STEP-UP, 600 kHz, PWM CONTROL or PWM / PFM SWITCHABLE BUILT-IN TRANSISTOR SWITCHING REGULATOR (MULTICHIP PACKAGE) S-83M355/83M356 Series

The S-83M355/83M356 Series is a CMOS step-up switching regulator with power MOS FET (multichip package) which mainly consists of a reference voltage source, an oscillation circuit, an error amplifier, a phase compensation circuit, a PWM control circuit (S-83M355 Series) and a PWM / PFM switching control circuit (S-83M356 Series). With a built-in low on-state resistance power MOS FET, this product can adapt to applications requiring high efficiency and a high output current with few external parts.

The S-83M355 Series employs a PWM control circuit whose duty ratio can be varied linearly, is ideal for applications requiring a low ripple voltage.

The S-83M356 Series features a PWM / PFM switching control circuit that can prevent a decline in the efficiency during a light load.

S-83M335/83M356 Series is ideal for applications requiring high efficiency and a high output current due to its built-in 20 V withstanding voltage power MOS FET.

■ Features

- Built-in power MOS FET
  - : 75 mΩ (typ.)
  - : 20 V withstanding voltage
- Input voltage : 1.5 V to 6.5 V
- Output voltage : 2.0 V to 15 V
  - : can be changed by an external resistor
- Oscillation frequency : 600 kHz
- Efficiency : 85% (typ.)
- Soft start function
- Shutdown function
- Lead-free products

■ 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

■ Package

Package Name	Drawing Code			
	Package	Tape	Reel	Land
PLP-8B	XB008-A	XA008-A	XA008-A	XB008-A

■ Example of Typical Circuit

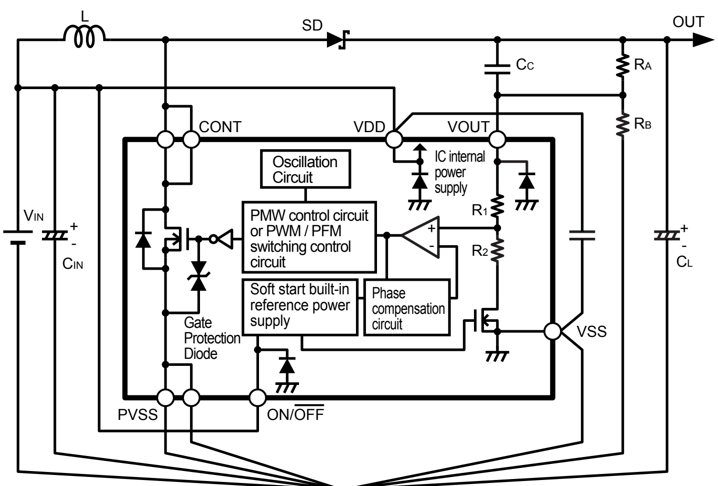


Figure 1

■ Example of Typical Characteristics

S-83M356Q50 (V_{OUT} = 5.0 V, f_{OSC} = 600 kHz)
PWM / PFM at automatic switching operation

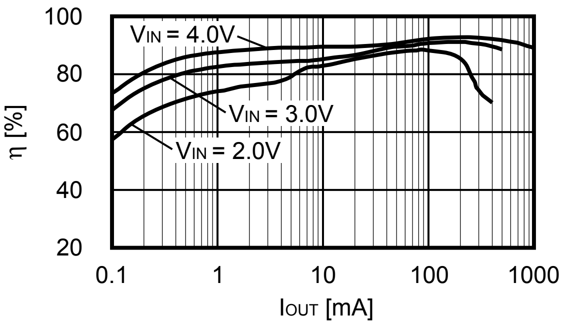


Figure 2

■ Product Name Structure

The control system, product types, and output voltage for the S-83M355/83M356 Series can be selected at the user's request. Please refer to the "**2. Product Name**" for the definition of the product name.

1. Function List

Table 1

Product Name	Output voltage [V]	The corresponding voltage value by an output voltage setting resistor *1 [V]	Control system	
			PWM control	PWM / PFM switching control
S-83M355Q20	2.0	$2.0 \leq V_{OUT(S)} \leq 15.0$	Yes	No
S-83M355Q50	5.0	$5.0 \leq V_{OUT(S)} \leq 15.0$	Yes	No
S-83M356Q20	2.0	$2.0 \leq V_{OUT(S)} \leq 15.0$	No	Yes
S-83M356Q50	5.0	$5.0 \leq V_{OUT(S)} \leq 15.0$	No	Yes

***1.** The output voltage value can optionally be set by an external divider resistor in the S-83M355/83M356 Series. Refer to "**■ External Parts Selection**" **(4. Output voltage setting resistors (R_A, R_B))**, "**■ Application circuit**" for the setting.

Caution If the output voltage is set 6.5 V or higher by an external divider resistor, be careful of the connection of VDD and ON/$\overline{OFF}$ pins. Determine the connection with attention for withstanding voltage not to be applied the value exceeding absolute maximum ratings on VDD and ON/$\overline{OFF}$ pins. Refer to Figure 1 for the setting.

2. Product Name

S-83M3 xx Q xx - X8T1

- X8T1 — Package name(abbreviation) and IC packing specifications *1
  - X8T1 : PLP-8B, Tape
- xx (second) — Output voltage
  - 20 or 50
  - (e.g. When the output voltage is 2.0 V, it is expressed as 20.)
- Q — Product type
  - Q : With shutdown function + V_{DD} / V_{OUT} separate type, f_{OSC} = 600 kHz
- xx (first) — Control system
  - 55 : PWM control
  - 56 : PWM / PFM switching control

***1.** Refer to the taping specifications.

■ Pin Configurations

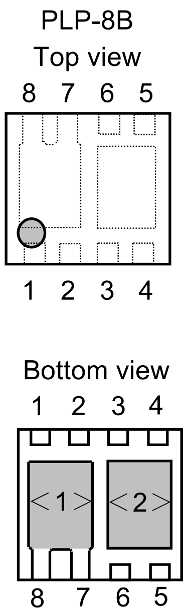


Figure 3

Table 2

Pin No.	Symbol	Pin Description
1, 2	PVSS	Power GND pin
3	VSS	GND pin
4	ON/$\overline{\text{OFF}}$	Shutdown pin "H" : Normal operation (Step-up operation) "L" : Stop step-up (Whole circuit stop)
5	VOUT	Output voltage pin
6	VDD	IC power supply pin
7, 8	CONT	External inductor connection pin

Caution The heatsinks of backside at shadowed area <1> and <2> cannot be used short-circuited since they have a different electric potential.
Connect the heatsink of backside at shadowed area <1> to the board, set electric potential open or CONT.
Connect the heatsink of backside at shadowed area <2> to the board, set electric potential open or VDD.
Although the heatsink of backside at shadowed area <2> is connected internally to VDD, do not use it as the function of electrode.
Refer to Land Recommendation (No. XB008-A-L-SD) for board pattern.

■ Absolute Maximum Ratings

Table 3

(Ta = 25 °C unless otherwise specified)

Item		Symbol	Absolute maximum rating	Unit
VOUT pin voltage		V_{OUT}	V_{SS} − 0.3 to V_{SS} + 12	V
ON / $\overline{OFF}$ pin voltage		$V_{ON/\overline{OFF}}$	V_{SS} − 0.3 to V_{SS} + 12	
VDD pin voltage		V_{DD}	V_{SS} − 0.3 to V_{SS} + 8	
CONT pin voltage		V_{CONT}	V_{SS} − 0.3 to V_{SS} + 20	
CONT pin current	DC	I_{CONT}	1	A
	Pulse	I_{CONTP}	4 *1	
Power dissipation		P_D	400 *2	mW
Operating ambient temperature		Topr	− 40 to + 85	°C
Storage temperature		Tstg	− 40 to + 125	

***1.** Condition : PW = 10 μs, Duty cycle ≤ 1%
***2.** Measurement conditions
(1) Measurement environment : Mounted on board (with no wind)
(2) Board material : FR4
(3) Board size : 30 mm × 70 mm × 1.6 mm (wired on both sides 120%)

Caution 1. 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.
2. Since this IC has a built-in power MOS FET, make sure that dissipation of the power MOS FET does not exceed the allowable power dissipation of the package (Refer to Figure 4).
Generally, dissipation of a switching regulator can be calculated by the following equation.
Dissipation = (100 (%) − efficiency (%)) × output voltage × load current
The greater part of dissipation depends on the built-in power MOS FET, however, dissipation of the external diode or inductor is also included.
In addition, since power dissipation of the package also changes according to a mounting board or a mounting state, fully check them using an actually mounted model.

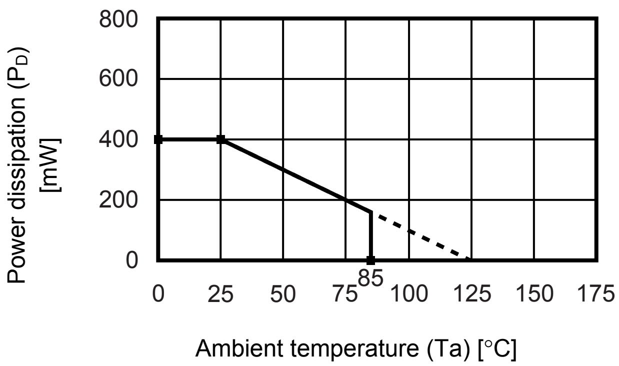


Figure 4 Power Dissipation of The Package (Mounted on board)

■ Electrical Characteristics

Table 4

(Ta = 25°C unless otherwise specified)

Item	Symbol	Condition	Min.	Typ.	Max.	Unit	Measurement circuit
Output voltage	V_{OUT}	–	$V_{OUT(S)} \times 0.976$	$V_{OUT(S)}$	$V_{OUT(S)} \times 1.024$	V	4
Input voltage	V_{IN}	–	–	–	6.5		
Operation start voltage	V_{ST1}	I_{OUT} = 1 mA	–	–	1.5		
Oscillation start voltage	V_{ST2}	No external parts, Voltage applied to V_{DD}	–	–	1.4		1
Operation holding voltage	V_{HLD}	I_{OUT} = 1 mA, Judged by decreasing V_{IN} voltage gradually	0.7	–	–		4
Current consumption 1	I_{SS1}	$V_{OUT} = V_{OUT(S)} \times 0.95$	–	1.25	2.0	mA	1
Current consumption 2	I_{SS2}	$V_{OUT} = V_{OUT(S)} + 0.5$ V	–	16.2	32.4	μA	
Current consumption during shutdown	I_{SSS}	$V_{ON/\overline{OFF}} = 0$ V	–	–	0.5		
Switching transistor on-state resistance	$R_{DS(ON)}$	V_{GS} = 3.3 V, I_{CONT} = 300 mA (Pulse test)	–	75	150	mΩ	3
Switching transistor leakage current	I_{SWQ}	V_{CONT} = 20 V, $V_{ON/\overline{OFF}} = 0$ V	–	–	10	μA	2
Line regulation	ΔV_{OUT1}	$V_{OUT(S)}$ = 5 V : $V_{IN} = V_{OUT(S)} \times 0.4$ to $\times 0.6$, I_{OUT} = 1 mA $V_{OUT(S)}$ = 2 V : $V_{IN} = V_{OUT(S)} - 0.5$ to -0.3, I_{OUT} = 1 mA	–	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 to +85°C	–	± 50	–	ppm /°C	
Oscillation frequency	f_{OSC}	V_{DD} = 3.3 V	510	600	690	kHz	1
Maximum duty ratio	MaxDuty	V_{DD} = 3.3 V	65	78	85	%	
PWM / PFM switching duty ratio (For S-83M356 Series)	PFMDuty	$V_{IN} = V_{OUT(S)} - 0.1$ V, No-load	10	15	24	%	4
ON/$\overline{OFF}$ pin input voltage	V_{SH}	Measured oscillation at CONT pin	0.75	–	–	V	1
	V_{SL}	Measured oscillation stop at CONT pin	–	–	0.3		
ON/$\overline{OFF}$ pin input current	I_{SH}	$V_{ON/\overline{OFF}} = V_{OUT(S)} \times 0.95$	−0.1	–	0.1	μA	
	I_{SL}	$V_{ON/\overline{OFF}} = 0$ V	−0.1	–	0.1		
Soft start time	t_{SS}	–	1.5	3.0	6.0	ms	
Efficiency	EFFI	–	–	85	–	%	4

External parts
- Coil: CDRH8D28-100 of Sumida Corporation
- Diode: M1FH3 (Schottky type) of Shindengen electric MFG. Co., LTD.
- Capacitor: F93 (20 V, 47 μF tantalum type) of Nichicon Corporation

$V_{OUT(S)}$ = 5 V : $V_{IN} = V_{OUT(S)} \times 0.6$ applied, $I_{OUT} = V_{OUT(S)}$ / 50 Ω, V_{DD} = ON/$\overline{OFF}$ = V_{OUT}
$V_{OUT(S)}$ = 2 V : $V_{IN} = V_{OUT(S)} - 0.5$ applied, $I_{OUT} = V_{OUT(S)}$ / 50 Ω, V_{DD} = ON/$\overline{OFF}$ = V_{OUT}

Remark **1.** $V_{OUT(S)}$ specified above is the set output voltage value, and V_{OUT} is the typical value of the actual output voltage.
2. A step-up operation is performed from V_{DD} = 1.5 V. However, 1.8 V ≤ V_{DD} ≤ 6.5 V is recommended stabilizing the output voltage and oscillation frequency.

■ Measurement Circuits

1.

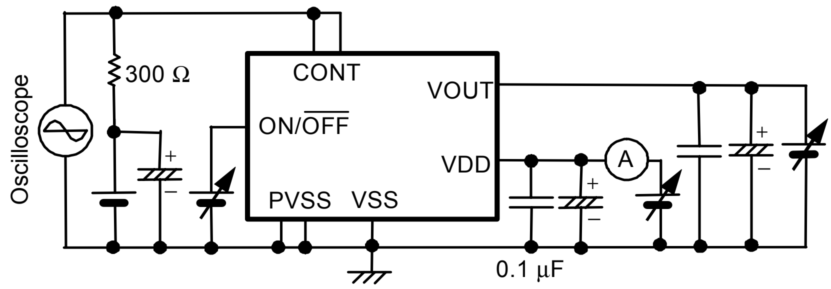


Figure 5

2.

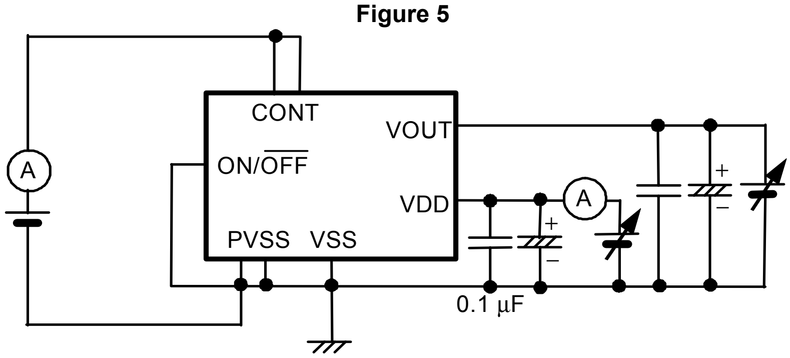


Figure 6

3.

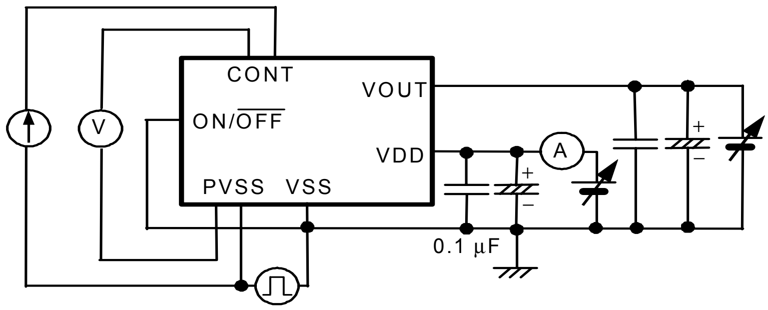


Figure 7 (Pulse test)

4.

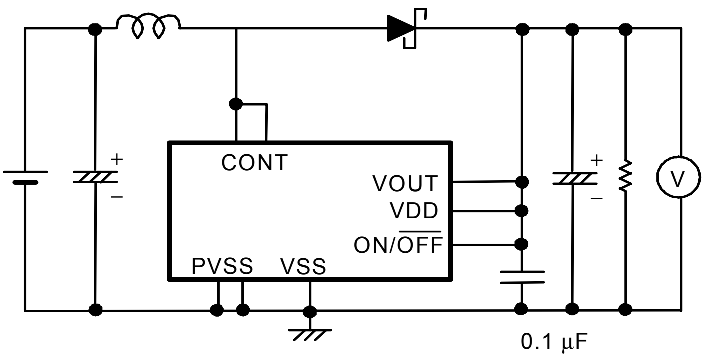


Figure 8

■ Operation

1. Switching Control Types

1. 1 PWM Control (S-83M355 Series)

The S-83M355 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. The switching frequency does not change, although the pulse width changes from 0 to 78% 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. Also, if the pulse width is 0% (During no-load or the input voltage is high), pulses are skipped so that the current will be low.

1. 2 PWM / PFM Switching Control (S-83M356 Series)

The S-83M356 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 low current consumption.
The S-83M356 series operates under PWM control with the pulse width duty changing from 15 to 78% when the output load current is high. On the other hand, when the output current is low, the S-83M356 series operates under PFM control with the pulse width duty fixed at 15%, and pulses are skipped according to the load current. The oscillator thus oscillates intermittently so that the resultant lower current consumption prevents a reduction in the efficiency when the load current is low. The switching point from PWM control to PFM control depends on the external devices (coil, diode, etc.), input voltage, and output voltage. This series is an especially efficient DC-DC converter at an output current around of 100 μA.

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 $\mathrm{ON}/\overline{\mathrm{OFF}}$ pin is switched to the “H” level.

3. ON/$\overline{\text{OFF}}$ Pin (Shutdown Pin)

ON/$\overline{\text{OFF}}$ pin stops or starts step-up operation.

Setting the ON/$\overline{\text{OFF}}$ pin to the "L" level stops operation of all the internal circuits and reduces the current consumption significantly.

DO NOT use the ON/$\overline{\text{OFF}}$ pin in a floating state because it has the structure shown in **Figure 9** and is not pulled up or pulled down internally. DO NOT apply a voltage of between 0.3 V and 0.75 V to the ON/$\overline{\text{OFF}}$ pin because applying such a voltage increases the current consumption. If the ON/$\overline{\text{OFF}}$ pin is not used, connect it to the VDD pin.

The ON/$\overline{\text{OFF}}$ pin does not have hysteresis.

Table 5

ON/$\overline{\text{OFF}}$ 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 the DC resistance of the inductor and the diode forward voltage from V_{IN}.

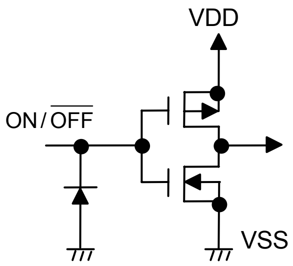


Figure 9 ON/$\overline{\text{OFF}}$ Pin Structure

4. Power MOS FET

This IC has a low on-state resistance power MOS FET, can adopt to applications requiring high efficiency and a high output current with few external parts. A characteristic example of drain current vs. the voltage between drain and source in this IC's built-in power MOS FET is shown in **Figure 10**.

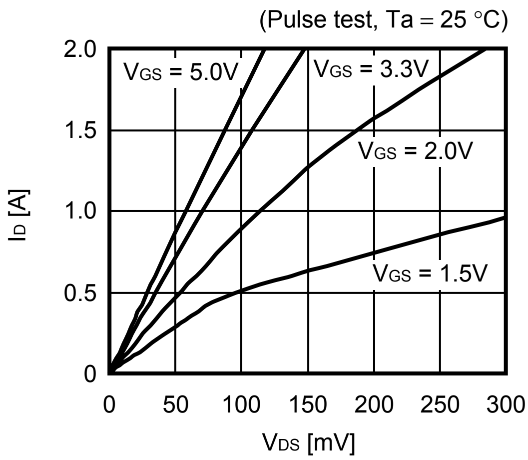
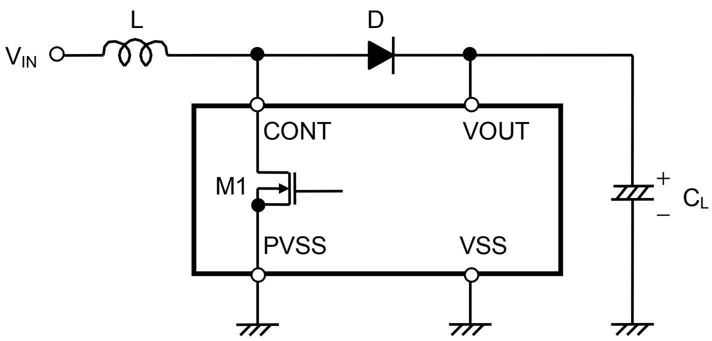


Figure 10 Drain Current vs. Drain to Source Voltage

5. Operation

The followings are the basic equations [(1) through (7)] of the step-up switching regulator (Refer to **Figure 11**).



Remark The positive power supply of circuit in this IC is a VDD pin.

Figure 11 Step-Up Switching Regulator Circuit for Basic Equation

Voltage at CONT pin at the moment M1 is turned ON (V_A) *1:

$V_A = V_S$ *2 .... (1)

***1.** Current flowing through L (I_L) is zero.
***2.** Non-saturated voltage of M1.

The change in I_L over time :

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

Integration of equation (2) (I_L) :

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

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

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

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

$V_L = (V_{OUT} + V_F$ *3$) - V_{IN}$ .... (5)

***3.** Diode forward voltage

The voltage at CONT pin rises only by $V_{OUT} + V_F$.
The change in the current (I_L) flowing through the diode into V_{OUT} during t_{OFF} :

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

Integration of the equation (6) is as follows :

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

During t_{ON}, the energy is stored in L and is not transmitted to V_{OUT}. When receiving the 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 rapidly. V_{OUT} is a time function, and therefore indicates 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 :

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

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

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

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

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 :

$$\Delta Q_1 = \int_0^{t1} I_L dt = I_{PK} \bullet \int_0^{t1} dt - \frac{V_{OUT} + V_F - V_{IN}}{L} \bullet \int_0^{t1} tdt = I_{PK} \bullet t_1 - \frac{V_{OUT} + V_F - V_{IN}}{L} \bullet \frac{1}{2} t_1^{\,2} \quad \text{.......... (12)}$$

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

$$\Delta Q1 = I_{PK} - \frac{1}{2}(I_{PK} - I_{OUT}) \bullet t_1 = \frac{I_{PK} + I_{OUT}}{2} \bullet t_1 \quad \text{.......... (13)}$$

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 the Equivalent Series Resistance (R_{ESR}) of C_L :

$$V_{P-P} = \frac{\Delta Q_1}{C_L} = \frac{1}{C_L} \bullet \left(\frac{I_{PK} + I_{OUT}}{2}\right) \bullet t1 + \left(\frac{I_{PK} + I_{OUT}}{2}\right) \bullet R_{ESR} - \frac{I_{OUT} \bullet t_1}{C_L} \quad \text{.......... (15)}$$

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 R_{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 12**.

For larger output current ?	For higher efficiency ?		For smaller ripple voltage ?
	Operation efficiency	Stand-by efficiency	
Smaller inductance	Larger inductance		
Smaller direct current resistance of inductor			
Larger output capacitance			Larger output capacitance

Figure 12 Relationship between Major Characteristics and External Parts

1. Inductor

The peak current (I_{PK}) increases by decreasing L value and the stability of the circuit improves and I_{OUT} increases. If L value is decreased, the efficiency falls causing a decline in the current drive capacity for the switching transistor, and I_{OUT} decreases.
The loss of I_{PK} by the switching transistor decreases by increasing L value and the efficiency becomes maximum at a certain L value. Further increasing L value decreases the efficiency due to the loss of the direct current resistance of the coil. I_{OUT} also decreases.
A higher oscillation frequency allows selection of a lower L value, making the coil smaller.
The recommended inductances is 3.0 to 22 μH for the S-83M355/83M356 Series.
Be careful of the allowable inductor current when choosing an inductor. Exceeding the allowable current of the inductor causes magnetic saturation, much lower efficiency and destruction of the IC chip due to a large current.
Choose an inductor so that I_{PK} does not exceed the allowable current. I_{PK} in discontinuous mode is calculated by the following equation:

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

f_{osc} = oscillation frequency, $V_F \cong 0.4$ 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
- Current rate : 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. And the capacitor value needs 10 μF or more although it depends on the use condition.
Select an appropriate capacitor the equivalent series resistance (R_{ESR}) for stable output voltage. The stable voltage range in this IC depends on the R_{ESR}. Although the inductance value (L value) is also a factor, an R_{ESR} of 30 to 500 mΩ maximizes the characteristics. However, the best R_{ESR} value may depend on the L value, the capacitance, the wiring, and the applications (output load). Therefore, fully evaluate the R_{ESR} under the actual operating conditions to determine the best value.

4. Output voltage setting resistors (R_A, R_B)

The output voltage value can optionally be set by an external divider resistor in the S-83M355/83M356 Series. Refer to "■ **Application circuit**" for the setting.
Select the product in **Table 6** depending on desired set output voltage.

Table 6

Output voltage [$V_{OUT(S)}$]	2 V ≤ $V_{OUT(S)}$ < 5 V	5 V ≤ $V_{OUT(S)}$ ≤ 15 V	Reference circuit
S-83M35xQ20	Yes	Yes	Application circuit (**Figure 14**)
S-83M35xQ50	No	Yes	Application circuit (**Figure 14**)

■ Standard Circuit

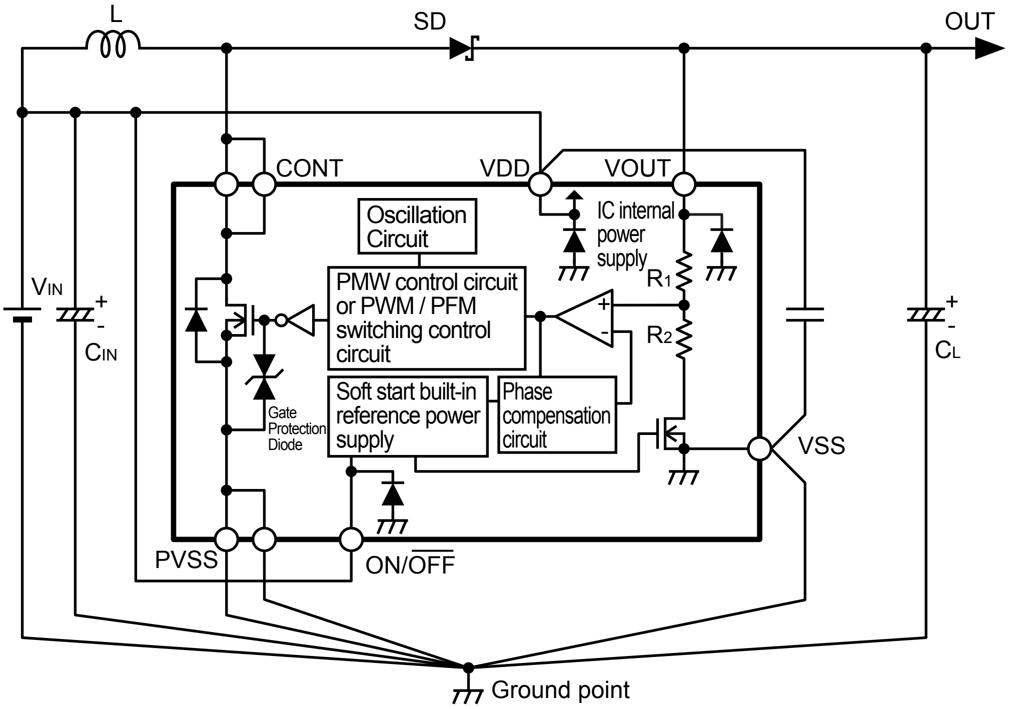


Figure 13 Standard Circuit

■ Precautions

- Mount external capacitors, the diode, and the coil as close as possible to the IC.
- Characteristics ripple voltage and spike noise occur in IC containing switching regulators. Moreover rush current flows at the time of a power supply injection. Because these largely depend on the coil, the capacitor and impedance of power supply used, fully 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.
- The power GND pin of power MOS FET (PVSS) and the GND pin in this IC (VSS) are different pins. Connect PVSS and VSS as a fluctuation of PVSS does not affect on the connection.
- 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 Circuit

1. Usage example of output voltage setting resistors (R_A, R_B)

The S-83M355/83M356 Series allows you to adjust the output voltage or to set the output voltage to a value over the set output voltage of the products of this series, when external resistor (R_A and R_B), and capacitor (C_C) are added, as illustrated in **Figure 14**.

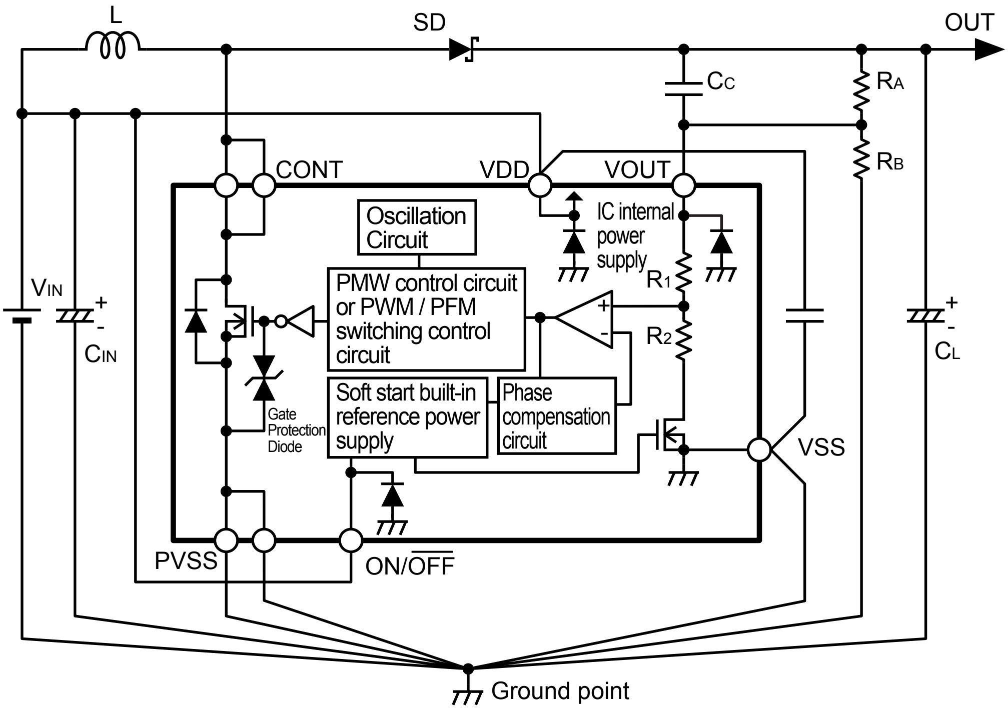


Figure 14 Usage Example of Output Voltage Setting Resistors

The S-83M355/83M356 Series have an internal impedance of R_1 and R_2 between the VOUT pin and the VSS pin, as shown in **Figure 14.** Therefore, OUT (the output voltage) is determined by the output voltage value (V_{OUT}) of the S-83M355/83M356 Series, and the ratio of the parallel resistance value of external resistance (R_B) and internal resistances ($R_1 + R_2$) of the IC, to external resistance (R_A). The output voltage is expressed by the following equation:

$$OUT = V_{OUT} + V_{OUT} \times R_A \div (R_B \mathbin{//}^{*1} (R_1 + R_2))$$

***1.** // shows the combined resistance in parallel.

The voltage accuracy of the OUT set by resistances (R_A and R_B) is not only affected by the IC's output voltage accuracy (V_{OUT} ± 2.4 %), but also by the absolute precision of external resistances (R_A and R_B) in use and the absolute value deviations of internal resistances (R_1 and R_2) in the IC. Let us designate the maximum deviations of the absolute value of R_A and R_B by $R_A$max. and $R_B$max., respectively, the minimum deviations by R_A min. and R_B min., respectively, and the maximum and minimum deviations of the absolute value of R_1 and R_2 in the IC by ($R_1 + R_2$) max and ($R_1 + R_2$) min, respectively. Then, the minimum deviation value OUT min and the maximum deviation value OUT max of the OUT are expressed by the following equations:

$$OUT\ min. = V_{OUT} \times 0.976 + V_{OUT} \times 0.976 \times R_A min. \div (R_B max. \mathbin{//} (R_1 + R_2)\ max.)$$

$$OUT\ max. = V_{OUT} \times 1.024 + V_{OUT} \times 1.024 \times R_A max. \div (R_B min. \mathbin{//} (R_1 + R_2)\ min.)$$

The voltage accuracy of the OUT cannot be made higher than the output voltage accuracy ($V_{OUT} \pm 2.4$ %) of the IC itself, without adjusting the R_A and R_B involved. The closer the voltage value of the output OUT and the output voltage value (V_{OUT}) of the IC are brought to one other, the more the output voltage remains immune to deviations in the absolute accuracy of R_A and R_B and the absolute value of R_1 and R_2 in the IC. In particular, to suppress the influence of deviations in R_1 and R_2 in the IC, a major contributor to deviations in the OUT, the R_A and R_B must be limited to a much smaller value than that of R_1 and R_2 in the IC.
On the other hand, a reactive current flows through R_A and R_B. This reactive current must be reduced to a negligible value with respect to the load current in the actual use of the IC so that the efficiency characteristics will not be degraded. This requires that the value of R_A and R_B be made sufficiently large. However, too large a value (more than 1 MΩ) for the R_A and R_B would make the IC vulnerable to external noise. Check the influence of this value on actual equipment. There is a tradeoff between the voltage accuracy of the OUT and the reactive current. This should be taken into consideration based on the requirements of the intended application. Deviations in the absolute value of the internal resistances (R_1 and R_2) in the IC vary with the output voltage of the S-83M355/83M356 Series, and are broadly classified as follows:

Table 7

Output voltage	Deviations in the absolute value of R_1 and R_2 in the IC
2.0 V	1.4 MΩ to 14.8 MΩ
5.0 V	1.4 MΩ to 12.1 MΩ

When a value of $R_1 + R_2$ given by the equation indicated below is taken in calculating the voltage value of the output OUT, a median voltage deviation will be obtained for the OUT.

$R_1 + R_2 = 2 \div (1 \div$ maximum deviation in absolute value of R_1 and $R_2 + 1 \div$ minimum deviation in absolute value of R_1 and $R_2)$

Moreover, add a capacitor (C_C) in parallel to the external resistance (R_A) in order to avoid output oscillations and other types of instability (Refer to **Figure 14**). Make sure that C_C is larger than the value given by the following equation:

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

If a large C_C value is selected, a longer soft start time than the one set up in the IC will be set.

Table 8

Condition	Output Voltage	IC	L Type Name	SD Type Name	C_L	R_a	R_b	Cc
1	15 V	S-83M356Q50	CDRH8D28-100	M1FH3	F93 (20 V, 47 μF)	750 kΩ	390 kΩ	12 pF
2	10 V	S-83M356Q50	CDRH8D28-100	M1FH3	F93 (25 V, 47 μF)	560 kΩ	560 kΩ	15 pF
3	3.3 V	S-83M356Q20	CDRH8D28-100	M1FH3	F93 (20 V, 47 μF)	150 kΩ	240 kΩ	56 pF

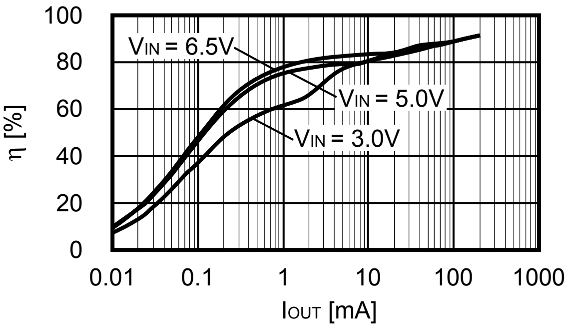
Caution 1. The above connection diagram and constant will not guarantee successful operation. Perform through evaluation using the actual application to set the constant.
2. This IC starts a step-up operation at V_{DD} = 1.5 V, but set 1.8 V ≤ V_{DD} ≤ 6.5 V to stabilize the output voltage and frequency of the oscillator. An input voltage of 1.8 to 6.5 V at the VDD pin allows connection of the VDD pin to either the input power VIN pin or output power VOUT pin.

2. Characteristic Examples of Using Output Voltage Setting Resistors (R_A, R_B)

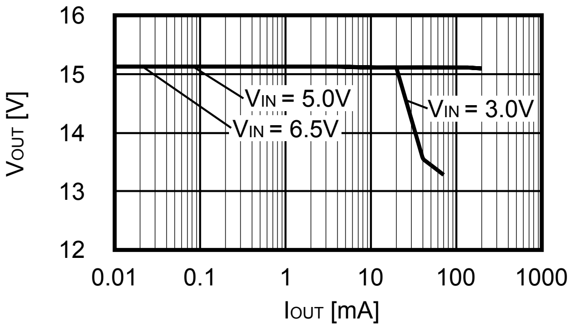
The data of the characteristics (a) Output current (I_{OUT}) vs. Efficiency (η) characteristics, (b) Output current (I_{OUT}) vs. Output voltage (V_{OUT}) characteristics under conditions of 1 to 3 in **Table 8** is shown below.

Condition 1

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

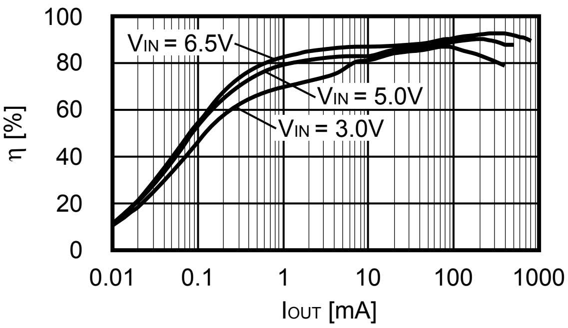


(b) Output current (I_{OUT}) vs. Output voltage (V_{OUT})

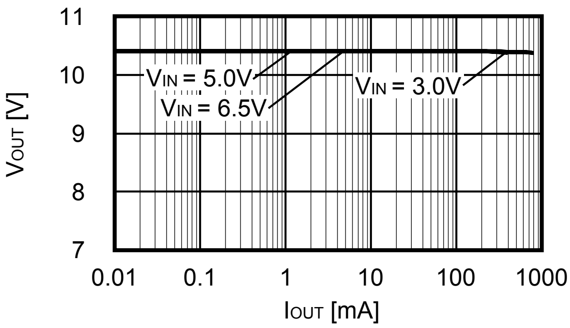


Condition 2

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

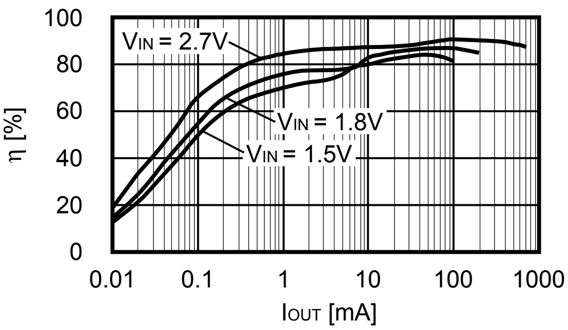


(b) Output current (I_{OUT}) vs. Output voltage (V_{OUT})

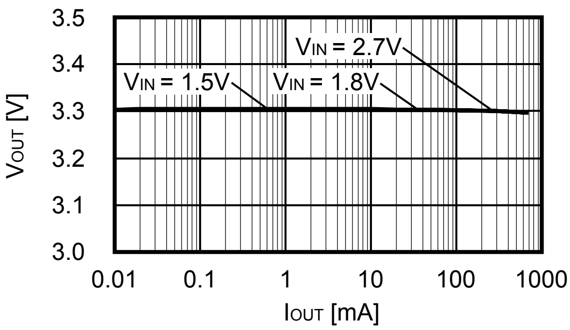


Condition 3

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



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



3. Using Ceramic Capacitor Example

When using small R_{ESR} parts such as ceramic capacitors for the output capacitance, mount a resistor (R_E) corresponding to the R_{ESR} in series with the ceramic capacitor (C_L) as shown in the below figure.
R_E differs depending on "L" value, the capacitance, the wiring, and the application (output load). The following example shows a circuit using R_E = 100 mΩ, input voltage = 3.0 V, output voltage = 5.0 V, output load = 400 mA and its characteristics.

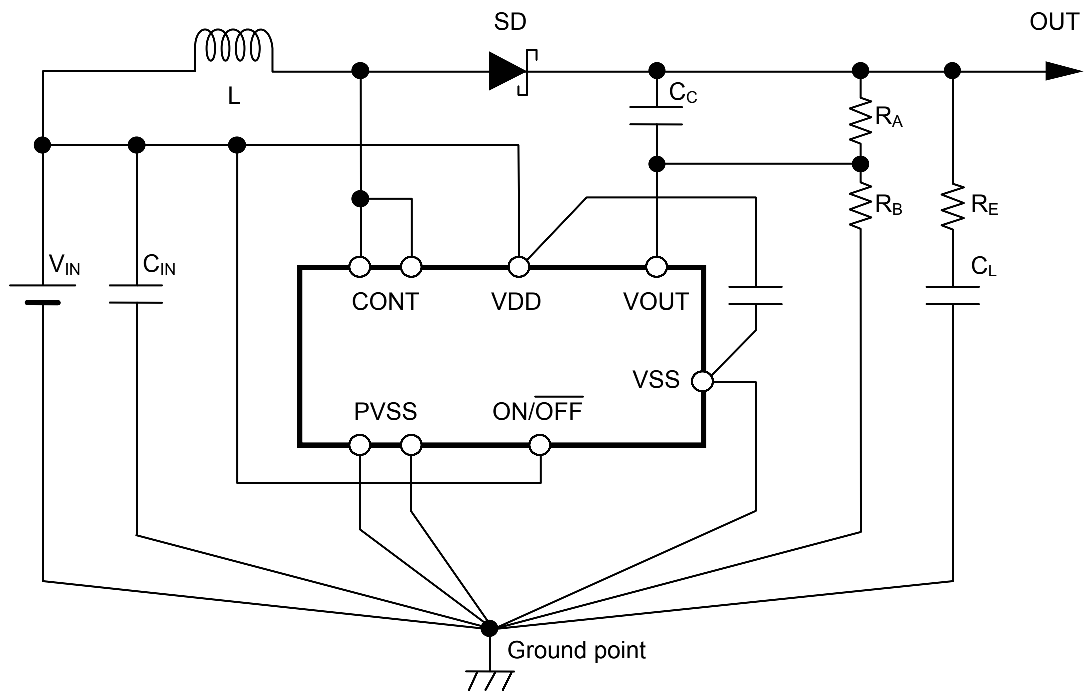


Figure 15 Using Ceramic Capacitor Circuit Example

Table 9

Condition	Output voltage	IC	L Type Name	SD Type Name	C_L (Ceramic capacitor)	R_E	R_A	R_B	C_C
1	5.0 V	S-83M356Q50	CDRH8D28-100	M1FH3	10 μF × 3	100 mΩ	Short	Open	Open
2	3.3 V	S-83M356Q20	CDRH8D28-100	M1FH3	10 μF × 3	100 mΩ	150 kΩ	240 kΩ	56 pF

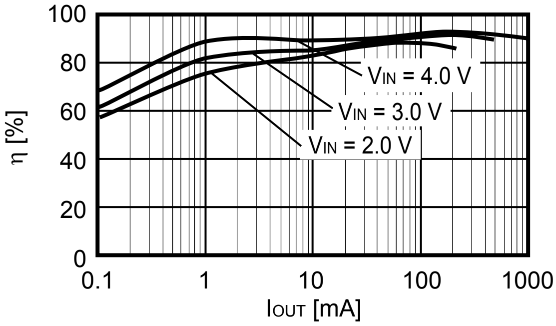
Caution The above connection diagram and constant will not guarantee successful operation. Perform through evaluation using the actual application to set the constant.

4. Characteristic Examples of Circuit Using Ceramic Capacitor

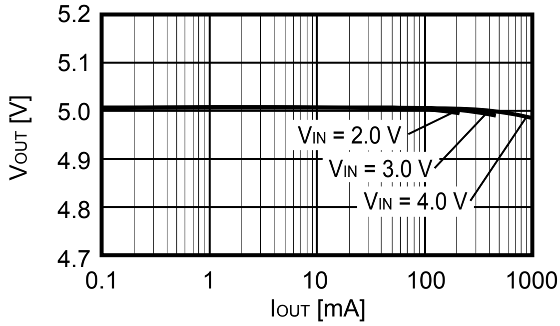
The data of the step-up characteristics (a) Output current (I_{OUT}) vs. Efficiency (η) characteristics, (b) Output current (I_{OUT}) vs. Output voltage (V_{OUT}) characteristics, (c) Output current (I_{OUT}) vs. Ripple voltage (V_r) under conditions of 1 to 2 in **Table 9** is shown below.

Condition 1

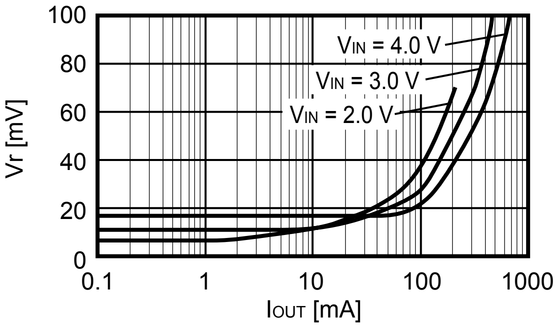
(a) Output current (I_{OUT}) vs. Efficiency (η)



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

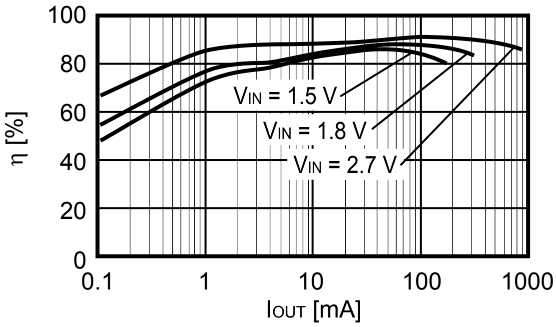


(c) Output current (I_{OUT}) vs. Ripple voltage (V_r)

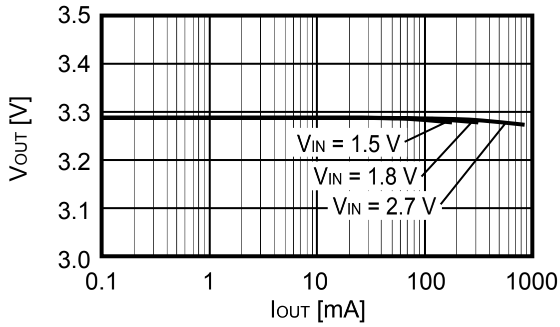


Condition 2

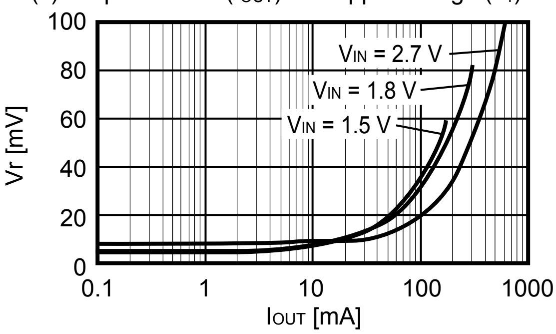
(a) Output current (I_{OUT}) vs. Efficiency (η)



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



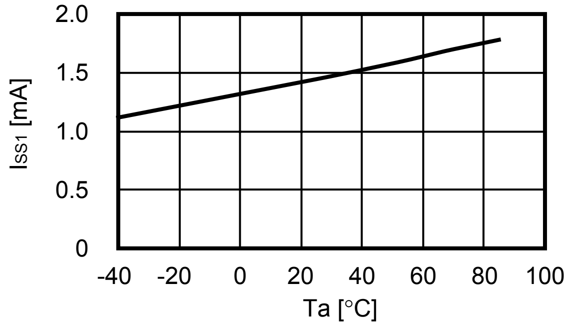
(c) Output current (I_{OUT}) vs. Ripple voltage (V_r)



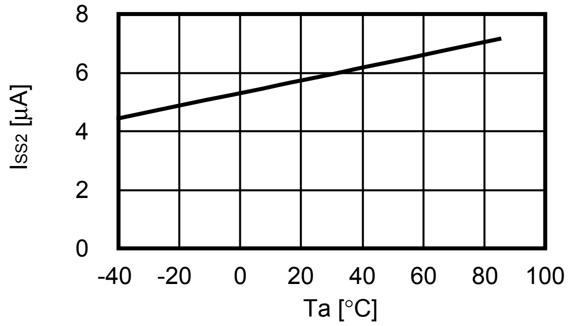
■ Characteristics (Typical Data)

1. Example of Major Temperature Characteristics (Ta = –40 to +85 °C, V_{OUT} = 5.0 V f_{OSC} = 600 kHz)

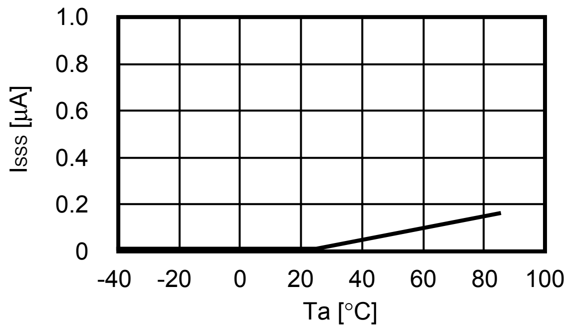
(1) Current consumption 1 (I_{SS1}) vs. Temperature (Ta)



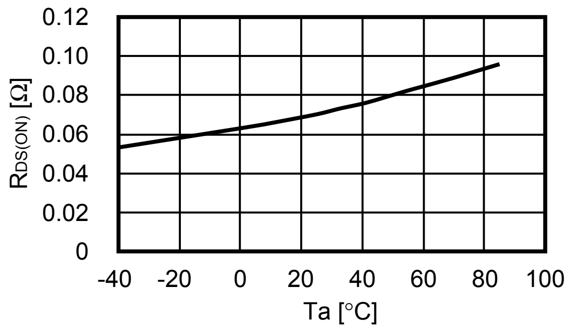
(2) Current consumption 2 (I_{SS2}) vs. Temperature (Ta)



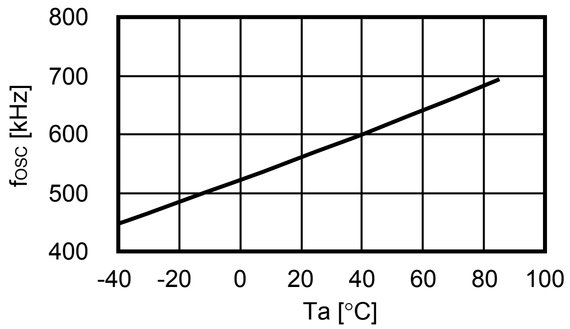
(3) Current consumption at shutdown (I_{SSS}) vs. Temperature (Ta)



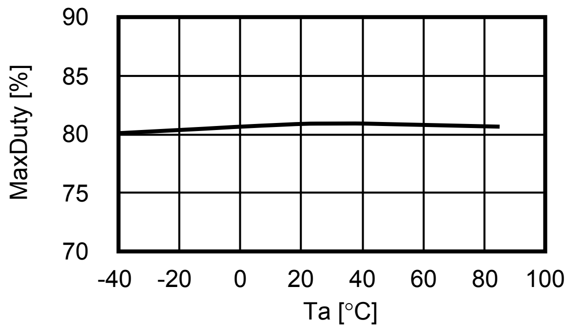
(4) Switching transistor on-state resistance ($R_{DS(ON)}$) vs. Temperature (Ta)



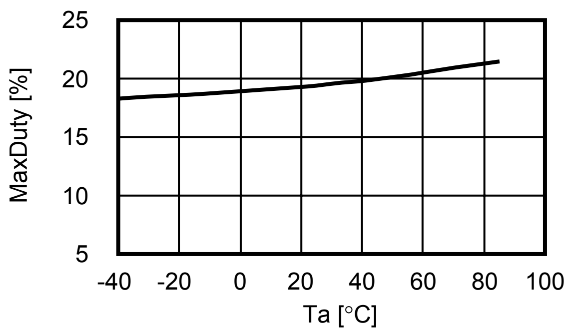
(5) Oscillation frequency (f_{OSC}) vs. Temperature (Ta)



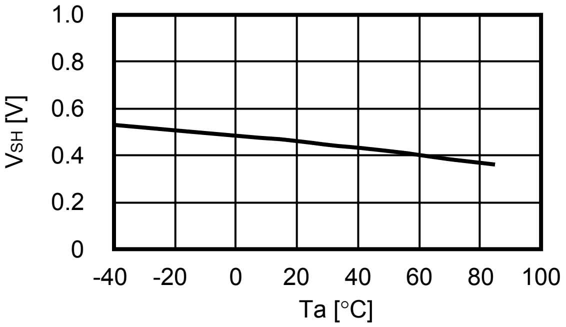
(6) Maximum duty ratio (MaxDuty) vs. Temperature (Ta)



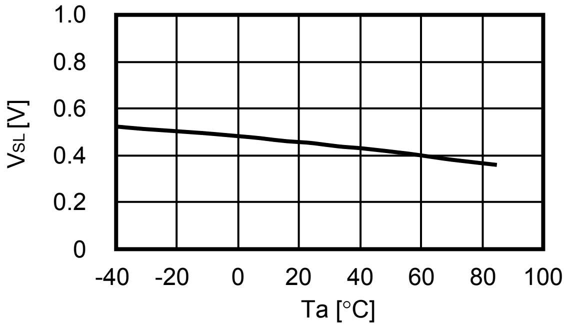
(7) PWM /PFM switching duty ratio (PFMDuty) vs. Temperature (Ta) (S-83M356 Series)



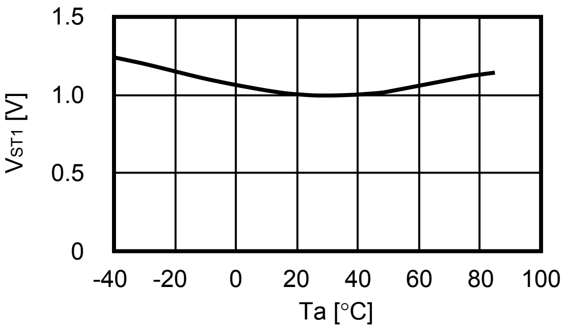
(8) ON / $\overline{\text{OFF}}$ pin input voltage "H" (V_{SH}) vs. Temperature (Ta)



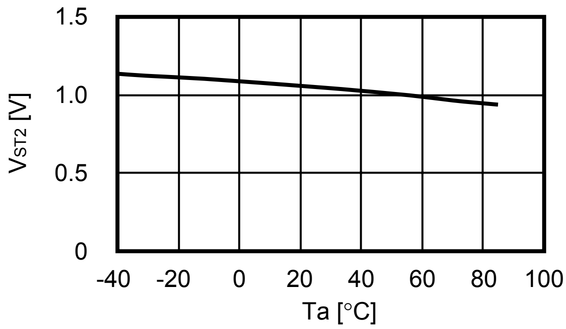
(9) ON / $\overline{\text{OFF}}$ pin input voltage "L" (V_{SL}) vs. Temperature (Ta)



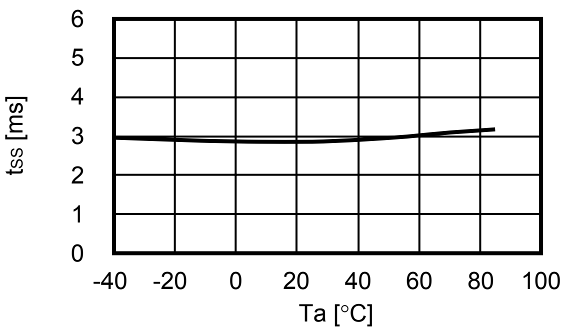
(10) Operation start voltage (V_{ST1}) vs. Temperature (Ta)



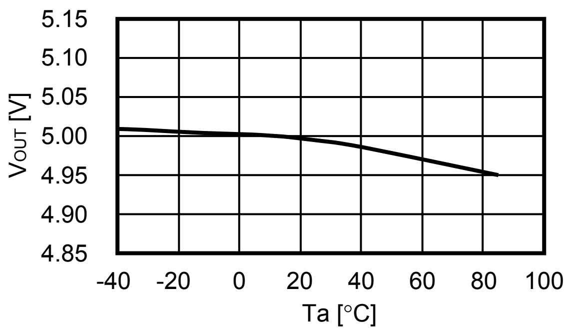
(11) Oscillation start voltage (V_{ST2}) vs. Temperature (Ta)



(12) Soft start time (t_{SS}) vs. Temperature (Ta)

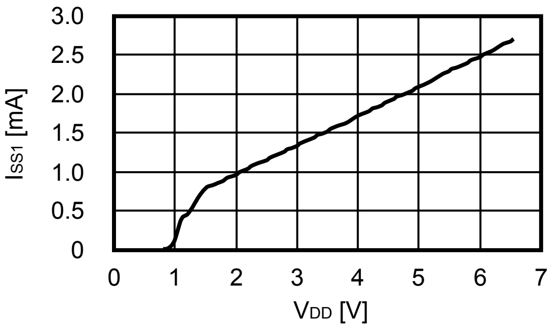


(13) Output voltage (V_{OUT}) vs. Temperature (Ta)

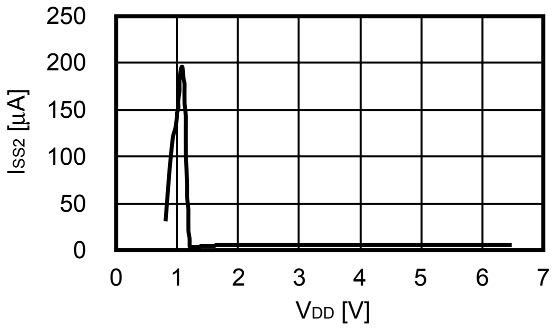


2. Examples of Major Power Supply Dependence Characteristics (Ta = 25 °C, V_{OUT} = 5.0 V f_{OSC} = 600 kHz)

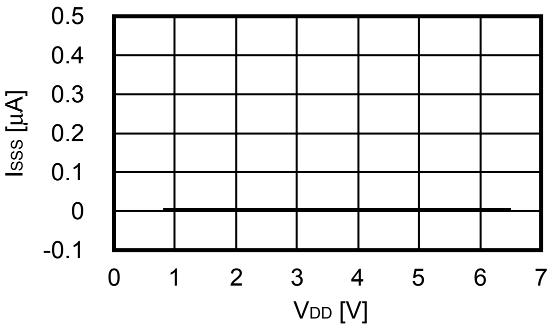
(1) Current consumption 1 (I_{SS1}) vs. Power supply voltage (V_{DD})



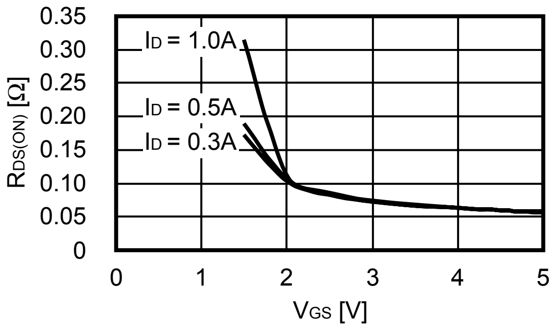
(2) Current consumption 2 (I_{SS2}) vs. Power supply voltage (V_{DD})



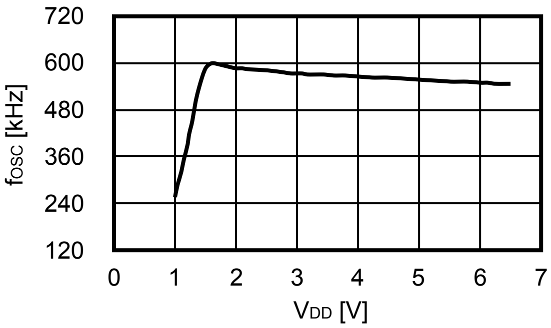
(3) Current consumption at shutdown (I_{SSS}) vs. Power supply voltage (V_{DD})



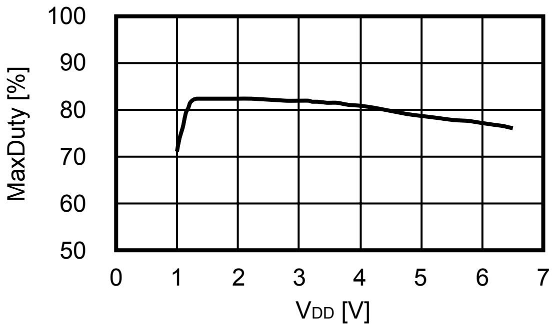
(4) Switching transistor on-state resistance ($R_{DS(ON)}$) vs. Voltage between gate and source (V_{GS})



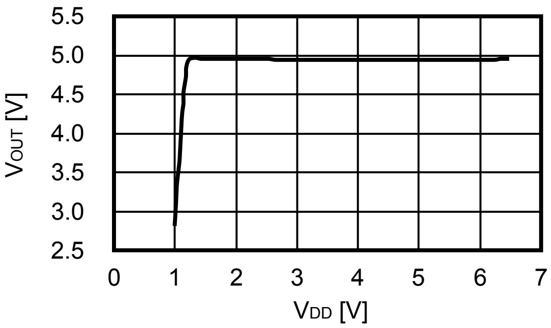
(5) Oscillation frequency (f_{OSC}) vs. Power supply voltage (V_{DD})



(6) Maximum duty ratio (MaxDuty) vs. Power supply voltage (V_{DD})

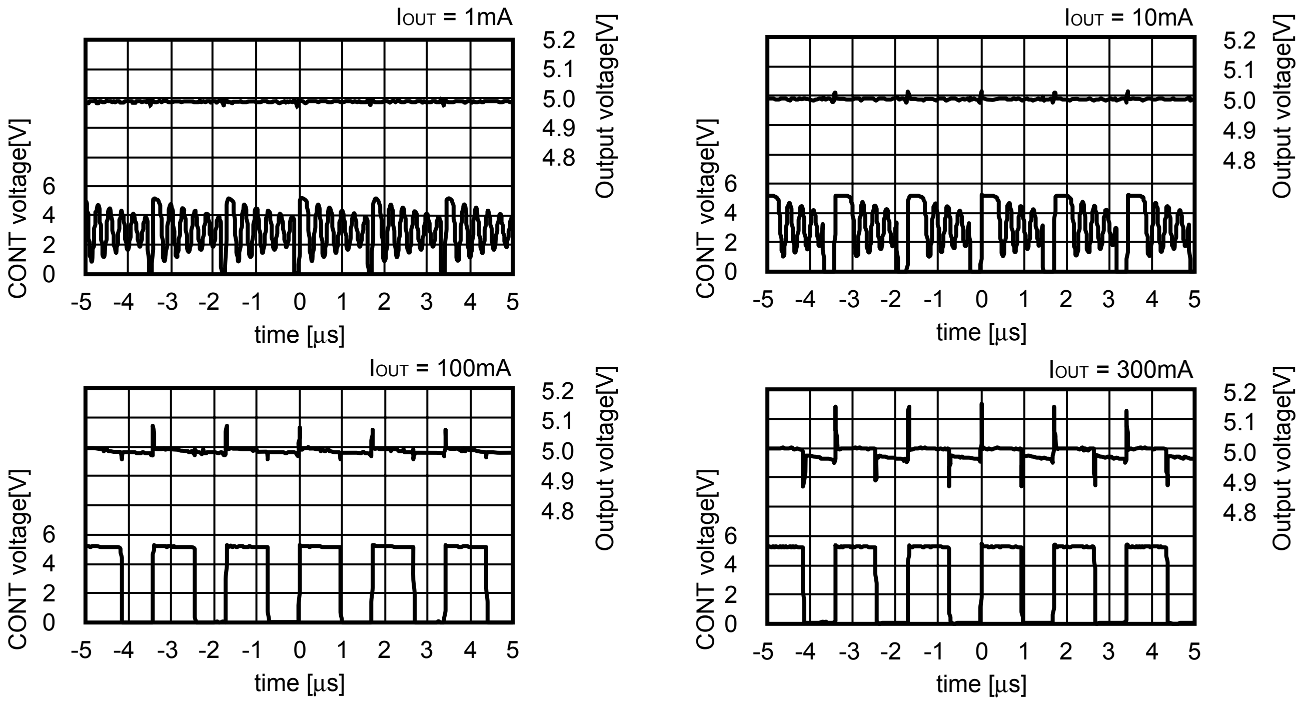


(7) Output voltage (V_{OUT}) vs. Power supply voltage (V_{DD}) (V_{IN} = 3.0 V, I_{OUT} = 100 mA)

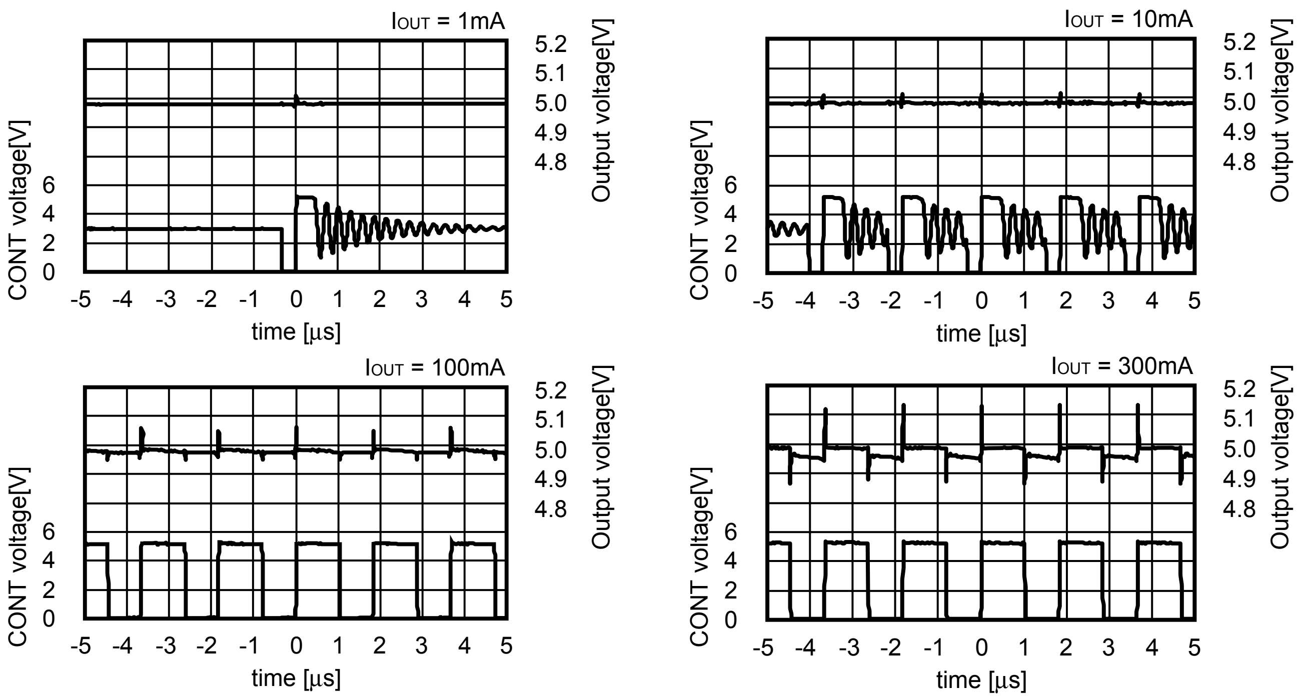


3. Output Waveforms

(1) S-83M355Q50

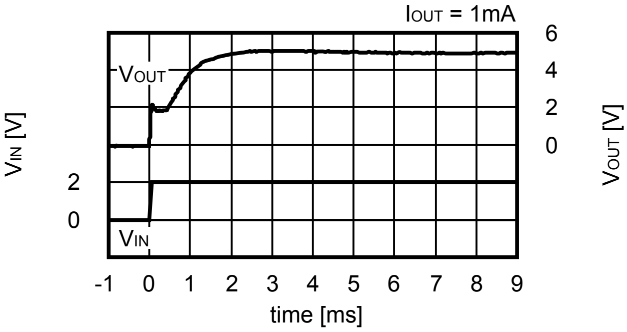


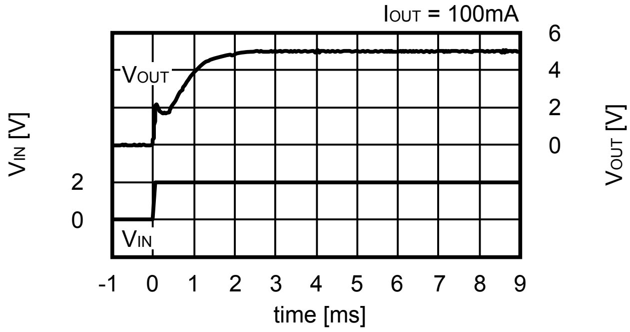
(2) S-83M356Q50



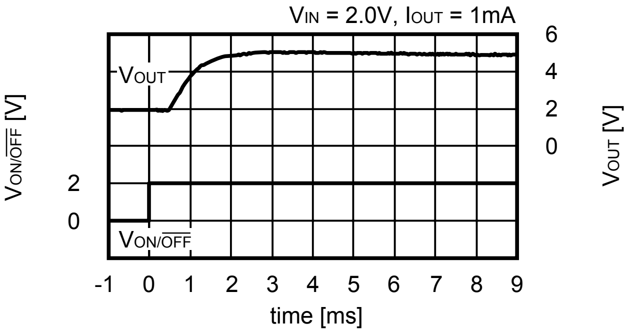
4. Examples of Transient Response Characteristics (V_{OUT} = 5.0 V f_{OSC} = 600 kHz)

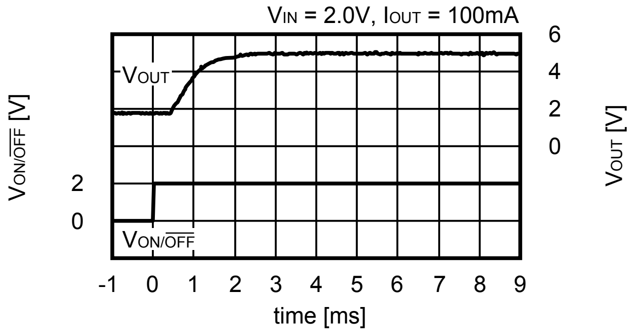
(1) Power-On (V_{IN} : 0 V→2 V)



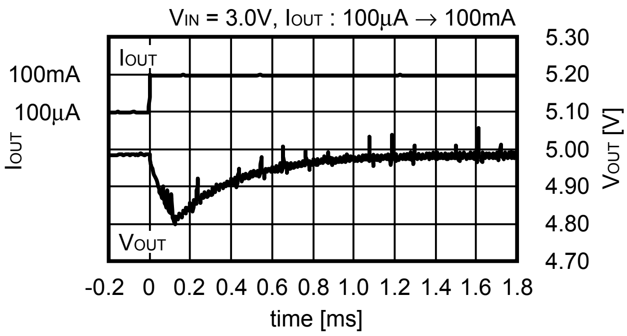


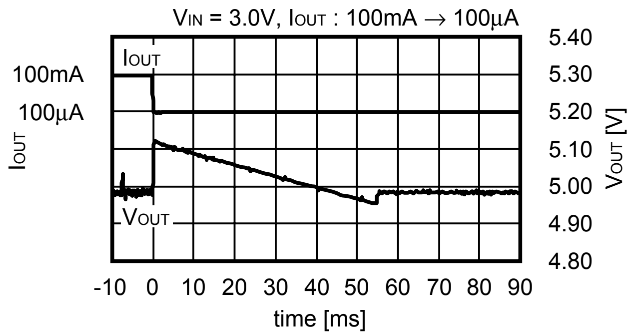
(2) ON/$\overline{OFF}$ Pin Response ($V_{ON/\overline{OFF}}$: 0 V → 2 V)



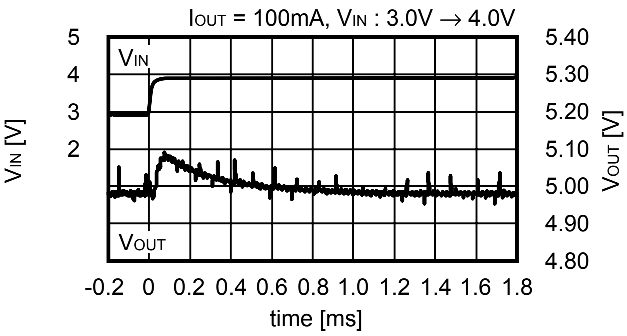


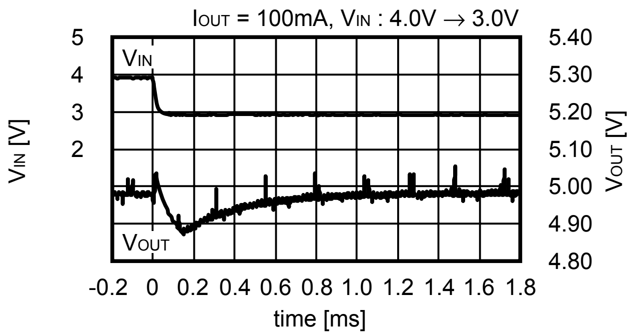
(3) Load Fluctuations





(4) Input Voltage Fluctuations (I_{OUT} = 100 mA)





■ 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. External Parts for Reference Data

Table 10 Efficiency vs. Output Current Characteristics and Output Voltage vs. Output Current Characteristics for External Parts

Condition	Product Name	Oscillation Frequency	Output Voltage	Control System	Inductor	Diode	Output capacitor
1	S-83M355Q20	600 kHz	2.0 V	PWM	CDRH8D28-100	M1FH3	F93 (20 V, 47 μF)
2	S-83M355Q50	600 kHz	5.0 V	PWM			
3	S-83M356Q20	600 kHz	2.0 V	PWM / PFM			
4	S-83M356Q50	600 kHz	5.0 V	PWM / PFM			

The properties of the external parts are shown below.

Table 11 Properties of External Parts

Compornent	Product Name	Manufacturer	Characteristics
Inductor	CDRH8D28-100	Sumida Corporation	10 μH, DCR *1 = 47 mΩ, $I_{MAX.}$ *2 = 2.7 A, Component height = 3.0 mm
Diode	M1FH3	Shindengen Electric MFG. Co., LTD.	V_F *3 = 0.3 V, I_F *4 = 1.5 A
Capacitor (Output Capacitance)	F93	Nichicon Corporation	20 V, 47 μF

***1.** Direct current resistance
***2.** Maximum allowable current
***3.** Forward voltage
***4.** Forward current

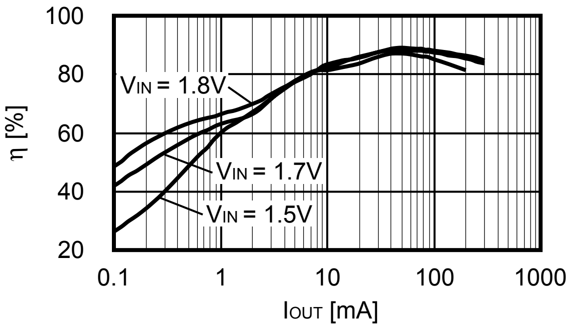
Caution The values shown in the characteristics column of Table 11 above are based on the materials provided by each manufacturer. However, consider the characteristics of the original materials when using the above products.

2. Output Current (I_{OUT}) vs. Efficiency (η) Characteristics, Output Current (I_{OUT}) vs. Output Voltage (V_{OUT}) and Output current (I_{OUT}) vs. Ripple voltage (V_r) Characteristics

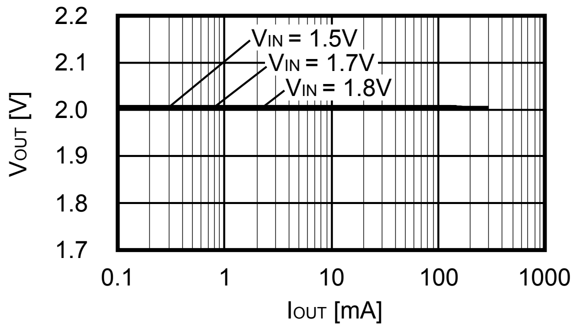
The following shows the actual (a) Output current (I_{OUT}) vs. Efficiency (η) characteristics and (b) Output current (I_{OUT}) vs. Output voltage (V_{OUT}) and (C) Output current (I_{OUT}) vs. Ripple voltage (V_r) characteristics under the conditions of No. 1 to 4 in **Table 10**.

Condition 1 S-83M355Q20

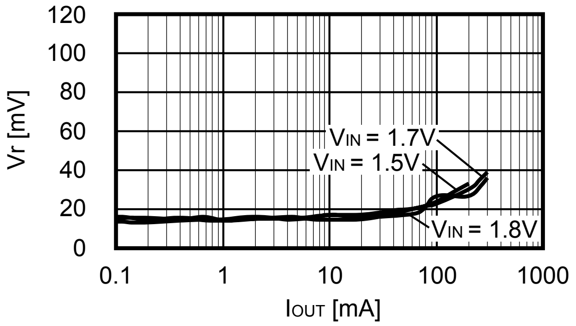
(a) Output current (I_{OUT}) vs. Efficiency (η)



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

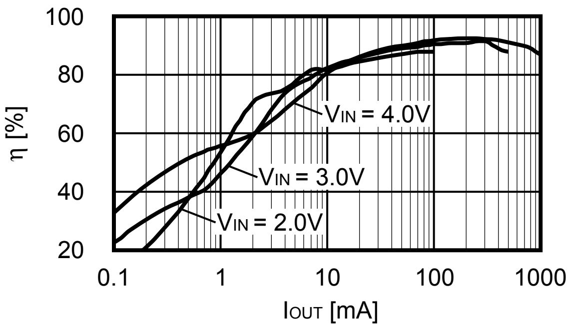


(c) Output current (I_{OUT}) vs. Ripple voltage (V_r)

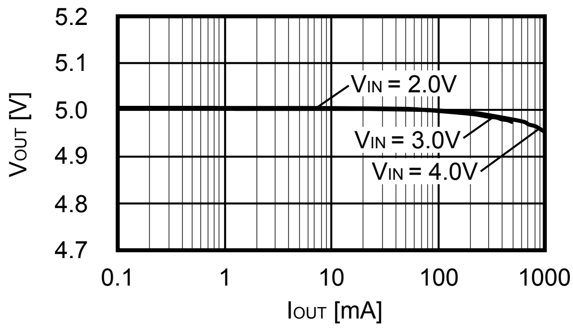


Condition 2 S-83M355Q50

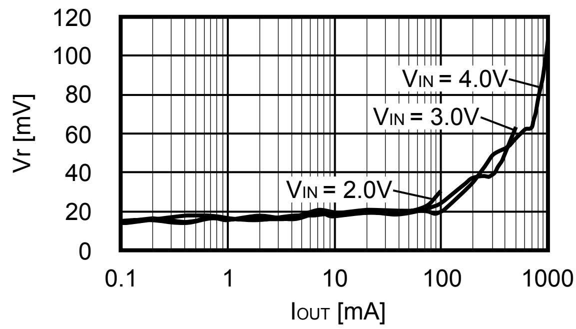
(a) Output current (I_{OUT}) vs. Efficiency (η)



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

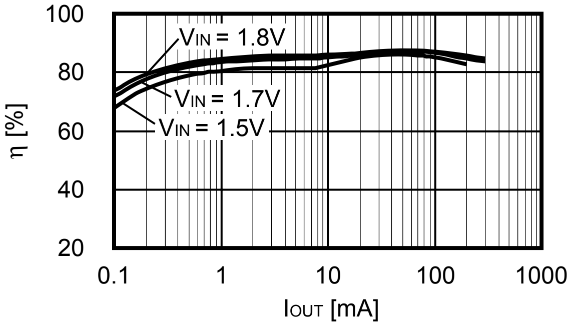


(c) Output current (I_{OUT}) vs. Ripple voltage (V_r)

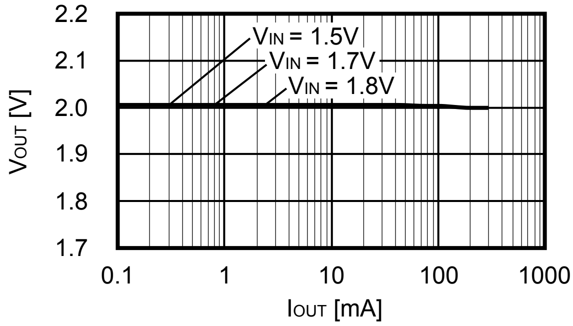


Condition 3 S-83M356Q20

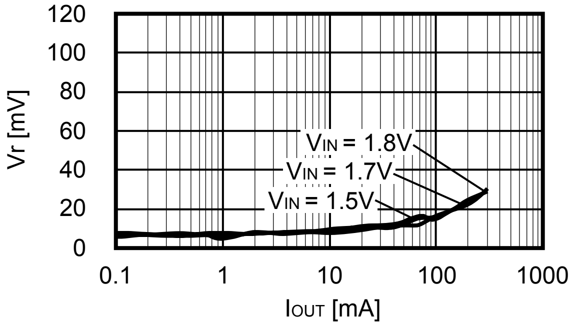
(a) Output current (I_{OUT}) vs. Efficiency (η)



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

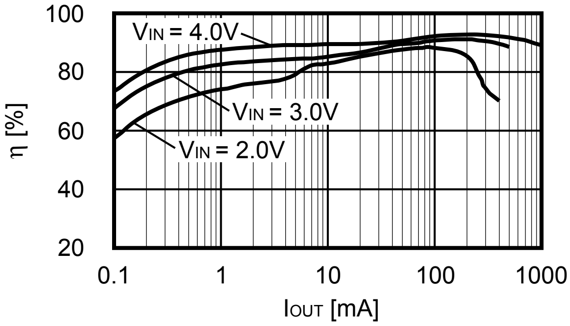


(c) Output current (I_{OUT}) vs. Ripple voltage (V_r)

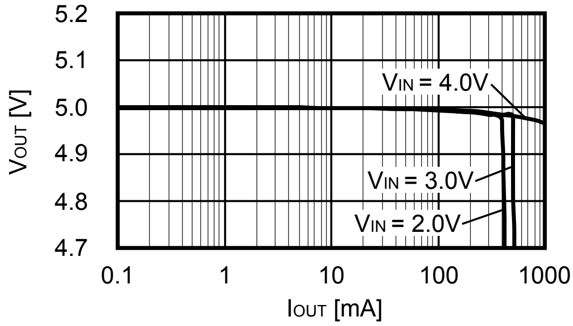


Condition 4 S-83M356Q50

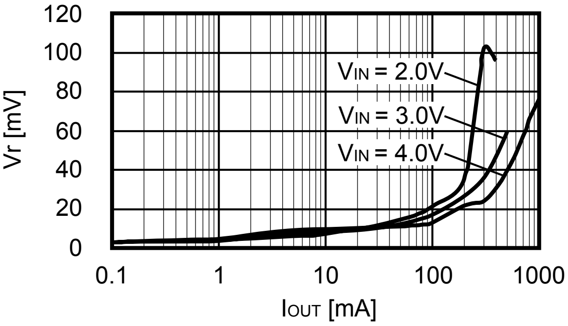
(a) Output current (I_{OUT}) vs. Efficiency (η)



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

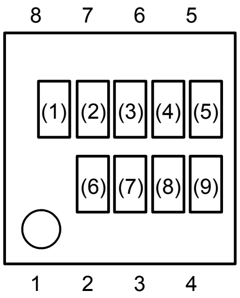


(c) Output current (I_{OUT}) vs. Ripple voltage (V_r)



■ Marking specification

PLP-8B
Top view



(1) to (3) : Product code (Refer to **Product name vs. Product code**)
(4) to (9) : Lot number

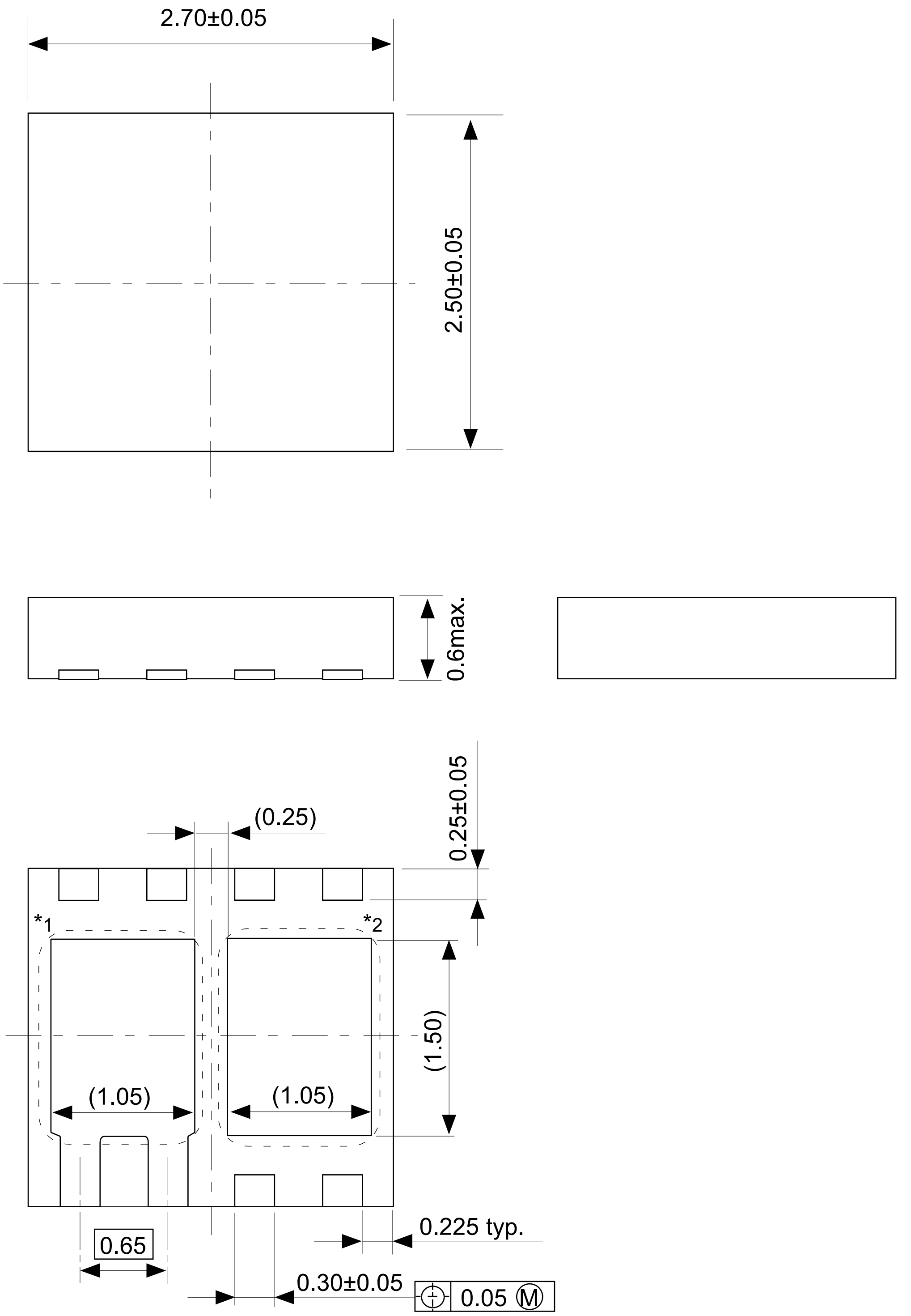
Product name vs. Product code

(a) **S-83M355 Series**

Product name	Product code		
	(1)	(2)	(3)
S-83M355Q20-X8T1	J	P	A
S-83M355Q50-X8T1	J	P	B

(b) **S-83M356 Series**

Product name	Product code		
	(1)	(2)	(3)
S-83M356Q20-X8T1	J	P	K
S-83M356Q50-X8T1	J	P	L



No. XB008-A-P-SD-1.0

※ Two heatsinks of back side has different electric potential depending on the product.
Confirm specifications of each product.
Do not use it as the function of electrode.

TITLE	PLP8B-A-PKG Dimensions
No.	XB008-A-P-SD-1.0
SCALE	
UNIT	mm

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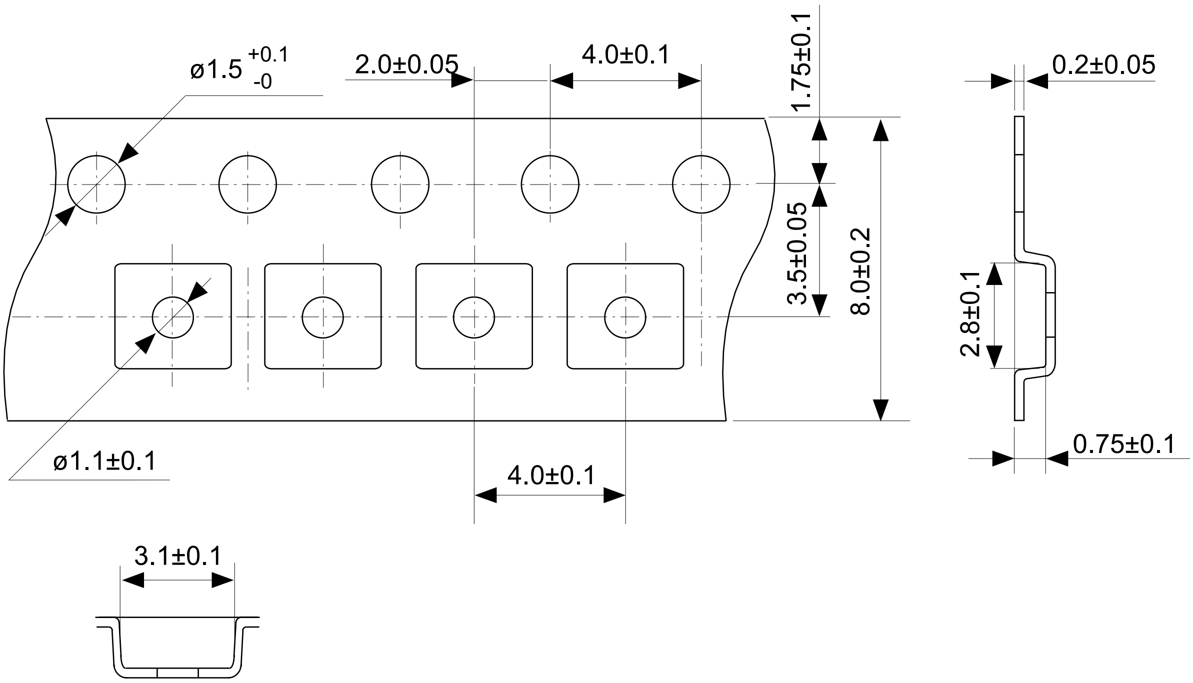
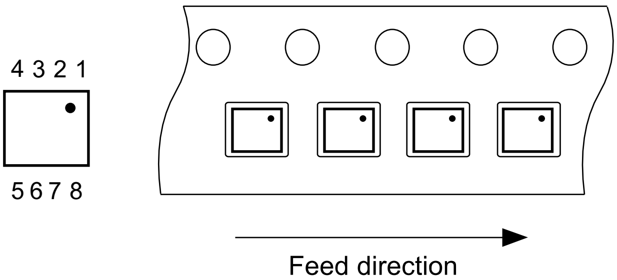
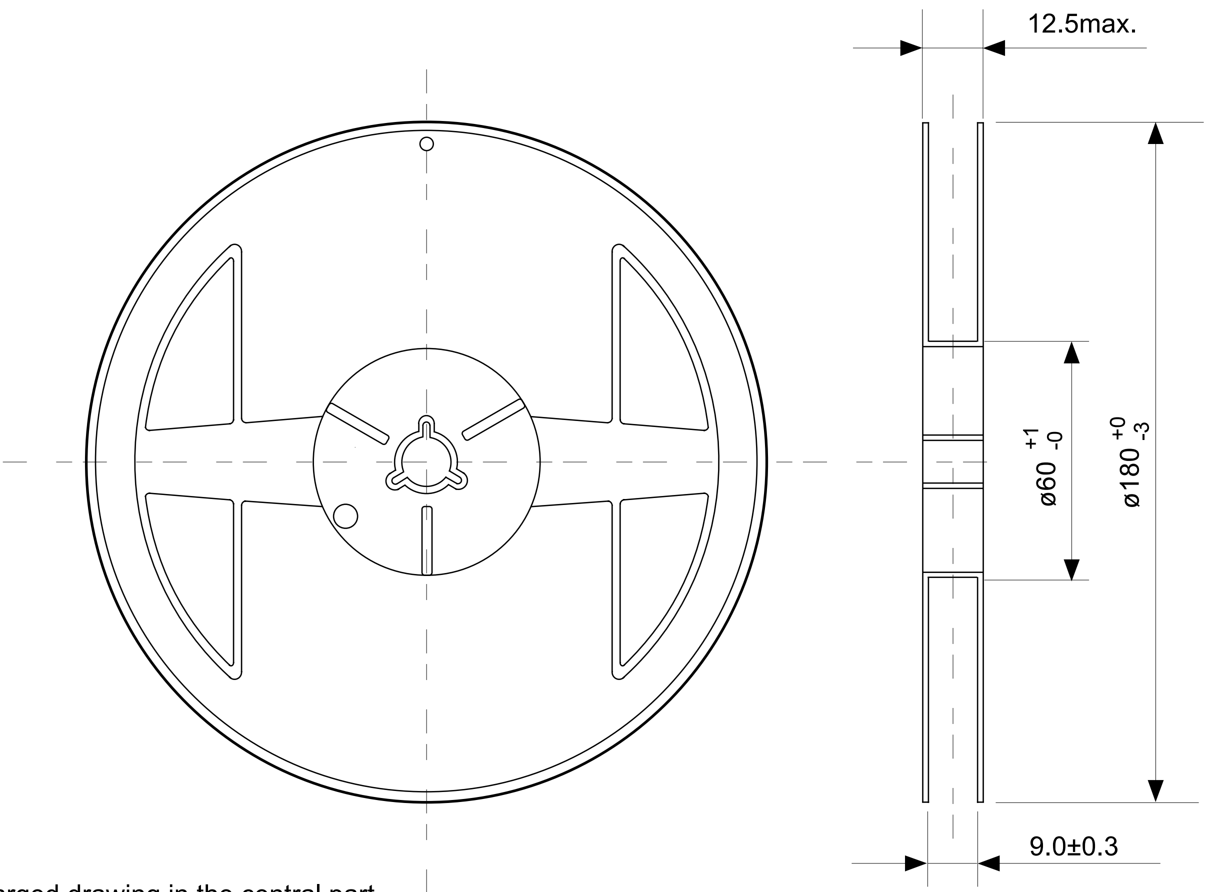




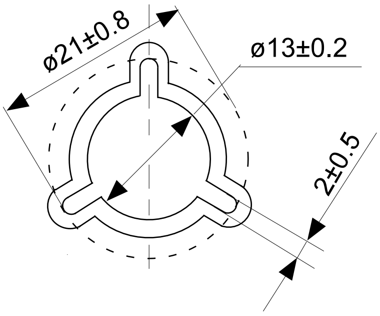
No. XA008-A-C-SD-1.0

TITLE	PLP8B-A-Carrier Tape
No.	XA008-A-C-SD-1.0
SCALE	
UNIT	mm

Seiko Instruments Inc.



Enlarged drawing in the central part

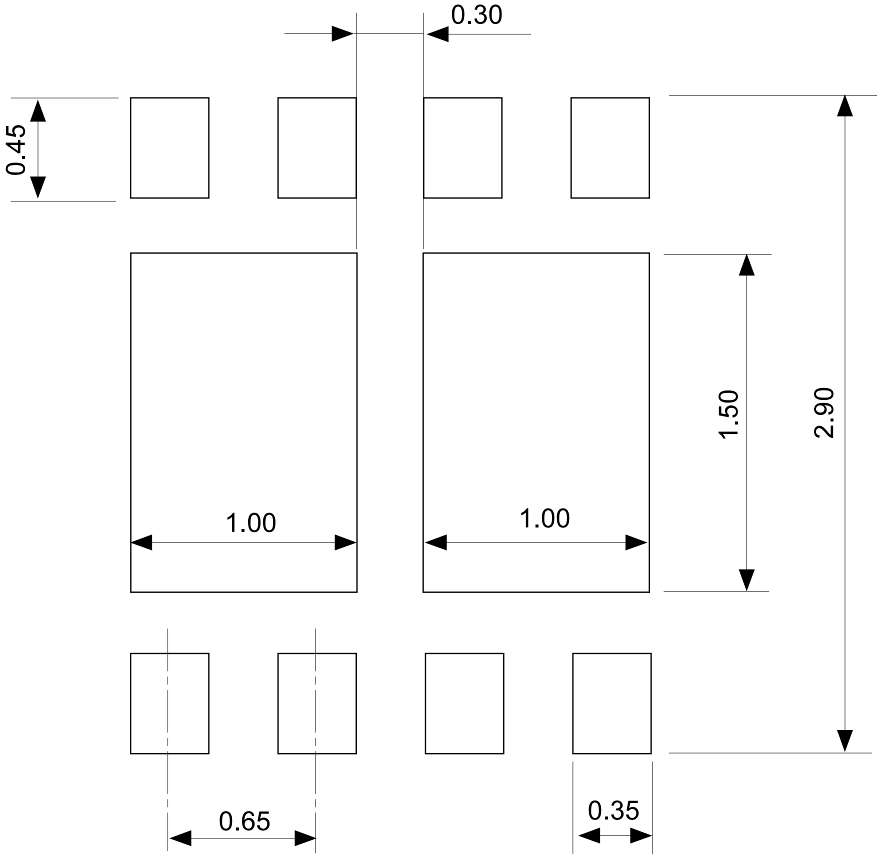


No. XA008-A-R-SD-1.0

TITLE	PLP8B-A-Reel		
No.	XA008-A-R-SD-1.0		
SCALE		QTY.	3,000
UNIT	mm		

Seiko Instruments Inc.

Land Recommendation



Cautions
Please use the above-mentioned land figure as a reference drawing.
When you use it, please carry out sufficient evaluation by an actual substrate etc.

No. XB008-A-L-SD-1.0

TITLE	PLP8B-A-Land Recommendation
No.	XB008-A-L-SD-1.0
SCALE	
UNIT	mm

Seiko Instruments Inc.