ON Semiconductor®

APPLICATION NOTE

LV5068V

Low power consumption and high efficiency

Step-down switching regulator controller

Introduction

This document presents the information on IC, application, schematic, pattern layout, Bill of Materials and Evaluation Board.

Table of contents

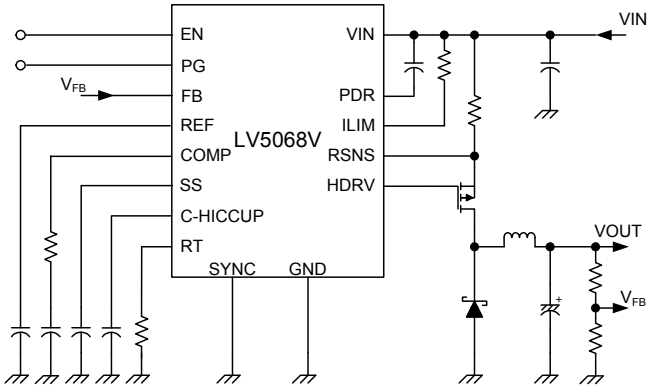
1. Overview

LV5068V is 1ch step-down switching regulator. The operation current is about 80uA, and low power consumption is achieved.

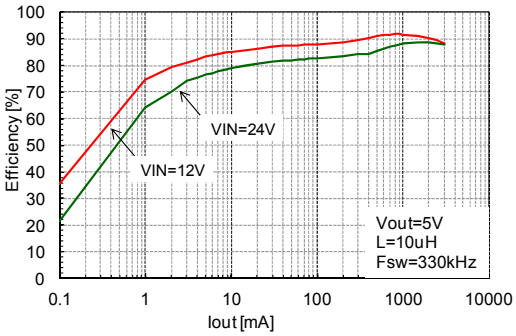
2. Features

- 1ch diode rectifying controller
- Maximum value of light load mode current is 80uA
- Built-in OCP circuit with P-by-P method
- When P-by-P is generated continuously, it shifts to the HICCUP operation.
- If connect C-HICCUP to GND pin, then latch-off when over current.
- The oscillatory frequency can be set by the external pin.
  The oscillatory frequency is 300kHz to 2.2MHz
- Built-in UVLO, TSD
- Synchronous operation by external signal

Application Circuit Example



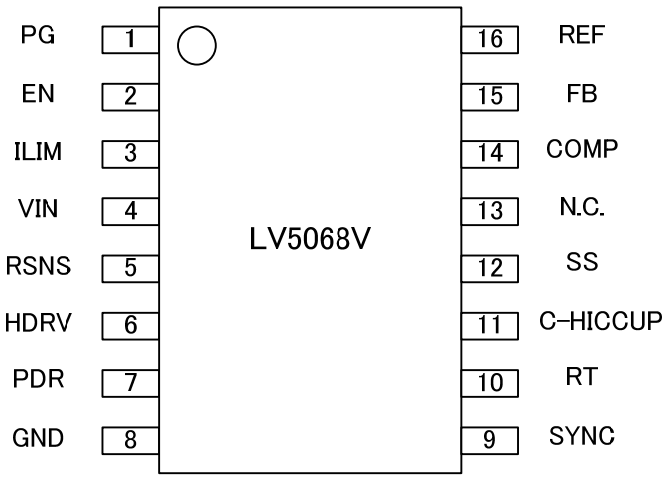
Efficiency



3. Typical applications

- Printers
- Set-Top Boxes, DVD Drives and HDD
- LCD Monitors and TVs

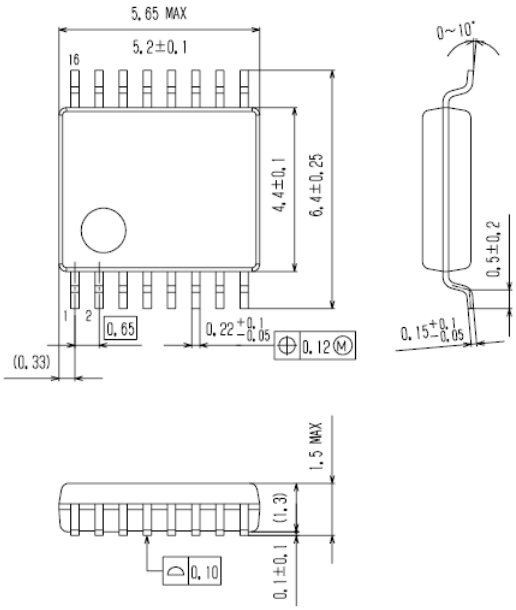
4. Pin assignment

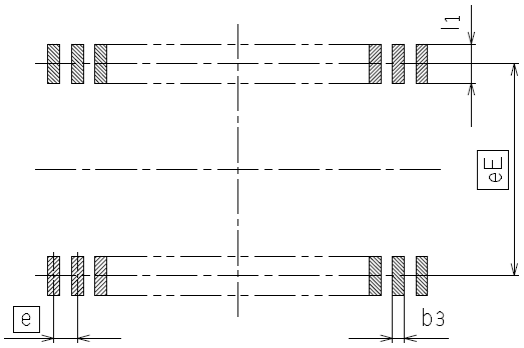


Top View

5. Package dimensions and mounting pad sketch

SSOP16(225mil)



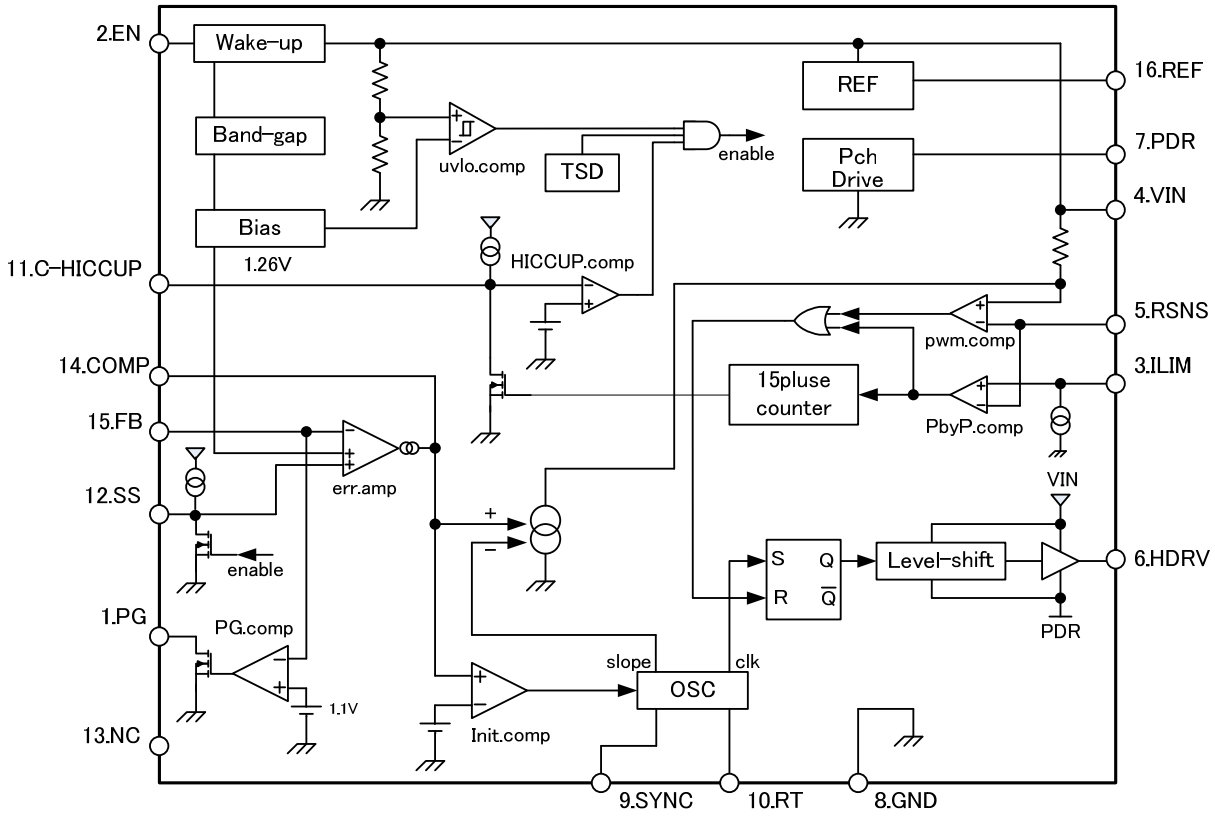


(Unit:mm)

Reference symbol	SSOP16(225mil)
eE	5.80
e	0.65
b3	0.32
l1	1.00

Caution: The package dimension is a reference value, which is not a guaranteed value.

6. Block diagram



7. Specifications

Absolute maximum ratings at Ta=25°C

Parameter	Symbol	Conditions	Ratings	Unit
Input Voltage	V_{IN} max		45	V
Allowable Pin Voltage	PDR, HDRV, RSNS ILIM, EN, PG		V_{IN}	V
	V_{IN}-PDR		6	V
	REF		6	V
	SS, FB, COMP, RT C-HICCUP, SYNC		REF	V
Allowable Power Dissipation	Pd max	Specified substrate *1	0.74	W
Operating Temperature	Topr		-40 to +85	°C
Storage Temperature	Tstg		-55 to +150	°C

*1 specified substrate 114.3mm × 76.1mm × 1.6mm glass-epoxy

Recommended operating conditions at Ta=25°C

Parameter	Symbol	Conditions	Ratings	Unit
Input Voltage Range	V_{IN}		4.5 to 40	V

Electrical characteristics at Ta=25°C, V_{IN}=15V

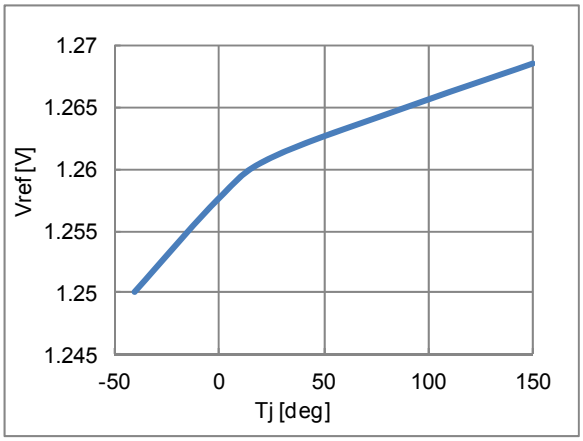
Parameter	Symbol	Conditions	Min.	Typ.	Max.	Units
[Reference Voltage]						
Internal Reference Voltage	Vref		1.241	1.26	1.279	V
Pch Drive Voltage	VPDR	I_{OUT}=0 to -5mA	V_{CC}-5.5	V_{CC}-5.0	V_{CC}-4.5	V
[Saw Wave Oscillator]						
Oscillatory Frequency	F_{OSC}	RT=470kΩ	280	330	380	kHz
[ON/OFF Circuit]						
IC Startup Voltage	Vcnt_on		1.5		V_{IN}	V
Disable Voltage	Vcnt_off		0		0.3	V
[Soft Start Circuit]						
Soft Start Source Current	I_{SS_SC}	EN>1.5V	1.3	2	2.7	μA
Soft Start Sink Current	I_{SS_SK}	EN<0.3V SS=4V	1	1.6	2.2	mA
[UVLO Circuit]						
UVLO unlocking voltage	V_{UVLON}	FB=COMP	3.3	3.7	4.1	V
UVLO Lock Voltage	V_{UVLOF}	FB=COMP	2.5	2.9	3.3	V
[Error Amplifier]						
Input Bias Current	I_{EA_IN}		-100	-50	100	nA
Error amplifier gain	G_{EA}		100	250	400	μA/V
Output Sink Current	I_{EA_OSK}	FB=1.75V	-40	-20	-10	μA
Output Source Current	I_{ES_OSC}	FB=0.75V	10	20	40	μA
[Over Current Limit Circuit]						
Reference current	ILIM1		48.4	55	61.6	μA
Over current detection comparator offset voltage	V_{LIM_OFS}		-5		+5	mV
RSNS pin input range	VRSNS		V_{IN}-0.175		V_{IN}	V
HICCUP Timer Startup Cycle	$N_{LCYCLES}$			15		cycle
HICCUP Comparator Threshold Voltage	V_{tHIC}		1.2	1.26	1.32	V
HICCUP Timer Charge Current	IHIC		1	2	3	μA
[PWM Comparator]						
Maximum On-Duty	D_{MAX}		95			%

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Units
【Logic Output】						
Power Good “L” Sink Current	I_{pwrgd_L}	PG=5V	4	5	6	mA
Power Good “H” Leakage Current	I_{pwrgd_H}	PG=5V	0		1	μA
Power GoodThreshold Voltage	V_{tPG}		1.0	1.1	1.2	V
Power Good Hysteresis	V_{PG_H}		40	50	60	mV
[Output]						
Output On-Resistance (high)	R_{ONH}			3		Ω
Output On-Resistance (low)	R_{ONL}			3		Ω
Output On-current (high)	I_{ONH}		500			mA
Output On-current (low)	I_{ONL}		500			mA
[The entire device]						
Standby current	I_{CCS}	EN < 0.3V	0		1	μA
Light Load Mode Consumption Current	I_{sleep1}	EN > 1.5V No Switching	30	55	80	μA
Thermal Shutdown	TSD	*2	150	170	190	°C

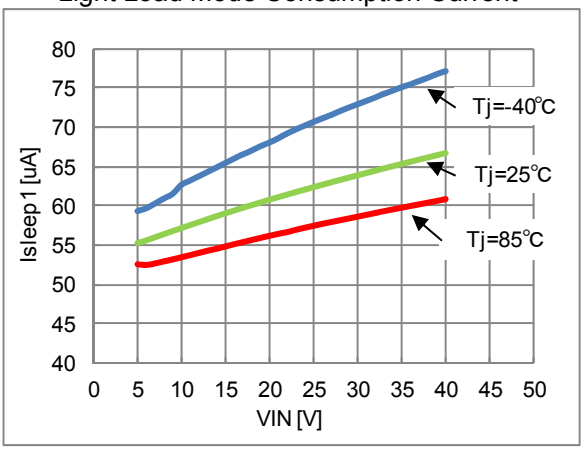
*2: Design certification

Characterization curves VIN=15V, RT=470kΩ

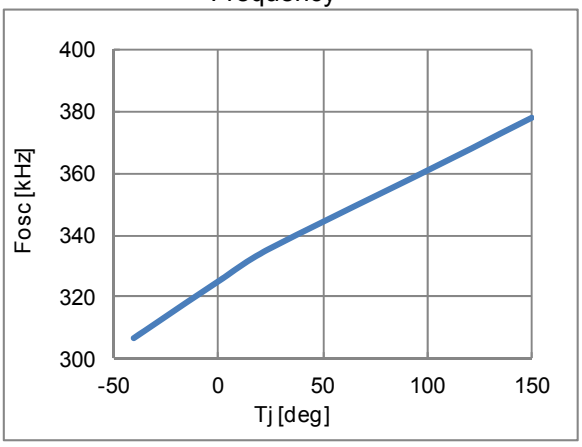
Reference Voltage



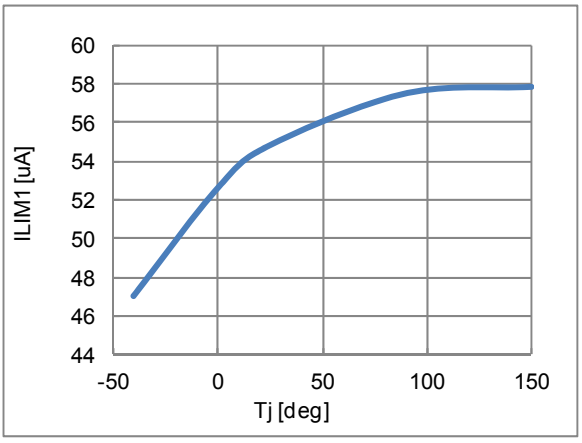
Light Load Mode Consumption Current



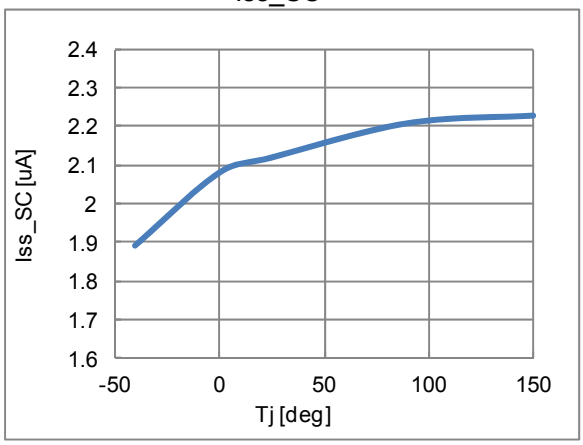
Frequency



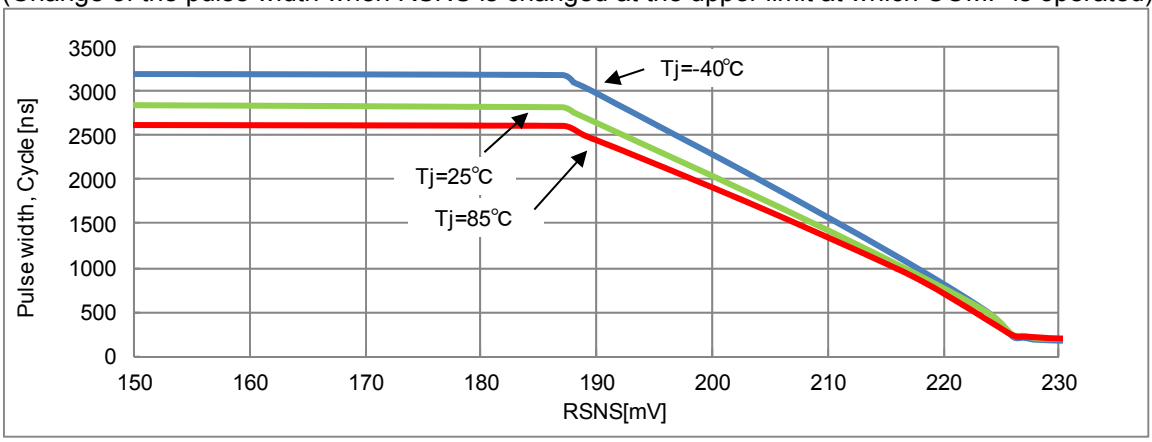
Over current limit



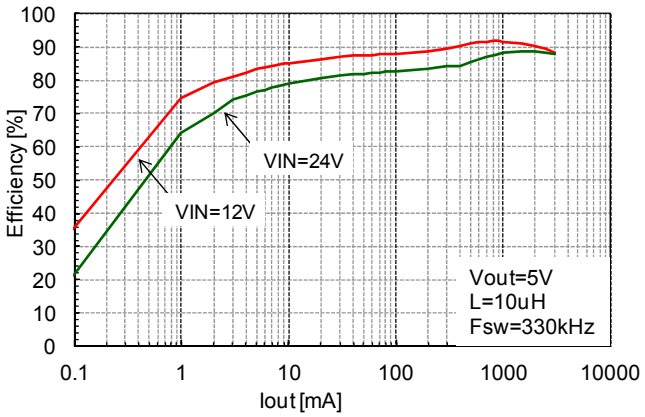
Iss_SC



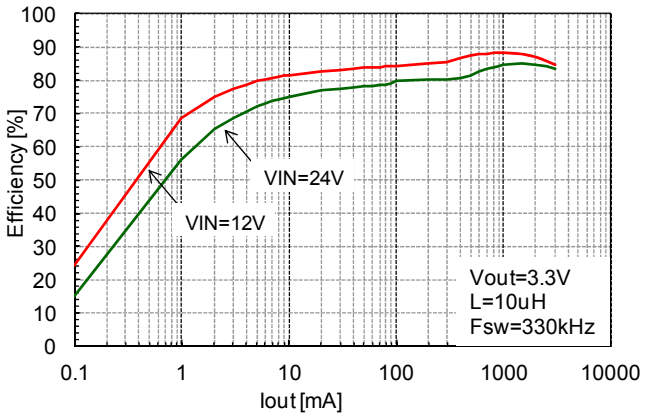
Relationship between RSNS and pulse width
(Change of the pulse width when RSNS is changed at the upper limit at which COMP is operated)



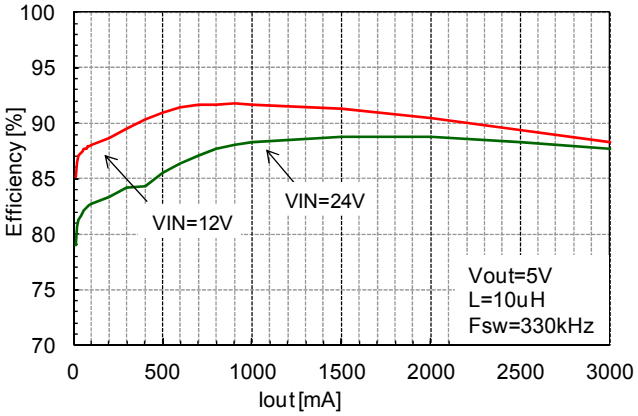
Efficiency vs load current Vout=5V



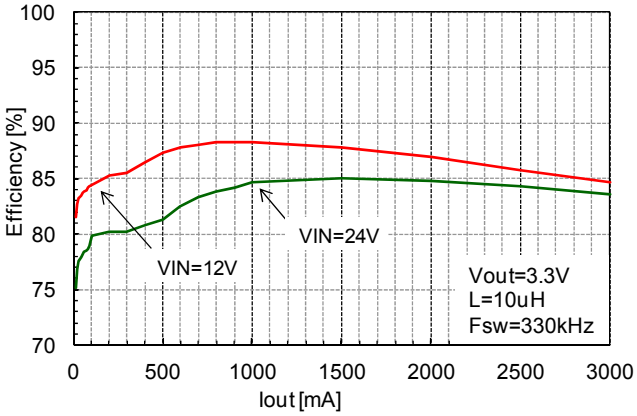
Efficiency vs load current Vout=3.3V



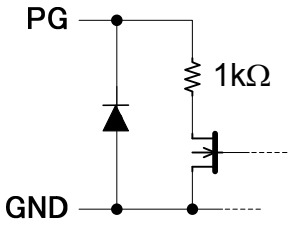
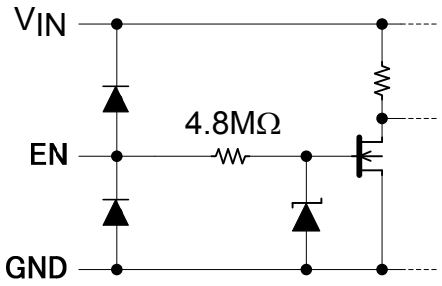
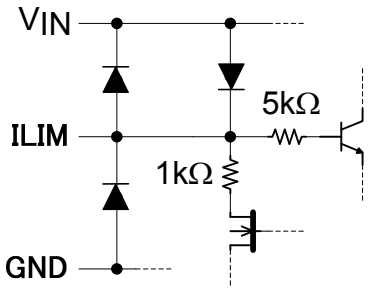
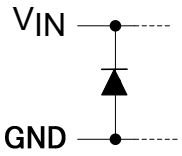
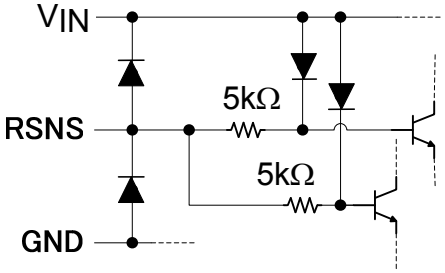
Efficiency vs load current Vout=5V

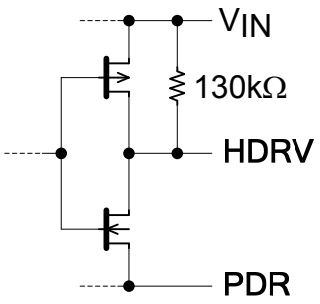
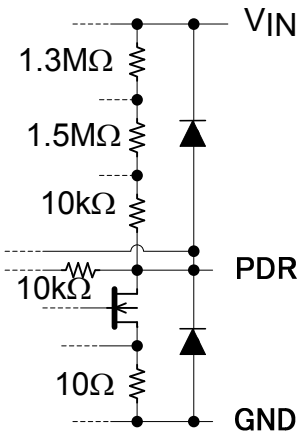
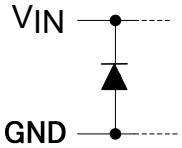
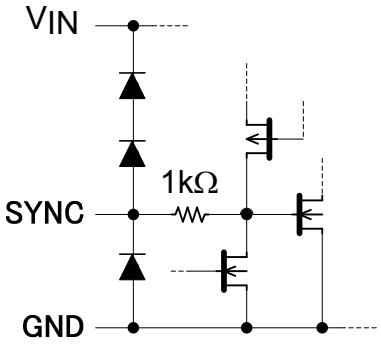


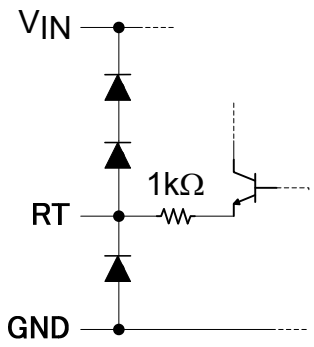
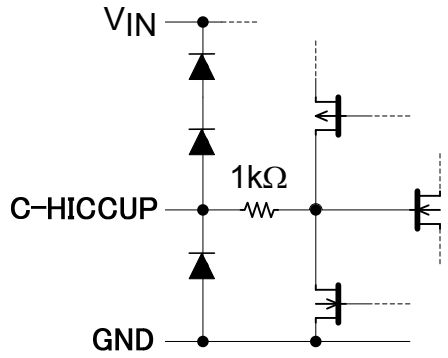
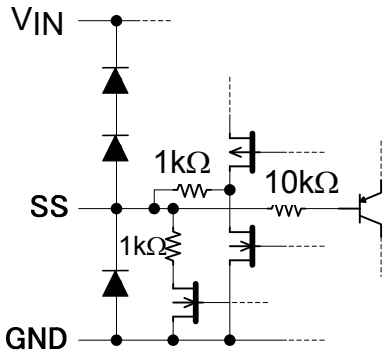
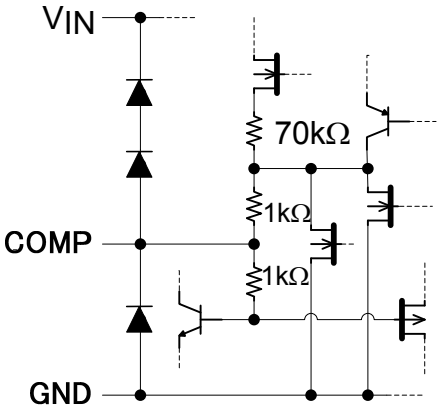
Efficiency vs load current Vout=3.3V

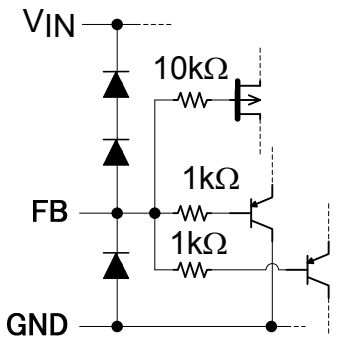
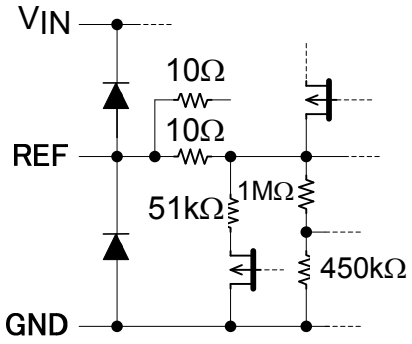


8. Pin function

Pin No.	Pin name	Pin Function	Equivalent circuit
1	PG	Power good pin. Connect to open drain of MOS-FET in ICs inside. Setting output voltage to “L”, when FB voltage is about 1.05V or less.	
2	EN	ON/OFF pin.	
3	ILIM	For current detection. Sink current is about 55uA. The current limiter comparator works when an external resistor is connected between this pin and V_{IN}, and if the voltage of this resistor is less than the voltage of RSNS then PchMOS is turned off. This operation is reset each PWM pulse.	
4	V_{IN}	Power pin. Monitored by the UVLO function. When this pin exceeds 3.7V, the UVLO function causes IC to start, entering the soft start mode.	
5	RSNS	Current detection resistor connection pin. Resistor is connected between V_{IN} and this pin, and the current flows to MOSFET is measured.	

Pin No.	Pin name	Pin Function	Equivalent circuit
6	HDRV	The external high-side MOSFET gate drive pin.	
7	PDR	Gate drive voltage of the external PchMOSFET. Meanwhile, the bypass capacitor is connected between V_{IN} and this pin.	
8	GND	Ground Pin. Ground pin voltage is reference voltage.	
9	SYNC	Pin used also as the external synchronizing signal input pin. Do not leave the pin floating.	

Pin No.	Pin name	Pin Function	Equivalent circuit
10	RT	Oscillation frequency setting pin. Resistor is connected between this pin and GND.	
11	C-HICCUP	It is capacitor connection pin for setting re-startup cycle in HICCUP mode. If connect it to GND pin, then latch-off when over current.	
12	SS	Capacitor connection pin for soft start. About 2uA current charges the soft start capacitor.	
13	NC	NC pin.	
14	COMP	Error Amplifier Output Pin. The phase compensation network is connected between GND pin and COMP pin.Thanks to current-mode control, COMP pin voltage would tell you the output current amplitude. COMP pin is connected internally to an int. comparator which compares with 0.9V reference. If COMP pin voltage is larger than 0.9V, IC operates in “continuous mode”. If COMP pin voltage is smaller than 0.9V, IC operates in “discontinuous mode (low consumption mode)”.	

Pin No.	Pin name	Pin Function	Equivalent circuit
15	FB	Error amplifier reverse input pin. ICs make its voltage keep 1.26V. Output voltage is divided by external resistors, and it across FB.	
16	REF	Reference voltage.	

9. Operation explanation

9.1 Power-saving feature

This IC has power-saving feature to enhance efficiency at light load. By shutting down unnecessary circuits, operating current of the IC is minimized and high efficiency is realized.

9.2 Output voltage setting

The output voltage is set by resistor R4 (Between VOUT and FB) and resistor R5 (Between FB and GND). The output voltage is determined by the following expression (1).

$$V_{OUT} = (1 + \frac{R4}{R5}) \times V_{REF} = (1 + \frac{R4}{R5}) \times 1.26 \ [V] \quad \textbf{(1)}$$

ex) The resistor that sets the output voltage to 5V are R4=470k and R5=160k.

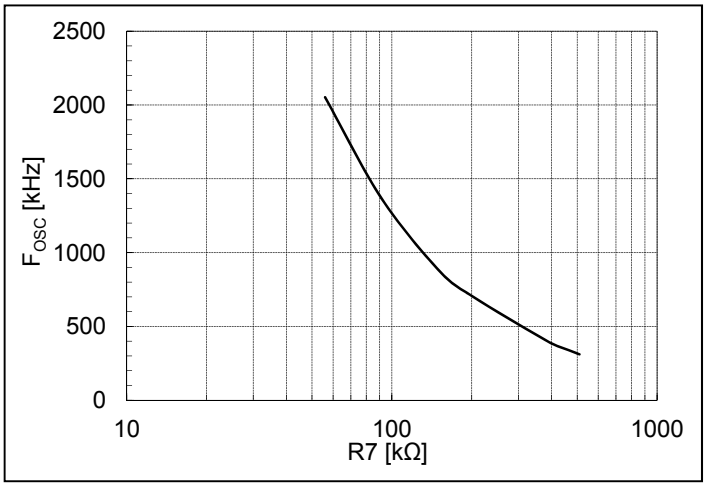
$$V_{OUT} = (1 + \frac{470 \times 10^3}{160 \times 10^3}) \times 1.26 = 4.96 \ [V] \quad \textbf{(2)}$$

9.3 Switching frequency setting

The switching frequency (F_{OSC}) is set by resistor R7 (Between RT and GND).
The relation of resistor R7 with F_{OSC} is shown in Graph 1. And please set F_{OSC} taking the minimum on-time =200ns into consideration.

ex) Where R7=470kΩ, F_{OSC} is 330kHz.

Graph1. R7 vs F_{OSC}



9.4 Soft start setting

Soft start time (T_{SS}) is set with the capacitor C7 (Between SS and GND). T_{SS} is determined by the following expression (3).

$$T_{SS} = C7 \times \frac{V_{REF}}{I_{SS}} = C7 \times \frac{1.26}{2.0 \times 10^{-6}} \ [s] \quad \textbf{(3)}$$

ex) Where C7=2200pF, T_{SS} is 1.38ms.

$$T_{SS} = 2200 \times 10^{-12} \times \frac{1.26}{2.0 \times 10^{-6}} = 1.386 \ [ms] \ \textbf{(4)}$$

9.5 Overcurrent protection setting

When the RSNS pin exceeds the overcurrent limit value for 15 cycles of the oscillatory frequency, the overcurrent protection detects the overcurrent state, and stops the IC. Overcurrent detection voltage (VLIM) is determined by the resistor R2 (between VIN and ILIM) and the reference current (ILIM1).
The overcurrent detection voltage (VLIM) is determined by the following expression.

$$VLIM = R2 \times ILIM1 \ [V] \quad \textbf{(5)}$$

ex) Where R2=2.7kΩ, ILIM1=55uA, VILIM is 0.1485V.

$$VLIM = 2.7 \times 10^3 \times 55 \times 10^{-6} = 0.1485 \ [V] \quad \textbf{(6)}$$

When the current sensing resistor R1 is 30mΩ, the value of the overcurrent is 4.95A.
You can select R1 from 20mΩ to 100mΩ according to the above-mentioned figure which shows the relationship between RSNS and pulse width.

9.6 Hiccup Setting

The stop time of the overcurrent protection is determined by the capacitor (C8). IC restarts when the C-HICCUP pin exceeds 1.26V.

$$T_{HIC} = \frac{C8 \times V_{tHIC}}{I_{HIC}} = \frac{C8 \times 1.26}{2.0 \times 10^{-6}} \ [s] \quad \textbf{(7)}$$

ex) Where C8=22000pF, T_{HIC} is 13.86msec.

$$T_{HIC} = \frac{22000 \times 10^{-12} \times 1.26}{2.0 \times 10^{-6}} = 13.86 [ms] \quad \textbf{(8)}$$

9.7 Power good function

The Output voltage is observed with the voltage of the FB pin. The PG pin turns “Low” when the voltage of FB pin is about 1.05V or less. Because the PG pin is open-drain, the PG pin can be Wired-OR.

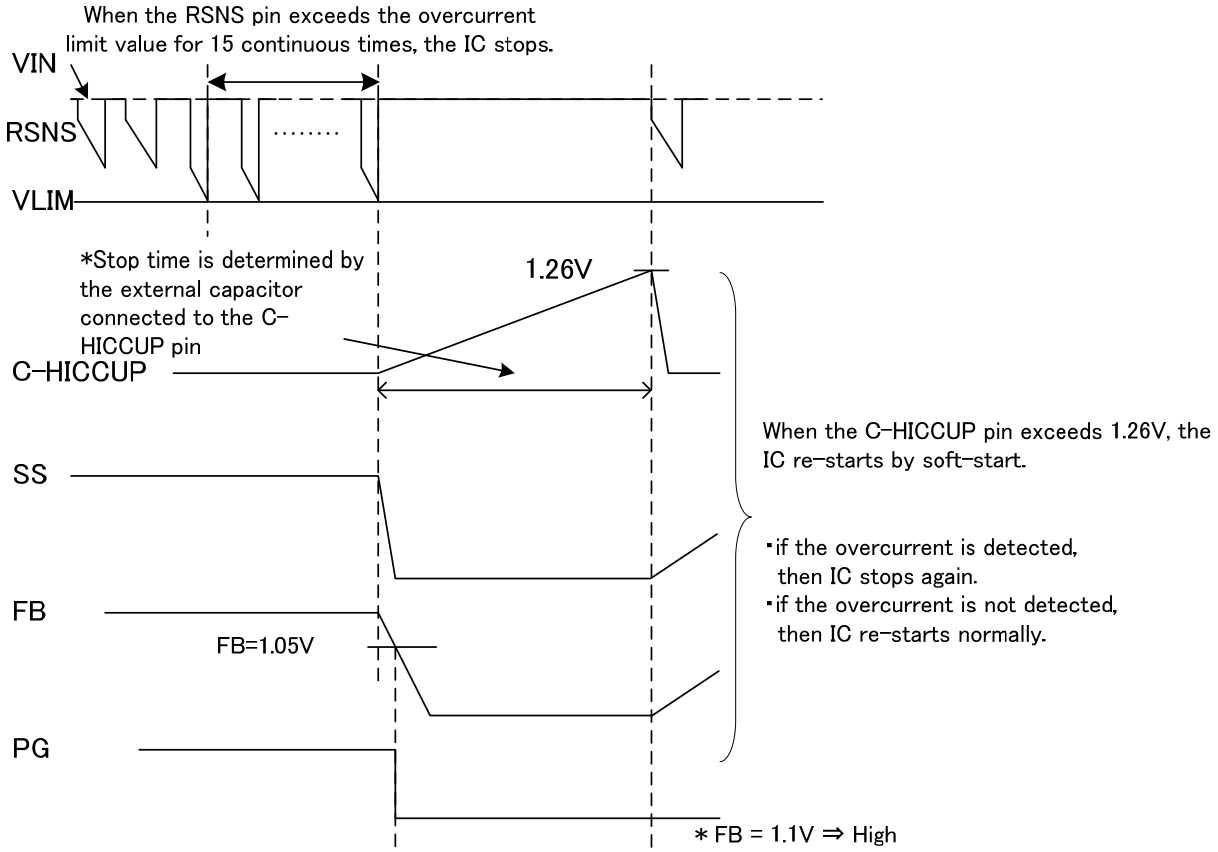


Fig. Timing chart: Hiccup overcurrent protection / Power good function

9.8 External synchronous frequency

LV5068V performs the synchronous operation by inputting external signal in continuous current mode. The synchronous frequency=F_{SYNC} inputted to the SYNC pin shall be set higher than F_{OSC} or lower than twice the F_{OSC}. If F_{SYNC} is higher than twice the F_{OSC}, the amplitude of internal slope becomes low and the gain becomes high. So F_{SYNC} is determined by the following expression.

$$F_{OSC} < F_{SYNC} < 2 \times F_{OSC}$$

When synchronous operation is not used, make sure to connect the SYNC pin to GND.

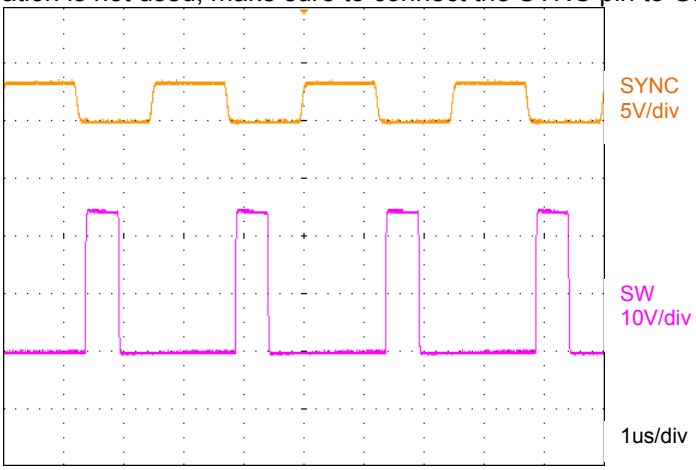


Fig. synchronous operation by external signal (SYNC input : 0V⇔3.3V)

9.9 Leading edge blanking time

LV5068V has the leading edge blanking time whose design value is 120ns.

10. Evaluation board manual

Performance summary

Table 1. LV5068V_DemoBoard Performance Summary

Parameter	Conditions	Rating			Unit
		Min	Typ	Max	
Input Supply Voltage			24		V
Output Voltage			5		V
Current Limit Peak		4.36	4.95	5.54	A
Oscillatory Frequency			330		kHz

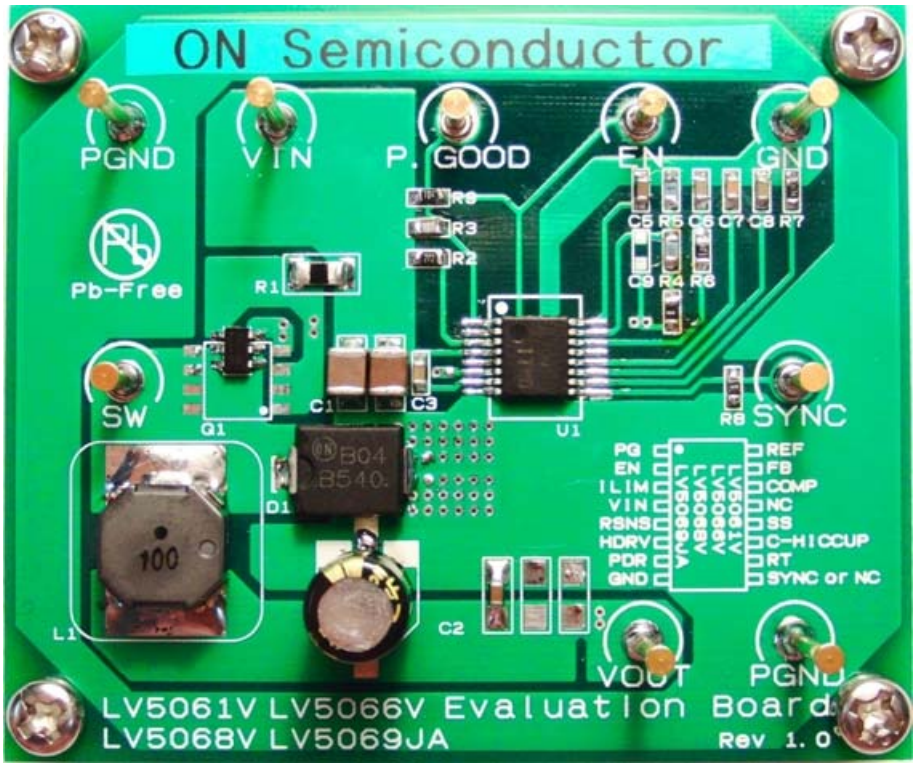
Output voltage setting

Table 2. LV5068V_DemoBoard Output Voltage Point Setting

Output Voltage [V]	R4 [kΩ]	R5 [kΩ]
3.3	270	160
5	470	160

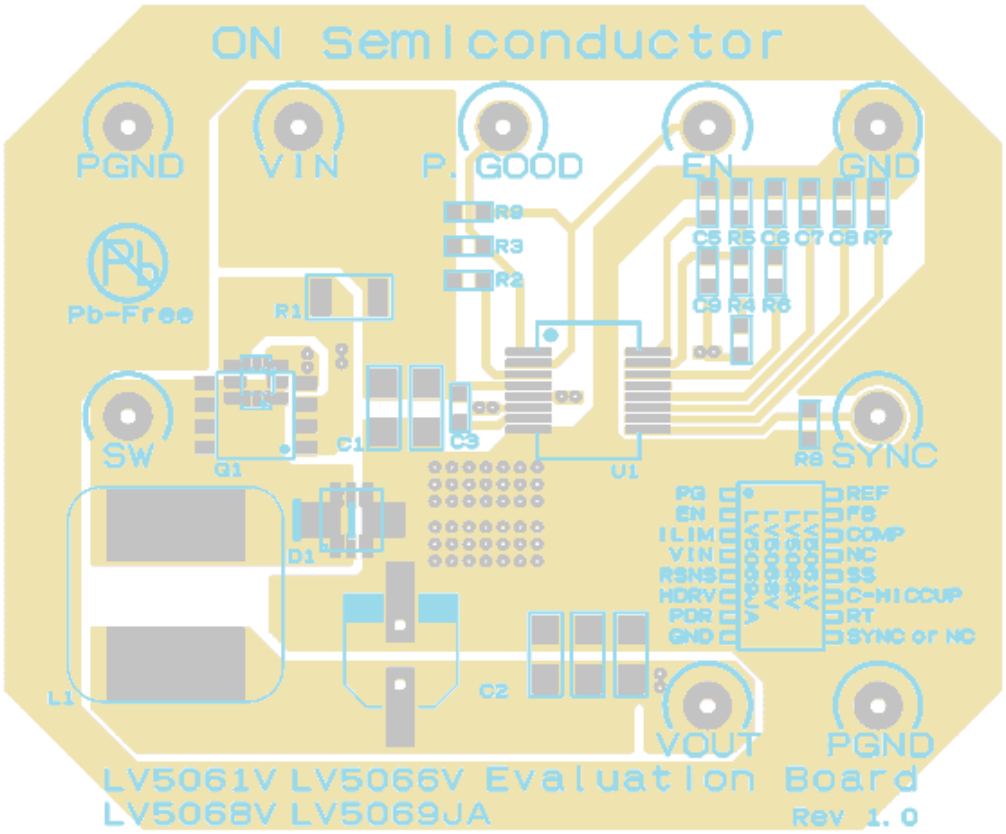
Manipulation method

1. Connect the load between OUT and GND.
2. Connect the input power supply with VIN and GND.
3. The output becomes a set voltage.

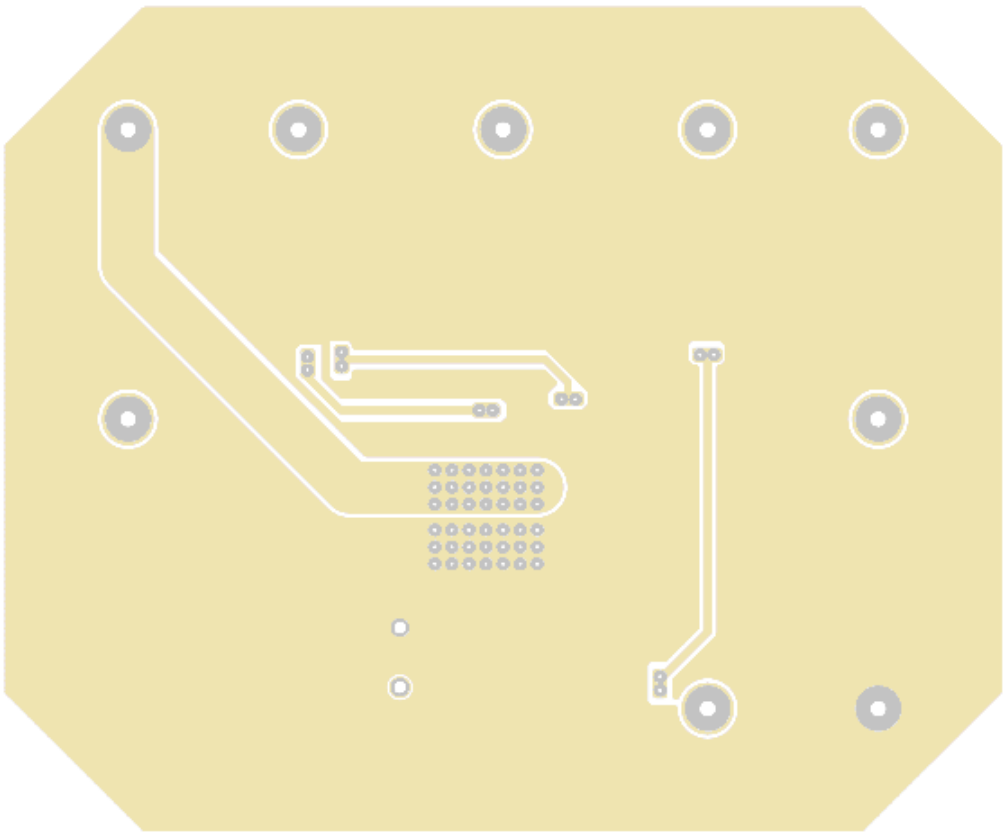


Layout

4-layer printed circuit board
Top layer



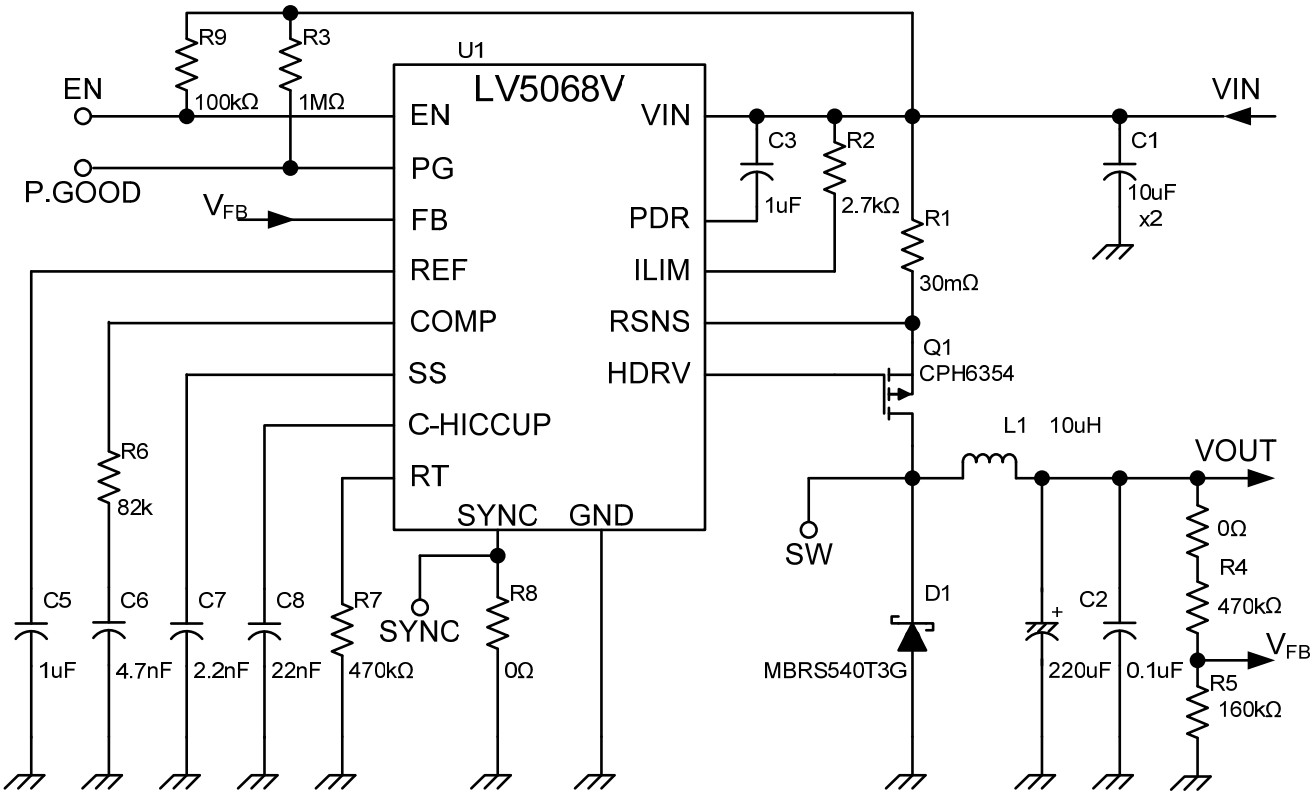
Bottom layer



4-layer printed circuit board
2nd layer

3rd layer

Schematic



Bill of Materials

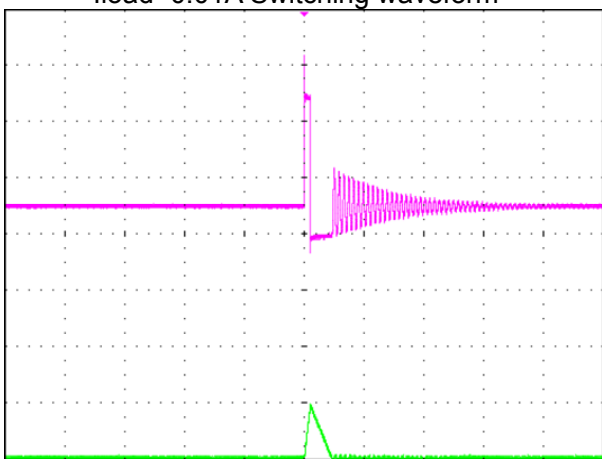
Table 5. LV5068V_DemoBoard Bill of Materials

Designator	Manufacturer Part Number	Value	Tolerance	Quantity	Manufacturer
U1	LV5068V	-	-	1	SANYO Semiconductor
L1	1217AS-H-100M	10uH / 4.3A	10%	1	TOKO INC
R1	ERJ8BWFR030V	30mohms	1%	1	Panasonic
R2	RK73B1JTTD272J	2.7kohms	5%	1	KOA
R3	RK73B1JTTD105J	1Mohms	5%	1	KOA
R4	RK73Z1JTTD	0ohms	-	1	KOA
	RK73H1JTTD4703F	470kohms	1%	1	KOA
R5	RK73H1JTTD1603F	160kohms	1%	1	KOA
R6	RK73B1JTTD823J	82kohms	5%	1	KOA
R7	RK73B1JTTD434J	470kohms	5%	1	KOA
R8	RK73Z1JTTD	0ohms	-	1	KOA
R9	RK73B1JTTD104J	100kohms	5%	1	KOA
C1	GRM32ER7YA106K	10uF / 35V	10%	2	Murata
C2	GRM188B31H104K	0.1uF / 50V	10%	1	Murata
	10ME220SWG	220uF / 10V	20%	1	SUN Electronic Industries
C3	GRM188B31E105K	1uF / 25V	10%	1	Murata
C5	GRM188B31E105K	1uF / 25V	10%	1	Murata
C6	GRM188B11H472K	4.7nF / 50V	10%	1	Murata
C7	GRM188B11H222K	2.2nF / 50V	10%	1	Murata
C8	GRM188B11E223K	22nF / 50V	10%	1	Murata
C9	-	-	-	-	-
D1	MBRS540T3	-	-	1	ON Semiconductor
Q1	CPH6354	-	-	1	SANYO Semiconductor

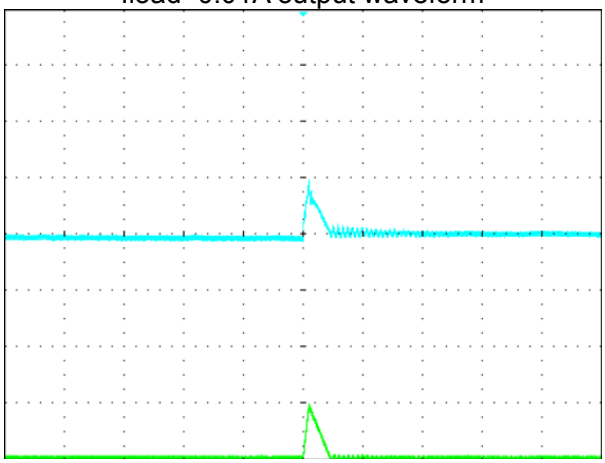
Waveforms

Power saving feature

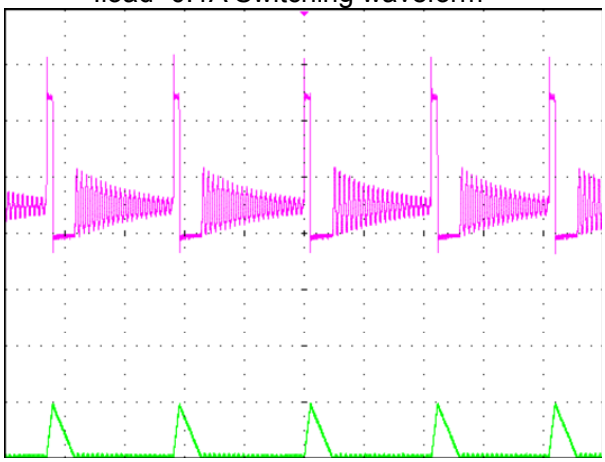
Iload=0.01A Switching waveform



Iload=0.01A output waveform

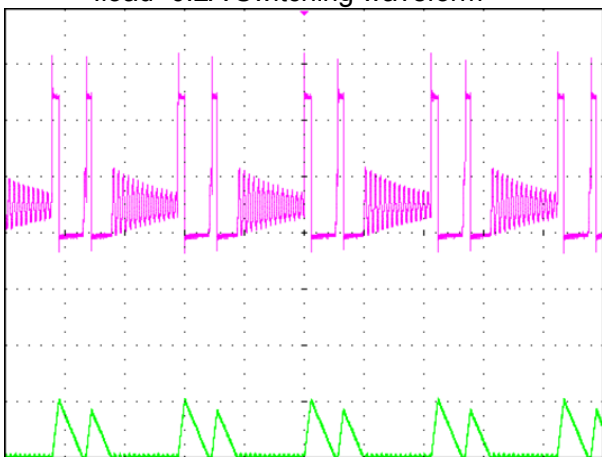


Iload=0.1A Switching waveform



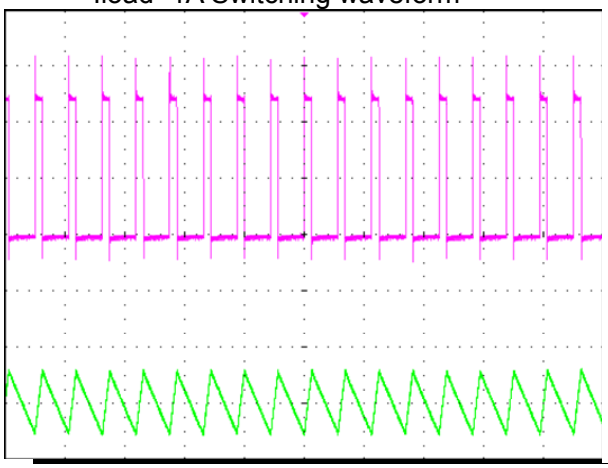
Iload=0.1A output waveform

Iload=0.2A Switching waveform

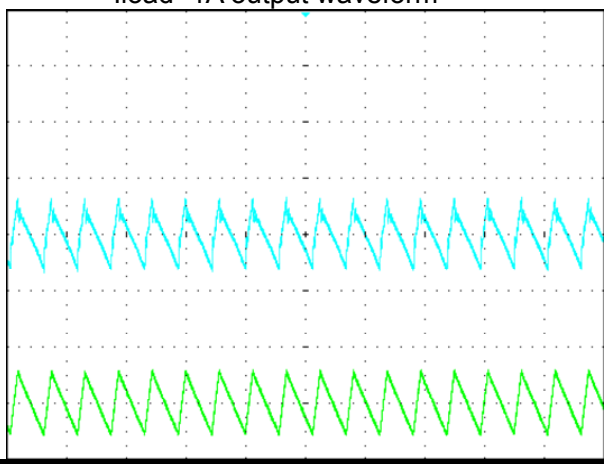


Iload=0.2A output waveform

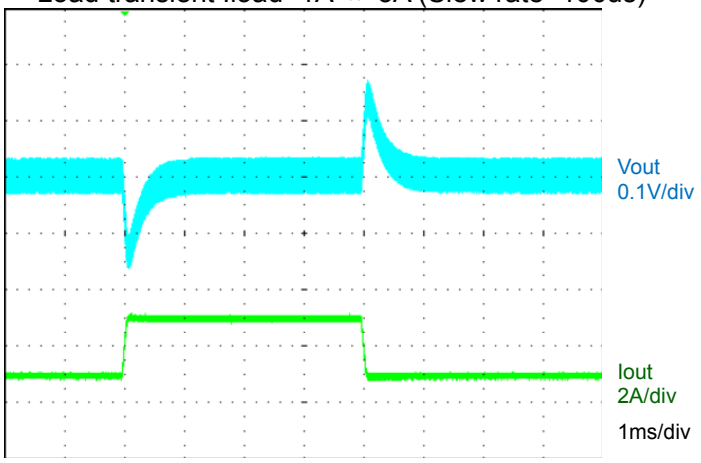
Iload=1A Switching waveform



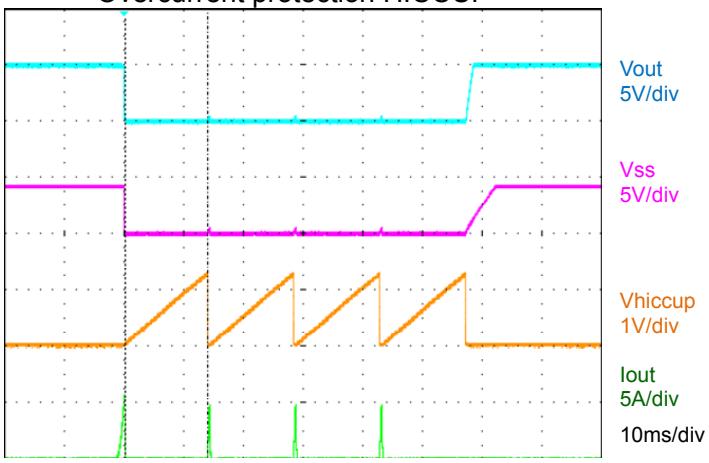
Iload=1A output waveform



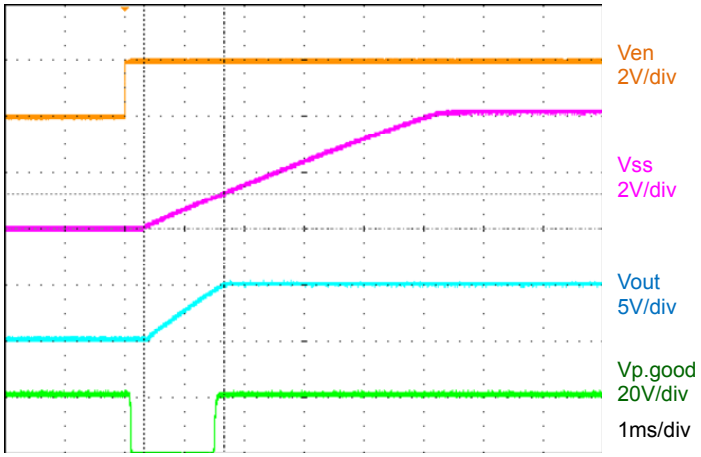
Load transient Iload=1A ⇔ 3A (Slew rate=100us)



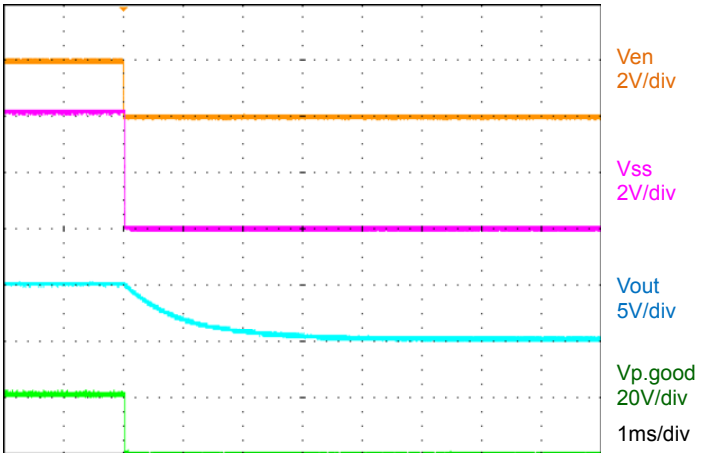
Overcurrent protection HICCUP



Soft start



Shutdown



11. Selection of main parts

11.1 Choke coil

When conditions for input voltage, output voltage and ripple current are defined, the following equation (9) gives inductance value.

Make sure to set ripple current (ΔIR) to be lower than 20% of the output current.

$$\left\{\begin{array}{l} L = \dfrac{VIN\text{-}VOUT}{\Delta IR} \times Ton \\ Ton = \dfrac{1}{\{((V_{IN} - V_{OUT}) \div (V_{OUT} + VF)) + 1\} \times F_{OSC}} \\ F_{OSC} : \text{Oscillatory Frequency} \\ VF : \text{Forward voltage of Schottky Barrier diode} \\ VIN : \text{Input voltage} \\ VOUT : \text{Output voltage} \end{array}\right. \quad (9)$$

・Inductor current: Peak value (IRP)

Current peak value (IRP) of the inductor is given by the equation (10).

$$IRP = Iout + \frac{VIN\text{-}VOUT}{2L} \times Ton \quad (10)$$

Make sure that rating current value of the inductor is higher than a peak value of ripple current.

・Inductor current: ripple current (ΔIR)

Ripple current (ΔIR) is given by the equation (11).

$$\Delta IR = \frac{VIN\text{-}VOUT}{L} \times Ton \quad (11)$$

When load current (Iout) is less than 1/2 of the ripple current, inductor current flows discontinuously.

11.2 Output capacitor

Make sure to use a capacitor with high frequency impedance for switching power supply because a large ripple current flows through output capacitor.

Effective value is given by the equation (12) because the ripple current (AC) that flows through output capacitor is sawtooth wave.

$$I_{C\_OUT} = \frac{1}{2\sqrt{3}} \times \frac{V_{OUT} \times (V_{IN} - V_{OUT})}{L \times F_{OSC} \times V_{IN}} \ [Arms] \quad (12)$$

11.3 Input capacitor

Ripple current flows through input capacitor which is higher than that of the output capacitors.

Therefore, caution is also required for allowable ripple current value.

The effective value of the ripple current which flows through input capacitor is given by the equation (13).

$$I_{C\_IN} = \sqrt{D\ (1 - D)} \times I_{OUT} \ [Arms] \quad (13)$$

$$D = \frac{T_{ON}}{T} = \frac{V_{OUT}}{V_{IN}}$$

In (13), D signifies the ratio between ON/OFF period. When the value is 0.5, the ripple current is at a maximum. Make sure that the input capacitor does not exceed the allowable ripple current value given by (13). With (13), if V_{IN}=24V, V_{OUT}=5V, I_{OUT}=3.0A and F_{OSC}=330 kHz, then I_{C_IN} value is about 1.22Arms.

In the board wiring from input capacitor, V_{IN} to GND, make sure that wiring is wide enough to keep impedance low because of the current fluctuation. Make sure to connect input capacitor near output capacitor to lower voltage bound due to regeneration current. When change of load current is excessive (I_{OUT}: high ⇒ low), the power of output electric capacitor is regenerated to input capacitor. If input capacitor is small, input voltage increases. Therefore, you need to implement a large input capacitor. Regeneration power changes according to the change of output voltage, inductance of a coil and load current.

11.4 External phase compensation components

This IC adopts the power saving feature which requires electronic capacitor with low ESR and solid polymer capacitor (e.g. OS capacitor), which are used as output capacitors for phase compensation.
The frequency characteristic of this IC consists of the following transfer functions.

(1) Output resistance breeder : H_R
(2) Voltage gain of error amplifier : G_{VEA}
Current gain : G_{MEA}
(3) Impedance of phase compensation external element : Z_C
(4) Current sense loop gain : G_{CS}
(5) Output smoothing impedance : Z_O

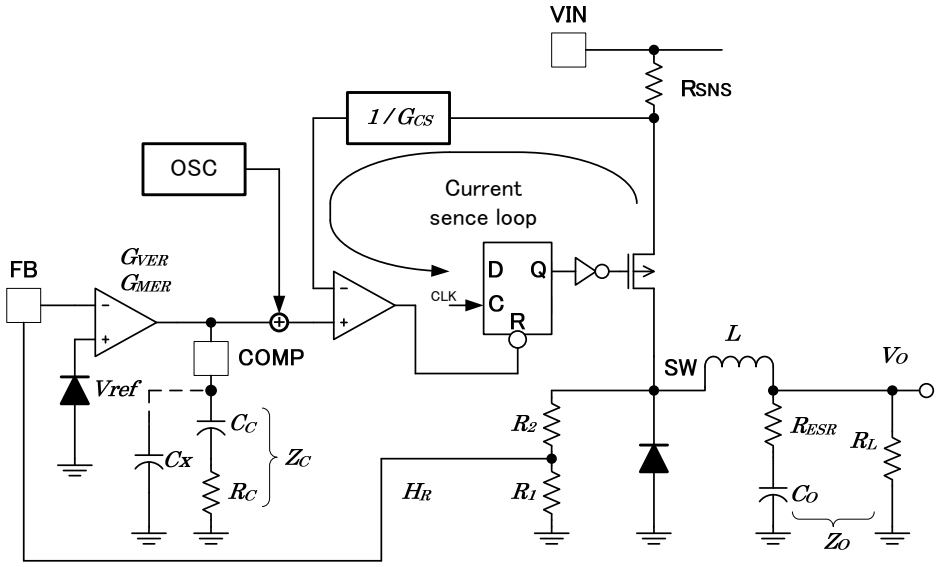


Fig. LV5068V compensation networks

Closed loop gain is obtained with the following formula (14).

$$G = H_R \cdot G_{MER} \cdot Z_C \cdot G_{CS} \cdot Z_O \quad (14)$$

The table of compensation values for 330 kHz is provided below electronic capacitor with low ESR.

VIN (V)	Vout (V)	RSNS (mohm)	L (uH)	RC (kohm)	CC (nF)	Co (uF)	R_{ESR} (mohm)	Manufacturer Part	Manufacturer
12 24	5	30	10	82	4.7	220	82	10ME220SWG	SUN electronic Industries
12 24	3.3	30	10	56	4.7	220	82	10ME220SWG	SUN electronic Industries
12 24	5	20	10	56	4.7	220	82	10ME220SWG	SUN electronic Industries
12 24	3.3	20	10	33	4.7	220	82	10ME220SWG	SUN electronic Industries

For this IC, R_{ESR} of output capacitor should be lower than 100m ohm. Where R_{ESR} of output capacitor is high, C_X is required for compensation. C_X can be determined by:

$$C_X = \frac{R_{ESR} \times C_O}{R_C}$$

The zero-cross frequency required in the actual system board, in other word, transient response is adjusted by R_C. Also, if the influence of noise is significant, use of C_C or C_X with higher value is recommended.