3A Step-down DC/DC

Features

- **3A Output Current**
- **0.15Ω Internal Power MOSFET Switch**
- **Stable with Low ESR Output Ceramic Capacitors**
- **Up to 95% Efficiency**
- **30μA Shutdown Mode**
- **Fixed 380kHz Frequency**
- **Thermal Shutdown**
- **Cycle-by-Cycle Over Current Protection**
- **Wide 4.5V to 28V Operating Input Range**
- **Output Adjustable from 1.22V to 21.6V**
- **Available in SOP-8 (FD) Package**

Applications

- **PC Monitors**
- **DSL Modems**
- **Distributed Power Systems**
- **Pre-Regulator for Linear Regulators**

General Description

The G5764 is a monolithic step-down switch mode regulator with a built in internal power MOSFET. It achieves 3A continuous output current over a wide input supply range with excellent load and line regulation.

Current mode operation provides fast transient response and eases loop stabilization.

Fault condition protection includes cycle-by-cycle current limiting, output short circuit protection and thermal shutdown. In shutdown mode the regulator draws 30μA of supply current. Programmable soft-start overwrites the internal soft-start for various requirement of output power up ramp and minimizes the inrush supply current at initial startup.

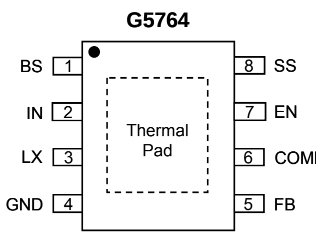
The G5764 requires a minimum number of readily available standard external components. It is available in a SOP-8 (FD) package.

Ordering Information

ORDER NUMBER	MARKING	TEMP. RANGE	PACKAGE (Green)
G5764F11U	G5764	-40°C to +85°C	SOP-8 (FD)

Note: F1: SOP-8 (FD)
1: Bonding Code
U : Tape & Reel

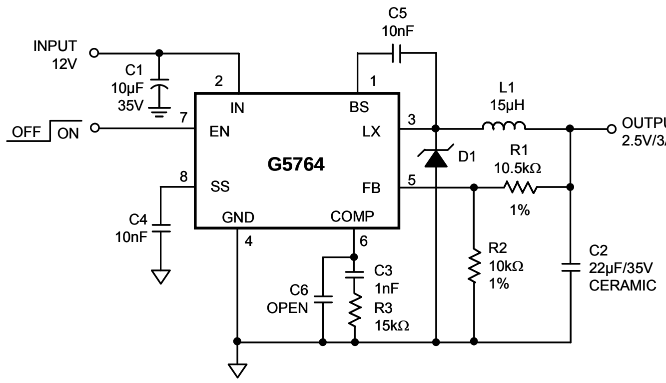
Pin Configuration



SOP-8 (FD)

Note: Recommend connecting the Thermal Pad to the Ground for excellent power dissipation.

Typical Application Circuit



Absolute Maximum Ratings

IN, EN to GND . . . . -0.3V to 40V
LX to GND . . . . -0.7V to V_{IN}+0.3V
BS Voltage . . . . V_{LX}-0.3V to V_{LX}+6V
All other Pins. . . . . -0.3V to 4.5V
Thermal Resistance Junction to Ambient, (θ_{JA})*
SOP-8 (FD). . . . . 50°C/W
Continuous Power Dissipation (T_A = +25°C)*
SOP-8 (FD) 2.3W

Thermal Resistance Junction to Case, (θ_{Jc})
SOP-8 (FD) . . . . 12°C/W
Operating Temperature Range. . . . . . -40°C to 85°C
Junction Temperature. .150°C
Storage Temperature Range. . . . .-65°C to 165°C
Reflow Temperature (soldeing,10 sec) . . . . . . .260°C

Operating Ratings

Supply Voltage . . . . .4.5V to 28V
Temperature Range . . . .-40°C≦T_J≦+85°C

* Please Refer to Minimum Footprint PCB Layout Section.

Note: Applying V_{IN} higher than maximum rating will damage IC.
Applying V_{IN} at maximum rating for extended period will damage IC.
Stress beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device.

Electrical Characteristics

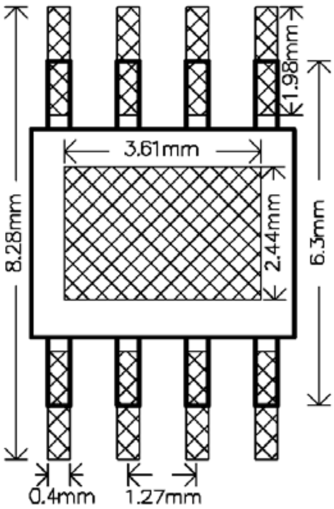
(V_{IN}=12V, V_{EN}=5V, V_{OUT}=2.5V, T_A = 25°C)

The device is not guaranteed to function outside its operating conditions. Parameters with MIN and/or MAX limits are 100% tested at +25°C, unless otherwise specified.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Voltage Range		4.5	---	28	V
Quiescent Current	V_{FB} = 1.5V (no switching)	---	---	1.5	mA
	V_{FB} = 0V (switching)	---	2	---	mA
	V_{EN} = 0V	---	30	50	µA
FB Pin Voltage		-2%	1.22	+2%	V
Bootstrap Voltage		---	5	---	V
Upper Switch $R_{DS(ON)}$	I_{LX} = 1A	---	0.15	---	Ω
Lower Switch $R_{DS(ON)}$	I_{LX} = -50mA	---	7	---	Ω
Upper Switch Leakage Current	V_{EN} = V_{LX} = 0V	---	0.1	10	µA
Upper Switch Current Limit		3.5	4.2	---	A
Lower Switch Current Limit		---	-0.1	---	A
Current Loop Transconductance		---	3.2	---	A/V
Error Amp Transconductance		---	450	---	µmho
Error Amp Voltage Gain		---	10000	---	V/V
Switching Frequency		-20%	380	+20%	kHz
Short Circuit Switching Frequency		---	40	---	kHz
SS Pin Source Current		---	20	---	µA
Maximum Duty		---	90	---	%
Minimum On Time		---	---	150	nS
Enable Threshold		0.7	1	1.3	V
Enable pull high current	EN=0	---	1	---	µA
Thermal Shutdown Protection	Rising	---	150	---	ºC
	Hysteresis	---	-20	---	ºC

Minimum Footprint PCB Layout Section

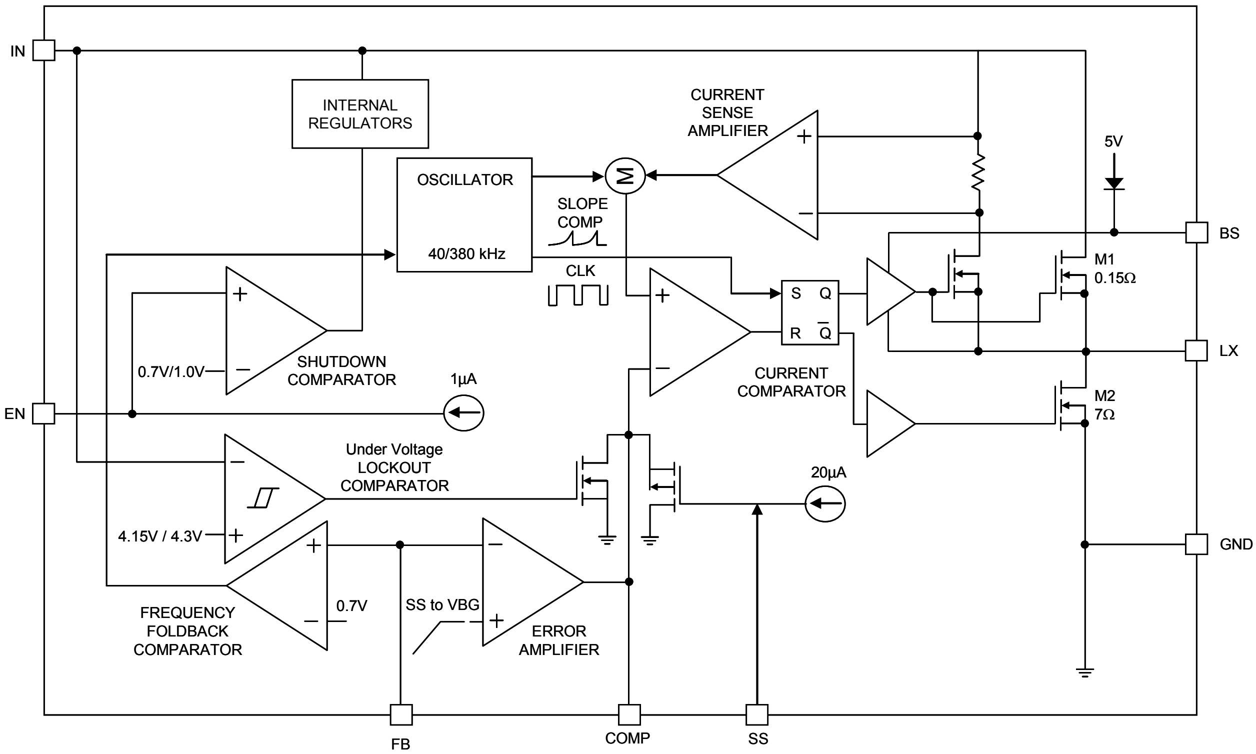
SOP-8 (FD)



Pin Descriptions

PIN	NAME	FUNCTION
1	BS	High-Side Gate Boost Input
2	IN	Input Power Supply.
3	LX	Switching node.
4	GND	Power Ground.
5	FB	Feedback pin.
6	COMP	Loop Compensation.
7	EN	Enable pin. Active high. Open automatic startup.
8	SS	Soft start control Input pin.
Thermal Pad		Recommend connecting the Thermal Pad to the GND for excellent power dissipation.

Block Diagram



Function Description

Normal Operation

The G5764 uses a constant frequency, current mode step-down architecture with internal high-side switch. During normal operation, the internal high-side (NMOS) switch is turned on each cycle when the oscillator sets the SR latch, and turned off when the comparator resets the SR latch. Since the NMOSFET requires a gate voltage greater than the input voltage, a boost capacitor connected between LX and BS drives the gate. The capacitor is internally charged while LX is low.

An internal 7Ω switch from LX to GND is used to insure that LX is pulled to GND when LX is low to fully charge the BS capacitor.

The peak inductor current at which comparator resets the SR latch is controlled by the output of error amplifier EA. While the high-side switch is off, the external schottky diode turns on until either the inductor current starts to reverse or the beginning of the next switching cycle.

Over Temperature Protection

In most applications the G5764 does not dissipate much heat due to high efficiency. But, in applications where the G5764 is running at high ambient temperature with low supply voltage and high duty cycles, such as in dropout, the heat dissipated may exceed the maximum junction temperature of the part. If the junction temperature reaches approximately 150°C, the internal power switch will be turned off and the LX node will become high impedance.

Over Current Protection

The G5764 cycle-by-cycle limits the peak inductor current to protect embedded switch from damage. Hence the maximum output current (the average of inductor current) is also limited. In case the load increases, the inductor current is also increase. Whenever the current limit level is reached, the output voltage can not be regulated and starting to drop.

Soft-Start

The G5764 employs soft-start circuitry to reduce supply inrush current during startup conditions. When the device exits under-voltage lockout or shut-down mode, the soft-start circuitry will slowly ramp up the output voltage.

A SS pin source current to charge external capacitor overwrites the internal soft start. It is often used to program the output voltage ramp speed.

Short-circuit Protection

Short-circuit protection will activate once the feedback voltage falls below 0.7V, and the operating frequency is switched to 40kHz and duty cycle is limited to reduce power delivered from input to output.

Application Information

Inductor Selection

For most applications, the value of the inductor will fall in the range of 4.7µH to 22µH. Its value is chosen based on the desired ripple current. Large value inductors lower ripple current and small value inductors result in higher ripple currents. Higher V_{IN} or V_{OUT} also increase the ripple current ΔI_L:

$$\Delta I_L = \frac{1}{f \times L} V_{OUT}\left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

where f=switching frequency, L=inductance. A reasonable inductor current ripple is usually set as 1/2 to 1/5 of maximum out current.

The DC current rating of the inductor should be at least equal to the maximum load current plus half the ripple current to prevent core saturation. For better efficiency, choose a low DCR inductor.

Output Rectifier Diode

The output rectifier diode supplies the current to the inductor when the high-side switch is off. To reduce losses due to the diode forward voltage and recovery times, use a Schottky diode.

Choose a diode whose maximum reverse voltage rating is greater than the maximum input voltage, and whose current rating is greater than the current limit level.

Capacitor Selection

In continuous mode, the source current of the top MOSFET is a square wave of duty cycle V_{OUT}/V_{IN}. To prevent large voltage transients, a low ESR input capacitor sized for maximum RMS current must be used. The maximum RMS capacitor current is given by:

$$C_{IN} \text{ requires } I_{RMS} \cong I_{OMAX} \frac{\sqrt{V_{OUT}(V_{IN} - V_{OUT})}}{V_{IN}}$$

This formula has a maximum at V_{IN}=2V_{OUT}, where I_{RMS}=I_{OUT}/2. This simple worst case condition is commonly used for design because even significant deviations do not offer much relief.

The selection of C_{OUT} is driven by the required effective series resistance (ESR). Typically, once the ESR requirement for C_{OUT} has been met, the RMS current rating generally far exceeds the $I_{RIPPLE(P-P)}$ requirement. The output ripple ΔV_{OUT} is determined by:

$$\Delta V_{OUT} \cong \Delta I_L \left(ESR + \frac{1}{8fC_{OUT}}\right)$$

For a fixed output voltage, the output ripple is highest at maximum input voltage since ΔI_L increases with input voltage.

Nowadays, higher value, lower cost ceramic capacitors are becoming available in smaller case sizes. Their high ripple current, high voltage rating and low ESR make them ideal for switching regulator applications. Because the G5764's control loop does not depend on the output capacitor's ESR for stable operation, ceramic capacitors can be used freely to achieve very low output ripple and small circuit size.

When choosing the input and output ceramic capacitors, choose the X5R or X7R dielectric formulations. These dielectrics have the best temperature and voltage characteristics of all the ceramics for given value and size.

Output Voltage Programming

The output voltage of the G5764 is set by a resistive divider according to the following formula:

$$V_{OUT} = 1.22 \times [1 + \frac{R1}{R2}] \text{Volt.}$$

Some standard value of R1, R2 for most commonly used output voltage values are listed in Table 1

Table 1.

V_{OUT} (V)	R1 (kΩ)	R2 (kΩ)
1.5	2.4	10
1.8	4.7	10
2.5	10.5	10
3.3	17.4	10
5	31.6	10
9	64	10
12	88	10

Loop Compensation

The G5764 employs peak current mode control for easy use and fast transient response. Peak current mode control eliminates the double pole effect of the output L-C filter. It greatly simplifies the compensation loop design.

With peak current mode control, the buck power stage can be simplified to be a one-pole and one-zero system in frequency domain. The pole can be calculated by:

$$f_{P1} = \frac{1}{2\pi \times C_{OUT} \times R_L}$$

The zero is an ESR zero due to output capacitance and its ESR. It can be calculated by:

$$f_{Z1} = \frac{1}{2\pi \times C_{OUT} \times ESR_{COUT}}$$

Where C_{OUT} is the output capacitor; R_L is load resistance; ESR_{COUT} is the equivalent series resistance of output capacitor.

The compensation design is to shape the converter close loop transfer function to get desired gain and phase. For most cases, a series capacitor and resistor network connected to the COMP pin sets the pole-zero and is adequate for a stable high-bandwidth control loop.

In the G5764, FB pin and COMP pin are the inverting input and the output of internal transconductance error amplifier (EA). A series R_3 and C_3 compensation network connected to COMP pin provides one pole and one zero:

for $R_3 << A_{EA}/G_{EA}$

$$f_{P2} = \frac{1}{2\pi \times C_3 \times (R_3 + \frac{A_{EA}}{G_{EA}})} \approx \frac{G_{EA}}{2\pi \times C_3 \times A_{EA}}$$

$$f_{Z2} = \frac{1}{2\pi \times C_3 \times R_3}$$

Where G_{EA} is the error amplifier transconductance
A_{EA} is the error amplifier voltage gain
R_3 is the compensation resistor
C_3 is the compensation capacitor

The desired crossover frequency f_C of the system is defined to be the frequency where the control loop has unity gain. It is also called the bandwidth of the converter. In general, a higher bandwidth means faster response to load transient. However, the bandwidth should not be too high because of system stability concern. When designing the compensation loop, converter stability under all line and load condition must be considered. Usually, it is recommended to set the bandwidth to be less than 1/10 of switching frequency.

Using selected crossover frequency, f_C, to calculate R_3:

$$R_3 = f_C \times \frac{V_{OUT}}{V_{FB}} \times \frac{2\pi \times C_{OUT}}{G_{EA} \times G_{CS}},$$

where G_{CS}=3.4A/V is the current sense transconductance.

The compensation capacitor C_3 and resistor R_3 together make zero. This zero is put somewhere close to the pole f_{P1}. C_3 is selected by:

$$C_3 = \frac{C_{OUT} \times R_L}{R_3}$$

Checking Transient Response

The regulator loop response can be checked by looking at the load transient response. Switching regulators take several cycles to respond to a step in load current. When a load step occurs, V_{OUT} immediately shifts by an amount equal to ($\Delta I_{LOAD} \times ESR$), where ESR is the effective series resistance of C_{OUT}. ΔI_{LOAD} also begins to charge or discharge C_{OUT}, which generates a feedback error signal. The regulator loop then acts to return V_{OUT} to its steady-state value. During this recovery time V_{OUT} can be monitored for overshoot or ringing that would indicate a stability problem.

Efficiency Considerations

Although all dissipative elements in the circuit produce losses, one major source usually account for most of the losses in G5764 circuits: I^2R losses. The I^2R loss dominates the efficiency loss at medium to high load currents.

The I^2R losses are calculated from the resistances of the internal switches, R_{LX}, and external inductor R_L. In continuous mode, the average output current flowing through inductor L is "chopped" between the main switch and the external diode. Thus the series resistance looking into the LX pin is a function of internal high-side switch's $R_{DS(ON)}$, external low-side diode's forward resistance $R_{D(F)}$ and the duty cycle (D) as follows:

$$R_{LX} = (R_{DS(ON)})D + (R_{D(F)})(1-D)$$

Thus, to obtained I^2R losses, simply add R_{LX} to R_L and multiply the result by the square of the average output current.

Other losses including C_{IN} and C_{OUT} ESR dissipative losses and inductor core losses generally account for less than 2% total additional loss.

External Bootstrap Diode

It is recommended that an external bootstrap diode be added when the system has a 5V fixed input or the power supply generates a 5V output. This helps improve the efficiency of the regulator. The bootstrap diode can be a low cost one such as IN4148 or BAT54.

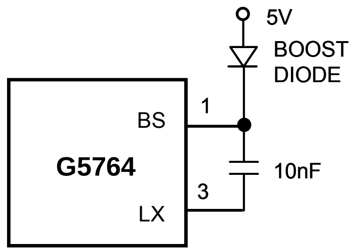
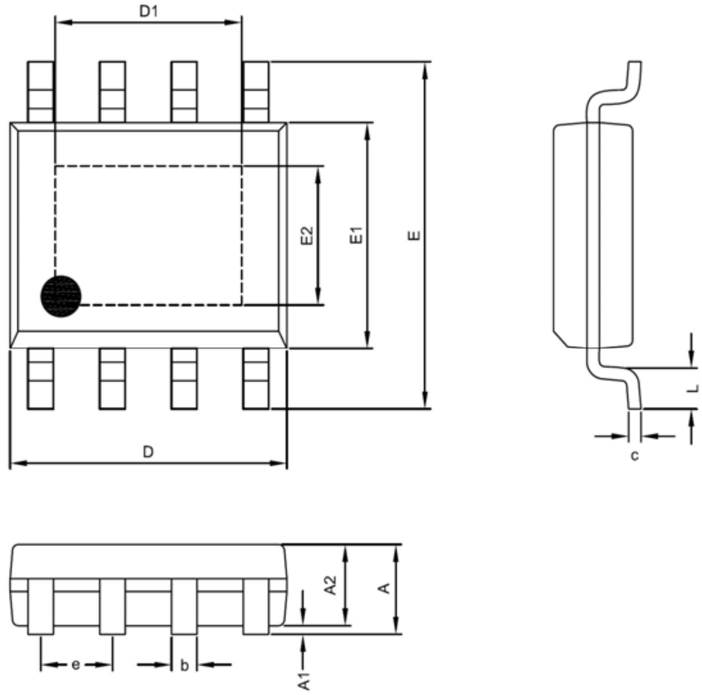


Figure 1---External Bootstrap Diode

This diode is also recommended for high duty cycle operation (when $\frac{V_{OUT}}{V_{IN}} > 65\%$) and high output voltage (V_{OUT}>12V) applications.

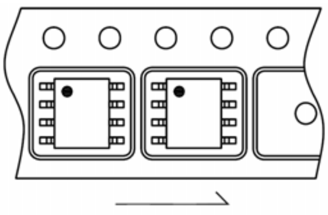
Package Information



SOP-8 (FD) Package

Symble	DIMENSION IN MM			DIMENSION IN INCH		
	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.
A	1.35	1.55	1.65	0.053	0.061	0.065
A1	0.00	- - -	0.15	0.000	- - -	0.006
A2	1.15	1.35	1.50	0.045	0.053	0.059
D	4.80	4.90	5.00	0.189	0.192	0.197
D1	2.29	- - -	3.71	0.090	- - -	0.146
E	5.80	6.00	6.20	0.228	0.236	0.244
E1	3.80	3.90	4.00	0.150	0.153	0.157
E2	2.29	- - -	2.64	0.090	- - -	0.104
c	0.19	0.23	0.27	0.007	0.009	0.011
b	0.33	0.43	0.53	0.013	0.017	0.021
e	1.27 BSC			0.050 BSC		
L	0.40	0.70	1.00	0.016	0.028	0.039

Taping Specification



PACKAGE	Q'TY/REEL
SOP-8 (FD)	2,500 ea