

# 4.5V to 28V, 3A 1ch Synchronous Buck Converter Integrated FET

BD95513MUV

## General Description

BD95513MUV is a switching regulator with current capability of 3A and the ability to achieve low output voltages of 0.7V to 5.0V from a wide input voltage range of 4.5V to 28V. It has built-in N-MOS power transistors and implementation of Simple Light Load Mode (SLLM™) technology make this device highly-efficient. SLLM™ improves efficiency when the device is used with light load, providing high efficiency over a wider range of loads. The device also uses a new technology called H<sup>3</sup>Reg™ proprietary control method, to achieve ultra-fast transient response against load changes. BD95513MUV is especially designed for various applications and is integrated with protection features such as soft-start, variable frequency, short circuit protection with timer latch, over voltage protection, and power good function.

## Features

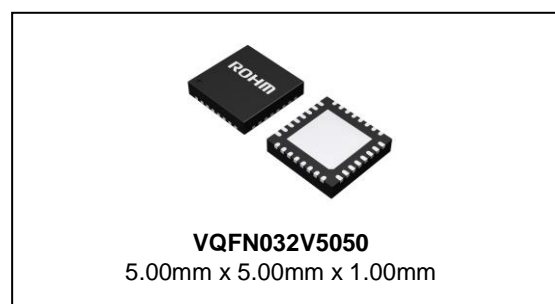
- Integrated 5V Linear Voltage Regulator
- H<sup>3</sup>Reg™ DC/DC Converter Controller
- Adjustable Simple Light Load Mode (SLLM™), Quiet Light Load Mode (QLLM) and Forced Continuous Mode
- Built-in Thermal Shutdown (TSD), Low Input, Over Current Protection (OCP), Over Voltage Protection (OVP) and Under Voltage Lockout (UVLO) Protection
- Soft Start Function that Minimizes Rush Current during Startup
- Adjustable Switching Frequency ( $f = 200 \text{ kHz}$  to  $600 \text{ kHz}$ )
- Built-in Output Discharge Function
- Tracking Function
- Integrated Bootstrap Diode

### Key Specification

- Input Voltage Range: 4.5V to 28V
- Output Voltage Range: 0.7V to 5.0V
- Output Current: 3.0A(Max)
- High Side ON-Resistance: 120mΩ(Typ)
- Low Side ON-Resistance: 120mΩ(Typ)
- Standby Current: 0μA (Typ)
- Operating Temperature Range: -10°C to +100°C

## Package

W (Typ) x D (Typ) x H (Max)



## Application

Mobile PC, Desktop PC, LCD-TV, Digital Household Electronics

### Typical Application Circuit

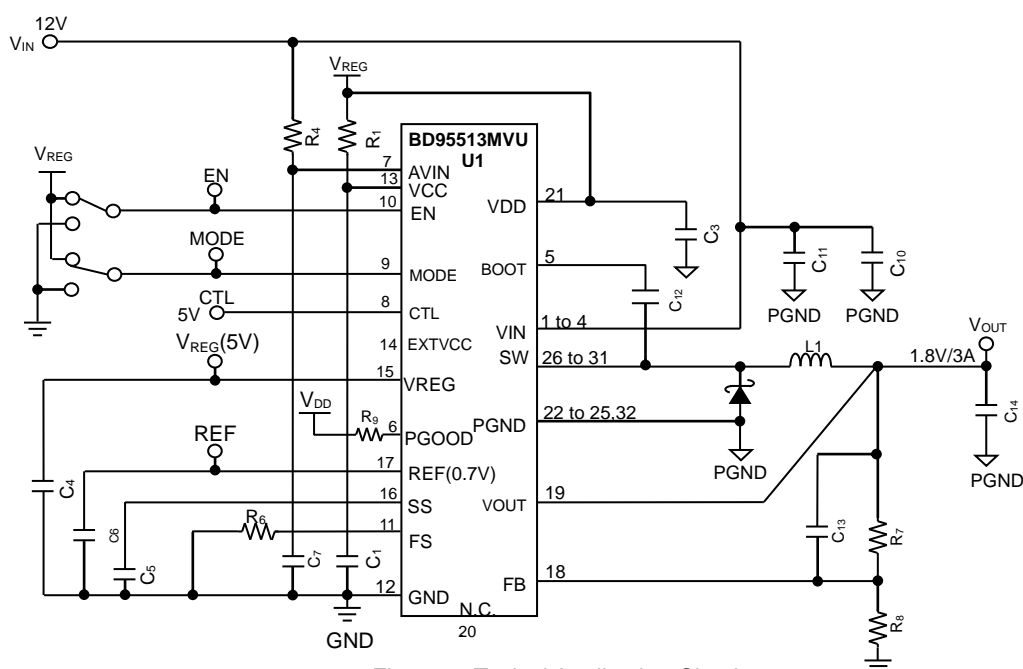


Figure 1. Typical Application Circuit

## Pin Configuration

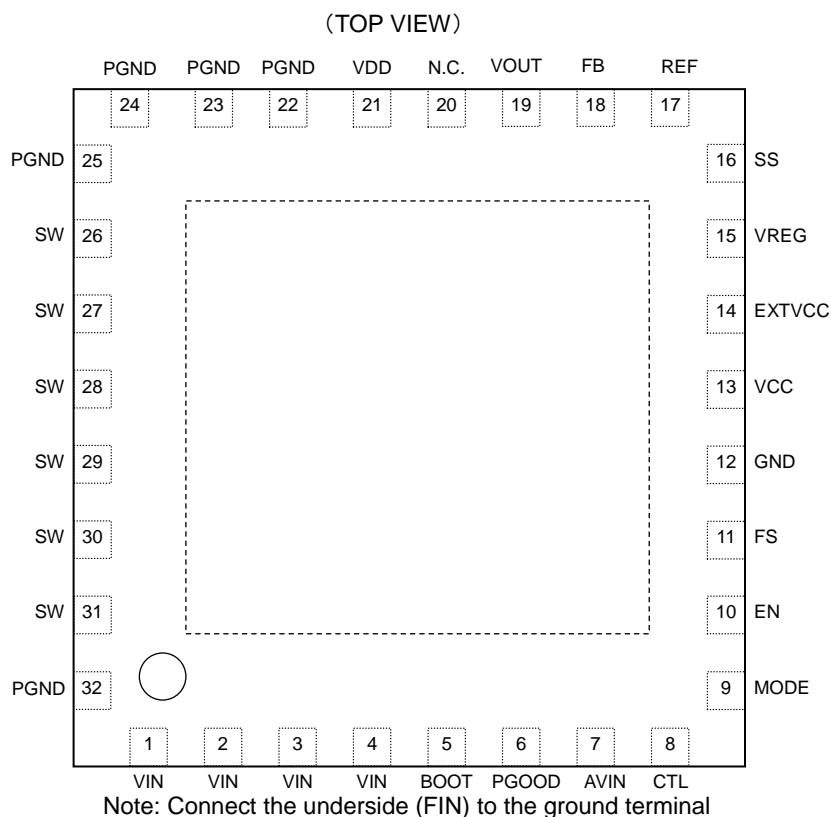


Figure. 2 Pin Configuration

## Pin Description

(Function Table)

Pin No.	Pin Name	Pin Description
1 to 4	VIN	Battery voltage input (4.5V to 28 V)
5	BOOT	HG driver power supply
6	PGOOD	Power good output (high when output $\pm 10\%$ of regulation)
7	AVIN	Battery voltage sense
8	CTL	Linear regulator on/off (high = 5.0V, low = OFF)
9	MODE	Control mode selection GND : Continuous Mode 3.0V : QLLM VCC : SLLM™
10	EN	Enable output (high when VOUT ON)
11	FS	Switching frequency adjustment ( $R_{FS} = 30k\Omega$ to $100k\Omega$ )
12	GND	Sense ground
13	VCC	Power supply input
14	EXTVCC	External power supply input
15	VREG	IC reference voltage (5.0V / 200mA)
16	SS	Soft start condenser input
17	REF	Output reference voltage (0.7V)
18	FB	Feedback input (0.7V)
19	VOUT	Voltage discharge output
20	N.C.	No Connect Pin
21	VDD	Power supply input (5V)
22 to 25	PGND	Power ground
26 to 31	SW	Output to inductor
32	PGND	Power ground
Underside	FIN	Substrate connection

## Block Diagram

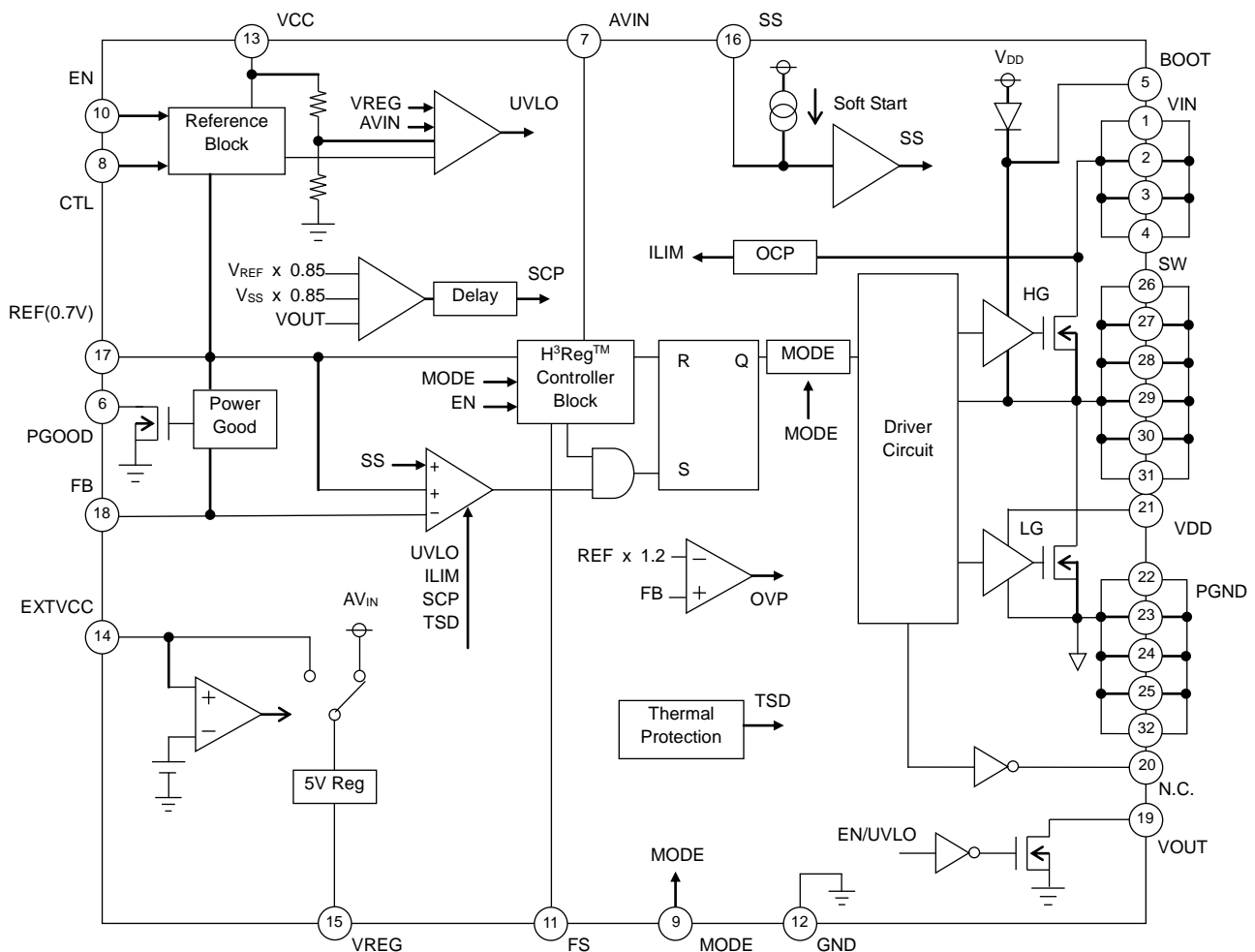


Figure 3. Block Diagram

## Description of Blocks

- VCC (Pin 13)**  
This is the power supply pin for the IC's internal circuits, except for the FET driver. Use by connecting it to VREG output. Using RC filter with 10Ω, 1μF(app.) for VCC pin is recommended.
- EN (Pin 10)**  
This pin enables or disables the switching regulator. When the voltage on EN pin is at least 2.3V, the switching regulator is ON. Conversely, it is OFF when the voltage at EN pin is lower than 0.8V.
- VDD (Pin 21)**  
This is the power supply pin that drives the LOW side FET and the bootstrap diode. It is recommended that a 1 μF to 10μF bypass capacitor be connected to compensate for rush current during the FET ON/OFF transition.
- VREG (Pin 15)**  
Output pin of the 5V linear regulator. This pin also supplies power to the internal driver and control circuitry. VREG standby function is controlled by the CTL pin. The output supplies 5V at 100 mA and should be bypassed to ground using a 10 μF capacitor with a rating of X5R or X7R.
- EXTVCC (Pin 14)**  
External power supply input for the linear regulator. When the voltage on the EXTVCC pin exceeds 4.4V, the regulator uses it in conjunction with other power sources to supply VREG. Leave the EXTVCC pin floating when not in use.
- REF (Pin 17)**  
Reference voltage output pin. The reference voltage is set internally by the IC to 0.7V, and the IC works to keep  $V_{REF}$  approximately equal to  $V_{FB}$ . Variations in voltage levels on this pin affect the output voltage, so the pin should be bypassed with a 100pF to 0.1μF ceramic capacitor.

**Description of Blocks – continued**

7. SS (Pin 16)  
Soft start/stop pin. When EN is set to high, the capacitor between the internal current source and SS-GND controls the startup time of the IC. When the voltage on the SS pin is lower than the REF output voltage (0.7V), the output voltage is held at the same voltage as the SS pin.
8. AVIN (Pin 7)  
The BD95513MUV controls the duty cycle and output voltage based on the input voltage at this pin, so voltage variations or oscillations on this line can cause unstable operation. This pin also acts as the voltage input for the switching block, so insufficient coupling impedance can also cause unstable operation. Therefore, this line should be bypassed with either a power capacitor or RC filter.
9. FS (Pin 11)  
Frequency-adjusting resistance input pin. Attaching a resistance of 30 kΩ to 100 kΩ adjusts the switching frequency from 200 kHz to 600kHz.
10. BOOT (Pin 5)  
This pin serves as the power source for the high side of the FET driver. A bootstrap diode is integrated within the IC. The maximum voltage on this pin should not exceed +35V with reference to GND or +7V with reference to SW. When operating the switching regulator, the operation of the bootstrap circuitry causes the BOOT voltage to swing from ( $V_{IN} + V_{DD}$ ) to  $V_{DD}$ .
11. PGOOD (Pin 6)  
Power good indicator. This open-drain output should be connected to a power supply via a 100 kΩ pull-up resistor.
12. MODE (Pin 9)  
Mode selection pin. When low, the IC functions in forced-continuous mode; at voltages from 0V to 3V, QLLM mode; when high, SLLM™ mode.
13. CTL (Pin 8)  
Linear regulator control pin. When voltage is 2.3V or higher, a logic HIGH is recognized and the internal regulator ( $V_{REG} = 5V$ ) is switched ON. At voltages of 0.8V or lower, a logic LOW is recognized and the regulator is switched OFF. However, even if EN is logic HIGH, the switching regulator will not operate if CTL is logic LOW.
14. FB (Pin 18)  
Output voltage feedback input.  $V_{FB}$  is held at 0.7V by the IC.
15. SW (Pin 26 to 31)  
Output from the switching regulator to the inductor. This output swings from  $V_{IN}$  to GND. The trace from the output to the inductor should be as short and wide as possible.
16. VOUT (Pin 19)  
Voltage output discharge pin. When EN is off, this output is pulled to low.
17. VIN (Pin 1 to 4)  
Power supply input. The IC can accept any input from 4.5V to 28V. This pin should be bypassed directly to ground by a power capacitor.
18. PGND (Pin 22 to 25, 32)  
Power ground terminal.

**Absolute Maximum Ratings** (Ta = 25°C)

Parameter	Symbol	Rating	Unit
Input Voltage 1	V <sub>CC</sub>	7 (Note 1)	V
Input Voltage 2	V <sub>DD</sub>	7 (Note 1)	V
Input Voltage 3	AV <sub>IN</sub>	30 (Note 1)	V
Input Voltage 4	V <sub>IN</sub>	30 (Note 1)	V
External VCC Voltage	EXTV <sub>CC</sub>	7 (Note 1)	V
BOOT Voltage	V <sub>BOOT</sub>	35	V
BOOT-SW Voltage	V <sub>BOOT-SW</sub>	7 (Note 1)	V
Output Feedback Voltage	V <sub>FB</sub>	V <sub>CC</sub>	V
SS/FS/MODE Voltage	V <sub>SS</sub> /V <sub>FS</sub> /V <sub>MODE</sub>	V <sub>CC</sub>	V
VREG Voltage	V <sub>REG</sub>	V <sub>CC</sub>	V
EN/CTL Input Voltage	V <sub>EN</sub> /V <sub>CTL</sub>	7 (Note 1)	V
PGOOD Voltage	V <sub>PGOOD</sub>	7 (Note 1)	V
Output Current (Average)	I <sub>SW</sub>	3 (Note 1)	A
Power Dissipation 1	Pd1	0.38 (Note 2)	W
Power Dissipation 2	Pd2	0.88 (Note 3 and Note 6)	W
Power Dissipation 3	Pd3	3.26 (Note 4 and Note 6)	W
Power Dissipation 4	Pd4	4.56 (Note 5 and Note 6)	W
Operating Temperature Range	T <sub>opr</sub>	-10 to +100	°C
Storage Temperature Range	T <sub>stg</sub>	-55 to +150	°C
Junction Temperature	T <sub>jmax</sub>	+150	°C

(Note 1) Should not exceed Pd.

(Note 2) Ta ≥ 25°C (IC only),

Power dissipated at 3.0 mW/°C.

(Note 3) Ta ≥ 25°C (single-layer board, 20.2 mm<sup>2</sup> copper heat dissipation pad),

Power dissipated at 7.0 mW/°C.

(Note 4) Ta ≥ 25°C (4-layer board, 20.2 mm<sup>2</sup> copper heat dissipation pad on top layer, 5505 mm<sup>2</sup> pad on 2nd and 3rd layer),

Power dissipated at 26.1 mW/°C.

(Note 5) Ta ≥ 25°C (4-layer board, all layers with 5505 mm<sup>2</sup> copper heat dissipation pads),

Power dissipated at 36.5 mW/°C.

(Note 6) Values observed with chip backside soldered. When unsoldered, power dissipation is lower.

Caution: Operating the IC over the absolute maximum ratings may damage the IC. The damage can either be a short circuit between pins or an open circuit between pins and internal circuitry. Therefore, it is important to consider circuit protection measures, such as adding a fuse, in case the IC is operated over the absolute maximum ratings.

**Recommended Operating Conditions** (Ta = 25°C)

Parameter	Symbol	Rating		Unit
		Min	Max	
Input Voltage 1	V <sub>CC</sub>	4.5	5.5	V
Input Voltage 2	V <sub>DD</sub>	4.5	5.5	V
Input Voltage 3	AV <sub>IN</sub>	4.5	28	V
Input Voltage 4	V <sub>IN</sub>	4.5	28	V
External VCC Voltage	EXTV <sub>CC</sub>	4.5	5.5	V
BOOT Voltage	V <sub>BOOT</sub>	4.5	33	V
SW Voltage	V <sub>SW</sub>	-0.7	+28	V
BOOT-SW Voltage	V <sub>BOOT-SW</sub>	4.5	5.5	V
MODE Input Voltage	V <sub>MODE</sub>	0	5.5	V
EN/CTL Input Voltage	V <sub>EN</sub> /V <sub>CTL</sub>	0	5.5	V
PGOOD Voltage	V <sub>PGOOD</sub>	0	5.5	V
Minimum On Time	t <sub>ON_MIN</sub>	-	100	ns

## Electrical Characteristics

(Unless otherwise noted, Ta=25°C, AVIN=12V, VCC=VDD=VREG, VEN/VCTL=5V, VMODE=0V, RFS=180kΩ)

Parameter	Symbol	Limit			Unit	Conditions
		Min	Typ	Max		
[Whole Device]						
AVIN Bias Current 1	I <sub>IN1</sub>	-	1200	1800	μA	
AVIN Bias Current 2	I <sub>IN2</sub>	-	150	250	μA	EXTV <sub>CC</sub> =5V
AVIN Standby Current	I <sub>INSTB</sub>	-	0	10	μA	V <sub>CTL</sub> =V <sub>EN</sub> =0V
EN Low Voltage	V <sub>ENLOW</sub>	GND	-	0.8	V	
EN High Voltage	V <sub>ENHIGH</sub>	2.3	-	5.5	V	
EN Bias Voltage	I <sub>EN</sub>	-	12	20	μA	
CTL Low Voltage	V <sub>CTLLOW</sub>	GND	-	0.8	V	
CTL High Voltage	V <sub>CTLHIGH</sub>	2.3	-	5.5	V	
CTL Bias Current	I <sub>CTL</sub>	-	1	6	μA	
[5V Regulator]						
VREG Input Voltage	V <sub>REG</sub>	4.90	5.00	5.10	V	AV <sub>IN</sub> =6.0V to 25V I <sub>REG</sub> =0 to 100mA
Maximum Current	I <sub>REG</sub>	100	-	-	mA	
[5V Switch]						
EXTV <sub>CC</sub> Input Threshold Voltage	E <sub>V<sub>CC</sub></sub> _UVLO	4.2	4.4	4.6	V	EXTV <sub>CC</sub> : Sweep up
Switch Resistance	R <sub>EV<sub>CC</sub></sub>	-	1.0	2.0	Ω	
[Under-Voltage Lockout Protection]						
AVIN Threshold Voltage	AV <sub>IN</sub> _UVLO	4.1	4.3	4.5	V	V <sub>CC</sub> : Sweep up
AVIN Hysteresis Voltage	dAV <sub>IN</sub> _UVLO	100	160	220	mV	V <sub>CC</sub> : Sweep down
VREG Threshold Voltage	V <sub>REG</sub> _UVLO	4.1	4.3	4.5	V	V <sub>REG</sub> : Sweep up
VREG Hysteresis Voltage	dV <sub>REG</sub> _UVLO	100	160	220	mV	V <sub>REG</sub> : Sweep down
[H <sup>3</sup> Reg™ Control Block]						
ON Time	t <sub>ON</sub>	400	500	600	nsec	
MAX ON Time	t <sub>ONMAX</sub>	10.0	22.0	40.0	μsec	
MIN OFF Time	t <sub>OFFMIN</sub>	-	450	550	nsec	
[FET Block]						
High Side ON-Resistance	R <sub>ON_HIGH</sub>	-	120	200	mΩ	
Low Side ON-Resistance	R <sub>ON_LOW</sub>	-	120	200	mΩ	
[SCP Block]						
SCP Startup Voltage	V <sub>SCP</sub>	0.420	0.490	0.560	V	When V <sub>FB</sub> : 30% down
Delay	t <sub>SCP</sub>	0.5	1	2	ms	

**Electrical Characteristics - continued**

(Unless otherwise noted, Ta=25°C, AVIN=12V, VCC=VDD=VREG, VEN/VCTL=5V, VMODE=0V, RFS=180kΩ)

Parameter	Symbol	Limit			Unit	Conditions
		Min	Typ	Max		
[Over-Voltage Protection Block]						
OVP Detect Voltage	V <sub>OVP</sub>	0.800	0.840	0.880	V	When V <sub>FB</sub> : 20% up
[Soft Start Block]						
Charge Current	I <sub>SS</sub>	1.4	2.2	3.0	μA	
Standby Voltage	V <sub>SS_STB</sub>	-	-	100	mV	
[Current Regulation Block]						
Maximum Output Current	I <sub>OC</sub> P	3	-	-	A	
[Voltage Detection Block]						
Feedback Terminal Voltage 1	V <sub>FB1</sub>	0.693	0.700	0.707	V	
Feedback Terminal Voltage 2	V <sub>FB2</sub>	0.690	0.700	0.710	V	Ta =-10°C to +100°C I <sub>OUT</sub> = 0A to 3A
Feedback Terminal Bias Current	I <sub>FB</sub>	-100	0	+100	nA	
[MODE Block]						
SLLM™ Condition	V <sub>THSLLM</sub>	V <sub>CC</sub> -0.5	-	V <sub>CC</sub>	V	SLLM™ Longest low-gate off time: ∞
Forced Continuous Mode	V <sub>THCONT</sub>	GND	-	0.5	V	Continuous mode
Open Voltage	V <sub>MODE</sub>	1.5	-	3.0	V	
[Power Good Block]						
VFB Power Good Low Voltage	V <sub>FBPL</sub>	0.605	0.63	0.655	V	When V <sub>FB</sub> : 10% down
VFB Power Good High Voltage	V <sub>FBPH</sub>	0.745	0.77	0.795	V	When V <sub>FB</sub> : 10% up

## Typical Performance Curves

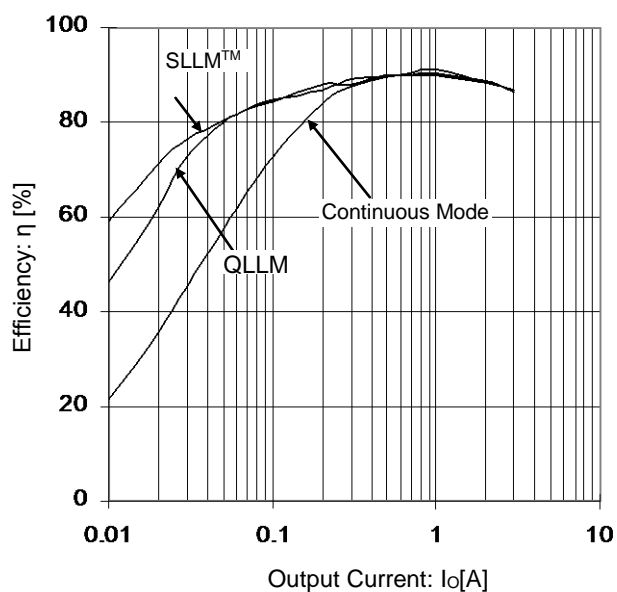


Figure 4. Efficiency vs Output Current  
( $V_{IN}=7V$ ,  $V_{OUT}=2.5V$ )

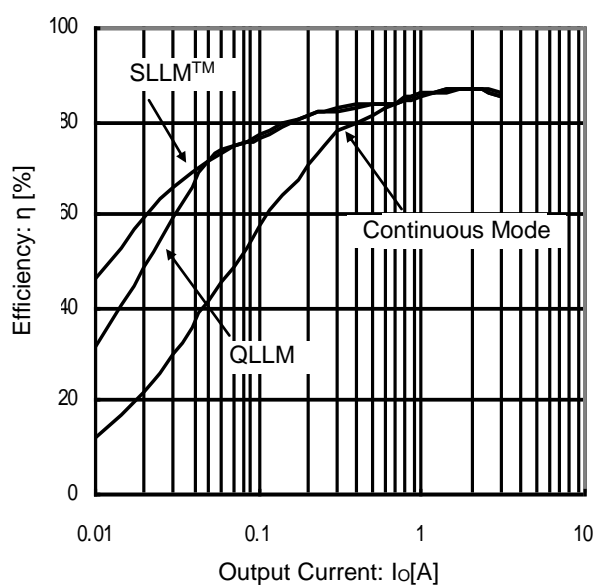


Figure 5. Efficiency vs Output Current  
( $V_{IN}=12V$ ,  $V_{OUT}=2.5V$ )

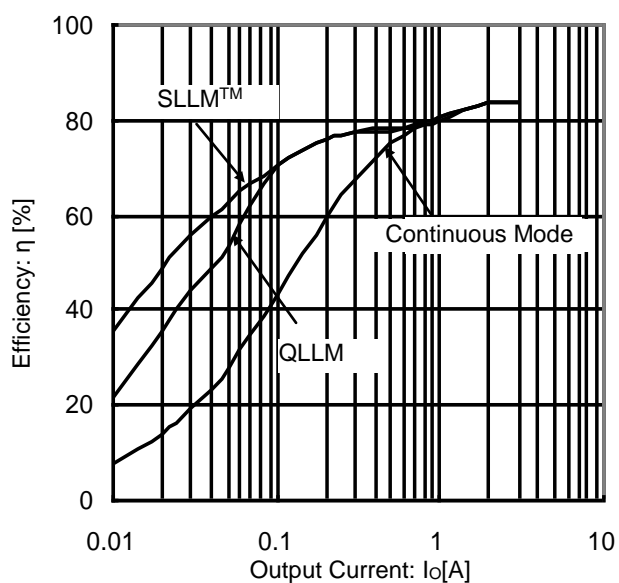


Figure 6. Efficiency vs Output Current  
( $V_{IN}=19V$ ,  $V_{OUT}=2.5V$ )



## Typical Waveforms

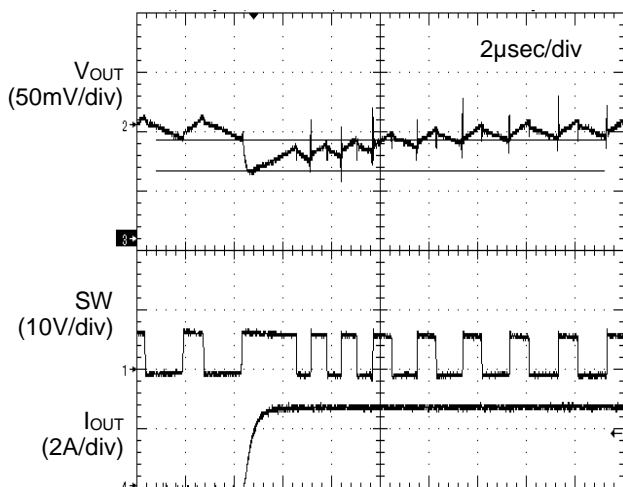


Figure 7. Transient Response  
( $V_{IN}=7V$ ,  $V_{OUT}=2.5V$ )

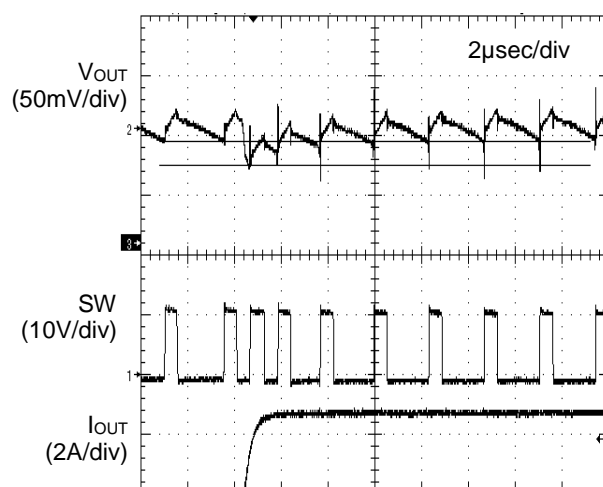


Figure 8. Transient Response  
( $V_{IN}=12V$ ,  $V_{OUT}=2.5V$ )

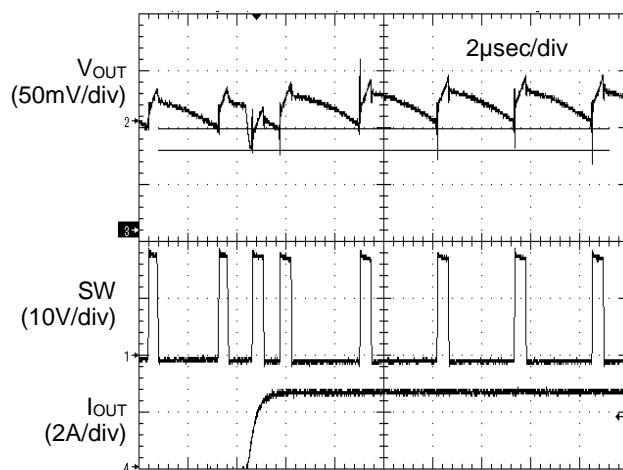


Figure 9. Transient Response  
( $V_{IN}=19V$ ,  $V_{OUT}=2.5V$ )

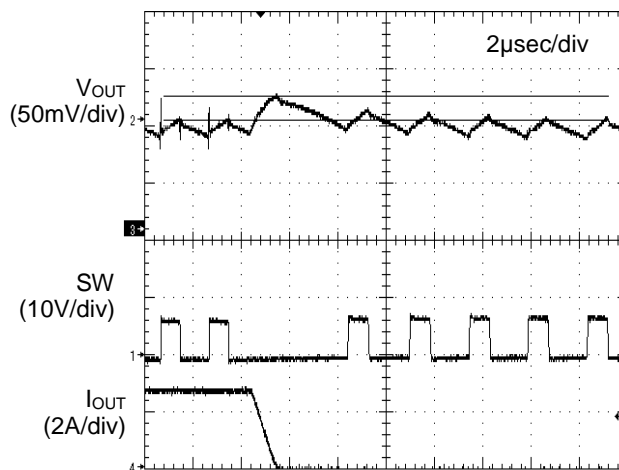


Figure 10. Transient Response  
( $V_{IN}=7V$ ,  $V_{OUT}=2.5V$ )

## Typical Waveforms - continued

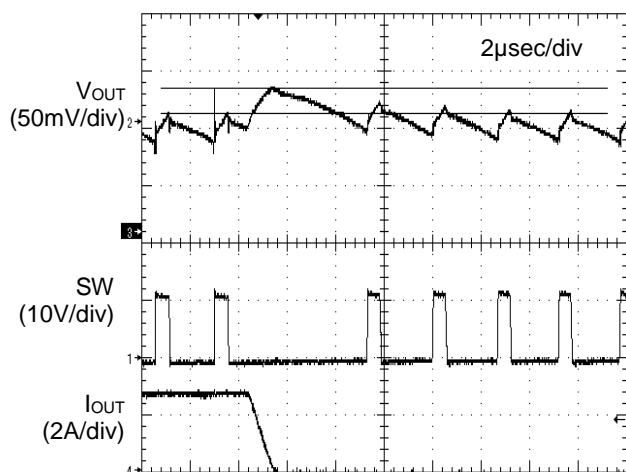


Figure 11. Transient Response  
( $V_{IN}=12V$ ,  $V_{OUT}=2.5V$ )

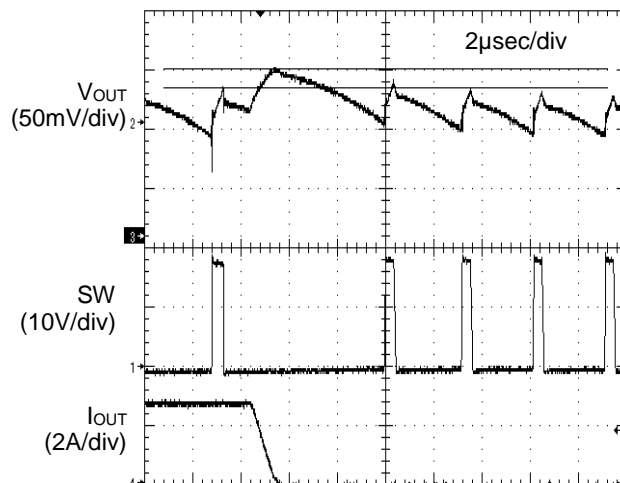


Figure 12. Transient Response  
( $V_{IN}=19V$ ,  $V_{OUT}=2.5V$ )

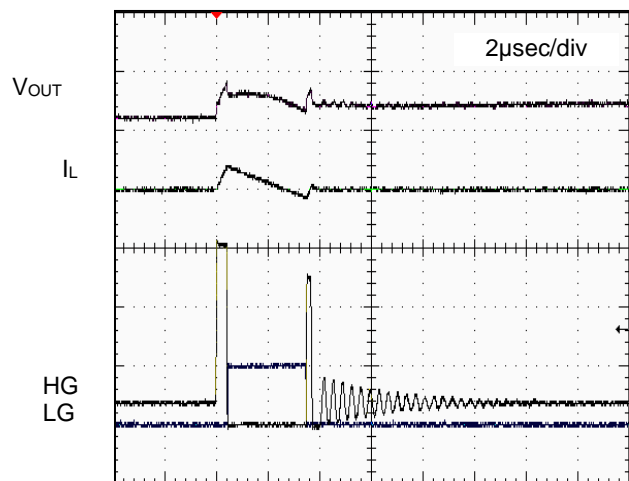


Figure 13. SLLM™ Mode  
( $I_{OUT}=0A$ )

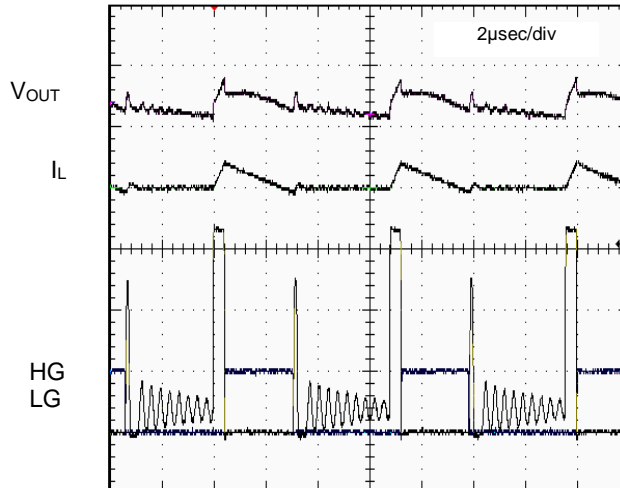


Figure 14. SLLM™ Mode  
( $I_{OUT}=0.4A$ )

## Typical Waveforms - continued

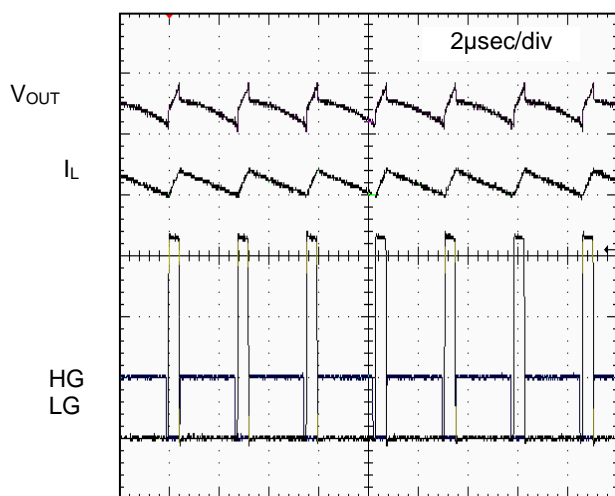
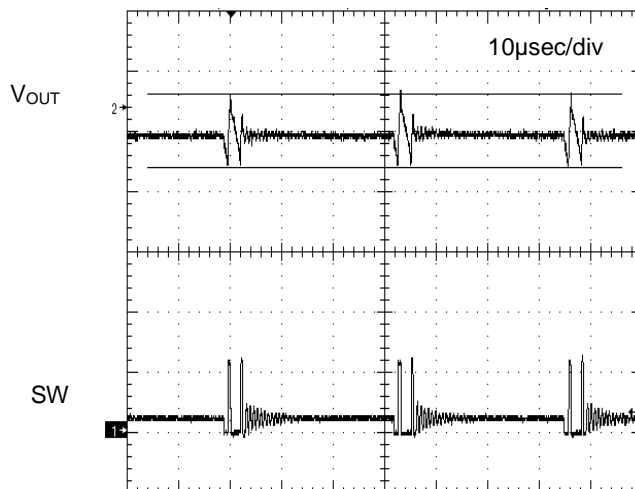
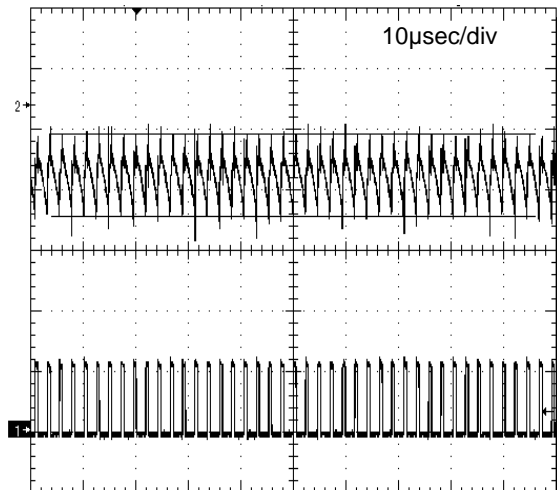
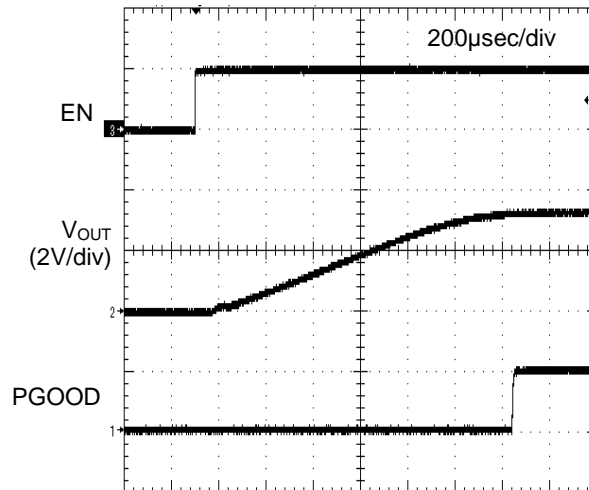
Figure 15. 1 SLLM™ Mode  
( $I_{OUT} = 1A$ )Figure 16. QLLM Mode  
( $I_{OUT} = 0A$ )Figure 17. QLLM Mode  
( $I_{OUT} = 1A$ )

Figure 18. PGOOD Rising Waveform

## Typical Waveforms - continued

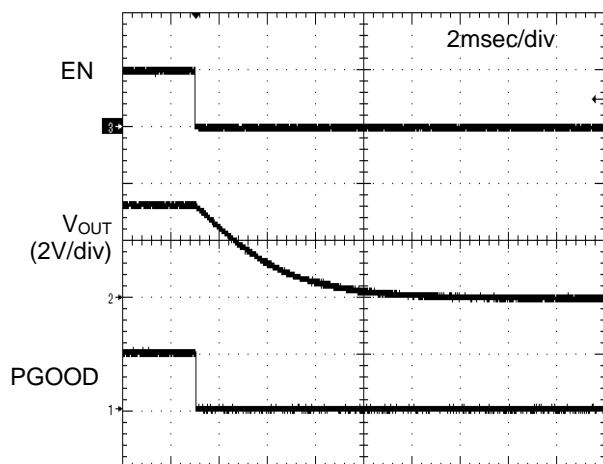


Figure 19. PGOOD Falling Waveform

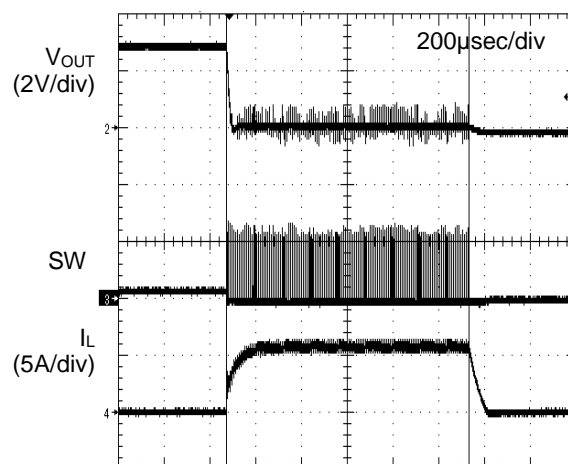
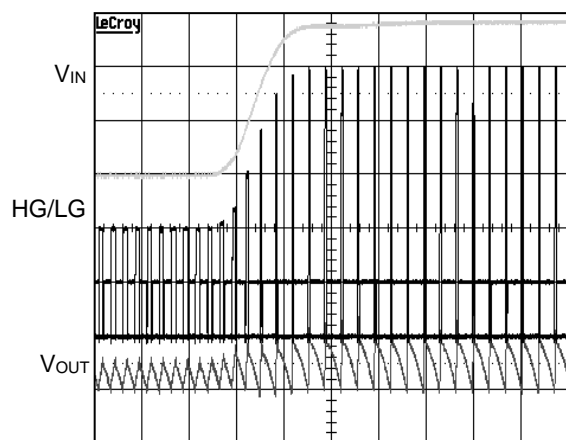
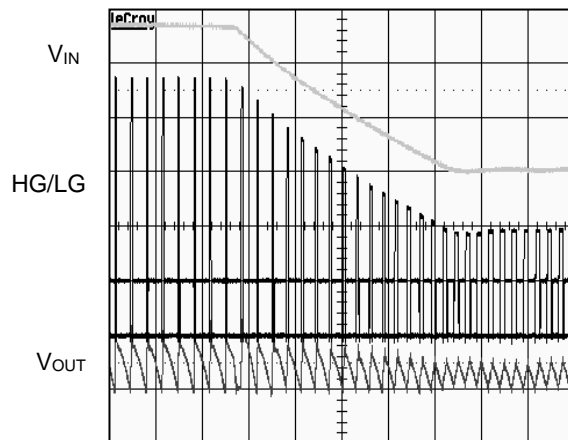


Figure 20. SCP Timer Latch Waveform

Figure 21. VIN Change  
(5V → 19V)Figure 22. VIN Change  
(19V → 5V)

## Typical Waveforms - continued

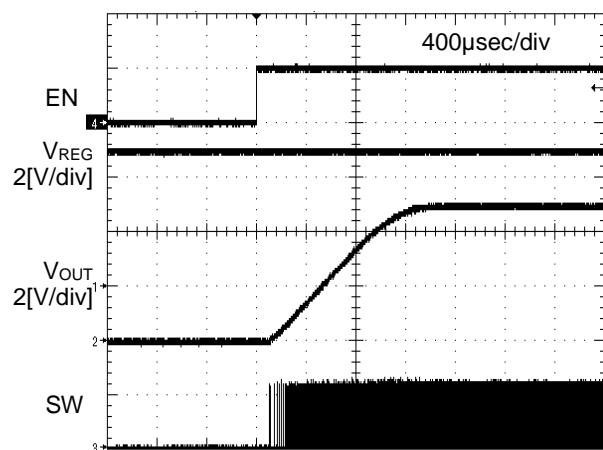


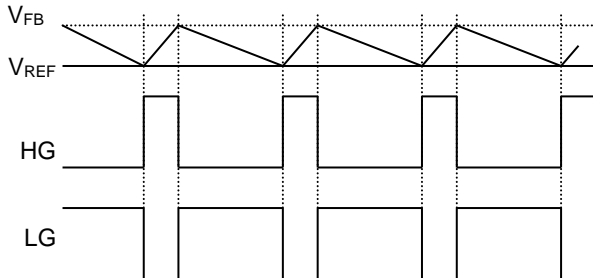
Figure 23. EN Wake Up

## Application Information

## 1. Explanation of Operation

The BD95513MUV is a switching regulator incorporating ROHM's proprietary H<sup>3</sup>Reg<sup>TM</sup> CONTROLLA control system.

When V<sub>OUT</sub> drops suddenly due to changes in load, the system quickly restores the output voltage by extending the t<sub>ON</sub> time interval. This improves the regulator's transient response. When light-load mode is activated, the IC employs the Simple Light Load Mode (SLLM<sup>TM</sup>) controller, further improving system efficiency.

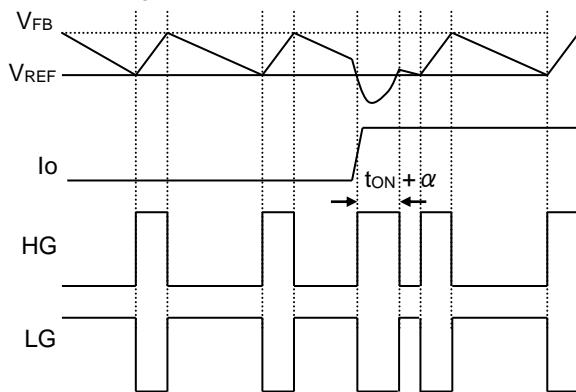
H<sup>3</sup>Reg<sup>TM</sup> Control  
(Normal Operation)

When V<sub>FB</sub> falls below the reference voltage (0.7V), the H<sup>3</sup>Reg<sup>TM</sup> CONTROLLA is activated;

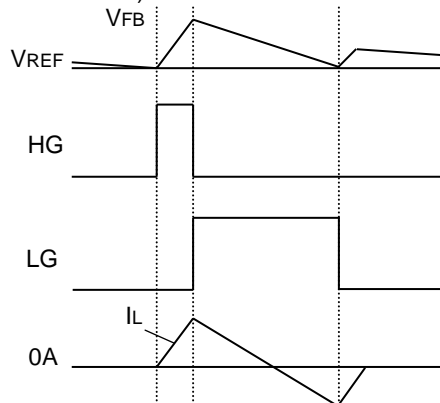
$$t_{ON} = \frac{V_{REF}}{V_{IN}} \times \frac{1}{f} \quad [\text{sec}] \quad (1)$$

High gate output is determined by the above formula.

## (Rapid Changes in Load)



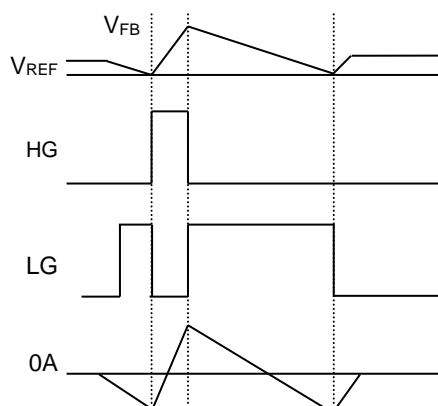
When V<sub>OUT</sub> drops due to a sudden change in load and the voltage remains below V<sub>REF</sub> after the preprogrammed t<sub>ON</sub> time interval has elapsed, the system quickly restores V<sub>OUT</sub> by extending the t<sub>ON</sub> time, thereby improving transient response.

Light Load Control  
(SLLM<sup>TM</sup> Mode)

SLLM<sup>TM</sup> mode is enabled by setting the MODE pin to logic high. When the low gate is off and the current through the inductor is 0 (current flowing from V<sub>OUT</sub> to SW), the SLLM<sup>TM</sup> function is activated, disabling high gate output.

If V<sub>FB</sub> falls below V<sub>REF</sub> again, the high gate is switched back on, lowering the switching frequency of the regulator and yielding higher efficiency when powering light loads.

## (QLLM Mode)



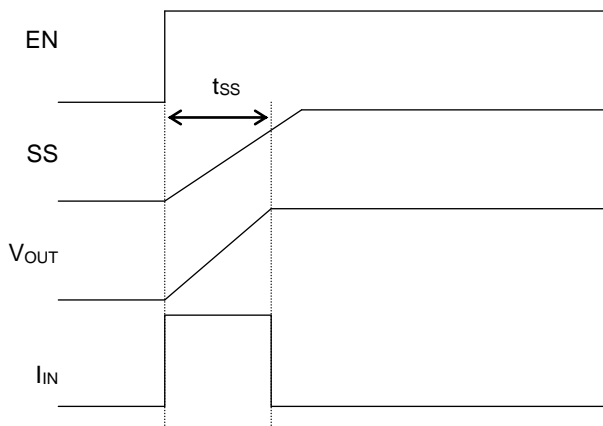
QLLM mode is enabled by setting the MODE pin to Hi-Z or middle voltage. When the lower gate is off and the current through the inductor is 0 (current flowing from V<sub>OUT</sub> to SW), QLLM mode is activated, disabling high gate output.

If V<sub>FB</sub> falls below V<sub>REF</sub> within a programmed time interval (typ 40 μsec), the high gate is switched on, but if V<sub>FB</sub> does not fall below V<sub>REF</sub>, the lower gate is forced on, dropping V<sub>FB</sub> and switching the high gate back on.

The minimum switching frequency is set to 25 kHz (T=40μsec), which keeps the regulator's frequency from entering the audible spectrum but yields less efficient results than SLLM<sup>TM</sup> mode.

## 2. Timing Chart

## (1) Soft Start Function



The soft start function is enabled when the EN pin is set to high. Current control circuitry takes effect at startup, yielding a moderate "ramping start" in output voltage. Soft start timing and incoming current are given by equation (2) and (3) below:

Soft start period:

$$t_{ss} = \frac{0.7(V) \times C_{ss}}{2.2\mu A(typ)} \quad [sec] \quad (2)$$

Rush current:

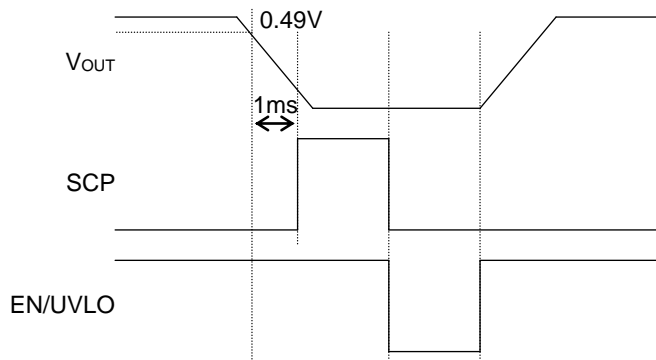
$$I_{IN(ON)} = \frac{C_o \times V_{OUT}}{t_{ss}} \quad [A] \quad (3)$$

Where:

$C_{ss}$  is the soft start capacitor

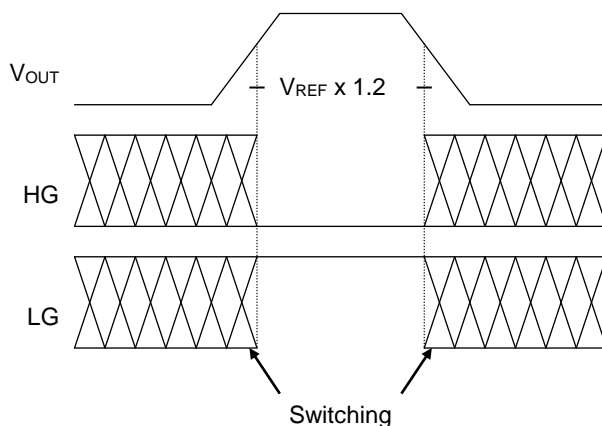
$C_o$  is the output capacitor.

## (2) Timer Latch-type Short Circuit Protection



When output voltage falls to  $V_{REF} \times 0.70$  ( $V_{FB} \leq 0.49V$ ) or less, the output short circuit protection is triggered, turning the IC off after a set period of time to prevent internal damage. When EN is switched back on or when UVLO is cleared, output continues. The time period before shutting off is set internally at 1ms.

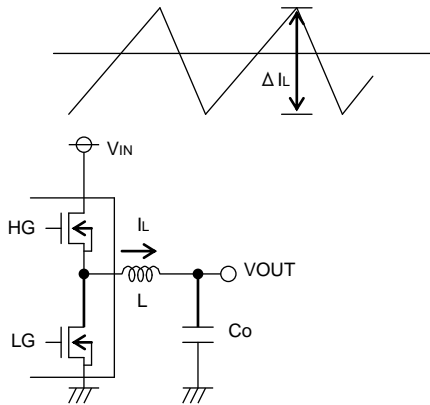
## (3) Output Over-Voltage Protection



When output reaches or exceeds  $V_{REF} \times 1.2$  ( $V_{FB} \geq 0.84V$ ), the output over-voltage protection is triggered, turning the low-side FET completely on to reduce the output (low gate on, high gate OFF). When the output falls, it returns to standard mode.

### 3. External Component Selection

#### (1) Inductor (L) Selection



Output ripple current

The inductor's value directly influences the output ripple current. As indicated by equation (4) below, the greater the inductance or switching frequency, the lower the ripple current:

$$\Delta I_L = \frac{(V_{IN} - V_{OUT}) \times V_{OUT}}{L \times V_{IN} \times f} \quad [A] \quad (4)$$

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

$$\Delta I_L = 0.3 \times I_{OUT\max} \quad [A] \quad (5)$$

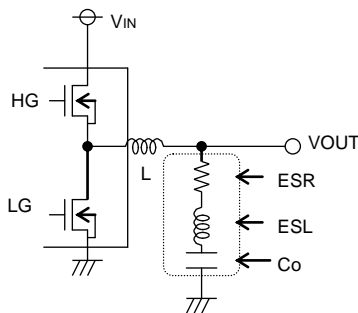
$$L = \frac{(V_{IN} - V_{OUT}) \times V_{OUT}}{\Delta I_L \times V_{IN} \times f} \quad [H] \quad (6)$$

Where:

$\Delta I_L$  is the output ripple current and  $f$  is the switching frequency

- (a) 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's rated current value.
- (b) To minimize possible inductor damage and maximize efficiency, choose an inductor with a low DCR and ACR resistance.

#### (2) Output Capacitor Selection ( $C_O$ )



Output Capacitor

When determining the proper output capacitor, be sure to consider the equivalent series resistance (ESR) and equivalent series inductance (ESL) required to set the output ripple voltage to 20 mV or more.

When selecting the limit of the inductor, be sure to allow enough margin for the output voltage. Output ripple voltage is determined by equation (7) below:

$$\Delta V_{OUT} = \Delta I_L \times ESR + ESL \times \Delta I_L / T_{ON} \quad (7)$$

Where:

$\Delta I_L$  is the output ripple current

$ESR$  is the equivalent series resistance

$ESL$  is the equivalent series inductance

Give special consideration to the conditions of equation (8) for output capacitance. Also, keep in mind that the output rise time must be established within the soft start timeframe.

$$C_O \leq \frac{t_{SS} \times (I_{limit} - I_{OUT})}{V_{OUT}} \quad (8)$$

Where:

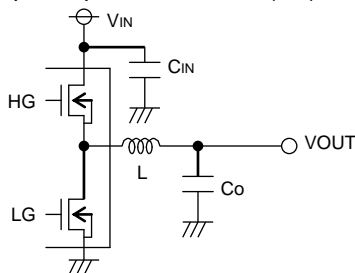
$t_{SS}$  is the Soft start timeframe (see p. 15, equation (2))

$I_{limit}$  is the Maximum output current.)

$I_{OUT}$  is the load current

Choosing a capacitance that is too large can cause startup malfunctions, or in some cases, may trigger the short circuit protection.

#### (3) Input Capacitor Selection ( $C_{IN}$ )



Input Capacitor

In order to prevent extreme over-current conditions, the input capacitor must have a low enough ESR to fully support a large ripple in the output. The formula for RMS ripple current ( $I_{RMS}$ ) is given by equation (9) below:

$$I_{RMS} = I_{OUT} \times \frac{\sqrt{V_{IN} (V_{IN} - V_{OUT})}}{V_{IN}} \quad [A] \quad (9)$$

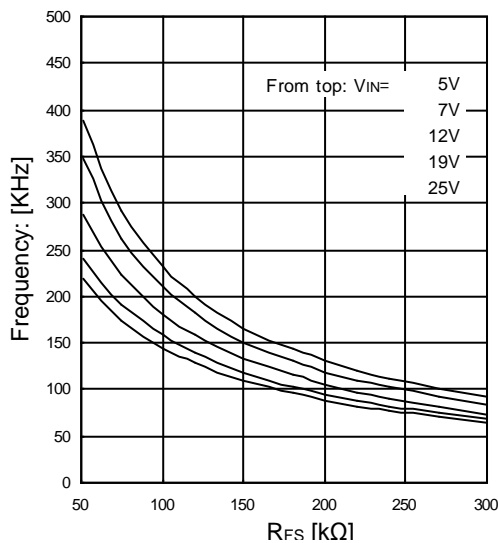
$$\text{When } V_{IN} = 2 \times V_{OUT}, \quad I_{RMS} = \frac{I_{OUT}}{2}$$

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



## External Component Selection – continued

## (4) Frequency Adjustment



The resistance connected to the FS terminal adjusts the on-time ( $t_{ON}$ ) during normal operation as illustrated on the left. When  $t_{ON}$ , input voltage and  $V_{REF}$  voltage are known, the switching frequency can be determined by the following equation:

$$F = \frac{V_{REF}}{V_{IN} \times t_{ON}} \quad (10)$$

However, real-life considerations (such as external MOSFET gate capacitance and switching time) must be factored in as they affect the overall switching rise and fall time. This leads to an increase in  $t_{ON}$ , lowering the total frequency slightly.

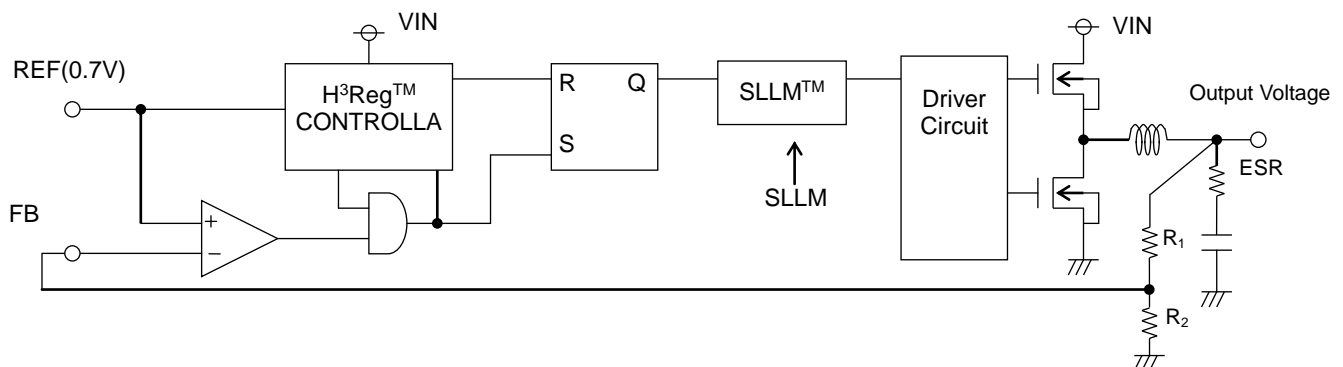
Additionally, when output current is around 0A in continuous mode, this “dead time” also has an effect upon  $t_{ON}$ , further lowering the switching frequency. Confirm the switching frequency by measuring the current through the coil (at the point where current does not flow backwards) during normal operation.

The BD95513MUV operates by feeding the output voltage back through a resistive voltage divider. The output voltage is set by the following equation (see schematic below):

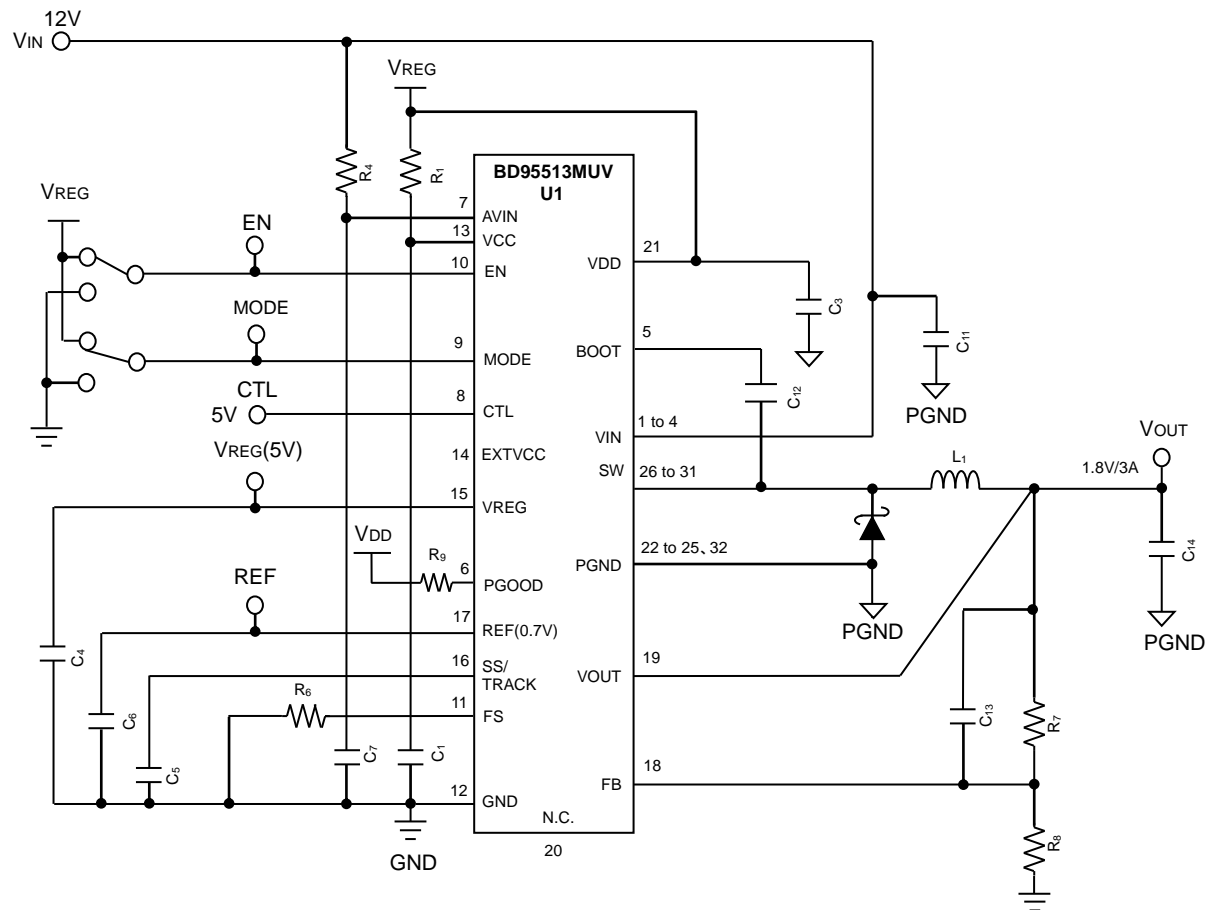
$$\text{Output Voltage} = \frac{R_1 + R_2}{R_2} \times V_{REF}(0.7V) + \frac{1}{2} \Delta I_L \times ESR \quad (11)$$

The switching frequency is also amplified by the same resistive voltage divider network:

$$f_{SW} = \frac{R_1 + R_2}{R_2} \times (\text{frequency set by } R_{FS}) \quad [\text{Hz}] \quad (12)$$



4. Evaluation Board Circuit (Frequency=300kHz Continuous Mode/QLLM/SLLM™ Sample Circuit)

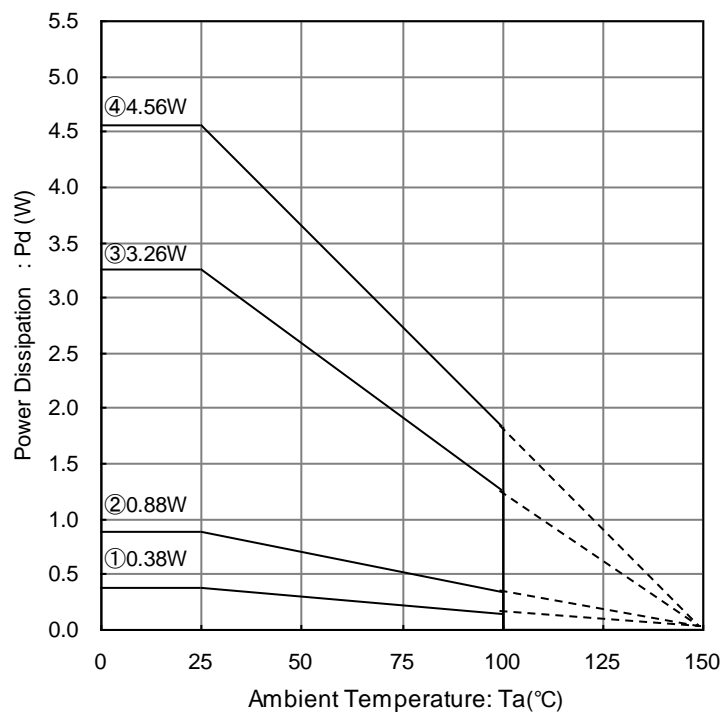


5. Evaluation Board Parts List

Part No.	Value	Company	Part Name	Part No.	Value	Company	Part Name
U1		ROHM	BD95513MUV	R1	10Ω	ROHM	MCR03
D1		ROHM	RB051L-40	R4	10Ω	ROHM	MCR03
C1	1μF	KYOCERA	CM105B105K06A	R6	180KΩ	ROHM	MCR03
C3	1μF	KYOCERA	CM105B105K16A	R7	31kΩ	ROHM	MCR03
C4	10μF	KYOCERA	CM316B106K06A	R8	20kΩ	ROHM	MCR03
C5	1000pF	MURATA	GRM39X7R102K50	R9	100kΩ	ROHM	MCR03
C6	0.1μF	KYOCERA	CM105B104K06A	L1	1.8μH	SUMIDA	CDEP104-1R8ML
C7	1μF	KYOCERA	CM105B105K16A	C14	470μF	SANYO	2R5TPE470ML
C11	10μF	KYOCERA	CM316B106M16A				
C12	0.1μF	KYOCERA	CM05B104K25A				
C13	220pF	MURATA	GRM39C0G221J50				

## Power Dissipation

VQFN032V5050



① IC Only

 $\theta_{j-a} = 328.9 \text{ }^{\circ}\text{C/W}$ ② IC mounted on 1-layer board (with 20.2 mm<sup>2</sup> copper thermal pad) $\theta_{j-a} = 142.0 \text{ }^{\circ}\text{C/W}$ ③ IC mounted on 4-layer board (with 20.2 mm<sup>2</sup> pad on top layer, 5505 mm<sup>2</sup> pad on layers 2,3) $\theta_{j-a} = 38.3 \text{ }^{\circ}\text{C/W}$ ④ IC mounted on 4-layer board (with 5505mm<sup>2</sup> pad on all layers) $\theta_{j-a} = 27.4 \text{ }^{\circ}\text{C/W}$

## Operational Notes

### 1. Reverse Connection of Power Supply

Connecting the power supply in reverse polarity can damage the IC. Take precautions against reverse polarity when connecting the power supply, such as mounting an external diode between the power supply and the IC's power supply pins.

### 2. Power Supply Lines

Design the PCB layout pattern to provide low impedance supply lines. Separate the ground and supply lines of the digital and analog blocks to prevent noise in the ground and supply lines of the digital block from affecting the analog block. Furthermore, connect a capacitor to ground at all power supply pins. Consider the effect of temperature and aging on the capacitance value when using electrolytic capacitors.

### 3. Ground Voltage

Ensure that no pins are at a voltage below that of the ground pin at any time, even during transient condition.

### 4. Ground Wiring Pattern

When using both small-signal and large-current ground traces, the two ground traces should be routed separately but connected to a single ground at the reference point of the application board to avoid fluctuations in the small-signal ground caused by large currents. Also ensure that the ground traces of external components do not cause variations on the ground voltage. The ground lines must be as short and thick as possible to reduce line impedance.

### 5. Thermal Consideration

Should by any chance the power dissipation rating be exceeded the rise in temperature of the chip may result in deterioration of the properties of the chip. In case of exceeding this absolute maximum rating, increase the board size and copper area to prevent exceeding the Pd rating.

### 6. Recommended Operating Conditions

These conditions represent a range within which the expected characteristics of the IC can be approximately obtained. The electrical characteristics are guaranteed under the conditions of each parameter.

### 7. Inrush Current

When power is first supplied to the IC, it is possible that the internal logic may be unstable and inrush current may flow instantaneously due to the internal powering sequence and delays, especially if the IC has more than one power supply. Therefore, give special consideration to power coupling capacitance, power wiring, width of ground wiring, and routing of connections.

### 8. Operation Under Strong Electromagnetic Field

Operating the IC in the presence of a strong electromagnetic field may cause the IC to malfunction.

### 9. Testing on Application Boards

When testing the IC on an application board, connecting a capacitor directly to a low-impedance output pin may subject the IC to stress. Always discharge capacitors completely after each process or step. The IC's power supply should always be turned off completely before connecting or removing it from the test setup during the inspection process. To prevent damage from static discharge, ground the IC during assembly and use similar precautions during transport and storage.

### 10. Inter-pin Short and Mounting Errors

Ensure that the direction and position are correct when mounting the IC on the PCB. Incorrect mounting may result in damaging the IC. Avoid nearby pins being shorted to each other especially to ground, power supply and output pin. Inter-pin shorts could be due to many reasons such as metal particles, water droplets (in very humid environment) and unintentional solder bridge deposited in between pins during assembly to name a few.

## Operational Notes – continued

**11. Unused Input Pins**

Input pins of an IC are often connected to the gate of a MOS transistor. The gate has extremely high impedance and extremely low capacitance. If left unconnected, the electric field from the outside can easily charge it. The small charge acquired in this way is enough to produce a significant effect on the conduction through the transistor and cause unexpected operation of the IC. So unless otherwise specified, unused input pins should be connected to the power supply or ground line.

**12. Regarding the 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 the P layers with the N layers of other elements, creating a parasitic diode or transistor. For example (refer to figure below):

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 inevitably occur in the structure of the IC. The operation of parasitic diodes can result in mutual interference among circuits, operational faults, or physical damage. Therefore, conditions that cause these diodes to operate, such as applying a voltage lower than the GND voltage to an input pin (and thus to the P substrate) should be avoided.

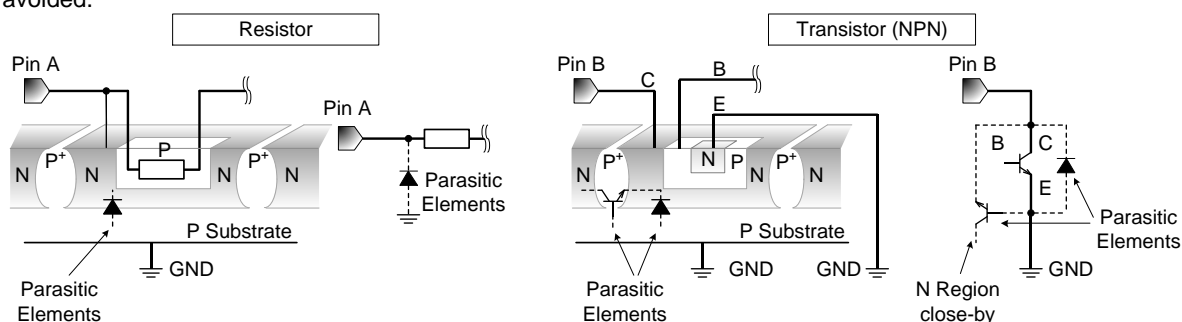


Figure 24. Example of monolithic IC structure

**13. Area of Safe Operation (ASO)**

Operate the IC such that the output voltage, output current, and power dissipation are all within the Area of Safe Operation (ASO).

**14. Thermal Shutdown Circuit(TSD)**

This IC has a built-in thermal shutdown circuit that prevents heat damage to the IC. Normal operation should always be within the IC's power dissipation rating. If however the rating is exceeded for a continued period, the junction temperature ( $T_j$ ) will rise which will activate the TSD circuit that will turn OFF all output pins. When the  $T_j$  falls below the TSD threshold, the circuits are automatically restored to normal operation.

Note that the TSD circuit operates in a situation that exceeds the absolute maximum ratings and therefore, under no circumstances, should the TSD circuit be used in a set design or for any purpose other than protecting the IC from heat damage.

	TSD ON Temp. [°C] (typ)	Hysteresis Temp. [°C] (typ)
BD95513MUV	175	15

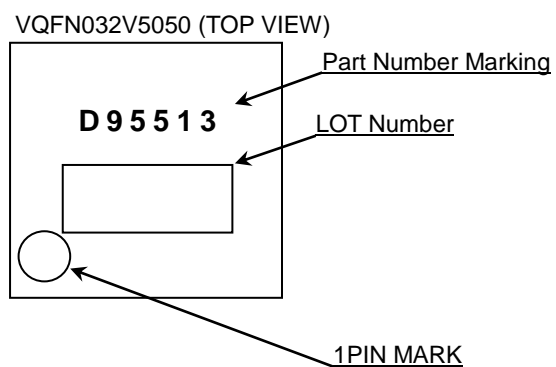
**15. Ground wiring traces**

When using both small-signal and large-current GND traces, the two ground traces should be routed separately but connected to a single ground potential within the application in order to avoid variations in the small-signal ground caused by large currents. Also ensure that the GND traces of external components do not cause variations on GND voltage.

## Ordering Information

B D 9 5 5 1 3 M U V										-	E 2	
Part Number										Package	Packaging and forming specification	
										MUV: VQFN032V5050	E2: Embossed tape and reel	

## Marking Diagram



### **Physical Dimension, Tape and Reel information**

Package Name

VQFN032V5050

Top View Dimensions:

- Overall Width:  $5.0 \pm 0.1$
- Overall Height:  $5.0 \pm 0.1$
- 1PIN MARK: Indicated by a circle and arrow at the bottom-left corner.

Side View Dimensions:

- Maximum Height: 1.0 MAX
- Pin Pitch:  $0.08$  S
- Pin Height:  $0.02^{+0.03}_{-0.02}$  (0.22)

Detailed Pin View Dimensions:

- Pin Pitch:  $0.2$
- Pin Width:  $3.4 \pm 0.1$
- Pin Height:  $0.4 \pm 0.1$
- Pin Spacing:  $0.75$
- Pin Width:  $0.5$
- Pin Height:  $0.25^{+0.05}_{-0.04}$

(UNIT : mm)  
 PKG : VQFN032V5050  
 Drawing No. EX461-5001-2

<Tape and Reel information>

Tape	Embossed carrier tape
Quantity	2500pcs
Direction of feed	E2 ( The direction is the 1pin of product is at the upper left when you hold reel on the left hand and you pull out the tape on the right hand )

Diagram illustrating the tape and reel information. The tape is shown with the direction of feed indicated by an arrow pointing right. The 1pin location is marked with a dot and labeled "1pin". The reel is shown on the left side of the tape.

\* Order quantity needs to be multiple of the minimum quantity.

**Revision History**

Date	Revision	Changes
17.Nov.2014	001	New Release
02.Aug.2016	002	Modify some typo



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(Note1) Medical Equipment Classification of the Specific Applications

JAPAN	USA	EU	CHINA
CLASS III	CLASS III	CLASS II b	CLASS III
CLASS IV		CLASS III	

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  - Use of our Products outdoors or in places where the Products are exposed to direct sunlight or dust
  - Use of our Products in places where the Products are exposed to sea wind or corrosive gases, including Cl<sub>2</sub>, H<sub>2</sub>S, NH<sub>3</sub>, SO<sub>2</sub>, and NO<sub>2</sub>
  - Use of our Products in places where the Products are exposed to static electricity or electromagnetic waves
  - Use of our Products in proximity to heat-producing components, plastic cords, or other flammable items
  - Sealing or coating our Products with resin or other coating materials
  - Use of our Products without cleaning residue of flux (even if you use no-clean type fluxes, cleaning residue of flux is recommended); or Washing our Products by using water or water-soluble cleaning agents for cleaning residue after soldering
  - Use of the Products in places subject to dew condensation
- The Products are not subject to radiation-proof design.
- Please verify and confirm characteristics of the final or mounted products in using the Products.
- In particular, if a transient load (a large amount of load applied in a short period of time, such as pulse. is applied, confirmation of performance characteristics after on-board mounting is strongly recommended. Avoid applying power exceeding normal rated power; exceeding the power rating under steady-state loading condition may negatively affect product performance and reliability.
- De-rate Power Dissipation depending on ambient temperature. When used in sealed area, confirm that it is the use in the range that does not exceed the maximum junction temperature.
- Confirm that operation temperature is within the specified range described in the product specification.
- ROHM shall not be in any way responsible or liable for failure induced under deviant condition from what is defined in this document.

## Precaution for Mounting / Circuit board design

- When a highly active halogenous (chlorine, bromine, etc.) flux is used, the residue of flux may negatively affect product performance and reliability.
- In principle, the reflow soldering method must be used on a surface-mount products, the flow soldering method must be used on a through hole mount products. If the flow soldering method is preferred on a surface-mount products, please consult with the ROHM representative in advance.

For details, please refer to ROHM Mounting specification

## Precautions Regarding Application Examples and External Circuits

1. If change is made to the constant of an external circuit, please allow a sufficient margin considering variations of the characteristics of the Products and external components, including transient characteristics, as well as static characteristics.
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## Precaution for Storage / Transportation

1. Product performance and soldered connections may deteriorate if the Products are stored in the places where:
  - [a] the Products are exposed to sea winds or corrosive gases, including Cl<sub>2</sub>, H<sub>2</sub>S, NH<sub>3</sub>, SO<sub>2</sub>, and NO<sub>2</sub>
  - [b] the temperature or humidity exceeds those recommended by ROHM
  - [c] the Products are exposed to direct sunshine or condensation
  - [d] the Products are exposed to high Electrostatic
2. Even under ROHM recommended storage condition, solderability of products out of recommended storage time period may be degraded. It is strongly recommended to confirm solderability before using Products of which storage time is exceeding the recommended storage time period.
3. Store / transport cartons in the correct direction, which is indicated on a carton with a symbol. Otherwise bent leads may occur due to excessive stress applied when dropping of a carton.
4. Use Products within the specified time after opening a humidity barrier bag. Baking is required before using Products of which storage time is exceeding the recommended storage time period.

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