

Single-chip Type with Built-in FET Switching Regulator Series

# Step-down Switching regulators with Built-in Power MOSFET

## BU9000xGWZ series

### ●General Description

The BU9000xGWZ are a high efficiency 6MHz synchronous step-down switching regulator with ultra low current PFM mode. It provides up to 1.0A load current and an input voltage range from 3.0V to 5.5V, optimized for battery powered portable applications. BU9000xGWZ has a mode control pin that allows the user to select Forced PWM (Pulse Width Modulation) mode or PFM (Pulse Frequency Modulation) and PWM auto change mode utilized power save operation at light load current.

### ●Features

- Fast transient response
- Automatic PFM/PWM operation
- Forced PWM operation
- Internal Soft Start
- Under voltage lockout
- Over current protection
- Thermal shutdown

### ●Applications

Smart phones, Cell phones, Portable applications, Micro DC/DC modules, and USB accessories

### ●Package(s) UCSP35L1

W(Typ.) x D(Typ.) x H(Max.)  
 1.30mm x 0.90mm x 0.40mm

### ●Typical Application Circuit(s)

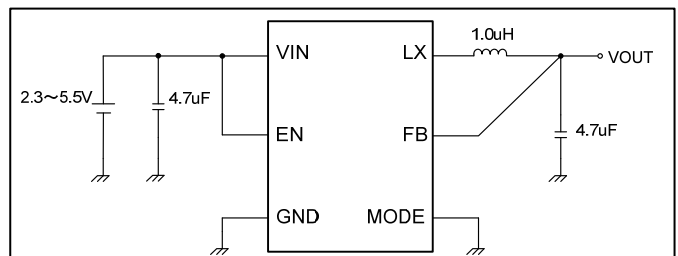


Figure 1. Typical Application Circuit(s)

### ●Lineup

Part No.	Output voltage	Input voltage	Switching frequency	Operating mode	
				MODE=L	MODE=H
BU90002GWZ	3.30V	4.0V to 5.5V	5.4MHz to 6.6MHz	Automatic PFM/PWM	Forced PWM
BU90003GWZ	1.20V	2.3V to 5.5V	3.6MHz to 4.4MHz		
BU90004GWZ	1.80V	2.3V to 5.5V	4.8MHz to 6.0MHz		
BU90005GWZ	2.50V	2.3V to 5.5V	5.4MHz to 6.6MHz	Forced PFM	
BU90006GWZ	3.00V	2.3V to 5.5V	5.4MHz to 6.6MHz	Automatic PFM/PWM	
BU90007GWZ	1.25V	2.3V to 5.5V	3.6MHz to 4.4MHz		
BU90008GWZ	1.00V	2.3V to 5.5V	3.2MHz to 4.0MHz		
BU90009GWZ	1.30V	2.3V to 5.5V	3.8MHz to 4.8MHz		

### ●Pin Configuration(s)

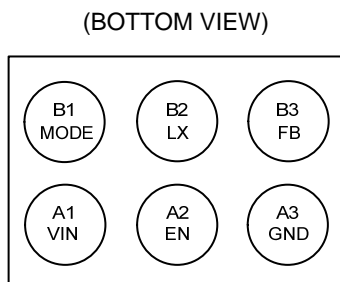


Figure 2. Pin Configuration(s)

### ●Pin Description(s)

Pin No.	Symbol	Function
A1	VIN	Power supply input pin
A2	EN	Enable pin
A3	GND	GND pin
B1	MODE	Forced PWM mode pin
B2	LX	Inductor connection pin
B3	FB	Feedback voltage input pin

## ●Block Diagram(s)

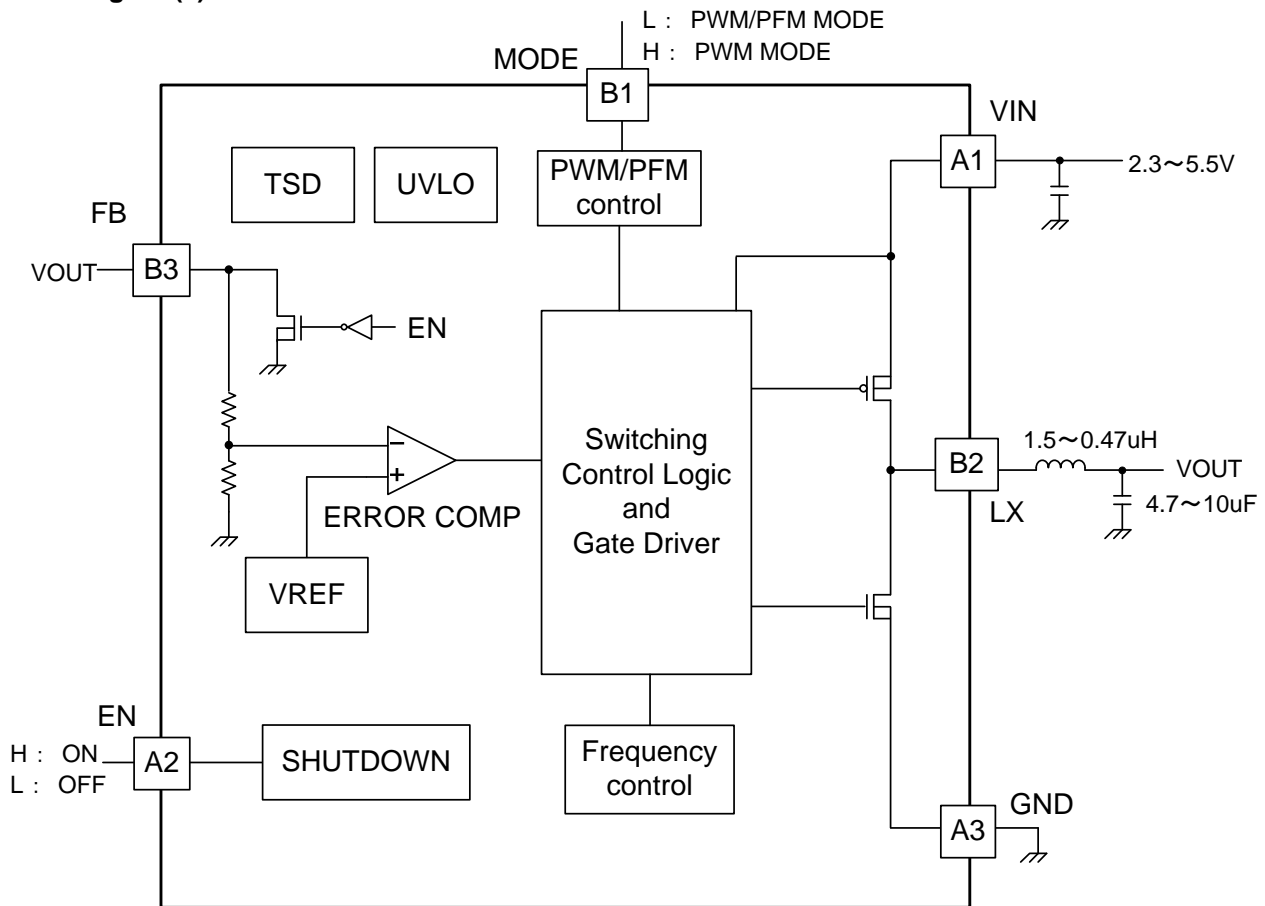


Figure 3. Block Diagram(s)

## ●Description of Block(s)

The BU9000xGWZ are a synchronous step-down DC/DC converter that achieves fast transient response from light load to heavy load by hysteretic PWM control system and current constant PFM control system.

### OPWM control

BU9000xGWZ operates by hysteretic PWM control. This scheme ensures fast switching, high efficiency, and fast transient response.

When the output voltage is below the VREF voltage, the error comparator output is low to high and turning on P-channel MOSFET until above the VREF voltage and minimum on time.

### OPFM control

At light load the regulator and MODE=low, the regulator operates with reduced switching frequency and improves the efficiency. During PFM operation, the output voltage slightly higher than typical output voltage.

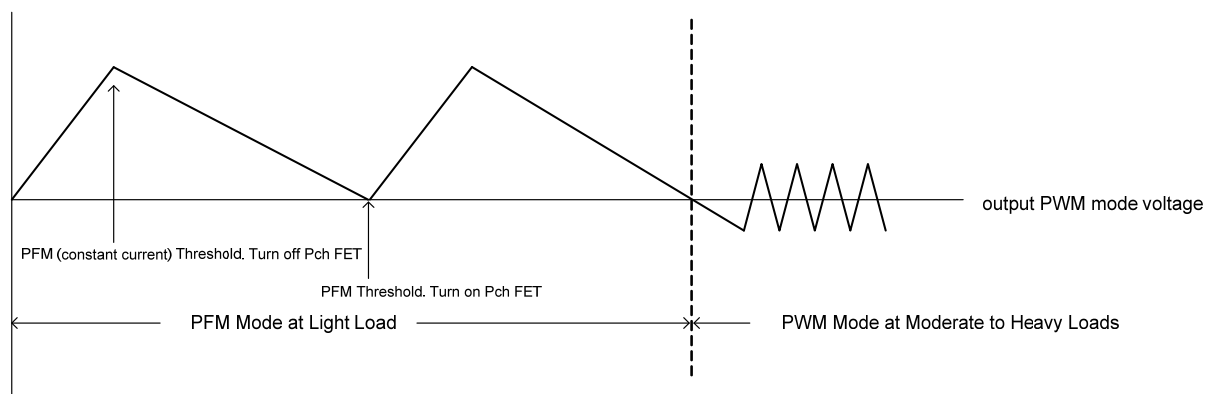


Figure 4. Operation of PFM mode and PWM mode

## ●Description of operations

### 1) Shutdown

If the EN input pin set to low ( $<0.4V$ ), all circuit are shut down and the regulator is standby mode.  
Do not leave the EN pin floating.

### 2) Soft start function

The regulator has a soft start circuit that reduces in-rush current at start-up. Typical start up times with a 4.7uF output capacitor is 120usec.

### 3) Current limit

The BU9000xGWZ has a current limit circuit that protects itself and external components during overload condition.

### 4) UVLO

The BU9000xGWZ has a Under Voltage Lock Out circuit that turn off device when  $V_{IN} > 2.05V$ (typ.)

### 5) FORCED PWM MODE

Setting MODE pin high ( $>1.4V$ ) places the regulator in forced PWM. This control provides noise reduction and output stability. Do not leave the MODE pin floating.

### 6) FORCED PFM MODE ( BU90005GWZ)

Setting MODE pin low ( $<0.4V$ ) places the regulator in forced PFM. It is effective in light load mode.

### 7) TSD

The BU9000xGWZ has a thermal shutdown feature to protect the device if the junction temperature exceeds  $150^{\circ}C$ . In thermal shutdown, the DRIVER is disabled.

This circuit is only to cut off the IC from thermal runaway, and has not been design to protect or guarantee the IC. Therefore, the user should not plan to activate this circuit with continued operation in mind.

## ●Absolute Maximum Ratings ( $T_a = 25^{\circ}C$ )

Parameter	Symbol	Rating	Unit
Maximum input power supply voltage	VIN	7	V
Maximum voltage at EN, FB, LX, MODE	VEN, VFB, VLX, VMODE	7	V
Power dissipation	Pd	0.39(*1)	W
Operating temperature range	Topr	-40 to +85	$^{\circ}C$
Storage temperature range	Tstg	-55 to +125	$^{\circ}C$
Junction temperature	Tjmax	+125	$^{\circ}C$

(\*1) When mounted on the specified PCB (55mm x 63mm), Deducted by 3.9m W/c when used over  $T_a = 25^{\circ}C$

## ●Recommended Operating Rating(s)

Parameter	Symbol	Rating			Unit	Serie
		Min.	Typ.	Max.		
Input voltage	VIN	4.0	-	5.5	V	BU90002GWZ
		2.3	-	5.5		BU90003~BU90009GWZ

● **Electrical Characteristic(s)** (unless otherwise specified VIN=3.6V, Ta=25°C)

Item		Symbol	Rating			Unit	Condition
			Min.	Typ.	Max.		
【Switching regulator】							
Output voltage accuracy	VOUTA	-2	-	+2	%	MODE:H(PWM Operation)	
		-2	-	+3		MODE:L(PFM Operation)	
Maximum load current	IoutMAX1	-	-	1.0	A	3.0V≤VIN<5.5V	
	IoutMAX2	-	-	0.8	A	2.7V≤VIN<3.0V	
	IoutMAX3	-	-	0.6	A	2.3V≤VIN<2.7V	
	IoutMAX4	-	-	0.1	A	MODE:L(PFM Operation) (BU90005GWZ,)	
【Soft start】							
Soft start time	Tss	65	120	240	usec	( BU90002GWZ, BU90003GWZ, BU90004GWZ, BU90005GWZ, BU90006GWZ, BU90007GWZ, BU90009GWZ )	
		55	110	220	usec	( BU90008GWZ )	
【Frequency control】							
Switching frequency	fosc	5.4	6.0	6.6	MHz	No load, MODE:H ( BU90002GWZ, BU90005GWZ, BU90006GWZ )	
		4.8	5.4	6.0	MHz	No load, MODE:H ( BU90004GWZ )	
		3.6	4.0	4.4	MHz	No load, MODE:H ( BU90003GWZ, BU90007GWZ )	
		3.2	3.6	4.0	MHz	No load, MODE:H ( BU90008GWZ )	
		3.8	4.3	4.8	MHz	No load, MODE:H ( BU90009GWZ )	
【Driver】							
PchFET on resistance	RonP1	-	250	400	mOhm	VIN=5.0V	
	RonP2		300	450	mOhm	VIN=3.6V	
NchFET on resistance	RonN1	-	220	350	mOhm	VIN=5.0V	
	RonN2		250	380	mOhm	VIN=3.6V	
【Control】							
EN pin control voltage	Operation	VENH	1.4	-	VIN	V	
	Non Operation	VENL	0	-	0.4	V	
MODE pin control voltage	Operation	VMODEH	1.4	-	VIN	V	Forced PWM
	Non Operation	VMODEL	0	-	0.4	V	Automatic PFM/PWM (BU90005GWZ : Forced PFM)
【UVLO】							
Protect threshold voltage	Uvth	1.95	2.05	2.15	V		
Hysteresis	Uvhy	50	100	150	mV		
【Current limit】							
Current limit threshold	ILIMIT	1.5	1.7	1.9	A		PMOS current detect, Open loop
【Output discharge】							
Output discharge resistance	DRES	15	30	60	Ohm		EN=0V, FB=0.5V
【Circuit current】							
Operating quiescent current	IINS1	-	45	65	uA		No load, EN:H, MODE:L, VOUT=3.6V forced Not switching ( BU90003GWZ, BU90004GWZ, BU90005GWZ, BU90007GWZ, BU90008GWZ, BU90009GWZ )
	IINS2	-	55	80	uA		No load, EN:H, MODE:L, VOUT=3.6V forced Not switching ( BU90002GWZ, BU90006GWZ )
	IQ1	-	5.2	-	mA		No load, EN:H, MODE:H, PWM operation L:LQM21MPN1R0NG0 ( BU90003GWZ )
	IQ2	-	5.6	-	mA		No load, EN:H, MODE:H, PWM operation L:LQM21MPN1R0NG0 ( BU90004GWZ )
Shutdown current	SHD	-	0	1	uA		EN=0V

# ●Electrical Characteristic curves (Reference data)

## BU90002GWZ (3.3V OUTPUT)

Parts

L:LQM21MPN1R0NG0 (2.0mm × 1.6mm × 1.0mm Murata)

COUT:GRM155R60J475M(1.0mm × 0.5mm × 0.5mm Murata)

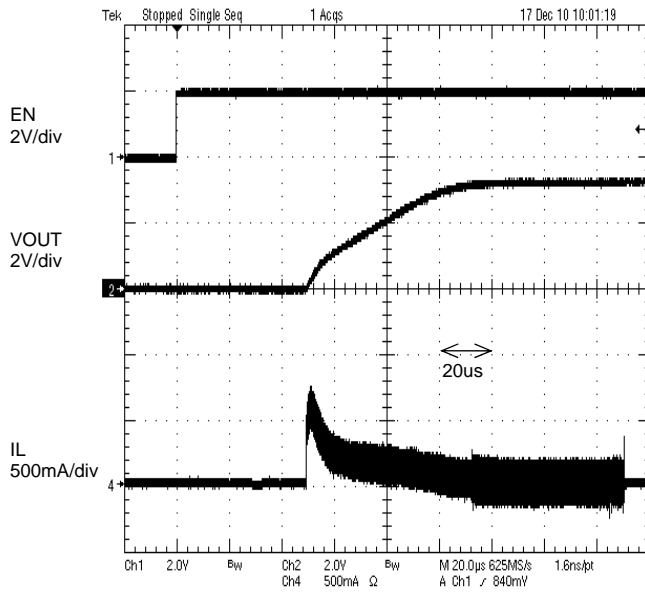


Figure 5. Start up

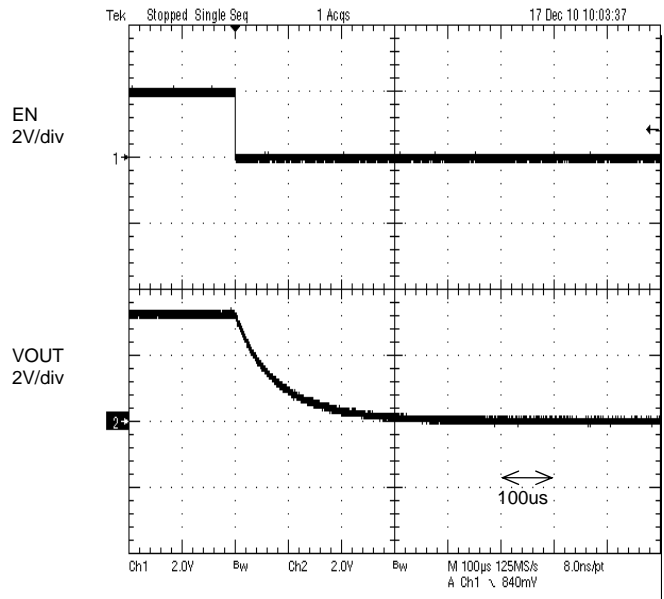


Figure 6. Shut down

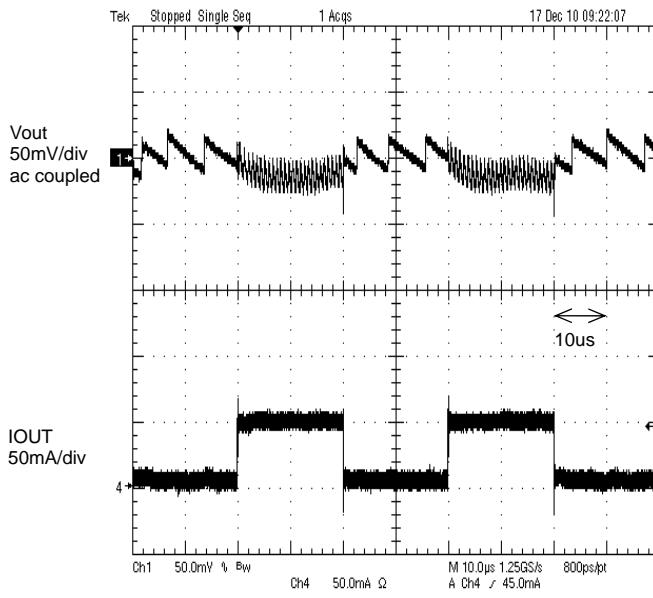


Figure 7. Load transient response 5mA to 50mA  
tr=tf=100ns, MODE : Low

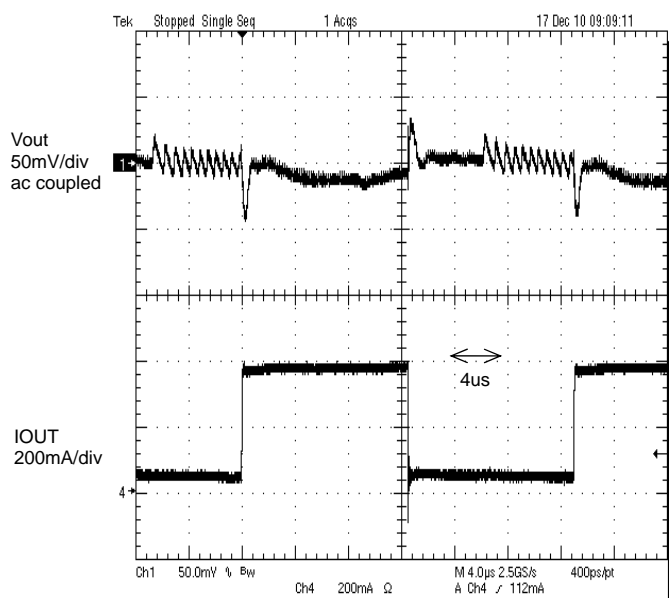


Figure 8. Load transient response 50mA to 350mA  
tr=tf=100ns, MODE : Low

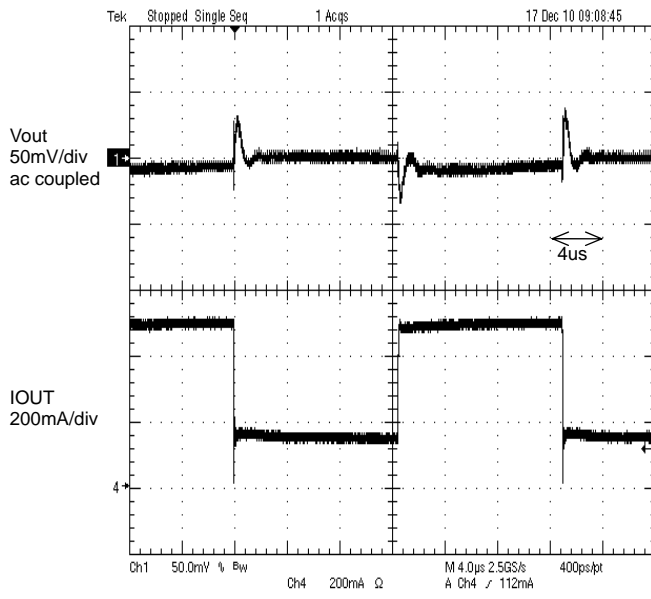


Figure 9. Load transient response 150mA to 500mA  
 $t_r = t_f = 100\text{ns}$ , MODE : High

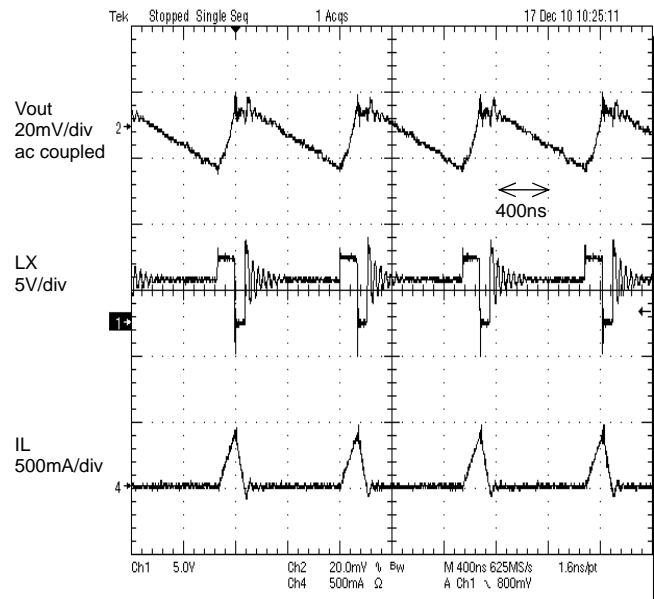


Figure 10. PFM mode Operation  
 $I_{out} = 40\text{mA}$

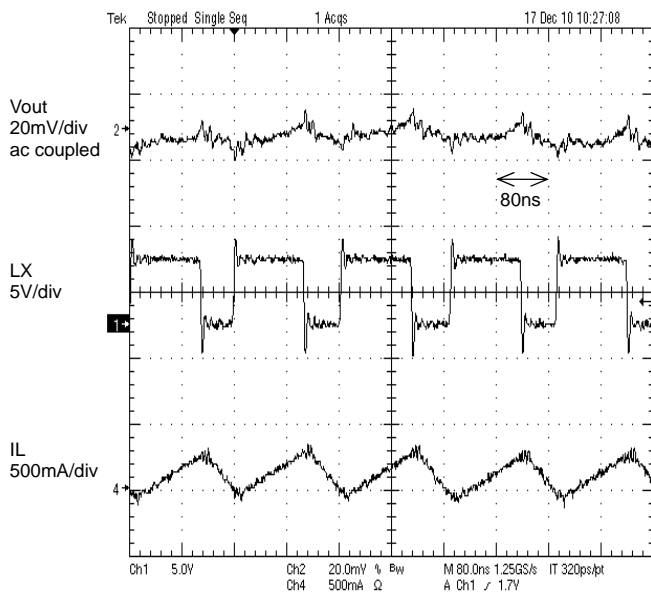


Figure 11. PWM mode Operation  
 $I_{out} = 100\text{mA}$

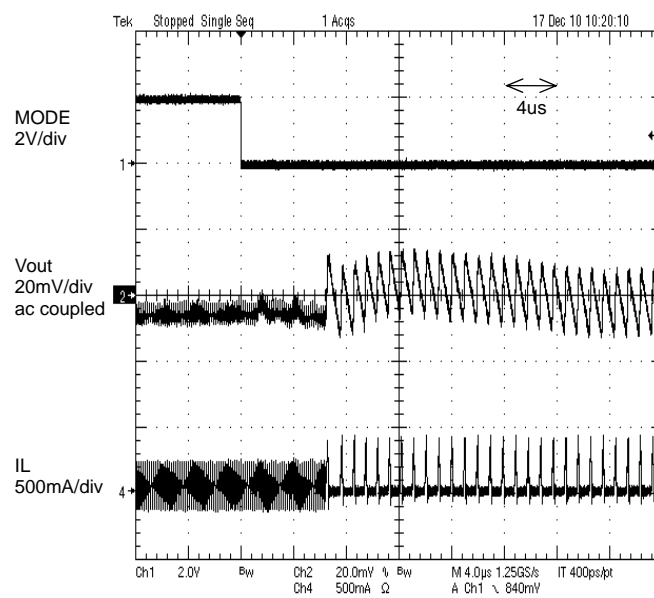


Figure 12. Mode Change Response  
 MODE : High to Low

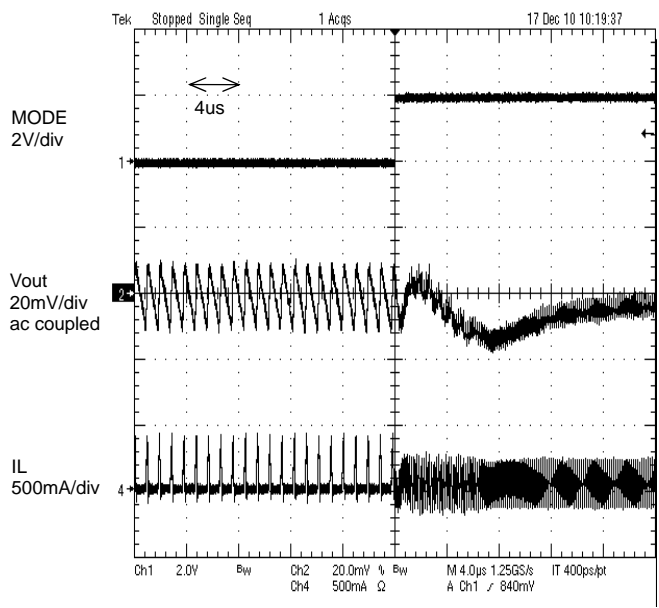


Figure 13. Mode Change Response  
MODE : Low to High

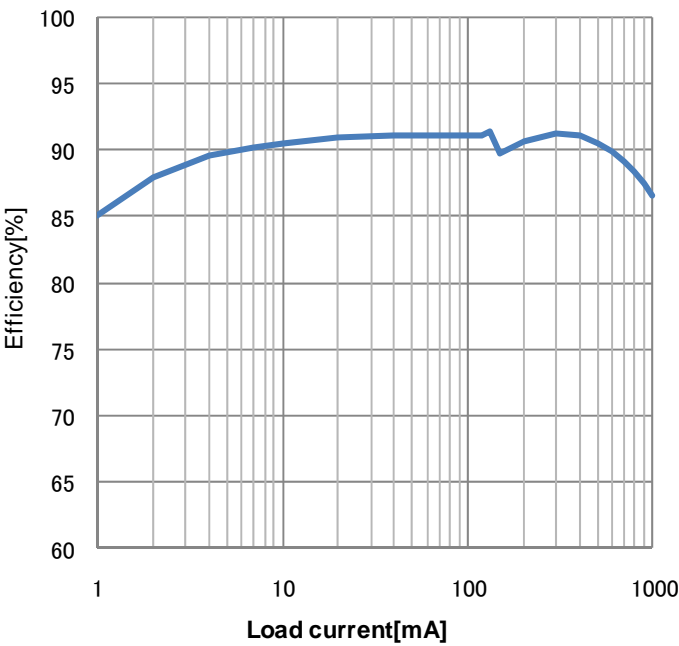


Figure 14. Efficiency vs Load current  
VIN=5V PWM/PFM Auto mode

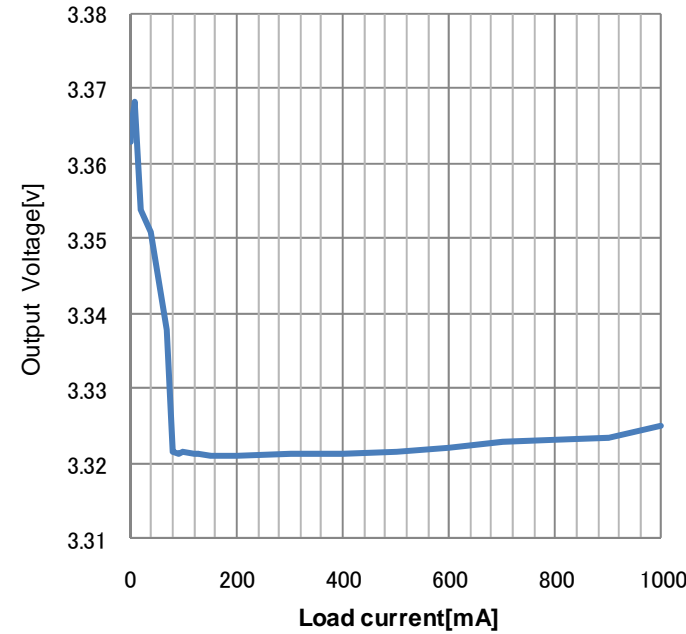


Figure 15. Load regulation  
VIN=5V PWM/PFM Auto mode

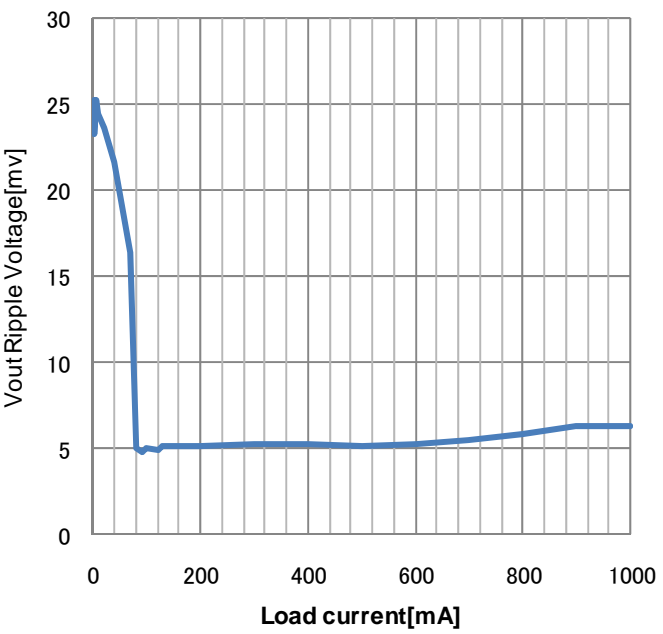


Figure 16. Vout Ripple Voltage  
VIN=5V PWM/PFM Auto mode

●Electrical characteristic curves (Reference data)  
BU90003GWZ (1.2V OUTPUT)

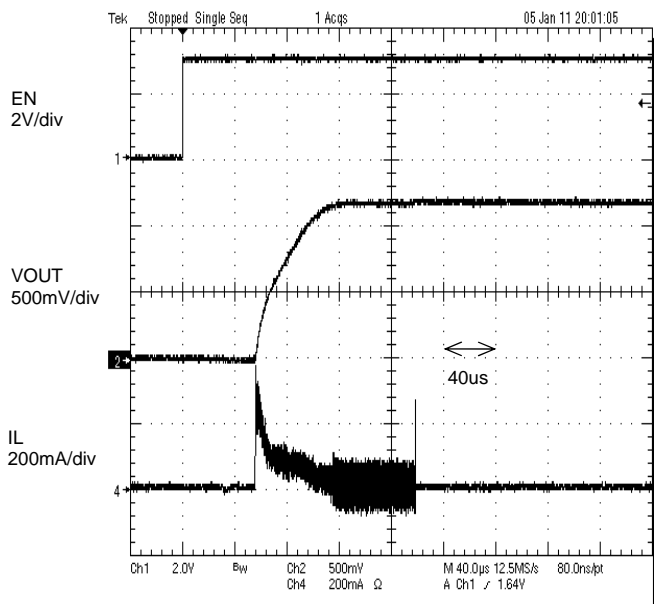


Figure 17. Start up

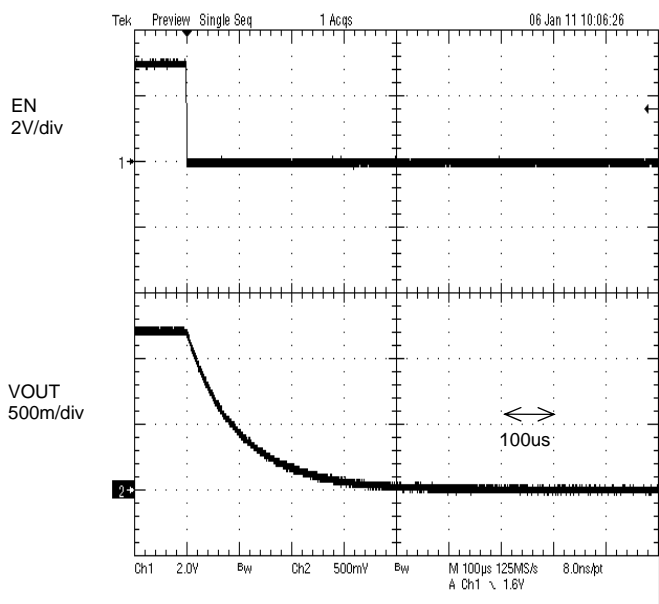


Figure 18. Shut down

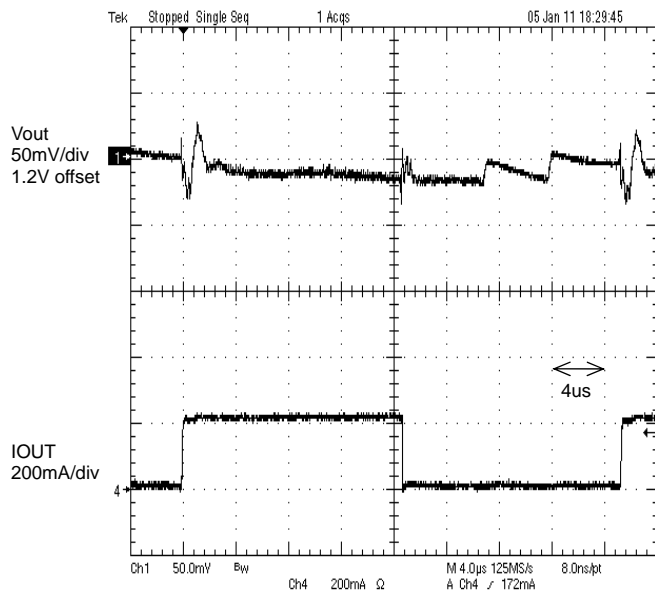


Figure 19. Load transient response 5mA to 200mA  
 $tr=100ns$ , MODE : Low

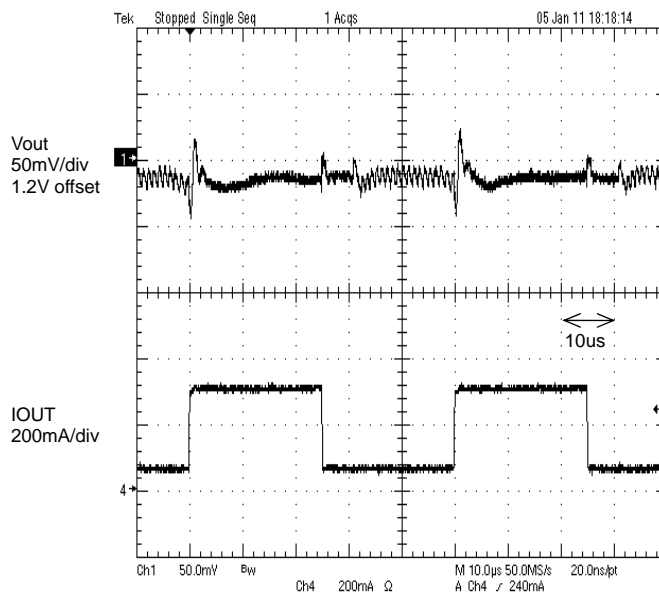


Figure 20. Load transient response 50mA to 350mA  
 $tr=100ns$ , MODE : Low



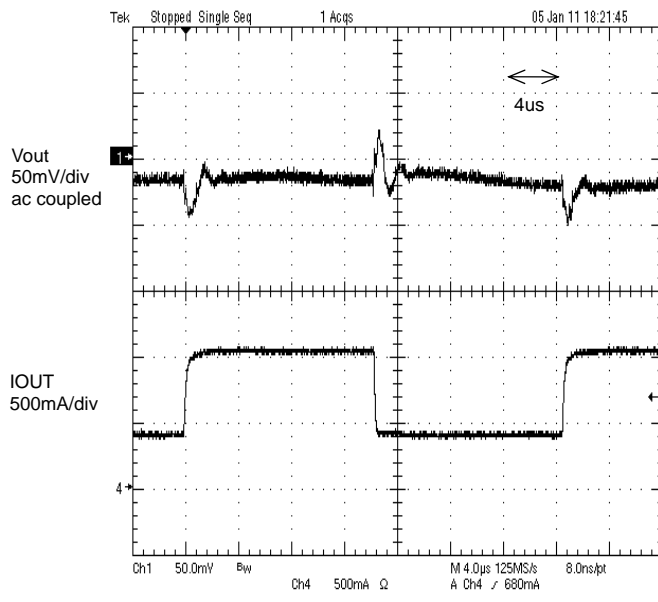


Figure 21. Load transient response 400mA to 1000mA  
tr=tf=100ns, MODE : Low

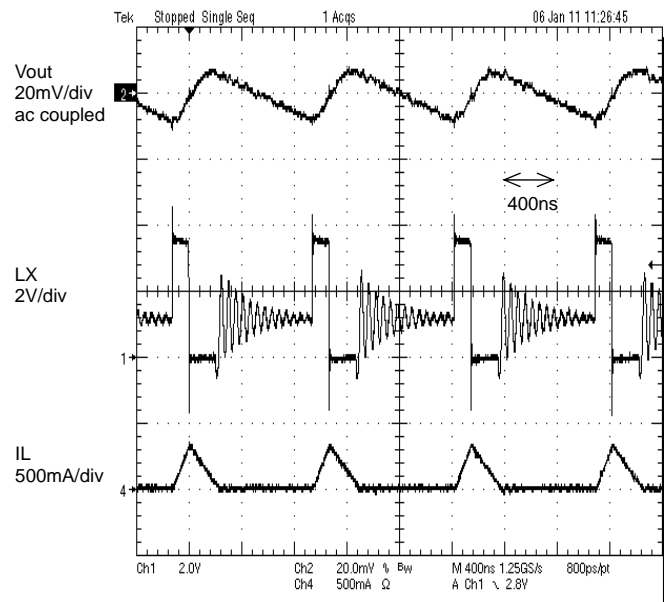


Figure 22. PFM mode Operation Iout=50mA

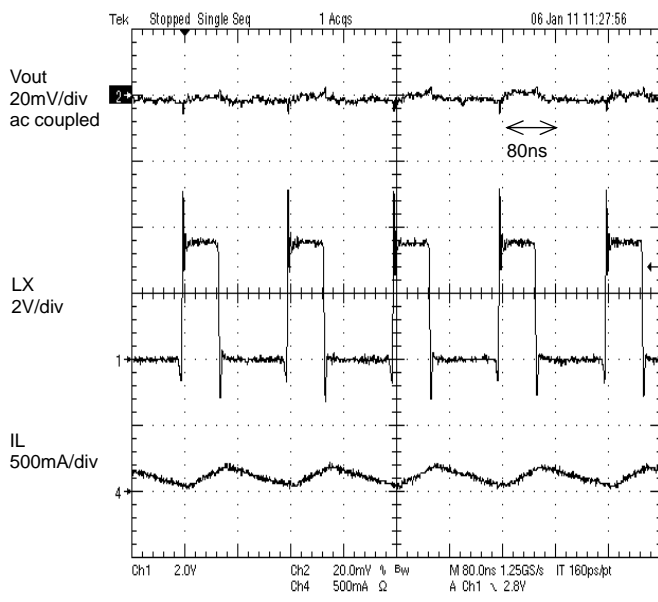


Figure 23. Fig.23 PWM mode Operation Iout=100mA

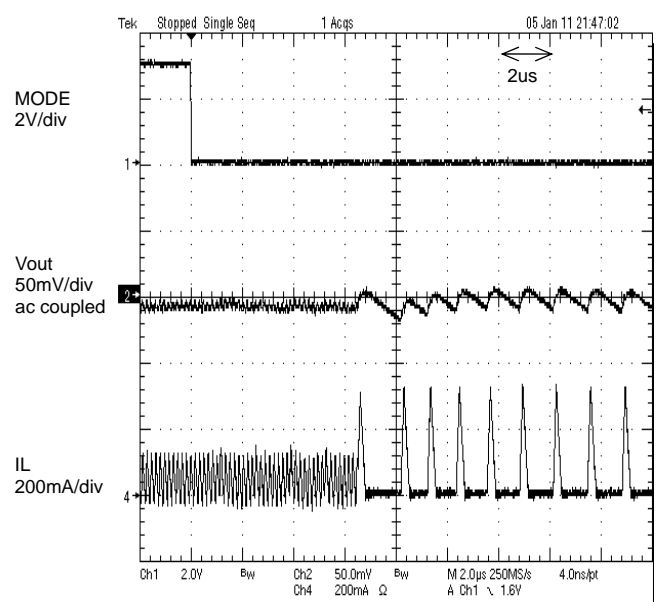


Figure 24. Mode Change Response  
MODE : High to Low

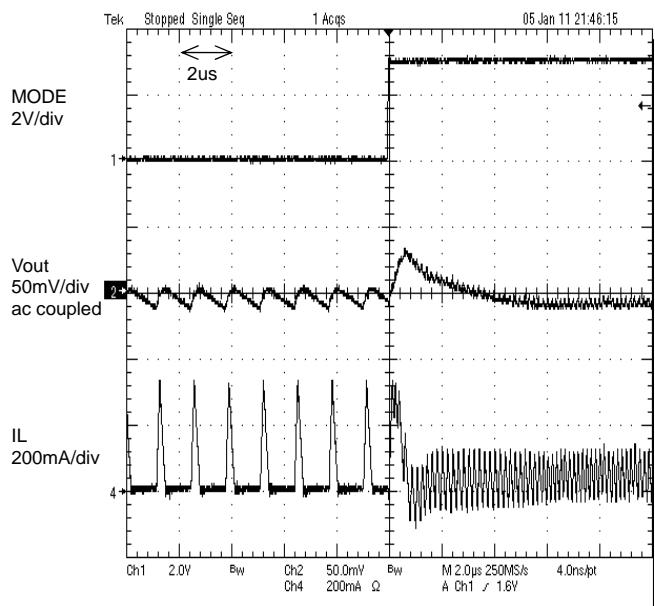


Figure 25. Mode Change Response  
MODE : Low to High

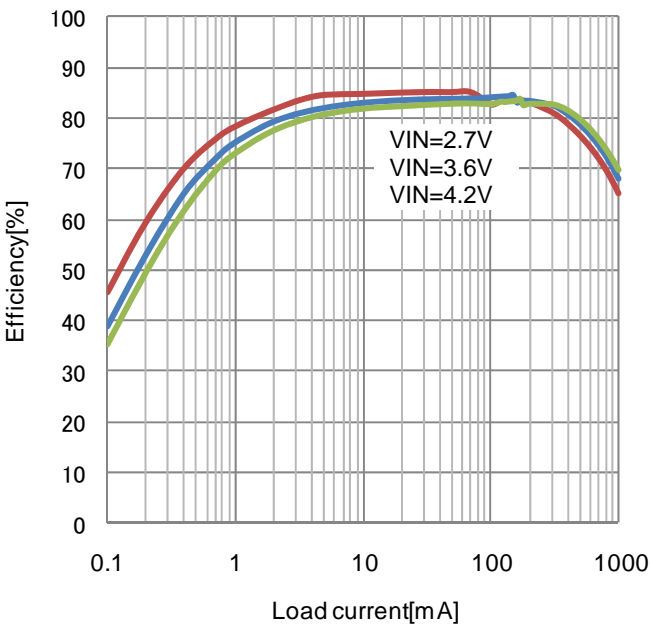


Figure 26. Efficiency vs Load current  
PWM/PFM Auto mode

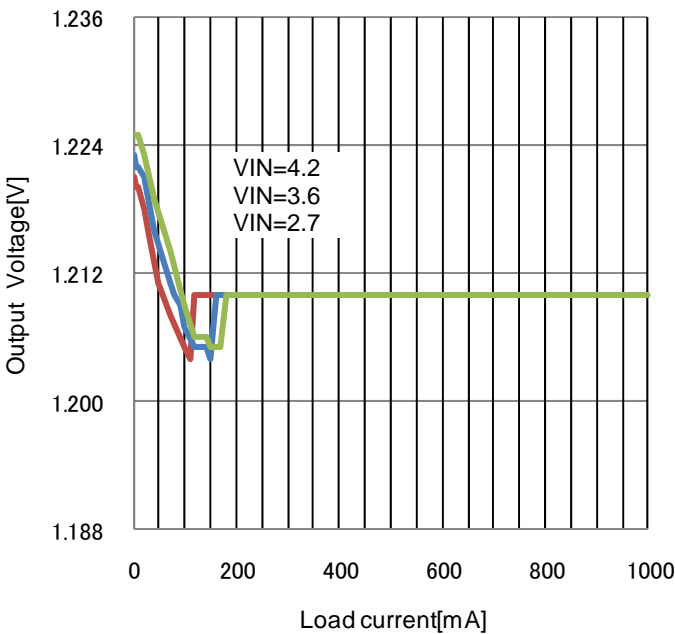


Figure 27. Load regulation  
PWM/PFM Auto mode

●Electrical characteristic curves (Reference data)  
BU90004GWZ (1.80V OUTPUT)

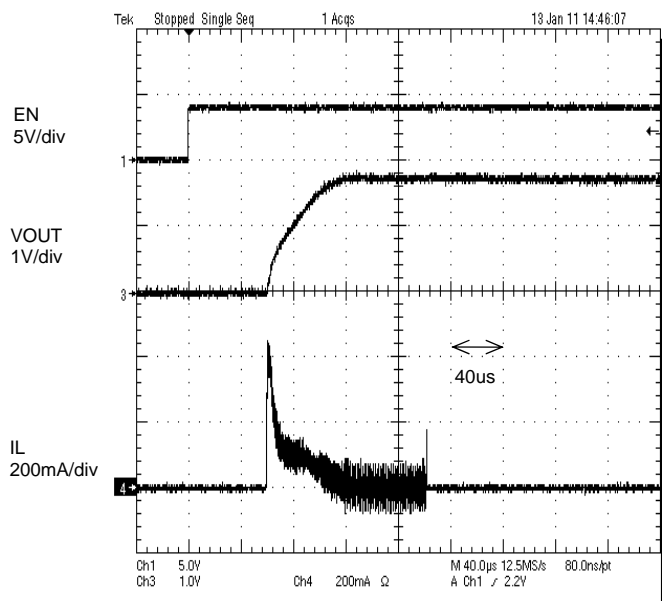


Figure 28. Start up

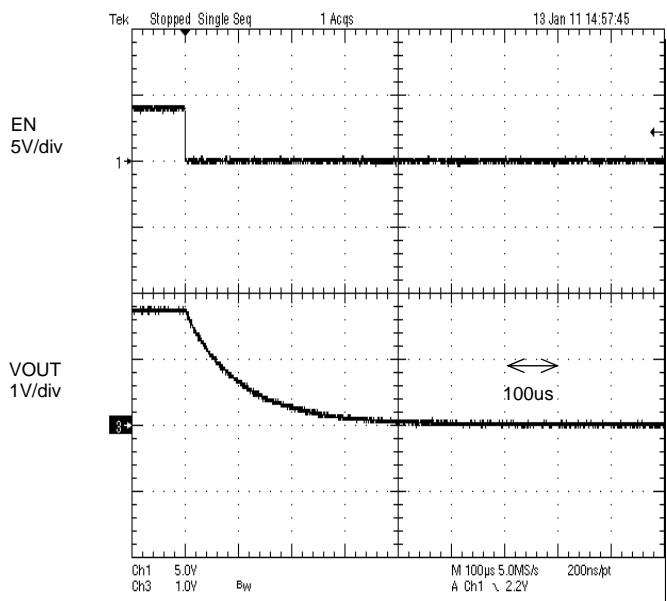


Figure 29. Shut down

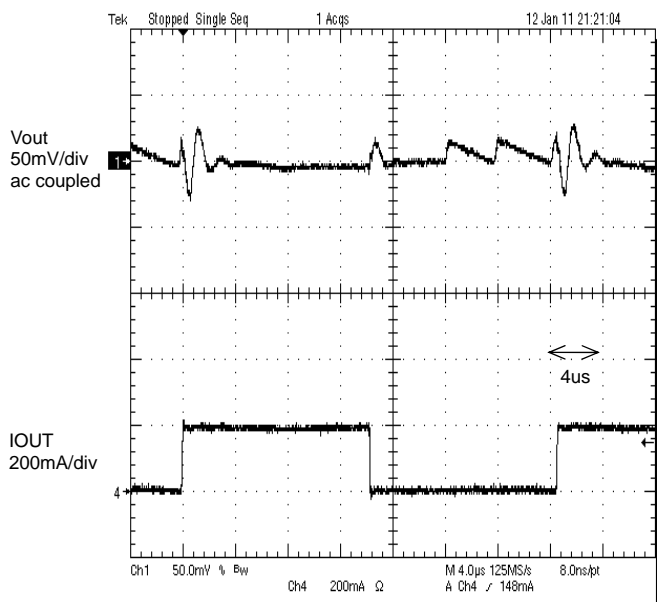


Figure 30. Load transient response 5mA to 200mA  
tr=tf=100ns, Mode : Low

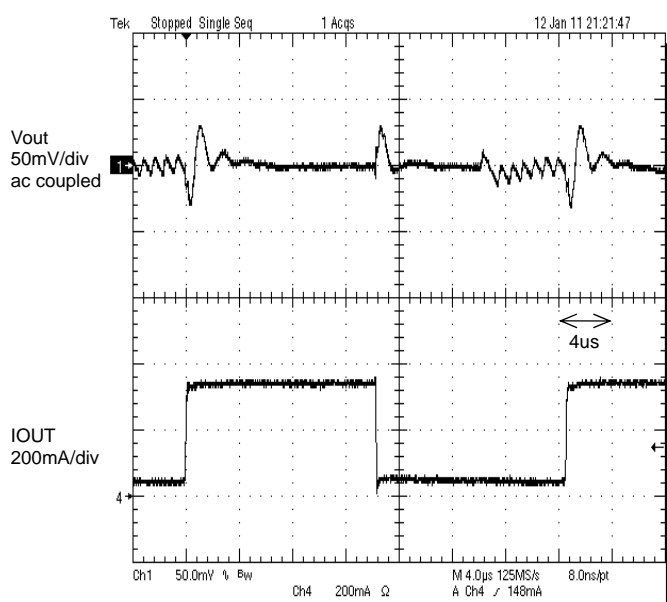


Figure 31. Load transient response 50mA to 350mA  
tr=tf=100ns, Mode :Low

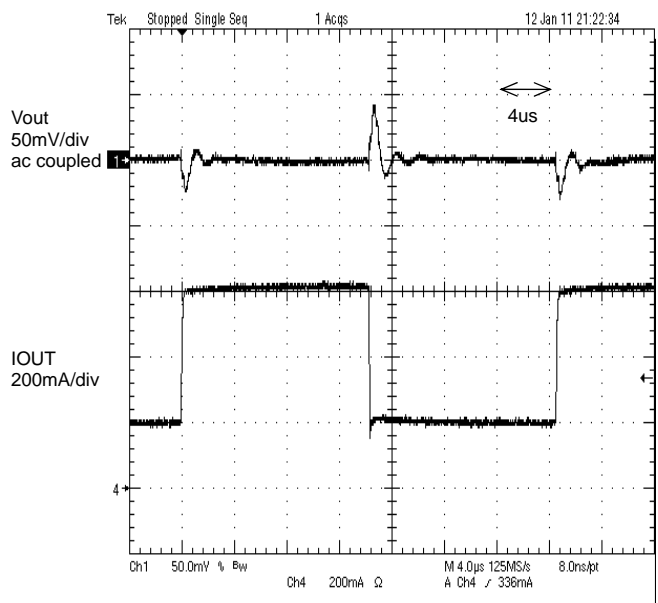


Figure 32. Load transient response 200mA to 600mA  
tr=tf=100ns, MODE : Low

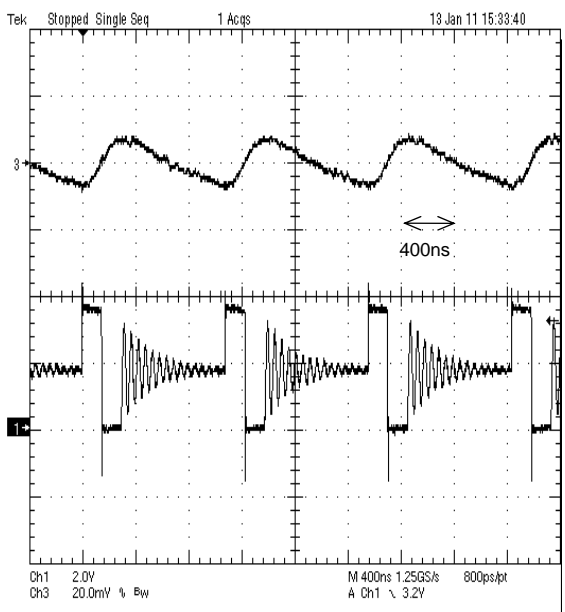


Figure 33. PFM mode Operation Iout=50mA

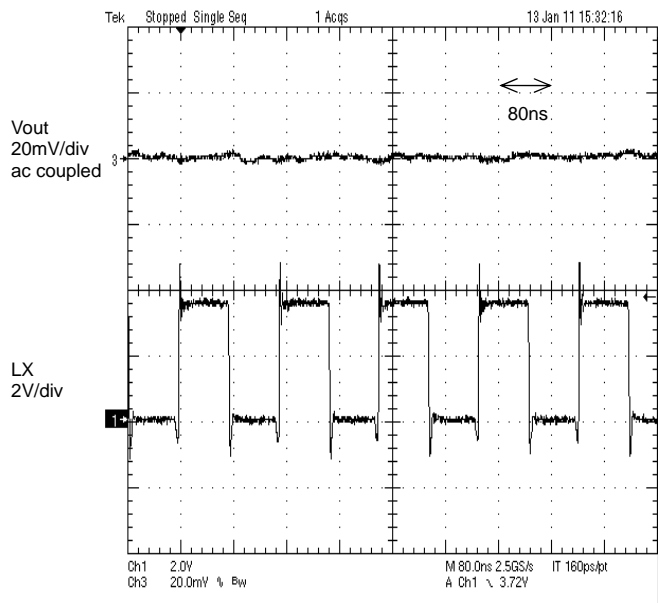


Figure 34. PWM mode Operation Iout=100mA

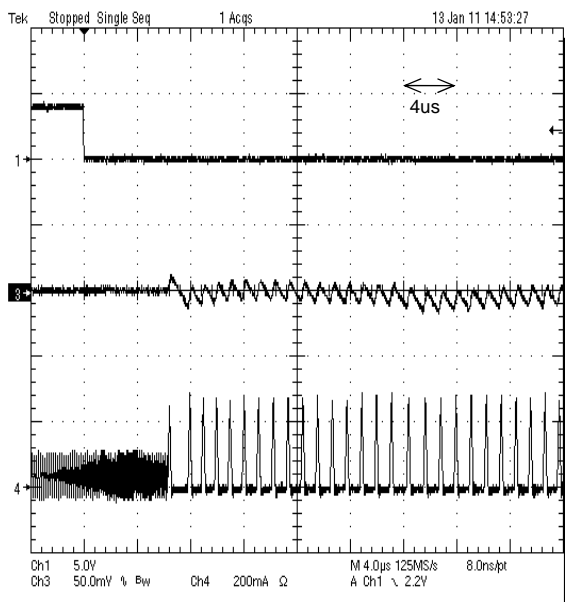


Figure 35. Mode Change Response  
MODE : High to Low

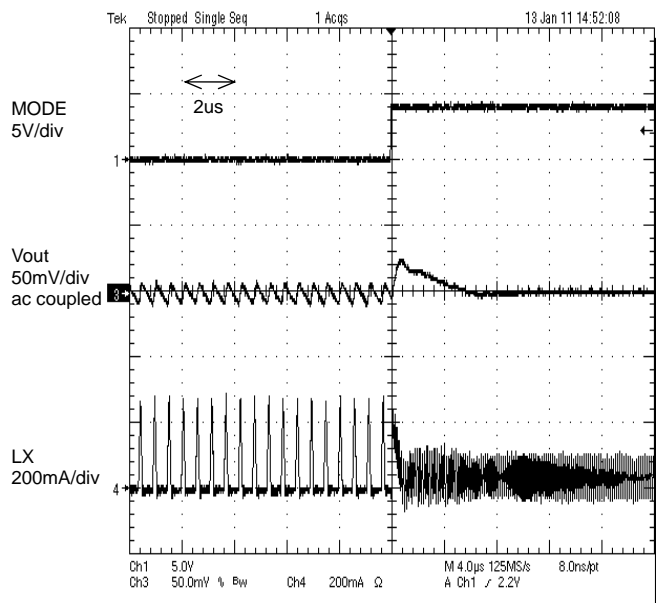


Figure 36. Mode Change Response  
MODE : Low to High

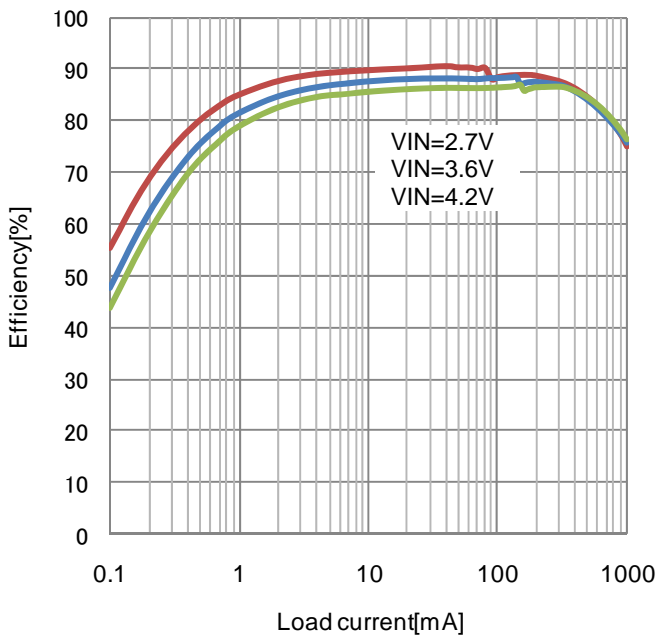


Figure 37. Efficiency vs Load current  
PWM/PFM Auto mode

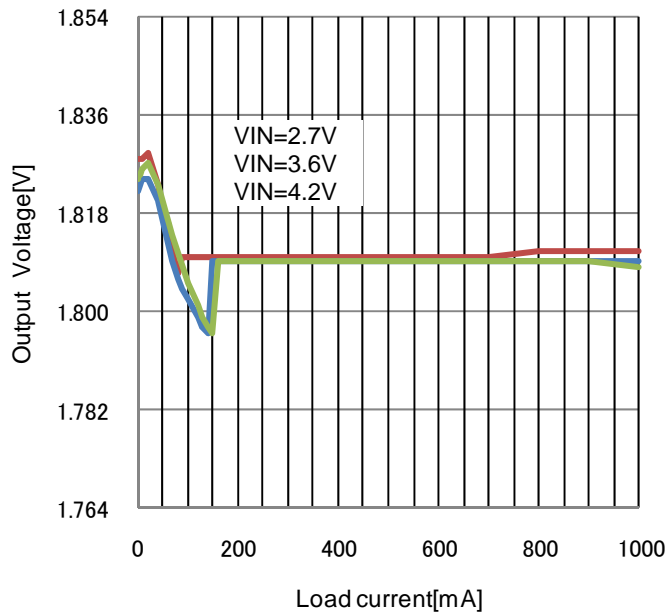


Figure 38. Load regulation  
PWM/PFM Auto mode

●Electrical characteristic curves (Reference data)  
BU90005GWZ (2.50V OUTPUT)

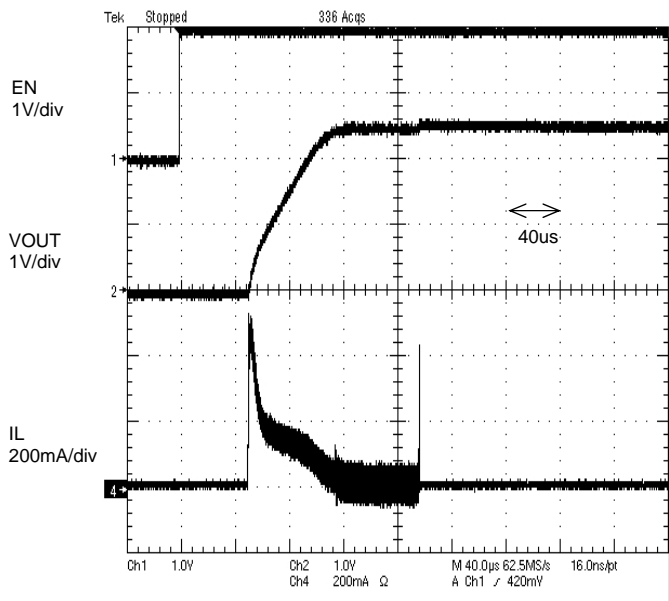


Figure 39. Start up

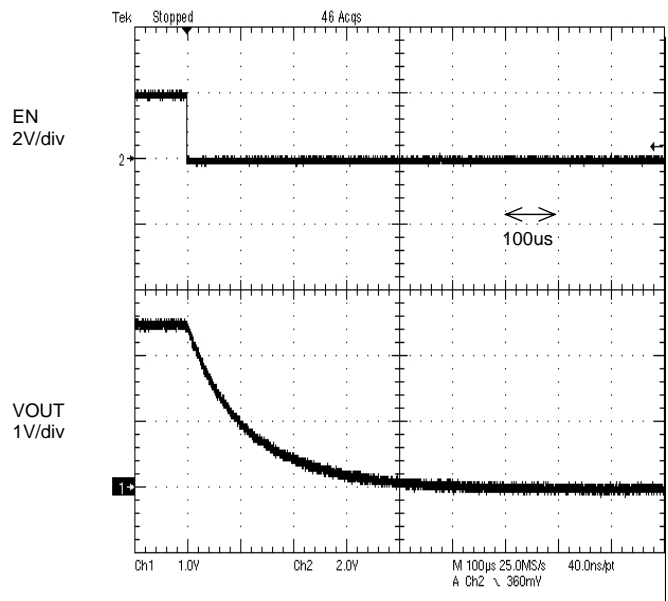


Figure 40. Shut down

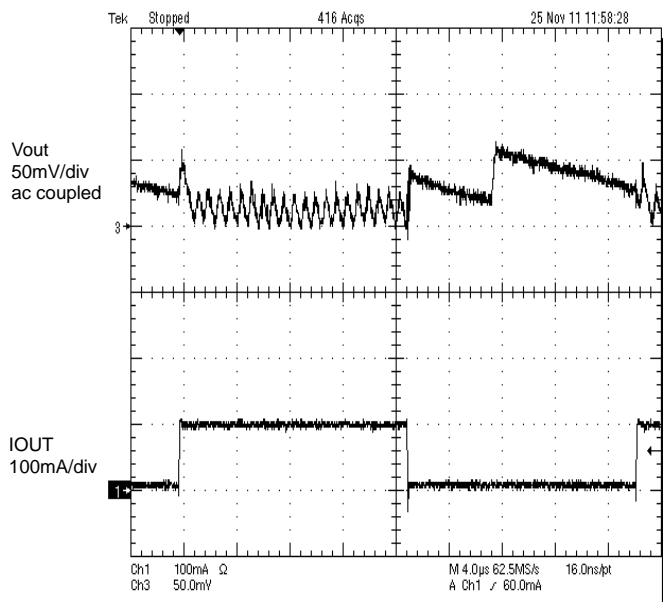


Figure 41. Load transient response 5mA to 100mA  
 $t_r=t_f=100\text{ns}$ , MODE : Low

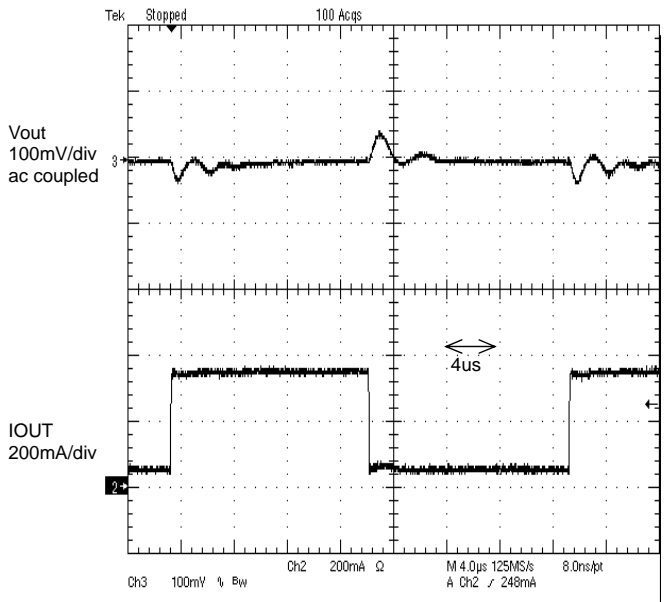


Figure 42. Load transient response 50mA to 350mA  
 $t_r=t_f=100\text{ns}$ , MODE : High

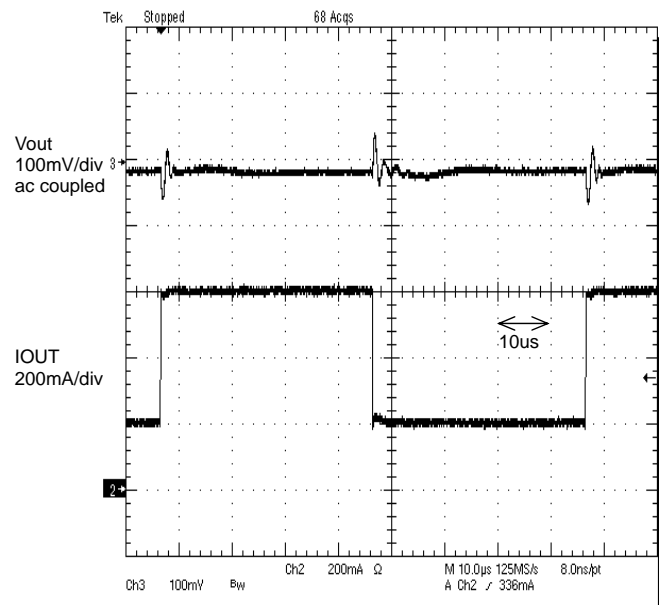


Figure 43. Load transient response 200mA to 600mA  
tr=tf=100ns, MODE : High

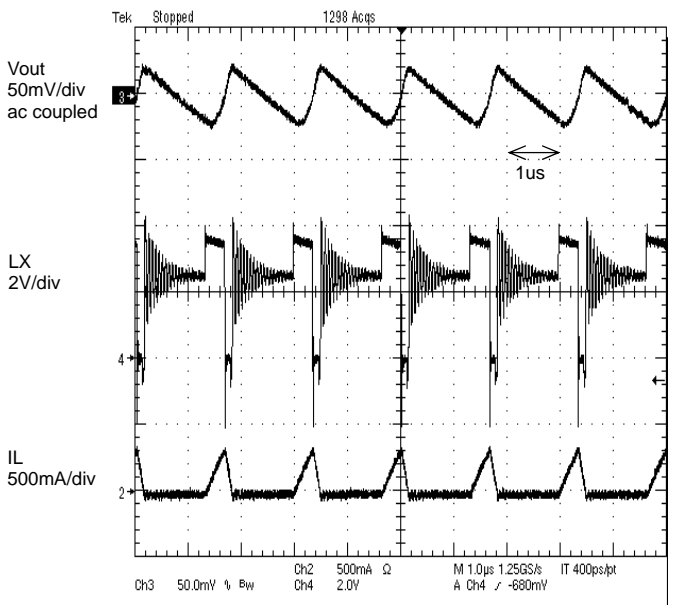


Figure 44. PFM mode Operation Iout=50mA

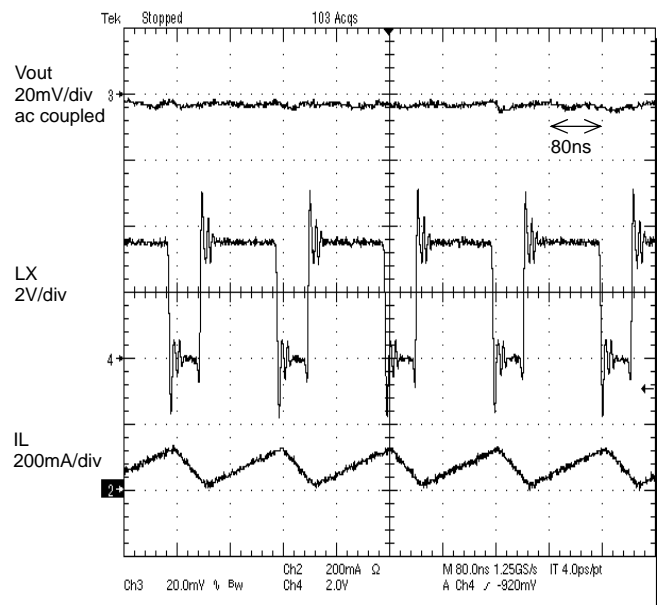


Figure 45. PWM mode Operation Iout=100mA

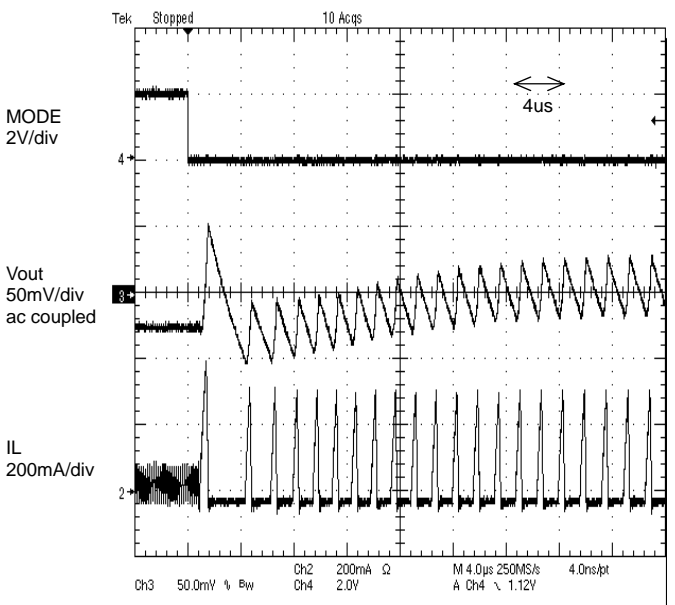


Figure 46. Mode Change Response  
MODE : High to Low

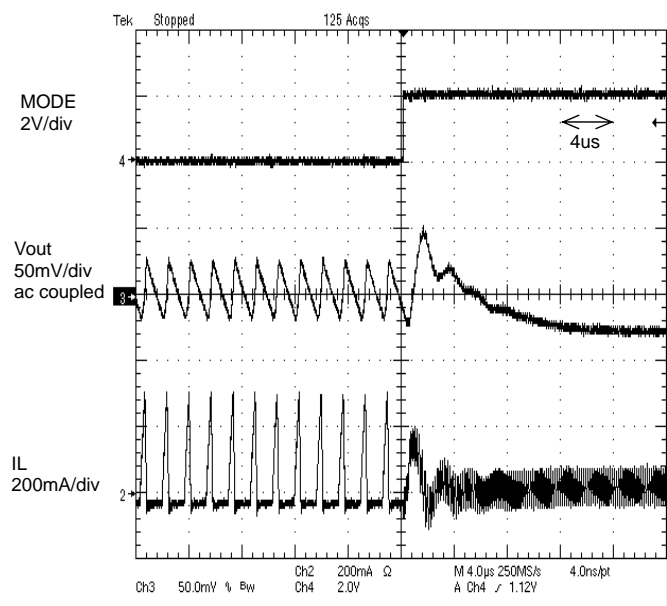


Figure 47. Mode Change Response  
MODE : Low to High

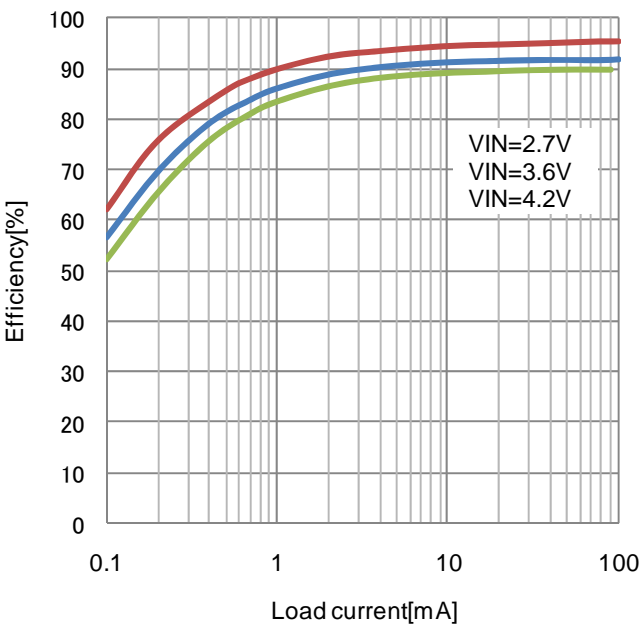


Figure 48. Efficiency vs Load current  
PFM mode

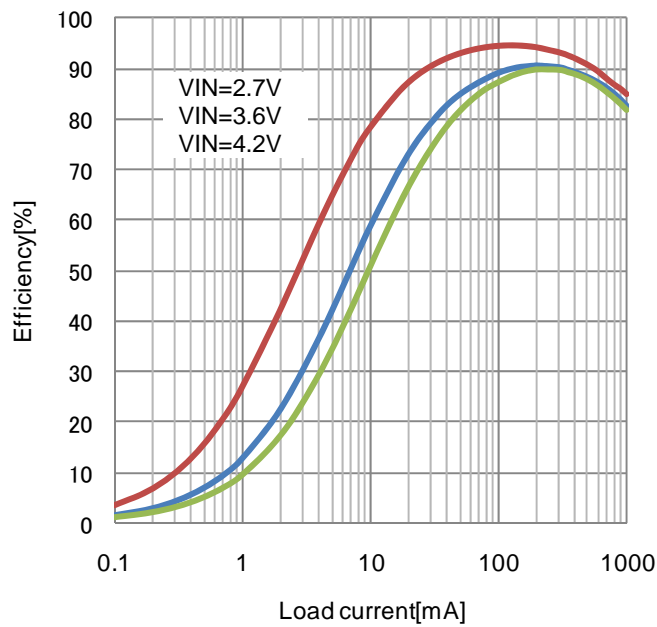


Figure 49. Efficiency vs Load current  
PWM mode



●Electrical characteristic curves (Reference data)  
BU90008GWZ (1.000V OUTPUT)

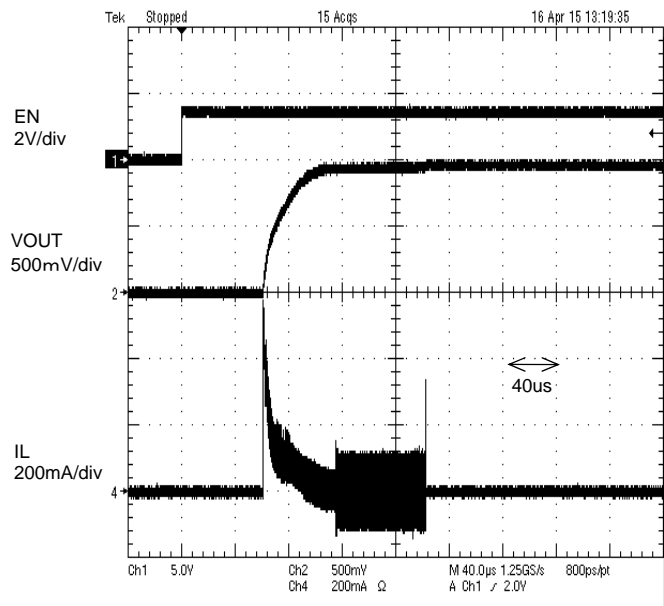


Figure 50. Start up

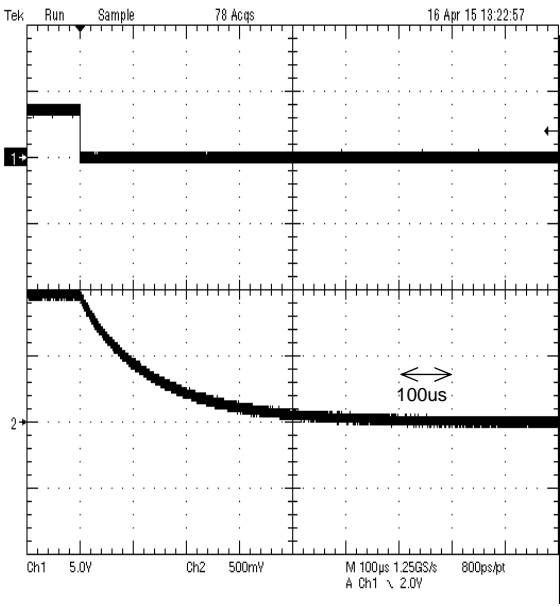


Figure 51. Shut down

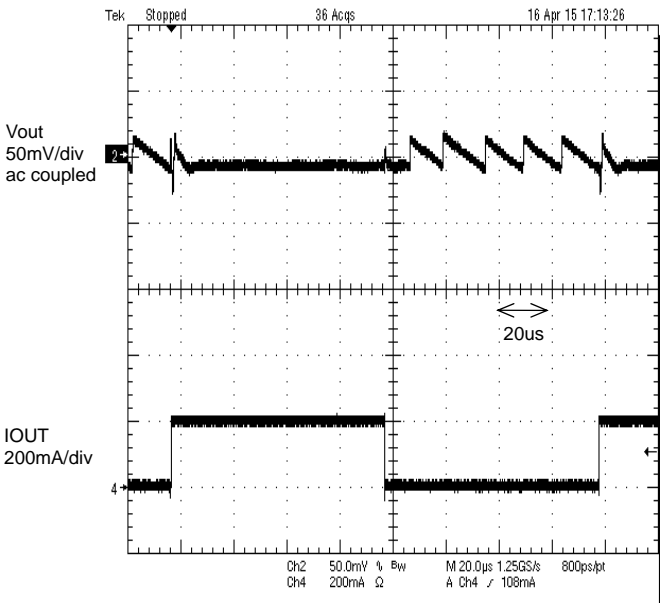


Figure 52. Load transient response 5mA to 100mA  
 $tr=tf=100ns$ , MODE : Low

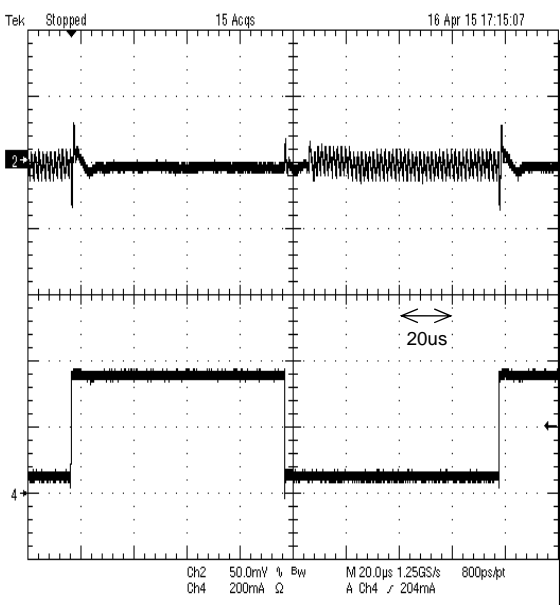


Figure 53. Load transient response 50mA to 350mA  
 $tr=tf=100ns$ , MODE : High

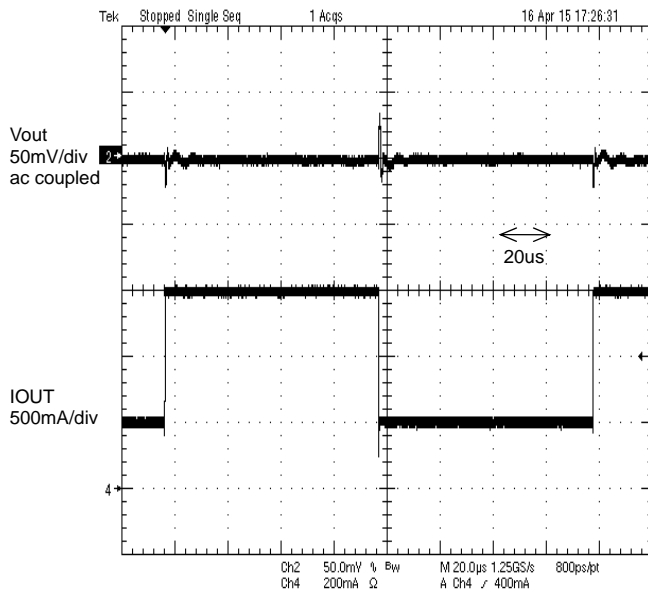


Figure 54. Load transient response 200mA to 600mA  
 $t_r=t_f=100\text{ns}$ , MODE : High

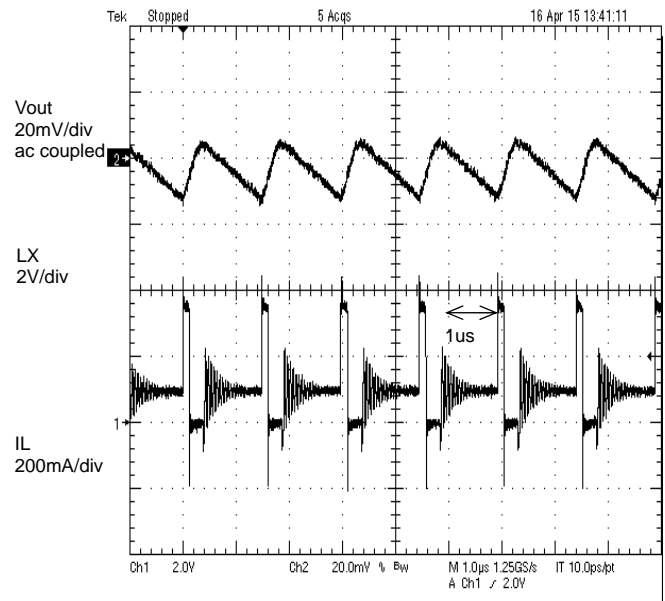


Figure 55. PFM mode Operation  $I_{out}=50\text{mA}$

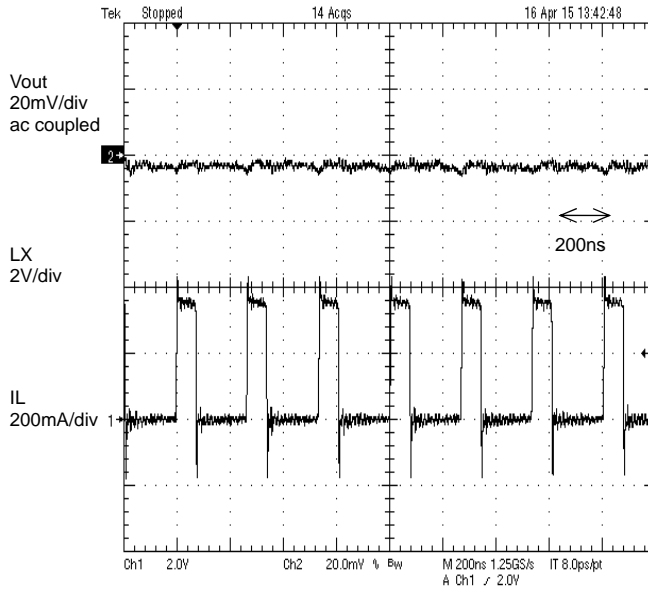


Figure 56. PWM mode Operation  $I_{out}=100\text{mA}$

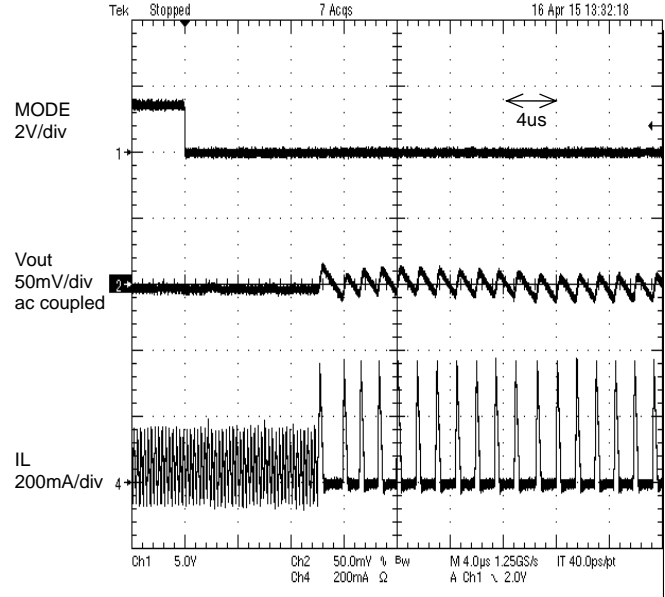


Figure 57. Mode Change Response  
 MODE : High to Low

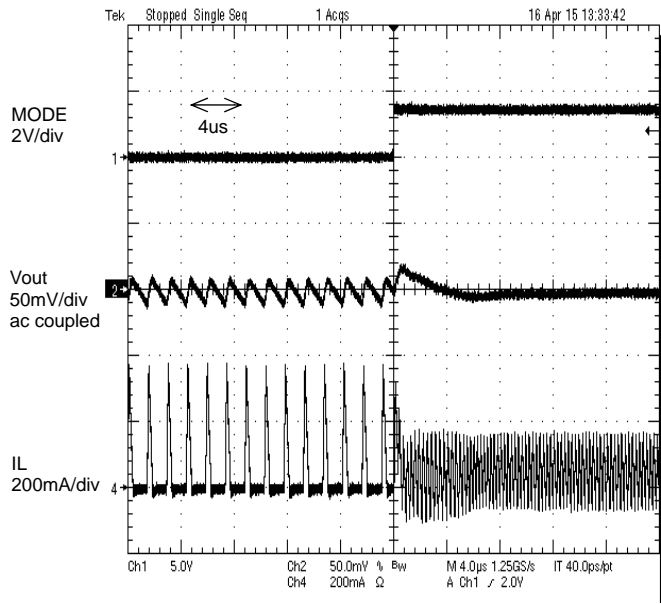


Figure 58. Mode Change Response  
MODE : Low to High

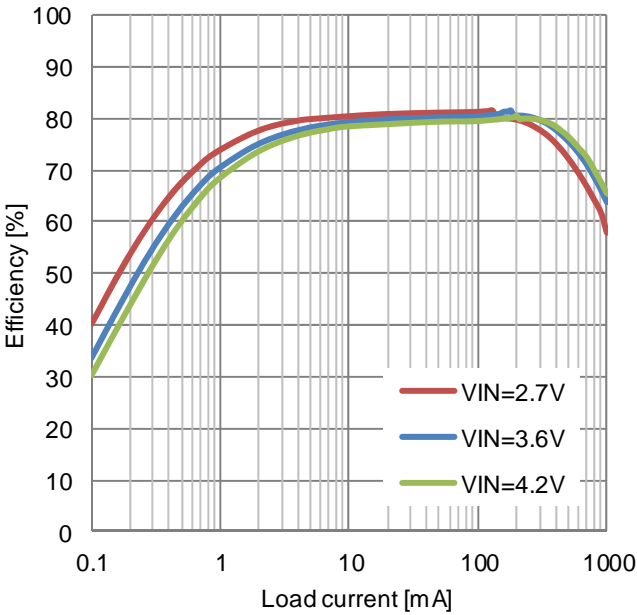


Figure 59. Efficiency vs Load current  
PFM mode

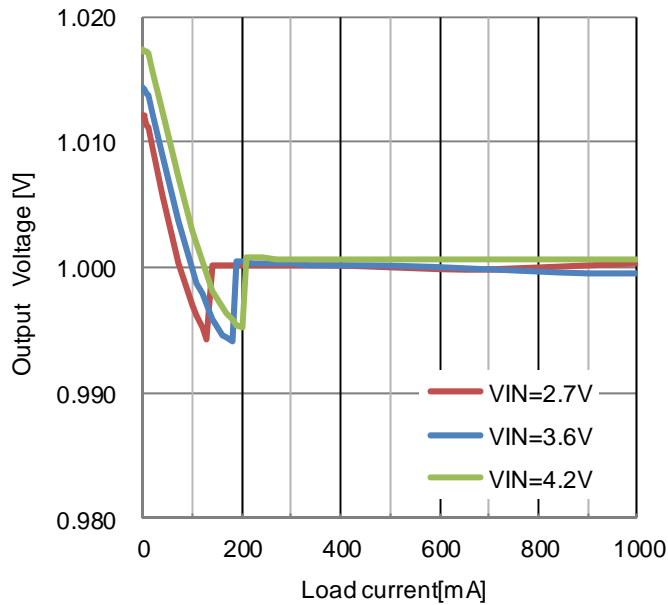


Figure 60. Efficiency vs Load current  
PWM mode

●Electrical characteristic curves (Reference data)  
BU90009GWZ (1.300V OUTPUT)

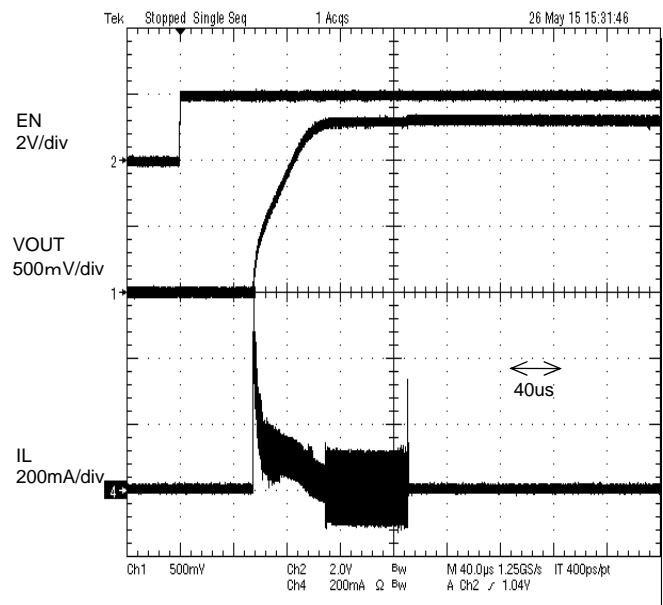


Figure 61. Start up

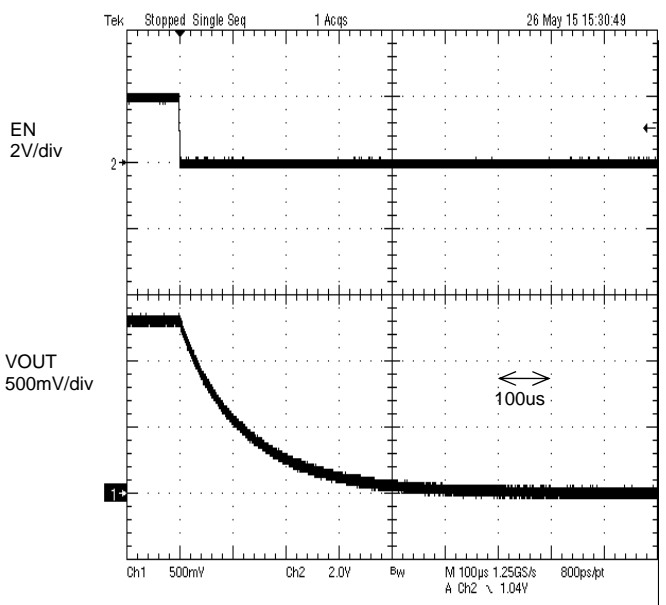


Figure 62. Shut down

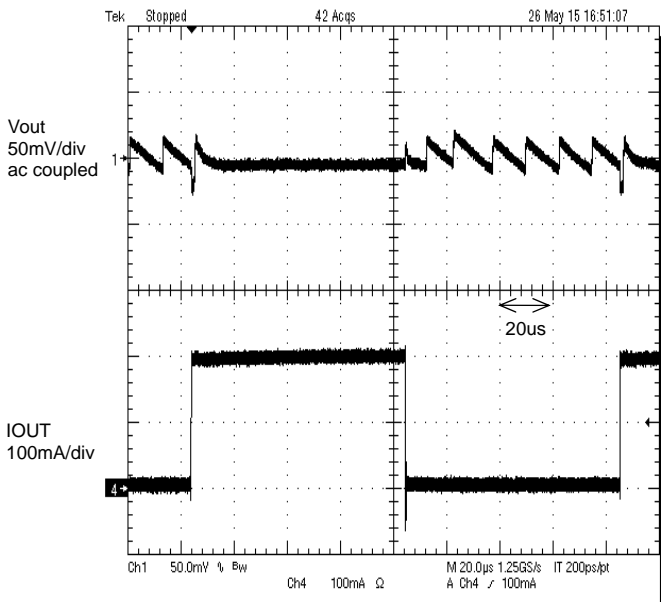


Figure 63. Load transient response 5mA to 50mA  
 $t_r=t_f=100\text{ns}$ , MODE : Low

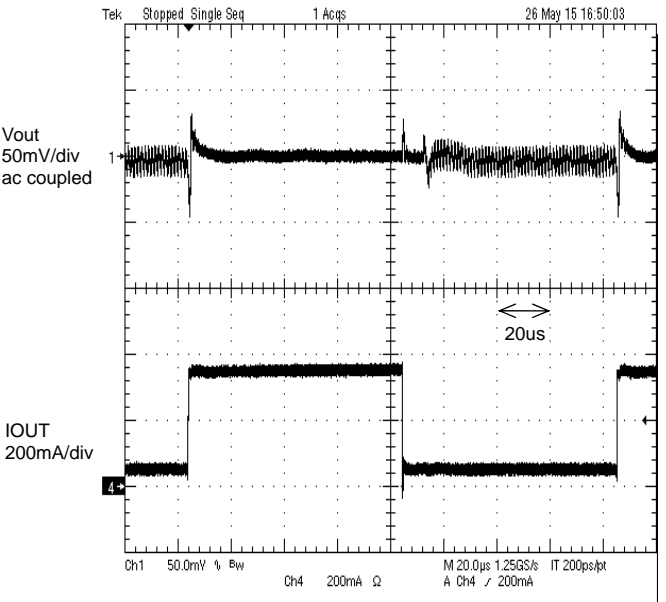


Figure 64. Load transient response 50mA to 350mA  
 $t_r=t_f=100\text{ns}$ , MODE : Low

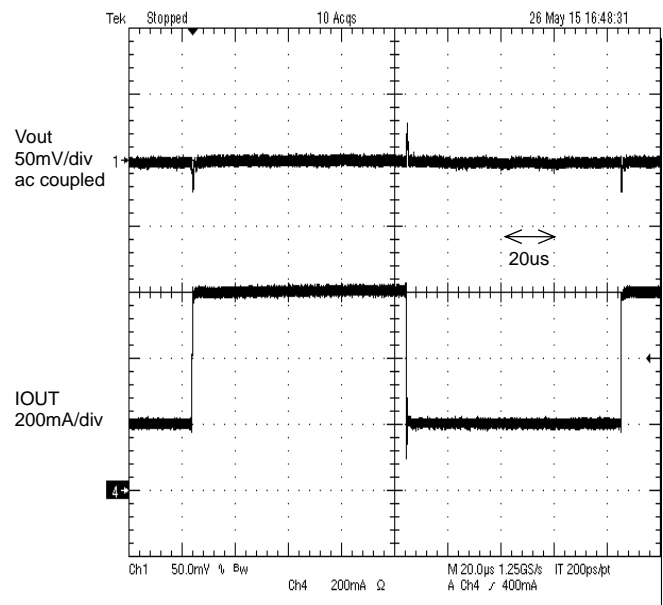


Figure 65. Load transient response 150mA to 500mA  
 $t_r=t_f=100\text{ns}$ , MODE : High

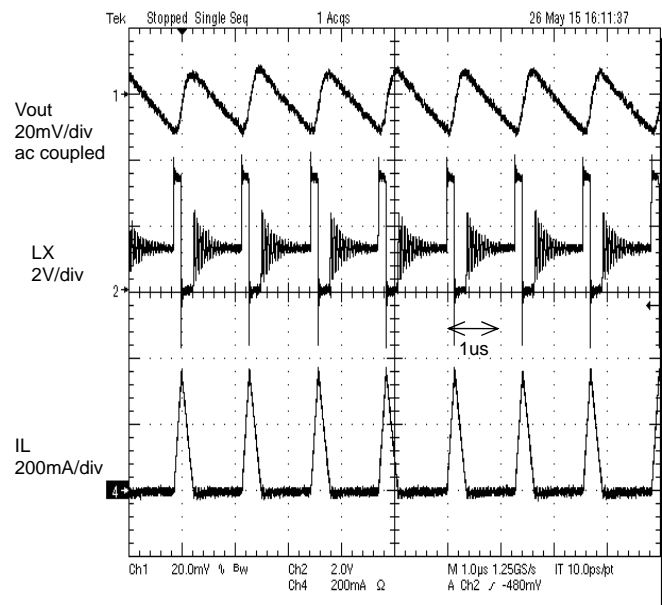


Figure 66. PFM mode Operation  
 $I_{out}=50\text{mA}$

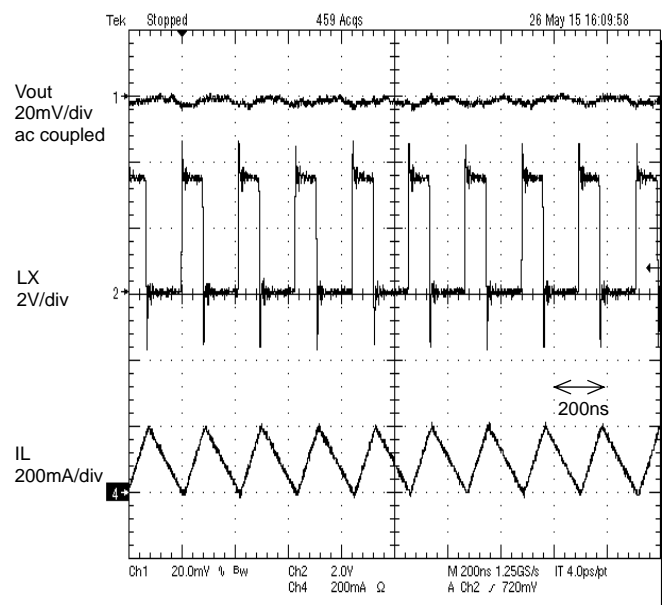


Figure 67. PWM mode Operation  $I_{out}=100\text{mA}$

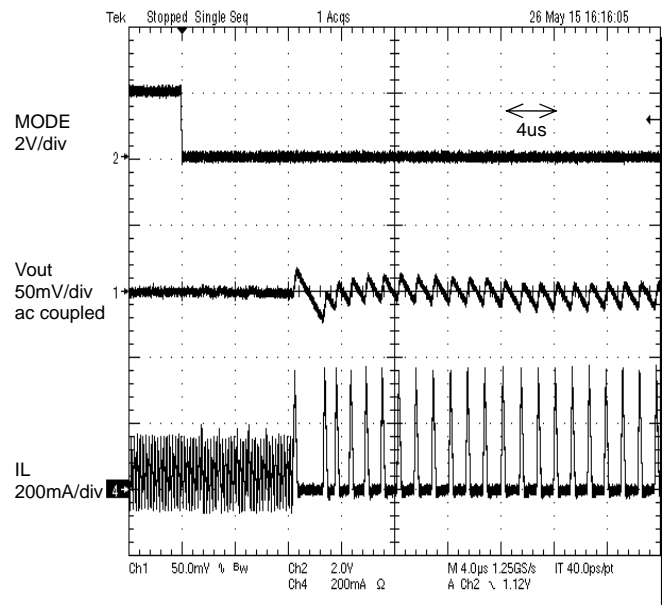


Figure 68. Mode Change Response  
MODE : High to Low

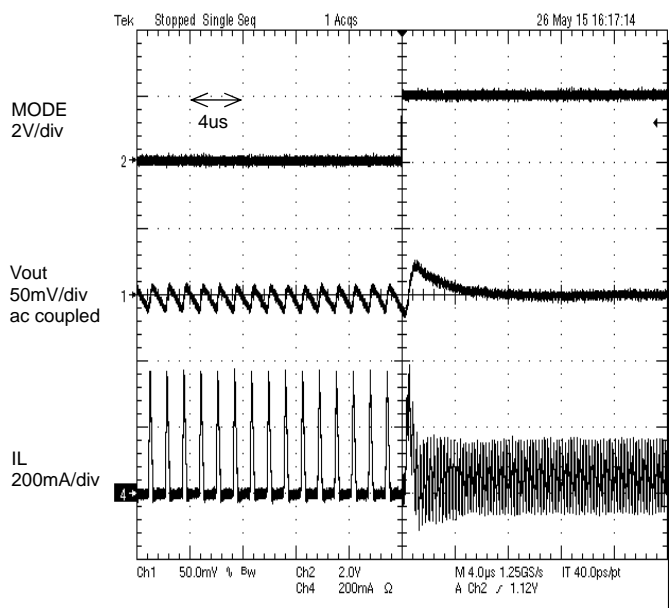


Figure 69. Mode Change Response  
MODE : Low to High

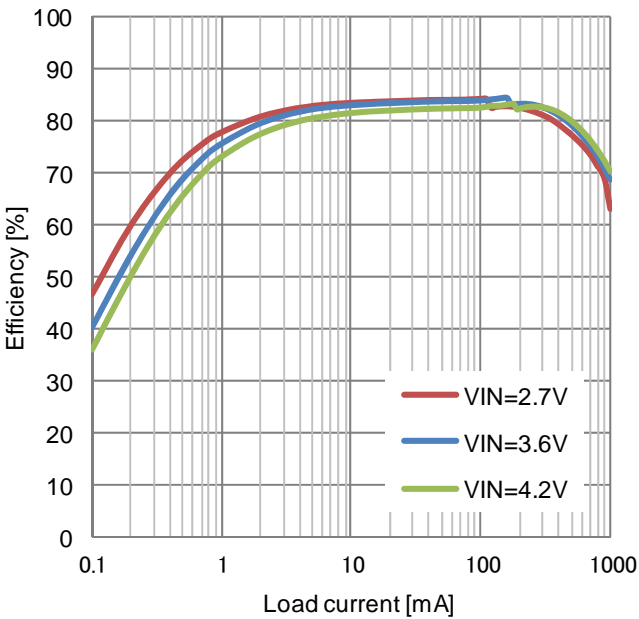


Figure 70. Efficiency vs Load current  
PWM/PFM Auto mode

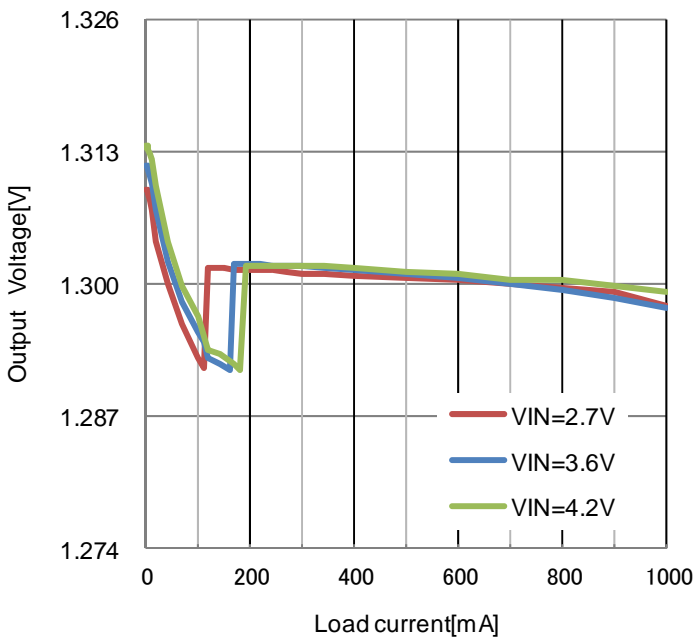


Figure 71. Load regulation  
PWM/PFM Auto mode

### ●PC Board layout

The suggested PCB layout for the BU9000xGWZ are shown in Figure. The following guidelines should be used to ensure a proper layout.

- 1) The input capacitor CIN should be connect as closely possible to VIN pin and GND pin.
- 2) From the output voltage to the FB pin line should be as separate as possible.
- 3) COUT and L should be connected as closely as possible. The connection of L to the LX pin should be as short as possible.

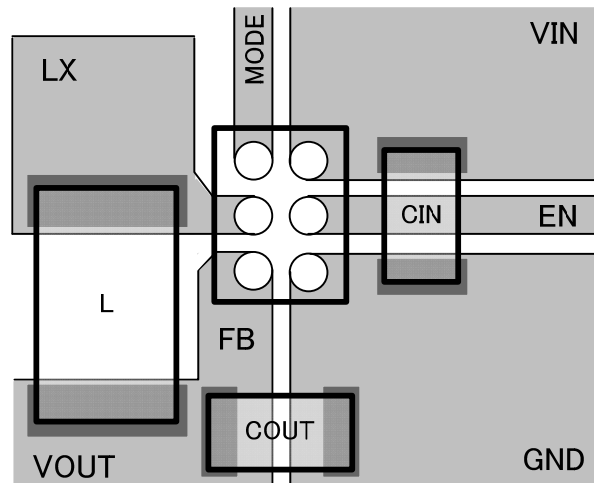


Figure 72. PCB layout

### ●External parts selection

#### Inductor selection

The inductance significantly depends on output ripple current. As shown by following equation, the ripple current decreases as the inductor and/or switching frequency increase.

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

f: switching frequency    L: inductance     $\Delta I_L$ : inductor current ripple

As a minimum requirement, the DC current rating of the inductor should be equal to the maximum load current plus half of the inductor current ripple as shown by the following equation.

$$I_{LPEAK} = I_{OUTMAX} + \frac{\Delta I_L}{2}$$

## 1 ) Recommended inductor selection

•  $I_{out} \leq 1A$ 

LQM2MPN1R0NG0 (2.0mm×1.6mm×1.0mm Murata)

MIPSZ2016D1R0FH (2.0mm×1.6mm×1.0mm FDK)

DFE252012C1R0 (2.5mm×2.0mm×1.2mm TOKO)

•  $I_{out} \leq 0.6A$ 

LQM21PN1R0NGC (2.0mm×1.2mm×1.0mm Murata)

MIPSZ2012D1R0 (2.0mm×1.2mm×1.0mm FDK)

MIPSTZ1608D1R0 (1.6mm × 0.8mm × 0.8mm FDK)

MLP2012H1R0M (2.0mm×1.2mm×1.0mm TDK)

CKP2012N1R0N (2.0mm×1.2mm×1.0mm Taiyo Yuden)

## 2 ) Recommended input capacitor(CIN) selection

GRM155R60J225M(1.0mm × 0.5mm × 0.5mm Murata)

GRM155R60J475M(1.0mm × 0.5mm × 0.5mm Murata)

GRM155R60G106M(1.0mm × 0.5mm × 0.5mm Murata)

## 3 ) Recommended output capacitor(COUT) selection

GRM155R60J475M(1.0mm × 0.5mm × 0.5mm Murata)

GRM155R60G106M(1.0mm × 0.5mm × 0.5mm Murata)

## ○Cautions on the output capacitor selection

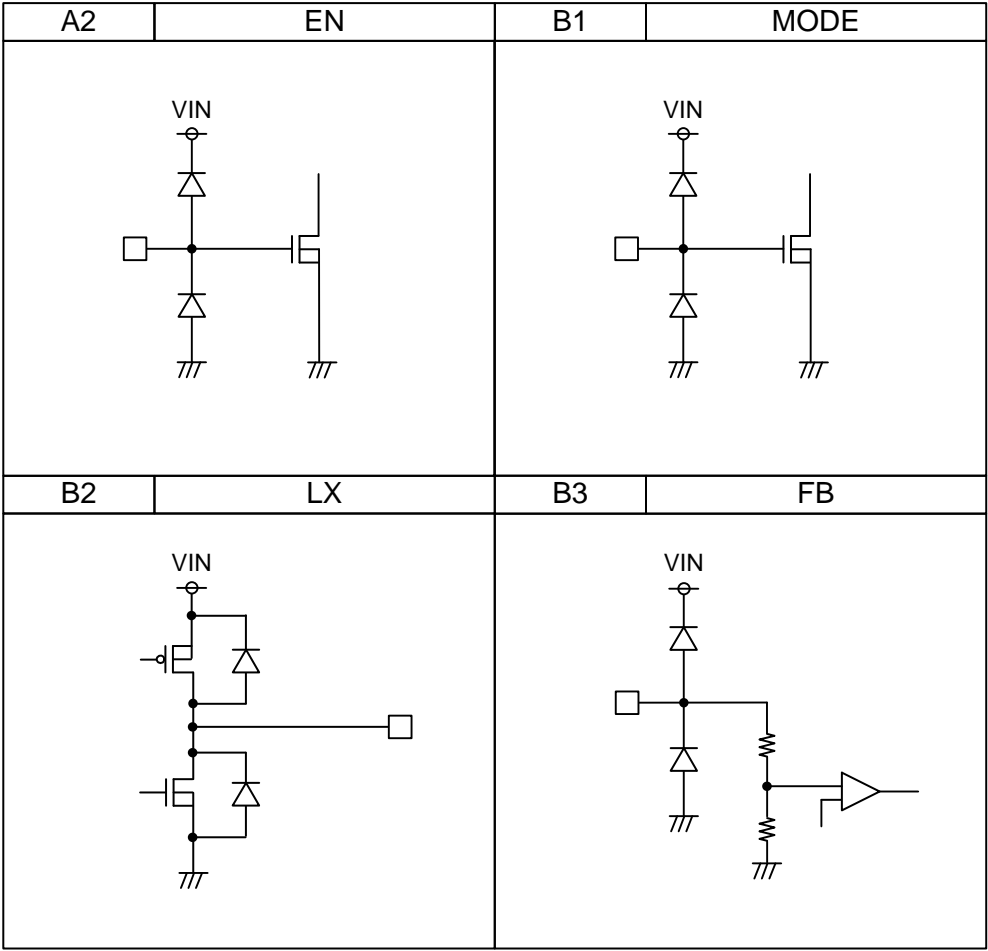
The BU9000xGWZ is designed to fixed soft-start time and operate with a maximum output capacitance of 10uF.

If the capacitance connected to the output is larger than 10uF, an overshoot of the output voltage will be caused.

It is possible to cause damage on the connected device.



●I/O equivalence circuit(s)



**●Caution of use**

## 1) Absolute maximum ratings

An excess in the absolute maximum rating, 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) GND voltage

The potential of GND pin must be minimum potential in all condition. As an exception, the circuit design allows voltages up to -0.3 V to be applied to the IC pin.

## 3) Thermal design

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

## 4) 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.

## 5) 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.

## 6) Mutual impedance

Power supply and ground wiring should reflect consideration of the need to lower mutual impedance and minimize ripple as much as possible (by making wiring as short and thick as possible or rejecting ripple by incorporating inductance and capacitance).

## 7) Thermal shutdown Circuit (TSD Circuit)

This model IC has a built-in TSD circuit. This circuit is only to cut off the IC from thermal runaway, and has not been design to protect or guarantee the IC. Therefore, the user should not plan to activate this circuit with continued operation in mind.

## 8) 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, as shown in the figures below, 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.

## 9) Disturbance light

In a device where a portion of silicon is exposed to light such as in a WL-CSP, IC characteristics may be affected due to photoelectric effect. For this reason, it is recommended to come up with countermeasures that will prevent the chip from being exposed to light.

## Status of this document

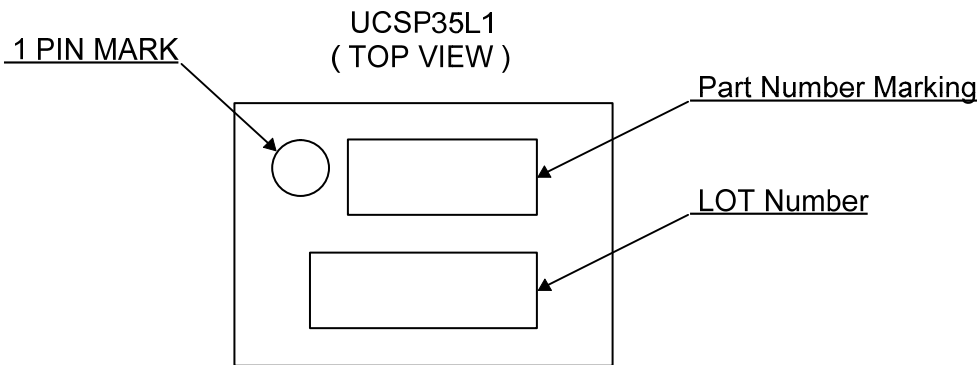
The Japanese version of this document is formal specification. A customer may use this translation version only for a reference to help reading the formal version.

If there are any differences in translation version of this document formal version takes priority

●Ordering Information

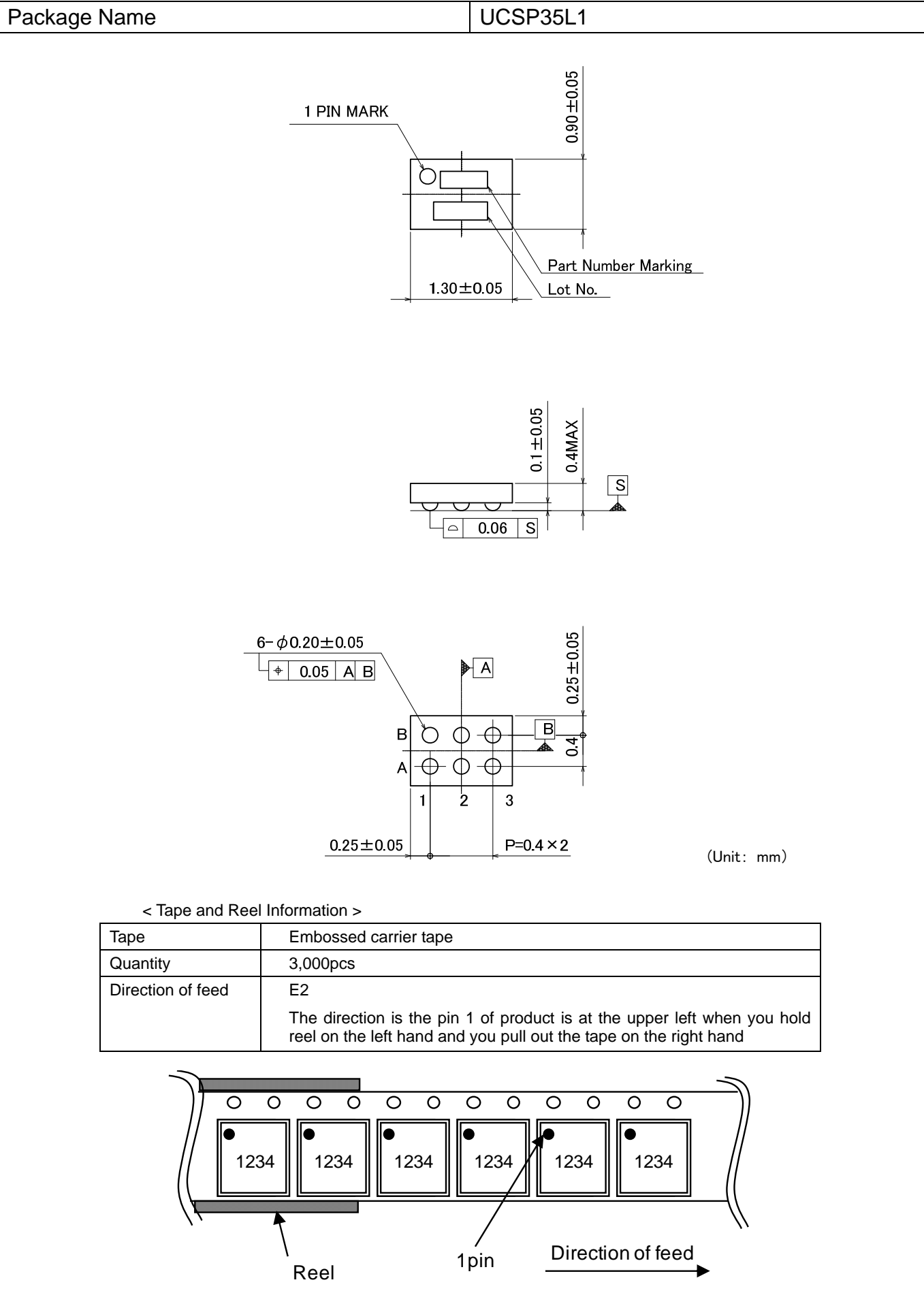


●Marking Diagram(s)(TOP VIEW)



Series	Part Number Marking
BU90002GWZ	AB4
BU90003GWZ	AB6
BU90004GWZ	AB7
BU90005GWZ	AB8
BU90006GWZ	AB9
BU90007GWZ	ACM
BU90008GWZ	ADW
BU90009GWZ	ADV

●Physical Dimension, Tape and Reel Information



## ●Revision History

Date	Revision	Changes
04.Jul.2012	001	New Release
16.Oct.2013	002	Page18 1 ) Recommended inductor selection MIPSZ2016D1R0FH, MIPSZ2012D1R0 added.
28.Oct.2013	003	Page4 Electrical Characteristic(s) Operating quiescent current IQ1(BU90003GWZ PWM operation), IQ2(BU90004GWZ PWM operation) added.
29.May.2014	004	Page19 I/O equivalence circuit added. Page20⇒Page22 Physical Dimension, Tape and Reel Information
8.Dec.2014	005	Page20 Caution of use 9) Disturbance light added.
15.May.2015	006	BU90008GWZ added.  Page 2 Figure 3. Block Diagram(s) Range of the output capacitor capacity added. Page21 Cautions on the output capacitor selection added.
7.Jul.2015	007	BU90009GWZ added.  Page 4 Output discharge resistance Correction of errors

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JAPAN	USA	EU	CHINA
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CLASS IV		CLASS III	

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  - Use of our Products in places where the Products are exposed to static electricity or electromagnetic waves
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  - Use of the Products in places subject to dew condensation
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- 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.
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- 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.

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- When a highly active halogenous (chlorine, bromine, etc.) flux is used, the residue of flux may negatively affect product performance and reliability.
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  - [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
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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.
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### Офис по работе с юридическими лицами:

105318, г.Москва, ул.Щербаковская д.3, офис 1107, 1118, ДЦ «Щербаковский»

Телефон: +7 495 668-12-70 (многоканальный)

Факс: +7 495 668-12-70 (доб.304)

E-mail: [info@moschip.ru](mailto:info@moschip.ru)

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