuit Current	$V_{COMP}=0\text{V}$	0.105	0.125	0.145	mA
Open Loop Voltage	COMP pin open	4.75	5.0	5.25	V
Green Mode Threshold VCOMP	*		2.4		V
Zero Duty Threshold VCOMP			1.4		V
Zero Duty Hysteresis			100		mV
Current Sensing (CS/OVP pin)					
Maximum Input Voltage, V_{CS_OFF}		0.837	0.85	0.863	V
OCP Compensation Current, I_{OCP}		234	240	246	μA
Leading Edge Blanking Time, LEB		170	230	290	ns
Internal Slope Compensation	*0% to D_{MAX} . (Linearly increase)		300		mV
Input impedance		1			$\text{M}\Omega$
Delay to Output	*		100		ns
Soft Start Duration	*		6.5		ms
Over Voltage Protection (CS/OVP pin)					
OVP Trip Current Level		0.182	0.2	0.218	V
De-bounce Cycle	*		8		Cycle

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Oscillator for Switching Frequency					
Frequency, FREQ		63	65	67	kHz
Green Mode Frequency, FREQG		21.5	25	28	kHz
Frequency Swapping	$V_{COMP} > 3V$		± 4.0		kHz
Temp. Stability	$(-20^{\circ}C \sim 85^{\circ}C)^*$	0	5		%
Voltage Stability	$(V_{CC}=11V-25V)^*$	0	1		%
Gate Drive Output (OUT Pin)					
Output Low Level	$V_{CC}=15V, I_o=20mA$			1	V
Output High Level	$V_{CC}=15V, I_o=20mA$	8		15	V
Output High Clamp Level	$V_{CC}=20V$	13	15	17	V
Rising Time	Load Capacitance=1000pF	--	150	250	ns
Falling Time	Load Capacitance=1000pF		50	100	ns
Max. Duty		71	75	79	%
OLP (Over Load Protection)					
OLP Trip Level		4.2	4.4	4.6	V
OLP Delay Time at start-up	OLP+ soft start*		71.5		ms
OLP Delay Time after start-up		60	65	70	ms
OTP Pin Latch Protection (OTP Pin)					
OTP Pin Source Current		93	100	107	μA
OTP Turn-On Trip Level		1.00	1.05	1.10	V
OTP Turn-Off Trip Level		0.9	0.95	1.0	V
OTP pin de-bounce time	$V_{COMP} > 3V$	400	500	600	μs

*: Guaranteed by design.

Typical Performance Characteristics

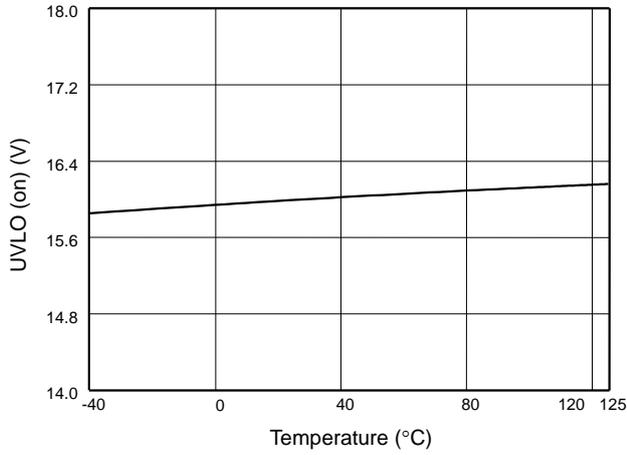


Fig. 1 UVLO (on) vs. Temperature

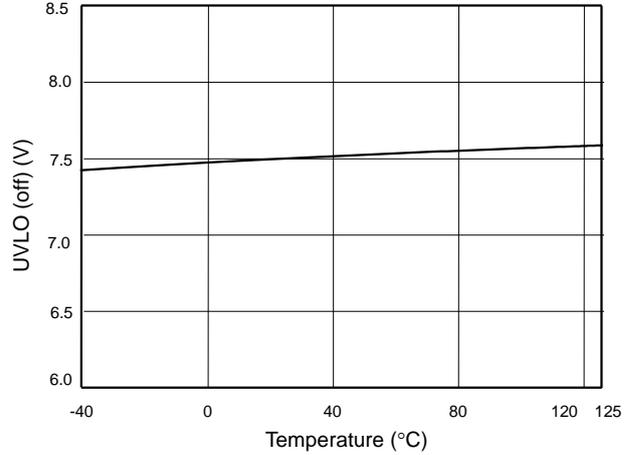


Fig. 2 UVLO (off) vs. Temperature

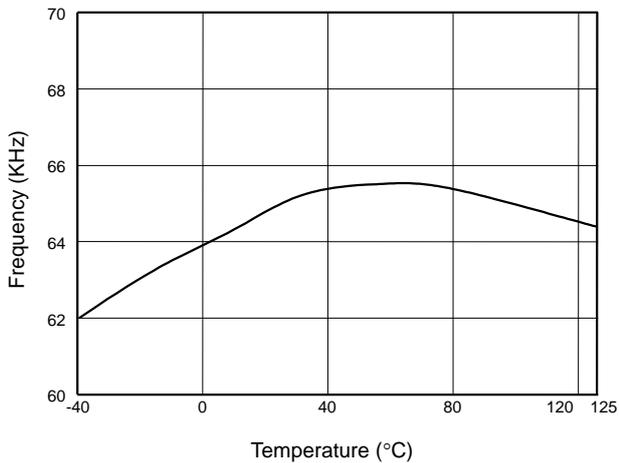


Fig. 3 Frequency vs. Temperature

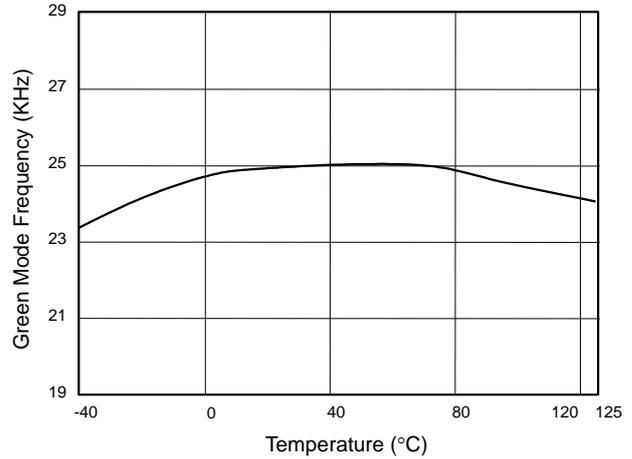


Fig. 4 Green Mode Frequency vs. Temperature

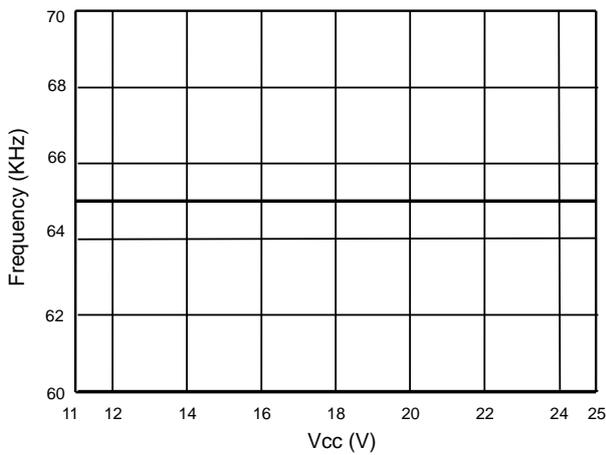


Fig. 5 Frequency vs. Vcc

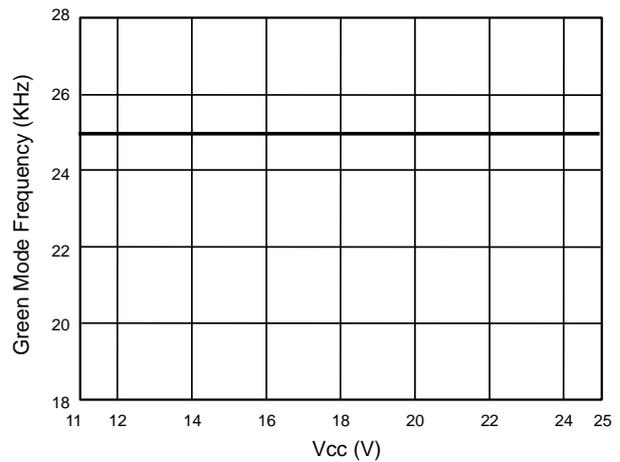


Fig. 6 Green Mode Frequency vs. Vcc

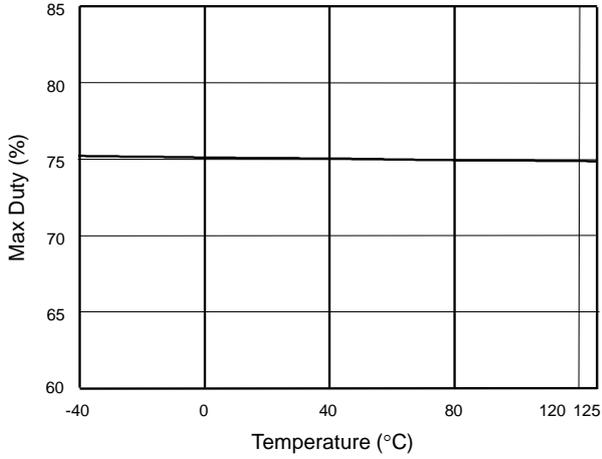


Fig. 7 Max Duty vs. Temperature

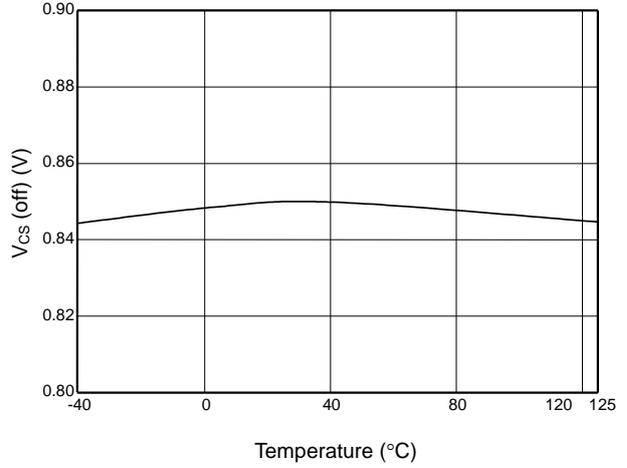


Fig. 8 V_{CS} (off) vs. Temperature

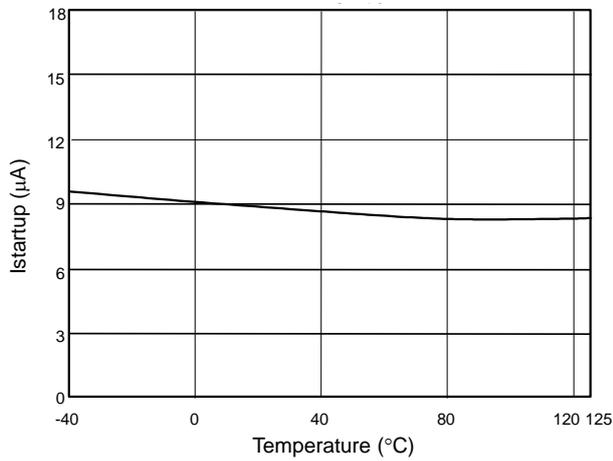


Fig. 9 Startup Current (I_{startup}) vs. Temperature

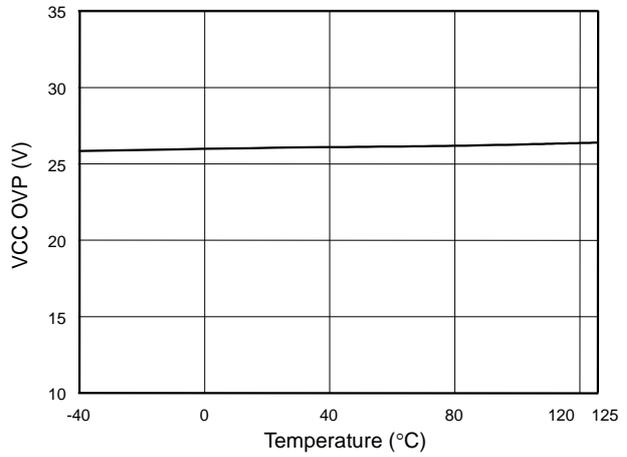


Fig. 10 VCC OVP vs. Temperature

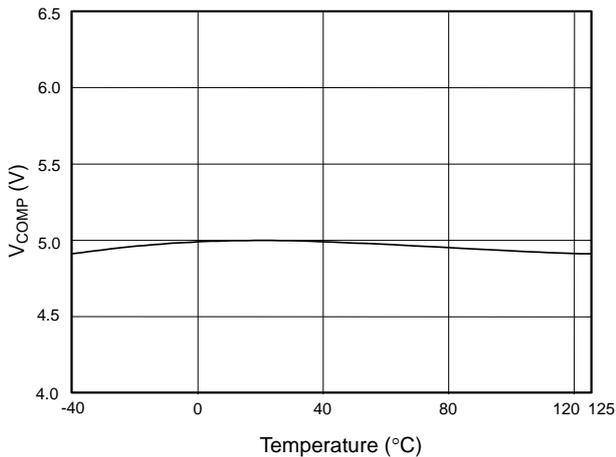


Fig. 11 V_{COMP} open loop voltage vs. Temperature

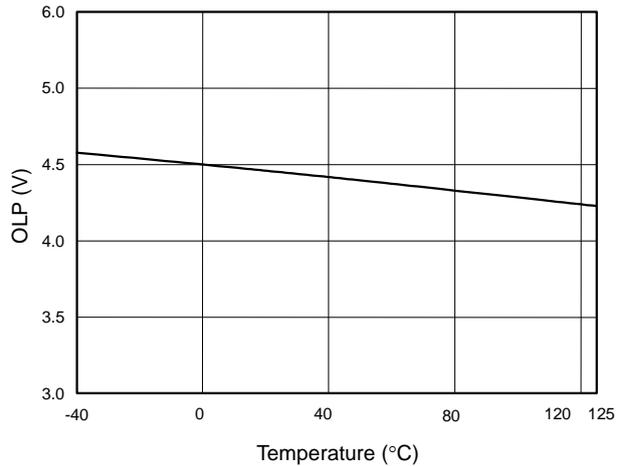


Fig. 12 OLP-Trip Level vs. Temperature

Application Information

Operation Overview

The LD7538R meets the green-power requirement and is intended for the use in those modern switching power suppliers and adaptors which demand higher power efficiency and power-saving. It integrated more functions to reduce the external components counts and the size. Its major features are described as below.

Under Voltage Lockout (UVLO)

An UVLO comparator is implemented in it to detect the voltage on the VCC pin. It would assure the supply voltage enough to turn on the LD7538R PWM controller and further to drive the power MOSFET. As shown in Fig. 13, a hysteresis is built in to prevent the shutdown from the voltage dip during startup.

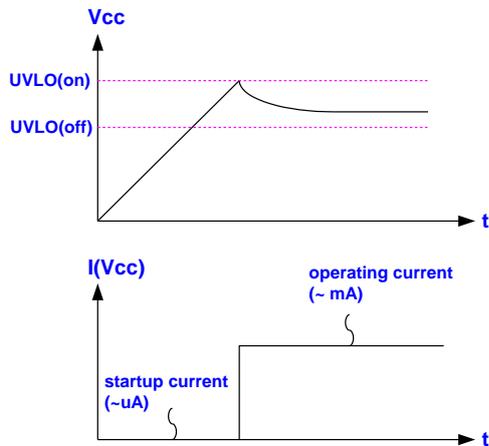


Fig. 13

Startup Current and Startup Circuit

The typical startup circuit to generate V_{CC} of the LD7538R is shown in Fig. 14. During the startup transient, the V_{CC} is below UVLO threshold. Before it has sufficient voltage to develop OUT pulse to drive the power MOSFET, R₁ will provide the startup current to charge the capacitor C₁. Once V_{CC} obtain enough voltage to turn on the LD7538R and further to deliver the gate drive signal, it will enable the auxiliary winding of the transformer to provide supply current. Lower startup current requirement on the PWM

controller will help to increase the value of R₁ and then reduce the power consumption on R₁. By using CMOS process and the special circuit design, the maximum startup current for LD7538R is only 14μA.

If a higher resistance value of the R₁ is chosen, it will usually take more time to start up. To carefully select the value of R₁ and C₁ will optimize the power consumption and startup time.

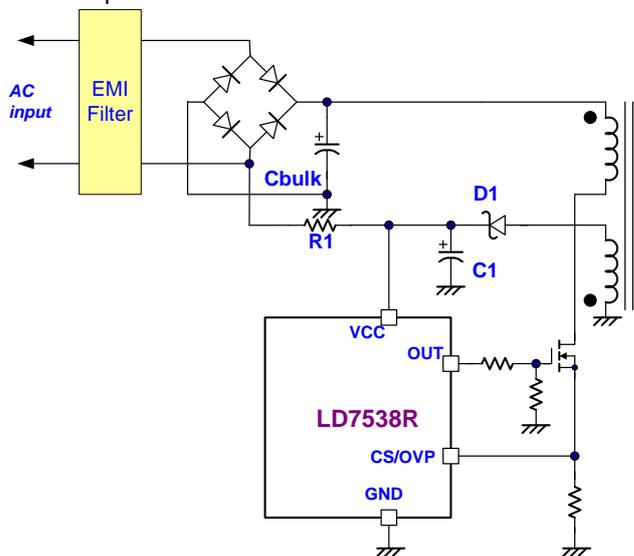


Fig. 14

Current Sensing and Leading-edge Blanking

The typical current mode of PWM controller feedbacks both current signal and voltage signal to close the control loop and achieve regulation. As shown in Fig. 15, the LD7538R detects the primary MOSFET current from the CS pin, which is not only for the peak current mode control but also for the pulse-by-pulse current limit. The maximum voltage threshold of the current sensing pin is set at 0.85V. From above, the MOSFET peak current can be obtained from below.

$$I_{PEAK(MAX)} = \frac{0.85V}{R_S}$$

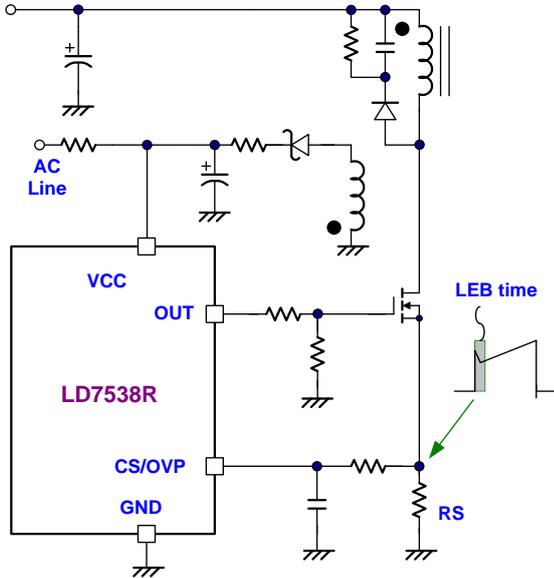


Fig. 15

A leading-edge blanking (LEB) time is included in the input of CS pin to prevent the false-trigger from the current spike.

Output Stage and Maximum Duty-Cycle

An output stage of a CMOS buffer, with typical 250/-500mA driving capability, is incorporated to drive a power MOSFET directly. And the maximum duty-cycle of LD7538R is limited to 75% to avoid the transformer saturation.

Voltage Feedback Loop

The voltage feedback signal is provided from the TL431 at the secondary side through the photo-coupler to the COMP pin of the LD7538R. Similar to UC3842, the LD7538R would carry a diode voltage offset at the stage to feed the voltage divider at the ratio of RA and RB, that is,

$$V_{-(PWM_{COMPARATOR})} = \frac{R}{R + 2R} \times (V_{COMP} - V_F)$$

A pull-high resistor is embedded internally and can be eliminated externally.

Oscillator and Switching Frequency

The LD7538R is implemented with Frequency Swapping function which helps the power supply designers to both optimize EMI performance and lower system cost. The switching frequency substantially centers at 65KHz, and swap between a range of ± 4 KHz.

Green-Mode Operation

By using the green-mode control, the switching frequency can be reduced under the light load condition. This feature helps to improve the efficiency in light load conditions. The green-mode control is Leadtrend Technology's own property. Fig. 16 shows the characteristics of the switching frequency vs. the comp pin voltage (V_{COMP})

On/Off Control

The LD7538R can be turned off by pulling COMP pin lower than 1.4V. The gate output pin of the LD7538R will be disabled immediately under such condition. The off-mode can be released when the pull-low signal is removed.

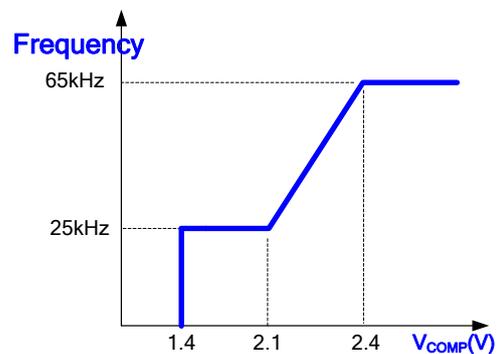


Fig. 16

Internal Slope Compensation

In the conventional applications, the problem of the stability is a critical issue for current mode controlling, when it operates over 50% duty-cycle. As UC384X, It takes slope compensation from injecting the ramp signal of the RT/CT pin through a coupling capacitor. It therefore

requires no extra design for the LD7538R since it has integrated it already.

Adjustable Over Current Compensation (CS/OVP Pin)

In general, the power converter can deliver more current with high input voltage than low input voltage. To compensate this, an offset voltage is added to the CS signal by an internal current source (I_{OCP}) and an external resistor (R_{OCP}) in series between the sense resistor (R_s) and the CS/OVP pin, as shown in Fig. 17. By selecting a proper value of the resistor in series with the CS pin, the amount of compensation can be adjusted. The value of I_{OCP} depends on the duty cycle of OUT pin. The equation of I_{OCP} is decreased as:

$$I_{OCP} = \begin{cases} (0.625 - \text{Duty}) \cdot 480\mu\text{A} & (0.125 < \text{Duty} < 0.625) \\ 0\mu\text{A} & (\text{Duty} \geq 0.625) \\ 240\mu\text{A} & (\text{Duty} \leq 0.125) \end{cases}$$

In light load, this offset is in same level of magnitude as the current sense signal, it shall be canceled. Therefore the compensation current will be fully added once the COMP voltage is above 2.9V.

R_{OCP} : 470Ω~1.2kΩ; C_{OCP} : 47pF~390pF

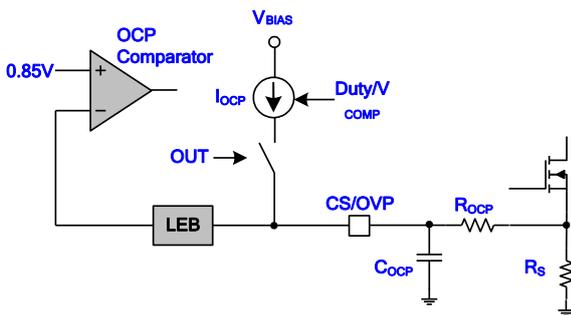


Fig. 17

Output Over Voltage Protection (CS/OVP Pin) - Auto Recovery

An output overvoltage protection is implemented in the LD7538R, as shown in Fig. 18 and 19. The auxiliary winding voltage is reflected to secondary winding and

therefore the flat voltage on the CS/OVP pin is proportional to the output voltage. By sensing the auxiliary voltage via the divided resistors, LD7538R can sample this flat voltage level after some delay time to perform output over-voltage protection. This delay time is used to ignore the voltage ringing from leakage inductance of PWM transformer. The sampling voltage level is compared with internal threshold voltage 0.2V. If the sampling voltage exceeds the OVP trip level, an internal counter starts counting subsequent OVP events. The counter has been added to prevent incorrect OVP detection which might occur during ESD or lightning events. However, if typically 8 cycles of subsequent OVP events are detected, the OVP circuit switches the power MOSFET off until the next UVLO(on).

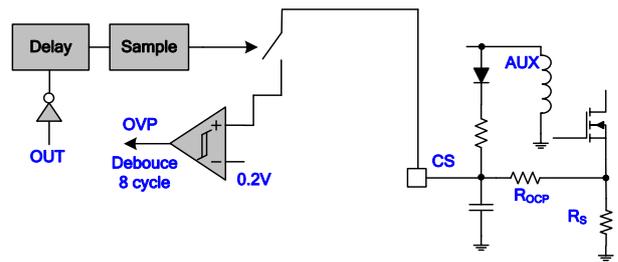


Fig. 18

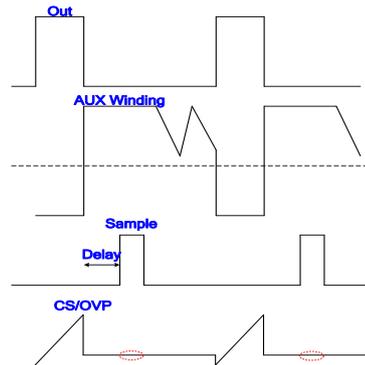


Fig. 19

Over Load Protection (OLP) - Auto Recovery

To protect the circuit from damage due to over-load condition and short or open-loop condition, the LD7538R

is implemented with smart OLP function. It also features auto recovery function; see Fig. 20 for the waveform. In case of fault condition, the feedback system will force the voltage loop toward the saturation and then pull the voltage high on COMP pin (V_{COMP}). When the V_{COMP} ramps up to the OLP threshold of 4.4V and continues over OLP delay time, the protection will be activated and then turn off the gate output to stop the switching of power circuit. With the protection mechanism, the average input power will be minimized to remain the component temperature and stress within the safe operating area.

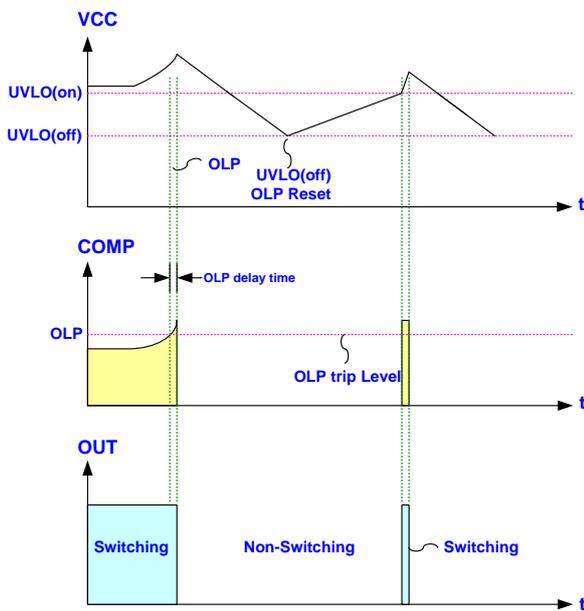


Fig. 20

OVP (Over Voltage Protection) on Vcc - Auto Recovery

The maximum VGS ratings of the power MOSFETs are mostly for 30V. To prevent the VGS enter fault condition, LD7538R is implemented with OVP function on Vcc. Whenever the Vcc voltage is higher than the OVP threshold, the output gate drive circuit will be shutdown simultaneously and the switching of the power MOSFET is disabled until the next UVLO(on). The Vcc OVP functions of LD7538R are auto-recoverable. If the OVP condition, usually caused by open-loop of feedback, is not

released, the Vcc will tripped the OVP level again and re-shutdown the output. The Vcc works in hiccup mode. Figure 21 shows its operation. Otherwise, when the OVP condition is removed, the Vcc level will be resumed and the output will automatically return to the normal operation.

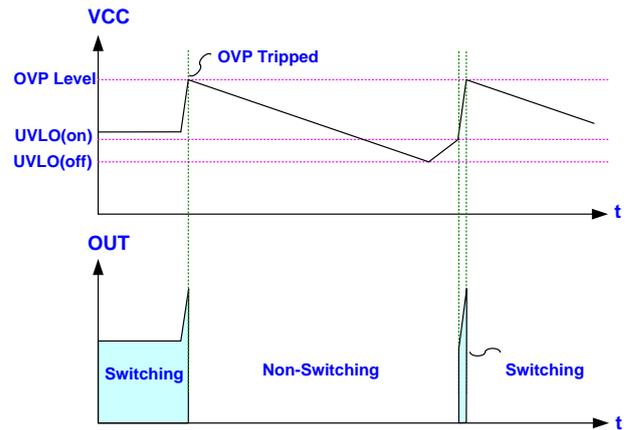


Fig. 21

OTP Pin --- Latched Mode Protection

The OTP circuit is implemented to sense a hot-spot of power circuit like power MOSFET or output rectifier. It can be easily achieved by connecting a NTC with OTP pin of LD7538R. As the device temperature or ambient temperature rises, the resistance of NTC decreases. So, the voltage on the OTP pin could be written as below.

$$V_{OTP} = 100\mu A \cdot R_{NTC}$$

When the V_{OTP} is below the defined voltage threshold (typ. 0.95V), LD7538R will shutdown the gate output and latch off the power supply. There are 2 conditions required to restart it successfully. First, cool down the circuit so that NTC resistance will increase and raise V_{OTP} up above 1.05V. Then, remove the AC power cord and restart AC power-on recycling.

MOSFET Characteristic

The MOSFET is divided into three operation regions, ohmic region, saturation region, and the cut-off region, shown as Fig. 22.

For switching power supply applications, it shall operate in ohmic and cut-off region. Never reach the region of saturation; it would cause damage for acting beyond the maximum safety operating area. It's necessary to check the characteristic of MOSFET.

Fig. 23 shows a totem pole architecture for the circuit of OUT. The output high level of OUT is at around $V_{CC}-1.5V$. Refer to on-region characteristics of the MOSFET, check the saturation current of $V_{GS_{H(MIN)}}$ to make sure the saturation current is high enough to activate MOSFET to operate in ohmic region. In order not to decrease the voltage across VG, it's recommended not to connect a forward diode between the gate of the MOSFET and OUT pin, for example like Fig 24.

In addition, pulling VCC level high can keep $V_{GS_{H}}$ in high level, for example:

1. Increase N_x value to pull VCC level high.
2. Increase VCC capacitance to improve VCC's performance to drop at startup transient, shown as Fig 25.

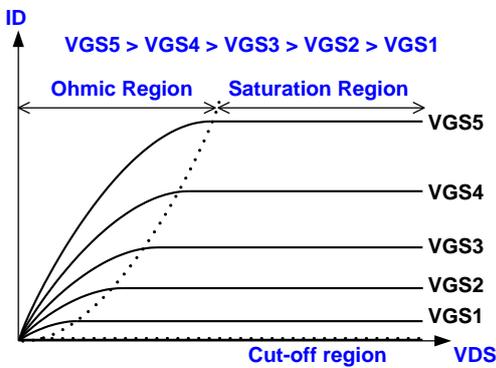


Fig. 22

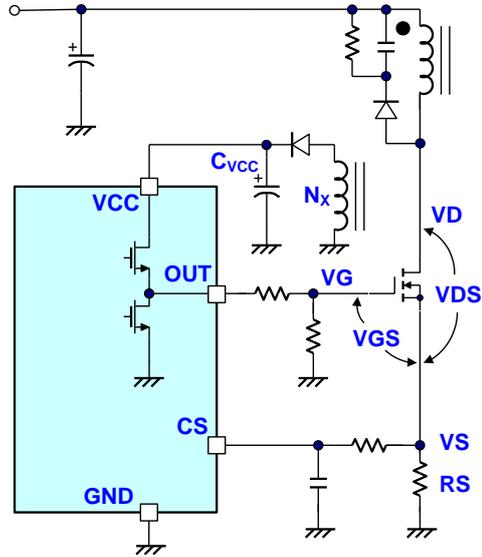


Fig. 23

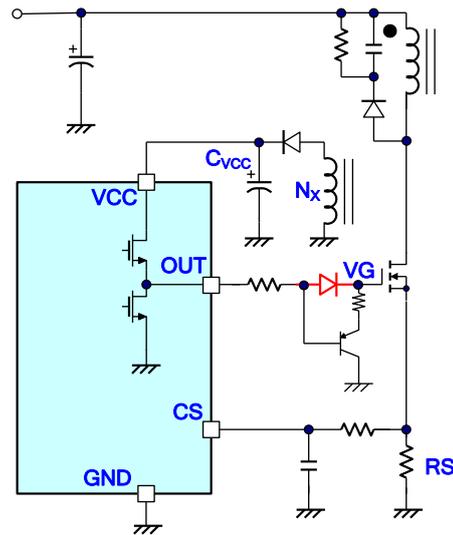


Fig. 24

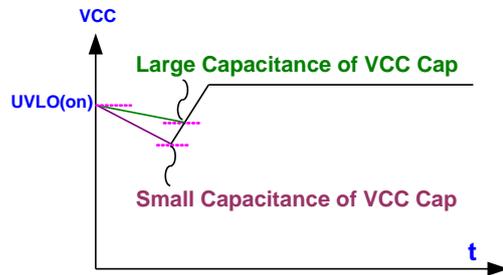
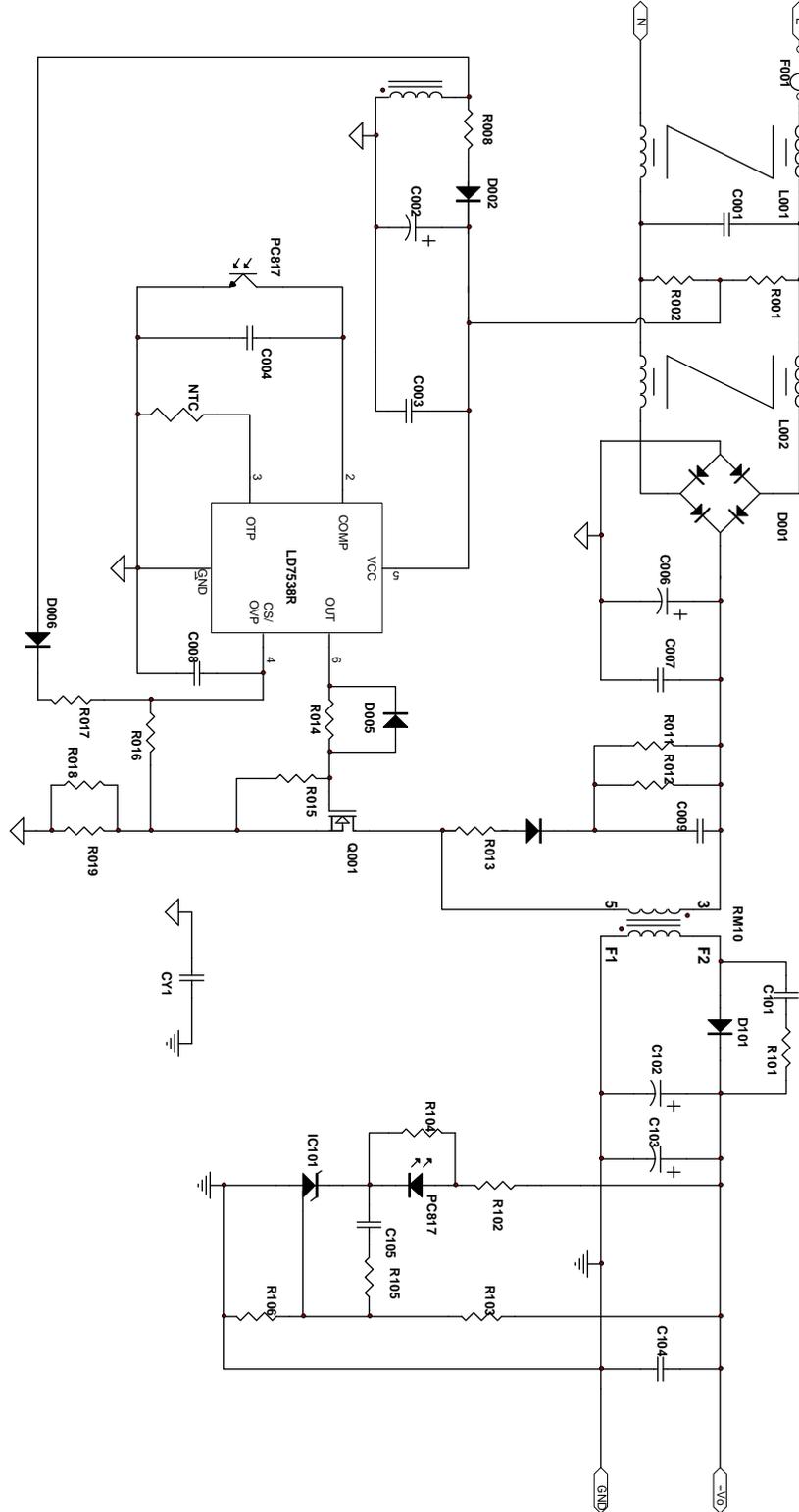


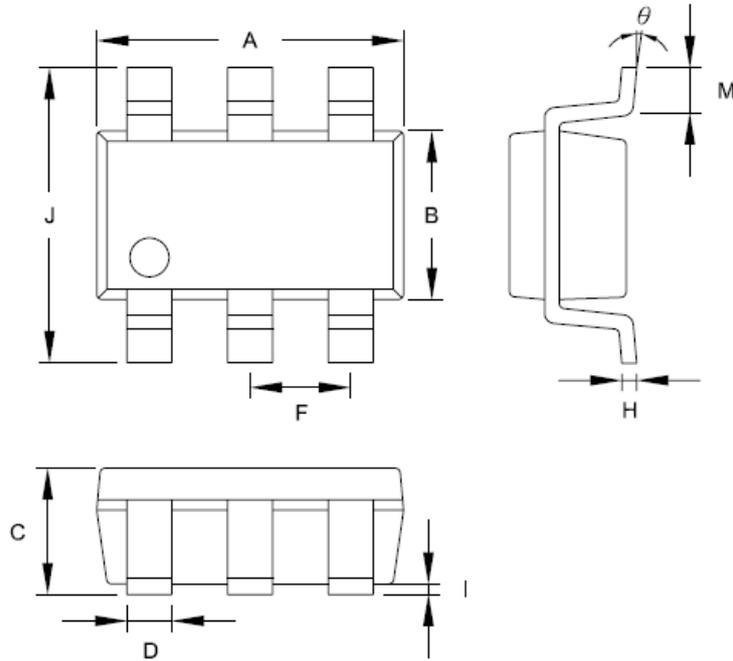
Fig. 25

Reference Application Circuit --- 65W (19V/3.42A) Adapter



Package Information

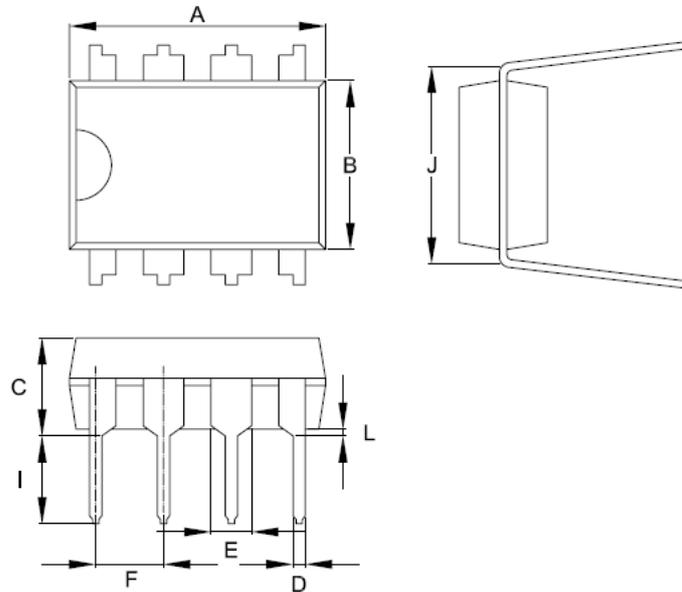
SOT-26



Symbol	Dimension in Millimeters		Dimensions in Inches	
	Min	Max	Min	Max
A	2.692	3.099	0.106	0.122
B	1.397	1.803	0.055	0.071
C	-----	1.450	-----	0.057
D	0.300	0.500	0.012	0.020
F	0.95 TYP		0.037 TYP	
H	0.080	0.254	0.003	0.010
I	0.050	0.150	0.002	0.006
J	2.600	3.000	0.102	0.118
M	0.300	0.600	0.012	0.024
θ	0°	10°	0°	10°

Package Information

DIP-8



Symbol	Dimension in Millimeters		Dimensions in Inches	
	Min	Max	Min	Max
A	9.017	10.160	0.355	0.400
B	6.096	7.112	0.240	0.280
C	-----	5.334	-----	0.210
D	0.356	0.584	0.014	0.023
E	1.143	1.778	0.045	0.070
F	2.337	2.743	0.092	0.108
I	2.921	3.556	0.115	0.140
J	7.366	8.255	0.29	0.325
L	0.381	-----	0.015	-----

Important Notice

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Revision History

Rev.	Date	Change Notice
00	12/10/2012	Original Specification.