

High-performance Regulator IC Series for PCs



Switching Regulators for DDR-SDRAM Cores

BD9535MUV

●Description

BD9535MUV is a 2ch switching regulator controller with high output current which can achieve low output voltage (0.7V~2.0V) from a wide input voltage range (4.5V~25V). High efficiency for the switching regulator can be realized by utilizing an external N-MOSFET power transistor. A new technology called H³RegTM is a Rohm proprietary control method to realize ultra high transient response against load change. SLLMTM (Simple Light Load Mode) technology is also integrated to improve efficiency in light load mode, providing high efficiency over a wide load range. For the soft start/stop function, variable frequency function, short circuit protection function with timer latch, and tracking function are all built in. This 2ch switching regulator is specially designed for Chipset and Front Side Bus.

●Features

- 1) 2ch H³REGTM Switching Regulator Controller
- 2) Light Load Mode and Continuous Mode Changeable
- 3) Thermal Shut Down (TSD), Under Voltage LockOut (UVLO),
Over Current (detect the peak current) Protection (OCP), Over Voltage Protection (OVP),
Short circuit protection with built-in timer-latch
- 4) Soft start function to minimize rush current during startup
- 5) Switching Frequency Variable (f=200KHz~600kHz)
- 6) VQFN032V5050 package
- 7) Built-in Power good circuit
- 8) Adjustable to chip set spec by tracking function

●Applications

Laptop PC, Desktop PC, LCD-TV, Digital Components

● Maximum Absolute Ratings (Ta=25°C)

Parameter	Symbol	Rating	Unit
Input Voltage 1	VCC	7 ^{*1}	V
Input Voltage 2	VDD	7 ^{*1}	V
Input Voltage 3	VIN	30 ^{*1}	V
BOOT Voltage	VBOOT1/2	35 ^{*1}	V
BOOT-SW Voltage	VBOOT1-VSW1, VBOOT2-VSW2	7 ^{*1}	V
HG-SW Voltage	VHG1-VSW1, VHG2-VSW2	7 ^{*1}	V
LG Voltage	VLG1/2	VDD	V
Setting for Output Voltage	VREF1/2	VCC	V
Output voltage	VIs+1/2, VIs-1/2	VCC	V
SS Voltage	VSS1/2	VCC	V
FS Voltage	VFS	VCC	V
VREG voltage	VREG	VCC	V
Current Limit setting Voltage	VILIM1/2	VCC	V
Logic Input Voltage	VEN1/2	7 ^{*1}	V
PGOOD Voltage	VPGOOD1/2	7 ^{*1}	V
CE Voltage	VCE1/2	7 ^{*1}	V
Power dissipation	Pd	T.B.D	W
Operating Temperature Range	Topr	-10~+100	°C
Storage Temperature Range	Tstg	-55~+150	°C
Junction Temperature	Tjmax	+150	°C

*1 Not to exceed Pd.

● Operating Conditions (Ta=25°C)

Parameter	Symbol	Min.	Max.	Unit
Input Voltage 1	VCC	4.5	5.5	V
Input Voltage 2	VDD	4.5	5.5	V
Input Voltage 3	VIN	3.0	28	V
BOOT Voltage	VBOOT1/2	4.5	30	V
SW Voltage	VSW1/2	-2	33	V
BOOT-SW Voltage	VHG1-VSW1, VHG2-VSW2	4.5	5.5	V
Logic Input Voltage	VEN1/2	0	5.5	V
Setting Voltage for Output Voltage	VREF1/2	0.7	2.0	V
Is Input Voltage	VIs+1/2, VIs-1/2	0.7	2.0	V
MIN ON time	tonmin	-	100	nsec

★ This product should not be used in a radioactive environment.

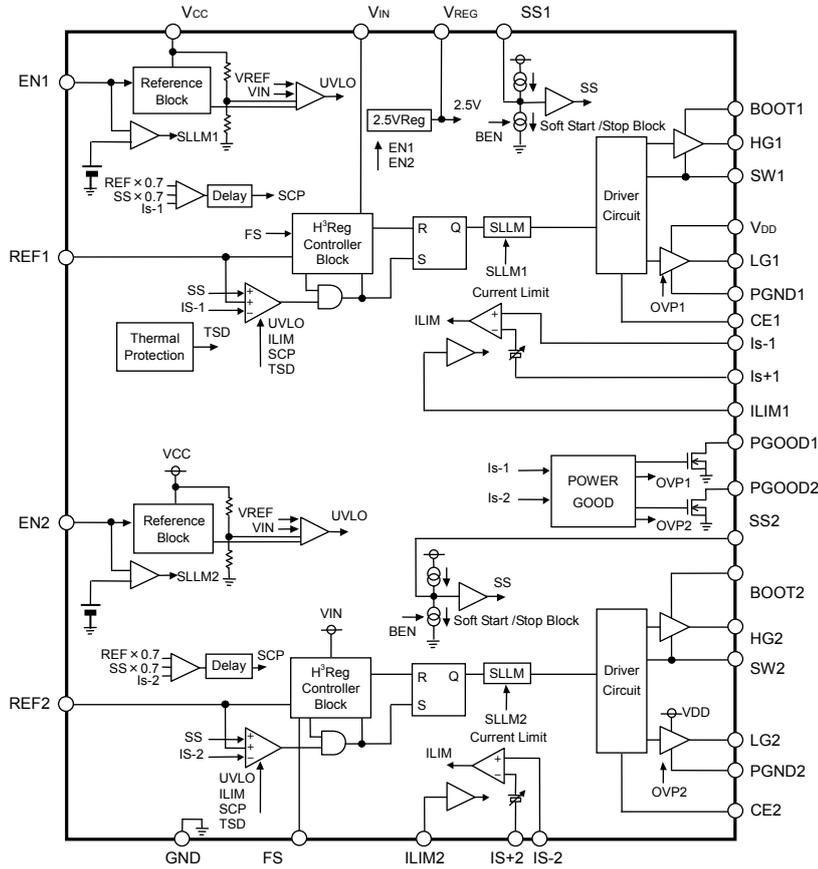
●ELECTRICAL CHARACTERISTICS

(unless otherwise noted, Ta=25°C VCC=5V,VDD=5V,VEN=3V,VIN=12V,VREF=1.8V,RFS=68kΩ)

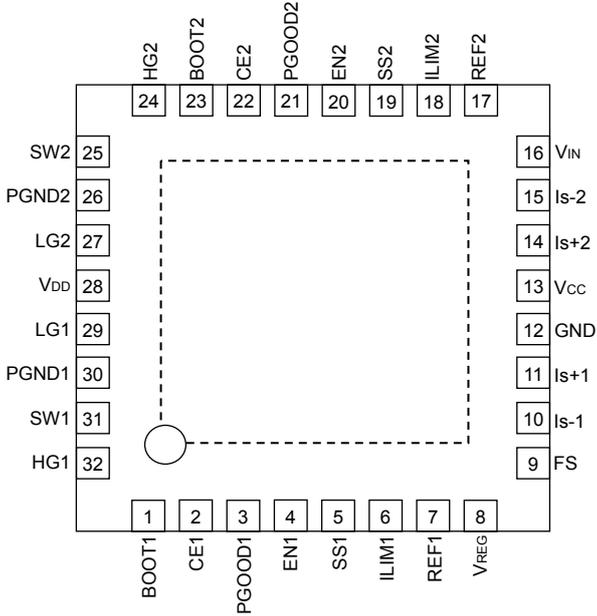
Parameter	Symbol	Standard Value			Unit	Conditions
		MIN.	TYP.	MAX.		
[Whole Device]						
VCC bias current	Icc	-	1.4	2.0	mA	
VIN bias current	IIN	-	200	400	μA	
VCC standby current	Istb	-	-	20	μA	VEN1=VEN2=0V
VIN standby current	IIN_Stb	-	20	40	μA	VEN1=VEN2=0V
EN Low voltage 1,2	VEN_low1,2	GND	-	0.8	V	
EN High voltage 1,2 (forced continuous mode)	VENth_con1,2	2.3	-	3.8	V	
EN High voltage 1,2 (SLLM mode)	VENth_sllm1,2	4.2	-	5.5	V	
EN bias current 1,2	IEN1,2	-	7	10	μA	
VREG voltage	VREG1,2	2.475	2.500	2.525	V	I _{REG} =500 μA Ta=-10~100°C ²
[Under voltage lock out block]						
VCC threshold voltage	Vcc_UVLO	4.1	4.3	4.5	V	VCC:Sweep up
VCC hysteresis voltage	dVcc_UVLO	100	160	220	mV	VCC:Sweep down
VIN threshold voltage	VIN_UVLO	2.4	2.6	2.8	V	VIN:Sweep up
VIN hysteresis voltage	dVIN_UVLO	100	160	220	mV	VIN:Sweep down
VREG threshold voltage	VREG_UVLO	2.0	2.2	2.4	V	VREG:Sweep up
VREG hysteresis voltage	dVREG_UVLO	100	160	220	mV	VREG:Sweep down
[Over Voltage Protection block]						
VOU _T threshold voltage 1,2	VOU _T _OVP1,2	VREF × 1.15	VREF × 1.20	VREF × 1.25	V	
[Power Good block]						
VOU _T Power Good Low voltage 1,2	VPGOOD_low1,2	VREF × 0.87	VREF × 0.90	VREF × 0.93	V	
VOU _T Power Good High voltage 1,2	VPGOOD_high1,2	VREF × 1.07	VREF × 1.10	VREF × 1.13	V	
Discharge ON resistance 1,2	Ron_PGOOD1,2	-	1.0	2.0	kΩ	
Delay time 1,2	TPGOOD1,2	150	250	350	μsec	
[H³REG™ Control block]						
ON Time1	ton1	400	500	600	nsec	RFS=68kΩ
MAX ON Time 1	Tonmax1	2.5	3.0	3.5	μsec	
MIN OFF Time 1	Toffmin1	500	600	700	nsec	
ON Time 2	ton2	250	350	450	nsec	RFS=68kΩ
MAX ON Time 2	Tonmax2	2.5	3.0	3.5	μsec	
MIN OFF Time 2	Toffmin2	500	600	700	nsec	
[FET Driver block]						
HG upper side ON resistance 1,2	RHGhon1,2	-	3.0	6.0	Ω	
HG lower side ON resistance 1,2	RHGlon1,2	-	2.0	4.0	Ω	
LG upper side ON resistance 1,2	RLGhon1,2	-	2.0	4.0	Ω	
LG lower side ON resistance 1,2	RLGlon1,2	-	0.5	1.0	Ω	
[Soft Start block]						
Charge current	ISS_char1,2	1.5	2	2.5	μA	
Discharge current	ISS_dis1,2	1.5	2	2.5	μA	
Discharge threshold voltage	VSS_disth1,2	-	0.1	0.2	V	
Standby voltage	VSS_STB1,2	-	-	50	mV	
[Current Limit block]						
Current limit threshold voltage 1_1,2	Vlim11,2	40	50	60	mV	VILIM=0.5V
Current limit threshold voltage 2_1,2	Vlim21,2	170	200	230	mV	VILIM =2.0V
Reflux current limit threshold voltage1_1,2	VRelim11,2	-60	-50	-40	mV	VILIM =0.5V
Reflux current limit threshold voltage2_1,2	VRelim21,2	-230	-200	-170	mV	VILIM =2.0V
[Output Voltage Sense block]						
Vis offset voltage1,2	Vis_off1,2	VREF -3m	VREF	VREF +3m	V	Ta=-10~100°C ²
REF bias current1,2	IREF1,2	-100	0	100	nA	
Is+ input current1,2	IIs+1,2	-100	0	100	nA	VIs+=1.8V
Is- input current1,2	IIs-1,2	-100	0	100	nA	VIs-=1.8V
[SCP block]						
Threshold voltage 1,2	Vthscp1,2	-	VREF × 0.7	-	V	
Delay time 1,2	tscp1,2	0.7	1	1.3	msec	

²Designed guarantee

●Block Diagram



●Pin Configuration



●Pin Function Table

PIN No.	PIN name	PIN function
1	BOOT1	HG driver power supply pin 1
2	CE1	Reactive pin 1 for lower ESR output capacitor
3	PGOOD1	Power good signal output pin 1
4	EN1	Enable input pin 1 (0~0.8V:OFF, 2.3~3.8V:continuous mode, 4.2~5.5V:SLLM™)
5	SS1	Connective pin 1 of capacitor for soft start/soft stop
6	ILIM1	Current limit setting pin 1
7	REF1	Output voltage setting pin 1
8	VREG	Reference voltage inside IC (Output : 2.5V)
9	FS	Resistance connective pin for setting frequency
10	IS-1	Current sense pin- 1
11	IS+1	Current sense pin+ 1
12	GND	Sense GND
13	VCC	Power supply input pin
14	IS+2	Current sense pin+ 2
15	IS-2	Current sense pin- 2
16	VIN	Battery voltage sense pin
17	REF2	Output voltage setting pin 2
18	ILIM2	Current limit setting pin 2
19	SS2	Connective pin 2 of capacitor for soft start/soft stop
20	EN2	Enable input pin 2 (0~0.8V:OFF, 2.3~3.8V:continuous mode, 4.2~5.5V:SLLM™)
21	PGOOD2	Power good signal input pin 2
22	CE2	Reactive pin 2 for lower ESR output capacitor
23	BOOT2	HG driver power supply pin 2
24	HG2	High side FET gate drive pin 2
25	SW2	High side FET source pin 2
26	PGND2	Power GND2
27	LG2	Low side FET gate drive pin 2
28	VDD	Power supply input pin
29	LG1	Low side FET gate drive pin 1
30	PGND1	Power GND 1
31	SW1	High side FET source pin 1
32	HG1	High side FET gate drive pin 1
reverse	FIN	substrate

● Reference Data

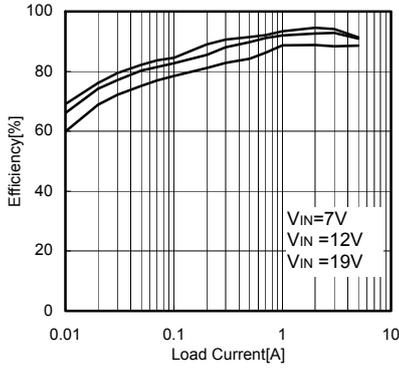


Fig.1 Io-efficiency (SLLM)

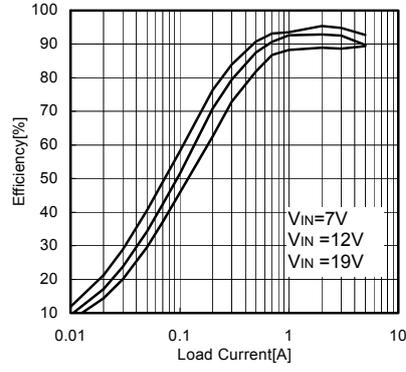


Fig.2 Io-efficiency (Continuous mode)

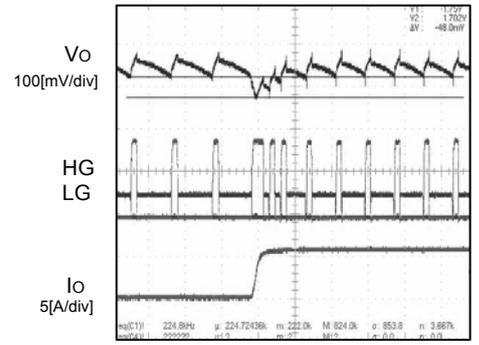


Fig.3 Transitional response (Io=0 to 5A) (Continuous mode)

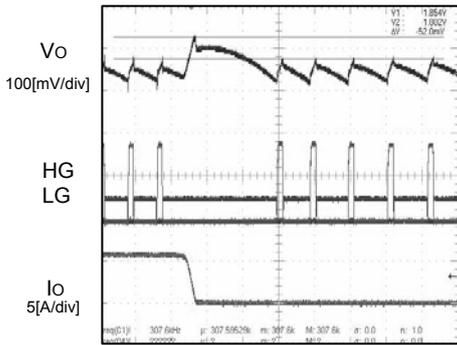


Fig.4 Transitional response (Io=5 to 0A) (Continuous mode)

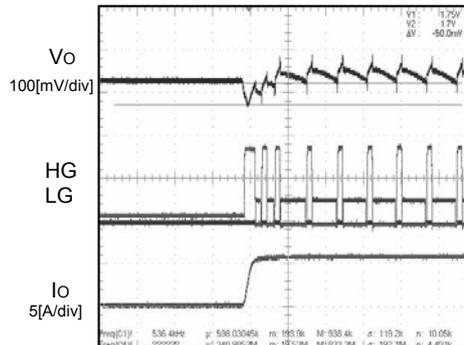


Fig.5 Transitional response (Io=0 to 5A) (SLLM)

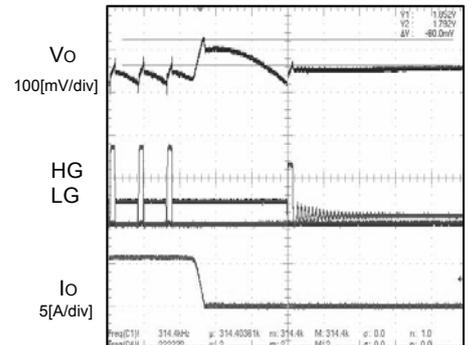


Fig.6 Transitional response (Io=5 to 0A) (SLLM)

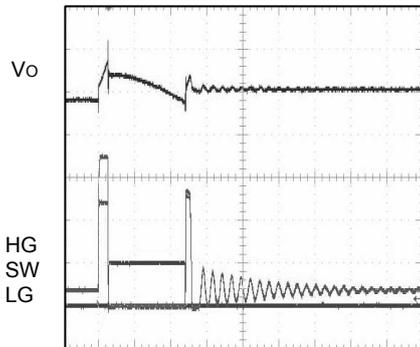


Fig.7 SLLM : Io=0A

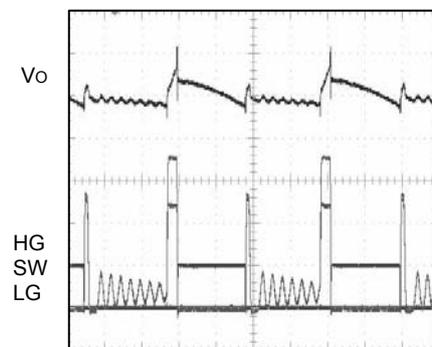


Fig.8 SLLM : Io=0.4A

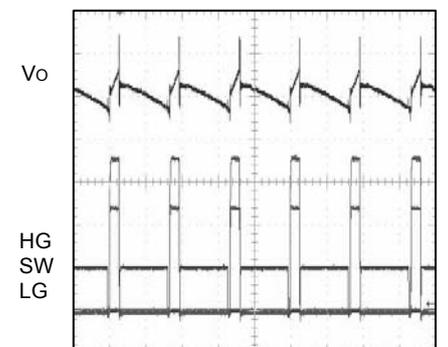


Fig.9 SLLM : Io=1A

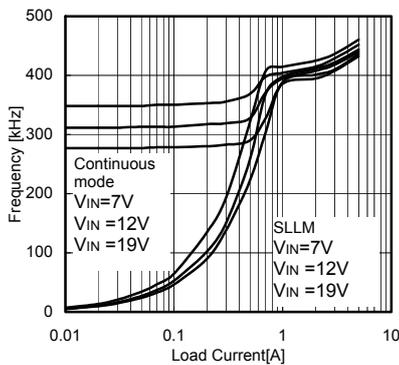


Fig.10 Io-Frequency

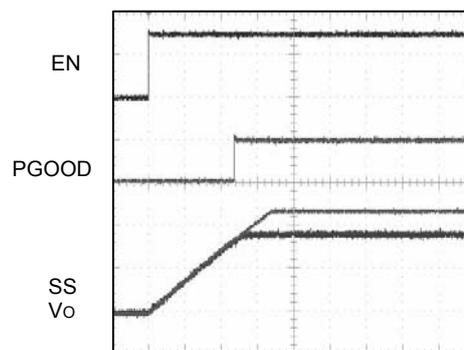


Fig.11 starting wave

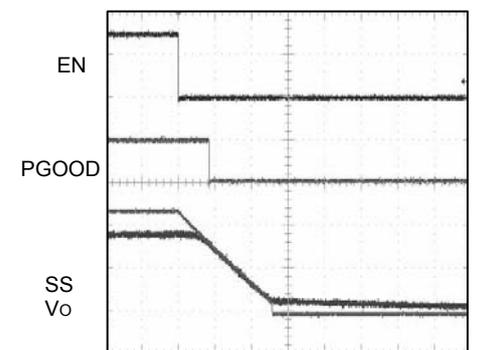
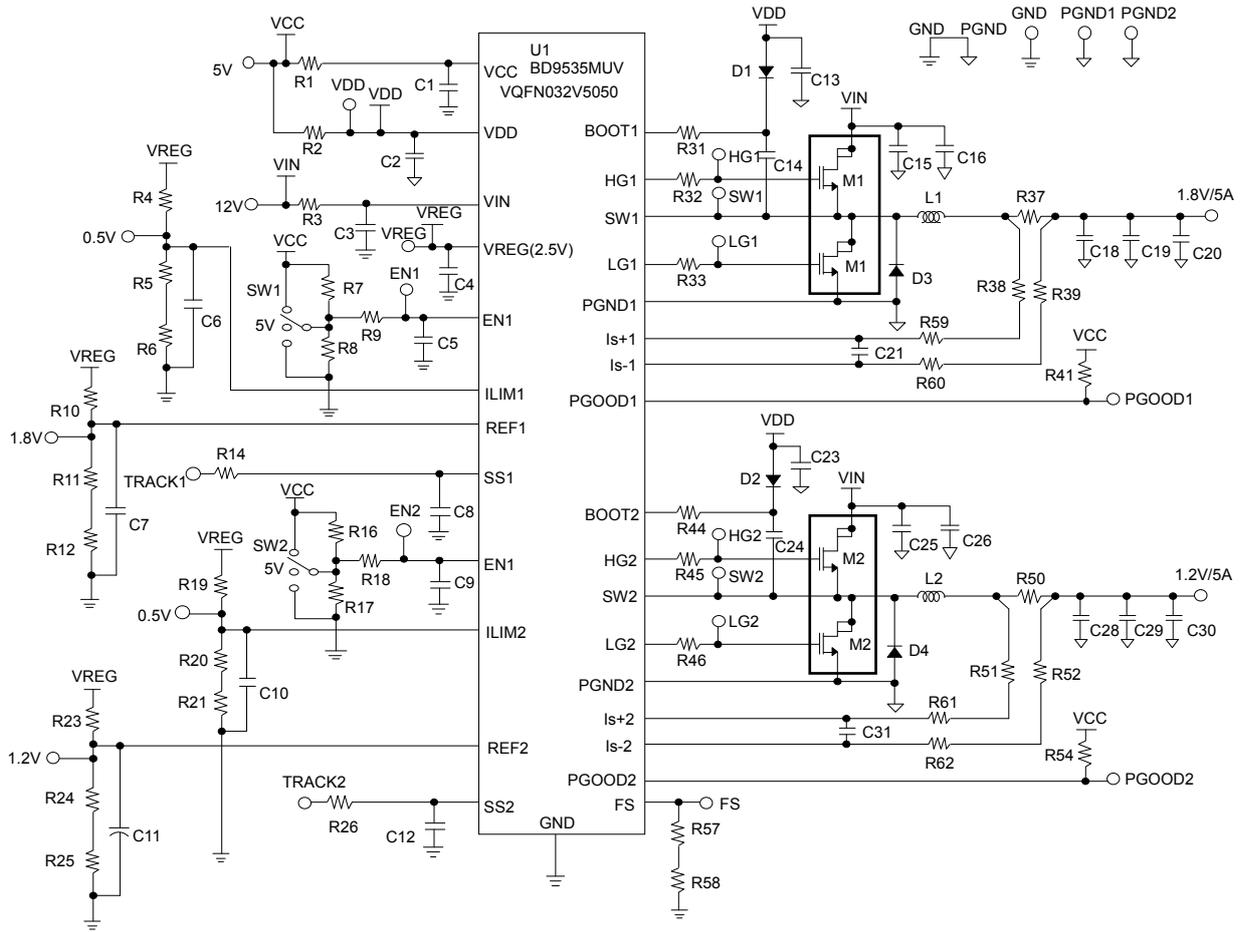


Fig.12 stopping wave

● Evaluation Board Circuit



● Evaluation Board Parts List

Designation	Value	Part No.	Company
R1	10 Ω	MCR03EZPF10R0	ROHM
R2	0 Ω	MCR03EZHZJ000	ROHM
R3	1k Ω	MCR03EZPF1001	ROHM
R4	200k Ω	MCR03EZPF2003	ROHM
R5	51k Ω	MCR03EZPF5102	ROHM
R6	0 Ω	MCR03EZHZJ000	ROHM
R7	51k Ω	MCR03EZPF5102	ROHM
R8	91k Ω	MCR03EZPF9102	ROHM
R9	0 Ω	MCR03EZHZJ000	ROHM
R10	22k Ω	MCR03EZPF2202	ROHM
R11	56k Ω	MCR03EZPF5602	ROHM
R12	0 Ω	MCR03EZHZJ000	ROHM
R14	10k Ω	MCR03EZPF1002	ROHM
R16	51k Ω	MCR03EZPF5102	ROHM
R17	91k Ω	MCR03EZPF9102	ROHM
R18	0 Ω	MCR03EZHZJ000	ROHM
R19	200k Ω	MCR03EZPF2003	ROHM
R20	51k Ω	MCR03EZPF5102	ROHM
R21	0 Ω	MCR03EZHZJ000	ROHM
R23	39k Ω	MCR03EZPF3902	ROHM
R24	36k Ω	MCR03EZPF3602	ROHM
R25	0 Ω	MCR03EZHZJ000	ROHM
R26	10k Ω	MCR03EZPF1002	ROHM
R31	0 Ω	MCR03EZHZJ000	ROHM
R32	0 Ω	MCR03EZHZJ000	ROHM
R33	0 Ω	MCR03EZHZJ000	ROHM
R37	7m Ω	PMR100HZPFU7L00	ROHM
R38	0 Ω	MCR03EZHZJ000	ROHM
R39	0 Ω	MCR03EZHZJ000	ROHM
R41	100k Ω	MCR03EZPF1003	ROHM
R44	0 Ω	MCR03EZHZJ000	ROHM
R45	0 Ω	MCR03EZHZJ000	ROHM
R46	0 Ω	MCR03EZHZJ000	ROHM
R50	7m Ω	PMR100HZPFU7L00	ROHM
R51	0 Ω	MCR03EZHZJ000	ROHM
R52	0 Ω	MCR03EZHZJ000	ROHM

Designation	Value	Part No.	Company
R54	100k Ω	MCR03EZPF1003	ROHM
R57	75k Ω	MCR03EZPF7502	ROHM
R58	0 Ω	MCR03EZHZJ000	ROHM
R59	100 Ω	MCR03EZPF1000	ROHM
R60	100 Ω	MCR03EZPF1000	ROHM
R61	100 Ω	MCR03EZPF1000	ROHM
R62	100 Ω	MCR03EZPF1000	ROHM
C1	10uF	CM21B106M06A	ROHM
C2	10uF	CM21B106M06A	ROHM
C3	0.01uF	MCH185CN103KB	ROHM
C4	1uF	CM105B105K06A	ROHM
C6	0.1uF	MCH185CN104K	ROHM
C7	0.1uF	MCH185CN104K	ROHM
C8	0.047uF	MCH185CN473K	ROHM
C10	0.1uF	MCH185CN104K	ROHM
C11	0.1uF	MCH185CN104K	ROHM
C12	0.047uF	MCH185CN473K	ROHM
C13	10uF	CM21B106M06A	ROHM
C14	0.1uF	MCH185CN104K	ROHM
C15	10uF(25V)	CT32X5R106K25A	KYOCERA
C18	200uF	2R5TPE220MF	SANYO
C21	100pF	MCH185A101J	ROHM
C23	10uF	CM21B106M06A	ROHM
C24	0.1uF	MCH185CN104K	ROHM
C26	10uF(25V)	CT32X5R106K25A	KYOCERA
C28	200uF	2R5TPE220MF	SANYO
C31	100pF	MCH185A101J	ROHM
D1	-	PB521S-30	ROHM
D2	-	PB521S-30	ROHM
D3	-	RSX501L-20	ROHM
D4	-	RSX501L-20	ROHM
L1	2.5uH	CDEP105-2R5MC-32	Sumida
L2	2.5uH	CDEP105-2R5MC-32	Sumida
M1	-	SP8K4(2in1)	ROHM
M2	-	SP8K4(2in1)	ROHM
U1	-	BD9535MUV	ROHM

● Pin Descriptions

- Vcc (13pin)

This is the power supply pin for IC internal circuits, except the FET driver. The maximum circuit current is 2.0mA. The input supply voltage range is 4.5V to 5.5V. It is recommended that a 0.1uF bypass capacitor be put in this pin.
- EN1/EN2 (4pin/20pin)

When EN pin voltage is at least 2.3V, the status of this switching regulator become active. Conversely, the status switches off when EN pin voltage goes lower than 0.8V and circuit current becomes 20uA or less. This pin is also switch pin of SLLM™. The voltage is 2.3V to 3.8V : forced continuous mode, 4.2V to 5.5V : SLLM™. These operating modes are changeable to control by power supply system 3.3V or 5V.
- VDD (28pin)

This is the power supply pin to drive the LOW side FET. It is recommended that a 1uF bypass capacitor be established to compensate for rush current during the FET ON/OFF transition.
- VREG (8pin)

This is the reference voltage output pin. The voltage is 2.5V, with 100uA current ability. It is recommended that a 1uF capacitor be established between VREF and GND. It is available to set VREF by the resistance division value from VREG in case VREF is not set from an external power supply.
- REF1/REF2 (7pin/17pin)

This is the setting pin for output voltage of switching regulator. It is so convenient to be synchronized to outside power supply. This IC controls the voltage in the status of $VREF1 \doteq V_{is-1}$ or $VREF2 \doteq V_{is-2}$.
- ILIM1/ILIM2 (6pin/18pin)

BD9535MUV detects the voltage between Is+ pin and Is- pin and limits the output current (OCP). Voltage equivalent to 1/10 of the ILIM voltage is the voltage drop of external current sense resistor. A very low current sense resistor or inductor DCR can also be used for this platform.
- SS1/SS2 (5pin/19pin)

This is the adjustment pin to set the soft start/stop time. SS voltage is low during standby status. When EN is ON, the soft start time can be determined by the SS charge current and capacitor between SS-GND. Until SS reaches REF voltage, the output voltage is equivalent to SS voltage.
- VIN (16pin)

The duty cycle is determined by input voltage and controls output voltage. In other words, the output voltage is affected by input voltage. Therefore, when VIN voltage fluctuates, the output voltage becomes also unstable. Since the VIN line is also the input voltage of the switching regulator, stability depends on the impedance of the voltage supply. It is recommended to establish a bypass capacitor or CR filter suitable for the actual application.
- FS (9pin)

This is the pin to adjust the switching frequency with the resistor. The frequency range is from 200kHz to 600kHz.
- Is+1/Is+2, Is-1/Is-2 (11pin/14pin/10pin/15pin)

These pins are connected to both sides of the current sense resistor to detect output current. The voltage drop between Is+ and Is- is compared with the voltage equivalent to 1/10 of ILIM voltage. When this voltage drop hits the specified voltage level, the output voltage is OFF.
- BOOT1/BOOT2 (1pin/23pin)

This is the voltage supply to drive the high side FET. The maximum absolute ratings are 35V (from GND) and 7V (from SW). BOOT voltage swings between (VIN+Vcc) and Vcc during active operation.
- HG1/HG2 (29pin/27pin)

This is the voltage supply to drive the Gate of the high side FET. This voltage swings between BOOT and SW. High-speed Gate driving for the high side FET is achieved due to the low on-resistance (3 ohm when HG is high, 2 ohm when HG is low) driver.
- SW1/SW2 (31pin/25pin)

This is the source pin for the high side FET. The maximum absolute ratings are 30V (from GND). SW voltage swings between VIN and GND.
- LG1/LG2 (29pin/27pin)

This is the voltage supply to drive the Gate of the low side FET. This voltage swings between VDD and PGND. High-speed Gate driving for the low side FET is achieved due to the low on-resistance (3 ohm when LG is high, 0.5 ohm when LG is low) driver.
- PGND1/PGND2 (30pin/26pin)

This is the power ground pin connected to the source of the low side FET. This is the source pin for low-side FET. It is prepared for each channel to reduce the interference among channels.
- PGOOD1/PGOOD2 (3pin/21pin)

This is the monitor pin for output voltage (Is-1/Is-2). When the output voltage is within 10% of setting voltage (REF1/2), High is output. It is open drain pin and connects to other power supply through the pull-up resistance.
- CE1/PCE2 (2pin/22pin)

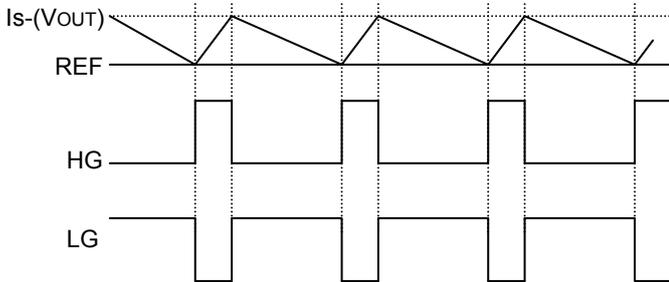
This pin is helpful for using ceramic capacitor as output capacitor. It is stable to use low ESR capacitor (small ripple voltage).
- GND (12pin)

This is GND pin for Analog and Digital series. Set the reverse side of IC equivalent to the voltage of this pin.

● Explanation of Operation

The BD9535MUV is a 2ch synchronous buck regulator controller incorporating ROHM's proprietary H³REG CONTROLLA control system. When V_{OUT} drops due to a rapid load change, the system quickly restores V_{OUT} by extending the TON time interval. Thus, it serves to improve the regulator's transient response. Activating the Light Load Mode will also exercise Simple Light Load Mode (SLLM) control when the load is light, to further increase efficiency.

H³Reg™ control
(Normal operation)

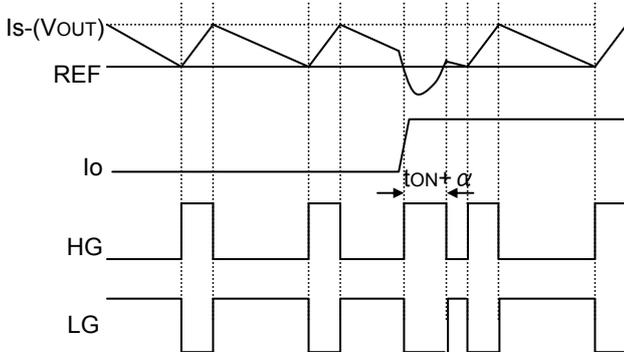


When V_{OUT} falls to a threshold voltage (REF), the drop is detected, activating the H³REG CONTROLLA system.

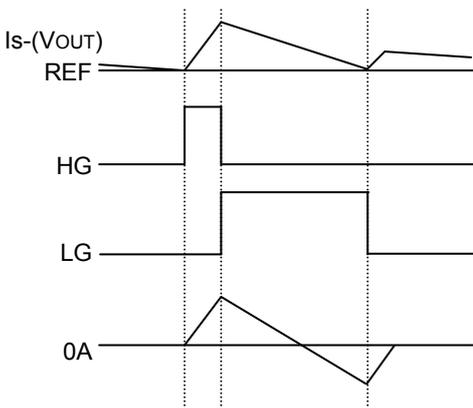
$$t_{ON} = \frac{REF}{V_{IN}} \times \frac{1}{f} \text{ [sec]} \dots (1)$$

HG output is determined by the formula above.

(V_{OUT} drops due to a rapid load change)

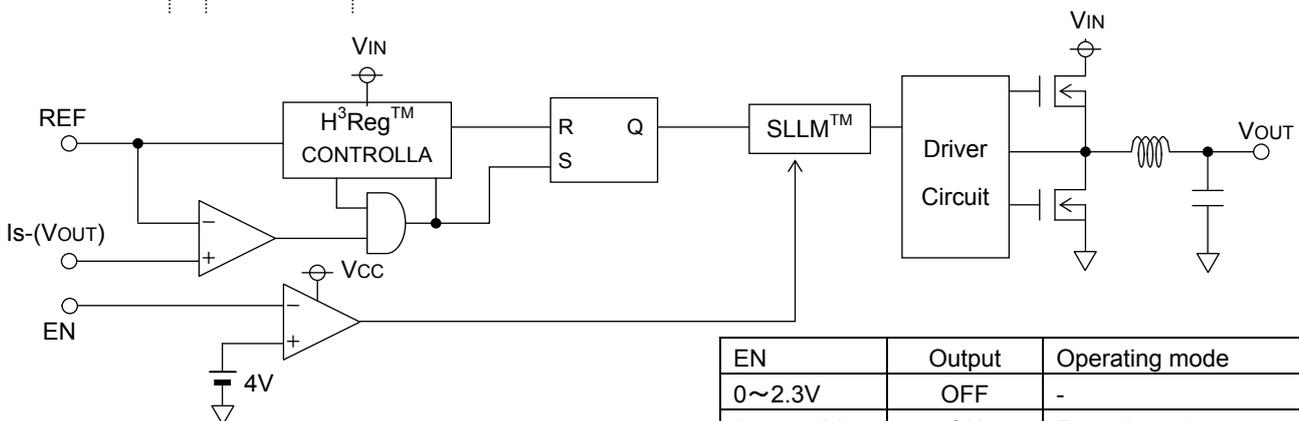


When V_{OUT} drops due to a rapid load change, and the voltage remains below REF after the programmed t_{ON} time interval has elapsed, the system quickly restores V_{OUT} by extending the t_{ON} time, improving the transient response.



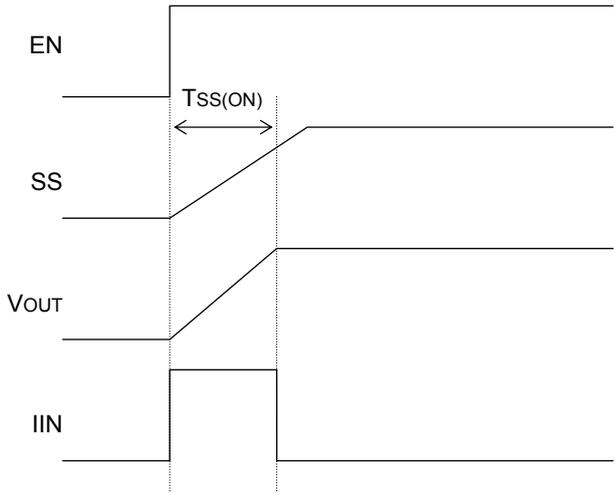
In SLLM (SLLM=0V), SLLM function is operated when LG pin is OFF and the coil current is lower than 0A (the current goes from V_{OUT} to SW). And it stops to output next HG.

When V_{OUT} goes lower than REF voltage again, the status of HG is ON.



EN	Output	Operating mode
0~2.3V	OFF	-
2.3~3.8V	ON	Forced continuous mode
4.2~5.5V	ON	SLLM™

● Timing Chart
 • Soft Start Function



Soft start is exercised with the EN pin set high. Current control takes effect at startup, enabling a moderate output voltage “ramping start.” Soft start timing and incoming current are calculated with formulas (2) and (3) below.

Soft start time

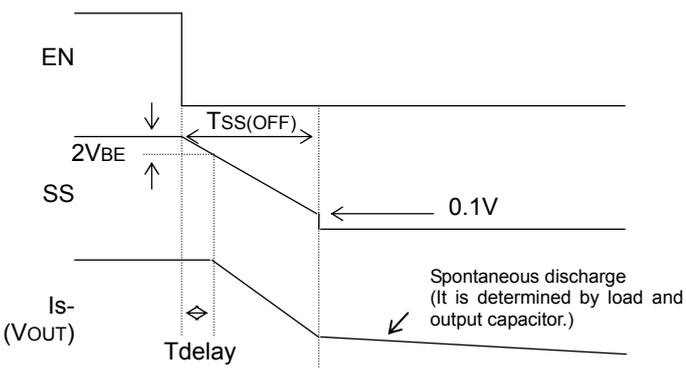
$$T_{SS(ON)} = \frac{REF \times C_{SS}}{2 \mu A (typ)} \text{ [sec]} \dots (2)$$

rush current

$$I_{IN} = \frac{C_o \times V_{OUT}}{T_{SS}} \text{ [A]} \dots (3)$$

(C_{SS}: Soft start capacitor; C_o: Output capacitor)

• Soft Stop Function



Soft stop is exercised with the EN pin set low. Current control takes effect at startup, enabling a moderate output voltage. Soft start timing and incoming current are calculated with formulas (4) below.

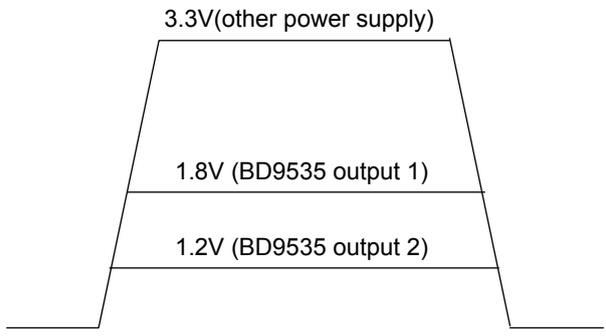
Soft stop time

$$T_{SS(OFF)} = \frac{(REF + 2V_{BE} - 0.1) \times C_{SS}}{2 \mu A (typ)} \text{ [sec]} \dots (4)$$

$V_{BE} = 0.6[V] \text{ (typ)}$

$T_{delay} = \frac{2V_{BE} \times C_{SS}}{2 \mu A (typ)} \text{ [sec]} \dots (5)$

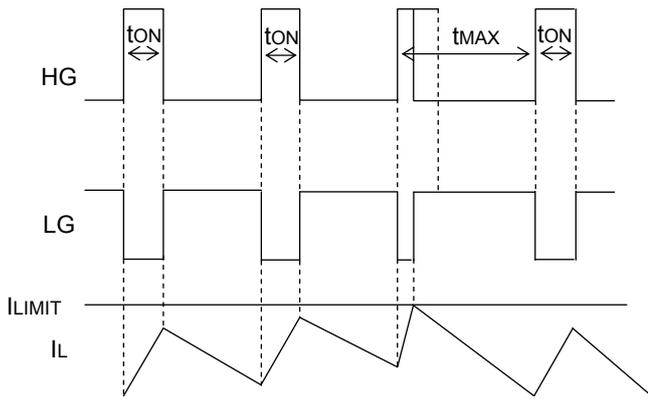
• Synchronous operation with other power supply



These power supply sequences are realized to connect SS pin to other power supply output through the resistance (10kΩ).

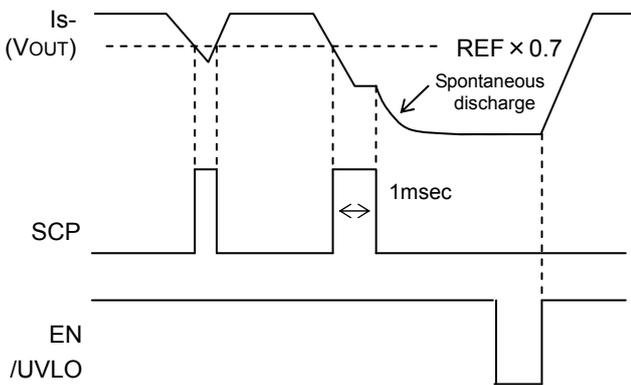
● Timing chart

• Over current protection circuit



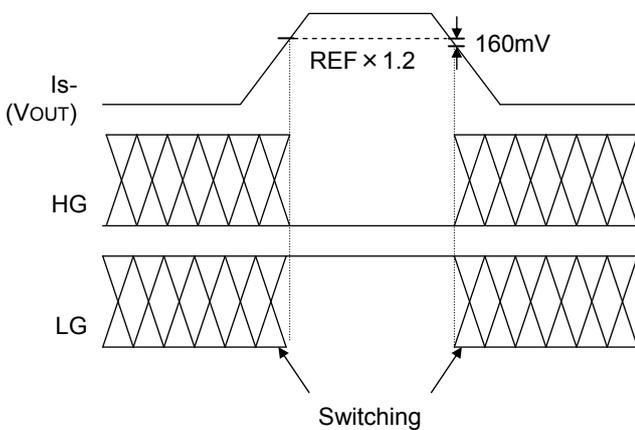
During the normal operation, when V_{OUT} becomes less than REF Voltage, HG becomes High during the time T_{ON}. However, when inductor current exceeds I_{LIMIT} threshold, HG becomes OFF. After MAX ON TIME, HG becomes ON again if the output voltage is lower than the specific voltage level and I_L is lower than I_{LIMIT} level.

• Timer Latch Type Short Circuit Protection



When output voltage (Is-) falls to REF × 0.7 or less, SCP comparator inside IC is exercised. If the status of High is continued 1ms or more (programmed time inside IC), the IC goes OFF. It can be restored either by reconnecting the EN pin or disabling UVLO.

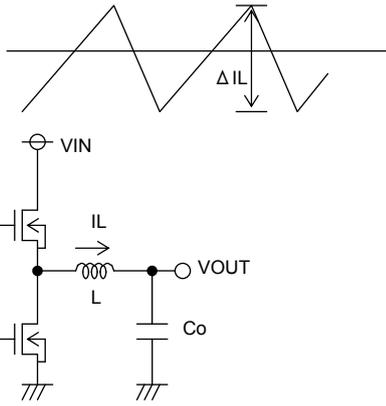
• Output Over Voltage Protection



When output rise to or above REF × 1.2, output over voltage protection is exercised, and low side FET goes up maximum for reducing output. (LG=High, HG=Low) . When output falls, it returns to the standard mode.

● External Component Selection

1. Inductor (L) selection



Output ripple current

The inductor value is a major influence on the output ripple current. As formula (5) below indicates, the greater the inductor or the switching frequency, the lower the ripple current.

$$\Delta I_L = \frac{(V_{IN} - V_{OUT}) \times V_{OUT}}{L \times V_{IN} \times f} \quad [A] \dots (6)$$

The proper output ripple current setting is about 30% of maximum output current.

$$\Delta I_L = 0.3 \times I_{OUTmax} \quad [A] \dots (7)$$

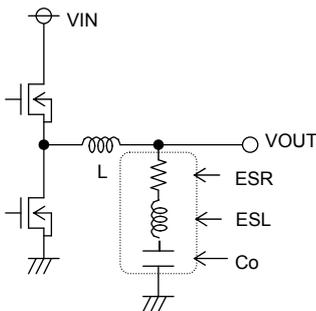
$$L = \frac{(V_{IN} - V_{OUT}) \times V_{OUT}}{L \times V_{IN} \times f} \quad [H] \dots (8)$$

(ΔI_L : output ripple current; f: switch frequency)

※ Passing a current larger than the inductor's rated current will cause magnetic saturation in the inductor and decrease system efficiency. In selecting the inductor, be sure to allow enough margin to assure that peak current does not exceed the inductor rated current value.

※ To minimize possible inductor damage and maximize efficiency, choose a inductor with a low (DCR, ACR) resistance.

2. Output Capacitor (Co) Selection



Output capacitor

When determining the proper output capacitor, be sure to factor in the equivalent series resistance required to smooth out ripple volume and maintain a stable output voltage range.

Output ripple voltage is determined as in formula (9) below.

$$\Delta V_{OUT} = \Delta I_L \times ESR + ESL \times \Delta I_L / T_{ON} \dots (9)$$

(ΔI_L : Output ripple current; ESR: Co equivalent series resistance, ESL: Co equivalent series inductance)

※ In selecting a capacitor, make sure the capacitor rating allows sufficient margin relative to output voltage. Note that a lower ESR can minimize output ripple voltage.

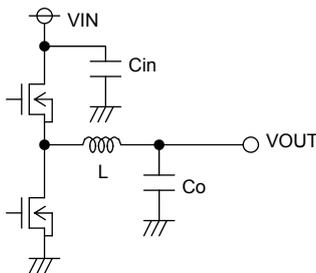
Please give due consideration to the conditions in formula (10) below for output capacity, bear in mind that output rise time must be established within the soft start time frame.

$$C_o \leq \frac{T_{SS} \times (\text{Limit} - I_{OUT})}{V_{OUT}} \dots (10)$$

T_{SS}: Soft start time
Limit: Over current detection
I_{OUT}: Output current

Note: Improper capacitor may cause startup malfunctions.

3. Input Capacitor (Cin) Selection



Input Capacitor

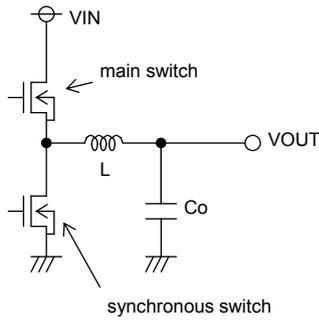
The input capacitor selected must have low enough ESR resistance to fully support large ripple output, in order to prevent extreme over current. The formula for ripple current IRMS is given in (11) below.

$$I_{RMS} = I_{OUT} \times \frac{\sqrt{V_{OUT} (V_{IN} - V_{OUT})}}{V_{IN}} \quad [A] \dots (11)$$

Where $V_{IN} = 2 \times V_{OUT}$, $I_{RMS} = \frac{I_{OUT}}{2}$

A low ESR capacitor is recommended to reduce ESR loss and maximize efficiency.

4. MOSFET Selection



Loss on the main MOSFET

$$P_{main} = P_{RON} + P_{GATE} + P_{TRAN}$$

$$= \frac{V_{OUT}}{V_{IN}} \times R_{ON} \times I_{OUT}^2 + Q_g \times f \times V_{DD} + \frac{V_{IN}^2 \times Cr_{SS} \times I_{OUT} \times f}{I_{DRIVE}} \dots (12)$$

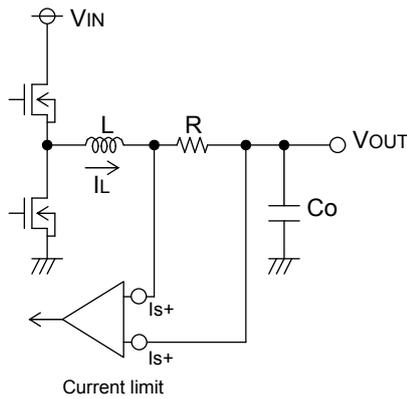
(R_{ON} : On-resistance of FET; Q_g : GATE total charge
 f : Switching frequency, Cr_{SS} : FET inverse transfer function;
 I_{DRIVE} : Gate peak current)

Loss on the synchronous MOSFET

$$P_{syn} = P_{RON} + P_{GATE}$$

$$= \frac{V_{IN} - V_{OUT}}{V_{IN}} \times R_{ON} \times I_{OUT}^2 + Q_g \times f \times V_{DD} \dots (13)$$

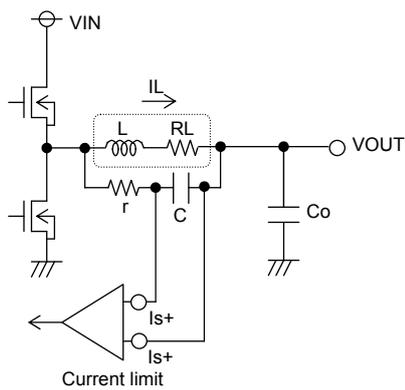
5. Setting Detection Resistance



The over current protection function detects the output ripple current peak value. This parameter (setting value) is determined as in formula (14) below.

$$I_{LIMIT} = \frac{V_{ILIM} \times 0.1}{R} [A] \dots (14)$$

(V_{ILIM} : ILIM voltage; R : Detection resistance)

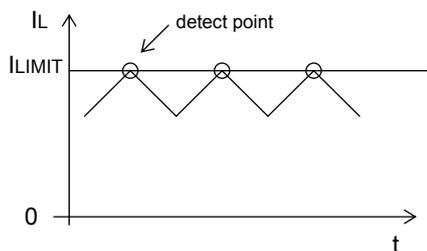


When the over current protection is detected by DCR of coil L, this parameter (setting value) is determined as in formula (14) below.

$$I_{LIMIT} = V_{ILIM} \times 0.1 \times \frac{r \times C}{L} [A] \dots (15)$$

$$(R_L = \frac{L}{r \times C})$$

(V_{ILIM} : ILIM voltage R_L : the DCR value of coil)

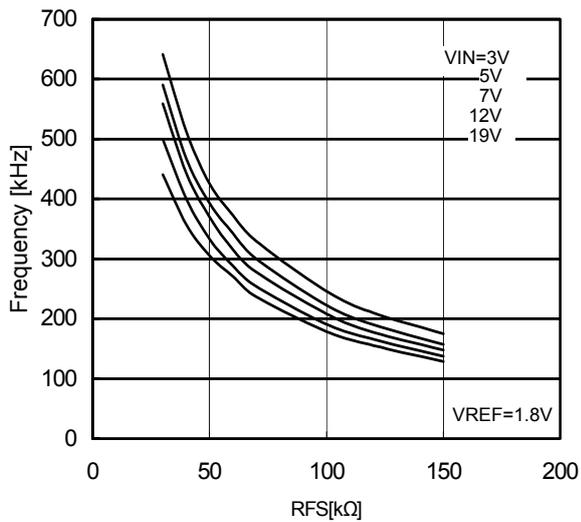


As soon as the voltage drop between $Is+$ and $Is-$ generated by the inductor current becomes specific threshold, the gate voltage of the high side MOSFET becomes low.

Since the peak voltage of the inductor ripple current is detected, this operation can sense high current ripple operation caused by inductance saturated rated current and lead to high reliable systems.

6. Setting frequency

【1ch】



The On Time (T_{ON}) at steady state is determined by resistance value connected to FS pin.

But actually SW rising time and falling time come up due to influence of the external MOSFET gate capacity or switching speed and T_{ON} is increased.

The frequency is determined by the following formula after T_{ON} , input current and the REF voltage are fixed.

$$F = \frac{REF}{V_{IN} \times T_{ON}} \dots (15)$$

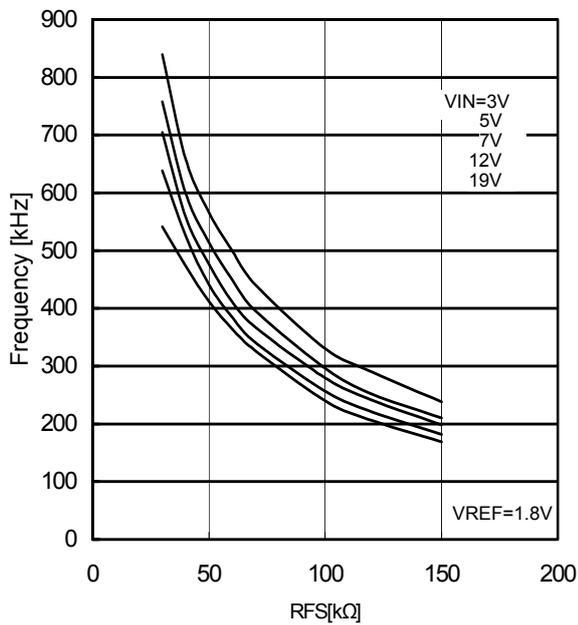
Consequently, total frequency becomes lower than the formula above.

T_{ON} is also influenced by Dead Time around the output current 0A area in continuous mode.

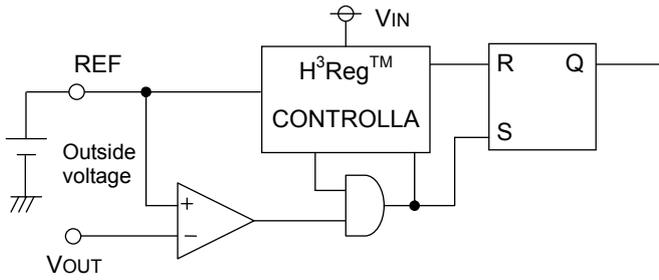
This frequency becomes lower than setting frequency.

It is recommended to check the steady frequency in large current area (at the point where the coil current doesn't back up).

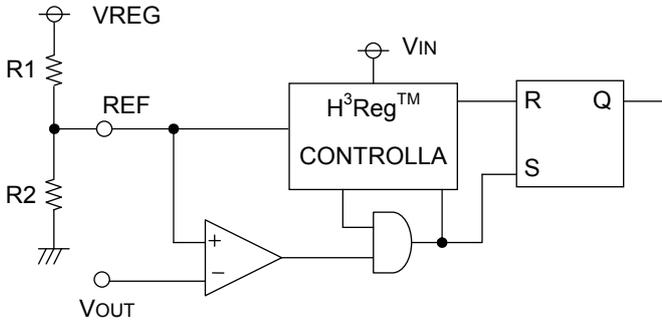
【2ch】



7. Setting standard voltage (REF)



It is available to synchronize setting the reference voltage (REF) with outside supply voltage [V] by using outside power supply voltage.



It is available to set the reference voltage (REF) by the resistance division value from VREG in case it is not set REF from an external power supply.

$$REF = \frac{R2}{R1+R2} \times VREG [V] \dots (17)$$

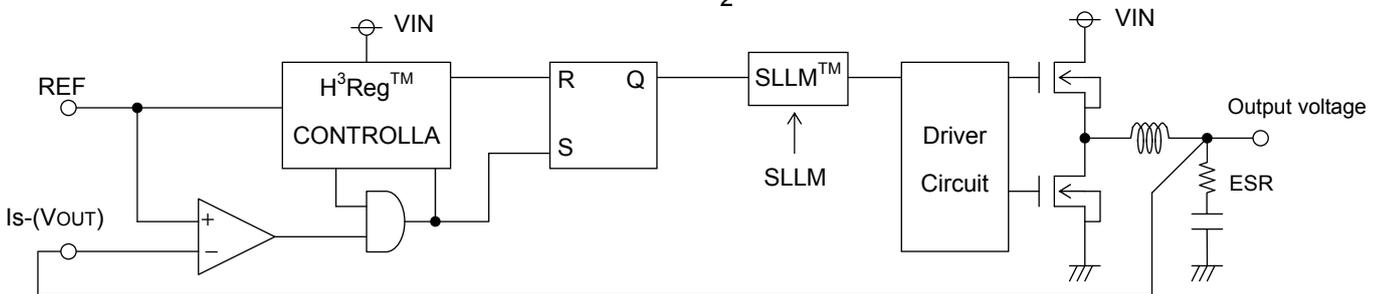
8. Setting output voltage

This IC is operated that output voltage is $REF \cong Is - (VOUT)$.

And it is operated that output voltage is feed back to FB pin in case the output voltage is 0.7V to 2.0V.

Actually, the average value of ripple voltage is added to output voltage.

$$\text{Output voltage} = REF + \frac{1}{2} \times \Delta IL \times ESR \dots (18)$$



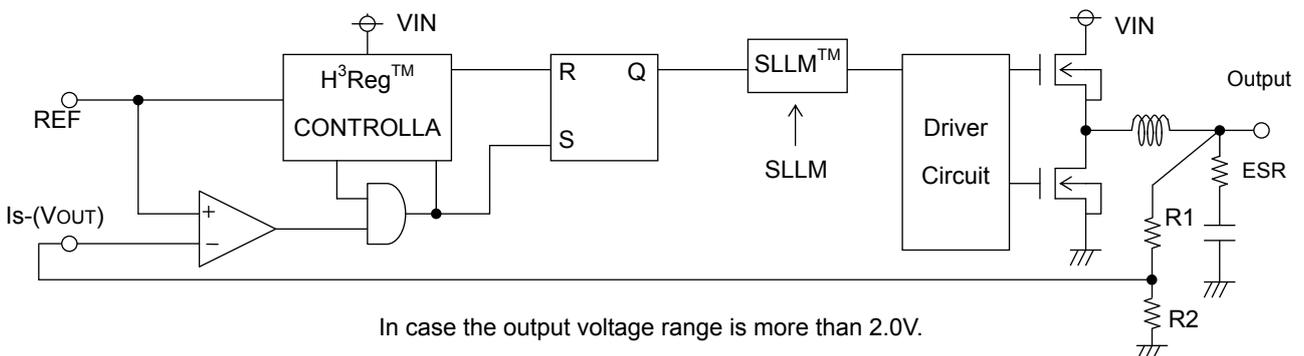
In case the output voltage range is 0.7V to 2.0V.

It is operated that the resistance division value of the output voltage is feed back to Is-pin in case the output voltage is more than 2.0V.

$$\text{output voltage} = \frac{R1+R2}{R2} \times REF + \frac{1}{2} \times \Delta IL \times ESR \dots (19)$$

In this time, the frequency is also amplified by power of the resistance division. It is determined as in formula (20) below.

$$\text{Frequency} = \frac{R1+R2}{R2} \times (\text{frequency determined by REF}) [Hz] \dots (20)$$



In case the output voltage range is more than 2.0V.

● I/O Equivalent Circuit

<p>1pin, 23pin (BOOT1/2)</p>	<p>2pin, 22pin (CE1/2)</p>	<p>3pin, 21pin (PGOOD1/2)</p>
<p>4pin, 20pin (EN1/2)</p>	<p>5pin, 19pin (SS1/2)</p>	<p>6pin, 18pin (ILIM1/2)</p>
<p>7pin, 17pin (REF1/2)</p>	<p>8pin (VREG)</p>	<p>9pin (FS)</p>
<p>10pin, 15pin (Is-1/2)</p>	<p>11pin, 14pin (Is+1/2)</p>	<p>16pin (VIN)</p>
<p>24pin, 32pin (HG1/2)</p>	<p>25pin, 31pin (SW1/2)</p>	<p>27pin, 29pin (LG1/2)</p>

● Operation Notes

1. Absolute maximum ratings

An excess in the absolute maximum ratings, such as supply voltage, temperature range of operating conditions, etc., can break down the devices, thus making impossible to identify breaking mode, such as a short circuit or an open circuit. If any over rated values will expect to exceed the absolute maximum ratings, consider adding circuit protection devices, such as fuses.

2. Connecting the power supply connector backward

Connecting of the power supply in reverse polarity can damage IC. Take precautions when connecting the power supply lines. An external direction diode can be added.

3. Power supply lines

Design PCB layout pattern to provide low impedance GND and supply lines. To obtain a low noise ground and supply line, separate the ground section and supply lines of the digital and analog blocks. Furthermore, for all power supply terminals to ICs, connect a capacitor between the power supply and the GND terminal. When applying electrolytic capacitors in the circuit, not that capacitance characteristic values are reduced at low temperatures.

4. GND voltage

The potential of GND pin must be minimum potential in all operating conditions.

5. Thermal design

Use a thermal design that allows for a sufficient margin in light of the power dissipation (Pd) in actual operating conditions.

6. Inter-pin shorts and mounting errors

Use caution when positioning the IC for mounting on printed circuit boards. The IC may be damaged if there is any connection error or if pins are shorted together.

7. Actions in strong electromagnetic field

Use caution when using the IC in the presence of a strong electromagnetic field as doing so may cause the IC to malfunction.

8. ASO

When using the IC, set the output transistor so that it does not exceed absolute maximum ratings or ASO.

9. Thermal shutdown circuit

The IC incorporates a built-in thermal shutdown circuit (TSD circuit). The thermal shutdown circuit (TSD circuit) is designed only to shut the IC off to prevent thermal runaway. It is not designed to protect the IC or guarantee its operation. Do not continue to use the IC after operating this circuit or use the IC in an environment where the operation of this circuit is assumed.

	TSD on temperature [°C] (typ.)	Hysteresis temperature [°C] (typ.)
BD9535MUV	175	15

10. Testing on application boards

When testing the IC on an application board, connecting a capacitor to a pin with low impedance subjects the IC to stress. Always discharge capacitors after each process or step. Always turn the IC's power supply off before connecting it to or removing it from a jig or fixture during the inspection process. Ground the IC during assembly steps as an antistatic measure. Use similar precaution when transporting or storing the IC.

11. Regarding input pin of the IC

This monolithic IC contains P+ isolation and P substrate layers between adjacent elements in order to keep them isolated. P-N junctions are formed at the intersection of these P layers with the N layers of other elements, creating a parasitic diode or transistor. For example, the relation between each potential is as follows:

When GND > Pin A and GND > Pin B, the P-N junction operates as a parasitic diode.

When GND > Pin B, the P-N junction operates as a parasitic transistor.

Parasitic diodes can occur inevitable in the structure of the IC. The operation of parasitic diodes can result in mutual interference among circuits, operational faults, or physical damage. Accordingly, methods by which parasitic diodes operate, such as applying a voltage that is lower than the GND (P substrate) voltage to an input pin, should not be used.

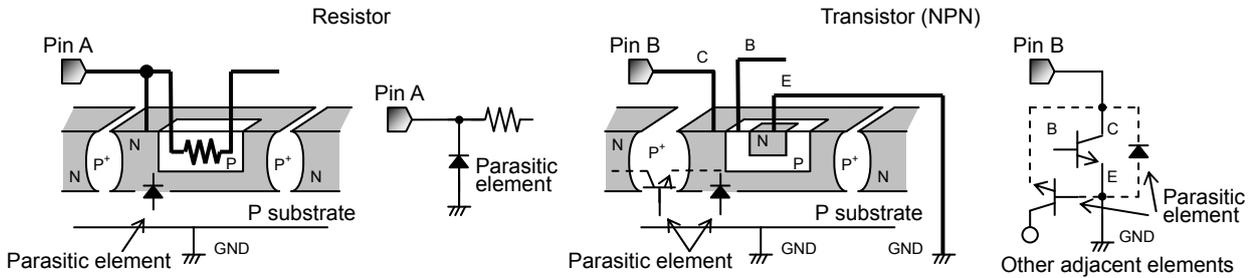
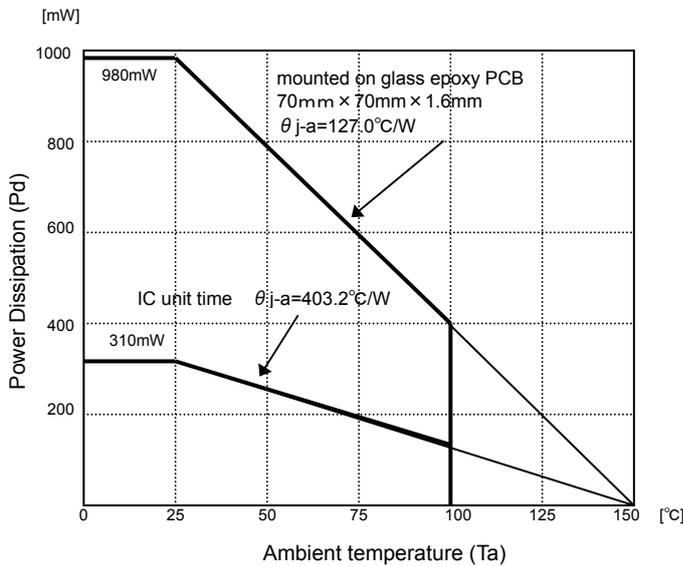


Fig. 13 Example of IC structure

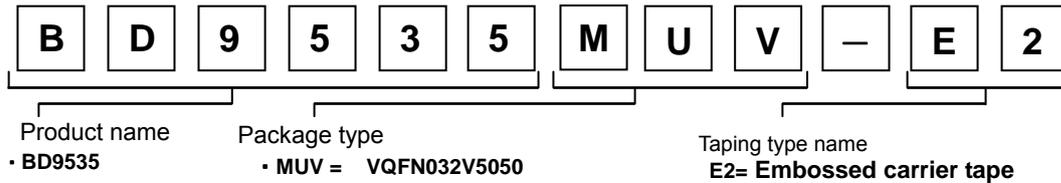
12. Ground Wiring Pattern

When using both small signal and large current GND patterns, it is recommended to isolate the two ground patterns, placing a single ground point at the ground potential of application so that the pattern wiring resistance and voltage variations caused by large currents do not cause variations in the small signal ground voltage. Be careful not to change the GND wiring pattern of any external components, either.

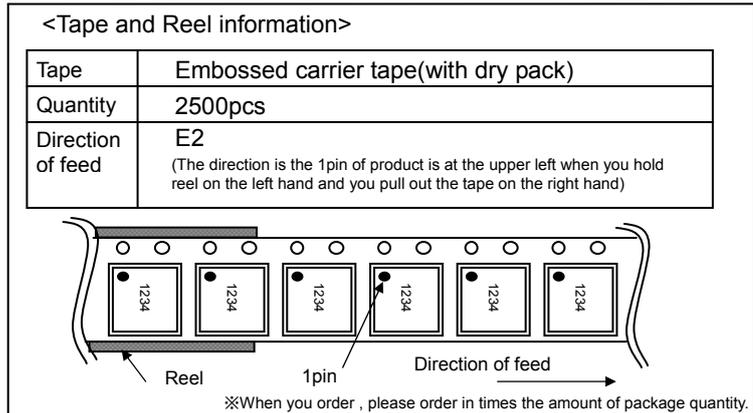
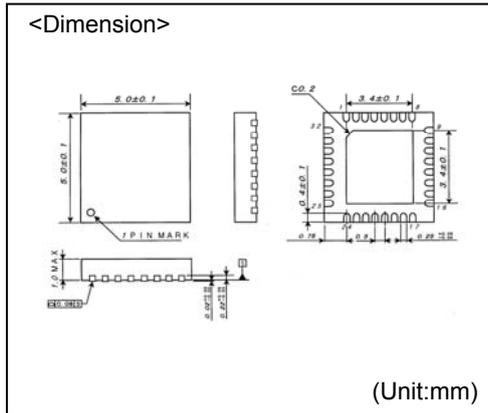
● Power Dissipation



● Type Designations (Selections) for Ordering



VQFN032V5050



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