SUPER-SMALL PACKAGE PWM CONTROL, PWM/PFM SWITCHING CONTROL STEP-UP SWITCHING REGULATOR

S-8355/56/57/58 Series

The S-8355/56/57/58 Series is a CMOS step-up switching regulator which mainly consists of a reference voltage source, an oscillation circuit, an error amplifier, a phase compensation circuit, a PWM control circuit (S-8355/57) and a PWM/PFM switching control circuit (S-8356/58). With an external low-on-resistance Nch Power MOS, this product is ideal for applications requiring high efficiency and a high output current.

The S-8355/57 Series realizes low ripple, high efficiency, and excellent transient characteristics due to a PWM control circuit whose duty ratio can be varied from 0% to 83% (from 0% to 78% for 250 kHz, 300 kHz, and 600 kHz models), an excellently designed error amplifier and a phase compensation circuit.

S-8356/58 Series operation can be switched under a light load to a PFM control circuit with a duty ratio of 15% via a PWM/PFM switching control circuit to prevent a decline in the efficiency due to the IC operating current.

■ Features

- Low voltage operation: Startup is guaranteed from 0.9 V (I_{OUT} = 1 mA)
- Low current consumption: During operation: 25.9 μA (3.3 V, 100 kHz, typ.)
  During shutdown: 0.5 μA (max.)
- Duty ratio: Built-in PWM/PFM switching control circuit (S-8356/58)
  15 to 83% (100 kHz models), 15 to 78% (250 kHz, 300 kHz, and 600 kHz models)
- External parts: Coil, diode, capacitor, and transistor
- Output voltage: Can be set between 1.5 and 6.5 V (for V_{DD}/V_{OUT} separate types) or 2.0 and 6.5 V (for other than V_{DD}/V_{OUT} separate types) in 0.1 V steps. Accuracy of ±2.4%.
- Oscillation frequency: 100 kHz, 250 kHz, 300 kHz, 600 kHz
- Soft start function: 6 ms (100 kHz, typ.)
- Shutdown function

■ Packages

- SOT-89-3 (Package code: UP003-A)
- SOT-23-3 (Package code: MP003-A)
- SOT-23-5 (Package code: MP005-A)
- 6-Pin SNB(B) (Package code: BD006-A)

■ Applications

- Power supplies for portable equipment such as digital cameras, electronic notebooks, and PDAs
- Power supplies for audio equipment such as portable CD/MD players
- Constant voltage power supplies for cameras, video equipment, and communications equipment
- Power supplies for microprocessors

■ Block Diagram

(1) S-8357/58 Series B, H, F Type
(Without shutdown function)

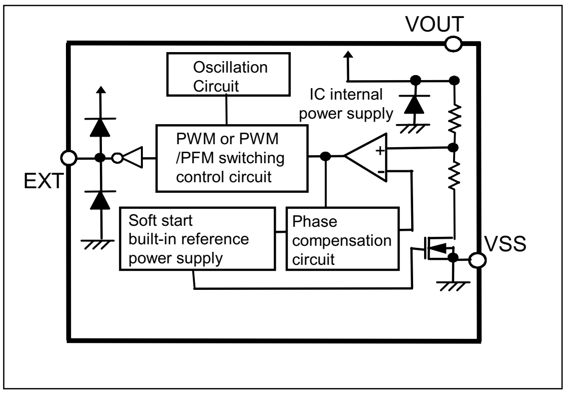


Figure 1

(2) S-8357/58 Series B, H, F, N Type (With shutdown function)

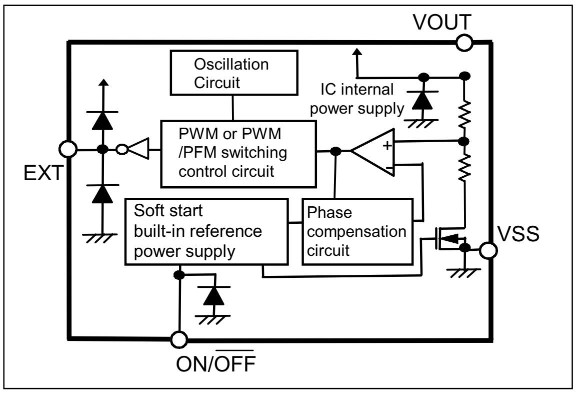


Figure 2

(3) S-8357/58 Series E, J, G, P Type
(V_{DD}/V_{OUT} separate type)

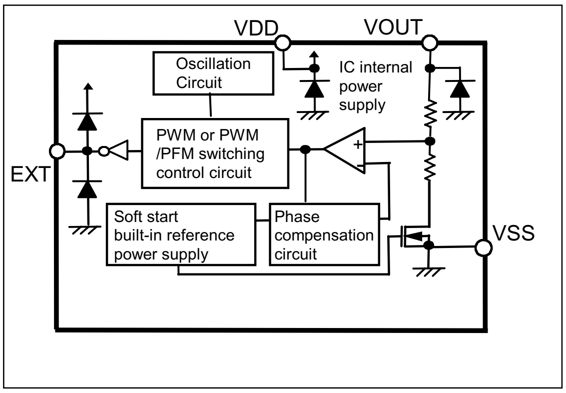


Figure 3

(4) S-8355/56 Series K, L, M, Q Type

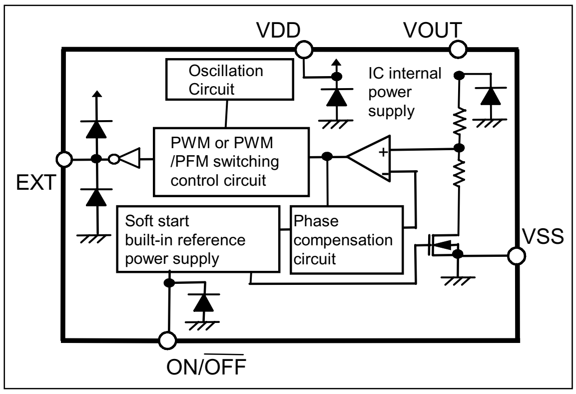


Figure 4

■ Selection Guide

- The control types, product types, output voltage, and packages for the S-8355/56/57/58 Series can be selected at the user's request. Please refer to the "Product name selection guide" for the definition of the product name and "Product Name List" for the full product names.

1. Function List

1-1. PWM control products

Table 1

Product Name	Switching Frequency (kHz)	Shutdown Function	V_{DD}/V_{OUT} Separate Type	Package	Application
S-8355KxxMC	100	Yes	Yes	SOT-23-5	Applications requiring variable output voltage and a shutdown function
S-8355LxxMC/BD	250	Yes	Yes	SOT-23-5/6-Pin SNB(B)	Applications requiring variable output voltage, a shutdown function, and a thin coil
S-8355MxxMC/BD	300	Yes	Yes	SOT-23-5/6 Pin-SNB(B)	Applications requiring variable output voltage, a shutdown function, and a thin coil
S-8355QxxMC/BD	600	Yes	Yes	SOT-23-5/6-Pin SNB(B)	Applications requiring variable output voltage, a shutdown function, and a thin coil
S-8357BxxMC	100	Yes	—	SOT-23-5	Applications requiring a shutdown function
S-8357BxxMA	100	—	—	SOT-23-3	Applications not requiring a shutdown function
S-8357BxxUA	100	—	—	SOT-89-3	Applications not requiring a shutdown function
S-8357ExxMC	100	—	Yes	SOT-23-5	Applications in which output voltage is adjusted by external resistor
S-8357FxxMC/BD	300	Yes	—	SOT-23-5/6-Pin SNB(B)	Applications requiring a shutdown function and a thin coil
S-8357GxxMC/BD	300	—	Yes	SOT-23-5/6-Pin SNB(B)	Applications requiring variable output voltage and a thin coil
S-8357HxxMC/BD	250	Yes	—	SOT-23-5/6-Pin SNB(B)	Applications requiring a shutdown function and a thin coil
S-8357JxxMC/BD	250	—	Yes	SOT-23-5/6-Pin SNB(B)	Applications requiring variable output voltage with an external resistor and a thin coil
S-8357NxxMC/BD	600	Yes	—	SOT-23-5/6-Pin SNB(B)	Applications requiring a shutdown function and a thin coil
S-8357PxxMC/BD	600	—	Yes	SOT-23-5/6-Pin SNB(B)	Applications requiring variable output voltage with an external resistor and a thin coil

1-2. PWM/PFM switching control products

Table 2

Product name	Switching Frequency (kHz)	Shutdown Function	V_{DD}/V_{OUT} Separate Type	Package	Application
S-8356KxxMC	100	Yes	Yes	SOT-23-5	Applications requiring variable output voltage and a shutdown function
S-8356LxxMC/BD	250	Yes	Yes	SOT-23-5/6-Pin SNB(B)	Applications requiring variable output voltage, a shutdown function, and a thin coil
S-8356MxxMC/BD	300	Yes	Yes	SOT-23-5/6-Pin SNB(B)	Applications requiring variable output voltage, a shutdown function, and a thin coil
S-8356QxxMC/BD	600	Yes	Yes	SOT-23-5/6-Pin SNB(B)	Applications requiring variable output voltage, a shutdown function, and a thin coil
S-8358BxxMC	100	Yes	—	SOT-23-5	Applications requiring a shutdown function
S-8358BxxMA	100	—	—	SOT-23-3	Applications not requiring a shutdown function
S-8358BxxUA	100	—	—	SOT-89-3	Applications not requiring a shutdown function
S-8358ExxMC	100	—	Yes	SOT-23-5	Applications in which output voltage is adjusted by external resistor
S-8358FxxMC/BD	300	Yes	—	SOT-23-5/6-Pin SNB(B)	Applications requiring a shutdown function and a thin coil
S-8358GxxMC/BD	300	—	Yes	SOT-23-5/6-Pin SNB(B)	Applications requiring variable output voltage and a thin coil
S-8358HxxMC/BD	250	Yes	—	SOT-23-5/6-Pin SNB(B)	Applications requiring a shutdown function and a thin coil
S-8358JxxMC/BD	250	—	Yes	SOT-23-5/6-Pin SNB(B)	Applications requiring variable output voltage with an external resistor and a thin coil
S-8358NxxMC/BD	600	Yes	—	SOT-23-5/6-Pin SNB(B)	Applications requiring a shutdown function and a thin coil
S-8358PxxMC/BD	600	—	Yes	SOT-23-5/6-Pin SNB(B)	Applications requiring variable output voltage with an external resistor and a thin coil

2. Package and Function List by Product Type

Table 3

Series Name	Type	Package Name (Abbreviation)	Shutdown Function Yes/No	V_{DD}/V_{OUT} Separate Type Yes/No
S-8355 Series S-8356 Series	K, L, M, Q (Shutdown function + V_{DD}/V_{OUT} separate type) K = 100 kHz, L = 250 kHz, M = 300 kHz, Q = 600 kHz	MC/BD	Yes	Yes
S-8357 Series	B, H, F (Normal product) B = 100 kHz, H = 250 kHz, F = 300 kHz	MA/UA	No	No
		MC/BD	Yes	
	N (Normal product) N = 600 kHz	MC/BD	Yes	No
	E, J, G, P (V_{DD}/V_{OUT} separate type) E = 100 kHz, J = 250 kHz, G = 300 kHz, P = 600 kHz	MC/BD	No	Yes
S-8358 Series	B, H, F (Normal product) B = 100 kHz, H = 250 kHz, F = 300 kHz	MA/UA	No	No
		MC/BD	Yes	
	N (Normal product) N = 600 kHz	MC/BD	Yes	No
	E, J, G, P (V_{DD}/V_{OUT} separate type) E = 100 kHz, J = 250 kHz, G = 300 kHz, P = 600 kHz	MC/BD	No	Yes

3. Product Name

S-835 x x xx xx - xxx - Tx

- IC direction in tape specifications*1
  - T2: SOT-89-3, SOT-23-3, SOT-23-5
  - TF: 6-Pin SNB(B)
- Product name (abbreviation)*2
- Package name (abbreviation)
  - UA: SOT-89-3
  - MA: SOT-23-3
  - MC: SOT-23-5
  - BD: 6-Pin-SNB(B)
- Output voltage 15 to 65 (Ex. When the output voltage is 1.5 V, it is expressed as 15.)
- Product type
  - B: Normal product, f_{OSC} = 100 kHz (S-8357/58)
  - H: Normal product, f_{OSC} = 250 kHz (S-8357/58)
  - F: Normal product, f_{OSC} = 300 kHz (S-8357/58)
  - N: Normal product, f_{OSC} = 600 kHz (S-8357/58)
  - E: V_{DD}/V_{OUT} separate type, f_{OSC} = 100 kHz (S-8357/58)
  - J: V_{DD}/V_{OUT} separate type, f_{OSC} = 250 kHz (S-8357/58)
  - G: V_{DD}/V_{OUT} separate type, f_{OSC} = 300 kHz (S-8357/58)
  - P: V_{DD}/V_{OUT} separate type, f_{OSC} = 600 kHz (S-8357/58)
  - K: Shutdown function + V_{DD}/V_{OUT} separate type, f_{OSC} = 100 kHz (S-8355/56)
  - L: Shutdown function + V_{DD}/V_{OUT} separate type, f_{OSC} = 250 kHz (S-8355/56)
  - M: Shutdown function + V_{DD}/V_{OUT} separate type, f_{OSC} = 300 kHz (S-8355/56)
  - Q: Shutdown function + V_{DD}/V_{OUT} separate type, f_{OSC} = 600 kHz (S-8355/56)
- Control system
  - 5 or 7: PWM control
  - 6 or 8: PWM/PFM switching control

***1.** Please refer to the taping specifications at the end of this document.
***2.** Please refer to the product name list.

4. Product Name List

4-1. S-8355 Series

Table 4

Output Voltage \ Model	S-8355KxxMC Series	S-8355LxxMC Series	S-8355MxxMC Series	S-8355MxxBD Series	S-8355QxxBD Series
1.5 V	—	—	—	—	S-8355Q15BD-OWA-TF
1.8 V	S-8355K18MC-NAD-T2	—	S-8355M18MC-MCD-T2	S-8355M18BD-MCD-TF	—
2.0 V	S-8355K20MC-NAF-T2	S-8355L20MC-NCF-T2	S-8355M20MC-MCF-T2	—	—
3.1 V	S-8355K31MC-NAQ-T2	—	S-8355M31MC-MCQ-T2	—	—
3.3 V	S-8355K33MC-NAS-T2	—	—	—	—
3.4 V	—	—	S-8355M34MC-MCT-T2	—	—
5.0 V	—	—	S-8355M50MC-MDJ-T2	—	—

Remark Please consult our sales person for products with an output voltage other than those specified above.

4-2. S-8356 Series

Table 5

Output Voltage \ Model	S-8356KxxMC Series	S-8356MxxMC Series	S-8355MxxBD Series	S-8356QxxMC Series
1.8 V	S-8356K18MC-NED-T2	S-8356M18MC-MED-T2	S-8356M18BD-MED-TF	—
3.0 V	—	S-8356M30MC-MEP-T2	—	—
3.3 V	S-8356K33MC-NES-T2	—	—	S-8356Q33MC-OYS-T2
5.0 V	S-8356K50MC-NFJ-T2	S-8356M50MC-MFJ-T2	—	S-8356Q50MC-OVJ-T2

Remark Please consult our sales person for products with an output voltage other than those specified above.

4-3. S-8357 Series (1)

Table 6

Output Voltage \ Model	S-8357BxxMC Series	S-8357BxxMA Series	S-8357BxxUA Series	S-8357ExxMC Series	S-8357FxxMC Series
2.0 V	—	—	—	S-8357E20MC-NKF-T2	—
2.5 V	—	—	—	—	—
2.6 V	S-8357B26MC-NIL-T2	—	—	—	—
3.0 V	S-8357B30MC-NIP-T2	S-8357B30MA-NIP-T2	—	—	—
3.1 V	—	—	—	—	—
3.2 V	—	—	—	—	S-8357F32MC-MGR-T2
3.3 V	S-8357B33MC-NIS-T2	S-8357B33MA-NIS-T2	S-8357B33UA-NIS-T2	—	S-8357F33MC-MGS-T2
3.5 V	—	—	—	—	—
3.6 V	S-8357B36MC-NIV-T2	—	—	—	—
4.8 V	S-8357B48MC-NJH-T2	—	S-8357B48UA-NJH-T2	—	—
5.0 V	S-8357B50MC-NJJ-T2	S-8357B50MA-NJJ-T2	S-8357B50UA-NJJ-T2	S-8357E50MC-NLJ-T2	S-8357F50MC-MHJ-T2
5.2 V	S-8357B52MC-NJL-T2	—	—	—	—
5.4 V	S-8357B54MC-NJN-T2	—	—	—	—
6.0 V	S-8357B60MC-NJT-T2	—	—	—	—

Remark Please consult our sales person for products with an output voltage other than those specified above.

4-4. S-8357 Series (2)

Table 7

Model / Output Voltage	S-8357GxxMC Series	S-8357HxxMC Series	S-8357JxxMC Series	S-8357NxxMC Series
2.0 V	—	—	—	—
2.5 V	—	—	S-8357J25MC-NOK-T2	—
2.6 V	—	—	—	—
3.0 V	—	—	—	—
3.1 V	—	S-8357H31MC-NMQ-T2	—	—
3.2 V	—	—	—	—
3.3 V	—	—	—	S-8357N33MC-O2S-T2
3.5 V	—	S-8357H35MC-NMU-T2	—	—
3.6 V	—	S-8357H36MC-NMV-T2	—	—
4.8 V	—	—	—	—
5.0 V	S-8357G50MC-MJJ-T2	—	S-8357J50MC-NPJ-T2	S-8357N50MC-O3J-T2
5.2 V	—	—	—	—
5.4 V	—	—	—	—
6.0 V	—	—	—	—

Remark Please consult our sales person for products with an output voltage other than those specified above.

4-5. S-8358 Series (1)

Table 8

Model / Output Voltage	S-8358BxxMC Series	S-8358BxxMA Series	S-8358BxxUA Series	S-8358ExxMC Series	S-8358FxxMC Series
2.0 V	—	—	—	S-8358E20MC-NSF-T2	—
2.5 V	S-8358B25MC-NQK-T2	—	—	—	—
2.6 V	S-8358B26MC-NQL-T2	—	—	—	—
3.0 V	S-8358B30MC-NQP-T2	—	—	—	—
3.1 V	S-8358B31MC-NQQ-T2	—	—	—	—
3.2 V	S-8357B32MC-NQR-T2	—	—	—	—
3.3 V	S-8358B33MC-NQS-T2	—	S-8358B33UA-NQS-T2	—	S-8358F33MC-MKS-T2
3.5 V	S-8358B35MC-NQU-T2	—	—	—	—
3.6 V	S-8358B36MC-NQV-T2	—	—	—	—
3.8 V	S-8358B38MC-NQX-T2	—	—	—	—
5.0 V	S-8358B50MC-NRJ-T2	S-8358B50MA-NRJ-T2	S-8358B50UA-NRJ-T2	S-8358E50MC-NTJ-T2	S-8358F50MC-MLJ-T2
5.3 V	—	—	—	—	S-8358F53MC-MLM-T2
6.0 V	S-8358B60MC-NRT-T2	—	—	—	—

Remark Please consult our sales person for products with an output voltage other than those specified above.

4-6. S-8358 Series (2)

Table 9

Model / Output Voltage	S-8357GxxMC Series	S-8357HxxMC Series	S-8358JxxMC Series
2.0 V	—	—	—
2.5 V	—	—	—
2.6 V	—	—	—
3.0 V	—	—	—
3.1 V	—	—	—
3.2 V	—	—	—
3.3 V	—	S-8358H33MC-NUS-T2	S-8358J33MC-NWS-T2
3.5 V	—	—	—
3.6 V	—	—	—
3.8 V	—	—	—
5.0 V	S-8358G50MC-MNJ-T2	S-8358H50MC-NVJ-T2	S-8358J50MC-NXJ-T2
5.3 V	—	—	—
6.0 V	—	—	—

Remark Please consult our sales person for products with an output voltage other than those specified above.

■ Pin Assignment

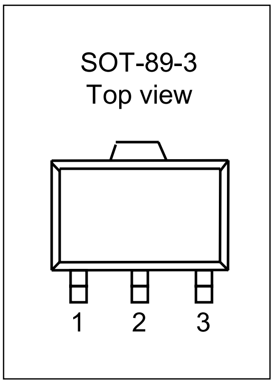


Figure 5

Table 10

Products: S-8357/58 Series B, H, F Types
(Without shutdown function, V_{DD}/V_{OUT} non-separate type)

Pin No.	Pin Name	Functions
1	VSS	GND pin
2	VOUT	Output voltage pin and IC power supply pin
3	EXT	External transistor connection pin

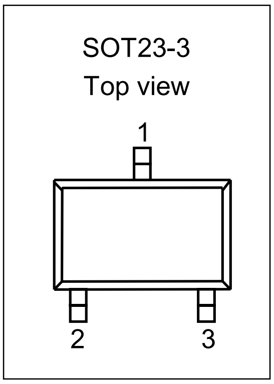


Figure 6

Table 11

Products: S-8357/58 Series B, H, F Types
(Without shutdown function, V_{DD}/V_{OUT} non-separate type)

Pin No.	Pin Name	Functions
1	VOUT	Output voltage pin and IC power supply pin
2	VSS	GND pin
3	EXT	External transistor connection pin

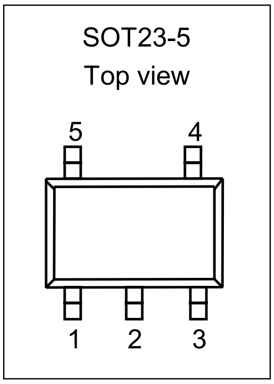


Figure 7

Table 12

Products: S-8355/56 Series K, L, M, Q Types
(With shutdown function, V_{DD}/V_{OUT} separate type)

Pin No.	Pin Name	Functions
1	VOUT	Output voltage pin
2	VDD	IC power supply pin
3	ON/$\overline{\text{OFF}}$	Shutdown pin “H”: Normal operation (Step-up operation) “L”: Stop step-up (Whole circuit stop)
4	VSS	GND pin
5	EXT	External transistor connection pin

Table 13

Products: S-8357/58 Series B, H, F, N Types
(With shutdown function, V_{DD}/V_{OUT} non-separate type)

Pin No.	Pin Name	Functions
1	ON/$\overline{\text{OFF}}$	Shutdown pin “H”: Normal operation (Step-up operation) “L”: Stop step-up (Whole circuit stop)
2	VOUT	Output voltage pin and IC power supply pin
3	NC[*1]	No connection
4	VSS	GND pin
5	EXT	External transistor connection pin

***1.** The NC pin indicates electrically open.

Table 14

Products: S-8357/58 Series E, J, G, P Types
(Without shutdown function, V_{DD}/V_{OUT} separate type)

Pin No.	Pin Name	Functions
1	VOUT	Output voltage pin
2	VDD	IC power supply pin
3	NC[*1]	No connection
4	VSS	GND pin
5	EXT	External transistor connection pin

***1.** The NC pin indicates electrically open.

6-Pin SNB(B)
Top view

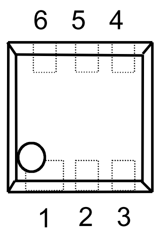


Figure 8

Table 15

Products: S-8355/56 Series K, L, M, Q Types
(With shutdown function, V_{DD}/V_{OUT} separate type)

Pin No.	Pin Name	Functions
1	ON/$\overline{\text{OFF}}$	Shutdown pin "H": Normal operation (Step-up operation) "L": Stop step-up (Whole circuit stop)
2	VOUT	Output voltage pin
3	VDD	IC power supply pin
4	EXT	External transistor connection pin
5	NC*1	No connection
6	VSS	GND pin

***1.** The NC pin indicates electrically open.

Table 16

Products: S-8357/58 Series B, H, F, N Types
(With shutdown function, V_{DD}/V_{OUT} non-separate type)

Pin No.	Pin Name	Functions
1	NC*1	No connection
2	ON/$\overline{\text{OFF}}$	Shutdown pin "H": Normal operation (Step-up operation) "L": Stop step-up (Whole circuit stop)
3	VOUT	Output voltage pin and IC power supply pin
4	EXT	External transistor connection pin
5	NC*1	No connection
6	VSS	GND pin

***1.** The NC pin indicates electrically open.

Table 17

Products: S-8357/58 Series E, J, G, P Types
(Without shutdown function, V_{DD}/V_{OUT} separate type)

Pin No.	Pin Name	Functions
1	NC*1	No connection
2	VOUT	Output voltage pin
3	VDD	IC power supply pin
4	EXT	External transistor connection pin
5	NC*1	No connection
6	VSS	GND pin

***1.** The NC pin indicates electrically open.

■ Absolute Maximum Ratings

Table 18

(Unless otherwise specified: Ta = 25°C)

Parameter	Symbol		Ratings	Unit
VOUT pin voltage	V_{OUT}		V_{SS} − 0.3 to V_{SS} + 12	V
ON/$\overline{\text{OFF}}$ pin voltage*1	$V_{ON/\overline{OFF}}$		V_{SS} − 0.3 to V_{SS} + 12	
VDD pin voltage*2	V_{DD}		V_{SS} − 0.3 to V_{SS} + 12	
EXT pin voltage	V_{EXT}	B, H, F, N type	V_{SS} − 0.3 to V_{OUT} + 0.3	
		Others	V_{SS} − 0.3 to V_{DD} + 0.3	
EXT pin current	I_{EXT}		±80	mA
Power dissipation	P_D	SOT-89-3	500	mW
		SOT-23-5	150	
		SOT-23-3	250	
		6-Pin SNB(B)	90	
Operating temperature	Topr		−40 to +85	°C
Storage temperature	Tstg		−40 to +125	

***1.** With shutdown function
***2.** For V_{DD}/V_{OUT} separate types

Caution The absolute maximum ratings are rated values exceeding which the product could suffer physical damage. These values must therefore not be exceeded under any conditions.

■ Electrical Characteristics

(1) 100 kHz types (S-835xBxx, S-835xExx, S-835xKxx)

Table 19

(Unless otherwise specified: Ta = 25°C)

Parameter	Symbol	Conditions		Min.	Typ.	Max.	Unit	Test Circuit
Output voltage	V_{OUT}	—		$V_{OUT(S)}$ × 0.976	$V_{OUT(S)}$	$V_{OUT(S)}$ × 1.024	V	2
Input voltage	V_{IN}	—		–	–	10		
Operation start voltage	V_{ST1}	I_{OUT} = 1 mA		–	–	0.9		
Oscillation start voltage	V_{ST2}	No external parts, voltage applied to V_{OUT}		–	–	0.8		1
Operation holding voltage	V_{HLD}	I_{OUT} = 1 mA, Measured by decreasing V_{IN} voltage gradually		0.7	–	–		2
Current consumption 1	I_{SS1}	$V_{OUT} = V_{OUT(S)} \times 0.95$	S-835xx15 to 19	–	14.0	23.4	µA	1
			S-835xx20 to 29	–	19.7	32.9		
			S-835xx30 to 39	–	25.9	43.2		
			S-835xx40 to 49	–	32.6	54.4		
			S-835xx50 to 59	–	39.8	66.4		
			S-835xx60 to 65	–	47.3	78.9		
Current consumption 2	I_{SS2}	$V_{OUT} = V_{OUT(S)} + 0.5$	S-835xx15 to 19	–	5.6	11.1		
			S-835xx20 to 29	–	5.8	11.5		
			S-835xx30 to 39	–	5.9	11.8		
			S-835xx40 to 49	–	6.1	12.1		
			S-835xx50 to 59	–	6.3	12.5		
			S-835xx60 to 65	–	6.4	12.8		
Current consumption during shutdown (with shutdown function)	I_{SSS}	$V_{ON/\overline{OFF}}$ = 0 V		–	–	0.5		
EXT pin output current	I_{EXTH}	$V_{EXT} = V_{OUT} - 0.4$	S-835xx15 to 19	−4.5	−8.9	–	mA	
			S-835xx20 to 24	−6.2	−12.3	–		
			S-835xx25 to 29	−7.8	−15.7	–		
			S-835xx30 to 39	−10.3	−20.7	–		
			S-835xx40 to 49	−13.3	−26.7	–		
			S-835xx50 to 59	−16.1	−32.3	–		
			S-835xx60 to 65	−18.9	−37.7	–		
	I_{EXTL}	V_{EXT} = 0.4 V	S-835xx15 to 19	9.5	19.0	–		
			S-835xx20 to 24	12.6	25.2	–		
			S-835xx25 to 29	15.5	31.0	–		
			S-835xx30 to 39	19.2	38.5	–		
			S-835xx40 to 49	23.8	47.6	–		
			S-835xx50 to 59	27.4	54.8	–		
			S-835xx60 to 65	30.3	60.6	–		
Line regulation	ΔV_{OUT1}	$V_{IN} = V_{OUT(S)} \times 0.4$ to $\times 0.6$		–	30	60	mV	2
Load regulation	ΔV_{OUT2}	I_{OUT} = 10 µA to $V_{OUT(S)}/50 \times 1.25$		–	30	60		
Output voltage temperature coefficient	$\frac{\Delta V_{OUT}}{\Delta Ta \bullet V_{OUT}}$	Ta = −40°C to +85°C		–	±50	–	ppm/°C	
Oscillation frequency	f_{OSC}	$V_{OUT} = V_{OUT(S)} \times 0.95$		85	100	115	kHz	1
Max. duty ratio	MaxDuty	$V_{OUT} = V_{OUT(S)} \times 0.95$		75	83	90	%	
PWM/PFM switching duty ratio (S-8356/58)	PFMDuty	$V_{IN} = V_{OUT(S)} - 0.1$ V, no load		10	15	24		
Shutdown pin input voltage (with shutdown function)	V_{SH}	Measured the oscillation at EXT pin		0.75	–	–	V	
	V_{SL1}	Judged the stop of oscillation at EXT pin	When $V_{OUT} \geq 1.5$ V	–	–	0.3		
	V_{SL2}		When $V_{OUT} < 1.5$ V	–	–	0.2		
Shutdown pin input current (with shutdown function)	I_{SH}	Shutdown pin = $V_{OUT(S)} \times 0.95$		−0.1	–	0.1	µA	
	I_{SL}	Shutdown pin = 0 V		−0.1	–	0.1		
Soft start time	t_{SS}	—		3.0	6.0	12.0	ms	2
Efficiency	EFFI	—		–	86	–	%	

External parts
- Coil: CDRH6D28-470 of Sumida Corporation
- Diode: RB461F (Schottky type) of Rohm Co., Ltd.
- Capacitor: F93 (16 V, 47 µF tantalum type) of Nichicon Corporation
- Transistor: CPH3210 of Sanyo Electric Co., Ltd.
- Base resistor (R_b): 1.0 kΩ
- Base capacitor (C_b): 2200 pF (ceramic type)

$V_{IN} = V_{OUT(S)} \times 0.6$ applied, $I_{OUT} = V_{OUT(S)}/50\ \Omega$

Shutdown function built-in type: ON/$\overline{\text{OFF}}$ pin is connected to V_{OUT}
V_{DD}/V_{OUT} separate type: VDD pin is connected to VOUT pin

Remarks **1.** $V_{OUT(S)}$ specified above is the set output voltage value, and V_{OUT} is the typical value of the output voltage.
2. V_{DD}/V_{OUT} separate type:
Step-up operation is performed from V_{DD} = 0.8 V.
However, $1.8 \leq V_{DD} \leq 10$ V is recommended to stabilize the output voltage and oscillation frequency.
($V_{DD} \geq 1.8$ V must be applied for products with a set value of less than 1.9 V.)

(2) 250 kHz types (S-835xHxx, S-835xJxx, S-835xLxx)

Table 20

(Unless otherwise specified: Ta = 25°C)

Parameter	Symbol	Conditions		Min.	Typ.	Max.	Unit	Test Circuit
Output voltage	V_{OUT}	—		$V_{OUT(S)}$ × 0.976	$V_{OUT(S)}$	$V_{OUT(S)}$ × 1.024	V	2
Input voltage	V_{IN}	—		–	–	10		
Operation start voltage	V_{ST1}	I_{OUT} = 1 mA		–	–	0.9		
Oscillation start voltage	V_{ST2}	No external parts, voltage applied to V_{OUT}		–	–	0.8		1
Operation holding voltage	V_{HLD}	I_{OUT} = 1 mA, Measured by decreasing V_{IN} voltage gradually		0.7	–	–		2
Current consumption 1	I_{SS1}	$V_{OUT} = V_{OUT(S)} \times 0.95$	S-835xx15 to 19	–	28.9	48.2	μA	1
			S-835xx20 to 29	–	42.7	71.1		
			S-835xx30 to 39	–	58.0	96.7		
			S-835xx40 to 49	–	74.5	124.1		
			S-835xx50 to 59	–	92.0	153.4		
			S-835xx60 to 65	–	110.5	184.2		
Current consumption 2	I_{SS2}	$V_{OUT} = V_{OUT(S)} + 0.5$	S-835xx15 to 19	–	8.7	17.3		
			S-835xx20 to 29	–	8.8	17.6		
			S-835xx30 to 39	–	9.0	18.0		
			S-835xx40 to 49	–	9.2	18.3		
			S-835xx50 to 59	–	9.3	18.6		
			S-835xx60 to 65	–	9.5	19.0		
Current consumption during shutdown (with shutdown function)	I_{SSS}	$V_{ON/\overline{OFF}}$ = 0 V		–	–	0.5		
EXT pin output current	I_{EXTH}	$V_{EXT} = V_{OUT} - 0.4$	S-835xx15 to 19	−4.5	−8.9	–	mA	
			S-835xx20 to 24	−6.2	−12.3	–		
			S-835xx25 to 29	−7.8	−15.7	–		
			S-835xx30 to 39	−10.3	−20.7	–		
			S-835xx40 to 49	−13.3	−26.7	–		
			S-835xx50 to 59	−16.1	−32.3	–		
			S-835xx60 to 65	−18.9	−37.7	–		
	I_{EXTL}	V_{EXT} = 0.4 V	S-835xx15 to 19	9.5	19.0	–		
			S-835xx20 to 24	12.6	25.2	–		
			S-835xx25 to 29	15.5	31.0	–		
			S-835xx30 to 39	19.2	38.5	–		
			S-835xx40 to 49	23.8	47.6	–		
			S-835xx50 to 59	27.4	54.8	–		
			S-835xx60 to 65	30.3	60.6	–		
Line regulation	ΔV_{OUT1}	$V_{IN} = V_{OUT(S)} \times 0.4$ to $\times 0.6$		–	30	60	mV	2
Load regulation	ΔV_{OUT2}	I_{OUT} = 10 μA to $V_{OUT(S)}/50 \times 1.25$		–	30	60		
Output voltage temperature coefficient	$\frac{\Delta V_{OUT}}{\Delta Ta \bullet V_{OUT}}$	Ta = −40°C to +85°C		–	±50	–	ppm/°C	
Oscillation frequency	f_{OSC}	$V_{OUT} = V_{OUT(S)} \times 0.95$		212.5	250	287.5	kHz	1
Max. duty ratio	MaxDuty	$V_{OUT} = V_{OUT(S)} \times 0.95$		70	78	85	%	
PWM/PFM switching duty ratio (S-8356/58)	PFMDuty	$V_{IN} = V_{OUT(S)} - 0.1$ V, no load		10	15	24		
Shutdown pin input voltage (with shutdown function)	V_{SH}	Measured the oscillation at EXT pin		0.75	–	–	V	
	V_{SL1}	Judged the stop of oscillation at EXT pin	When V_{OUT} ≥ 1.5 V	–	–	0.3		
	V_{SL2}		When V_{OUT} < 1.5 V	–	–	0.2		
Shutdown pin input current (with shutdown function)	I_{SH}	Shutdown pin = $V_{OUT(S)} \times 0.95$		−0.1	–	0.1	μA	
	I_{SL}	Shutdown pin = 0 V		−0.1	–	0.1		
Soft start time	t_{SS}	—		1.5	3.0	6.0	ms	2
Efficiency	EFFI	—		–	85	–	%	

External parts
- Coil: CDRH6D28-220 of Sumida Corporation
- Diode: RB461F (Schottky type) of Rohm Co., Ltd.
- Capacitor: F93 (16 V, 47 μF tantalum type) of Nichicon Corporation
- Transistor: CPH3210 of Sanyo Electric Co., Ltd.
- Base resistor (R_b): 1.0 kΩ
- Base capacitor (C_b): 2200 pF (ceramic type)

$V_{IN} = V_{OUT(S)} \times 0.6$ applied, $I_{OUT} = V_{OUT(S)}/50\ \Omega$

Shutdown function built-in type: ON/$\overline{\text{OFF}}$ pin is connected to V_{OUT}
V_{DD}/V_{OUT} separate type: VDD pin is connected to VOUT pin

Remarks **1.** $V_{OUT(S)}$ specified above is the set output voltage value, and V_{OUT} is the typical value of the output voltage.
2. V_{DD}/V_{OUT} separate type:
Step-up operation is performed from V_{DD} = 0.8 V.
However, 1.8 ≤ V_{DD} ≤ 10 V is recommended to stabilize the output voltage and oscillation frequency.
(V_{DD} ≥ 1.8 V must be applied for products with a set value of less than 1.9 V.)

(3) 300 kHz types (S-835xFxx, S-835xGxx, S-835xMxx)

Table 21

(Unless otherwise specified: Ta = 25°C)

Parameter	Symbol	Conditions		Min.	Typ.	Max.	Unit	Test Circuit
Output voltage	V_{OUT}	—		$V_{OUT(S)}$ × 0.976	$V_{OUT(S)}$	$V_{OUT(S)}$ × 1.024	V	2
Input voltage	V_{IN}	—		–	–	10		
Operation start voltage	V_{ST1}	I_{OUT} = 1 mA		–	–	0.9		
Oscillation start voltage	V_{ST2}	No external parts, voltage applied to V_{OUT}		–	–	0.8		1
Operation holding voltage	V_{HLD}	I_{OUT} = 1 mA, Measured by decreasing V_{IN} voltage gradually		0.7	–	–		2
Current consumption 1	I_{SS1}	$V_{OUT} = V_{OUT(S)} \times 0.95$	S-835xx15 to 19	–	33.8	56.4	µA	1
			S-835xx20 to 29	–	50.3	83.9		
			S-835xx30 to 39	–	68.6	114.4		
			S-835xx40 to 49	–	88.4	147.4		
			S-835xx50 to 59	–	109.4	182.4		
			S-835xx60 to 65	–	131.6	219.3		
Current consumption 2	I_{SS2}	$V_{OUT} = V_{OUT(S)} + 0.5$	S-835xx15 to 19	–	9.7	19.4		
			S-835xx20 to 29	–	9.9	19.7		
			S-835xx30 to 39	–	10.0	20.0		
			S-835xx40 to 49	–	10.2	20.4		
			S-835xx50 to 59	–	10.4	20.7		
			S-835xx60 to 65	–	10.5	21.0		
Current consumption during shutdown (with shutdown function)	I_{SSS}	$V_{ON/\overline{OFF}}$ = 0 V		–	–	0.5		
EXT pin output current	I_{EXTH}	$V_{EXT} = V_{OUT} - 0.4$	S-835xx15 to 19	–4.5	–8.9	–	mA	
			S-835xx20 to 24	–6.2	–12.3	–		
			S-835xx25 to 29	–7.8	–15.7	–		
			S-835xx30 to 39	–10.3	–20.7	–		
			S-835xx40 to 49	–13.3	–26.7	–		
			S-835xx50 to 59	–16.1	–32.3	–		
			S-835xx60 to 65	–18.9	–37.7	–		
	I_{EXTL}	V_{EXT} = 0.4 V	S-835xx15 to 19	9.5	19.0	–		
			S-835xx20 to 24	12.6	25.2	–		
			S-835xx25 to 29	15.5	31.0	–		
			S-835xx30 to 39	19.2	38.5	–		
			S-835xx40 to 49	23.8	47.6	–		
			S-835xx50 to 59	27.4	54.8	–		
			S-835xx60 to 65	30.3	60.6	–		
Line regulation	ΔV_{OUT1}	$V_{IN} = V_{OUT(S)} \times 0.4$ to $\times 0.6$		–	30	60	mV	2
Load regulation	ΔV_{OUT2}	I_{OUT} = 10 µA to $V_{OUT(S)}/50 \times 1.25$		–	30	60		
Output voltage temperature coefficient	$\frac{\Delta V_{OUT}}{\Delta Ta \bullet V_{OUT}}$	Ta = – 40°C to + 85°C		–	±50	–	ppm/°C	
Oscillation frequency	f_{OSC}	$V_{OUT} = V_{OUT(S)} \times 0.95$		255	300	345	kHz	1
Max. duty ratio	MaxDuty	$V_{OUT} = V_{OUT(S)} \times 0.95$		70	78	85	%	
PWM/PFM switching duty ratio (S-8356/58)	PFMDuty	$V_{IN} = V_{OUT(S)} - 0.1$ V, no load		10	15	24		
Shutdown pin input voltage (with shutdown function)	V_{SH}	Measured the oscillation at EXT pin		0.75	–	–	V	
	V_{SL1}	Judged the stop of oscillation at EXT pin	When $V_{OUT} \geq 1.5$ V	–	–	0.3		
	V_{SL2}		When $V_{OUT} < 1.5$ V	–	–	0.2		
Shutdown pin input current (with shutdown function)	I_{SH}	Shutdown pin = $V_{OUT(S)} \times 0.95$		–0.1	–	0.1	µA	
	I_{SL}	Shutdown pin = 0 V		–0.1	–	0.1		
Soft start time	t_{SS}	—		1.5	3.0	6.0	ms	2
Efficiency	EFFI	—		–	85	–	%	

External parts

- Coil: CDRH6D28-220 of Sumida Corporation
- Diode: RB461F (Schottky type) of Rohm Co., Ltd.
- Capacitor: F93 (16 V, 47 µF tantalum type) of Nichicon Corporation
- Transistor: CPH3210 of Sanyo Electric Co., Ltd.
- Base resistor (R_b): 1.0 kΩ
- Base capacitor (C_b): 2200 pF (ceramic type)

$V_{IN} = V_{OUT(S)} \times 0.6$ applied, $I_{OUT} = V_{OUT(S)}/50\ \Omega$

Shutdown function built-in type: ON/$\overline{\text{OFF}}$ pin is connected to V_{OUT}
V_{DD}/V_{OUT} separate type: VDD pin is connected to VOUT pin

Remarks **1.** $V_{OUT(S)}$ specified above is the set output voltage value, and V_{OUT} is the typical value of the output voltage.
2. V_{DD}/V_{OUT} separate type:
Step-up operation is performed from V_{DD} = 0.8 V.
However, $1.8 \leq V_{DD} \leq 10$ V is recommended to stabilize the output voltage and oscillation frequency.
($V_{DD} \geq 1.8$ V must be applied for products with a set value of less than 1.9 V.)

(4) 600 kHz types (S-835xNxx)

Table 22

(Unless otherwise specified: Ta = 25°C)

Parameter	Symbol	Conditions		Min.	Typ.	Max.	Unit	Test Circuit
Output voltage	V_{OUT}	—		$V_{OUT(S)} \times 0.976$	$V_{OUT(S)}$	$V_{OUT(S)} \times 1.024$	V	2
Input voltage	V_{IN}	—		–	–	10		
Operation start voltage	V_{ST1}	I_{OUT} = 1 mA		–	–	0.9		
Oscillation start voltage	V_{ST2}	No external parts, voltage applied to V_{OUT}		–	–	0.8		1
Operation holding voltage	V_{HLD}	I_{OUT} = 1 mA, Measured by decreasing V_{IN} voltage gradually		0.7	–	–		2
Current consumption 1	I_{SS1}	$V_{OUT} = V_{OUT(S)} \times 0.95$	S-835xx15 to 19	–	63.6	105.9	μA	1
			S-835xx20 to 29	–	96.4	160.6		
			S-835xx30 to 39	–	132.8	221.3		
			S-835xx40 to 49	–	172.2	286.9		
			S-835xx50 to 59	–	214.0	356.7		
			S-835xx60 to 65	–	240.2	400.3		
Current consumption 2	I_{SS2}	$V_{OUT} = V_{OUT(S)} + 0.5$	S-835xx15 to 19	–	15.9	31.8		
			S-835xx20 to 29	–	16.1	32.1		
			S-835xx30 to 39	–	16.2	32.4		
			S-835xx40 to 49	–	16.4	32.8		
			S-835xx50 to 59	–	16.6	33.1		
			S-835xx60 to 65	–	16.7	33.3		
Current consumption during shutdown	I_{SSS}	$V_{ON/\overline{OFF}}$ = 0 V		–	–	0.5		
EXT pin output current	I_{EXTH}	$V_{EXT} = V_{OUT} - 0.4$	S-835xx15 to 19	−4.5	−8.9	–	mA	
			S-835xx20 to 24	−6.2	−12.3	–		
			S-835xx25 to 29	−7.8	−15.7	–		
			S-835xx30 to 39	−10.3	−20.7	–		
			S-835xx40 to 49	−13.3	−26.7	–		
			S-835xx50 to 59	−16.1	−32.3	–		
			S-835xx60 to 65	−18.9	−37.7	–		
	I_{EXTL}	V_{EXT} = 0.4 V	S-835xx15 to 19	9.5	19.0	–		
			S-835xx20 to 24	12.6	25.2	–		
			S-835xx25 to 29	15.5	31.0	–		
			S-835xx30 to 39	19.2	38.5	–		
			S-835xx40 to 49	23.8	47.6	–		
			S-835xx50 to 59	27.4	54.8	–		
			S-835xx60 to 65	30.3	60.6	–		
Line regulation	ΔV_{OUT1}	$V_{IN} = V_{OUT(S)} \times 0.4$ to $\times 0.6$		–	30	60	mV	2
Load regulation	ΔV_{OUT2}	I_{OUT} = 10 μA to $V_{OUT(S)}/50 \times 1.25$		–	30	60		
Output voltage temperature coefficient	$\frac{\Delta V_{OUT}}{\Delta Ta \bullet V_{OUT}}$	Ta = −40°C to +85°C		–	±50	–	ppm/°C	
Oscillation frequency	f_{OSC}	$V_{OUT} = V_{OUT(S)} \times 0.95$		510	600	690	kHz	1
Max. duty ratio	MaxDuty	$V_{OUT} = V_{OUT(S)} \times 0.95$		65	78	85	%	
PWM/PFM switching duty ratio (S-8356/58)	PFMDuty	$V_{IN} = V_{OUT(S)} - 0.1$ V, no load		10	15	24		
Shutdown pin input voltage	V_{SH}	Measured the oscillation at EXT pin		0.75	–	–	V	
	V_{SL1}	Judged the stop of oscillation at EXT pin	When $V_{OUT} \geq 1.5$ V	–	–	0.3		
	V_{SL2}		When $V_{OUT} < 1.5$ V	–	–	0.2		
Shutdown pin input current	I_{SH}	Shutdown pin = $V_{OUT(S)} \times 0.95$		−0.1	–	0.1	μA	
	I_{SL}	Shutdown pin = 0 V		−0.1	–	0.1		
Soft start time	t_{SS}	—		1.5	3.0	6.0	ms	2
Efficiency	EFFI	—		–	85	–	%	

External parts
- Coil: CDRH6D28-100 of Sumida Corporation
- Diode: RB461F (Schottky type) of Rohm Co., Ltd.
- Capacitor: F93 (16 V, 47 μF tantalum type) of Nichicon Corporation
- Transistor: CPH3210 of Sanyo Electric Co., Ltd.
- Base resistor (Rb): 1.0 kΩ
- Base capacitor (Cb): 2200 pF (ceramic type)

$V_{IN} = V_{OUT(S)} \times 0.6$ applied, $I_{OUT} = V_{OUT(S)}/50\ \Omega$, $ON/\overline{OFF} = V_{OUT}$

Remark $V_{OUT(S)}$ specified above is the set output voltage value, and V_{OUT} is the typical value of the output voltage.

(5) 600 kHz types (S-835xPxx, S-835xQxx)

Table 23

(Unless otherwise specified: Ta = 25°C)

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit	Test Circuit
Output voltage	V_{OUT}	—	$V_{OUT(S)}$ × 0.976	$V_{OUT(S)}$	$V_{OUT(S)}$ × 1.024	V	4
Input voltage	V_{IN}	—	–	–	10		
Operation start voltage	V_{ST1}	I_{OUT} = 1 mA	–	–	0.9		
Oscillation start voltage	V_{ST2}	No external parts, voltage applied to V_{DD}	–	–	0.8		3
Operation holding voltage	V_{HLD}	I_{OUT} = 1 mA, Measured by decreasing V_{IN} voltage gradually	0.7	–	–		4
Current consumption 1	I_{SS1}	V_{DD} = 3.3 V	–	132.8	221.3	μA	3
Current consumption 2	I_{SS2}	V_{DD} = 3.3 V	–	16.2	32.4		
Current consumption during shutdown (with shutdown function)	I_{SSS}	$V_{ON/\overline{OFF}}$ = 0 V	–	–	0.5		
EXT pin output current	I_{EXTH}	V_{DD} = 3.3 V	−10.3	−20.7	–	mA	
	I_{EXTL}	V_{DD} = 3.3 V	19.2	38.5	–		
Line regulation	ΔV_{OUT1}	V_{IN} = $V_{OUT(S)}$ × 0.4 to × 0.6	–	30	60	mV	4
Load regulation	ΔV_{OUT2}	I_{OUT} = 10 μA to $V_{OUT(S)}$/50 × 1.25	–	30	60		
Output voltage temperature coefficient	$\frac{\Delta V_{OUT}}{\Delta Ta \bullet V_{OUT}}$	Ta = −40°C to +85°C	–	±50	–	ppm/°C	
Oscillation frequency	f_{OSC}	V_{DD} = 3.3 V	510	600	690	kHz	3
Max. duty ratio	MaxDuty	V_{DD} = 3.3 V	65	78	85	%	
PWM/PFM switching duty ratio (S-8356/58)	PFMDuty	V_{IN} = $V_{OUT(S)}$ − 0.1 V, no load	10	15	24		
Shutdown pin input voltage (with shutdown function)	V_{SH}	Measured the oscillation at EXT pin	0.75	–	–	V	
	V_{SL1}	Judged the stop of oscillation at EXT pin; When V_{OUT} ≥ 1.5 V	–	–	0.3		
	V_{SL2}	Judged the stop of oscillation at EXT pin; When V_{OUT} < 1.5 V	–	–	0.2		
Shutdown pin input current (with shutdown function)	I_{SH}	Shutdown pin = $V_{OUT(S)}$ × 0.95	−0.1	–	0.1	μA	
	I_{SL}	Shutdown pin = 0 V	−0.1	–	0.1		
Soft start time	t_{SS}	—	1.5	3.0	6.0	ms	4
Efficiency	EFFI	—	–	85	–	%	

External parts
- Coil: CDRH6D28-100 of Sumida Corporation
- Diode: RB461F(Schottky type) of Rohm Co., Ltd.
- Capacitor: F93 (16 V, 47 μF tantalum type) of Nichicon Corporation
- Transistor: CPH3210 of Sanyo Electric Co., Ltd.
- Base resistor (Rb): 1.0 kΩ
- Base capacitor (Cb): 2200 pF (ceramic type)

V_{IN} = $V_{OUT(S)}$ × 0.6 applied, I_{OUT} = $V_{OUT(S)}$/50 Ω, ON/$\overline{OFF}$ = 3.3 V

Remarks **1.** $V_{OUT(S)}$ specified above is the set output voltage value, and V_{OUT} is the typical value of the output voltage.
2. V_{DD}/V_{OUT} separate type:
Step-up operation is performed from V_{DD} = 0.8 V.
However, 1.8 ≤ V_{DD} ≤ 10 V is recommended to stabilize the output voltage and oscillation frequency.
(V_{DD} ≥ 1.8 V must be applied for products with a set value of less than 1.9 V.)

■ Test Circuits

1.

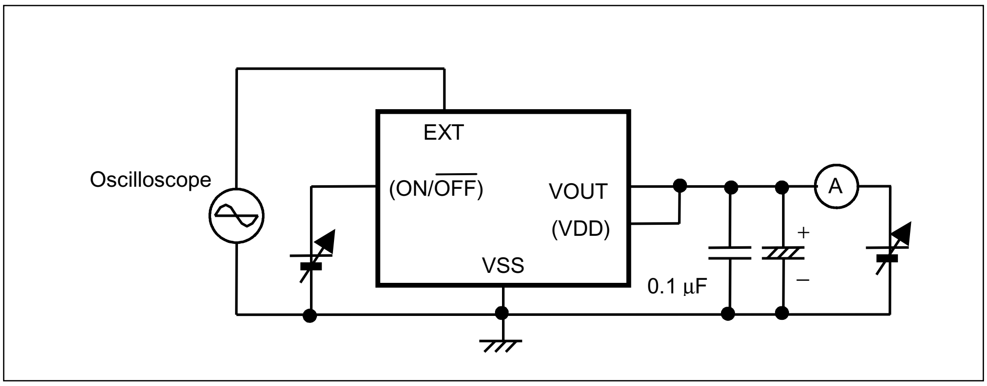


Figure 9

2.

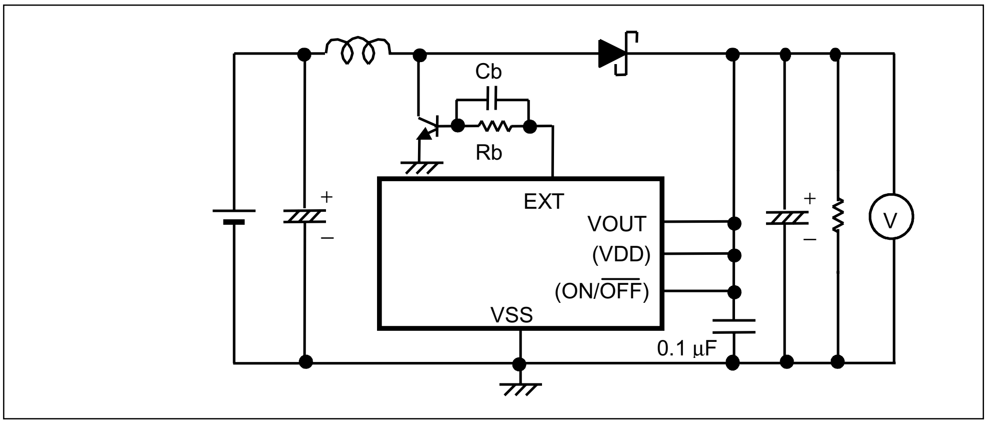


Figure 10

3.

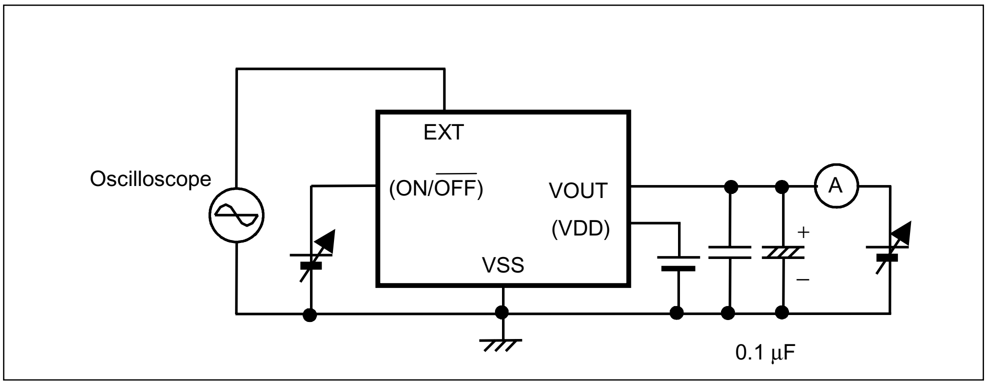


Figure 11

4.

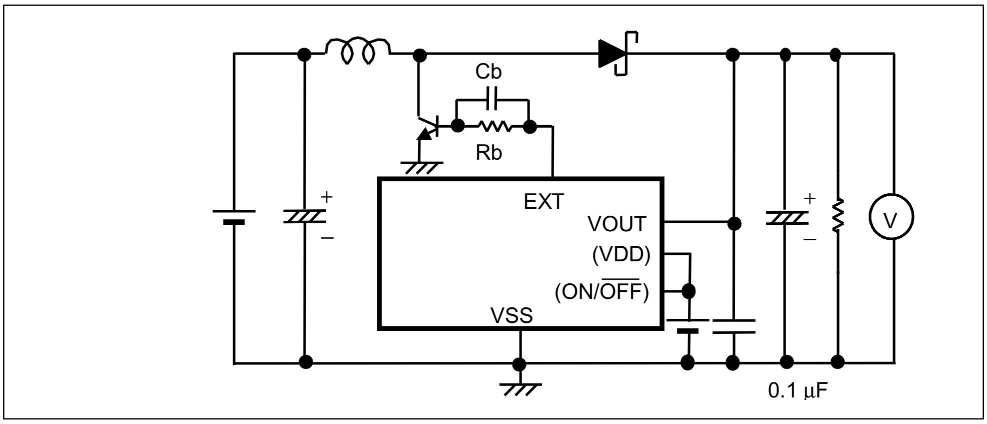


Figure 12

■ Operation

1. Switching control types

1-1. PWM control (S-8355/57 Series)

The S-8355/57 Series is a DC-DC converter using a pulse width modulation method (PWM) and features a low current consumption.
In conventional PFM DC-DC converters, pulses are skipped when the output load current is low, causing a fluctuation in the ripple frequency of the output voltage, resulting in an increase in the ripple voltage.
In S-8355/57 Series, the switching frequency does not change, although the pulse width changes from 0% to 83% (78% for F, G, H, J, L, M, N, P, Q types) corresponding to each load current. The ripple voltage generated from switching can thus be removed easily through a filter because the switching frequency is constant.

1-2. PWM/PFM switching control (S-8356/58 Series)

S-8356/58 Series is a DC-DC converter that automatically switches between a pulse width modulation method (PWM) and a pulse frequency modulation method (PFM), depending on the load current, and features a low current consumption. This series is a particularly highly efficient DC-DC converter at an output current of around 100 μA.
In conventional constant-duty PFM DC-DC converters, pulses are skipped when the output load current is low, causing a fluctuation in the ripple frequency of the output voltage, resulting in an increase in the ripple voltage. The S-8356/58 Series operates under PWM control with the pulse width duty changing from 15% to 83% (78% for F, G, H, J, L, M, N, P, Q types) in a high output load current area. On the other hand, the S-8356/58 Series operates under PFM control with the pulse width duty fixed at 15% in a low output load current area, and pulses are skipped when the low output load current is low according to the load current and output to the switching transistor. The oscillation circuit thus oscillates intermittently so that the resultant lower self-consumption can prevent a reduction in the efficiency at a low load current. The switching point from PWM control to PFM control depends on the external devices (coil, diode, etc.), input voltage and output voltage.

2. Soft start function

For this IC, the built-in soft start circuit controls the rush current and overshoot of the output voltage when powering on or when the ON/$\overline{\text{OFF}}$ pin is switched to the “H” level.

3. Shutdown pin (Only for SOT-23-5 package products of B, H, F, K, L, M, N, and Q types and for 6-Pin SNB(B) package products.)

   Stops or starts step-up operation.
   Switching the shutdown pin to the “L” level stops operation of all the internal circuits and reduces the current consumption significantly.
   DO NOT use the shutdown pin in a floating state because it has the structure shown in Figure 13 and is not pulled up or pulled down internally. DO NOT apply voltage of between 0.3 V and 0.75 V to the shutdown pin because applying such a voltage increases the current consumption. If the shutdown pin is not used, connect it to the VOUT (VDD for K, L, M, Q types) pin.
   The shutdown pin does not have hysteresis.

Table 24

Shutdown Pin	CR Oscillation Circuit	Output Voltage
“H”	Operation	Fixed
“L”	Stop	$\cong V_{IN}$ *1

***1.** Voltage obtained by subtracting the voltage drop due to DC resistance of the inductor and the diode forward voltage from V_{IN}.

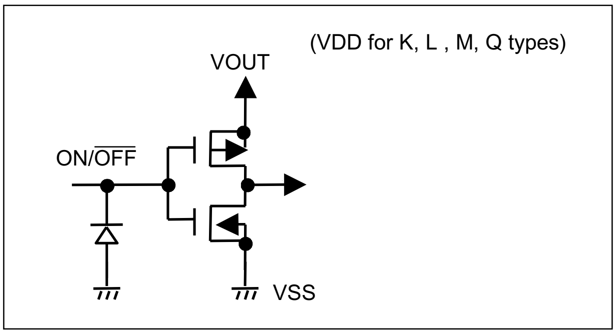


Figure 13 Shutdown Pin Structure

4. Operation

The following are basic equations [(1) through (7)] of the step-up switching regulator (refer to Figure 14).

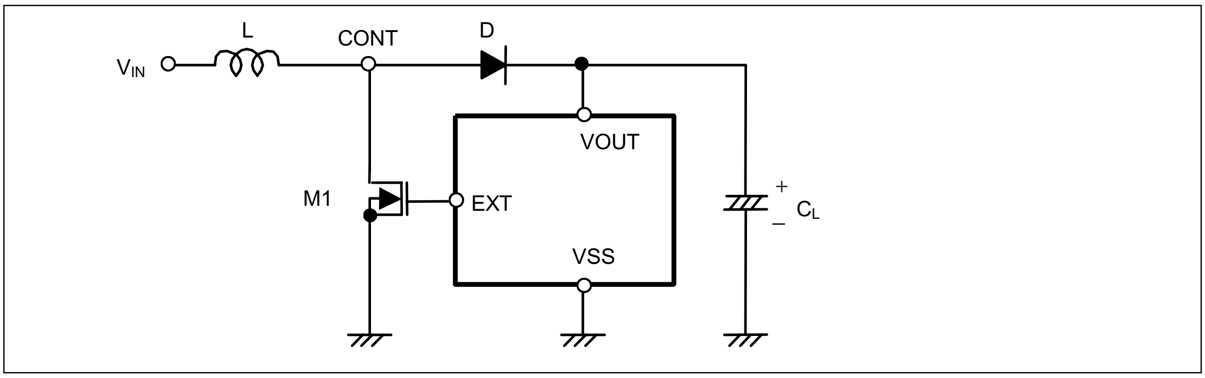


Figure 14 Step-up Switching Regulator Circuit for Basic Equations

Voltage at the CONT pin at the moment M1 is turned ON (current I_L flowing through L is zero), V_A:

$$V_A = V_S{}^{*1} \quad \text{......} \quad (1)$$

***1.** V_S: Non-saturated voltage of M1

Change in I_L over time:

$$\frac{dI_L}{dt} = \frac{V_L}{L} = \frac{V_{IN} - V_S}{L} \quad \text{......} \quad (2)$$

Integration of the above equation :

$$I_L = \left(\frac{V_{IN} - V_S}{L}\right) \bullet t \quad \text{......} \quad (3)$$

I_L flows while M1 is ON (t_{ON}). The time of t_{ON} is determined by the oscillation frequency of OSC.
Peak current (I_{PK}) after t_{ON}:

$$I_{PK} = \left(\frac{V_{IN} - V_S}{L}\right) \bullet t_{ON} \quad \text{......} \quad (4)$$

The energy stored in L is represented by $\frac{1}{2} \bullet L (I_{PK})^2$.
When M1 is turned OFF (t_{OFF}), the energy stored in L is transmitted through a diode to the output capacitor. Then, reverse voltage (V_L) is generated:

$$V_L = (V_{OUT} + V_D{}^{*2}) - V_{IN} \quad \text{......} \quad (5)$$

***2.** V_D: Diode forward voltage

The voltage at the CONT pin rises only by $V_{OUT} + V_D$.

Change in the current (I_L) flowing through the diode into V_{OUT} during t_{OFF}:

$$\frac{dI_L}{dt} = \frac{V_L}{L} = \frac{V_{OUT} + V_D - V_{IN}}{L} \quad \text{......} \quad (6)$$

Integration of the above equation is as follows:

$$I_L = I_{PK} - \left(\frac{V_{OUT} + V_D - V_{IN}}{L}\right) \bullet t \quad \text{......} \quad (7)$$

During t_{ON}, the energy is stored in L and is not transmitted to V_{OUT}. When receiving output current (I_{OUT}) from V_{OUT}, the energy of the capacitor (C_L) is consumed. As a result, the pin voltage of C_L is reduced, and goes to the lowest level after M1 is turned ON (t_{ON}). When M1 is turned OFF, the energy stored in L is transmitted through the diode to C_L, and the voltage of C_L rises drastically. V_{OUT} is a time function indicating the maximum value (ripple voltage: V_{P-P}) when the current flowing through into V_{OUT} and load current (I_{OUT}) match.

Next, the ripple voltage is determined as follows:
I_{OUT} vs t_1 (time) from when M1 is turned OFF (after t_{ON}) to when V_{OUT} reaches the maximum level:

$$I_{OUT} = I_{PK} - \left(\frac{V_{OUT} + V_D - V_{IN}}{L}\right) \bullet t_1 \quad \text{.......... (8)}$$

$$\therefore \quad t_1 = (I_{PK} - I_{OUT}) \bullet \left(\frac{L}{V_{OUT} + V_D - V_{IN}}\right) \quad \text{.......... (9)}$$

When M1 is turned ON (after t_{OFF}), $I_L = 0$ (when the energy of the inductor is completely transmitted):
Based on equation (7),

$$\left(\frac{L}{V_{OUT} + V_D - V_{IN}}\right) = \frac{t_{OFF}}{I_{PK}} \quad \text{.......... (10)}$$

When substituting equation (10) for equation (9),

$$t_1 = t_{OFF} - \left(\frac{I_{OUT}}{I_{PK}}\right) \bullet t_{OFF} \quad \text{.......... (11)}$$

Electric charge ΔQ_1 which is charged in C_L during t_1 :

$$\Delta Q_1 = \int_0^{t_1} I_L dt = I_{PK} \bullet \int_0^{t_1} dt - \frac{V_{OUT} + V_D - V_{IN}}{L} \bullet \int_0^{t_1} t dt = I_{PK} \bullet t_1 - \frac{V_{OUT} + V_D - V_{IN}}{L} \bullet \frac{1}{2} t_1^2 \quad \text{.......... (12)}$$

When substituting equation (12) for equation (9):

$$\Delta Q_1 = I_{PK} - \frac{1}{2} (I_{PK} - I_{OUT}) \bullet t_1 = \frac{I_{PK} + I_{OUT}}{2} \bullet t_1 \quad \text{.......... (13)}$$

A rise in voltage (V_{P-P}) due to ΔQ_1:

$$V_{P-P} = \frac{\Delta Q_1}{C_L} = \frac{1}{C_L} \bullet \left(\frac{I_{PK} + I_{OUT}}{2}\right) \bullet t_1 \quad \text{.......... (14)}$$

When taking into consideration I_{OUT} to be consumed during t_1 and ESR*1 of C_L:

$$V_{P-P} = \frac{\Delta Q_1}{C_L} = \frac{1}{C_L} \bullet \left(\frac{I_{PK} + I_{OUT}}{2}\right) \bullet t_1 + \left(\frac{I_{PK} + I_{OUT}}{2}\right) \bullet R_{ESR} - \frac{I_{OUT} \bullet t_1}{C_L} \quad \text{.......... (15)}$$

***1.** Equivalent Series Resistance

When substituting equation (11) for equation (15):

$$V_{P-P} = \frac{(I_{PK} - I_{OUT})^2}{2I_{PK}} \bullet \frac{t_{OFF}}{C_L} + \left(\frac{I_{PK} + I_{OUT}}{2}\right) \bullet R_{ESR} \quad \text{.......... (16)}$$

Therefore to reduce the ripple voltage, it is important that the capacitor connected to the output pin has a large capacity and a small ESR.

■ External Parts Selection

The relationship between the major characteristics of the step-up circuit and the characteristics parameters of the external parts are shown in Figure 15.

<table>
<tr><th rowspan="2">For larger output current?</th><th colspan="2">For higher efficiency?</th><th rowspan="2">For smaller ripple voltage?</th></tr>
<tr><th>Operation efficiency</th><th>Stand-by efficiency</th></tr>
<tr><td>Smaller inductance</td><td colspan="3">Larger inductance</td></tr>
<tr><td colspan="4">Smaller DC resistance of inductor</td></tr>
<tr><td>Larger output capacitance</td><td></td><td></td><td>Larger output capacitance</td></tr>
<tr><td colspan="2">With MOS FET, smaller ON resistance</td><td colspan="2">With MOS FET, smaller input capacitance</td></tr>
<tr><td colspan="2">With bipolar transistor, smaller external resistance Rb</td><td colspan="2">With bipolar transistor, larger external resistance Rb</td></tr>
</table>

Figure 15 Relationship Between Major Characteristics of Step-up Circuit and External Parts

1. Inductor

The inductance has a strong influence on the maximum output current I_{OUT} and efficiency η.
Figure 16 shows the relationship between the I_{OUT} and η dependency on L of S-8355/56/57/58.

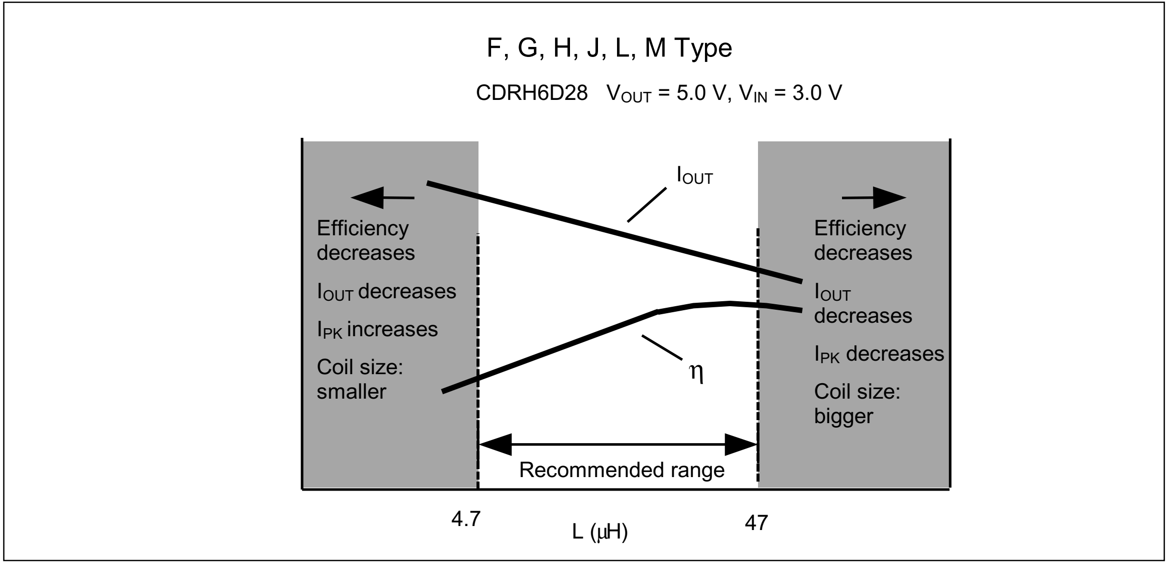


Figure 16 L-I_{OUT} and η Characteristics

The peak current (I_{PK}) increases by decreasing L and the stability of the circuit improves and I_{OUT} increases. If L is decreased further, the efficiency falls and if the current drive capability is insufficient, I_{OUT} decreases. (Based on the current drive capability of external switching transistor.)
The loss of I_{PK} by the switching transistor decreases by increasing L and the efficiency becomes maximum at a certain L value. Further increasing L decreases the efficiency due to the loss of the DC resistance of the coil. I_{OUT} also decreases.
If the oscillation frequency is higher, a smaller L value can be chosen, making the coil smaller.
The recommended inductances are a 22 to 100 μH inductor for B, E, and K types, a 4.7 to 47 μH inductor for F, G, H, J, L, and M types, 3.0 to 22 μH inductor for N, P, Q, types.
Choose an inductor so that I_{PK} does not exceed the allowable current. Exceeding the allowable current of the inductor causes magnetic saturation, much lower efficiency and destruction of the IC chip due to a large current.
I_{PK} in uncontinuous mode is calculated by the following equation:

$$I_{PK} = \sqrt{\frac{2\ I_{OUT}\ (V_{OUT} + V_D - V_{IN})}{f_{OSC} \bullet L}} \quad \text{(A)} \quad \text{.............................(17)}$$

f_{OSC} = Oscillation frequency, $V_D \cong 0.4$ V.

2. Diode

Use an external diode that meets the following requirements:

- Low forward voltage: ($V_F < 0.3$ V)
- High switching speed: (50 ns max.)
- Reverse voltage: $V_{OUT} + V_F$ or more
- Rated current: I_{PK} or more

3. Capacitor (C_{IN}, C_L)

A capacitor on the input side (C_{IN}) improves the efficiency by reducing the power impedance and stabilizing the input current. Select a C_{IN} value according to the impedance of the power supply used. A capacitor on the output side (C_L) is used for smoothing the output voltage. For step-up types, the output voltage flows intermittently to the load current, so step-up types need a larger capacitance than step-down types. Therefore, select an appropriate capacitor in accordance with the ripple voltage, which increases in case of a higher output voltage or a higher load current. The capacitor value should be 10 μF minimum.
Select an appropriate capacitor taking into consideration the ESR (Equivalent Series Resistance) for stable output voltage. A stable voltage range in this IC depends on the ESR. Although the inductance (L) is also a factor, an ESR of 30 mΩ to 500 mΩ draws out the characteristics. However, the best ESR may depend on L, the capacitance, the wiring and the application (output load). Therefore, fully evaluate the ESR under actual conditions to determine the best value.
“2 Ceramic capacitor” of “Application Circuits” shows an example of a circuit that uses a ceramic capacitor and external resistance (ESR) for reference.

4. External transistor

A bipolar (NPN) transistor or an enhancement (N-channel) MOS FET transistor can be used as the external transistor.

4.1 Bipolar (NPN) transistor

A circuit example using the CPH3210 (h_{FE} = 200 to 560) from Sanyo Electric Co., Ltd. as the bipolar transistor (NPN) is shown in Figure 19 of “Standard Circuits”. The h_{FE} value and the R_b value determine the driving capacity when the output current is increased using a bipolar transistor. A peripheral circuit example of the transistor is shown in Figure 17.

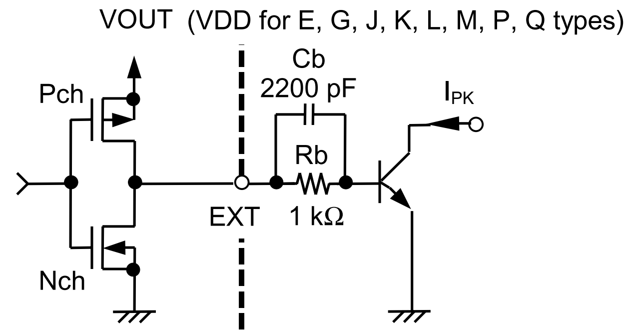


Figure 17 External Transistor Peripheral

1 kΩ is recommended for R_b. R_b is determined by the following calculation. Calculate the necessary base current (I_b) from the bipolar transistor h_{FE} using $I_b = \frac{I_{PK}}{h_{FE}}$.

$$R_b = \frac{V_{OUT} - 0.7}{I_b} - \frac{0.4}{|I_{EXTH}|} \quad \left(R_b = \frac{V_{DD} - 0.7}{I_b} - \frac{0.4}{|I_{EXTH}|} \text{ for E, G, J, K, L, M, P, and Q types}\right)$$

A small R_b increases the output current, but the efficiency decreases. The current flows pulsating and there is a voltage drop due to wiring resistance in the actual circuit, therefore the optimum R_b value should be determined by experiment.
A speed-up capacitor (C_b) connected in parallel with the R_b resistance as shown in Figure 17 decreases the switching loss and improves the efficiency.
C_b is calculated from the following equation:

$$C_b \leq \frac{1}{2\pi \bullet R_b \bullet f_{OSC} \bullet 0.7}$$

However, in practice, the optimum C_b value also varies depending on the characteristics of the bipolar transistor employed. Therefore, determine the optimum value by experiment.

4.2 Enhancement MOS FET type

Figure 18 is a circuit example using a MOS FET transistor (N-channel).
An N-channel power MOS FET should be used for the MOS FET. Because the gate voltage and current of the external power MOS FET are supplied from the stepped-up output voltage V_{OUT}, the MOS FET is driven more effectively.
Depending on the MOS FET you use in your device, there is a chance of a current overrun at power ON. Thoroughly test all settings with your device before deciding on which one to use. Also, try to use a MOS FET with an input capacitance of 700 pF or less.
Since the ON resistor of the MOS FET might depend on the difference between the output voltage V_{OUT} and the threshold voltage of the MOS FET, and affect the output current as well as the efficiency, the threshold voltage should be low.
When the output voltage is low, the circuit operates only when the MOS FET has a threshold voltage lower than the output voltage.

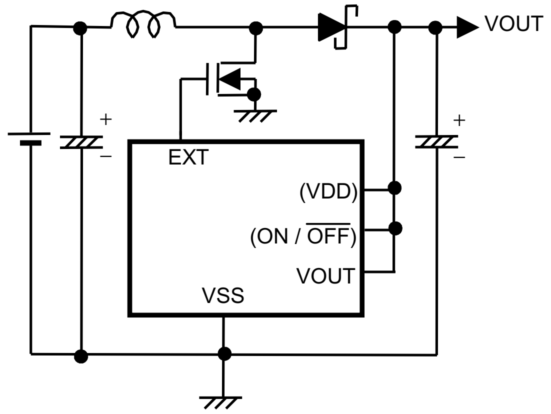


Figure 18 Circuit Example Using MOS FET

5. V_{DD}/V_{OUT} separate types (E, G, J, K, L, M, P, and Q types)

The E, G, J, K, L, M, P, and Q types are ideal for the following applications because the power pin for the IC chip and the VOUT pin for the output voltage are separated:

(1) When changing the output voltage by external resistance.

(2) When outputting a high voltage such as +15 V or + 20 V.

Choose the products in Table 25 according to applications (1) and (2) above.

Table 25

Output Voltage V_{CC}	$1.8\text{ V} \leq V_{CC} < 5\text{ V}$	$5\text{ V} \leq V_{CC}$	Reference Circuit
S-835xx18	Yes	Yes	Application circuit 1 (Figure 26)
S-835xx50	—	Yes	Application circuit 1 (Figure 26)
Connection to VDD pin	V_{IN} or V_{CC}	V_{IN}	—

Cautions 1. This IC starts a step-up operation at $V_{DD} = 0.8$ V, but set $1.8 \leq V_{DD} \leq 10$ V to stabilize the output voltage and frequency of the oscillator.

(Input a voltage of 1.8 V or more at the VDD pin for all products with a setting less than 1.9 V.)

An input voltage of 1.8 V or more at the VDD pin allows connection of the VDD pin to either the input power pin VIN or output power pin VOUT.

2. Choose external resistors R_A and R_B so as to not affect the output voltage, considering that there is impedance between the VOUT and VSS pins in the IC chip.

The internal resistance between the VOUT and VSS pins is as follows:

(1) S-835xx18 → 2.1 MΩ to 14.8 MΩ

(2) S-835xx20 → 1.4 MΩ to 14.8 MΩ

(3) S-835xx30 → 1.4 MΩ to 14.2 MΩ

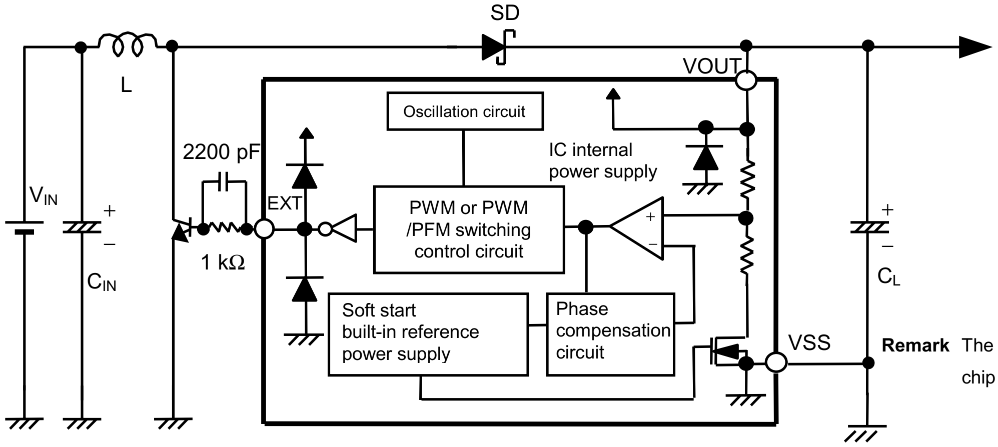
(4) S-835xx50 → 1.4 MΩ to 12.1 MΩ

3. Attach a capacitor (C_C) in parallel to the R_A resistance when an unstable event such as oscillation of the output voltage occurs. Calculate C_C using the following equation:

$$C_C(F) = \frac{1}{2 \bullet \pi \bullet R_A \bullet 20\text{ kHz}}$$

■ Standard Circuits

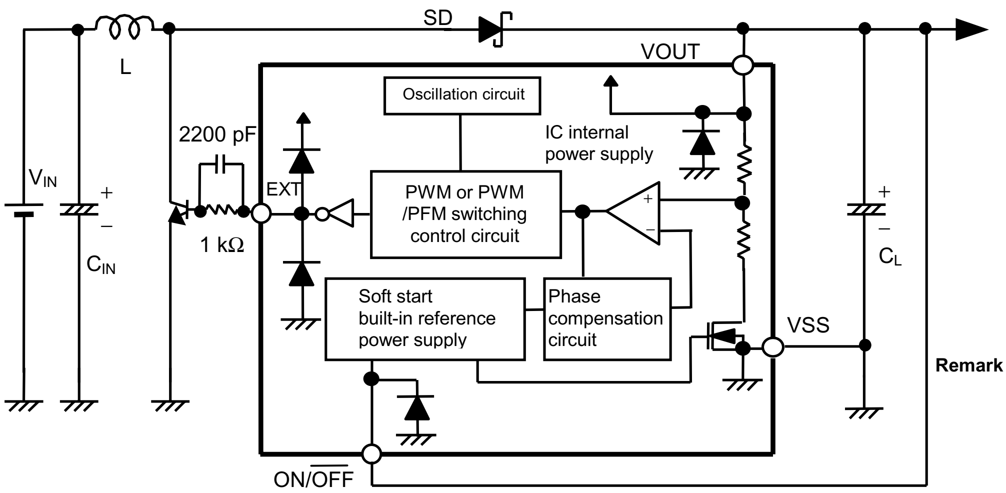
(1) S-8357BxxMA, S-8357BxxUA, S-8358BxxMA, S-8358BxxUA



Remark The power supply for the IC chip is from the VOUT pin.

Figure 19

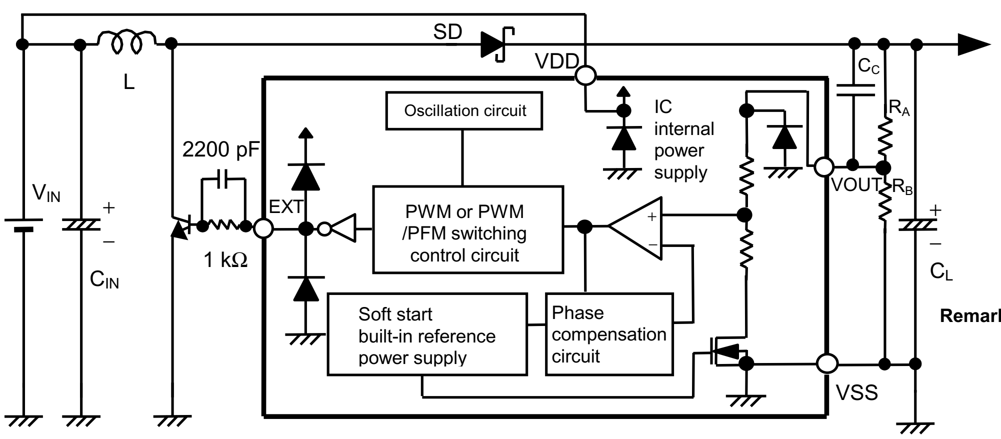
(2) S-8357BxxMC, S-8357FxxMC/BD, S-8357HxxMC/BD, S-8357NxxMC/BD
S-8358BxxMC, S-8358FxxMC/BD, S-8358HxxMC/BD, S-8358NxxMC/BD



Remark The power supply for the IC chip is from the VOUT pin.

Figure 20

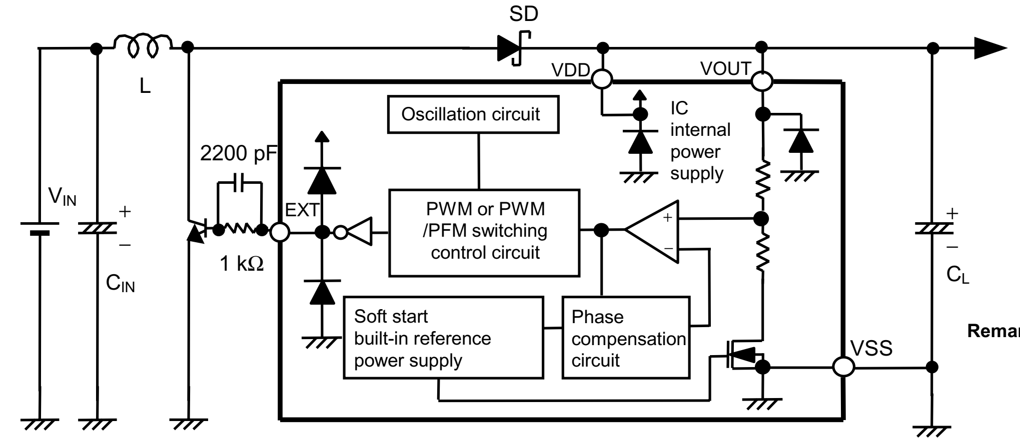
(3) S-8357ExxMC, S-8357GxxMC/BD, S-8357JxxMC/BD, S-8357PxxMC/BD
S-8358ExxMC, S-8358GxxMC/BD, S-8358JxxMC/BD, S-8358PxxMC/BD



Remark The power supply for the IC chip is from the VDD pin.

Figure 21

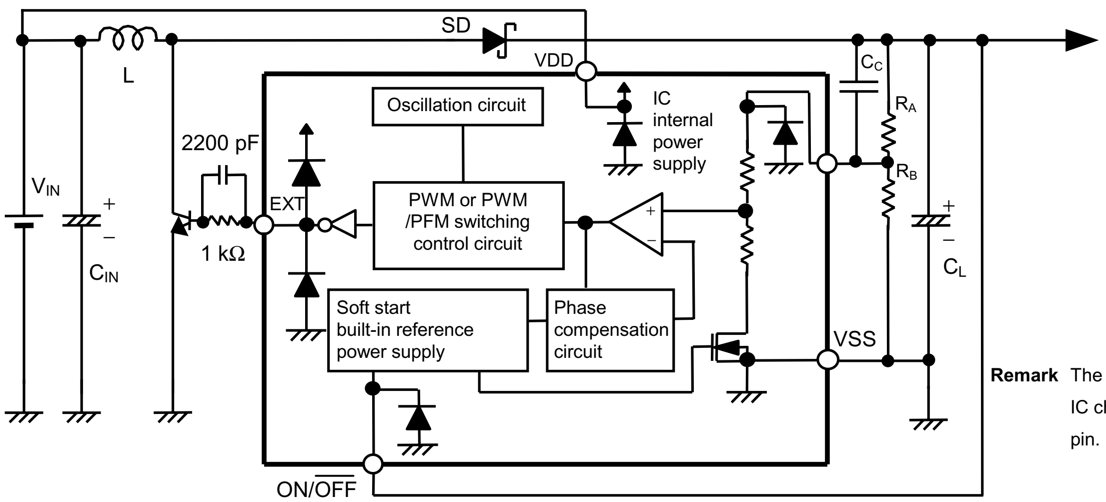
(4) S-8357ExxMC, S-8357GxxMC/BD, S-8357JxxMC/BD
S-8358ExxMC, S-8358GxxMC/BD, S-8358JxxMC/BD



Remark The power supply for the IC chip is from the VDD pin.

Figure 22

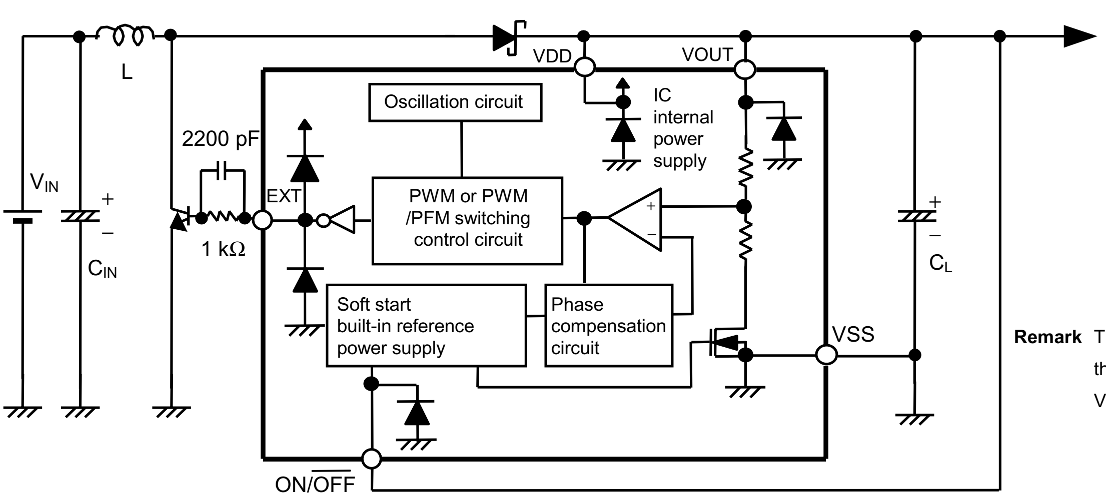
(5) S-8355KxxMC/BD, S-8355LxxMC/BD, S-8355MxxMC/BD, S-8355QxxMC/BD
S-8356KxxMC/BD, S-8356LxxMC/BD, S-8356MxxMC/BD, S-8356QxxMC/BD



Remark The power supply for the IC chip is from the VDD pin.

Figure 23

(6) S-8355KxxMC/BD, S-8355LxxMC/BD, S-8355MxxMC/BD
S-8356KxxMC/BD, S-8356LxxMC/BD, S-8356MxxMC/BD



Remark The power supply for the IC chip is from the VDD pin.

Figure 24

■ Power Dissipation of Package

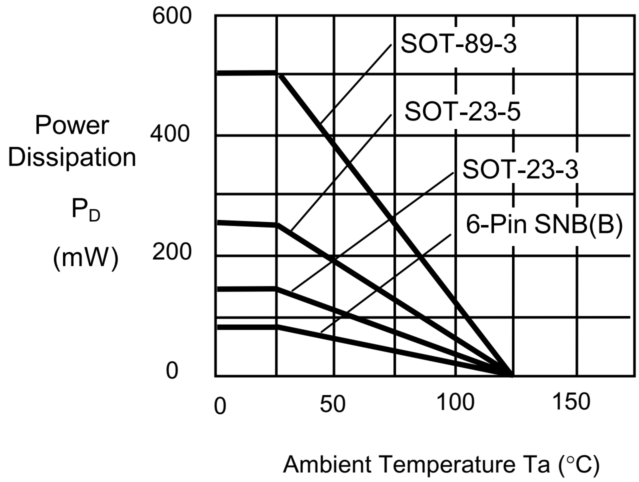


Figure 25 Power Dissipation of Package (Before Mounting)

■ Precautions

- Mount external capacitors, the diode, and the coil as close as possible to the IC.
- Characteristics ripple voltage and spike noise occur in switching regulators. Because these largely depend on the coil and the capacitor used, check them using an actually mounted model.
- Make sure that the dissipation of the switching transistor (especially at a high temperature) does not exceed the allowable power dissipation of the package.
- The performance of this IC varies depending on the design of the PCB patterns, peripheral circuits and external parts. Thoroughly test all settings with your device. Also, try to use the recommended external parts. If not, contact an SII sales person.
- Do not apply an electrostatic discharge to this IC that exceeds the performance ratings of the built-in electrostatic protection circuit.
- SII claims no responsibility for any disputes arising out of or in connection with any infringement by products including this IC of patents owned by a third party.

■ Application Circuits

1. LCD Power Supply

The following example is an application power supply circuit (15 V/20 V output) to drive an LCD panel, and its characteristics.

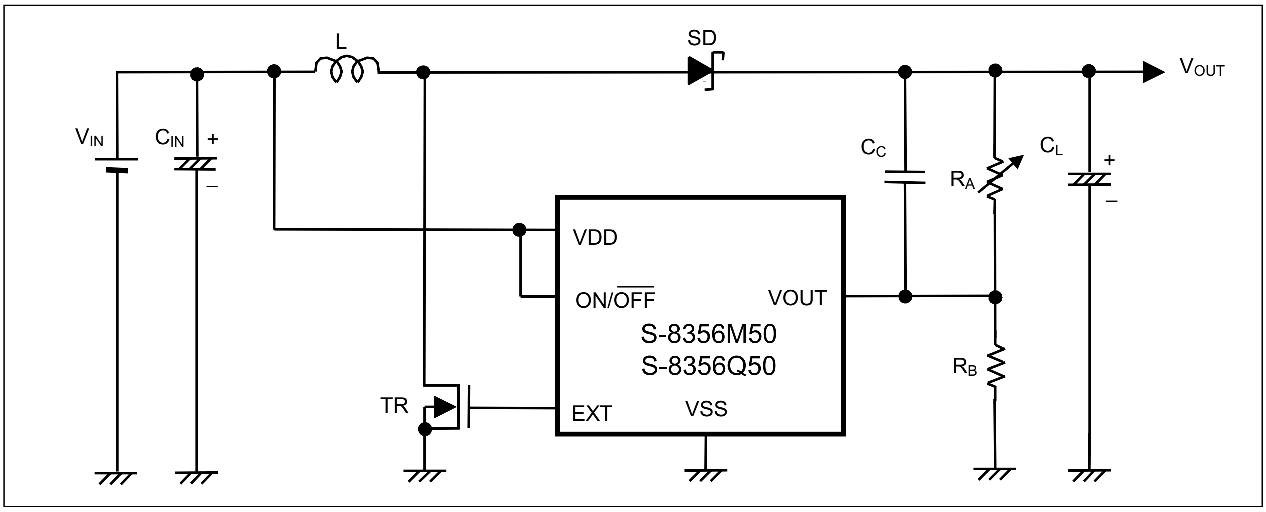
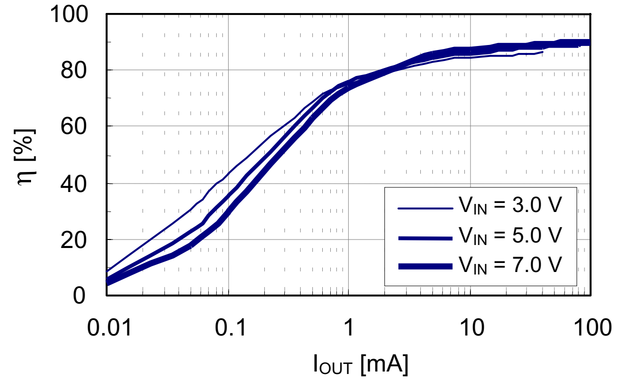


Figure 26 Power Supply Circuit for LCD

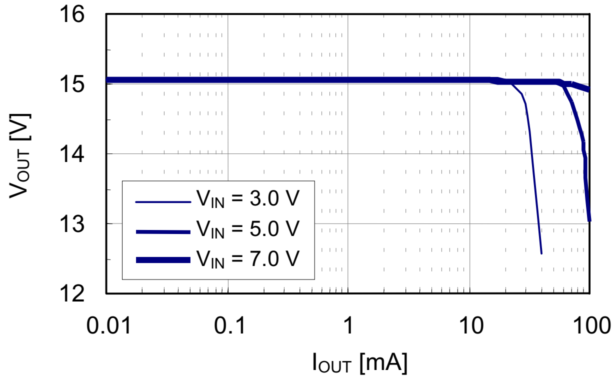
Table 26

	Output Voltage	IC	L Type Name	TR Type Name	SD Type Name	C_L	R_a	R_b	C_c	Output Characteristics
(1)	15 V	S-8356M50	CDRH5D18-220	MCH3405	MA2Z748	F93 (20 V,10 μF)	580 kΩ	300 kΩ	15 pF	(1-a),(1-b)
(2)	20 V	S-8356M50	CDRH5D18-220	FDN337N	MA729	F93 (25 V,10 μF)	575 kΩ	200 kΩ	15 pF	(2-a),(2-b)
(3)	10 V	S-8356Q50	CDRH5D18-100	MCH3405	MA2Z748	F93 (20 V,10 μF)	560 kΩ	560 kΩ	15 pF	(3-a),(3-b)

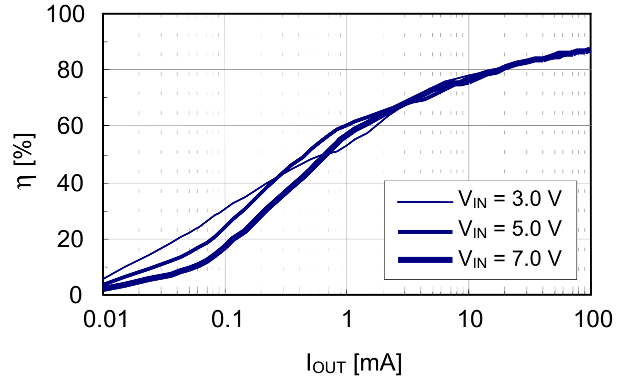
(1-a) Output current (I_{OUT}) vs. Efficiency (η)



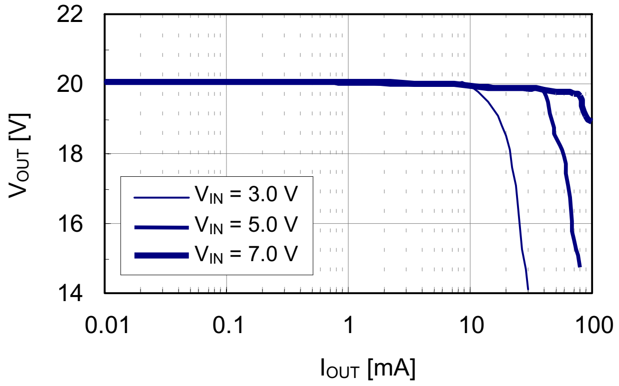
(1-b) Output current (I_{OUT}) vs. Output voltage (V_{OUT})



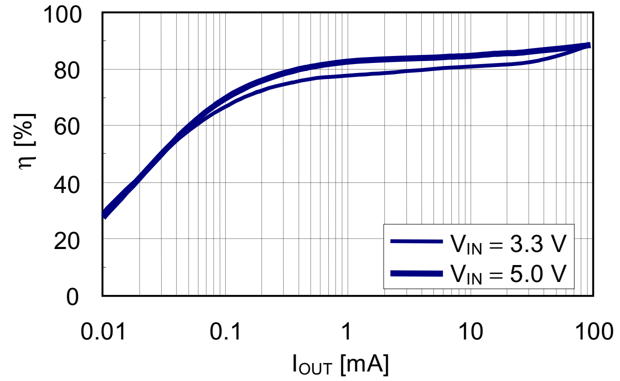
(2-a) Output current (I_{OUT}) vs. Efficiency (η)



(2-b) Output current (I_{OUT}) vs. Output voltage (V_{OUT})



(3-a) Output current (I_{OUT}) vs. Efficiency (η)



(3-b) Output current (I_{OUT}) vs. Output voltage (V_{OUT})

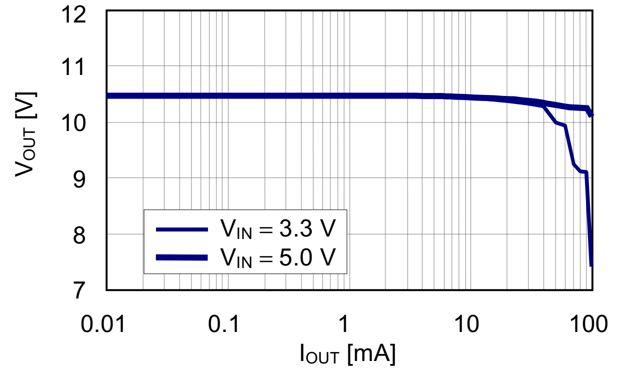


Figure 27 LCD Power Supply Output Characteristics

2. Ceramic Capacitor (Application Example)

If using small ESR parts such as ceramic capacitors for the output capacitance, attach a resistor (R1) corresponding to the ESR in series to the ceramic capacitor (C_L) as shown in the following circuit.

R1 may depend on L, the capacitance, the wiring, and the application (output load).

The following example is a circuit using R1 = 100 mΩ, output voltage = 3.3 V, output load = 500 mA and its characteristics.

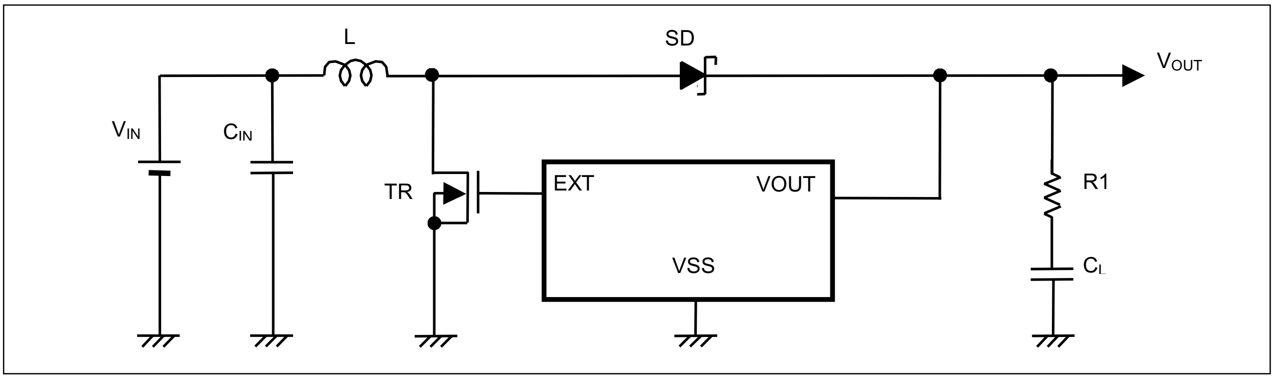
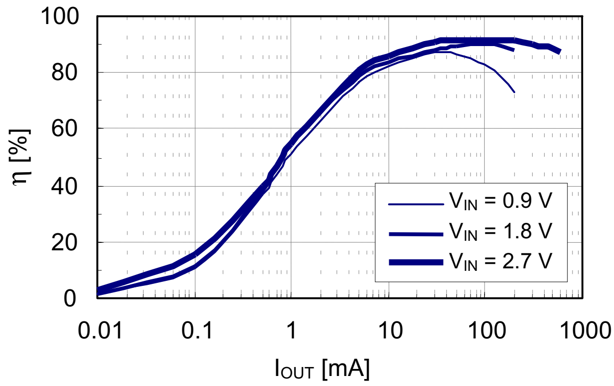


Figure 28 Circuit Using Ceramic Capacitor

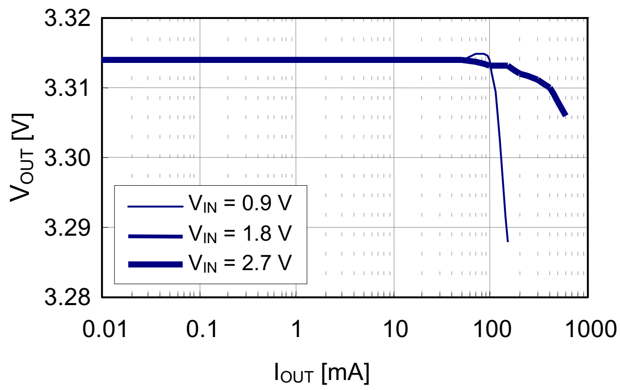
Table 27

	IC	L Type Name	TR Type Name	SD Type Name	C_L (Ceramic Capacitor)	R1	Output Characteristics
(1)	S-8357F33	CDRH6D28-220	FDN335N	M1FH3	10 μF × 2	100 mΩ	(1-a), (1-b), (1-c)
(2)	S-8358B50	CDRH6D28-470	FDN335N	M1FH3	10 μF × 2	100 mΩ	(2-a), (2-b), (2-c)
(3)	S-8357N33	CDRH6D28-100	FDN335N	M1FH3	10 μF × 2	100 mΩ	(3-a), (3-b), (3-c)

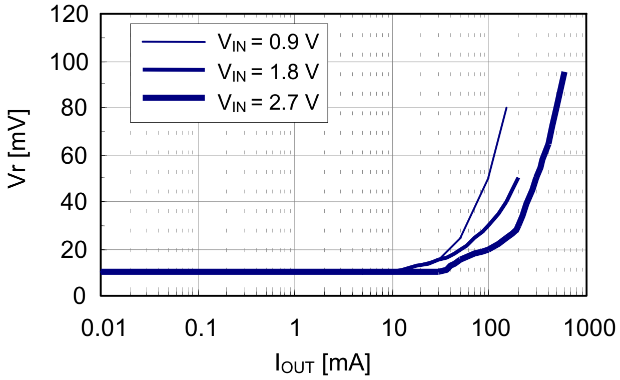
(1-a) Output current (I_{OUT}) vs. Efficiency (η)



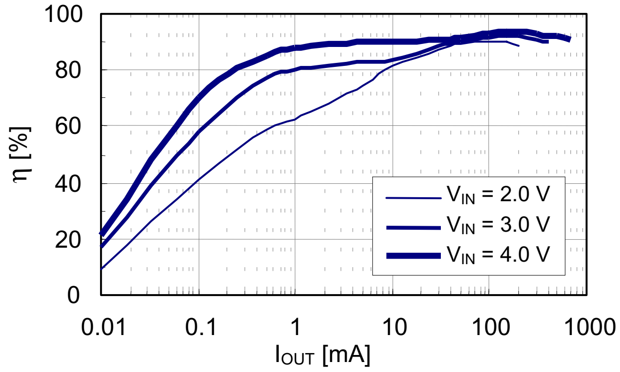
(1-b) Output current (I_{OUT}) vs. Output voltage (V_{OUT})



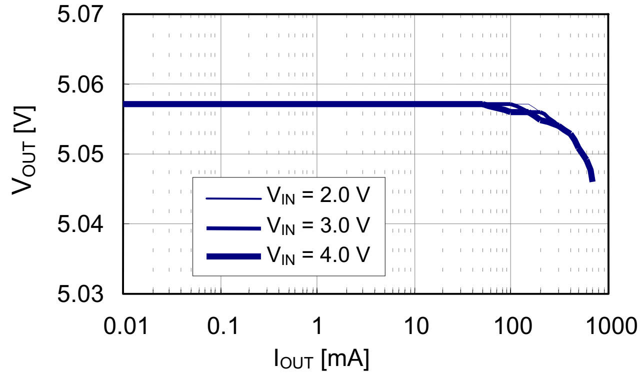
(1-c) Output current (I_{OUT}) vs. Ripple voltage (Vr)



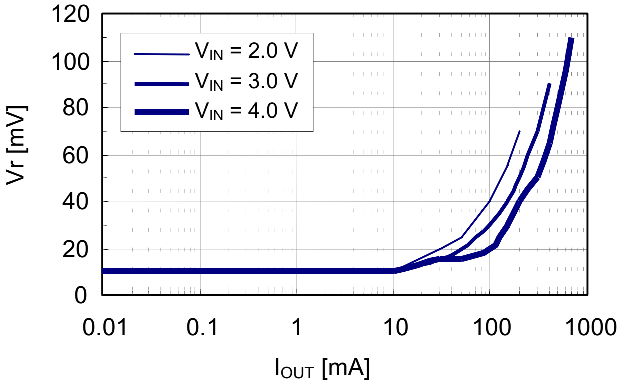
(2-a) Output current (I_{OUT}) vs. Efficiency (η)



(2-b) Output current (I_{OUT}) vs. Output voltage (V_{OUT})



(2-c) Output current (I_{OUT}) vs. Ripple voltage (Vr)



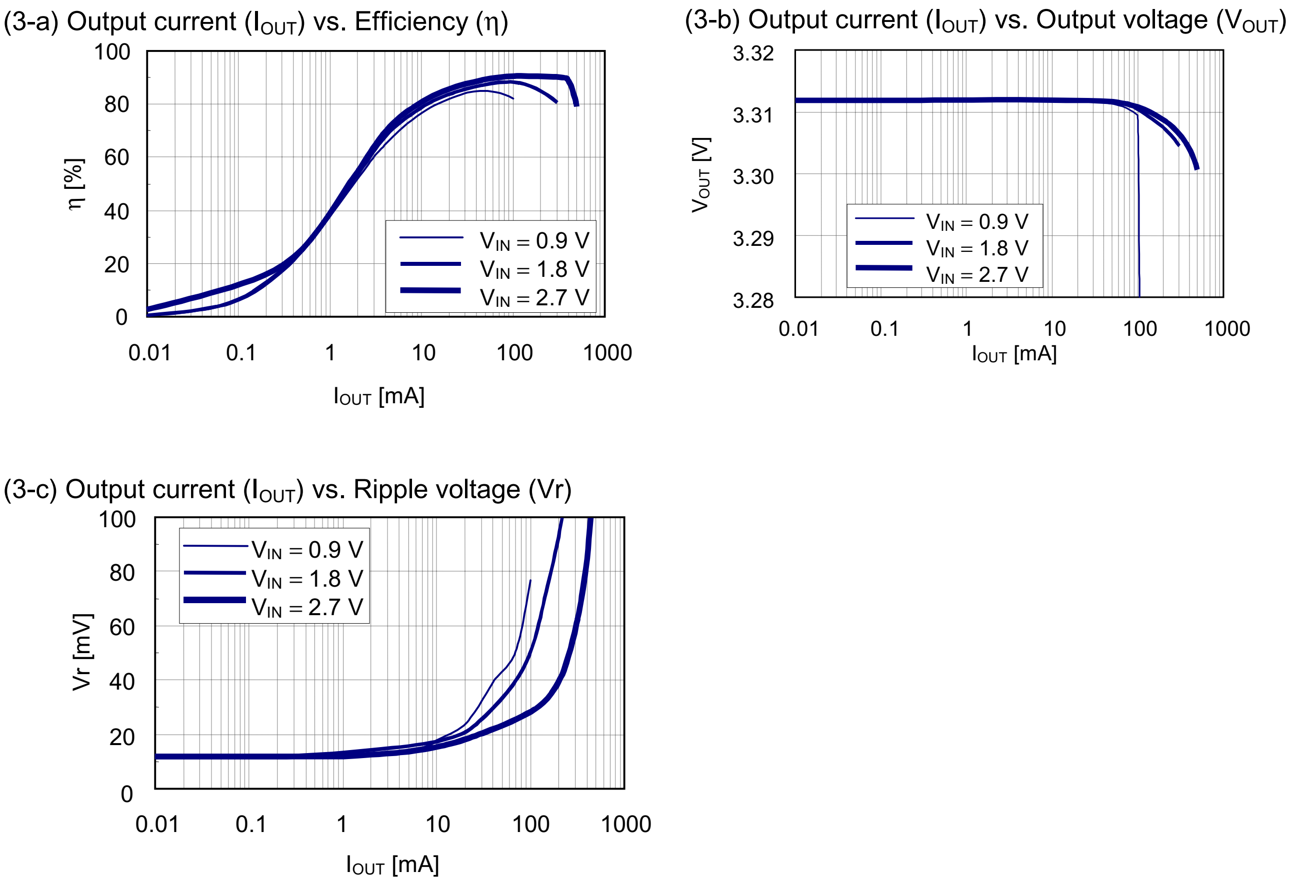
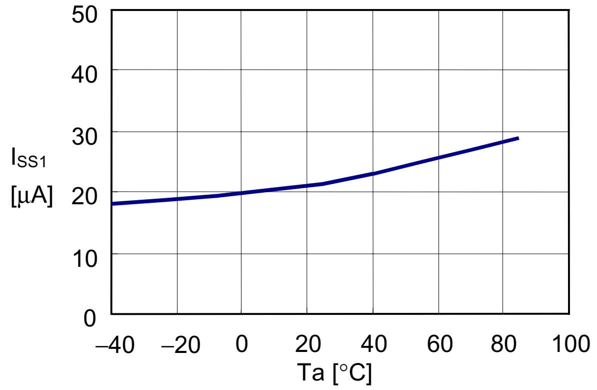


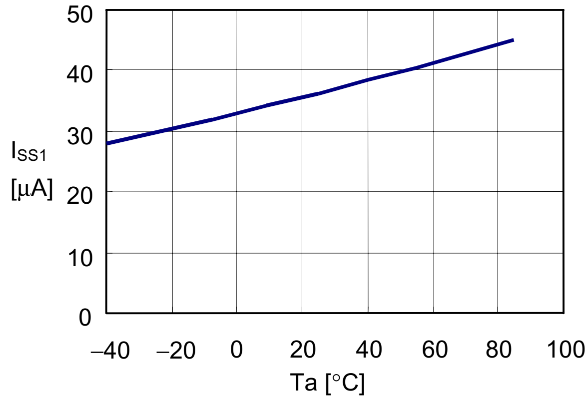
Figure 29 Ceramic Capacitor Circuit Output Characteristics

■ Example of Major Temperature Characteristics (Ta = –40 to 85°C)

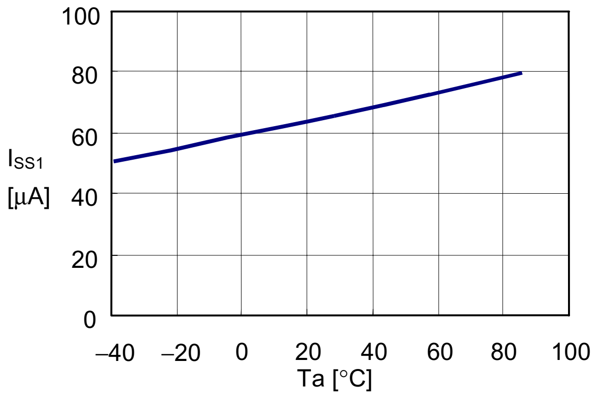
I_{SS1} vs. Ta (V_{OUT} = 3.3 V, f_{OSC} = 100 kHz)



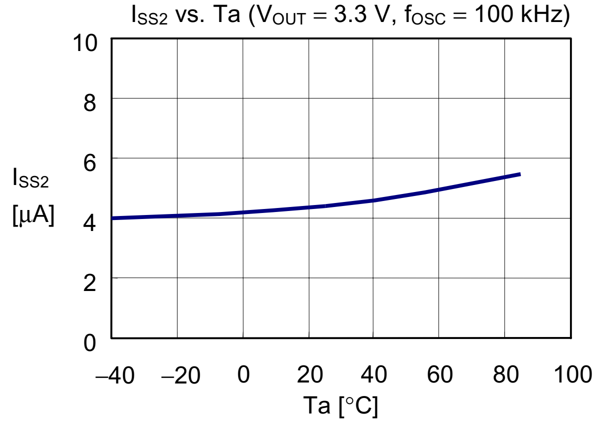
I_{SS1} vs. Ta (V_{OUT} = 3.3 V, f_{OSC} = 300 kHz)



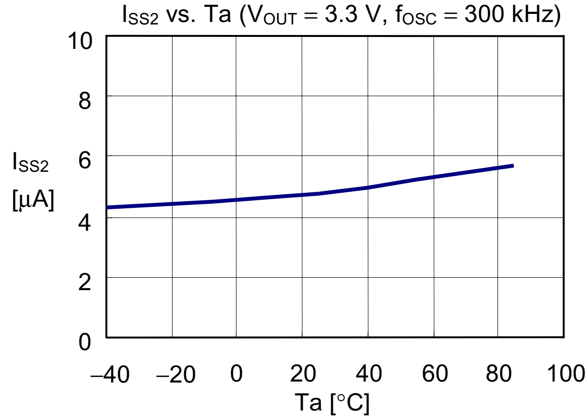
I_{SS1} vs. Ta (V_{OUT} = 3.3 V, f_{OSC} = 600 kHz)



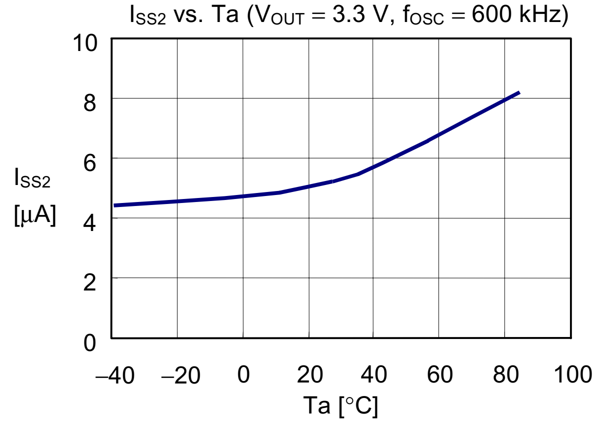
I_{SS2} vs. Ta (V_{OUT} = 3.3 V, f_{OSC} = 100 kHz)



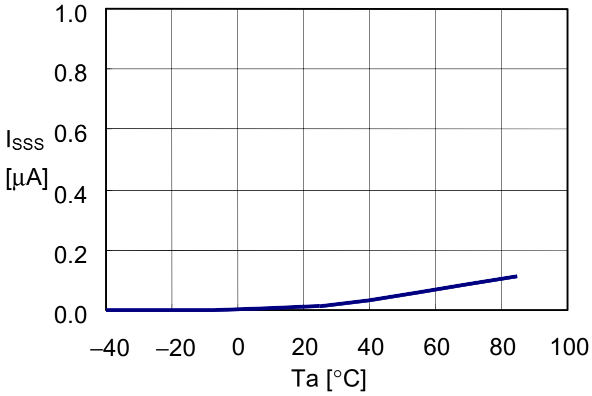
I_{SS2} vs. Ta (V_{OUT} = 3.3 V, f_{OSC} = 300 kHz)



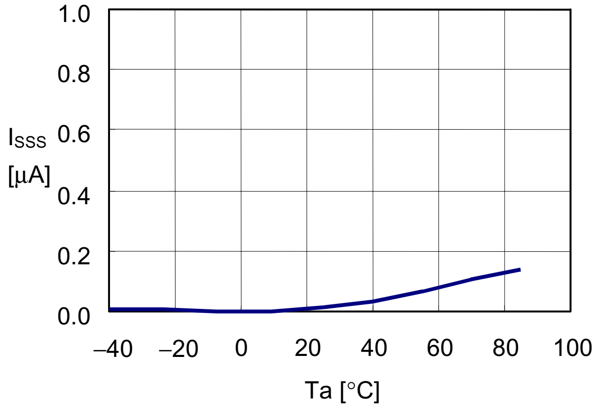
I_{SS2} vs. Ta (V_{OUT} = 3.3 V, f_{OSC} = 600 kHz)



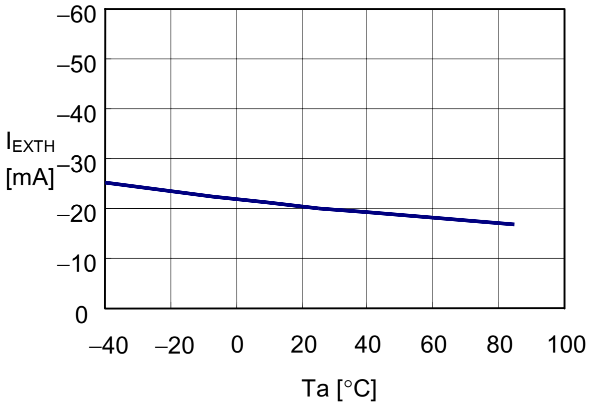
I_{SSS} vs. Ta (V_{OUT} = 3.3 V, f_{OSC} = 100 kHz)



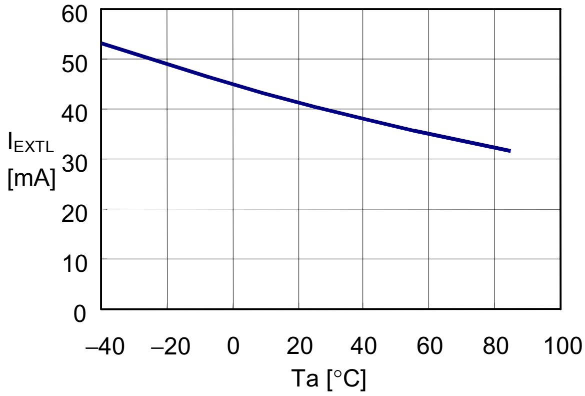
I_{SSS} vs. Ta (V_{OUT} = 3.3 V, f_{OSC} = 300 kHz)



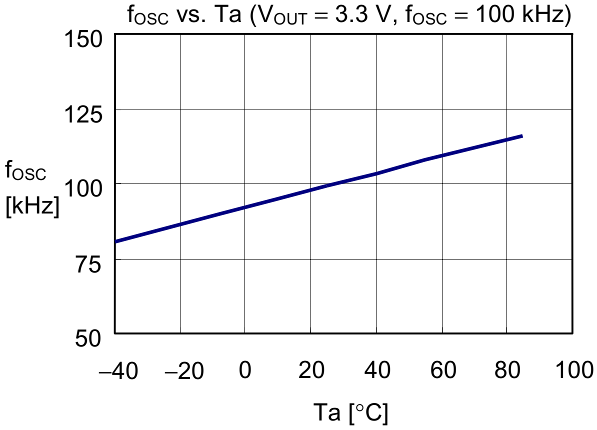
I_{EXTH} vs. Ta (V_{OUT} = 3.3 V, f_{OSC} = 300 kHz)



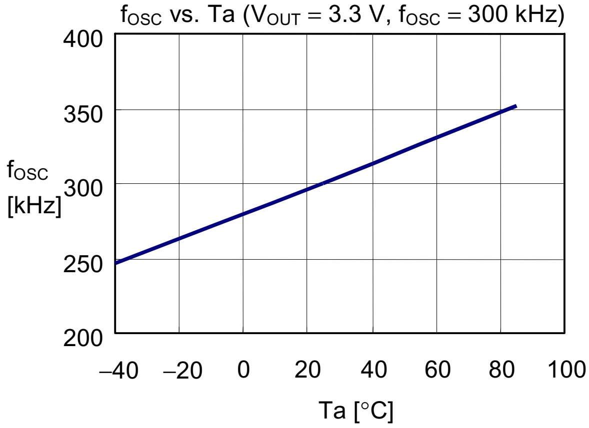
I_{EXTL} vs. Ta (V_{OUT} = 3.3 V, f_{OSC} = 300 kHz)



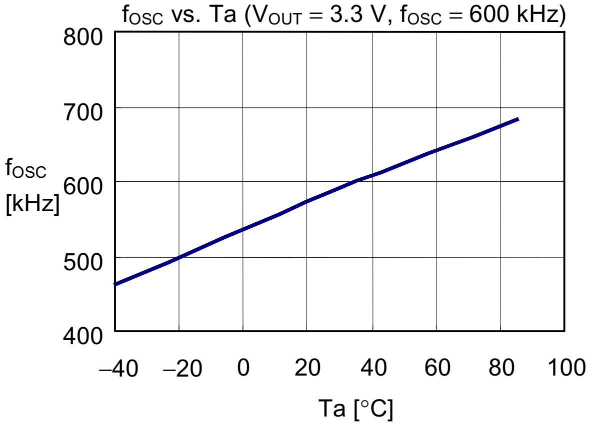
f_{OSC} vs. Ta (V_{OUT} = 3.3 V, f_{OSC} = 100 kHz)



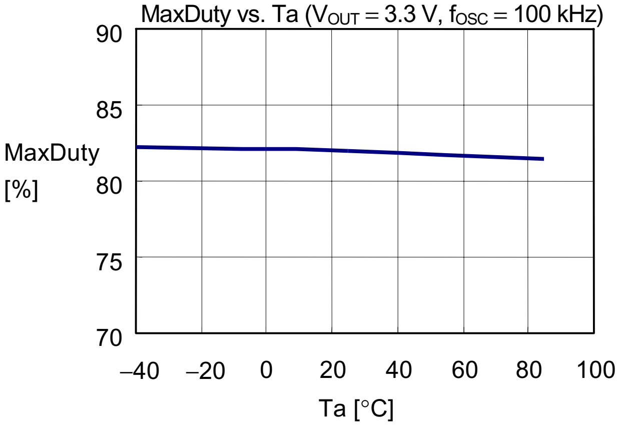
f_{OSC} vs. Ta (V_{OUT} = 3.3 V, f_{OSC} = 300 kHz)



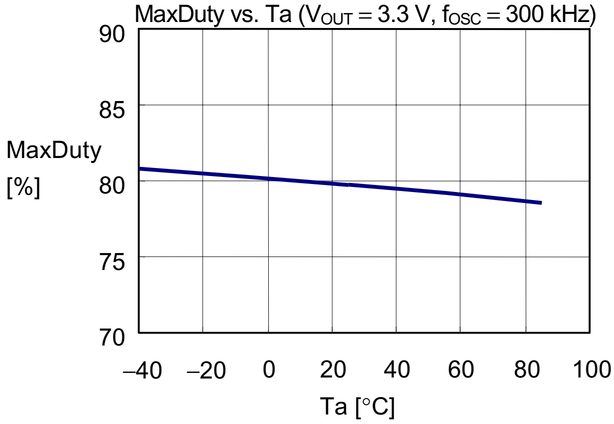
f_{OSC} vs. Ta (V_{OUT} = 3.3 V, f_{OSC} = 600 kHz)



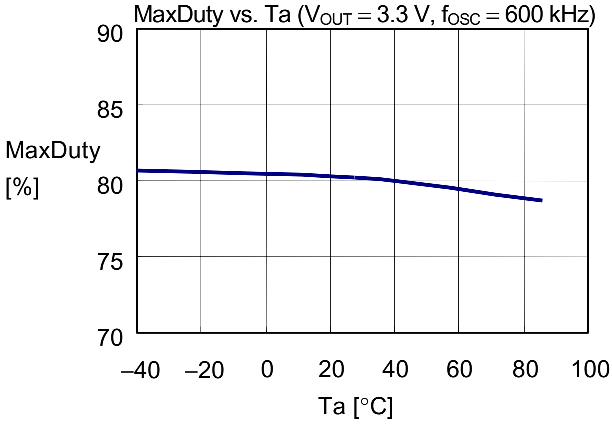
MaxDuty vs. Ta (V_{OUT} = 3.3 V, f_{OSC} = 100 kHz)



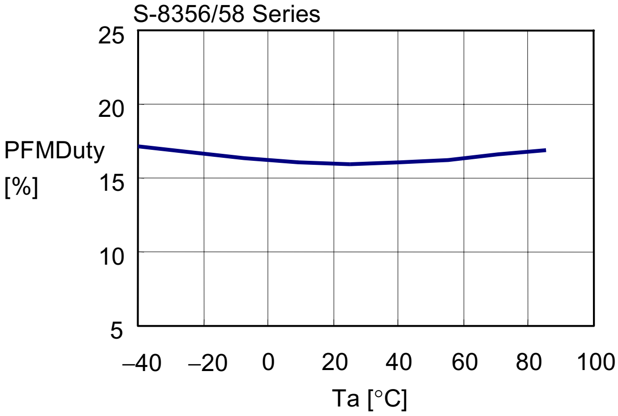
MaxDuty vs. Ta (V_{OUT} = 3.3 V, f_{OSC} = 300 kHz)



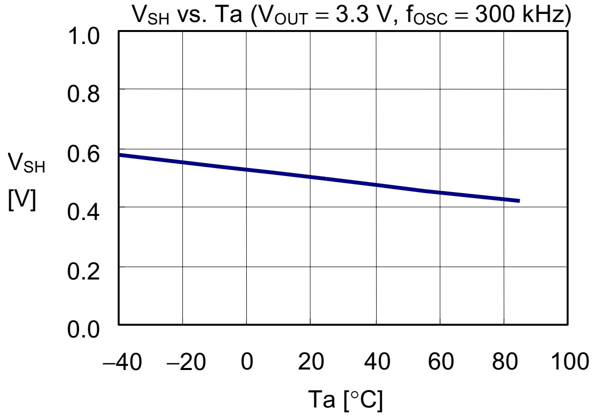
MaxDuty vs. Ta (V_{OUT} = 3.3 V, f_{OSC} = 600 kHz)



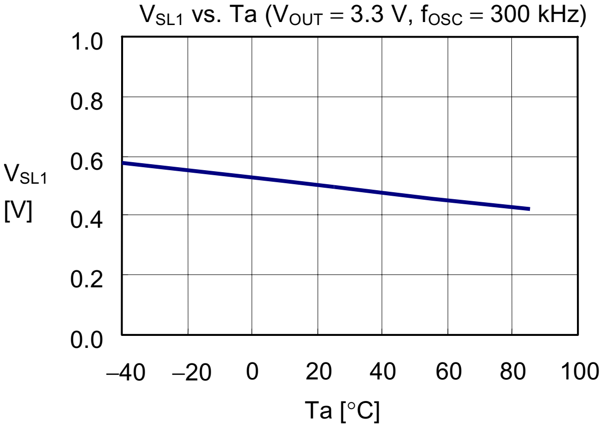
PFMDuty vs. Ta (V_{OUT} = 3.3 V, f_{OSC} = 100 kHz)
S-8356/58 Series



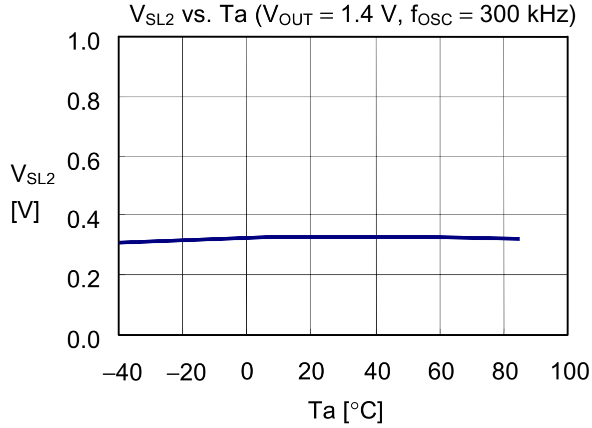
V_{SH} vs. Ta (V_{OUT} = 3.3 V, f_{OSC} = 300 kHz)

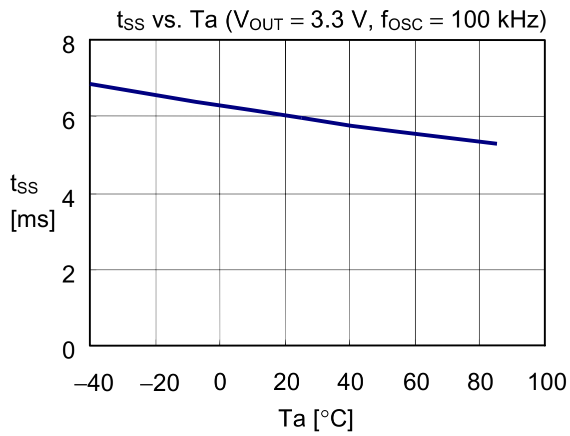


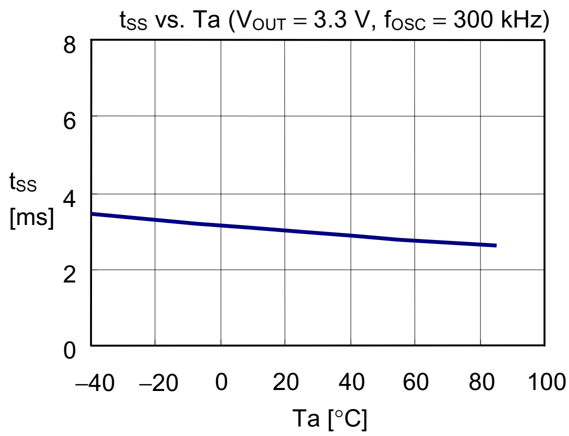
V_{SL1} vs. Ta (V_{OUT} = 3.3 V, f_{OSC} = 300 kHz)

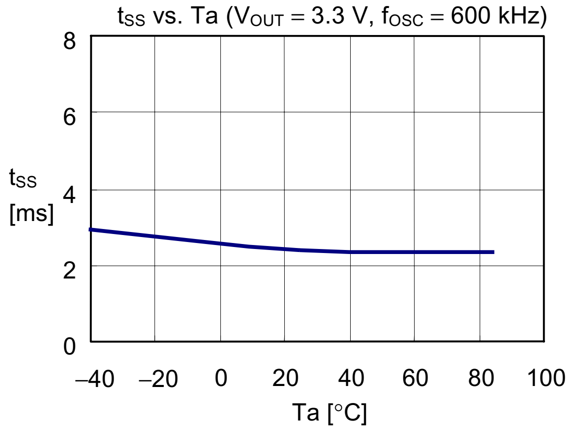


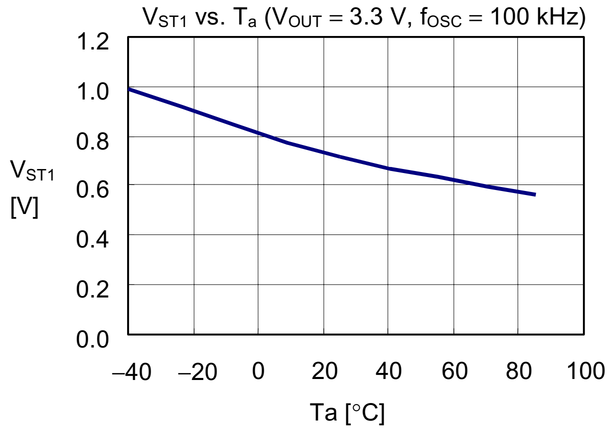
V_{SL2} vs. Ta (V_{OUT} = 1.4 V, f_{OSC} = 300 kHz)

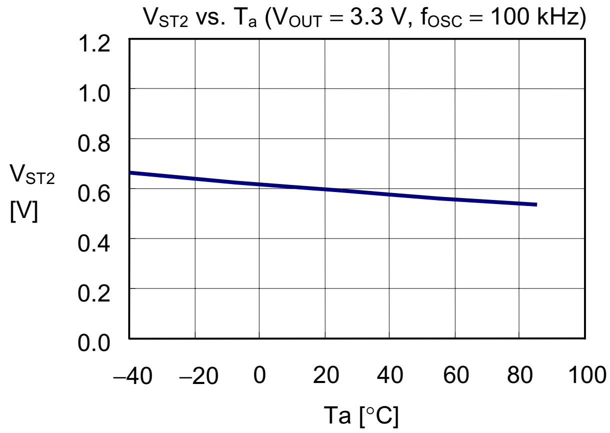


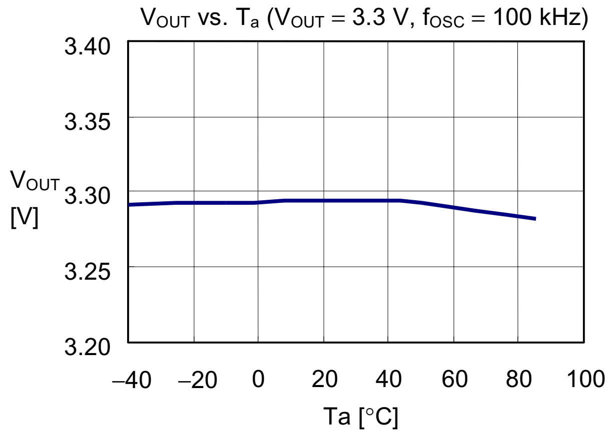

t_{SS} vs. Ta (V_{OUT} = 3.3 V, f_{OSC} = 100 kHz)
t_{SS} [ms]
Ta [°C]

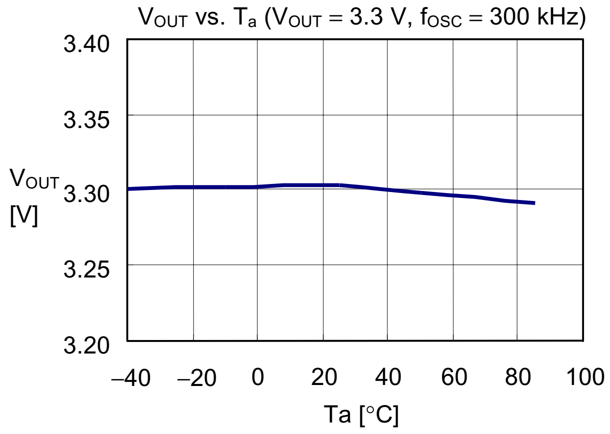

t_{SS} vs. Ta (V_{OUT} = 3.3 V, f_{OSC} = 300 kHz)
t_{SS} [ms]
Ta [°C]

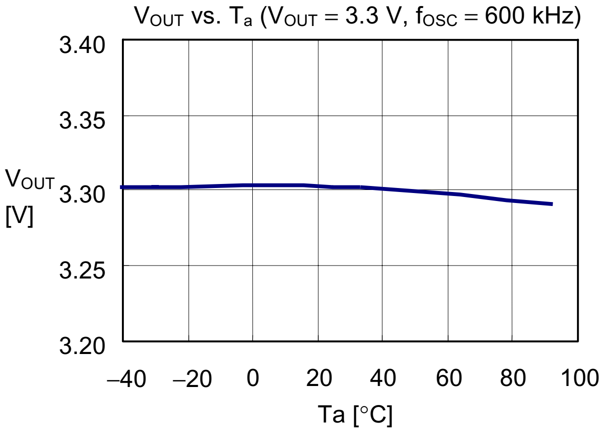

t_{SS} vs. Ta (V_{OUT} = 3.3 V, f_{OSC} = 600 kHz)
t_{SS} [ms]
Ta [°C]


V_{ST1} vs. T_a (V_{OUT} = 3.3 V, f_{OSC} = 100 kHz)
V_{ST1} [V]
Ta [°C]

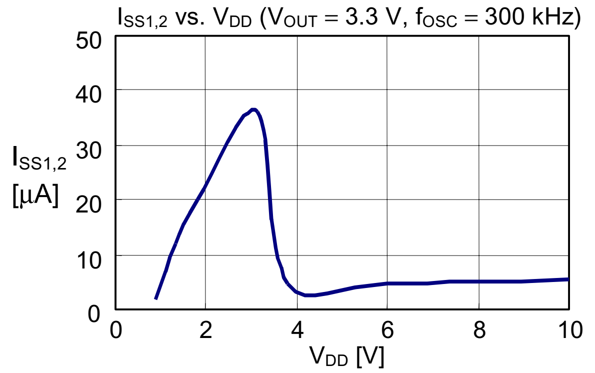

V_{ST2} vs. T_a (V_{OUT} = 3.3 V, f_{OSC} = 100 kHz)
V_{ST2} [V]
Ta [°C]

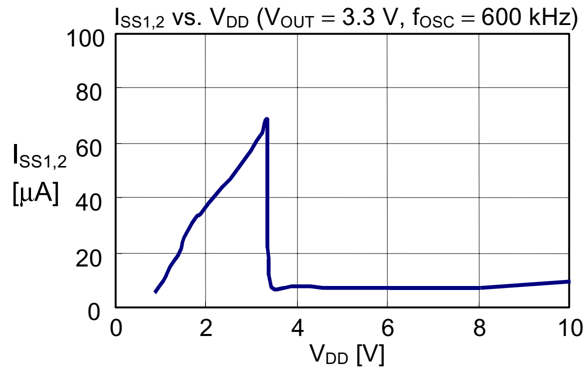

V_{OUT} vs. T_a (V_{OUT} = 3.3 V, f_{OSC} = 100 kHz)
V_{OUT} [V]
Ta [°C]

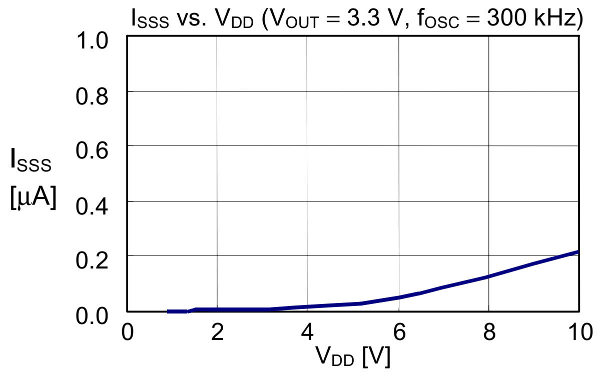

V_{OUT} vs. T_a (V_{OUT} = 3.3 V, f_{OSC} = 300 kHz)
V_{OUT} [V]
Ta [°C]

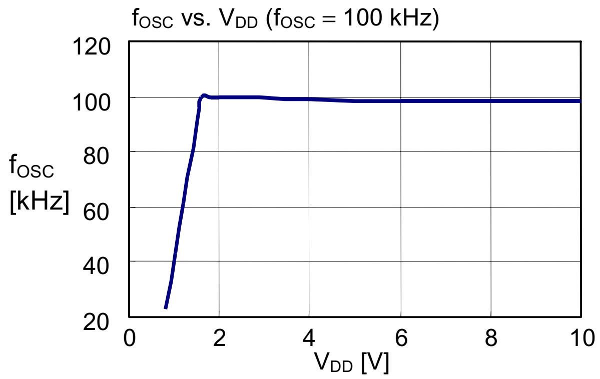

V_{OUT} vs. T_a (V_{OUT} = 3.3 V, f_{OSC} = 600 kHz)
3.40
3.35
V_{OUT} [V]
3.30
3.25
3.20
−40
−20
0
20
40
60
80
100
Ta [°C]

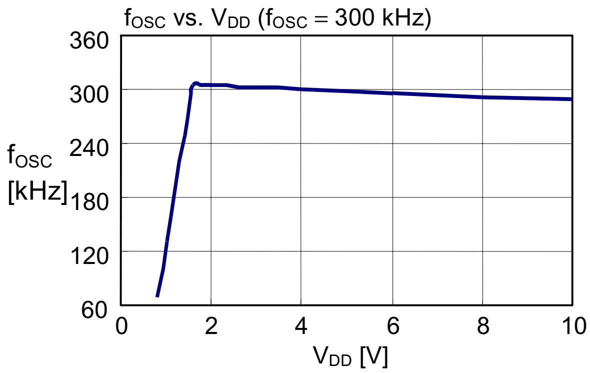
■ Example of Major Power Supply Dependence Characteristics (Ta = 25°C)

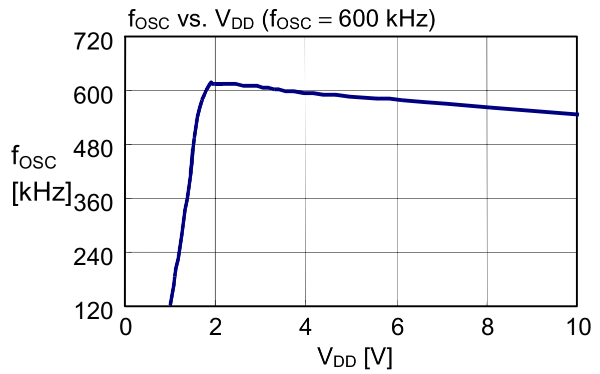




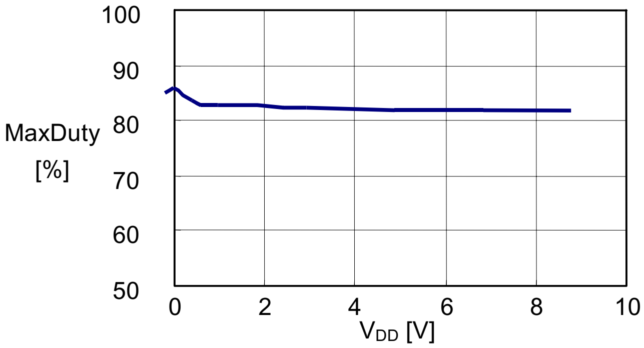




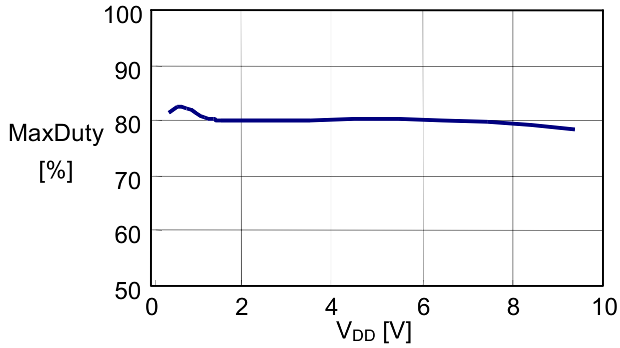




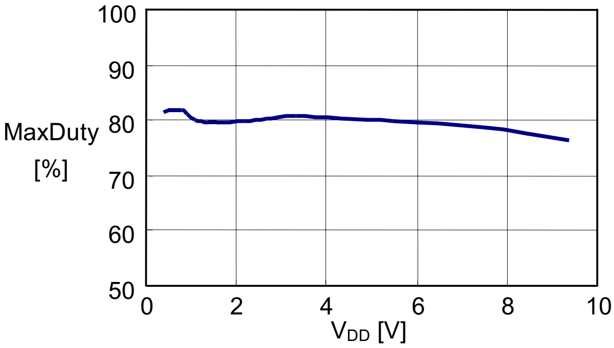
MaxDuty vs. V_{DD} (f_{OSC} = 100 kHz)



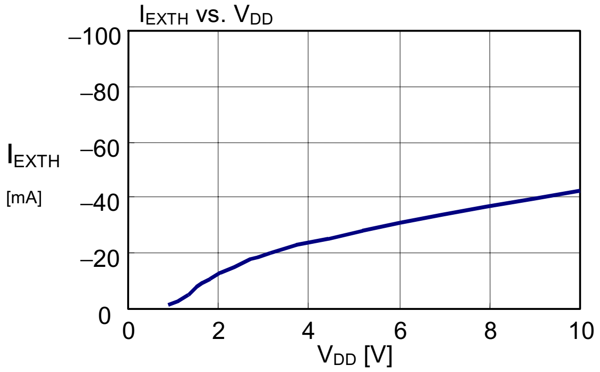
MaxDuty vs. V_{DD} (f_{OSC} = 300 kHz)



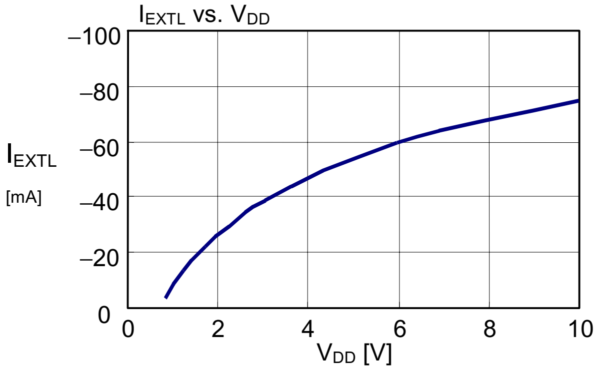
MaxDuty vs. V_{DD} (f_{OSC} = 600 kHz)



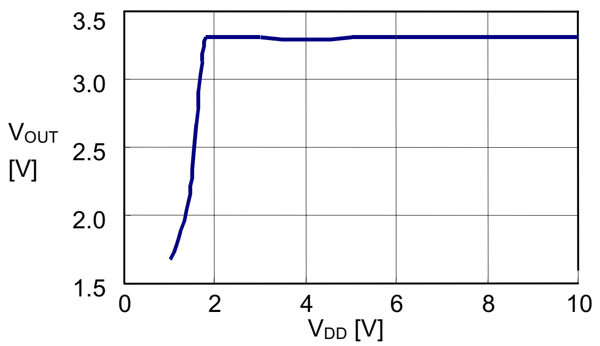
I_{EXTH} vs. V_{DD}



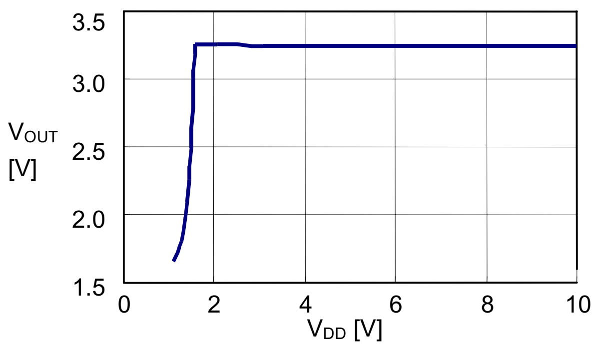
I_{EXTL} vs. V_{DD}



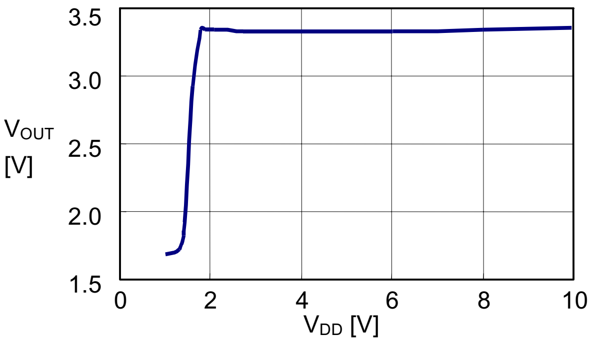
V_{OUT} vs. V_{DD}
(V_{OUT} = 3.3 V, f_{OSC} = 100 kHz, V_{DD} separate type)
V_{IN} = 1.98 V, I_{OUT} = 66 mA



V_{OUT} vs. V_{DD}
(V_{OUT} = 3.3 V, f_{OSC} = 300 kHz, V_{DD} separate type)
V_{IN} = 1.98 V, I_{OUT} = 66 mA



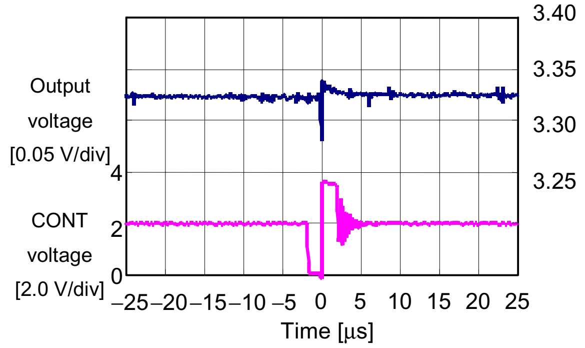
V_{OUT} vs. V_{DD}
(V_{OUT} = 3.3 V, f_{OSC} = 600 kHz, V_{DD} separate type)
V_{IN} = 1.98 V, I_{OUT} = 66 mA



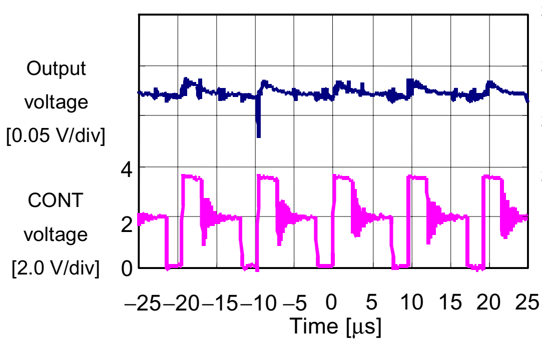
■ Output Waveforms

1. S-8358B33MC

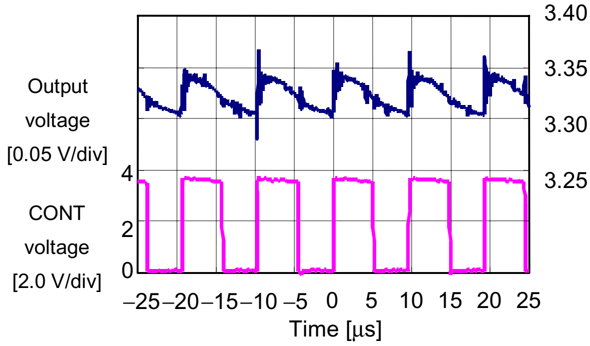
1-1. I_{OUT} = 1 mA



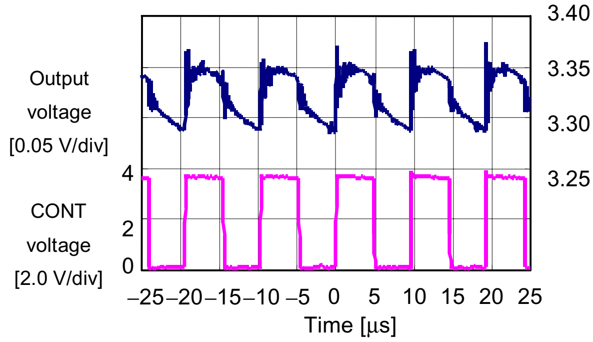
1-2. I_{OUT} = 20 mA



1-3. I_{OUT} = 100 mA

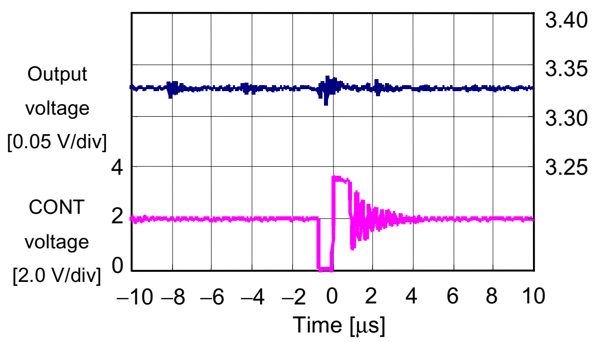


1-4. I_{OUT} = 200 mA

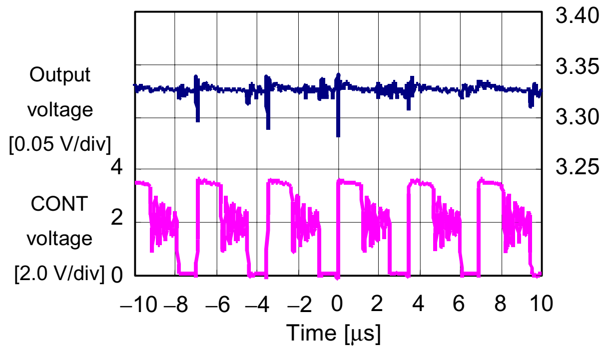


2. S-8358F33MC

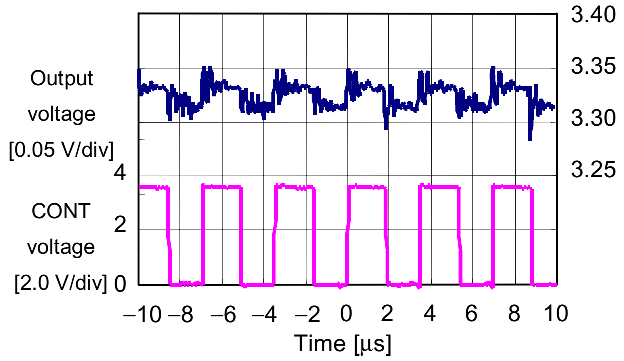
2-1. I_{OUT} = 1 mA



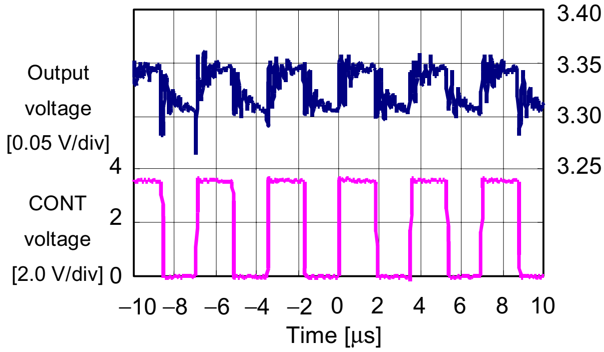
2-2. I_{OUT} = 10 mA



2-3. I_{OUT} = 100 mA

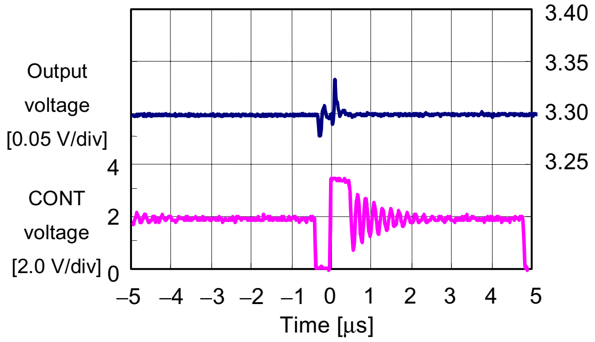


2-4. I_{OUT} = 200 mA

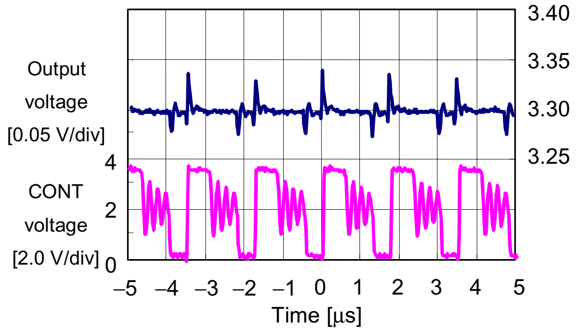


3. S-8358N33MC

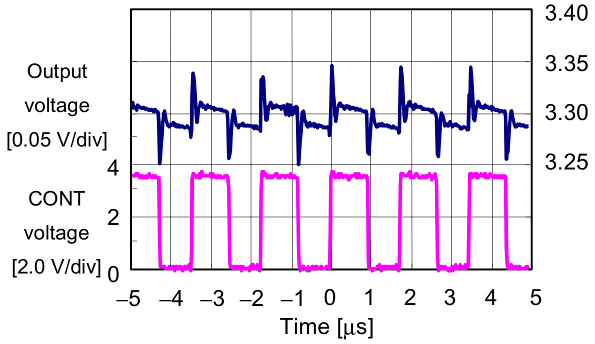
3-1. I_{OUT} = 1 mA



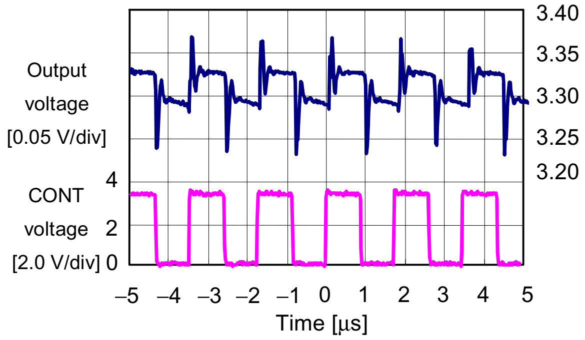
3-2. I_{OUT} = 10 mA



3-3. I_{OUT} = 100 mA



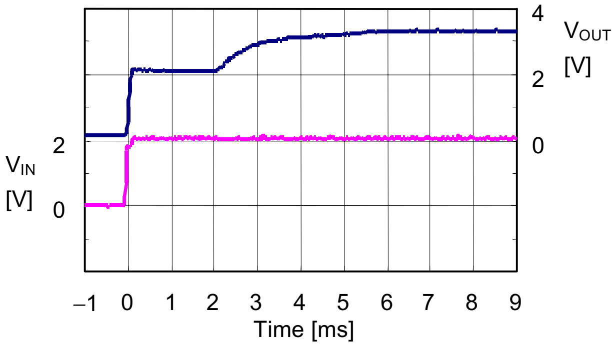
3-4. I_{OUT} = 200 mA



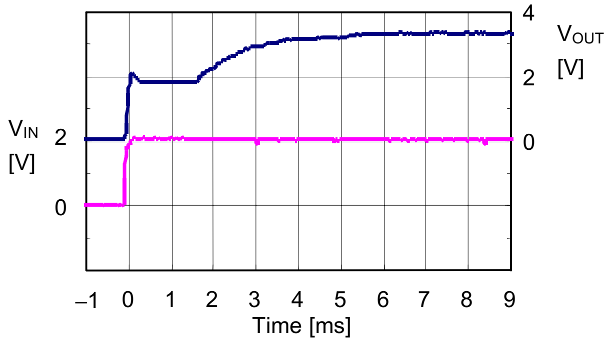
■ Examples of Transient Response characteristics

1. Powering ON (V_{IN}: 0 V → 2.0 V)

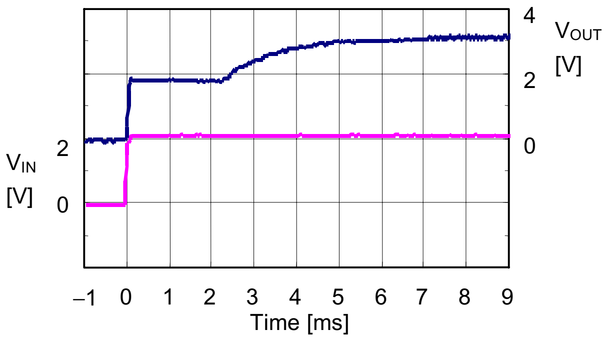
1-1. 100 kHz, I_{OUT} = 1 mA



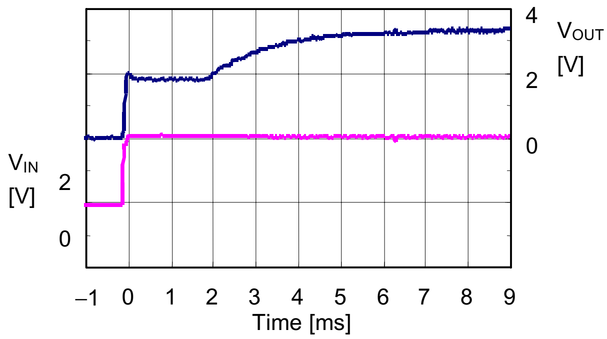
1-2. 100 kHz, I_{OUT} = 100 mA



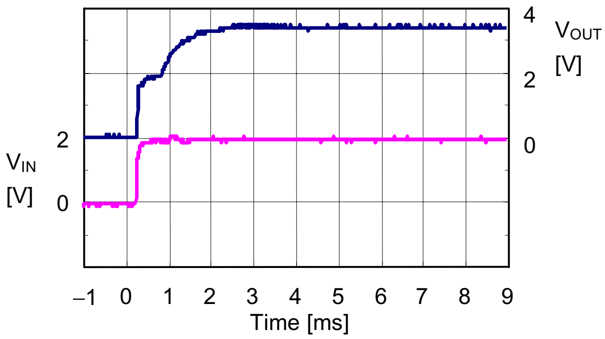
1-3. 300 kHz, I_{OUT} = 1 mA



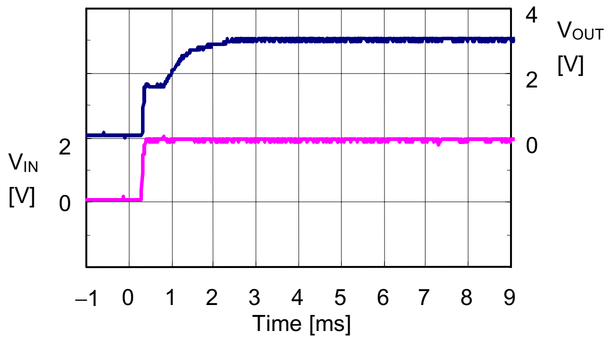
1-4. 300 kHz, I_{OUT} = 100 mA



1-5. 600 kHz, I_{OUT} = 1 mA

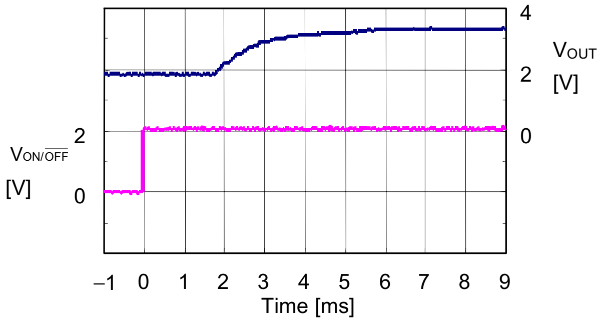


1-6. 600 kHz, I_{OUT} = 100 mA

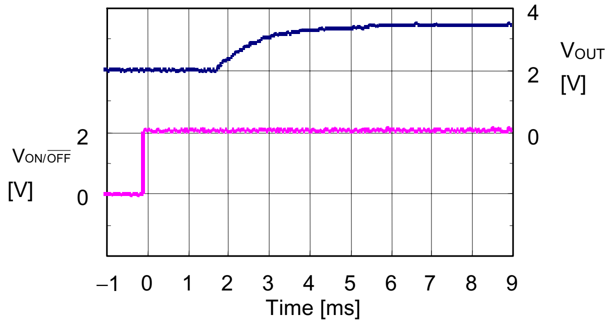


2. Responses of shutdown pin ($V_{ON/\overline{OFF}}$: 0 V → 2.0 V)

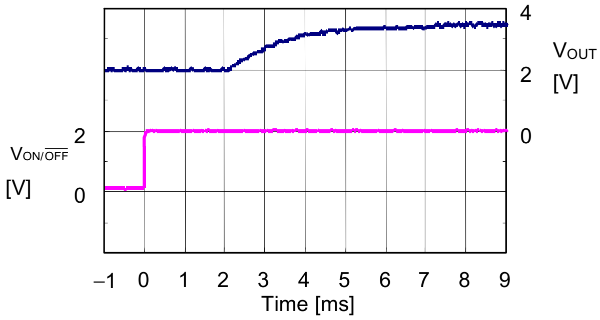
2-1. 100 kHz, I_{OUT} = 1 mA



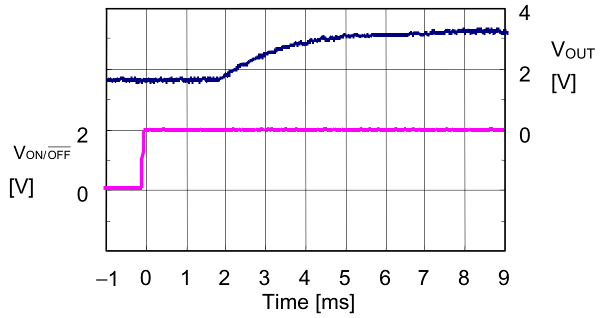
2-2. 100 kHz, I_{OUT} = 100 mA



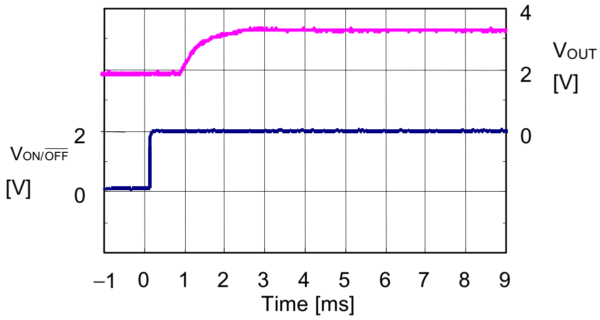
2-3. 300 kHz, I_{OUT} = 1 mA



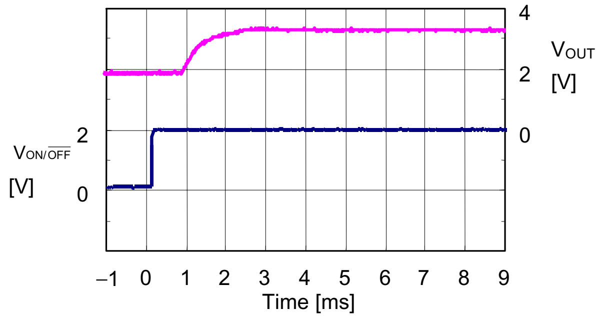
2-4. 300 kHz, I_{OUT} = 100 mA



2-5. 600 kHz, I_{OUT} = 1 mA

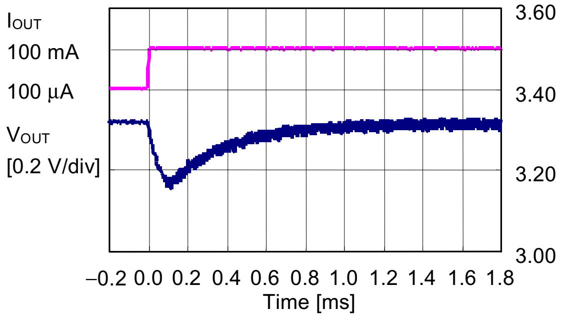


2-6. 600 kHz, I_{OUT} = 100 mA

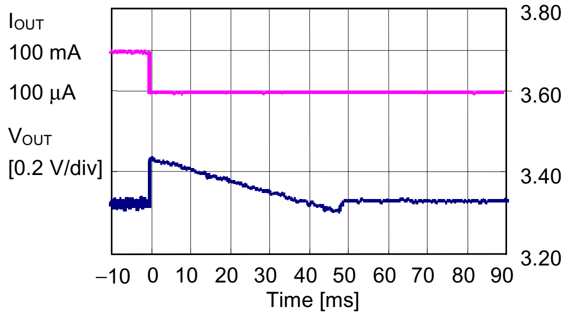


3. Load fluctuations

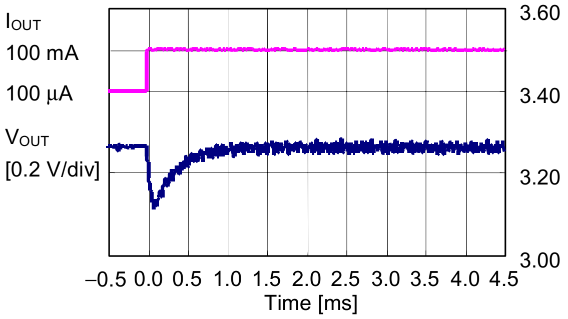
3-1. 100 kHz, I_{OUT}: 100 μA → 100 mA



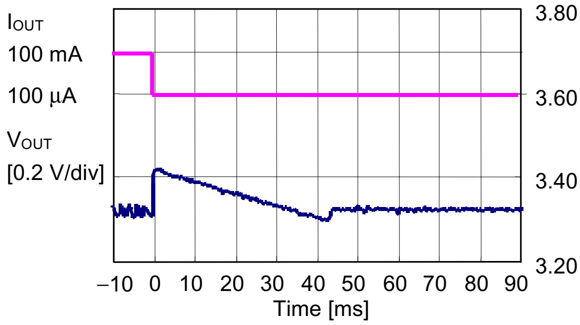
3-2. 100 kHz, I_{OUT}: 100 mA → 100 μA



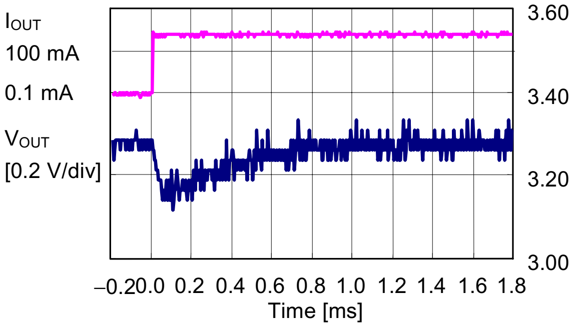
3-3. 300 kHz, I_{OUT}: 100 μA → 100 mA



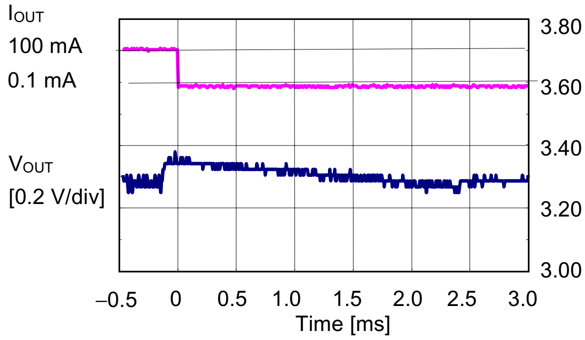
3-4. 300 kHz, I_{OUT}: 100 mA → 100 μA



3-5. 600 kHz, I_{OUT}: 0.1 mA → 100 mA

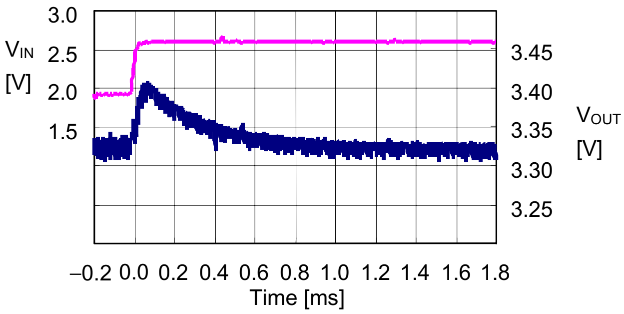


3-6. 600 kHz, I_{OUT}: 100 mA → 0.1 mA

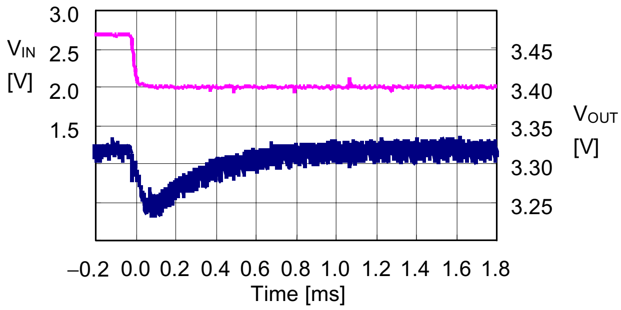


4. Input voltage fluctuations

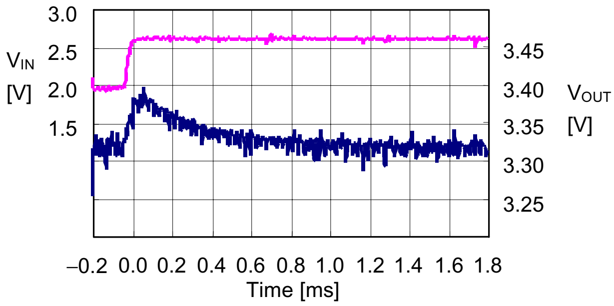
4-1. 100 kHz, I_{OUT} = 100 mA, V_{IN} = 1.98 V → 2.64 V



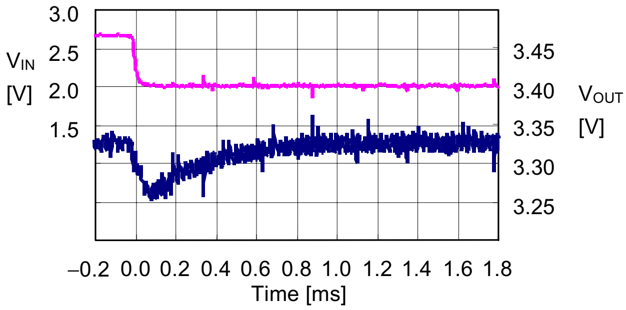
4-2. 100 kHz, I_{OUT} = 100 mA, V_{IN} = 2.64 V → 1.98 V



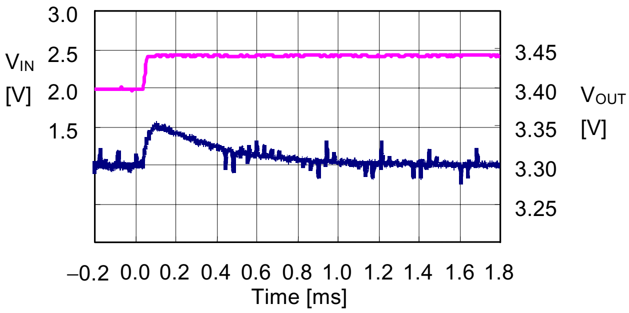
4-3. 300 kHz, I_{OUT} = 100 mA, V_{IN} = 1.98 V → 2.64 V



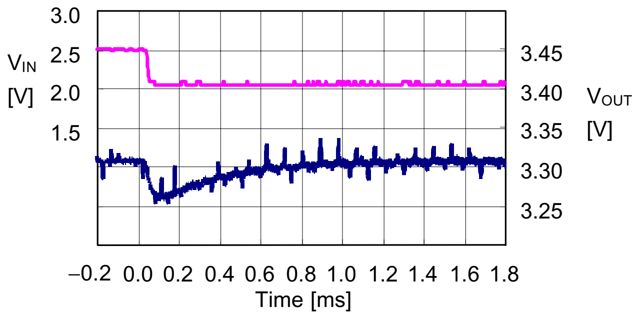
4-4. 100 kHz, I_{OUT} = 100 mA, V_{IN}=2.64 V → 1.98 V



4-5. 600 kHz, I_{OUT} = 100 mA, V_{IN} = 1.98 V → 2.64 V



4-6. 600 kHz, I_{OUT} = 100 mA, V_{IN} = 2.64 V → 1.98 V



■ Reference Data

Use this reference data to choose the external parts. This reference data makes it possible to choose the recommended external part based on the application and characteristics data.

1. Reference data for external parts

Table 28 Efficiency vs. Output Characteristics and Output Voltage vs. Output Current Characteristics for External Parts

No.	Product Name	Oscillation Frequency	Output Voltage	Control System	Inductor	Transistor	Diode	Output Capacitor
1	S-8357F33	300 kHz	3.3 V	PWM	CDRH104R-220	FDN335N	M1FH3	F93 (16 V, 47 μF) × 2
2	S-8357F50	300 kHz	5.0 V	PWM				
3	S-8356M50	300 kHz	5.0 V	PWM/PFM				
4	S-8357B33	100 kHz	3.3 V	PWM	CDRH104R-470			
5	S-8358B33	100 kHz	3.3 V	PWM/PFM				
6	S-8357B50	100 kHz	3.3 V	PWM				
7	S-8356M50	300 kHz	5.0 V	PWM/PFM	CDRH8D28-220			F93 (16 V, 47 μF)
8	S-8357B33	100 kHz	3.3 V	PWM	CDRH8D28-470			
9	S-8358B33	100 kHz	3.3 V	PWM/PFM				
10	S-8357B50	100 kHz	3.3 V	PWM				
11	S-8357F33	300 kHz	3.3 V	PWM	CXLP120-220	MCH3405	MA2Z748	F92 (6.3 V, 47 μF)
12	S-8356M50	300 kHz	5.0 V	PWM/PFM				
13	S-8357N33	600 kHz	3.3 V	PWM	CDRH8D28-100	FDN335N	M1FH3	F93 (16 V, 47 μF)
14	S-8357N50	600 kHz	5.0 V	PWM				
15	S-8356Q33	600 kHz	3.3 V	PWM/PFM				
16	S-8356Q50	600 kHz	5.0 V	PWM/PFM				
17	S-8357N33	600 kHz	3.3 V	PWM		S-90N0212SMA		
18	S-8357N50	600 kHz	5.0 V	PWM				
19	S-8356Q33	600 kHz	3.3 V	PWM/PFM				
20	S-8356Q50	600 kHz	5.0 V	PWM/PFM				

The properties of the external parts are shown below.

Table 29 Properties of External Parts

Part	Product Name	Manufacturer	Characteristics
Inductor	CDRH104R-220	Sumida Corporation	22 μH, DCR*1 = 73 mΩ, I_{MAX}*2 = 2.5 A, Height = 4.0 mm
	CDRH104R-470		47 μH, DCR*1 = 128 mΩ, I_{MAX}*2 = 1.9 A, Height = 4.0 mm
	CDRH8D28-100		10 μH, DCR*1 = 47 mΩ, I_{MAX}*2 = 2.7 A, Height = 3.0 mm
	CDRH8D28-220		22 μH, DCR*1 = 99 mΩ, I_{MAX}*2 = 1.8 A, Height = 3.0 mm
	CDRH8D28-470		47 μH, DCR*1 = 195 mΩ, I_{MAX}*2 = 1.25 A, Height = 3.0 mm
	CXLP120-220	Sumitomo Special Metals Co., Ltd.	22 μH, DCR*1 = 590 mΩ, I_{MAX}*2 = 0.55 A, Height = 1.2 mm
Diode	M1FH3	Shindengen Electric Manufacturing Co., Ltd.	V_F*3 = 0.3 V, I_F*4 = 1.5 A
	MA2Z748	Matsushita Electric Industrial Co., Ltd.	V_F*3 = 0.4 V, I_F*4 = 0.3 A
Capacitor (Output capacitance)	F93	Nichicon Corporation	16 V, 47 μF
	F92		6.3 V, 47 μF
Transistor (Nch FET)	S-90N0212SMA	Seiko Instruments Inc.	V_{DSS}*5 = 20 V max., V_{GSS}*6 = 12 V max., C_{ISS}*7 = 190 pF, $R_{DS(ON)}$*8 = 0.16 Ω max. (V_{GS}*9 = 2.5 V, I_D*10 = 0.5 A)
	FDN335N	Fairchild Semiconductor Japan Ltd.	V_{DSS}*5 = 20 V max., V_{GSS}*6 = 8 V max., C_{ISS}*7 = 310 pF, $R_{DS(ON)}$*8 = 0.10 Ω max. (V_{GS}*9 = 2.5 V, I_D*10 = 1.5 A)
	MCH3405	Sanyo Electric Co., Ltd.	V_{DSS}*5 = 20 V max., V_{GSS}*6 = 10 V max., C_{ISS}*7 = 100 pF, $R_{DS(ON)}$*8 = 0.28 Ω max. (V_{GS}*9 = 2.5 V, I_D*10 = 0.5 A) $R_{DS(ON)}$*8 = 0.39 Ω max. (V_{GS}*9 = 1.8 V, I_D*10 = 0.1 A)

***1.** DC resistance, ***2.** Maximum allowable current, ***3.** Forward voltage, ***4.** Forward current, ***5.** Drain-source voltage, ***6.** Gate-source voltage, ***7.** Input capacitance, ***8.** Drain-source on resistance, ***9** Gate-source voltage, ***10** Drain current

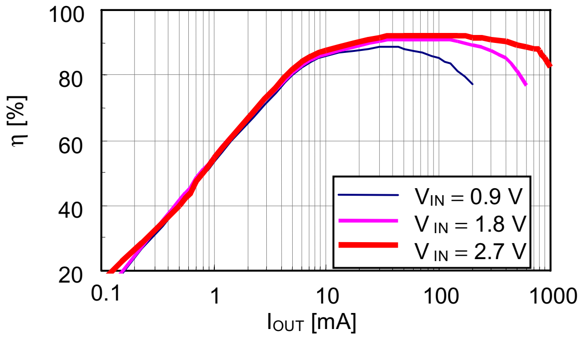
Caution The values shown in the characteristics column of Table 29 above are based on the materials provided by each manufacturer. However, consider the characteristics of the original materials when using the above products.

2. Reference data (1)

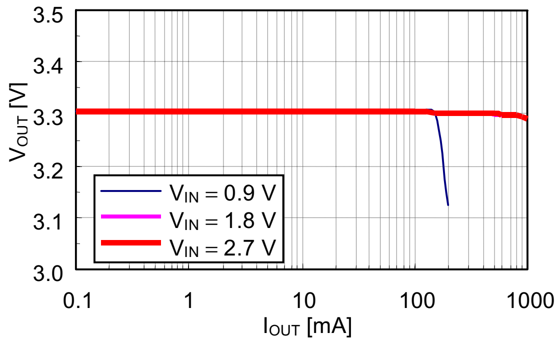
The data of (a) output current (I_{OUT}) vs. efficiency (η) characteristics and (b) output current (I_{OUT}) vs. output voltage (V_{OUT}) characteristics under conditions of (1) to (20) shown in Table 28 is shown below.

(1) S-8357F33

(a) Output current (I_{OUT}) vs. Efficiency (η)

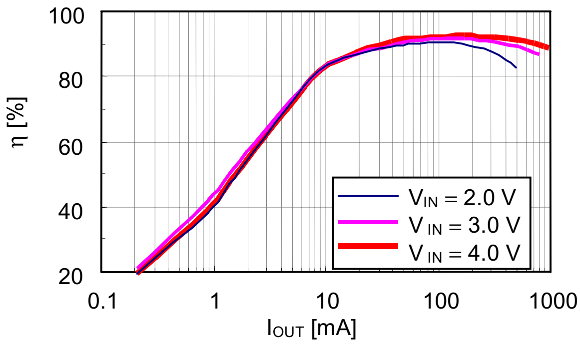


(b) Output current (I_{OUT}) vs. Output voltage (V_{OUT})

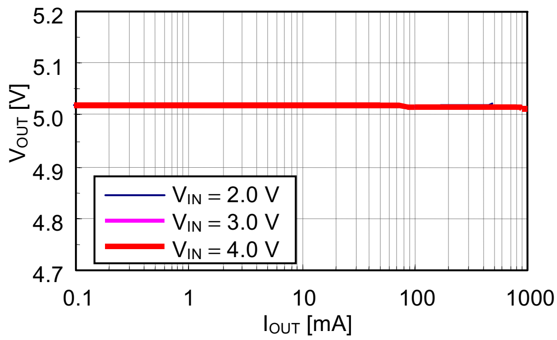


(2) S-8357F50

(a) Output current (I_{OUT}) vs. Efficiency (η)

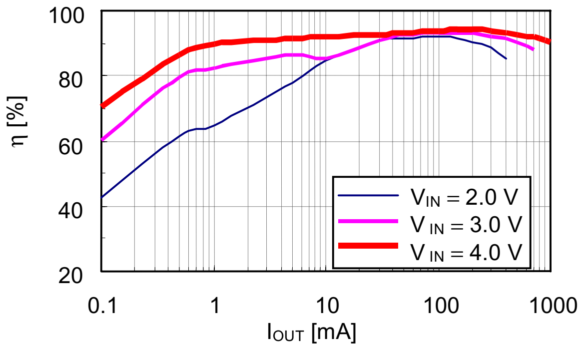


(b) Output current (I_{OUT}) vs. Output voltage (V_{OUT})

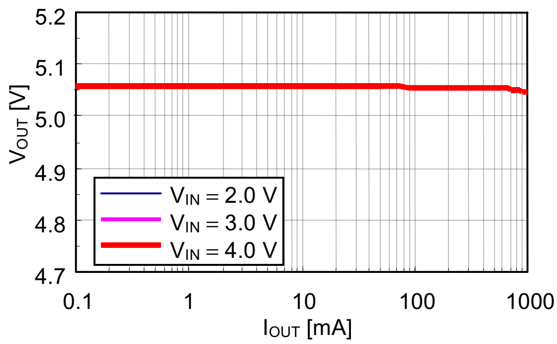


(3) S-8356M50

(a) Output current (I_{OUT}) vs. Efficiency (η)

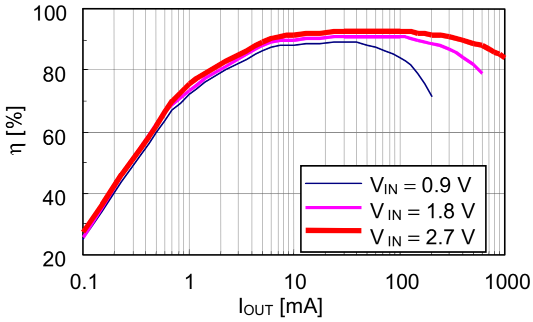


(b) Output current (I_{OUT}) vs. Output voltage (V_{OUT})

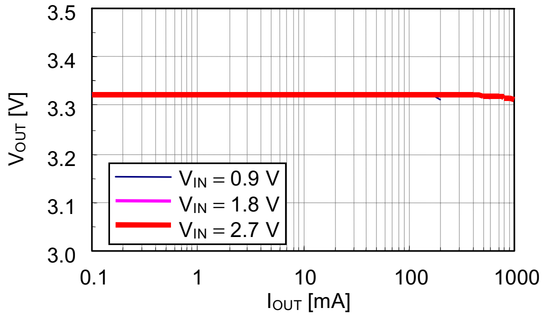


(4) S-8357B33

(a) Output current (I_{OUT}) vs. Efficiency (η)

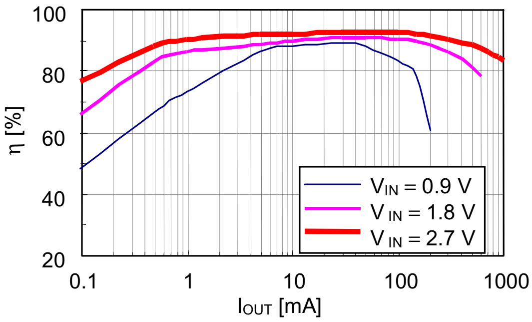


(b) Output current (I_{OUT}) vs. Output voltage (V_{OUT})

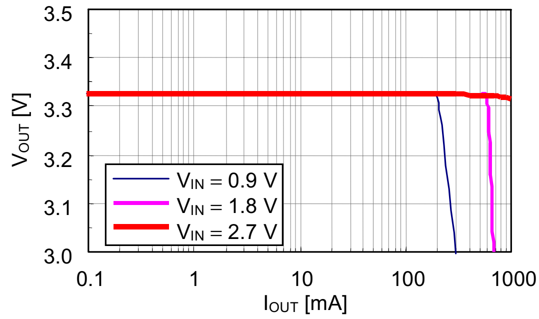


(5) S-8358B33

(a) Output current (I_{OUT}) vs. Efficiency (η)

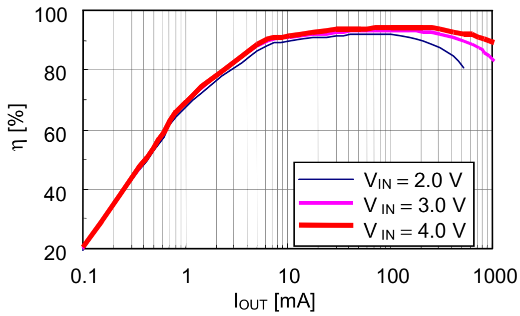


(b) Output current (I_{OUT}) vs. Output voltage (V_{OUT})

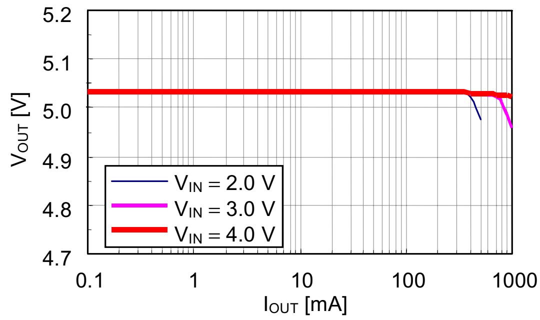


(6) S-8357B50

(a) Output current (I_{OUT}) vs. Efficiency (η)

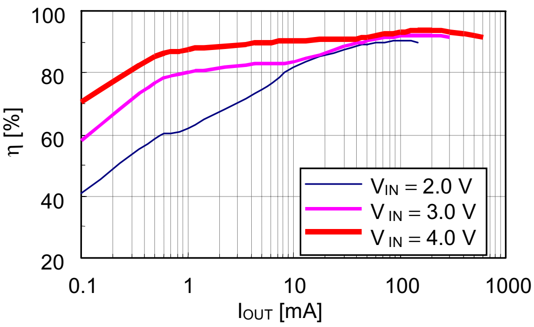


(b) Output current (I_{OUT}) vs. Output voltage (V_{OUT})

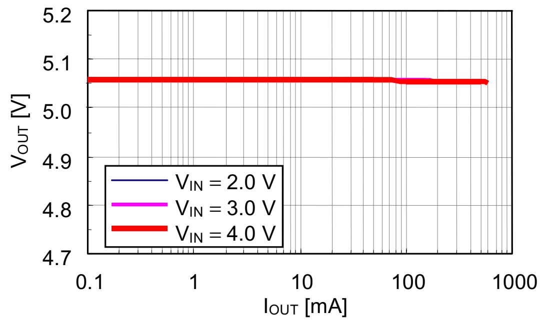


(7) S-8356M50

(a) Output current (I_{OUT}) vs. Efficiency (η)

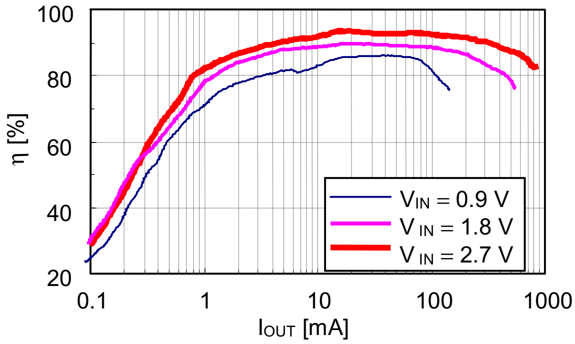


(b) Output current (I_{OUT}) vs. Output voltage (V_{OUT})

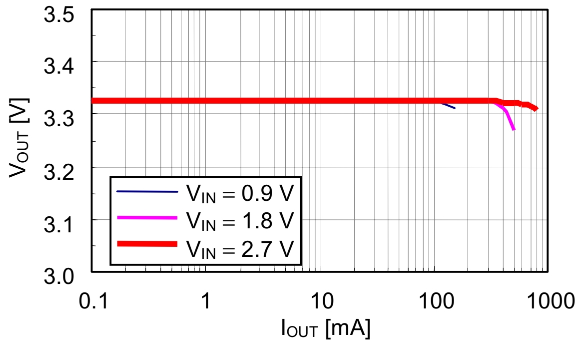


(8) S-8357B33

(a) Output current (I_{OUT}) vs. Efficiency (η)

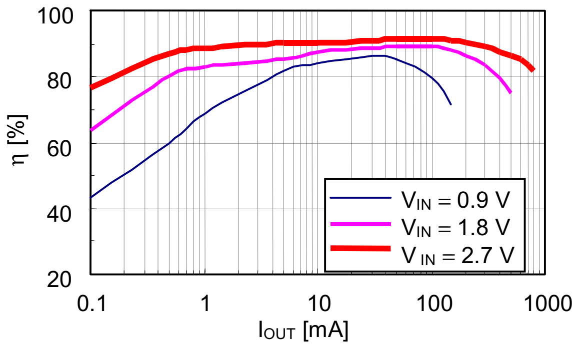


(b) Output current (I_{OUT}) vs. Output voltage (V_{OUT})

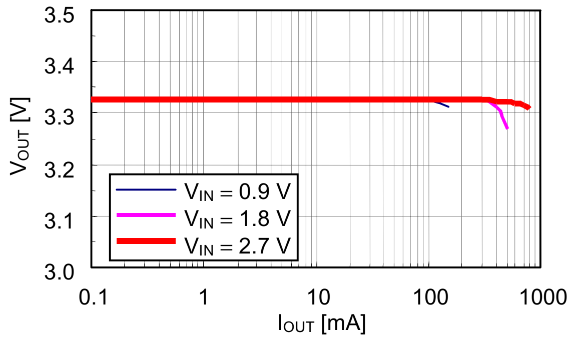


(9) S-8358B33

(a) Output current (I_{OUT}) vs. Efficiency (η)

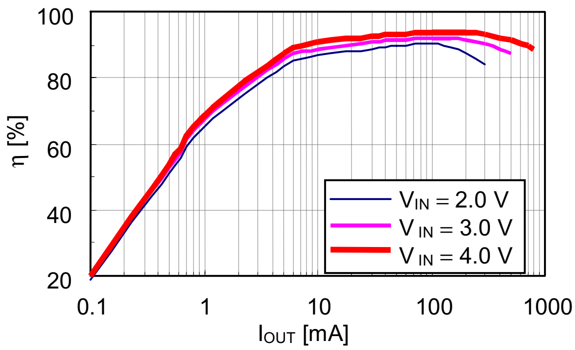


(b) Output current (I_{OUT}) vs. Output voltage (V_{OUT})

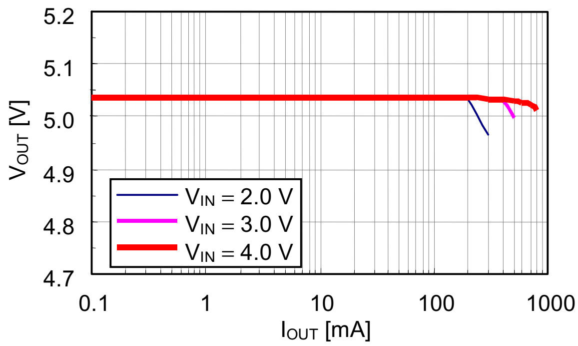


(10) S-8357B50

(a) Output current (I_{OUT}) vs. Efficiency (η)

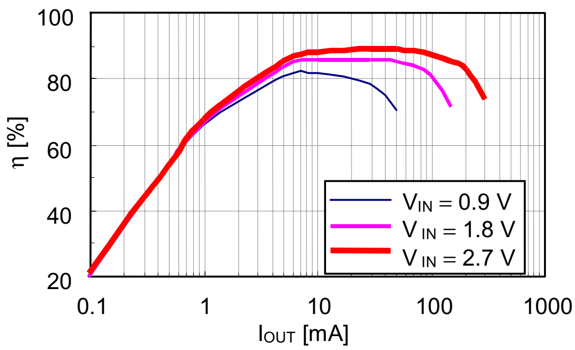


(b) Output current (I_{OUT}) vs. Output voltage (V_{OUT})

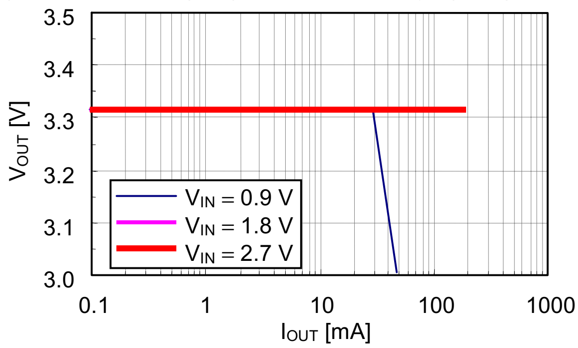


(11) S-8357F33

(a) Output current (I_{OUT}) vs. Efficiency (η)

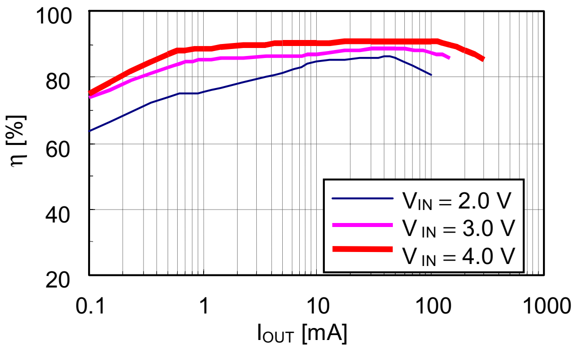


(b) Output current (I_{OUT}) vs. Output voltage (V_{OUT})

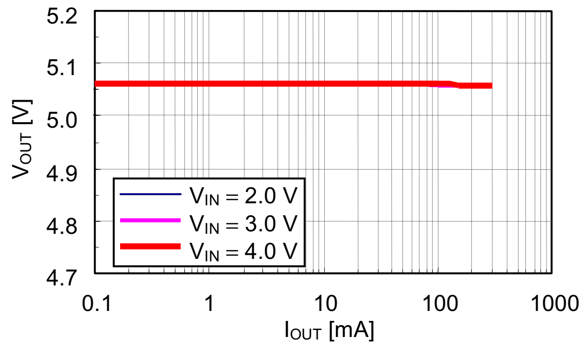


(12) S-8356M50

(a) Output current (I_{OUT}) vs. Efficiency (η)

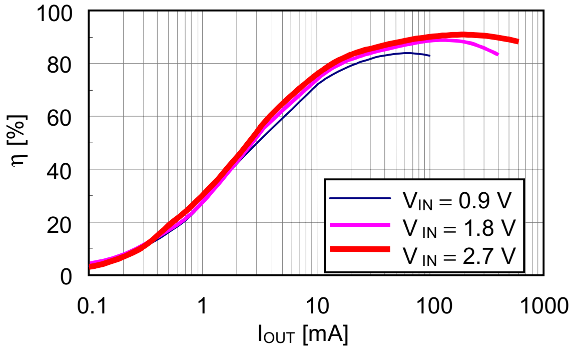


(b) Output current (I_{OUT}) vs. Output voltage (V_{OUT})

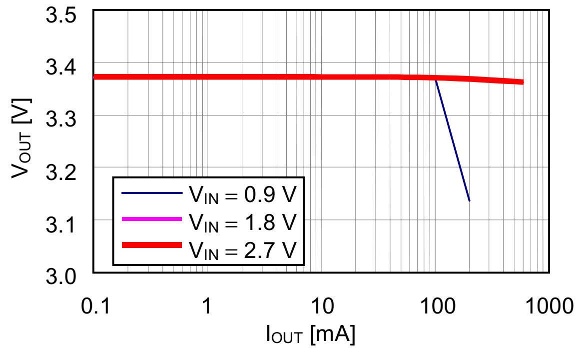


(13) S-8357N33

(a) Output current (I_{OUT}) vs. Efficiency (η)

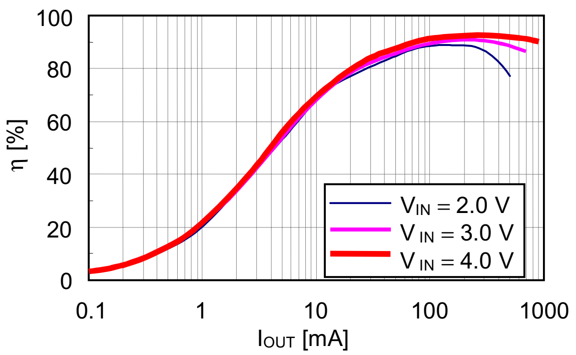


(b) Output current (I_{OUT}) vs. Output voltage (V_{OUT})

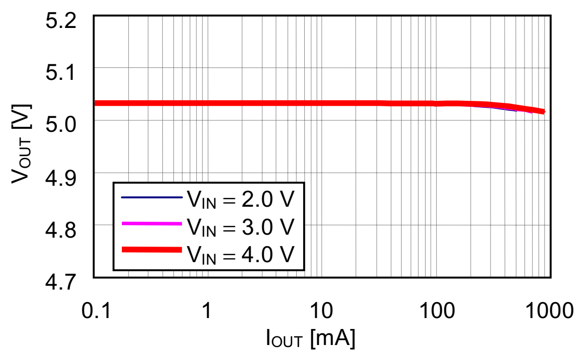


(14) S-8357N50

(a) Output current (I_{OUT}) vs. Efficiency (η)

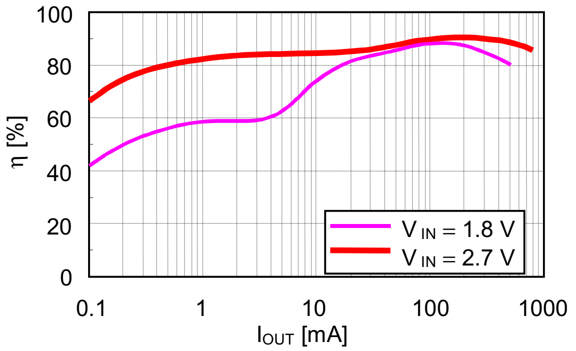


(b) Output current (I_{OUT}) vs. Output voltage (V_{OUT})

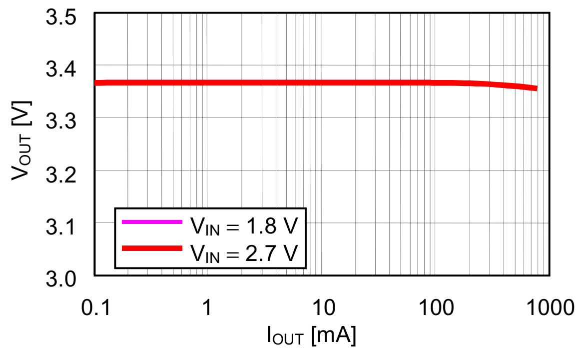


(15) S-8356Q33

(a) Output current (I_{OUT}) vs. Efficiency (η)

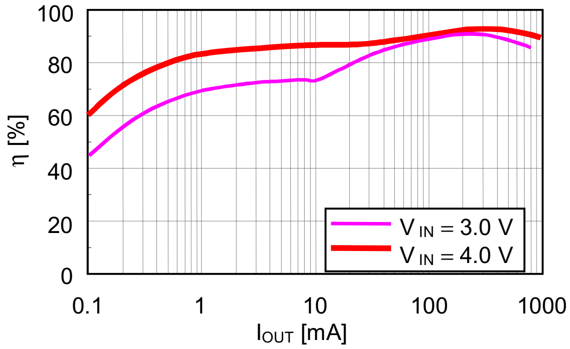


(b) Output current (I_{OUT}) vs. Output voltage (V_{OUT})

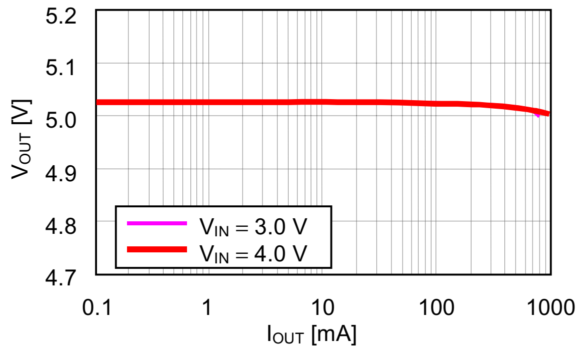


(16) S-8356Q50

(a) Output current (I_{OUT}) vs. Efficiency (η)

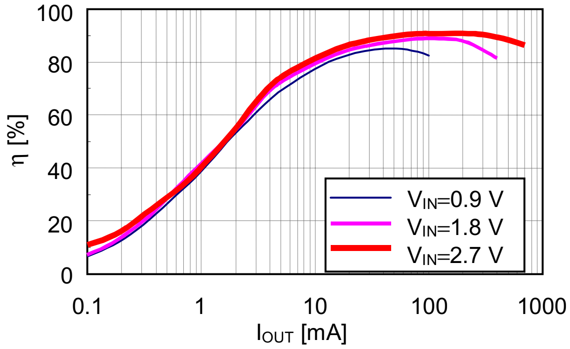


(b) Output current (I_{OUT}) vs. Output voltage (V_{OUT})

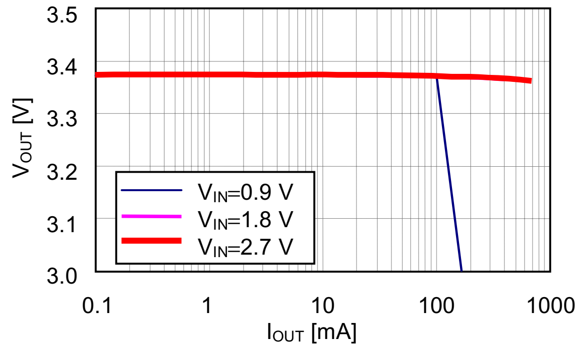


(17) S-8357N33

(a) Output current (I_{OUT}) vs. Efficiency (η)

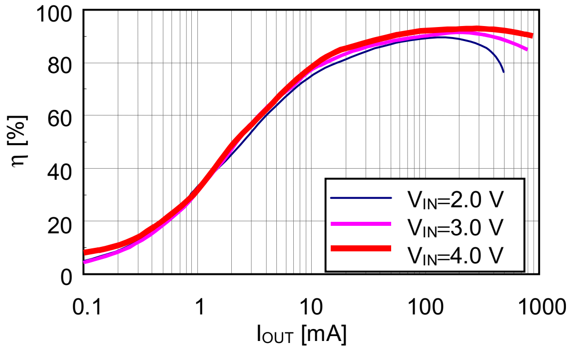


(b) Output current (I_{OUT}) vs. Output voltage (V_{OUT})

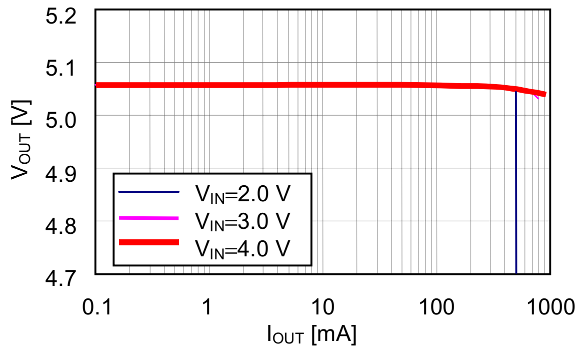


(18) S-8357N50

(a) Output current (I_{OUT}) vs. Efficiency (η)

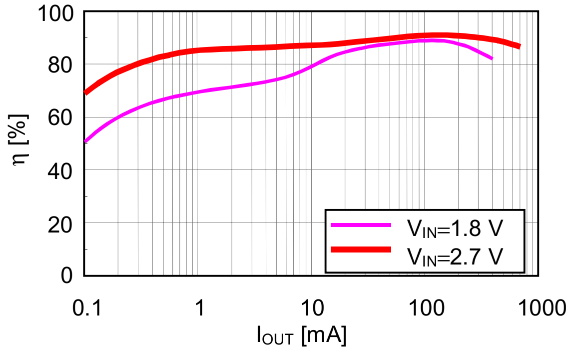


(b) Output current (I_{OUT}) vs. Output voltage (V_{OUT})

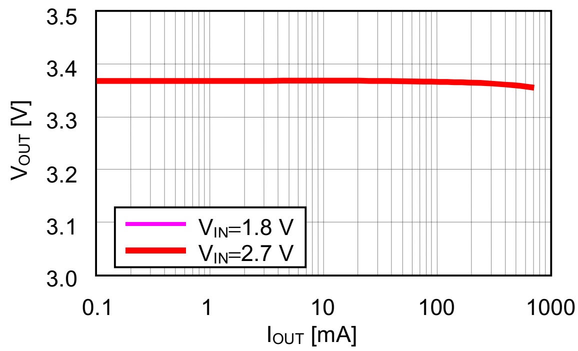


(19) S-8356Q33

(a) Output current (I_{OUT}) vs. Efficiency (η)

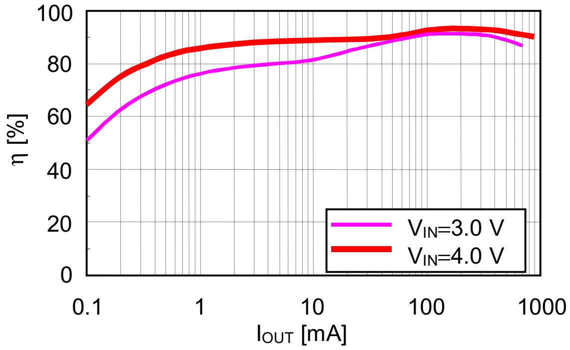


(b) Output current (I_{OUT}) vs. Output voltage (V_{OUT})

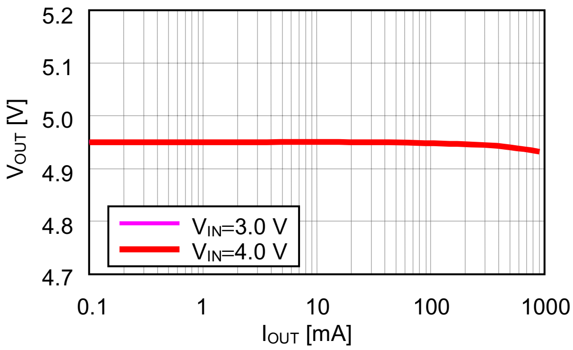


(20) S-8356Q50

(a) Output current (I_{OUT}) vs. Efficiency (η)



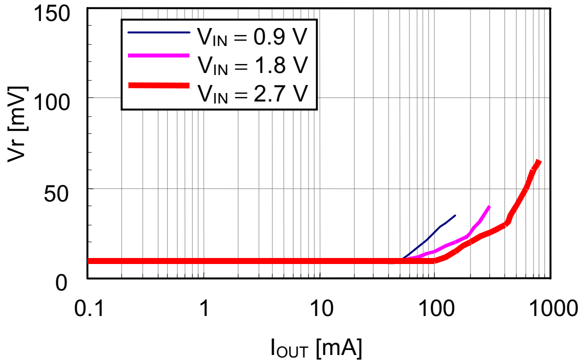
(b) Output current (I_{OUT}) vs. Output voltage (V_{OUT})



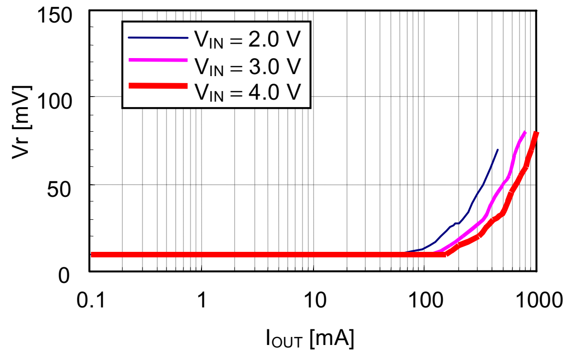
3. Reference data (2)

The actual output current vs. ripple voltage characteristics data under conditions of (1) to (20) in Table 28 are shown below.

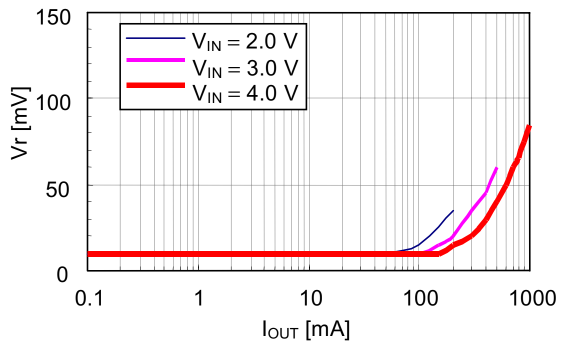
(1) S-8357F33



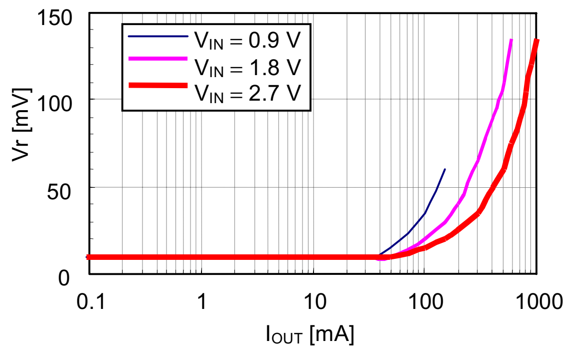
(2) S-8357F50



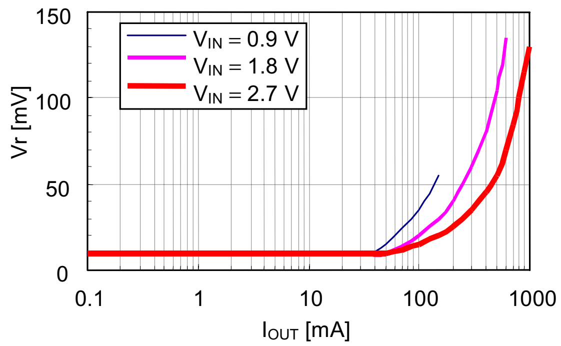
(3) S-8356M50



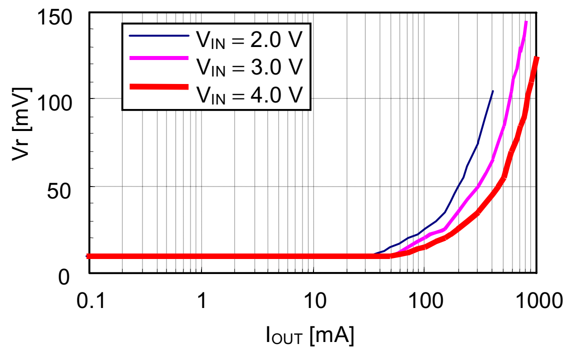
(4) S-8357B33



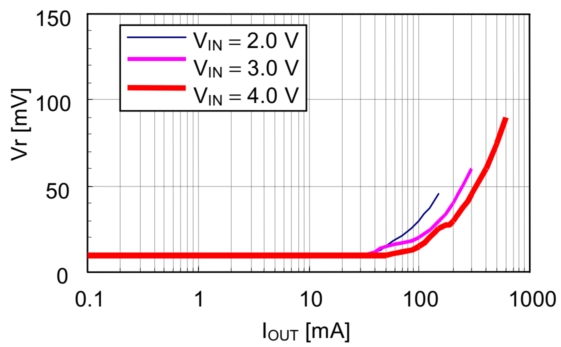
(5) S-8358B33



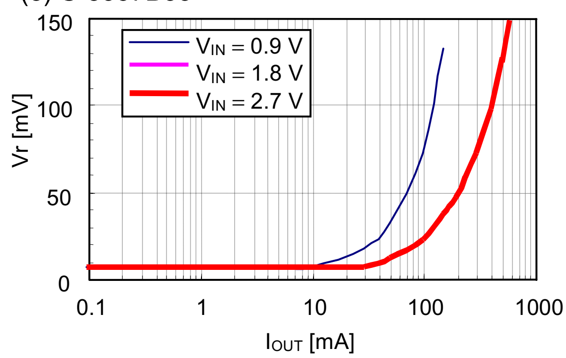
(6) S-8357B50



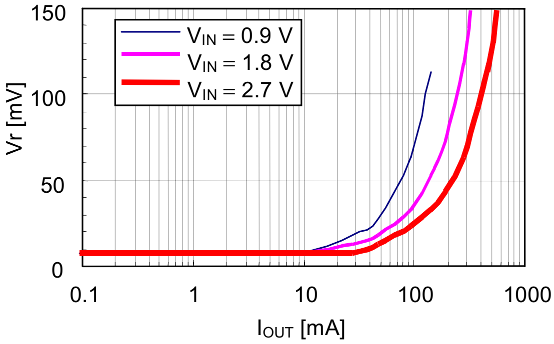
(7) S-8356M50



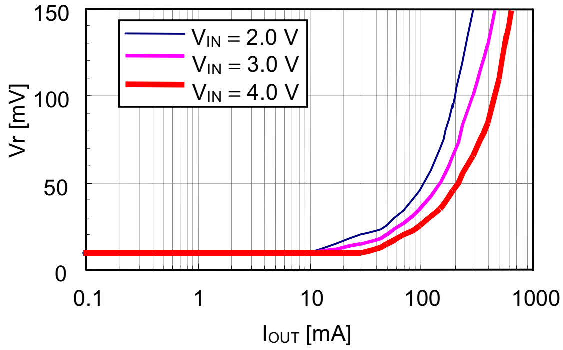
(8) S-8357B33



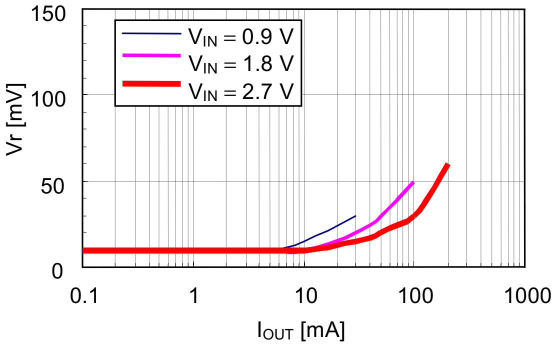
(9) S-8358B33



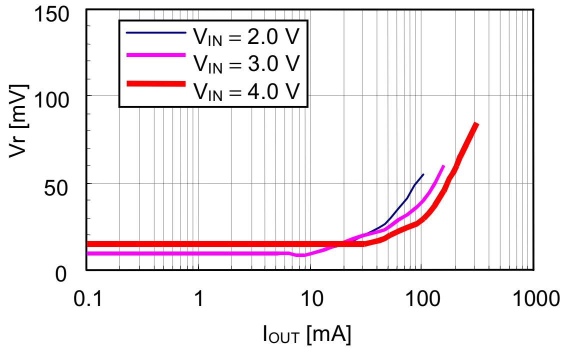
(10) S-8357B50



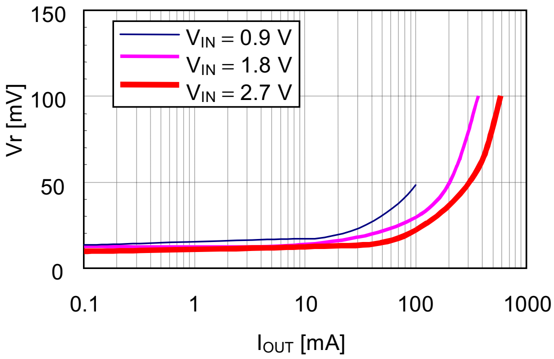
(11) S-8357F33



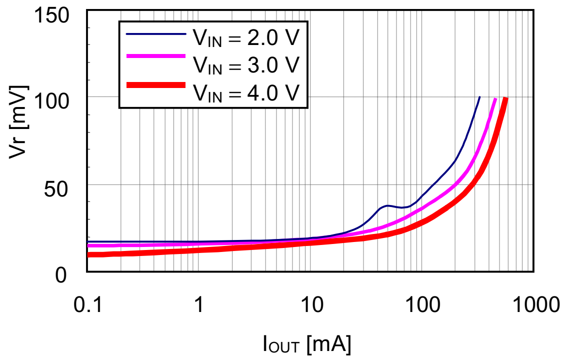
(12) S-8356M50



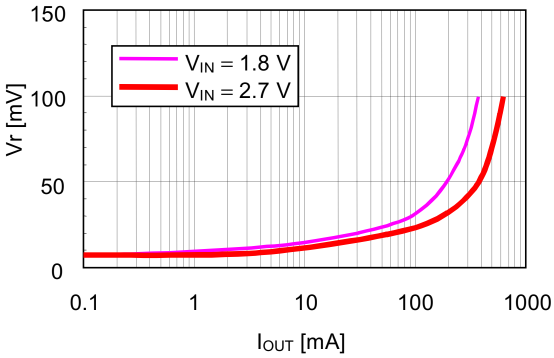
(13) S-8357N33



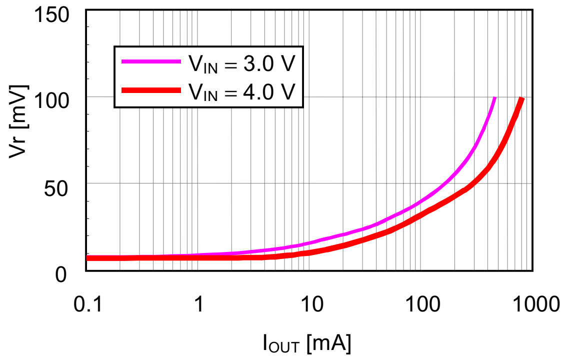
(14) S-8357N50



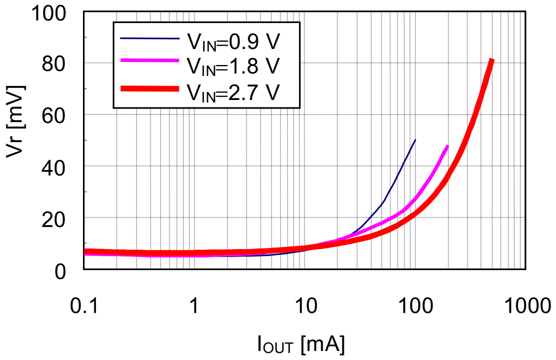
(15) S-8356Q33



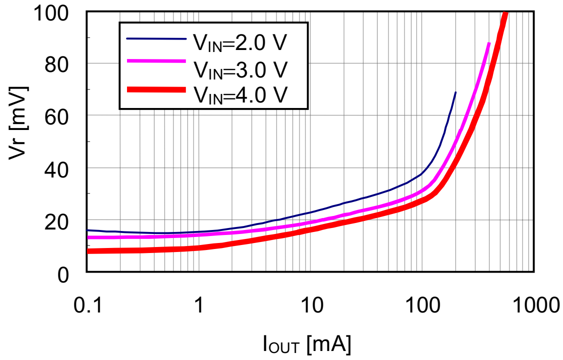
(16) S-8356Q50



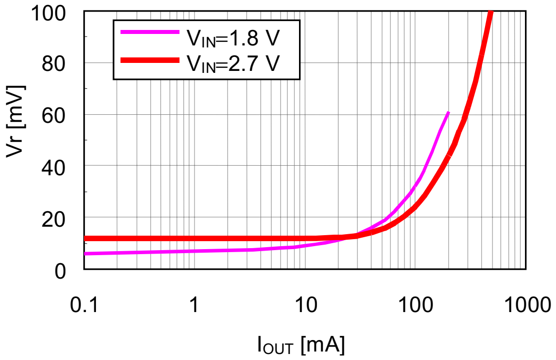
(17) S-8357N33



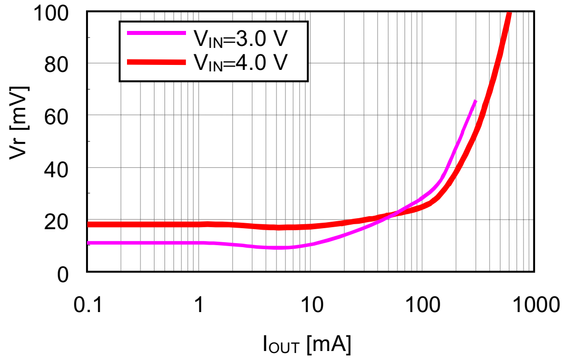
(18) S-8357N50

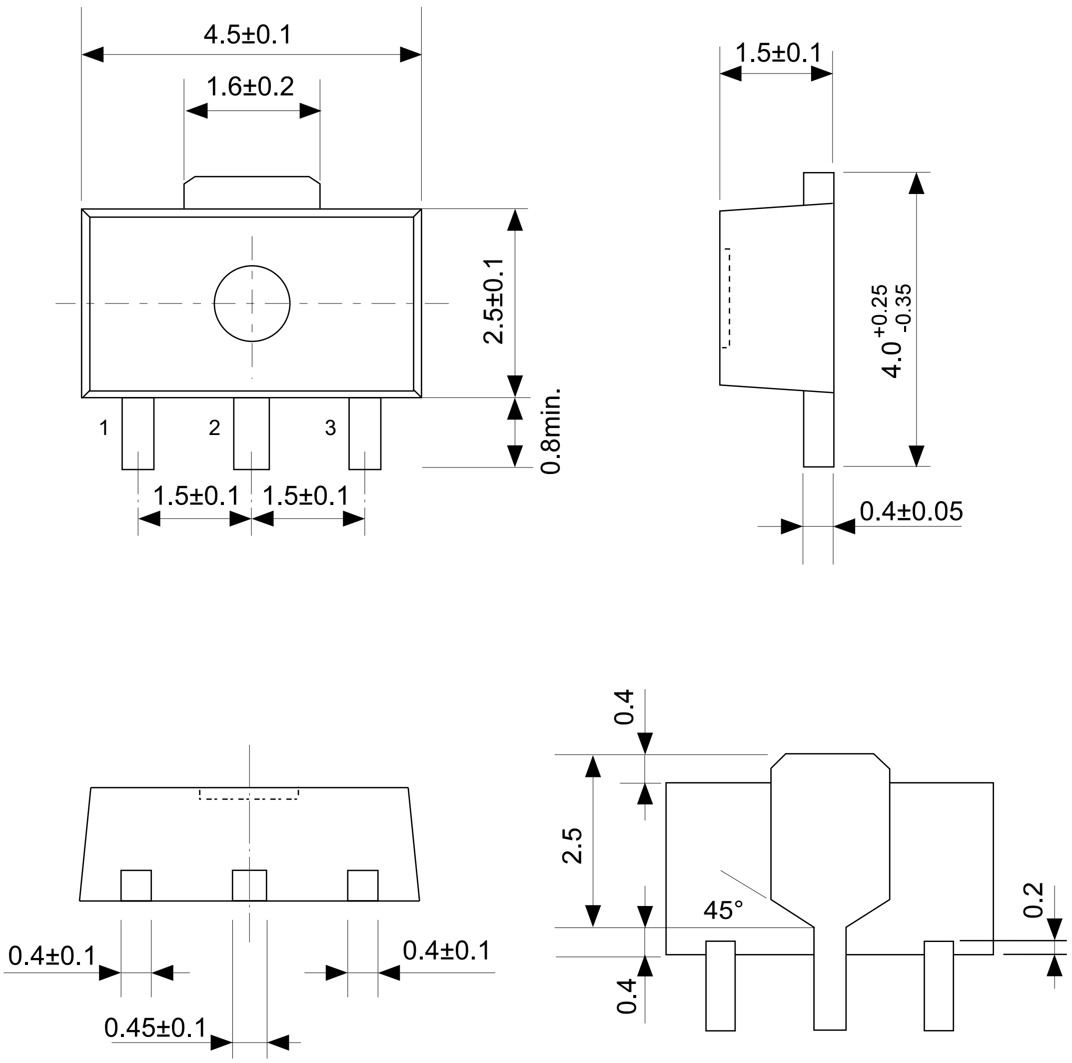


(19) S-8356Q33



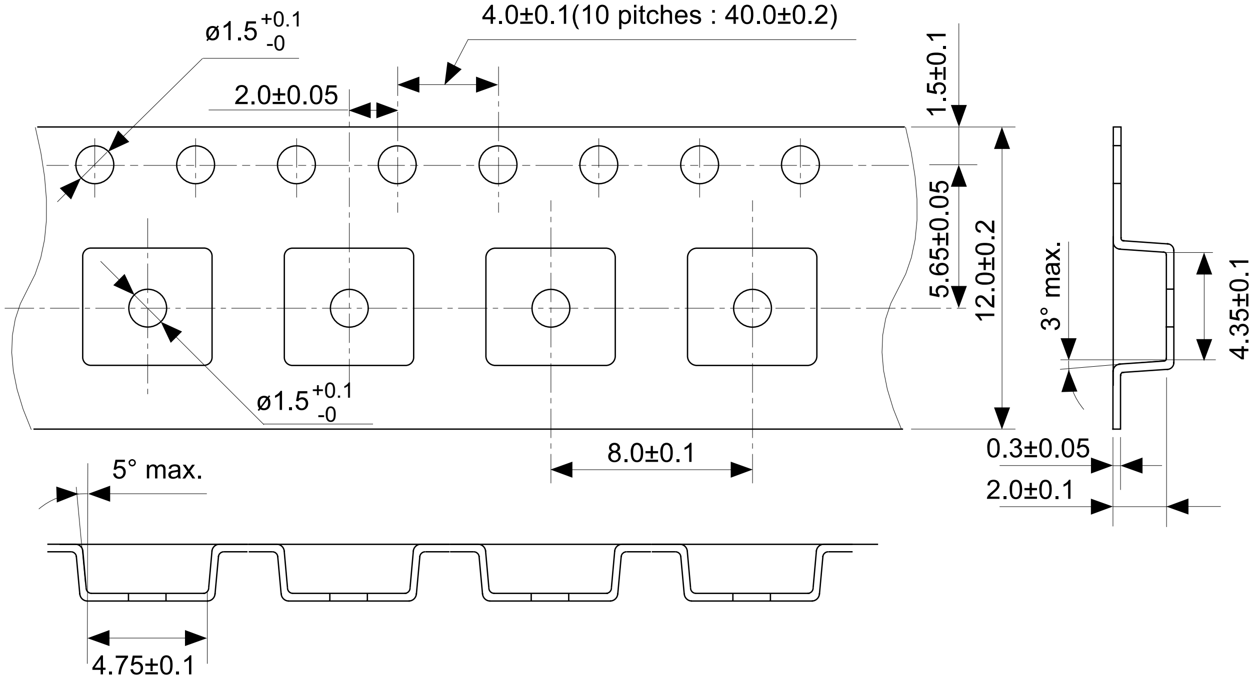
(20) S-8356Q50

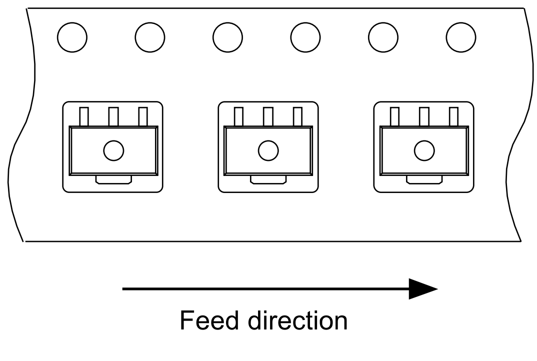




No. UP003-A-P-SD-1.1

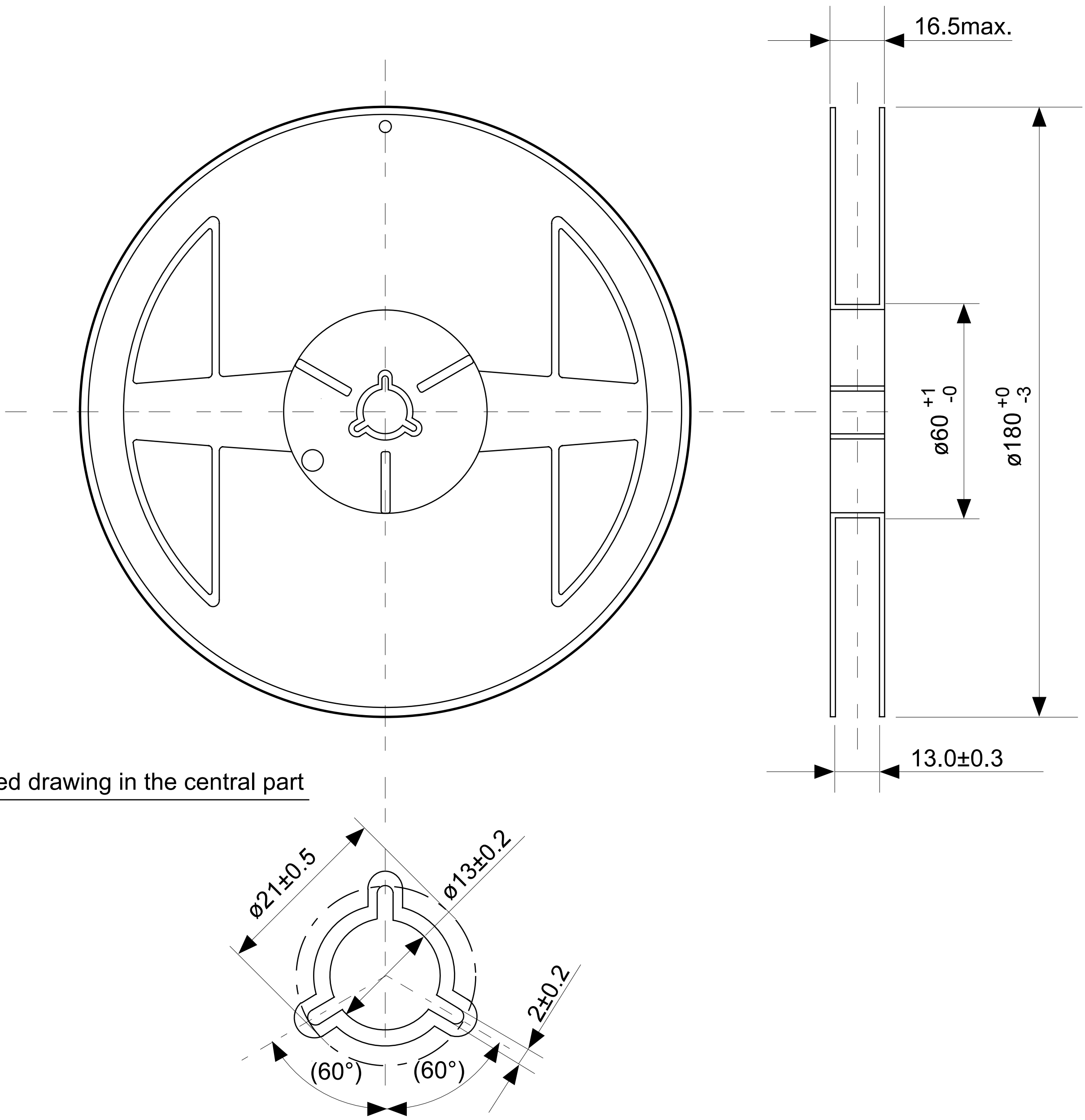
TITLE	SOT893-A-PKG Dimensions
No.	UP003-A-P-SD-1.1
SCALE	
UNIT	mm
Seiko Instruments Inc.	





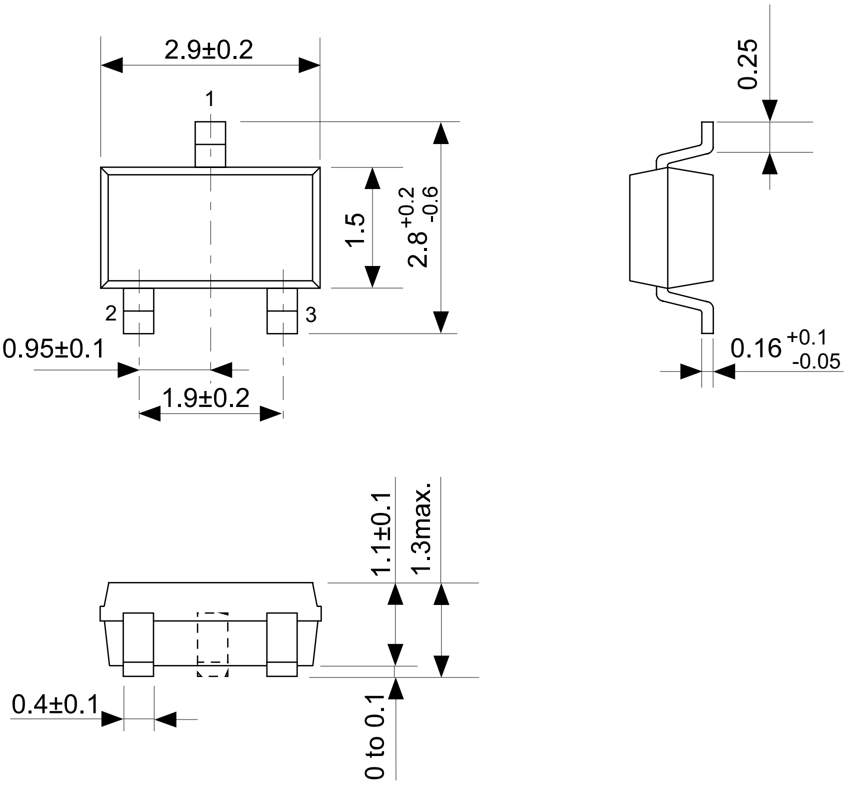
No. UP003-A-C-SD-1.1

TITLE	SOT893-A-Carrier Tape
No.	UP003-A-C-SD-1.1
SCALE	
UNIT	mm
Seiko Instruments Inc.	



No. UP003-A-R-SD-1.1

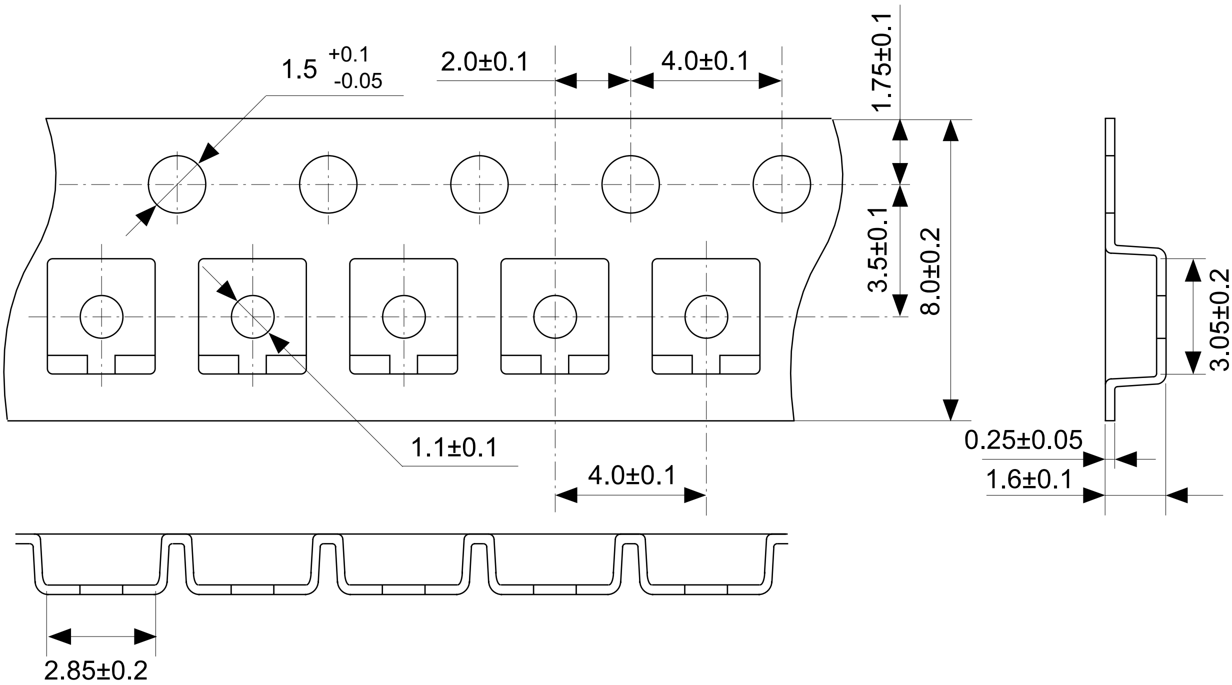
TITLE	SOT893-A-Reel		
No.	UP003-A-R-SD-1.1		
SCALE		QTY.	1,000
UNIT	mm		
Seiko Instruments Inc.			

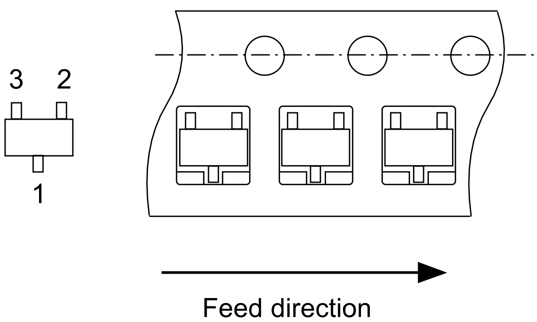


No. MP003-A-P-SD-1.1

TITLE	SOT233-A-PKG Dimensions
No.	MP003-A-P-SD-1.1
SCALE	
UNIT	mm

Seiko Instruments Inc.

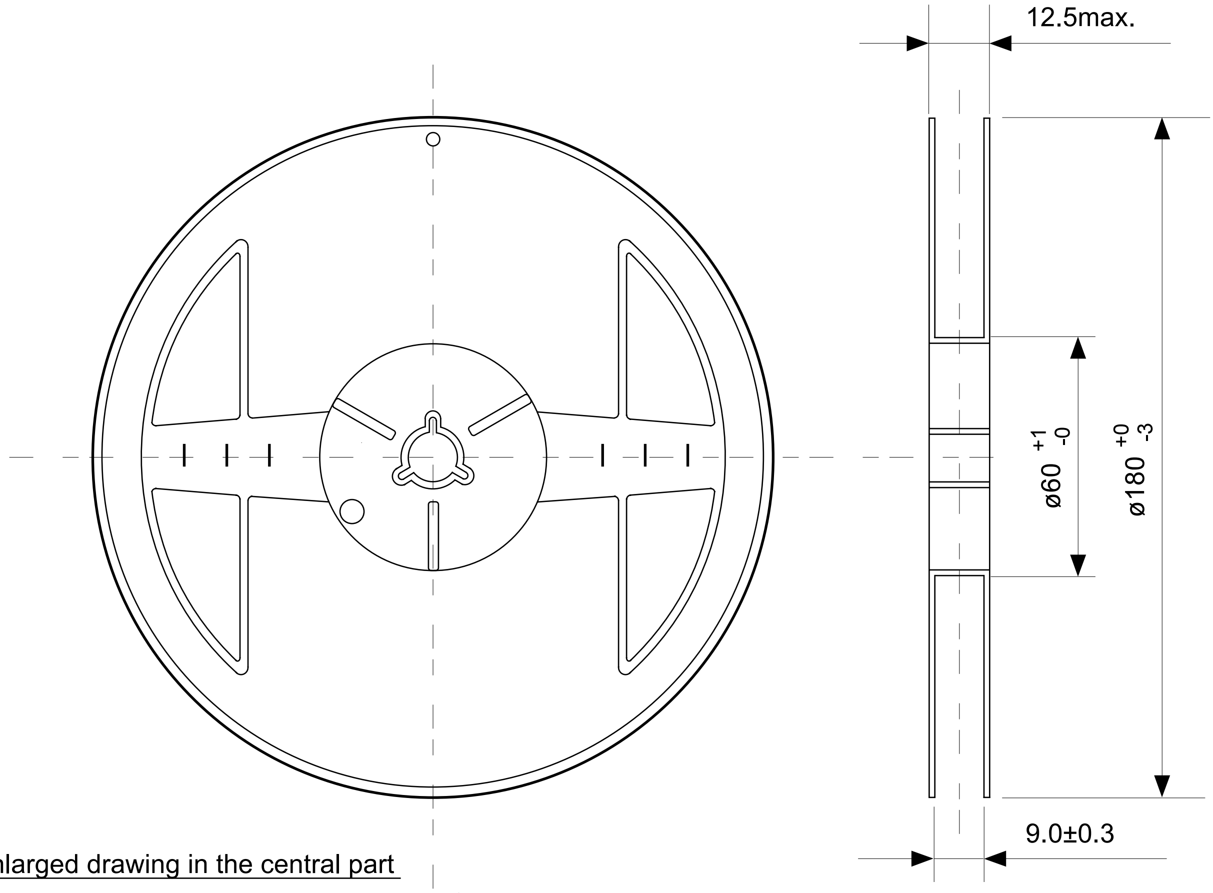




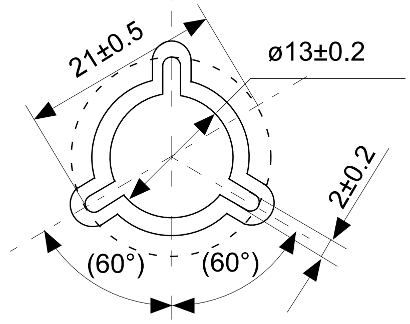
No. MP003-A-C-SD-1.1

TITLE	SOT233-A-Carrier Tape
No.	MP003-A-C-SD-1.1
SCALE	
UNIT	mm

Seiko Instruments Inc.



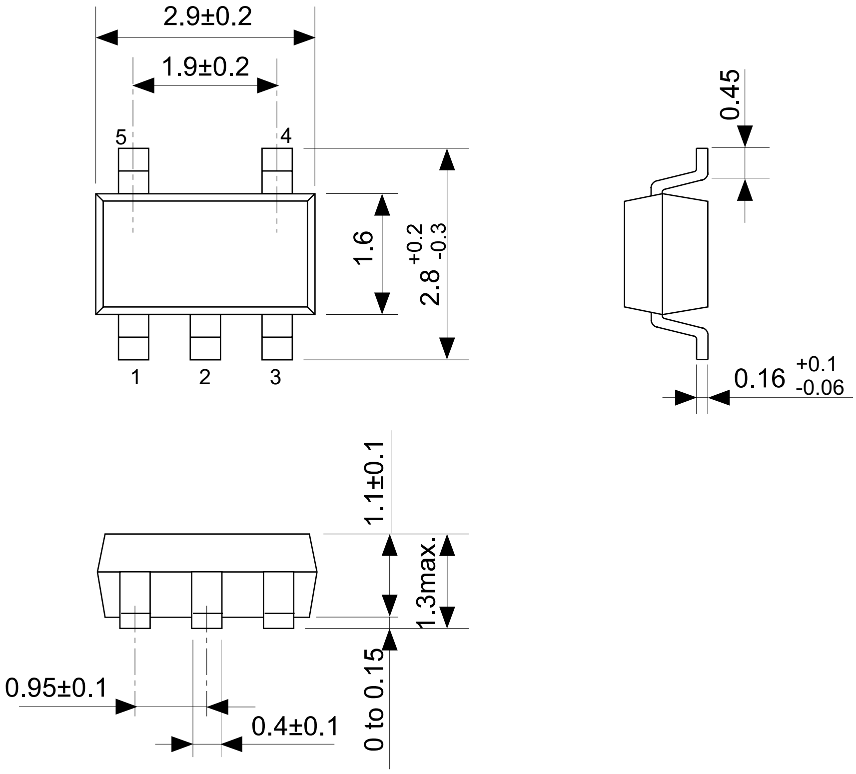
Enlarged drawing in the central part



No. MP003-A-R-SD-1.1

TITLE	SOT233-A-Reel		
No.	MP003-A-R-SD-1.1		
SCALE		QTY.	3,000
UNIT	mm		

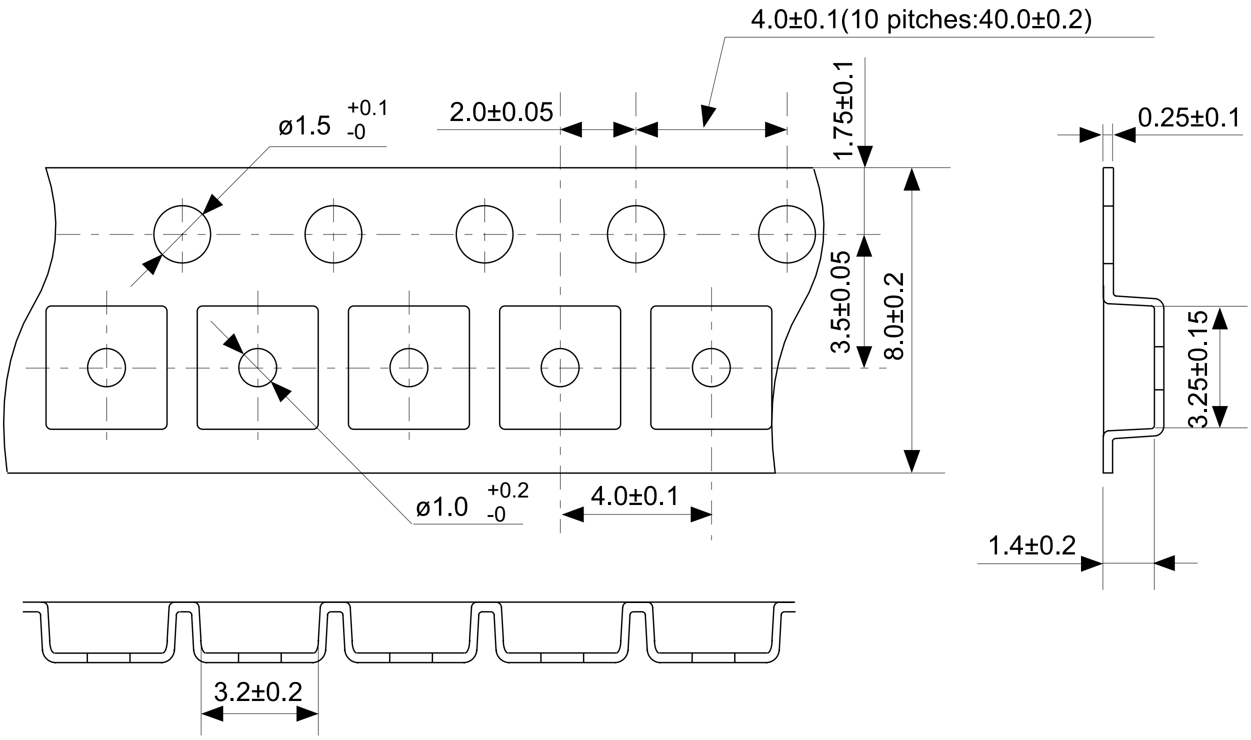
Seiko Instruments Inc.

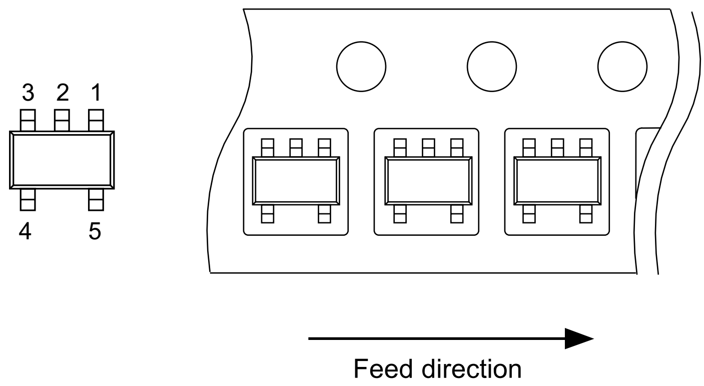


No. MP005-A-P-SD-1.2

TITLE	SOT235-A-PKG Dimensions
No.	MP005-A-P-SD-1.2
SCALE	
UNIT	mm

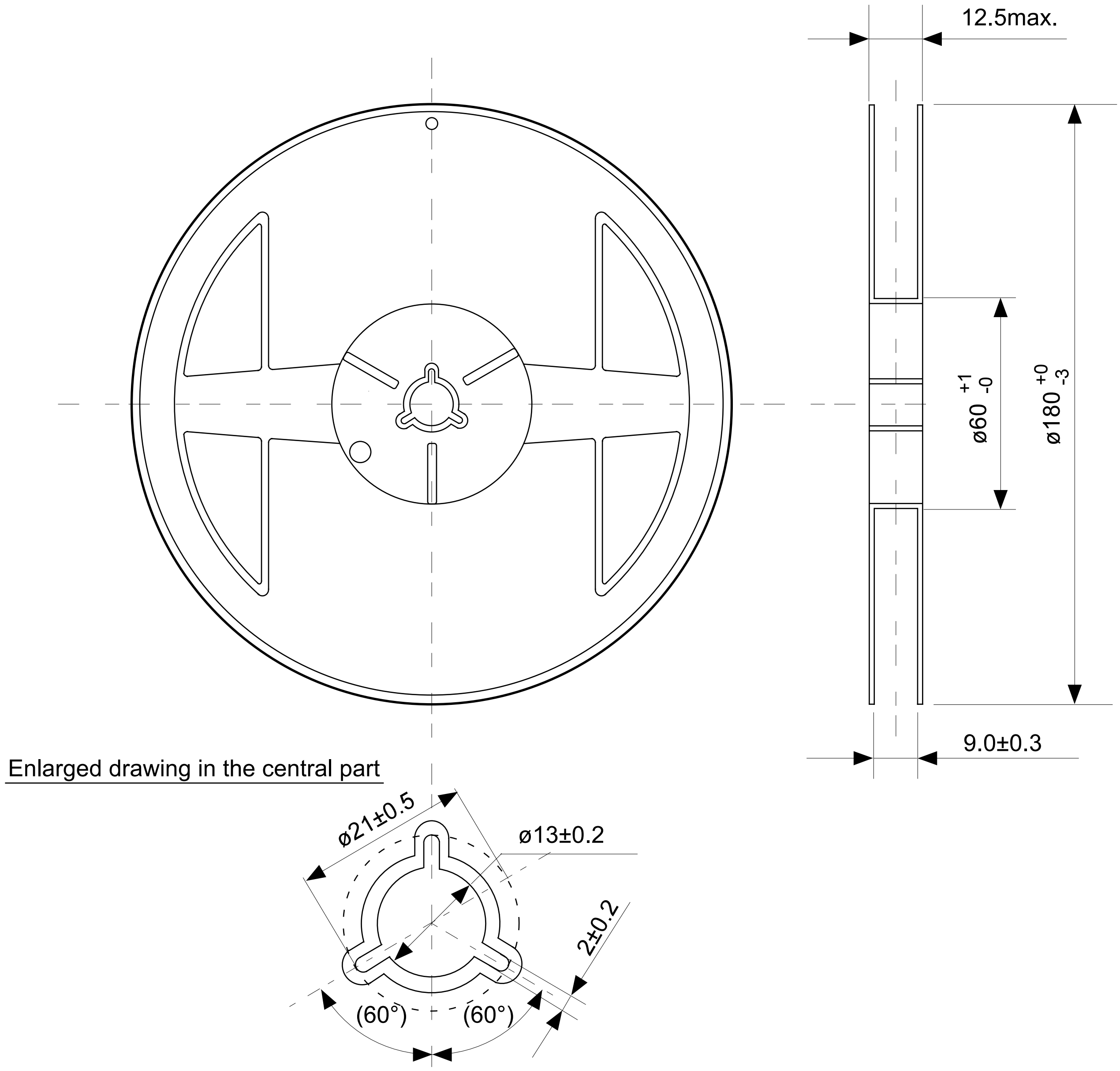
Seiko Instruments Inc.





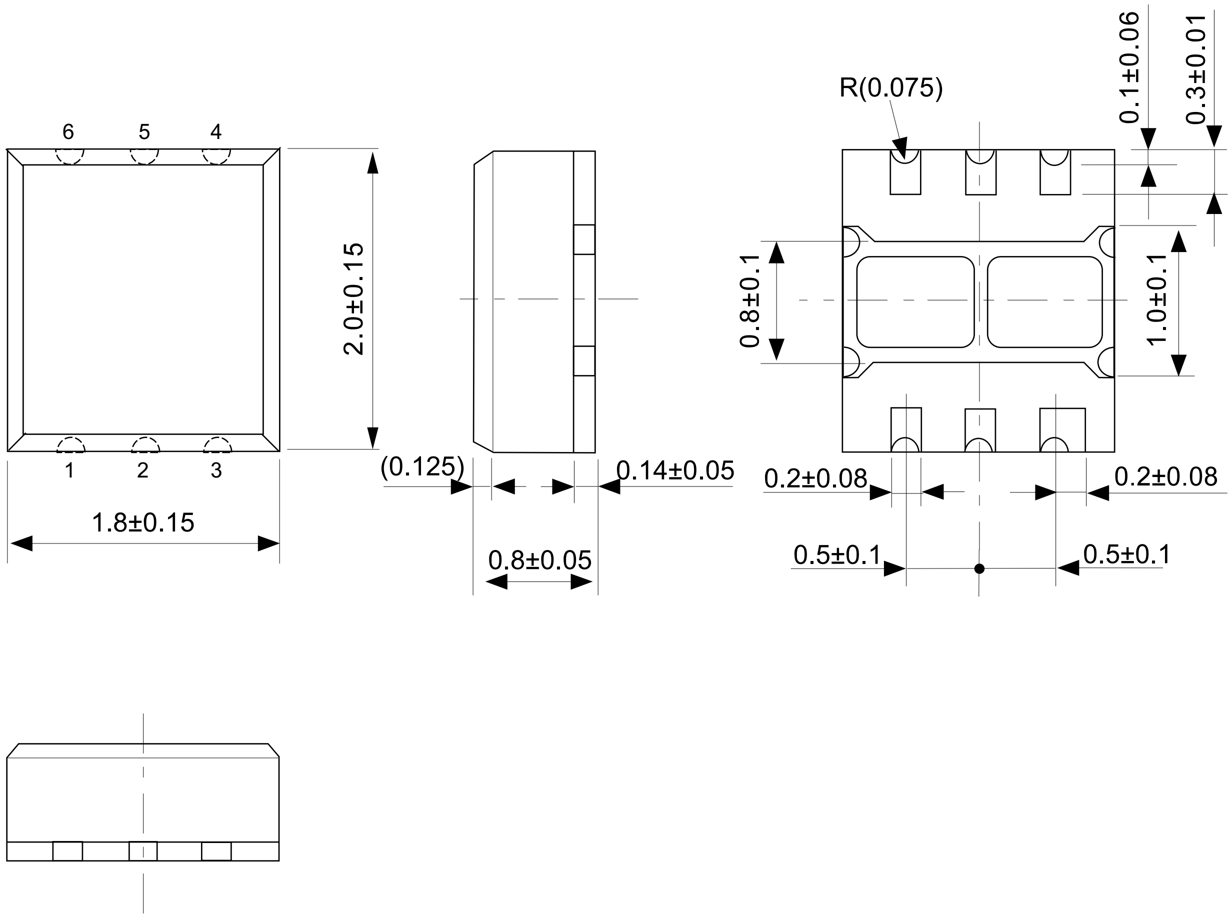
No. MP005-A-C-SD-2.1

TITLE	SOT235-A-Carrier Tape
No.	MP005-A-C-SD-2.1
SCALE	
UNIT	mm
Seiko Instruments Inc.	



No. MP005-A-R-SD-1.1

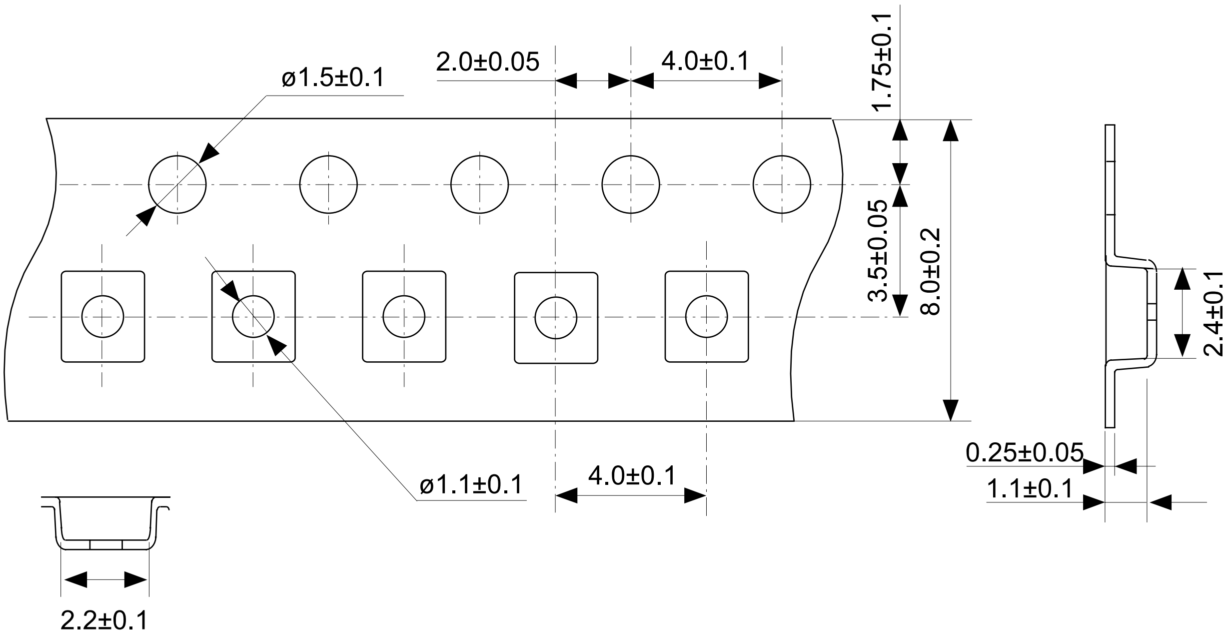
TITLE	SOT235-A-Reel		
No.	MP005-A-R-SD-1.1		
SCALE		QTY.	3,000
UNIT	mm		
Seiko Instruments Inc.			

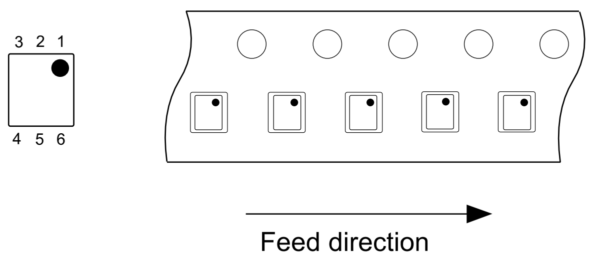


No. BD006-A-P-SD-1.1

TITLE	SNB6B-A-PKG Dimensions
No.	BD006-A-P-SD-1.1
SCALE	
UNIT	mm

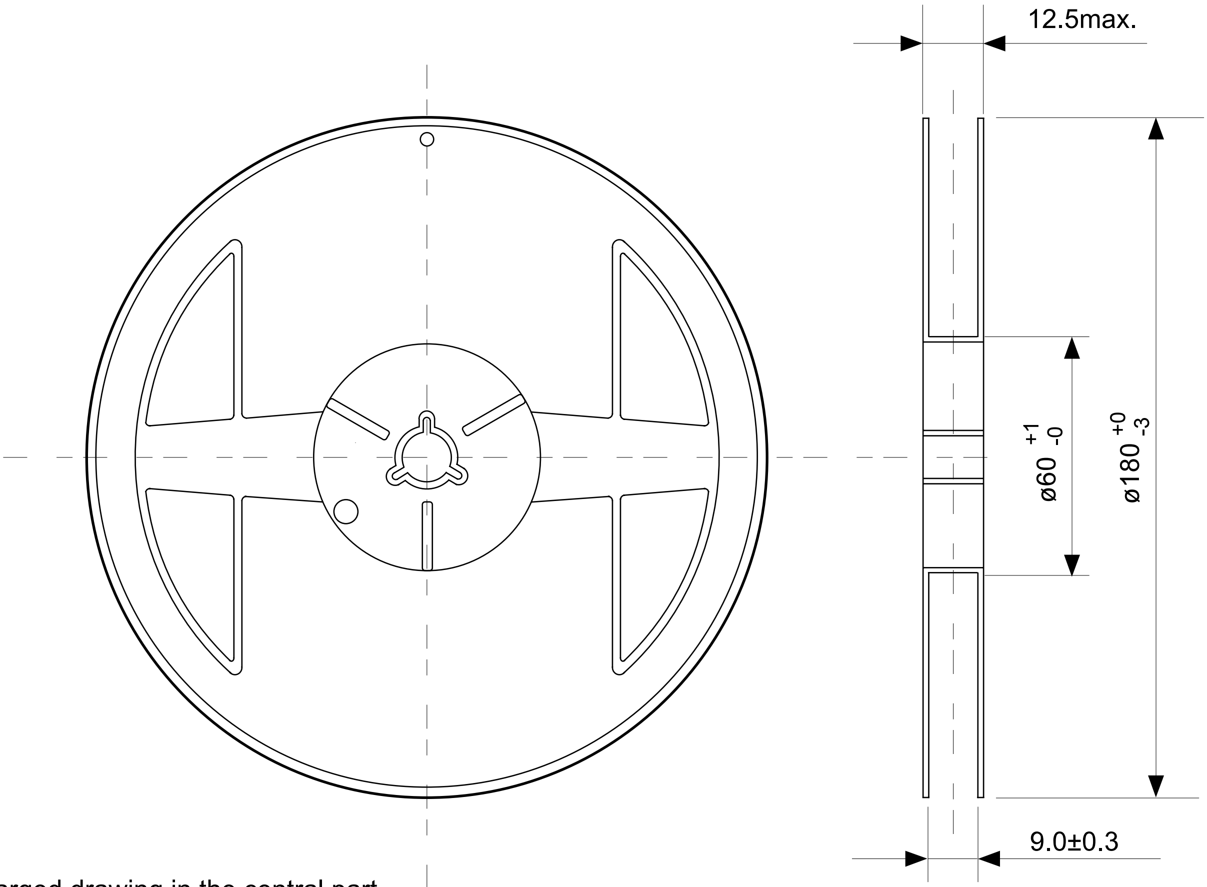
Seiko Instruments Inc.



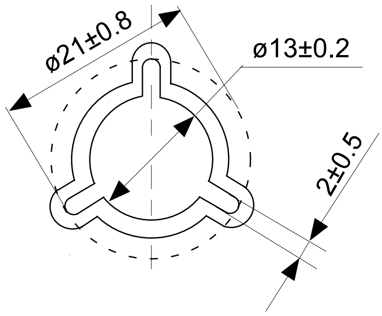


No. BD006-A-C-SD-2.1

TITLE	SNB6B-A-Carrier Tape
No.	BD006-A-C-SD-2.1
SCALE	
UNIT	mm
Seiko Instruments Inc.	



Enlarged drawing in the central part



No. BD006-A-R-SD-1.1

TITLE	SNB6B-A-Reel		
No.	BD006-A-R-SD-1.1		
SCALE		QTY.	3,000
UNIT	mm		

Seiko Instruments Inc.