S-8367/8368 Series

STEP-UP 1.2 MHz PWM CONTROL CURRENT LIMIT SWITCHING REGULATOR CONTROLLER

www.sii-ic.com

Rev.1.1_01

The S-8367/8368 Series is a CMOS step-up type switching regulator controller which consists of a reference voltage source, an oscillation circuit, an error amplifier, a phase compensation circuit, a current limit circuit, a short-circuit protection circuit, and a PWM control circuit etc.
With an external low ON-resistance enhanced Nch power MOS FET, this product is ideal for applications requiring high efficiency and a high output current.
In addition, the output current is limited by connecting the current detection resistance (R_{SENSE}) to the VSENSE pin. The loss which occurs in R_{SENSE} is reduced since the current detection voltage (V_{SENSE1}) is set to 100 mV ± 10%.
The S-8368 Series has a short-circuit protection circuit which can protect the circuit during output short-circuit status by using an external enhanced Nch power MOS FET.
Ceramic capacitors can be used for output capacitors. Small package, SOT-23-6 enables high-density mounting.

■ Features

- Input voltage range: 2.2 V to 5.5 V
- Oscillation frequency: 1.2 MHz typ.
- Output current: 3.0 A (V_{IN} = 3.6 V, V_{OUT} = 5.0 V)*1
- Reference voltage: 0.6 V ± 2.0%
- Soft-start function: 3 ms typ.
- Low current consumption: 120 μA typ. during switching off
- Maximum duty: 85% typ.
- Current limit function: V_{SENSE1} = 100 mV ± 10%
- Power-off function: I_{SSS} = 1.0 μA max.
- External parts: Inductor, diode, capacitor, transistor
- Short-circuit protection function (Only S-8368 Series): Limits short-circuit current by an external enhanced Nch power MOS FET.
- UVLO (under voltage lock out) function: Selectable in 0.1 V step between 2.1 V to 3.5 V
- Lead-free (Sn 100%), halogen-free

***1.** Values when the S-8367/8368 Series is used under conditions of "**Table 14 External Parts Examples**" with the circuit example of **Figure 23** in "**■ Application circuits**".

■ Applications

- Mobile power pack, digital audio player
- LED lighting, GPS, wireless transceiver
- Other portable devices

■ Package

- SOT-23-6

■ Block Diagrams

1. S-8367 Series (Without short-circuit protection function)

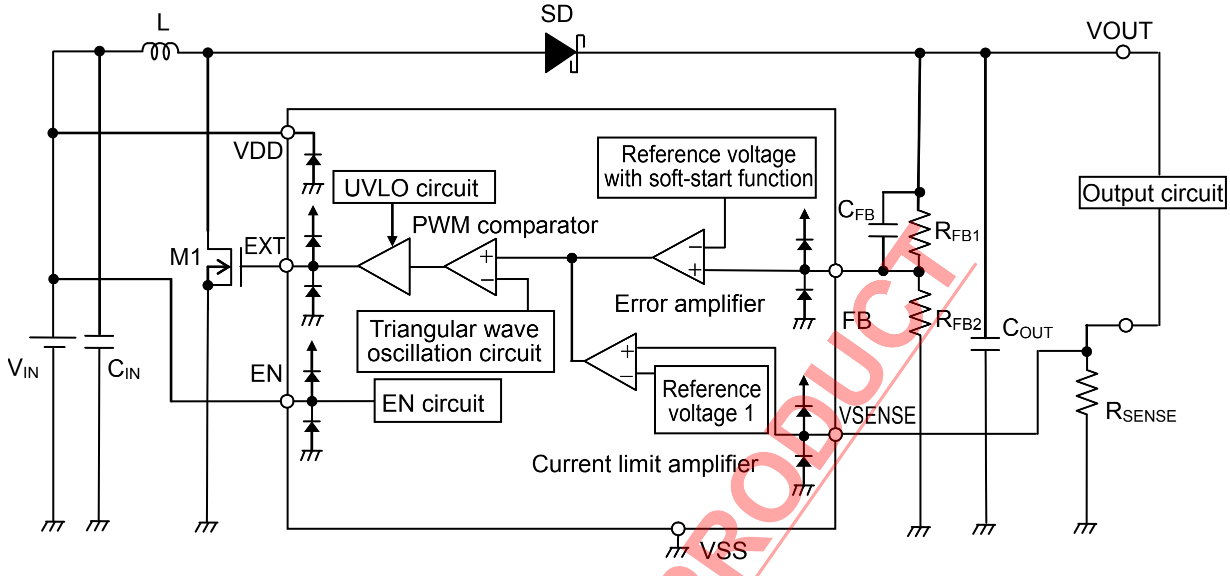


Figure 1

2. S-8368 Series (With short-circuit protection function)

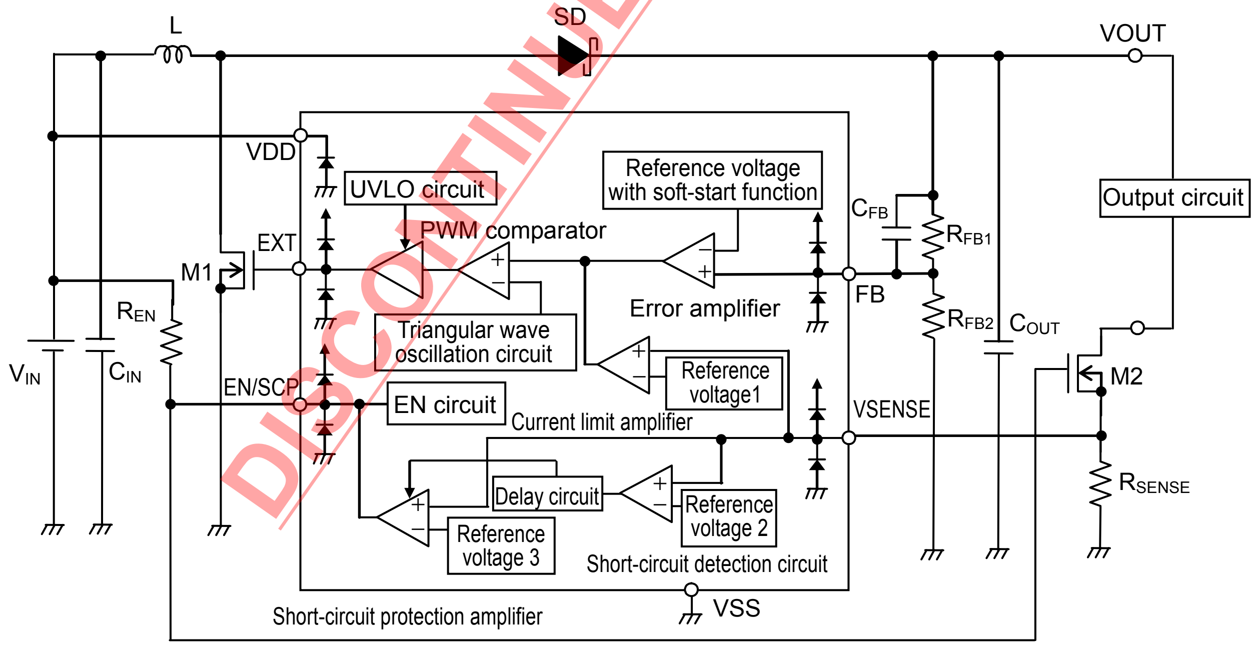


Figure 2

Caution **To stabilize the output voltage and oscillation frequency of the S-8367/8368 Series, the input voltage (V_{DD}) of 2.2 V $\leq V_{DD} \leq$ 5.5 V is necessary.**
When connecting the VOUT output to the VDD pin, set the output voltage (V_{OUT}) as to satisfy the above range, including the spike voltage generated in VOUT.

■ Product Name Structure

Users can select the short-circuit protection function, UVLO detection voltage for the S-8367/8368 Series. Refer to "**1. Product name**" regarding the contents of product name, "**2. Package**" regarding the package drawings and "**3. Product name list**" regarding the product type.

1. Product name

S-836 x A xx I - M6T1 U 2

- U — Environmental code
  - U: Lead-free (Sn 100%), halogen-free
- M6T1 — Package name (abbreviation) and IC packing specification*1
  - M6T1: SOT-23-6, Tape
- xx — UVLO detection voltage
  - 21 to 35
  - (e.g., when the UVLO detection voltage is 2.1 V, it is expressed as 21.)
- x — Short-circuit protection function
  - 7: Unavailable
  - 8: Available

***1.** Refer to the tape drawing.

2. Package

Table 1 Package Drawing Codes

Package Name	Dimension	Tape	Reel
SOT-23-6	MP006-A-P-SD	MP006-A-C-SD	MP006-A-R-SD

3. Product name list

3. 1 S-8367 Series (Without short-circuit protection function)

Table 2

Product Name	UVLO Detection Voltage
S-8367A21I-M6T1U2	2.1 V

Remark Please contact our sales office for products with specifications other than the above.

3. 2 S-8368 Series (With short-circuit protection function)

Table 3

Product Name	UVLO Detection Voltage
S-8368A21I-M6T1U2	2.1 V

Remark Please contact our sales office for products with specifications other than the above.

■ Pin Configurations

1. SOT-23-6

Top view

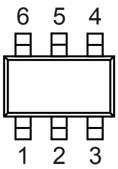


Figure 3

Table 4 S-8367 Series (Without Short-Circuit Protection Function)

Pin No.	Symbol	Description
1	VDD	Power supply input pin
2	VSENSE	Current detection resistance connection pin
3	FB	Output voltage feedback pin
4	EN	Power-off pin "H": Power-on (normal operation) "L": Power-off (standby)
5	VSS	GND pin
6	EXT	External transistor connection pin

Table 5 S-8368 Series (With Short-Circuit Protection Function)

<table>
<tr><th>Pin No.</th><th>Symbol</th><th colspan="2">Description</th></tr>
<tr><td>1</td><td>VDD</td><td colspan="2">Power supply input pin</td></tr>
<tr><td>2</td><td>VSENSE</td><td colspan="2">Current detection resistance connection pin</td></tr>
<tr><td>3</td><td>FB</td><td colspan="2">Output voltage feedback pin</td></tr>
<tr><td rowspan="2">4</td><td rowspan="2">EN/SCP*1</td><td>EN</td><td>Power-off pin
"H": Power-on (normal operation)
"L": Power-off (standby)</td></tr>
<tr><td>SCP</td><td>FET control pin for short-circuit protection</td></tr>
<tr><td>5</td><td>VSS</td><td colspan="2">GND pin</td></tr>
<tr><td>6</td><td>EXT</td><td colspan="2">External transistor connection pin</td></tr>
</table>

***1.** The EN/SCP pin combines the power-off pin and the FET control pin for short-circuit protection.

■ Absolute Maximum Ratings

Table 6

(Ta = +25°C, V_{SS} = 0 V unless otherwise specified)

Item	Symbol	Absolute Maximum Rating	Unit
VDD pin voltage	V_{DD}	V_{SS} − 0.3 to V_{SS} + 6.0	V
FB pin voltage	V_{FB}	V_{SS} − 0.3 to V_{DD} + 0.3	V
EXT pin voltage	V_{EXT}	V_{SS} − 0.3 to V_{DD} + 0.3	V
EN pin voltage, EN/SCP pin voltage	V_{EN}, $V_{EN/SCP}$	V_{SS} − 0.3 to V_{DD} + 0.3	V
VSENSE pin voltage	V_{SENSE}	V_{SS} − 0.3 to V_{DD} + 0.3	V
Power dissipation	P_D	650*1	mW
Operation ambient temperature	T_{opr}	−40 to +85	°C
Storage temperature	T_{stg}	−40 to +125	°C

***1.** When mounted on board
[Mounted board]
(1) Board size: 114.3 mm × 76.2 mm × t1.6 mm
(2) Name: JEDEC STANDARD51-7

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.

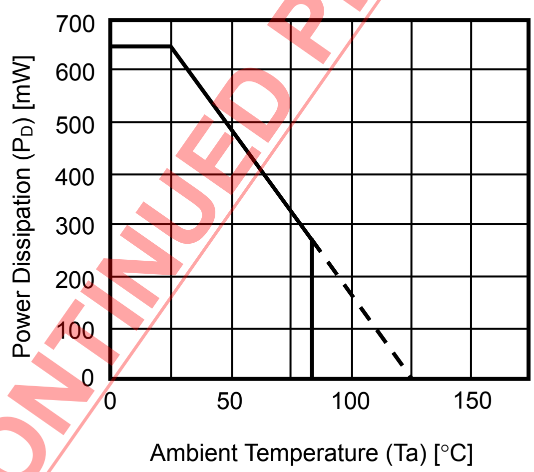


Figure 4 Package Power Dissipation (When Mounted on Board)

■ Electrical Characteristics

Table 7

(V_{DD} = 3.6 V, Ta = +25°C unless otherwise specified)

Item	Symbol	Condition	Min.	Typ.	Max.	Unit	Test Circuit
Input voltage	V_{DD}	–	2.2	–	5.5	V	1
FB pin voltage	V_{FB}	–	0.588	0.600	0.612	V	1
FB pin voltage temperature coefficient	$\frac{\Delta V_{FB}}{\Delta Ta}$	Ta = –40°C to +85°C	–	±100	–	ppm/°C	1
FB pin input current	I_{FB}	V_{DD} = 2.2 V to 5.5 V, FB pin	–0.1	–	0.1	µA	1
Current consumption during operation	I_{SS1}	When switching operates, $V_{FB} = V_{FB(S)}{}^{*1} \times 0.95$	–	300	–	µA	1
Current consumption during switching off	I_{SS2}	When switching stops, $V_{FB} = V_{FB(S)} \times 1.5$	–	120	210	µA	1
Current consumption during power-off	I_{SSS}	–	–	–	1.0	µA	1
EXT pin output current "H"	I_{EXTH}	$V_{EXT} = V_{DD} - 0.4$ V	–	–130	–60	mA	1
EXT pin output current "L"	I_{EXTL}	V_{EXT} = 0.4 V	100	200	–	mA	1
Oscillation frequency	f_{OSC}	–	1.0	1.2	1.4	MHz	1
Maximum duty	MaxDuty	$V_{FB} = V_{FB(S)} \times 0.95$	80	85	90	%	1
Current detection voltage	V_{SENSE1}	–	90	100	110	mV	1
VSENSE pin voltage for short-circuit detection	V_{SENSE2}	Only S-8368 Series	108	120	132	mV	1
VSENSE pin voltage during short-circuit protection operation	V_{SENSE3}	Only S-8368 Series	–	60	–	mV	1
VSENSE pin voltage for short-circuit protection release	V_{SENSE4}	Only S-8368 Series	–	40	–	mV	1
Short-circuit protection delay time	t_{PRO}	Only S-8368 Series	4.0	5.0	6.0	ms	1
EN pin sink current during short-circuit detection	I_{ENSINK}	V_{EN} = 0.90 V, Only S-8368 Series	5	60	–	µA	1
UVLO detection voltage	V_{UVLO}	Selectable in 0.1 V step between 2.1 V to 3.5 V	V_{UVLO} – 0.1	V_{UVLO}	V_{UVLO} + 0.1	V	1
UVLO hysteresis width	$V_{UVLOHYS}$	–	–	0.10	–	V	1
Soft-start time	t_{SS}	–	2.0	3.0	4.5	ms	1
EN pin input voltage "H"	V_{SH}	–	0.80	V_{DD}	–	V	1
EN pin input voltage "L"	V_{SL}	–	–	V_{SS}	0.3	V	1
EN pin input current "H"	I_{SH}	–	–0.1	–	0.1	µA	1
EN pin input current "L"	I_{SL}	–	–0.1	–	0.1	µA	1

***1.** $V_{FB(S)}$ is a set value for FB voltage.

■ Test Circuit

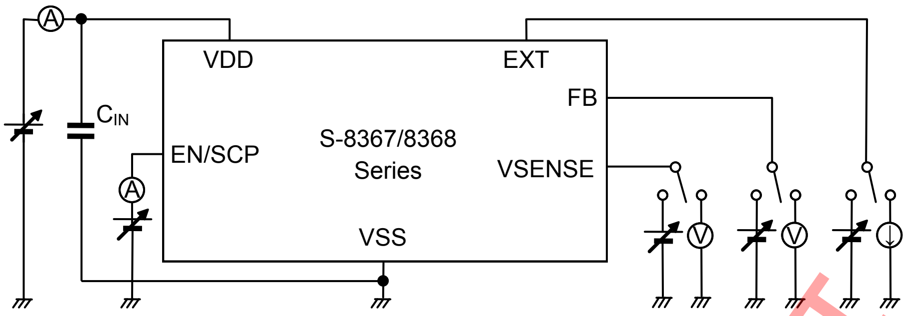


Figure 5 Test Circuit 1

■ Operation

1. Switching control method

1. 1 PWM control

The S-8367/8368 Series is a switching regulator controller that uses a pulse width modulation method (PWM).
In conventional PFM control switching regulators, pulses are skipped when the output load current is small, causing a fluctuation in the ripple frequency of the output voltage, resulting in increased ripple voltage.
For the S-8367/8368 Series, although the pulse width changes from 0% to 85% in accordance with each load current, the ripple voltage generated due to switching can be eliminated by filtering since the switching frequency does not change. The ripple voltage can thus be lowered in the wide input voltage and load current ranges.

2. Soft-start function

The S-8367/8368 Series has a soft-start circuit. The output voltage (V_{OUT}) gradually rises after power-on or startup when the power-off pin is set to "H", suppressing rush current and overshooting the output voltage. The soft-start time (t_{SS}) for the S-8367/8368 Series is defined as the time from startup until V_{OUT} reaches 90% of the output set voltage value ($V_{OUT(S)}$). A reference voltage adjustment method is used as the soft-start method and the reference voltage gradually rises from 0 V after soft-start.
The soft-start function operates by controlling the FB pin voltage so that it follows the rise of the reference voltage. After the reference voltage rises once, it is reset to 0 V if the power-off pin is set to "L", the power supply voltage decreases to the UVLO detection voltage or less, or the S-8367/8368 Series enters the short-circuit protection latch status. The soft-start function is operated regardless of conditions when resuming step-up operation.

3. UVLO function

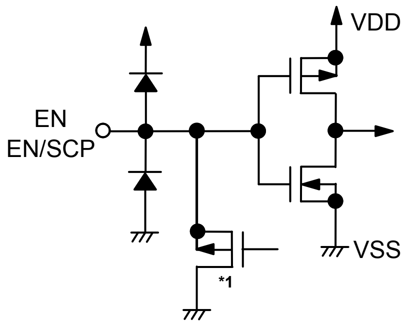
The S-8367/8368 Series has a UVLO (under voltage lock out) circuit for avoiding IC malfunctions due to power supply voltage decreases. The S-8367/8368 Series stops switching operation upon UVLO detection and retains the external transistor in the off status. After entering the UVLO detection status once, the soft-start function is reset.
Note, however, that the other internal circuits operate normally and that the status differs from the power-off status.

4. Power-off pin (S-8367 Series: EN pin, S-8368 Series: EN/SCP pin)

This pin stops or starts step-up operations.
When the power-off pin is set to "L", the EXT pin voltage is fixed to 0 V, and the external transistor and all internal circuits stop, substantially reducing the current consumption.
Do not use the power-off pin in a floating status because it is set up as shown in **Figure 6** and is not internally pulled up or down. Do not apply a voltage of between 0.30 V and 0.80 V to the power-off pin since the current consumption increases. If the EN pin is not used, connect it to the VDD pin.
The EN/SCP pin of the S-8368 Series combines the power-off pin and the FET control pin for short-circuit protection. Refer to "**6. Short-circuit protection function (Only S-8368 Series)**" for details.

Table 8

EN Pin, EN/SCP Pin	CR Oscillation Circuit	Output Voltage
"H"	Operate	Set value
"L"	Stop	"High-Z"



***1.** In the S-8367 Series, the MOS FET is always turned off.

Figure 6

5. Current limit circuit

The S-8367/8368 Series has a current limit circuit. The current is limited by connecting the current detection resistor (R_{SENSE}) between the VSENSE pin and VSS and connecting the output circuit between the VOUT pin and the VSENSE pin, as shown in **Figure 7**.
Refer to "**Figure 10 Current Limit Operation and Short-Circuit Protection Operation**" for details.

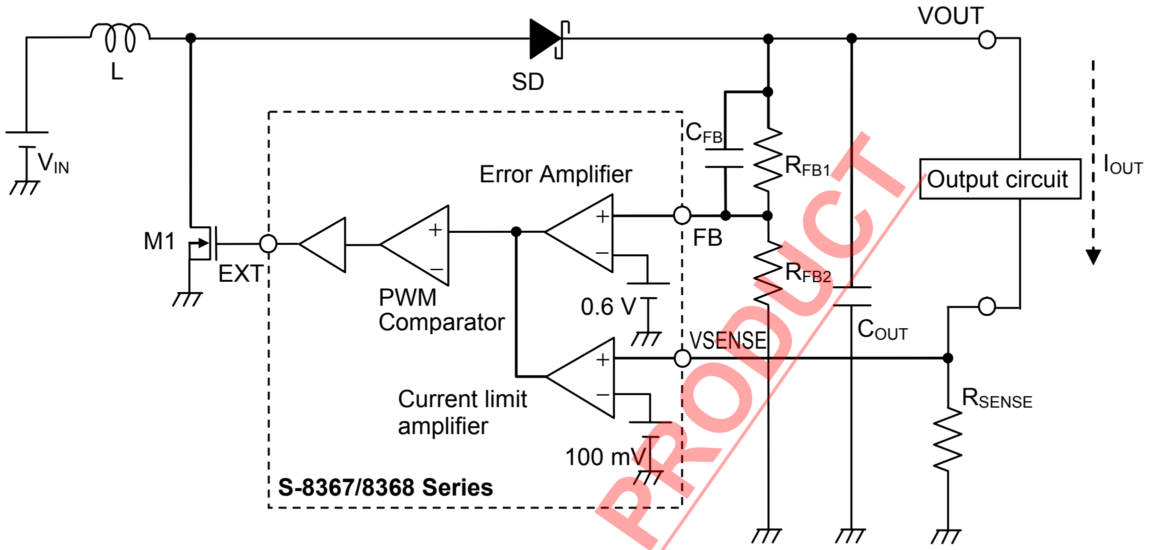


Figure 7

5. 1 Current limit operation

V_{SENSE} reaches the current detection voltage (V_{SENSE1} = 100 mV typ.), and then the voltage is held constant by the current limit amplifier.
Therefore, the output current (I_{OUT}) is held at a constant value regardless of the output load.
The limit current (I_{LIM}) can be set with R_{SENSE}. Calculate R_{SENSE} by using the following equation:

R_{SENSE} [Ω] = V_{SENSE} [V] / I_{LIM} [A]

R_{SENSE} is an ideal value; the theoretical values when V_{SENSE1} = 100 mV typ. are shown in "**Figure 8 I_{LIM} vs. R_{SENSE} Characteristics**". These values do not make allowances for deviations of a resistance and the IC.

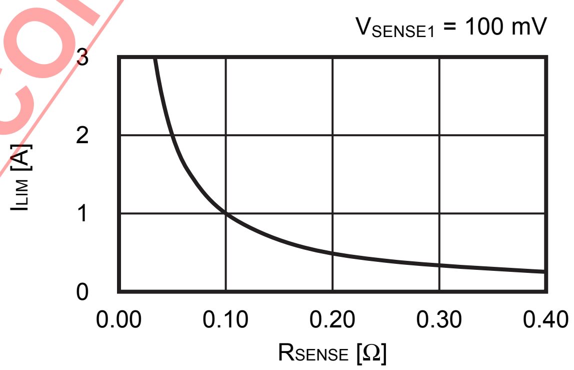


Figure 8 I_{LIM} vs. R_{SENSE} Characteristics

While the current is limited, the VSENSE pin is held at V_{SENSE} = 100 mV typ. by the current limit amplifier, and the VOUT voltage is decreased by narrowing PWM control pulse width. For that reason, note that the VOUT voltage is not a constant value, and fluctuates according to the output load. If V_{SENSE} falls below 100 mV typ. due to the load current decreasing, the circuit automatically returns to normal status from the current limit status. Connect the VSENSE pin to VSS when not using the current limit function.

Caution Note that the output voltage (V_{OUT}) may increase temporarily if the load current decreases due to load release or for some other reasons when the current limit function operates.

6. Short-circuit protection function (Only S-8368 Series)

The S-8368 Series has a current limit circuit. Since the S-8367/8368 Series includes the current limit function, the VOUT voltage is decreased by narrowing the PWM control pulse width so that the S-8367/8368 Series does not exceed the current limit value set by the resistance of R_{SENSE} when a heavy load is connected. However, in case of output short-circuit etc., the short-circuit current (I_{short}) flows as shown in **Figure 9** regardless of PWM control.

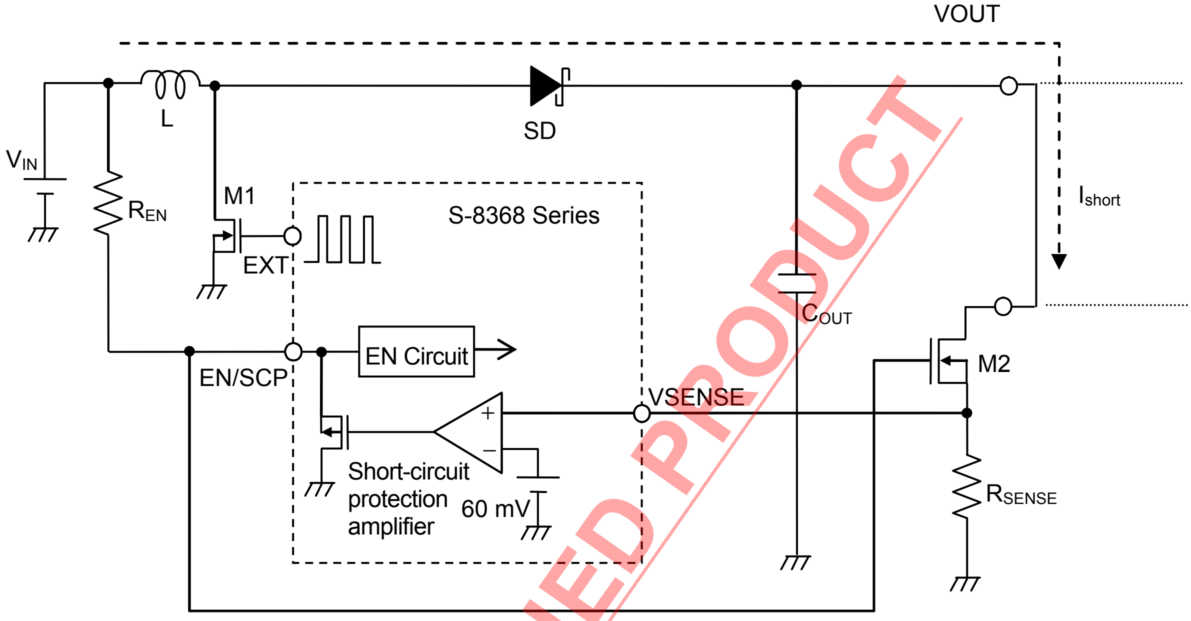


Figure 9

6. 1 Short-circuit protection operation

In the S-8368 Series, if the VSENSE pin voltage (V_{SENSE}) remains equal to or higher than the VSENSE pin voltage for short-circuit detection (V_{SENSE2} = 120 mV typ.) for 5 ms typ., the short-circuit protection circuit starts operating. The short-circuit protection function is implemented by using the external parts M2 (an enhanced Nch power MOS FET) and R_{EN} (a resistor of 50 kΩ to 500 kΩ).
The short-circuit protection function operates as described below. Switching operations stop during short-circuit protection operation.

(1) The short-circuit protection amplifier starts operating, and then brings in the current to the EN/SCP pin.
(2) A voltage drop occurs at both edges of R_{EN}, and then the EN/SCP pin voltage decreases.
(3) The ON-resistance (R_{ON}) of M2 increases since the EN/SCP pin is also connected to the M2 gate. As a result, I_{short} is limited.

The short-circuit protection amplifier controls V_{SENSE} so that the VSENSE pin voltage during short-circuit protection operation (V_{SENSE3}) maintains 60 mV typ. The output current (I_{OUT}) is therefore limited to half the value (60 mV / R_{SENSE}) of the current when a load short-circuit is detected. Thereby, even when short-circuit occurs, the S-8368 Series can suppress an overcurrent not exceeding 60 mV / R_{SENSE} of output current value during short-circuit.
The S-8368 Series returns to the normal status automatically since the load resistance increases due to load release or for some other reasons. If the load resistance increases substantially while the short-circuit protection function operates, V_{SENSE} decreases. When V_{SENSE} decreases to the VSENSE pin voltage for short-circuit protection release (V_{SENSE4} = 40 mV typ.), the S-8368 Series automatically resumes switching operations.
Refer to "**Figure 10 Current Limit Operation and Short-Circuit Protection Operation**" for details.

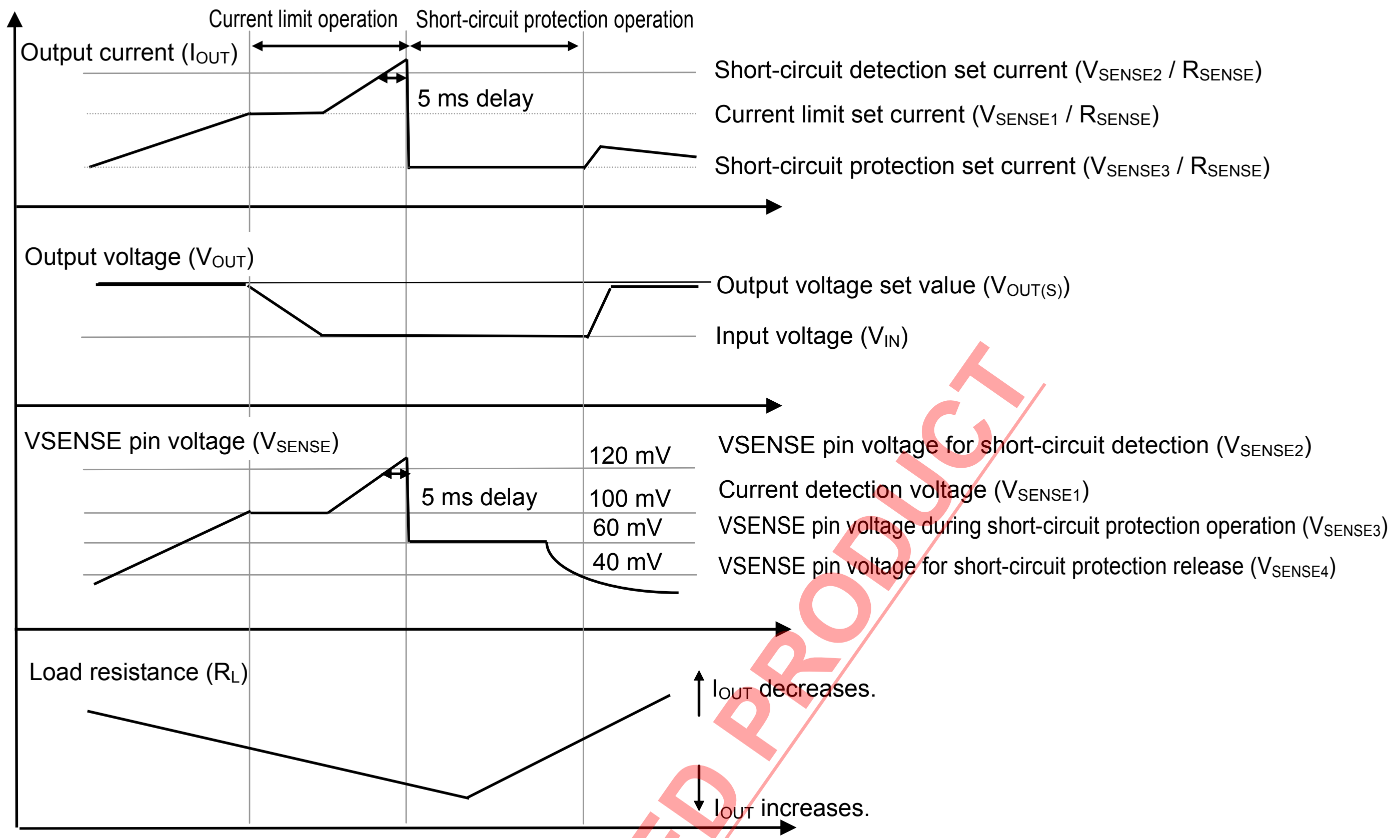


Figure 10 Current Limit Operation and Short-Circuit Protection Operation

6. 2 FET for short-circuit protection

Note the following conditions concerning an Nch MOS FET for short-circuit protection:

- The threshold voltage is higher than the EN pin input voltage "H" (V_{SH}) of the S-8368 Series.
- The power dissipation is large.
- The ON-resistance (R_{ON}) is low.
- The gate capacitance (C_{iss}) is small.

6. 2. 1 Threshold voltage

The short-circuit current (I_{short}) that flows through an Nch MOS FET during short-circuit protection operation is calculated by using the following equation:

$$I_{short} \text{ [A]} = 0.06 \text{ [V]} / R_{SENSE} \text{ [}\Omega\text{]}$$

The short-circuit protection amplifier controls the gate-to-source voltage (V_{GS}) in accordance with the characteristics of the Nch MOS FET to be used.
Select an Nch MOS FET so that the threshold voltage is higher than V_{SH} of the S-8368 Series.
Refer to the datasheet supplied by each FET manufacturer for details about the relationship between the gate-to-drain current (I_{DS}) of the Nch MOS FET and V_{GS}.

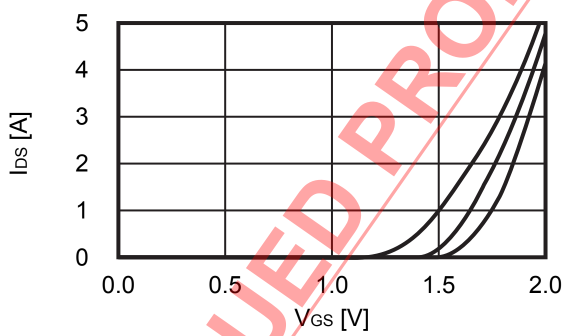


Figure 11 Example of I_{DS} vs. V_{GS} Characteristics

Caution The S-8368 Series may repeatedly turn on and turn off if V_{GS} of the FET for short-circuit protection during short-circuit protection operation falls below the EN pin input voltage "L" (V_{SL}).

6. 2. 2 Power dissipation

During short-circuit protection operation, a high voltage is applied between the drain and the source of the FET for short-circuit protection.
Select an FET for short-circuit protection with a sufficiently large power dissipation (P_D), taking into account the usage conditions.
The loss which occurs in an FET for short-circuit protection is calculated by using the following equation:

$$P_D = (V_{IN}{}^{*1} - V_f{}^{*2} - 60 \text{ mV}) \times I_{short}$$

***1.** V_{IN}: Power supply voltage
***2.** V_f: Forward voltage drop of SD when I_{short} flows.

Caution Note that the FET for short-circuit protection may burn out if the power dissipation does not satisfy the usage conditions.

6. 2. 3 ON-resistance (R_{ON})

Select an Nch MOS FET whose R_{ON} is low.
During switching operations, the load current (I_{OUT}) flows through an FET for short-circuit protection. Note that the efficiency may lower if R_{ON} is high.

6. 2. 4 Gate capacitance (C_{iss})

Select an Nch MOS FET whose C_{iss} is small. It is recommended that C_{iss} is 3000 pF or less.

Caution The short-circuit protection function may not operate when C_{iss} is large.

6. 3 EN/SCP pin pull-up resistor (R_{EN})

The resistance of the pull-up resistor (R_{EN}) to be added to the EN/SCP pin can be set in a range of 50 kΩ to 500 kΩ.

6. 3. 1 When not using power-off function

When not using the power-off function, connect R_{EN} between the EN/SCP pin and the power supply.

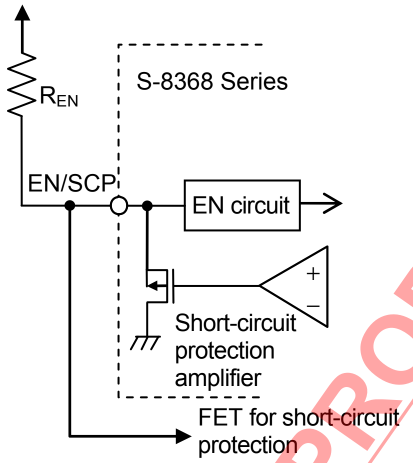


Figure 12

6. 3. 2 When using power-off function

When the power-off function is controlled by a microcomputer, add R_{EN} between the microcomputer output pin and the EN/SCP pin.

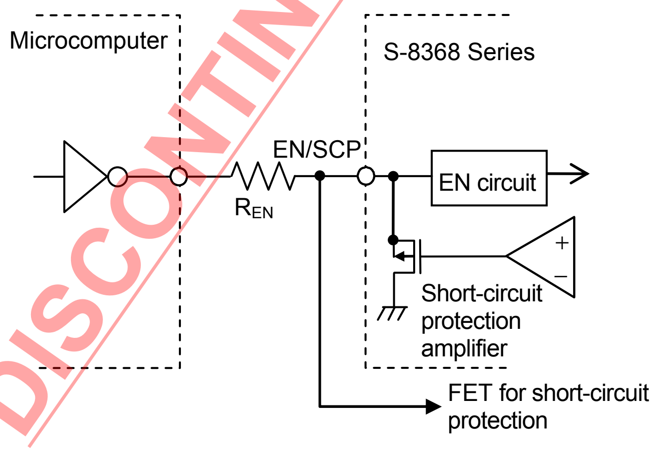


Figure 13

■ Operation Principles

The S-8367/8368 Series is a step-up type switching regulator controller. **Figure 14** shows the basic circuit.

Step-up type switching regulator starts current supply by the input voltage (V_{IN}) when the enhanced Nch power MOS FET is turned on and holds energy in the inductor at the same time. When the enhanced Nch power MOS FET is turned off, the CONT pin voltage is stepped up to discharge the energy held in the inductor and the current is discharged to V_{OUT} through the diode. When the discharged current is stored in the output capacitor (C_{OUT}), a voltage is generated, and the potential of V_{OUT} increases until the voltage of the FB pin reaches the same potential as the internal reference voltage.

For the PWM control method, the switching frequency (f_{OSC}) is fixed and the V_{OUT} voltage is held constant according to the ratio of the ON time (t_{ON}) and OFF time (t_{OFF}) of the enhanced Nch power MOS FET in each period (ON duty).

For the PWM control method, the V_{OUT} voltage is held constant by controlling t_{ON}.

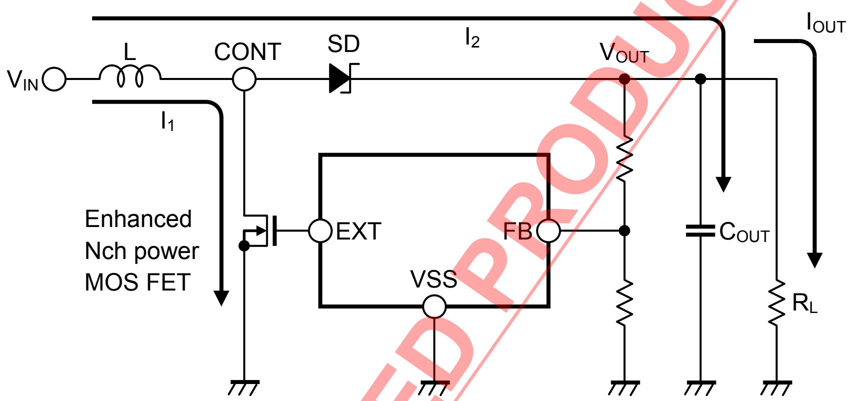


Figure 14 Basic Circuit of Step-up Type Switching Regulator

The ON duty in the current continuous mode can be calculated by using the equation below. Use the S-8367/8368 Series in the range where the ON duty is less than the maximum duty.

The maximum duty is 85% typ.

$$\text{ON duty} = \left(1 - \frac{V_{IN}}{V_{OUT} + V_D{}^{*1}}\right) \times 100\ [\%]$$

t_{ON} can be calculated by using the following equation:

$$t_{ON} = \frac{1}{f_{OSC}} \times \text{ON duty}$$

$$= \frac{1}{f_{OSC}} \times \left(1 - \frac{V_{IN}}{V_{OUT} + V_D{}^{*1}}\right) \cdots\cdots \quad (1)$$

***1.** V_D: Forward voltage of diode

1. Current continuous mode

The following explains the current that flows into the inductor when the step-up operation stabilizes in a certain status and the output current (I_{OUT}) is sufficiently large.
When the enhanced Nch power MOS FET is turned on, current (I_1) flows in the direction shown in "**Figure 14 Basic Circuit of Step-up Type Switching Regulator**". As shown in "**Figure 15 Continuous Mode (Current Cycle of I_L)**", the inductor current (I_L) at this time gradually increases in proportion with the ON time (t_{ON}) of the enhanced Nch power MOS FET.

Current change of inductor within t_{ON}:

$$\Delta I_{L(ON)} = I_L \text{ max.} - I_L \text{ min.}$$
$$= \frac{V_{IN}}{L} \times t_{ON}$$

When the enhanced Nch power MOS FET is turned off, as mentioned above, the voltage of the CONT pin is stepped up to $V_{OUT} + V_D$ and the voltage on both ends of the inductor becomes $V_{OUT} + V_D - V_{IN}$. However, it is assumed here that $V_{OUT} >> V_D$ and V_D is ignored.

Current change of inductor within t_{OFF}:

$$\Delta I_{L(OFF)} = \frac{V_{OUT} - V_{IN}}{L} \times t_{OFF}$$

The input power (P_{IN}) equals the output power (P_{OUT}) in an ideal situation where there is no loss by components.
Therefore, the average input current ($I_{IN(AV)}$) can be calculated by using the following equation.

$I_{IN(AV)}$:

$$P_{IN} = P_{OUT}$$
$$I_{IN(AV)} \times V_{IN} = I_{OUT} \times V_{OUT}$$
$$\therefore I_{IN(AV)} = \frac{V_{OUT}}{V_{IN}} \times I_{OUT} \text{ .... (2)}$$

The current that flows in the inductor consists of a ripple current that changes due to variation over time and a direct current.

From **Figure 15**:
$I_{IN(AV)}$:

$$I_{IN(AV)} = I_{IN(DC)} + \frac{\Delta I_L}{2}$$
$$= I_{IN(DC)} + \frac{V_{OUT} - V_{IN}}{2 \times L} \times t_{OFF}$$
$$= I_{IN(DC)} + \frac{V_{IN}}{2 \times L} \times t_{ON} \text{ .... (3)}$$

Above, the continuous mode is the operation mode when $I_{IN(DC)} > 0$ as shown in **Figure 15** and I_L continuously flows.
While I_{OUT} continues to decrease, $I_{IN(DC)}$ reaches 0 as shown in "**Figure 16 Critical Point (Current Cycle of I_L)**". This point is the critical point of the continuous mode.
As shown in equations (2) and (3), the direct current component ($I_{IN(DC)}$) depends on I_{OUT}.

$I_{OUT(0)}$ when $I_{IN(DC)}$ reaches 0 (critical point):

$$I_{OUT(0)} = \frac{t_{ON} \times V_{IN}^2}{2 \times L \times V_{OUT}}$$

t_{ON} can be calculated by using equation (1).
When the output current decreases below $I_{OUT(0)}$, the current flowing in the inductor stops flowing in the t_{OFF} period as shown in "**Figure 17 Discontinuous Mode (Current Cycle of I_L)**". This is the discontinuous mode.

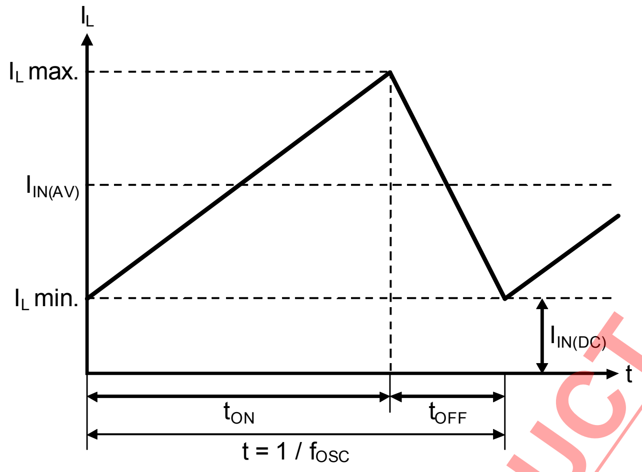


Figure 15 Continuous Mode (Current Cycle of I_L)

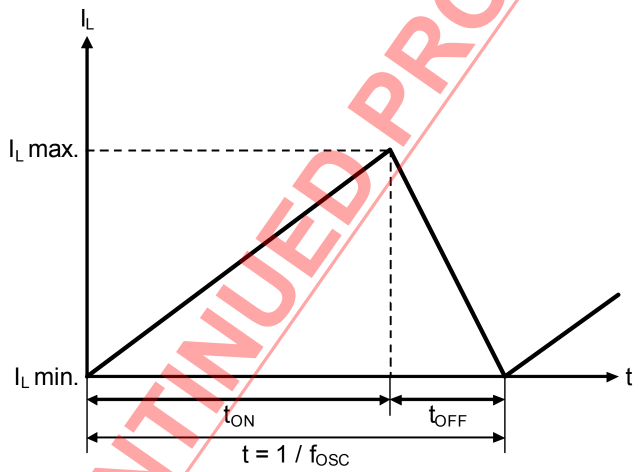


Figure 16 Critical Point (Current Cycle of I_L)

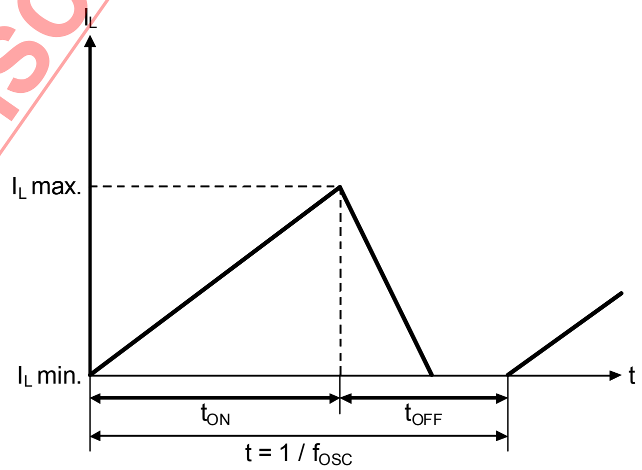


Figure 17 Discontinuous Mode (Current Cycle of I_L)

■ External Parts Selection

1. Inductor

The recommended inductance (L value) of the S-8367/8368 Series is 2.2 μH.
Note the followings when changing L value.

L value has a strong influence on the maximum output current (I_{OUT}) and efficiency (η).
The inductor peak current (I_{PK}) increases when L value is decreased, which improves the circuit stability and increases the I_{OUT} users can obtain. If L value is decreased further, the ability of the external transistor to drive the current becomes insufficient, reducing the efficiency and decreasing I_{OUT}.
The loss due to the I_{PK} of the switching transistor is decreased by increasing L value and the efficiency maximizes at a certain L value. If L value is increased further, the loss due to the serial resistance of the inductor increases, lowering the efficiency.

Caution When selecting an inductor, be careful about its allowable current. If a current exceeding the allowable current flows through the inductor, magnetic saturation occurs, substantially lowering the efficiency and destroying ICs due to large current. Therefore, select an inductor such that I_{PK} does not exceed the allowable current. The following equations express I_{PK} in the ideal statuses in the discontinuous and continuous modes:

$$I_{PK} = \sqrt{\frac{2 \times I_{OUT} \times (V_{OUT} + V_D{}^{*2} - V_{IN})}{f_{OSC}{}^{*1} \times L}} \quad \text{(Discontinuous mode)}$$

$$I_{PK} = \frac{V_{OUT} + V_D{}^{*2}}{V_{IN}} \times I_{OUT} + \frac{(V_{OUT} + V_D{}^{*2} - V_{IN}) \times V_{IN}}{2 \times (V_{OUT} + V_D{}^{*2}) \times f_{OSC}{}^{*1} \times L} \quad \text{(Continuous mode)}$$

***1.** f_{OSC}: oscillation frequency
***2.** V_D is the forward voltage of a diode. The reference value is 0.4 V.
However, current exceeding the above equation flows because conditions are practically not ideal. Perform sufficient evaluation with actual application.

Table 9 Typical Inductors (Mobile Battery Charger for Output Current 3.0 A)

Manufacturer	Product Name	L Value	DC Resistance	Rated Current	Dimension (L × W × H) [mm]
TDK Corporation	SPM6530T-2R2M	2.2 μH	0.019 Ω max.	8.4 A typ.	7.1 × 6.5 × 3.0

Table 10 Typical Inductors (Mobile Battery Charger for Output Current 2.1 A)

Manufacturer	Product Name	L Value	DC Resistance	Rated Current	Dimension (L × W × H) [mm]
TDK Corporation	VLP6045LT-2R2N	2.2 μH	0.026 Ω max.	6.4 A max.	6.8 × 6.8 × 4.5
Taiyo Yuden Co., Ltd.	NR5040T2R2N	2.2 μH	0.029 Ω max.	4.6 A typ.	4.9 × 4.9 × 4.1

Table 11 Typical Inductors (Mobile Battery Charger for Output Current 1.0 A)

Manufacturer	Product Name	L Value	DC Resistance	Rated Current	Dimension (L × W × H) [mm]
TDK Corporation	SPM3012T-2R2M	2.2 μH	0.115 Ω max.	3.4 A typ.	3.2 × 3.0 × 1.2
Taiyo Yuden Co., Ltd.	NR4018T2R2M	2.2 μH	0.072 Ω max.	2.7 A typ.	4.0 × 4.0 × 1.8

2. Diode

Use an external diode that meets the following conditions.

- Forward voltage is low (Schottky barrier diode or similar type)
- Switching speed is high
- Reverse withstand voltage is the output voltage (V_{OUT}) + spike voltage or more
- Rated current is the inductor peak current (I_{PK}) or more

3. Input capacitor (C_{IN}) and output capacitor (C_{OUT})

To improve efficiency, an input capacitor (C_{IN}) lowers the power supply impedance and averages the input current. Select C_{IN} according to the impedance of the power supply used. The recommended capacitance is 10 μF to 20 μF for the S-8367/8368 Series.
An output capacitor (C_{OUT}), which is used to smooth V_{OUT}, requires a capacitance larger than that of the step-down type because the current is intermittently supplied from the input to the output side in the step-up type. A ceramic capacitor of 20 μF to 40 μF is recommended for the S-8367/8368 Series. However, a higher capacitance is recommended if the output voltage is high or the load current is large. If V_{OUT} or load current is low, about 10 μF can be used without problems. Select C_{OUT} after sufficient evaluation with actual application.
A ceramic capacitor can be used for both C_{IN} and C_{OUT}.

4. External transistors

A bipolar NPN transistor or an enhanced Nch power MOS FET can be used as an external transistor.

4. 1 Bipolar NPN transistor

The driving ability to increase output current by using a bipolar NPN transistor is determined based on the direct current gain (h_{FE}) value and R_b value of the bipolar NPN transistor. **Figure 18** shows the peripheral circuit.

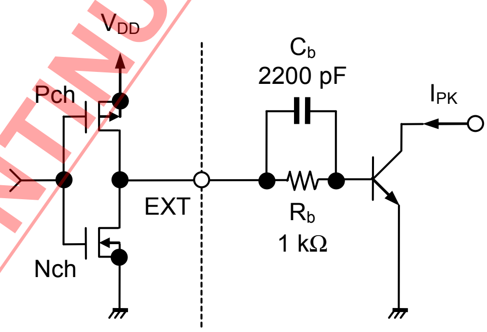


Figure 18 External Transistor Peripheral Circuit

The recommended R_b value is around 1 kΩ. Calculate the required base current (I_b) based on the h_{FE} value of the bipolar NPN transistor by using $I_b = \frac{I_{PK}}{h_{FE}}$, and then select an R_b value smaller than the one in the following equation:

$$R_b = \frac{V_{DD} - 0.7}{I_b} - \frac{0.4}{|I_{EXTH}|}$$

Smaller R_b values increase the output current, but decrease the efficiency. Actually, the current might flow on pulses or the V_{DD} or V_{SS} voltage might decrease due to wiring resistance, so determine the optimum value based on experimentation.
Inserting a speed-up capacitor (C_b) in parallel with the R_b resistor as shown in **Figure 18** reduces switching loss and increases efficiency.

Select a C_b value which satisfies $C_b \leq \frac{1}{2 \times \pi \times R_b \times f_{OSC} \times 0.7}$.

Actually, however, the optimum C_b value varies depending on the characteristics of the bipolar NPN transistor used, so determine the optimum value based on experimentation.

4. 2 Enhanced Nch Power MOS FET

Use an enhanced Nch power MOS FET. A MOS FET that has low ON-resistance (R_{ON}) and input capacitance (C_{ISS}) is ideal for gaining efficiency. R_{ON} and input capacitance generally have a tradeoff relationship. R_{ON} is efficient in the range where the output current is high with relatively low frequency switching, and input capacitance is efficient in the range where the output current is medium to low with high frequency switching. Therefore, select a MOS FET for which the R_{ON} and input capacitance are optimum under your usage conditions.
The input voltage (V_{DD}) is supplied as the gate voltage of a MOS FET, so select a MOS FET for which the gate withstand voltage is higher than the maximum value used for V_{DD}, and for which the drain withstand voltage is higher than or equal to the output voltage (V_{OUT}) + the forward voltage of the diode (V_D).
If a MOS FET for which the threshold value is near the UVLO detection voltage is used, a high current flows upon power-on, and, in the worst case, V_{OUT} might not increase. Therefore, select a MOS FET for which the threshold value is sufficiently lower than the UVLO detection voltage.

5. Output voltage set resistors (R_{FB1}, R_{FB2}), capacitor for phase compensation (C_{FB})

For the S-8367/8368 Series, V_{OUT} can be set to any value by using external divider resistors. Connect the divider resistors between the VOUT pin and the VSS pin.
Because V_{FB} = 0.6 V typ., V_{OUT} can be calculated by using the following equation:

$$V_{OUT} = \frac{R_{FB1} + R_{FB2}}{R_{FB2}} \times 0.6$$

Connect divider resistors R_{FB1} and R_{FB2} as close to the IC as possible to minimize the effects of noise. If noise has an effect, adjust the values of R_{FB1} and R_{FB2} so that $R_{FB1} + R_{FB2} < 100\ \text{k}\Omega$.
C_{FB}, which is connected in parallel with R_{FB1}, is a capacitor for phase compensation.
By setting the zero point (the phase feedback) by adding capacitor C_{FB} to R_{FB1} in parallel, the phase margin increases, improving the stability of the feedback loop. To effectively use the feedback portion of the phase based on the zero point, define C_{FB} by using the following equation:

$$C_{FB} \cong \frac{\sqrt{L \times C_{OUT}}}{5 \times R_{FB1}} \times \frac{V_{OUT}}{V_{DD}}$$

This equation is only a guide.

The following explains the optimum setting.

To efficiently use the feedback portion of the phase based on the zero point, specify settings so that the phase feeds back at the zero point frequency (f_{zero}) of R_{FB1} and C_{FB} according to the phase delay at the pole frequency (f_{pole}) of L and C_{OUT}. The zero point frequency is generally set slightly higher than the pole frequency.
The following equations are used to determine the pole frequency of L and C_{OUT} and the zero point frequency set using R_{FB1} and C_{FB}.

$$f_{pole} \cong \frac{1}{2 \times \pi \times \sqrt{L \times C_{OUT}}} \times \frac{V_{DD}}{V_{OUT}}$$

$$f_{zero} \cong \frac{1}{2 \times \pi \times R_{FB1} \times C_{FB}}$$

The transient response speed can be improved by setting the zero point frequency in a lower frequency range. If, however, the zero point frequency is set in a significantly lower range, the gain increases in the range of high frequency and the phase margin decreases. This might result in unstable operation. Determine the optimum value after sufficient evaluation with actual application.

The typical constants based on our evaluation are shown in **Table 12**.

Table 12 Example of Constants for External Parts

$V_{OUT(S)}$ [V]	V_{DD} [V]	R_{FB1} [kΩ]	R_{FB2} [kΩ]	C_{FB} [pF]	L [μH]	C_{OUT} [μF]
5.0	3.6	220	30	12	2.2	40
12.0	3.6	300	16	22	2.2	40

■ Standard Circuits

1. S-8367 Series (Without short-circuit protection function)

1. 1 When using current limit function

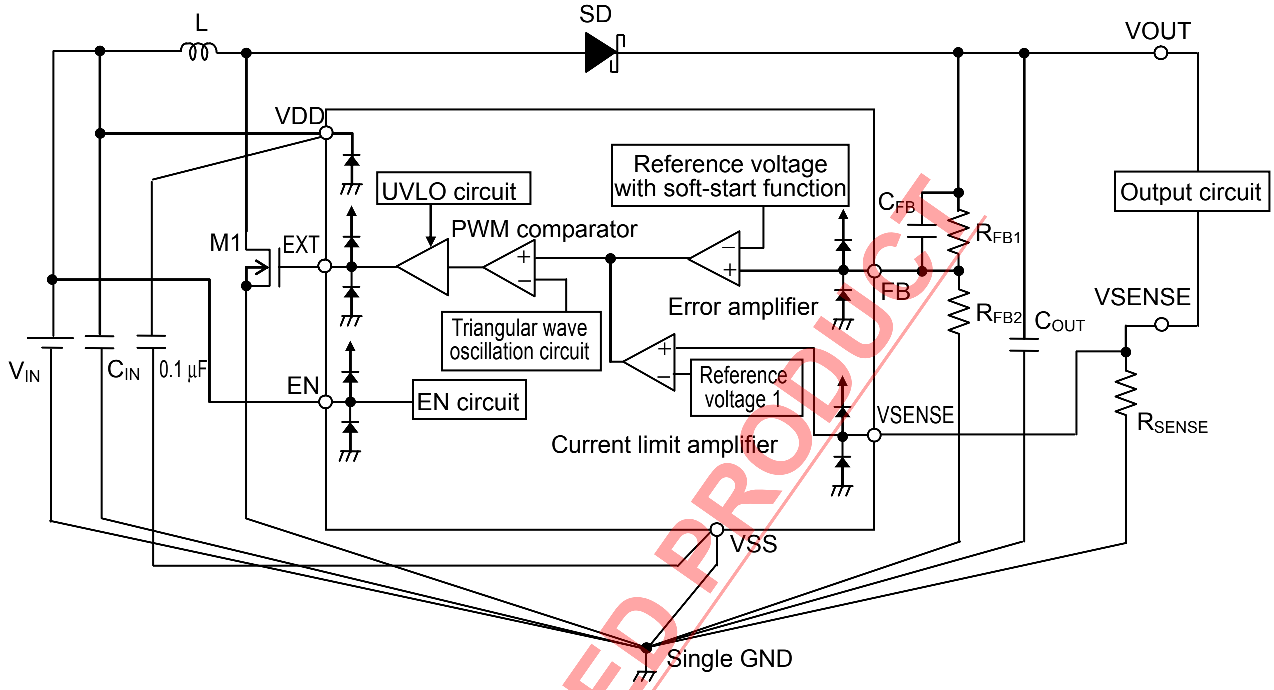


Figure 19

1. 2 When not using current limit function

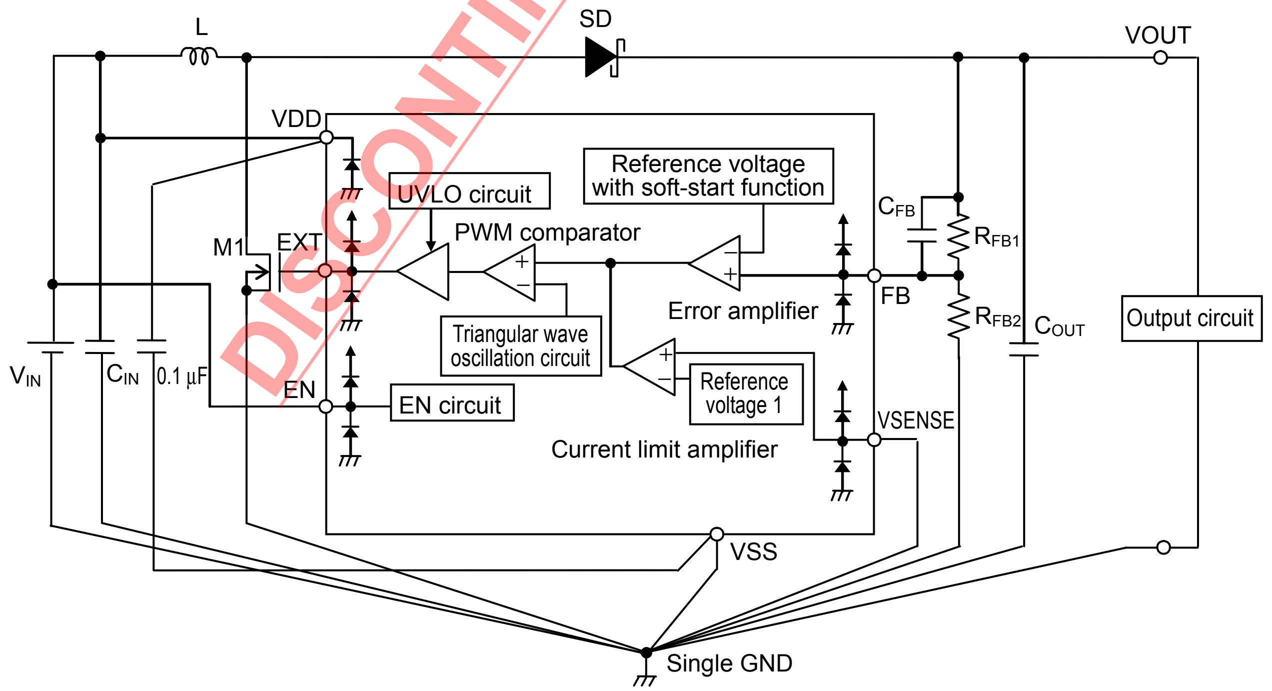


Figure 20

Caution **The above connection diagrams and constants will not guarantee successful operations. Perform thorough evaluation using an actual application to set the constants.**

2. S-8368 Series (With short-circuit protection function)

2. 1 When using current limit function

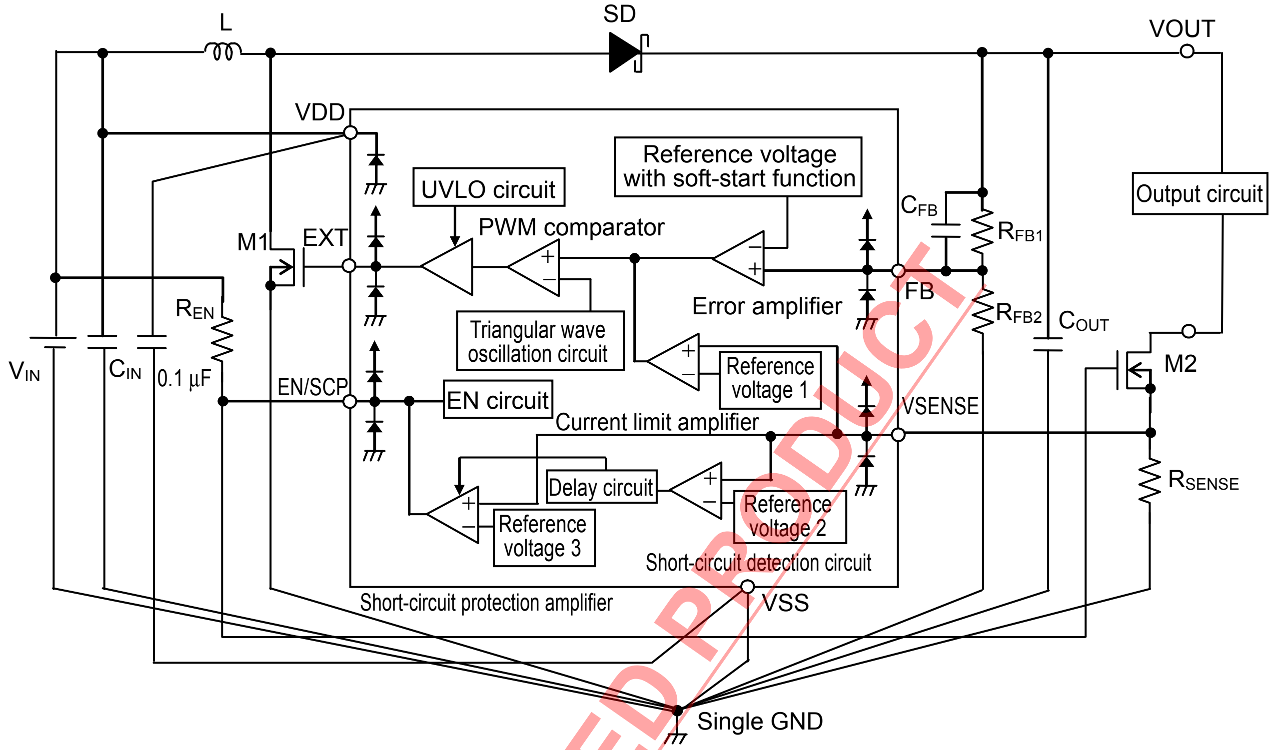


Figure 21

2. 2 When not using current limit function

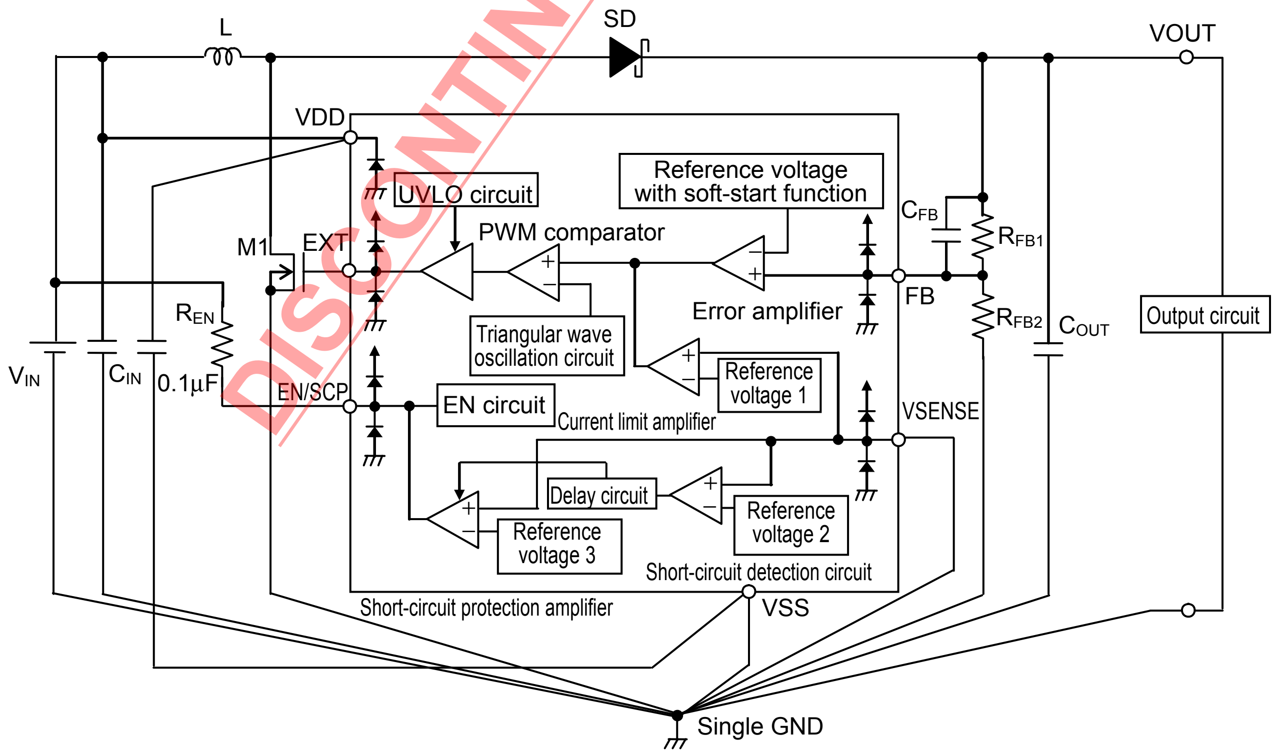


Figure 22

Caution **The above connection diagrams and constants will not guarantee successful operations. Perform thorough evaluation using an actual application to set the constants.**

■ Precautions

- Mount external capacitors and inductor as close as possible to the IC. Set single GND.
- Characteristics ripple voltage and spike noise occur in the IC containing switching regulators. Moreover, rush current flows at power-on. Since these are influenced greatly by inductors and capacitors to be used, or impedance of power supply, perform sufficient evaluation using an actual application before designing.
- The 0.1 μF capacitor connected between the VDD pin and the VSS pin is a bypass capacitor. It stabilizes the power supply in the IC when application is used with a heavy load, and thus effectively works for stable switching regulator operation. Allocate the bypass capacitor as close to the IC as possible, prioritized over other parts.
- Although the IC contains a static electricity protection circuit, static electricity or voltage that exceeds the limit of the protection circuit should not be applied.
- The power dissipation of the IC greatly varies depending on the size and material of the board to be connected. Perform sufficient evaluation using an actual application before designing.
- 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

Application circuits are specific examples. They may not always guarantee successful operations.

1. Mobile battery charger (Output current 3.0 A)

1. 1 Characteristics of external parts

Table 13

Part	Part Name	Manfuacturer	Characteristic
Inductor	SPM6530T-2R2M	TDK Corporation	2.2 µH, DCR*1 = 0.019 Ω max., I_{MAX}*2 = 8.4 A typ., L × W × H = 7.1 × 6.5 × 3.0 [mm]
Diode	RSX501L-20	Rohm Co., Ltd.	V_F*3 = 0.39 V max. (I_F*4 = 3.0 A), I_O*5 = 5.0 A L × W × H = 5.0 × 2.6 × 2.0 [mm]
	M2FH3	Shindengen Electric Manufacturing Co., Ltd.	V_F*3 = 0.30 V max. (I_F*4 = 2.0 A), I_O*5 = 6.0 A L × W × H = 5.1 × 3.75 × 2.0 [mm]
Transistor	Si3460BDV	VISHAY INTERTECHNOLOGY, INC.	V_{DSS}*6 = 20 V, V_{GSS}*7 = ±8 V, I_D*8 = 8.0 A, Q_G*9 = 9 nC typ. $R_{DS(ON)}$*10 = 0.027 Ω typ. (V_{GS}*11 = 2.5 V) L × W × H = 3.0 × 2.85 × 1.1 [mm]
	Si3464DV		V_{DSS}*6 = 20 V, V_{GSS}*7 = ±8 V, I_D*8 = 8.0 A, Q_G*9 = 11 nC typ. $R_{DS(ON)}$*10 = 0.023 Ω typ. (V_{GS}*11 = 2.5 V) L × W × H = 3.0 × 2.85 × 1.1 [mm]
Capacitor	GRM219R61C106KA73	Murata Manufacturing, Co., Ltd.	10 µF, E_{DC}*12 = 16 V, X5R, L × W × H = 2.0 × 1.25 × 0.85 [mm]
	GRM152R60J104KE19		0.1 µF, E_{DC}*12 = 6.3 V, X5R, L × W × H = 1.0 × 0.5 × 0.2 [mm]

***1.** DCR: DC resistance (Maximum value)
***2.** I_{MAX}: Maximum allowable current
***3.** V_F: Forward voltage
***4.** I_F: Forward current
***5.** I_O: Output current
***6.** V_{DSS}: Drain-to-source voltage (When short-circuiting between the gate and the source)
***7.** V_{GSS}: Gate-to-source voltage (When short-circuiting between the drain and the source)
***8.** I_D: Drain current
***9.** Q_G: Gate charge
***10.** $R_{DS(ON)}$: Drain-to-source ON-resistance
***11.** V_{GS}: Gate-to-source voltage
***12.** E_{DC}: Rated voltage

1. 2 Circuit example

The followings are a circuit example and its characteristics for realizing the output voltage of 5.0 V and the output current of 3.0 A for USB by using a lithium-ion rechargeable battery.

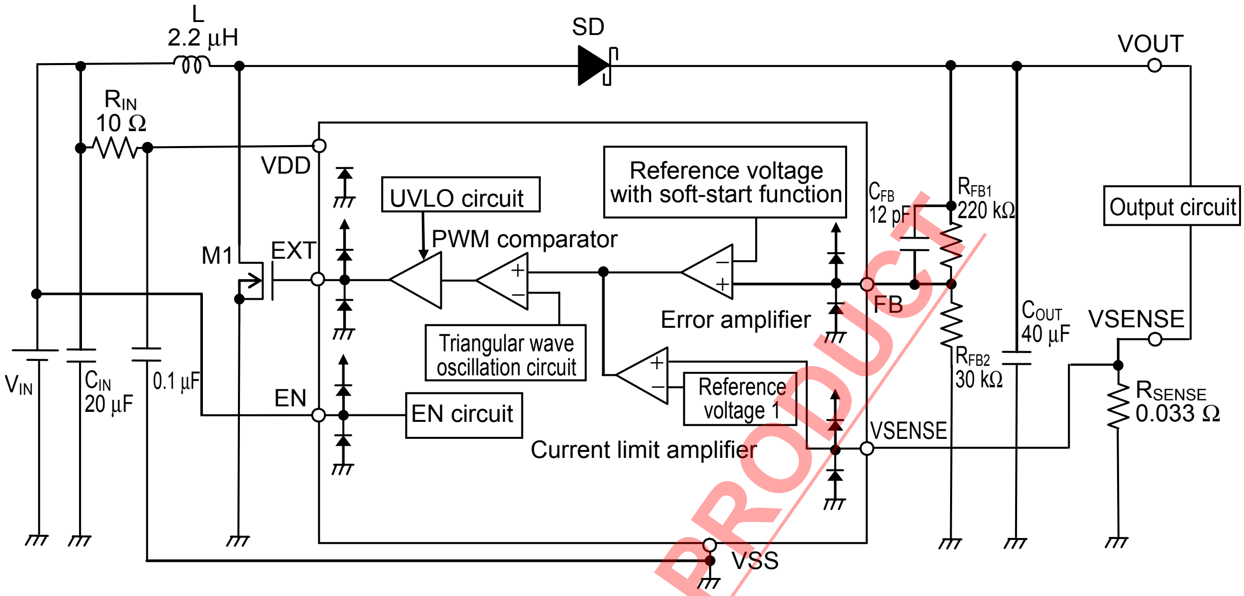


Figure 23

Table 14 External Parts Examples

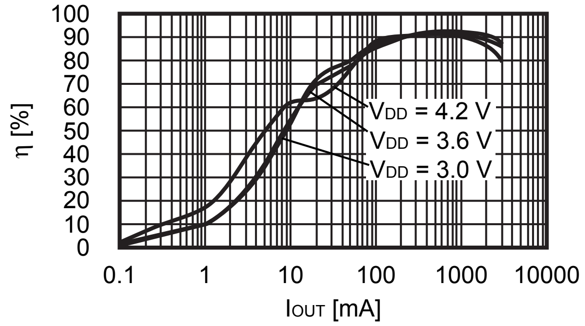
Condition	Output Voltage	IC Product Name	L Product Name	M1 Product Name	SD Product Name	C_{IN}	C_{OUT}	R_{FB1}	R_{FB2}	C_{FB}	R_{SENSE}
1	5 V	S-8367A21I	SPM6530T-2R2M	Si3460BDV	RSX501L-20 × 2	10 μF × 2	10 μF × 4	220 kΩ	30 kΩ	12 pF	0.033 Ω
2	5 V	S-8367A21I	SPM6530T-2R2M	Si3464DV	M2FH3	10 μF × 2	10 μF × 4	220 kΩ	30 kΩ	12 pF	0.033 Ω

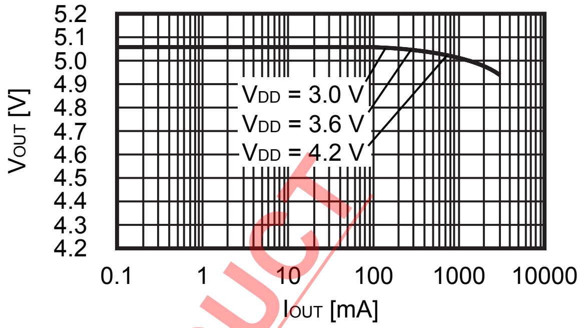
Caution The above connection will not guarantee successful operation. Perform thorough evaluation using an actual application to set the constant.

1. 3 Output characteristics

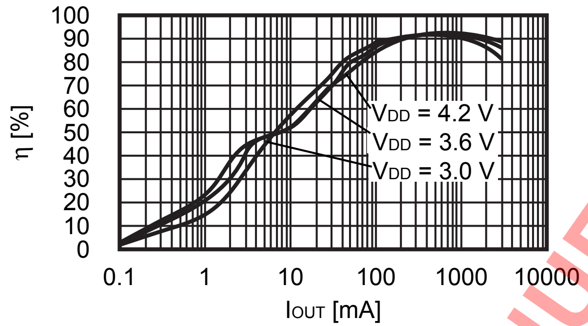
The followings show "Efficiency (η) vs. Output current (I_{OUT}) characteristics" and "Output voltage (V_{OUT}) vs. Output current (I_{OUT}) characteristics" for conditions 1 and 2 in "**Table 14 External Parts Examples**".

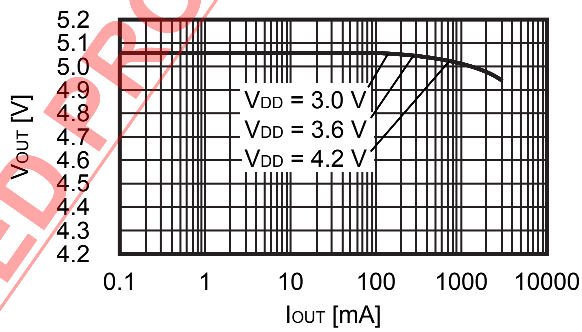
Condition 1





Condition 2





2. Mobile battery charger (Output current 2.1 A)

2. 1 Characteristics of external parts

Table 15

Part	Part Name	Manfuacturer	Characteristic
Inductor	VLP6045LT-2R2N	TDK Corporation	2.2 μH, DCR*1 = 0.026 Ω max., I_{MAX}*2 = 6.4 A max., L × W × H = 6.0 × 6.0 × 4.5 [mm]
	NR5040T2R2N	Taiyo Yuden Co., Ltd.	2.2 μH, DCR*1 = 0.029 Ω max., I_{MAX}*2 = 4.6 A, L × W × H = 4.9 × 4.9 × 4.1 [mm]
Diode	RSX501L-20	Rohm Co., Ltd.	V_F*3 = 0.39 V max. (I_F*4 = 3.0 A), I_O*5 = 5.0 A L × W × H = 5.0 × 2.6 × 2.0 mm
	M2FH3	Shindengen Electric Manufacturing Co., Ltd.	V_F*3 = 0.30 V max. (I_F*4 = 2.0 A), I_O*5 = 6.0 A L × W × H = 5.1 × 3.75 × 2.0 [mm]
Transistor	MCH6421	ON Semiconductor Corp.	V_{DSS}*6 = 20 V, V_{GSS}*7 = ±12 V, I_D*8 = 5.5 A, Q_G*9 = 5.1 nC typ. $R_{DS(ON)}$*10 = 0.043 Ω typ. (V_{GS}*11 = 2.5 V) L × W × H = 2.1 × 2.0 × 0.85 [mm]
	Si2312CDS	VISHAY INTERTECHNOLOGY, INC.	V_{DSS}*6 = 20 V, V_{GSS}*7 = ±8 V, I_D*8 = 6.0 A, Q_G*9 = 8.8 nC typ. $R_{DS(ON)}$*10 = 0.030 Ω typ. (V_{GS}*11 = 2.5 V) L × W × H = 3.0 × 2.6 × 1.1 [mm]
Capacitor	GRM219R61C106KA73	Murata Manufacturing, Co., Ltd.	10 μF, E_{DC}*12 = 16 V, X5R, L × W × H = 2.0 × 1.25 × 0.85 [mm]
	GRM152R60J104KE19		0.1 μF, E_{DC}*12 = 6.3 V, X5R, L × W × H = 1.0 × 0.5 × 0.2 [mm]

***1.** DCR: DC resistance (Maximum value)
***2.** I_{MAX}: Maximum allowable current
***3.** V_F: Forward voltage
***4.** I_F: Forward current
***5.** I_O: Output current
***6.** V_{DSS}: Drain-to-source voltage (When short-circuiting between the gate and the source)
***7.** V_{GSS}: Gate-to-source voltage (When short-circuiting between the drain and the source)
***8.** I_D: Drain current
***9.** Q_G: Gate charge
***10.** $R_{DS(ON)}$: Drain-to-source ON-resistance
***11.** V_{GS}: Gate-to-source voltage
***12.** E_{DC}: Rated voltage

2. 2 Circuit example

The followings are a circuit example and its characteristics for realizing the output voltage of 5.0 V and the output current of 2.1 A for USB by using a lithium-ion rechargeable battery.

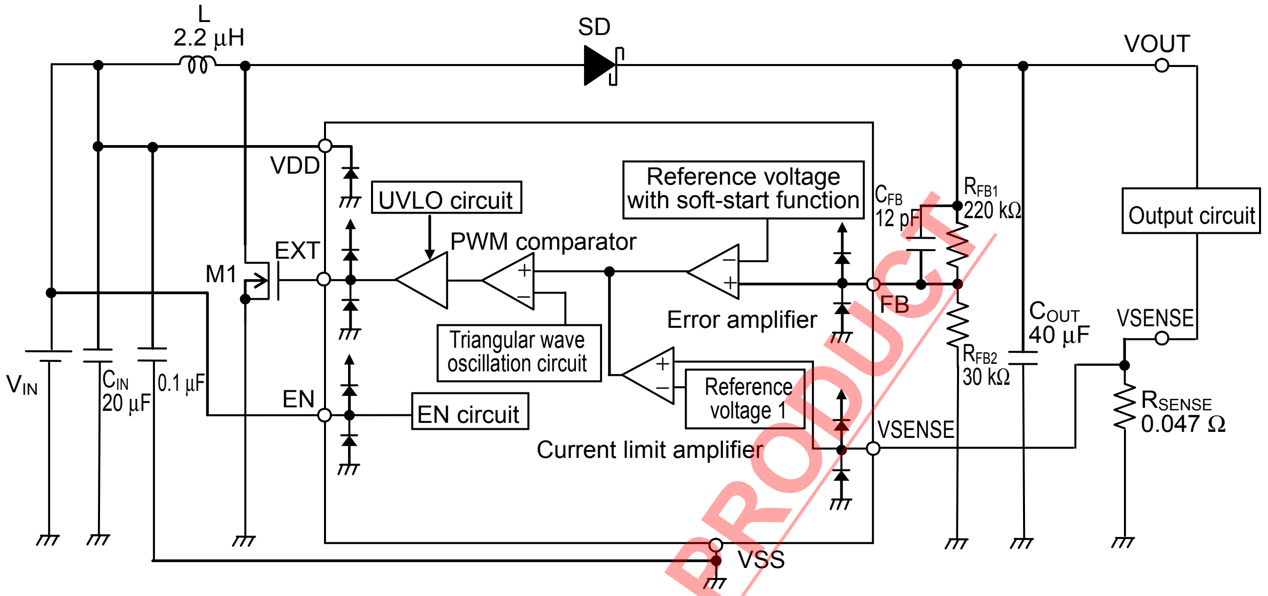


Figure 24

Table 16 External Parts Examples

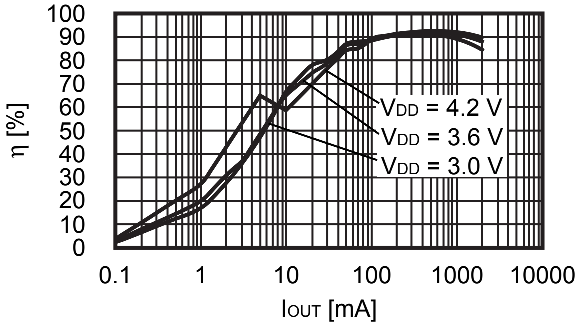
Condition	Output Voltage	IC Product Name	L Product Name	M1 Product Name	SD Product Name	C_{IN}	C_{OUT}	R_{FB1}	R_{FB2}	C_{FB}	R_{SENSE}
1	5 V	S-8367A21I	VLP6045LT-2R2N	MCH6421	RSX501L-20	10 µF × 2	10 µF × 4	220 kΩ	30 kΩ	12 pF	0.047 Ω
2	5 V	S-8367A21I	VLP6045LT-2R2N	Si2312CDS	M2FH3	10 µF × 2	10 µF × 4	220 kΩ	30 kΩ	12 pF	0.047 Ω
3	5 V	S-8367A21I	NR5040T2R2N	MCH6421	M2FH3	10 µF × 2	10 µF × 4	220 kΩ	30 kΩ	12 pF	0.047 Ω
4	5 V	S-8367A21I	NR5040T2R2N	Si2312CDS	RSX501L-20	10 µF × 2	10 µF × 4	220 kΩ	30 kΩ	12 pF	0.047 Ω

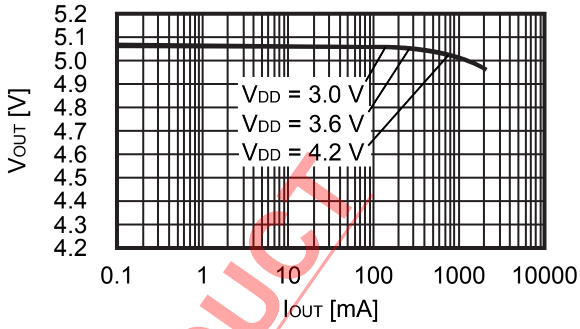
Caution The above connection will not guarantee successful operation. Perform thorough evaluation using an actual application to set the constant.

2. 3 Output characteristics

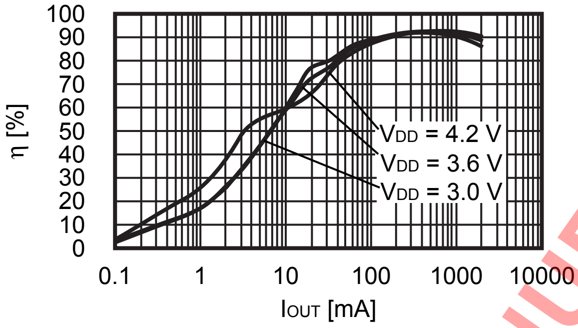
The followings show "Efficiency (η) vs. Output current (I_{OUT}) characteristics" and "Output voltage (V_{OUT}) vs. Output current (I_{OUT}) characteristics" for conditions 1 to 4 in "**Table 16 External Parts Examples**".

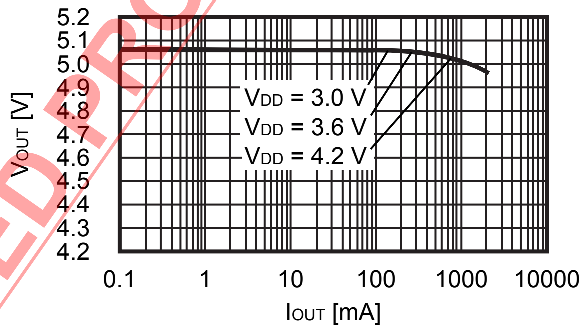
Condition 1



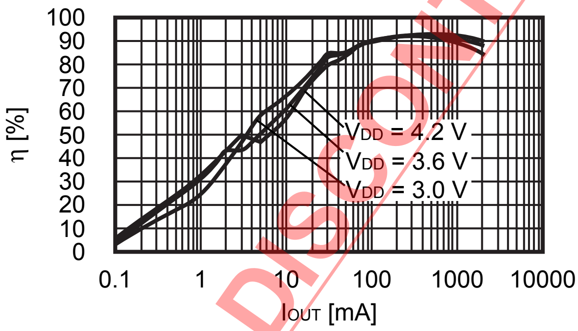


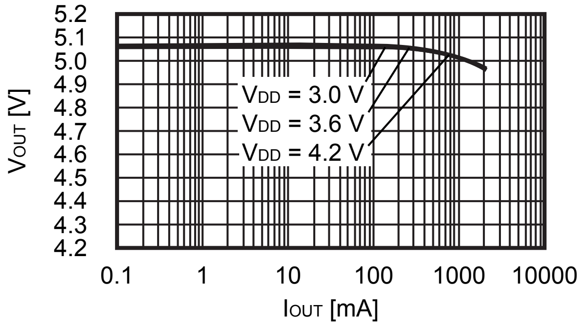
Condition 2



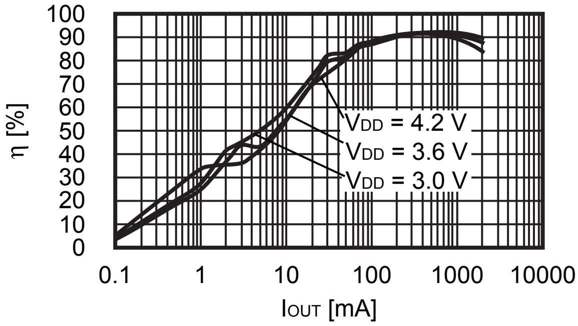


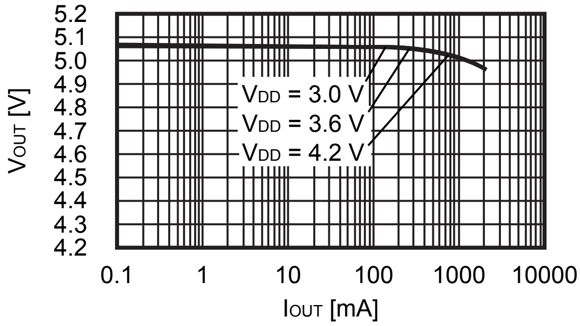
Condition 3





Condition 4





3. Mobile battery charger (Output current 1.0 A)

3. 1 Characteristics of external parts

Table 17

Part	Part Name	Manfuacturer	Characteristic
Inductor	SPM3012T-2R2M	TDK Corporation	2.2 μH, DCR*1 = 0.115 Ω max., I_{MAX}*2 = 3.4 A typ., L × W × H = 3.2 × 3.0 × 1.2 [mm]
	NR4018T2R2M	Taiyo Yuden Co., Ltd	2.2 μH, DCR*1 = 0.072 Ω max., I_{MAX}*2 = 2.7 A, L × W × H = 4.0 × 4.0 × 1.8 [mm]
Diode	SS24	ON Semiconductor Corp.	V_F*3 = 0.50 V max. (I_F*4 = 2.0 A), I_O*5 = 2.0 A L × W × H = 5.4 × 3.6 × 2.1 [mm]
	D1FH3	Shindengen Electric Manufacturing Co., Ltd.	V_F*3 = 0.30 V max. (I_F*4 = 1.0 A), I_O*5 = 3.0 A L × W × H = 5.0 × 2.5 × 2.0 [mm]
Transistor	MCH3406	ON Semiconductor Corp.	V_{DSS}*6 = 20 V, V_{GSS}*7 = ±10 V, I_D*8 = 3.0 A, Q_G*9 = 8.8 nC typ. $R_{DS(ON)}$*10 = 0.058 Ω typ. (V_{GS}*11 = 2.5 V) L × W × H = 2.1 × 2.0 × 0.85 [mm]
	MCH6421		V_{DSS}*6 = 20 V, V_{GSS}*7 = ±12 V, I_D*8 = 5.5 A, Q_G*9 = 5.1 nC typ. $R_{DS(ON)}$*10 = 0.043 Ω typ. (V_{GS}*11 = 2.5 V) L × W × H = 2.1 × 2.0 × 0.85 [mm]
Capacitor	GRM219R61C106KA73	Murata Manufacturing, Co., Ltd.	10 μF, E_{DC}*12 = 16 V, X5R, L × W × H = 2.0 × 1.25 × 0.85 [mm]
	GRM152R60J104KE19		0.1 μF, E_{DC}*12 = 6.3 V, X5R, L × W × H = 1.0 × 0.5 × 0.2 [mm]

***1.** DCR: DC resistance (Maximum value)
***2.** I_{MAX}: Maximum allowable current
***3.** V_F: Forward voltage
***4.** I_F: Forward current
***5.** I_O: Output current
***6.** V_{DSS}: Drain-to-source voltage (When short-circuiting between the gate and the source)
***7.** V_{GSS}: Gate-to-source voltage (When short-circuiting between the drain and the source)
***8.** I_D: Drain current
***9.** Q_G: Gate charge
***10.** $R_{DS(ON)}$: Drain-to-source ON-resistance
***11.** V_{GS}: Gate-to-source voltage
***12.** E_{DC}: Rated voltage

3. 2 Circuit example

The followings are a circuit example and its characteristics for realizing the output voltage of 5.0 V and the output current of 1.0 A for USB by using a lithium-ion rechargeable battery.

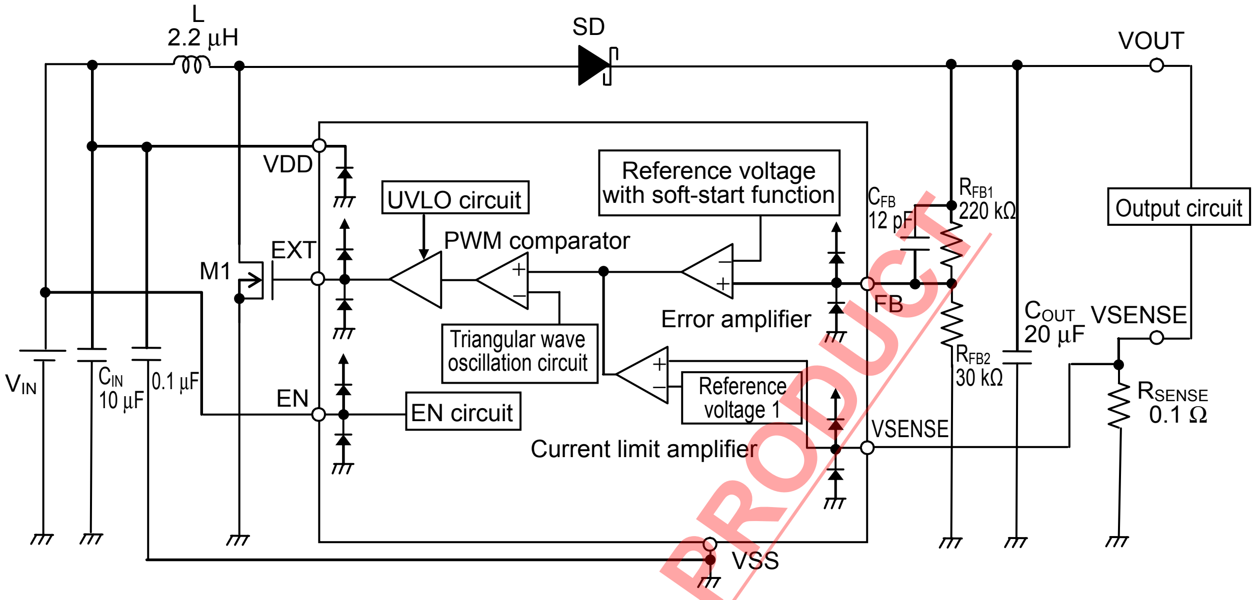


Figure 25

Table 18 External Parts Examples

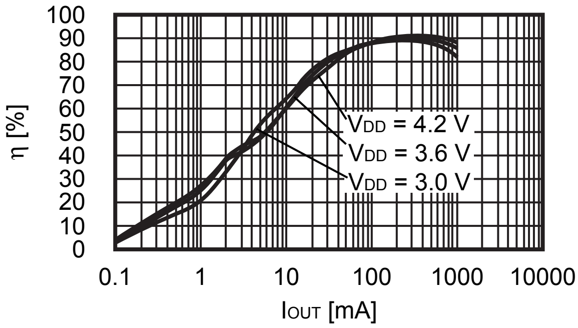
Condition	Output Voltage	IC Product Name	L Product Name	M1 Product Name	SD Product Name	C_{IN}	C_{OUT}	R_{FB1}	R_{FB2}	C_{FB}	R_{SENSE}
1	5 V	S-8367A21I	SPM3012T-2R2M	MCH6421	D1FH3	10 µF	10 µF × 2	220 kΩ	30 kΩ	12 pF	0.1 Ω
2	5 V	S-8367A21I	SPM3012T-2R2M	MCH3406	SS24	10 µF	10 µF × 2	220 kΩ	30 kΩ	12 pF	0.1 Ω
3	5 V	S-8367A21I	NR4018T2R2M	MCH3406	D1FH3	10 µF	10 µF × 2	220 kΩ	30 kΩ	12 pF	0.1 Ω

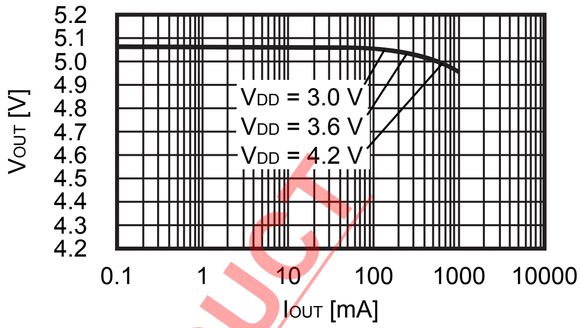
Caution The above connection will not guarantee successful operation. Perform thorough evaluation using an actual application to set the constant.

3. 3 Output Characteristics

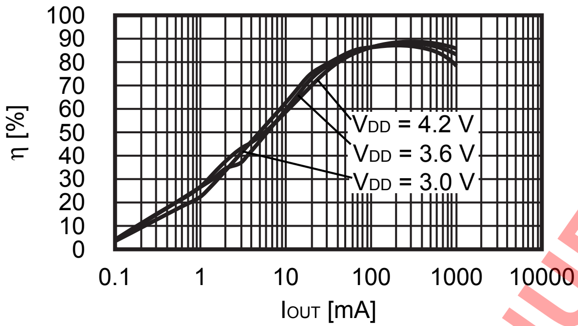
The followings show "Efficiency (η) vs. Output current (I_{OUT}) characteristics" and "Output voltage (V_{OUT}) vs. Output current (I_{OUT}) characteristics" for conditions 1 to 3 in "**Table 18 External Parts Examples**".

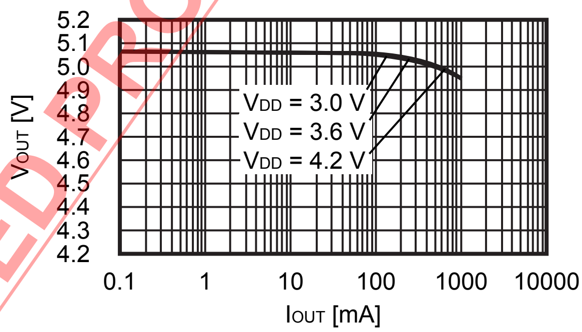
Condition 1



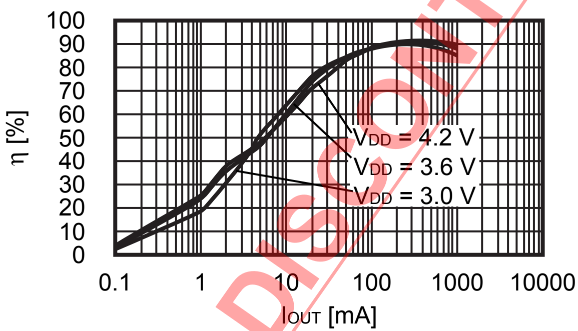


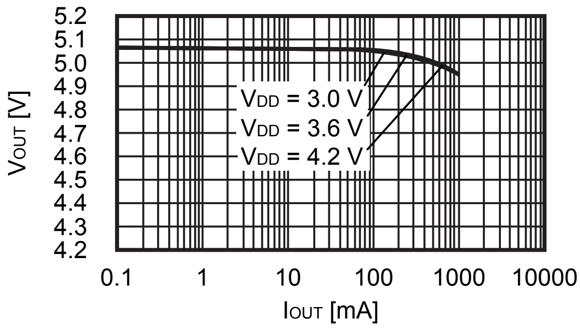
Condition 2





Condition 3





4. Output current 1.0 A, with short-circuit protection function

4. 1 Characteristics of external parts

Table 19

Part	Part Name	Manfuacturer	Characteristic
Inductor	NR4018T2R2M	Taiyo Yuden Co., Ltd	2.2 μH, DCR*1 = 0.072 Ω max., I_{MAX}*2 = 2.7 A, L × W × H = 4.0 × 4.0 × 1.8 [mm]
Diode	D1FH3	Shindengen Electric Manufacturing Co., Ltd.	V_F*3 = 0.30 V max. (I_F*4 = 1.0 A), I_O*5 = 3.0 A L × W × H = 5.0 × 2.5 × 2.0 [mm]
Transistor (M1)	MCH3406	ON Semiconductor Corp.	V_{DSS}*6 = 20 V, V_{GSS}*7 = ±10 V, I_D*8 = 3.0 A, Q_G*9 = 8.8 nC typ. $R_{DS(ON)}$*10 = 0.058 Ω typ. (V_{GS}*11 = 2.5 V) L × W × H = 2.1 × 2.0 × 0.85 [mm]
Transistor (M2)	FDD6530A	Fairchild semiconductor	V_{DSS}*6 = 20 V, V_{GSS}*7 = ±8 V, $R_{DS(ON)}$*10 = 0.026 Ω typ. (V_{GS}*11 = 4.5 V) C_{iss}*12 = 710 pF, $R_{\theta JA}$*13 = +45°C/W L × W × H = 10.4 × 6.7 × 2.4 [mm]
	Si4666DY	VISHAY INTERTECHNOLOGY, INC.	V_{DSS}*6 = 25 V, V_{GSS}*7 = ±12 V, $R_{DS(ON)}$*10 = 0.0091 Ω typ. (V_{GS}*11 = 4.5 V) C_{iss}*12 = 1145 pF, $R_{\theta JA}$*13 = +38°C/W L × W × H = 6.2 × 5.0 × 1.8 [mm]
Capacitor	GRM219R61C106KA73	Murata Manufacturing, Co., Ltd.	10 μF, E_{DC}*14 = 16 V, X5R, L × W × H = 2.0 × 1.25 × 0.85 [mm]
	GRM152R60J104KE19		0.1 μF, E_{DC}*14 = 6.3 V, X5R, L × W × H = 1.0 × 0.5 × 0.2 [mm]

***1.** DCR: DC resistance (Maximum value)
***2.** I_{MAX}: Maximum allowable current
***3.** V_F: Forward voltage
***4.** I_F: Forward current
***5.** I_O: Output current
***6.** V_{DSS}: Drain-to-source voltage (When short-circuiting between the gate and the source)
***7.** V_{GSS}: Gate-to-source voltage (When short-circuiting between the drain and the source)
***8.** I_D: Drain current
***9.** Q_G: Gate charge
***10.** $R_{DS(ON)}$: Drain-to-source ON-resistance
***11.** V_{GS}: Gate-to-source voltage
***12.** C_{iss}: Gate capacitance
***13.** $R_{\theta JA}$: Junction-to-board thermal resistance when mounted on board
***14.** E_{DC}: Rated voltage

4. 2 Circuit example

The followings are a circuit example with the short-circuit protection function and its characteristics.
In this example, the maximum output current during normal operation is 1.0 A. The short-circuit protection function operates when the output current increases to 1.2 A.

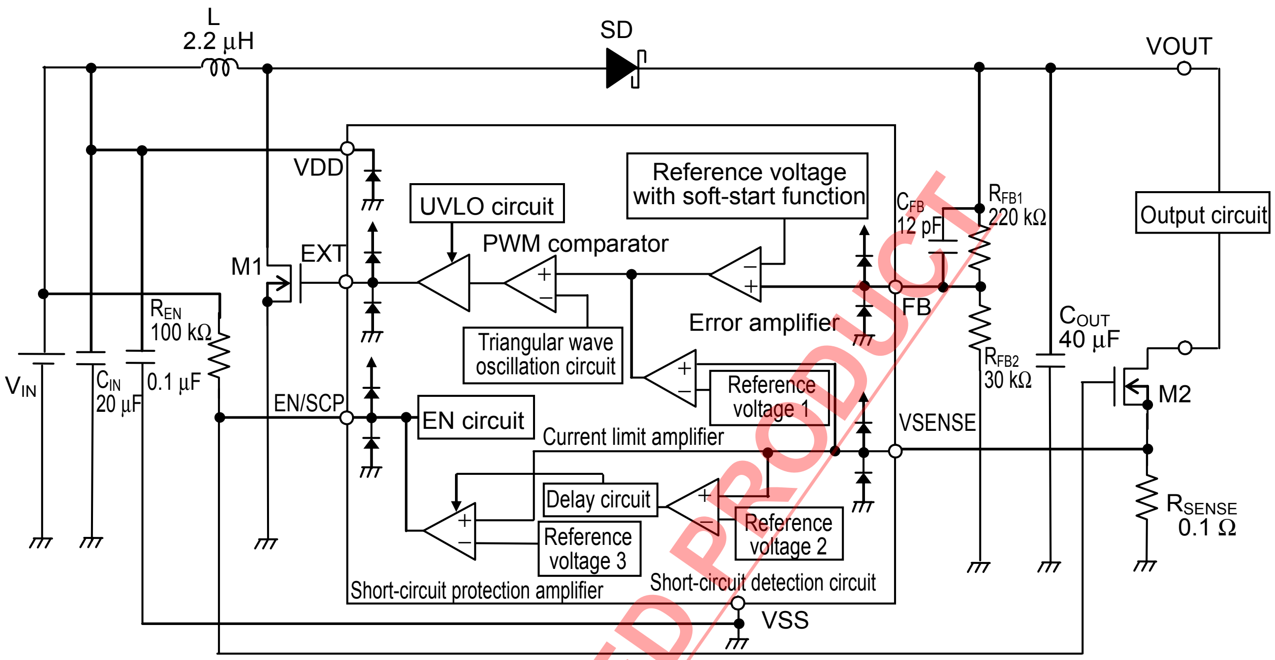


Figure 26

Table 20 External Parts Examples

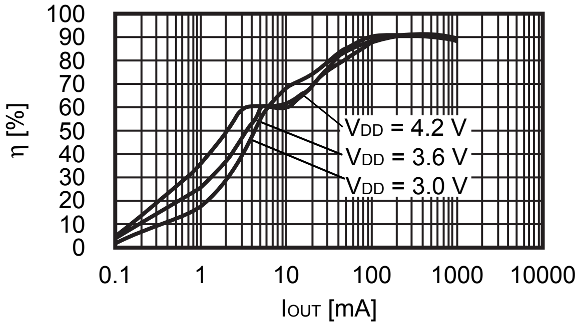
Condition	Output Voltage	IC Product Name	L Product Name	M1 Product Name	SD Product Name	M1 Product Name	C_{IN}	C_{OUT}	R_{FB1}	R_{FB2}	C_{FB}	R_{SENSE}
1	5 V	S-8368A21I	NR4018T2R2M	MCH3406	D1FH3	FDD6530A	10 µF × 2	10 µF × 4	220 kΩ	30 kΩ	12 pF	0.1 Ω
2	5 V	S-8368A21I	NR4018T2R2M	MCH3406	D1FH3	Si4666DY	10 µF × 2	10 µF × 4	220 kΩ	30 kΩ	12 pF	0.1 Ω

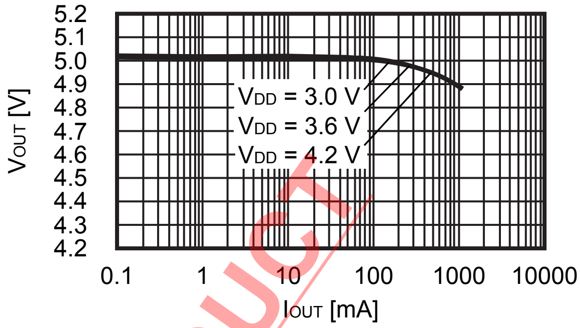
Caution The above connection will not guarantee successful operation. Perform thorough evaluation using an actual application to set the constant.

4. 3 Output characteristics

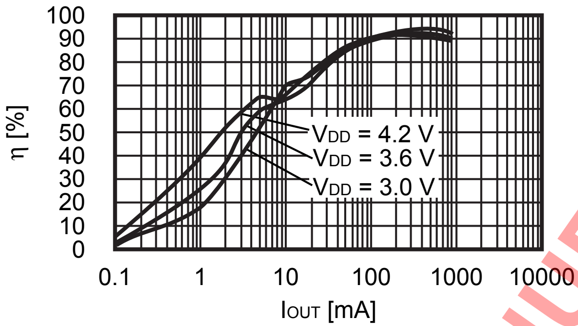
The followings show "Efficiency (η) vs. Output current (I_{OUT}) characteristics" and "Output voltage (V_{OUT}) vs. Output current (I_{OUT}) characteristics" for conditions 1 and 2 in "**Table 20 External Parts Examples**".

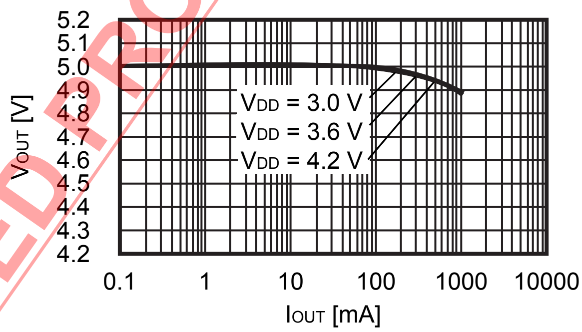
Condition 1





Condition 2

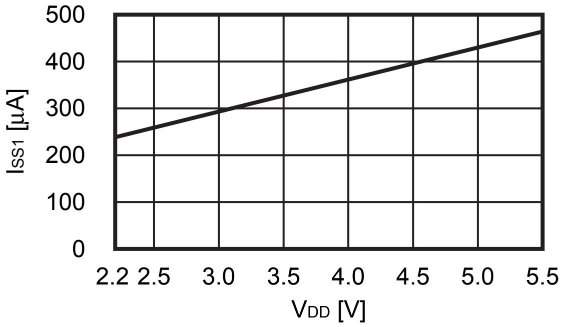




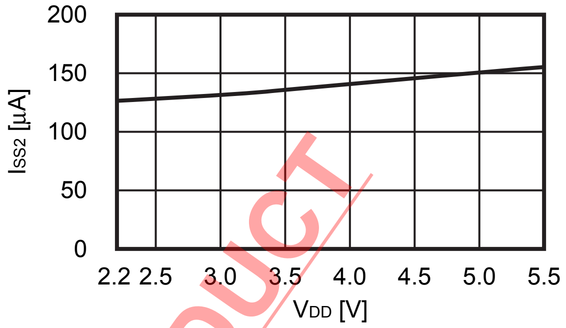
■ Characteristics (Typical Data)

1. Examples of Power Supply Dependence Characteristics (Ta = +25°C)

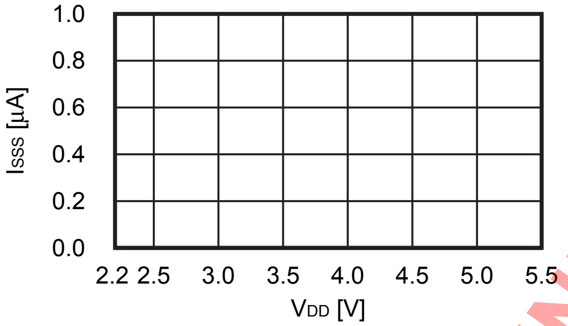
1. 1 Current consumption during operation (I_{SS1}) vs. Input voltage (V_{DD})



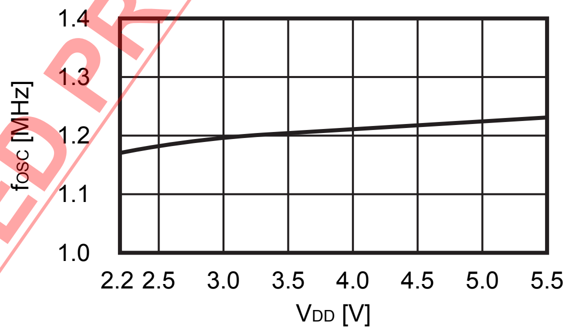
1. 2 Current consumption during switching off (I_{SS2}) vs. Input voltage (V_{DD})



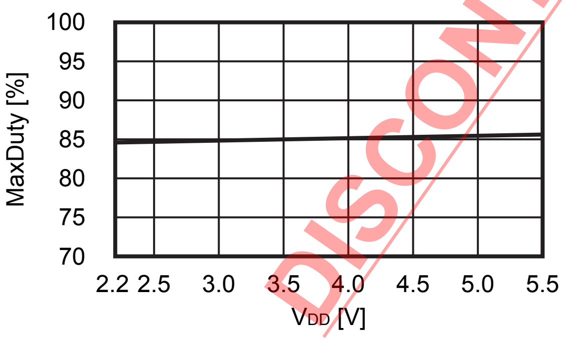
1. 3 Current consumption during power-off (I_{SSS}) vs. Input voltage (V_{DD})



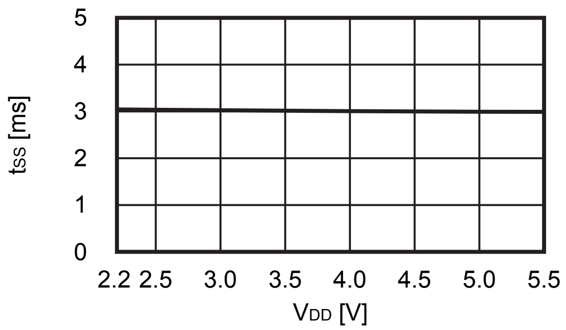
1. 4 Oscillation frequency (f_{OSC}) vs. Input voltage (V_{DD})



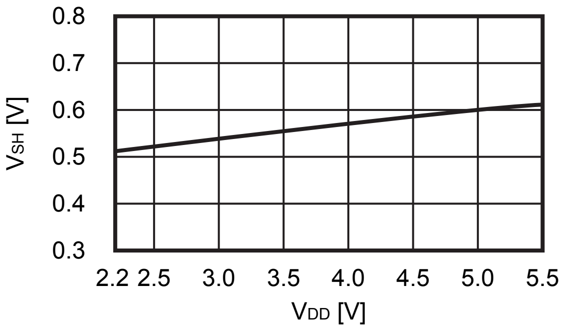
1. 5 Maximum duty (MaxDuty) vs. Input voltage (V_{DD})



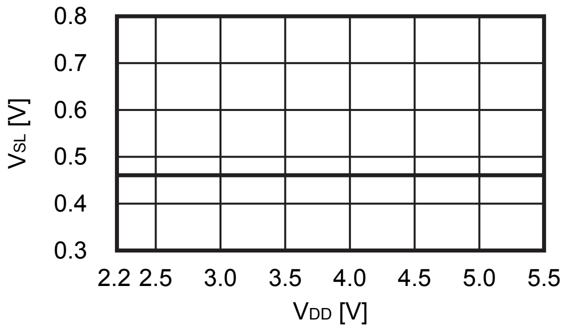
1. 6 Soft-start time (t_{SS}) vs. Input voltage (V_{DD})



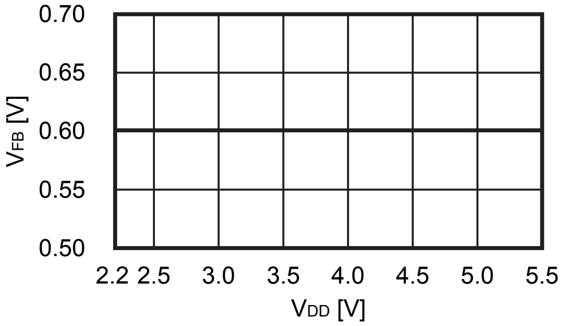
1. 7 EN pin input voltage "H" (V_{SH}) vs. Input voltage (V_{DD})



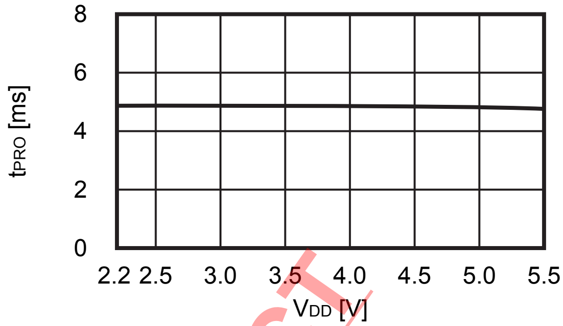
1. 8 EN pin input voltage "L" (V_{SL}) vs. Input voltage (V_{DD})



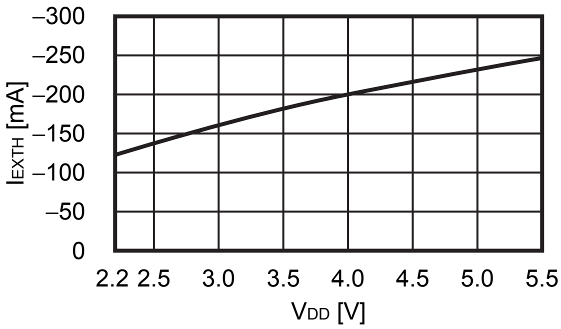
1. 9 FB pin voltage (V_{FB}) vs. Input voltage (V_{DD})



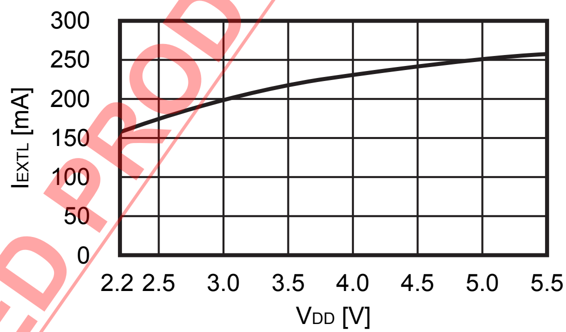
1. 10 Short-circuit protection delay time (t_{PRO}) vs. Input voltage (V_{DD})



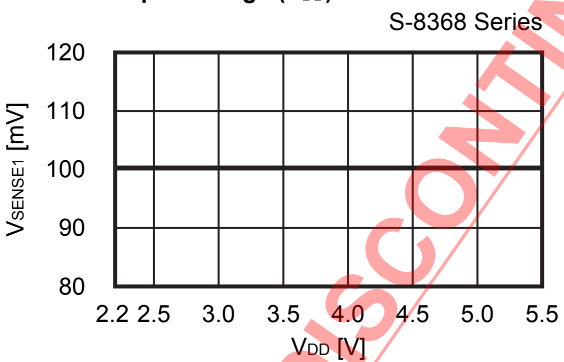
1. 11 EXT pin output current "H" (I_{EXTH}) vs. Input voltage (V_{DD})



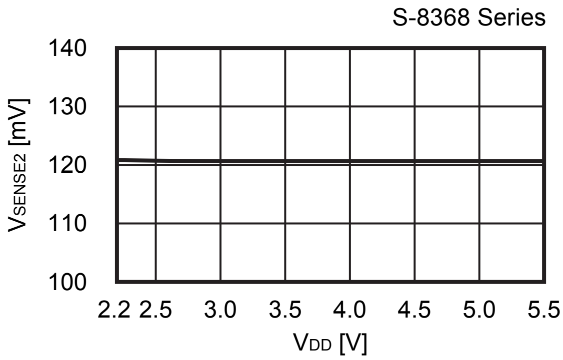
1. 12 EXT pin output current "L" (I_{EXTL}) vs. Input voltage (V_{DD})



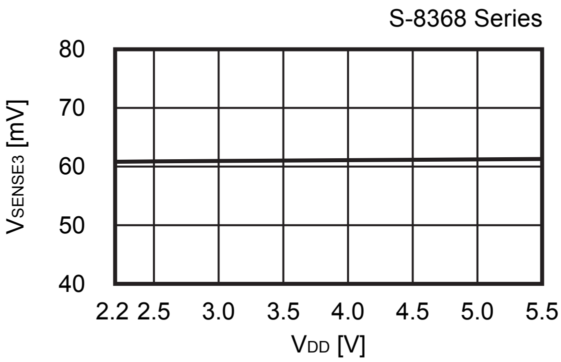
1. 13 Current detection voltage (V_{SENSE1}) vs. Input voltage (V_{DD})



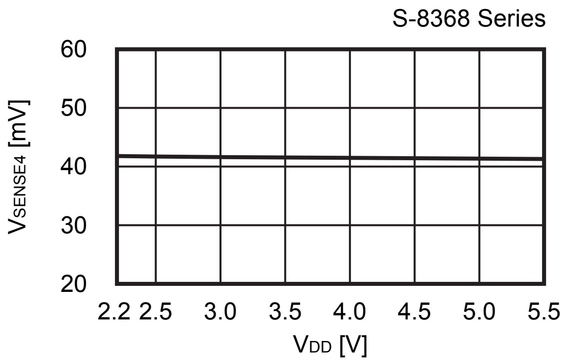
1. 14 VSENSE pin voltage for short-circuit detection (V_{SENSE2}) vs. Input voltage (V_{DD})



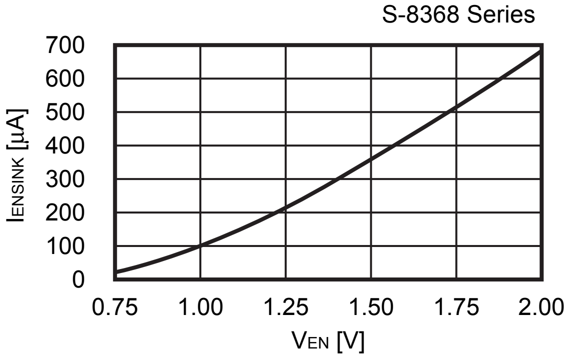
1. 15 VSENSE pin voltage during short-circuit protection operation (V_{SENSE3}) vs. Input voltage (V_{DD})



1. 16 VSENSE pin volotage for short-circuit protection release (V_{SENSE4}) vs. Input voltage (V_{DD})

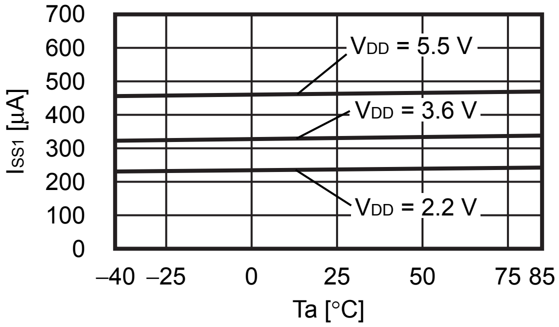


1. 17 EN pin sink current during short-circuit detection (I_{ENSINK}) vs. EN pin voltage (V_{EN})

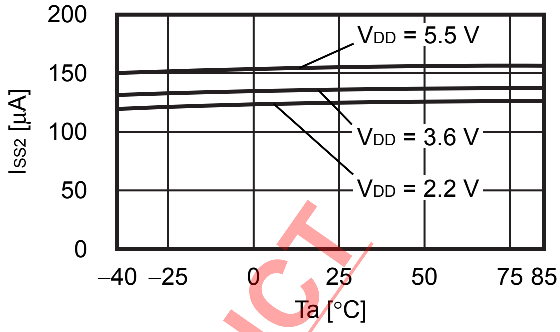


2. Examples of Temperature Characteristics (Ta = –40 to +85°C)

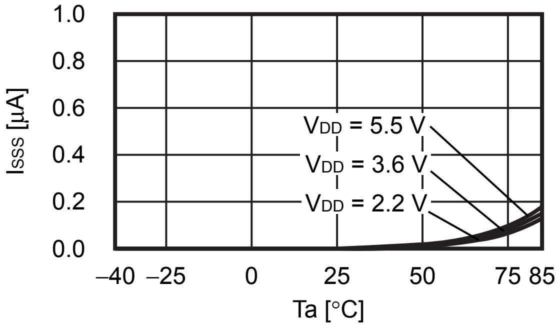
2. 1 Current consumption during operation (I_{SS1}) vs. Temperature (Ta)



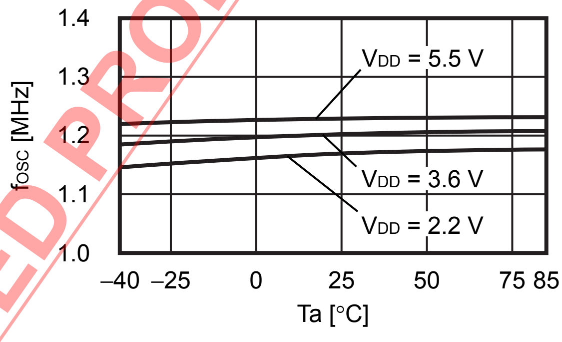
2. 2 Current consumption during switching off (I_{SS2}) vs. Temperature (Ta)



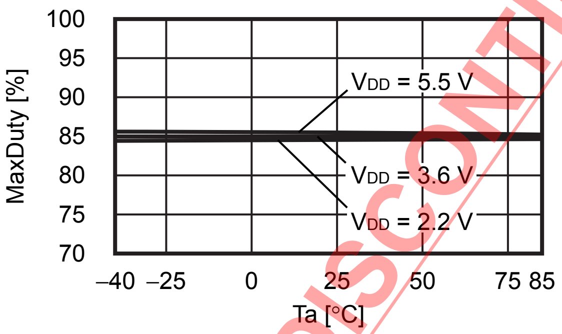
2. 3 Current consumption during power-off (I_{SSS}) vs. Temperature (Ta)



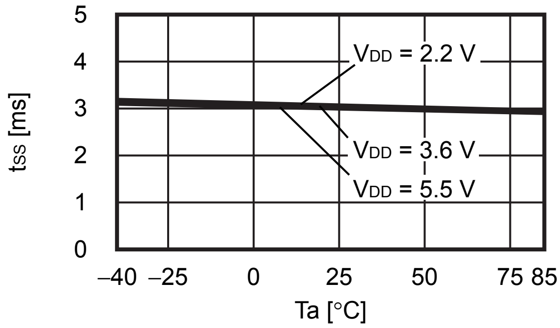
2. 4 Oscillation frequency (f_{OSC}) vs. Temperature (Ta)



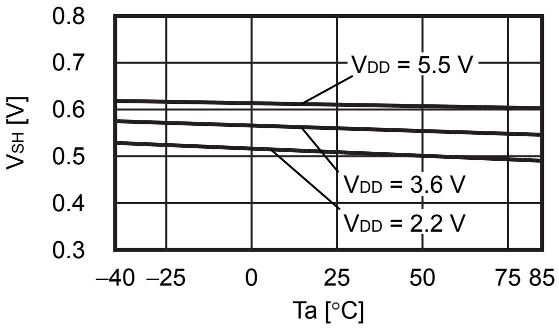
2. 5 Maximum duty (MaxDuty) vs. Temperature (Ta)



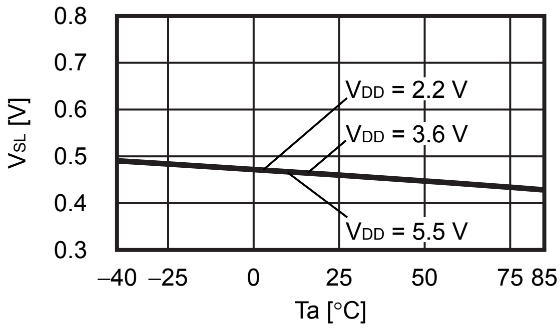
2. 6 Soft-start time (t_{SS}) vs. Temperature (Ta)



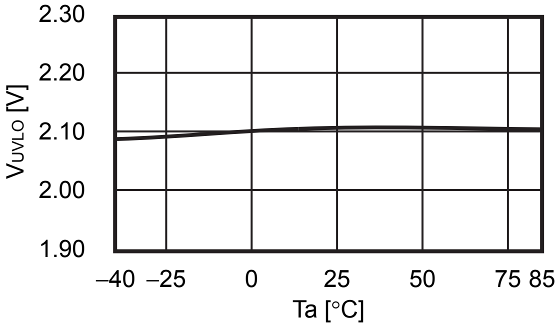
2. 7 EN pin input voltage "H" (V_{SH}) vs. Temperature (Ta)



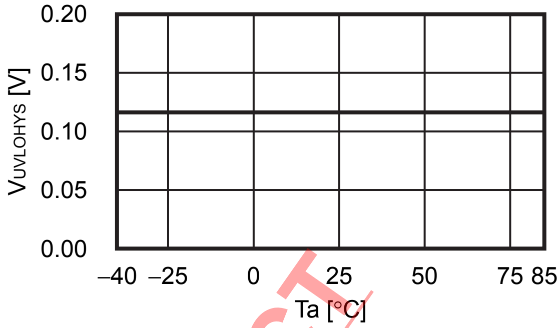
2. 8 EN pin input voltage "L" (V_{SL}) vs. Temperature (Ta)



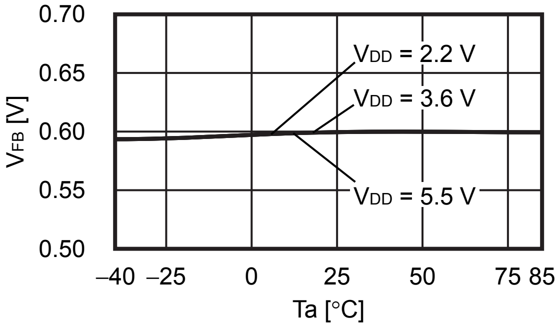
2. 9 UVLO detection voltage (V_{UVLO}) vs. Temperature (Ta)



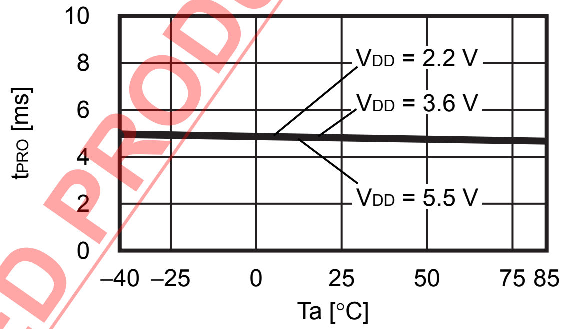
2. 10 UVLO hysteresis width ($V_{UVLOHYS}$) vs. Temperature (Ta)



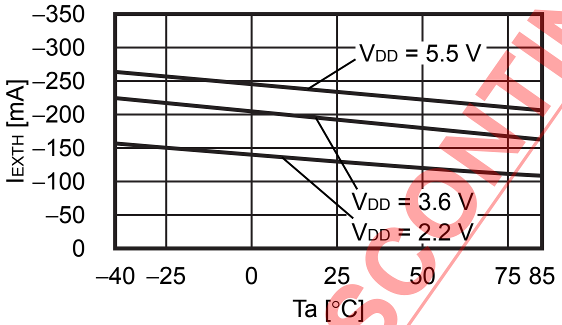
2. 11 FB pin voltage (V_{FB}) vs. Temperature (Ta)



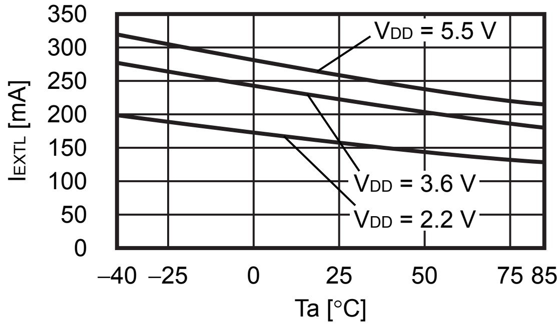
2. 12 Short-circuit protection delay time (t_{PRO}) vs. Temperature (Ta)



2. 13 EXT pin output current "H" (I_{EXTH}) vs. Temperature (Ta)

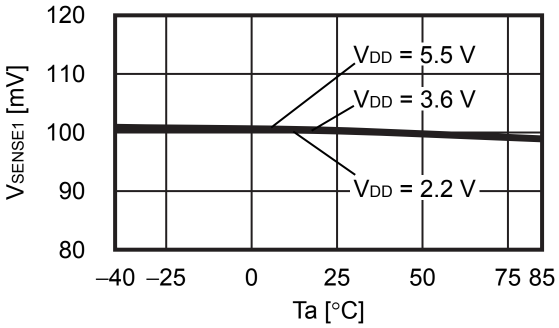


2. 14 EXT pin output current "L" (I_{EXTL}) vs. Temperature (Ta)



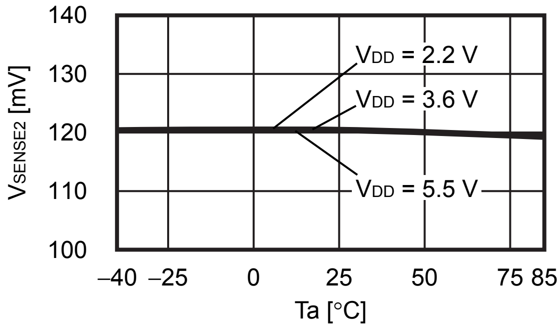
2. 15 Current detection voltage (V_{SENSE1}) vs. Temperature (Ta)

S-8368 Series

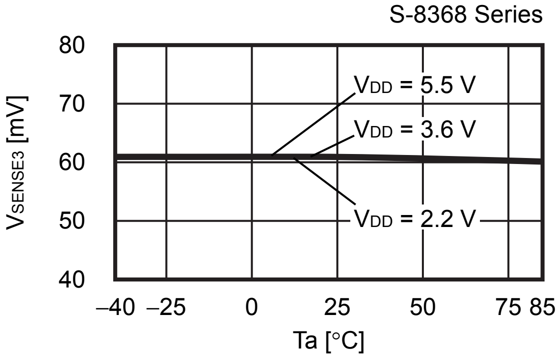


2. 16 VSENSE pin voltage for short-circuit detection (V_{SENSE2}) vs. Temperature (Ta)

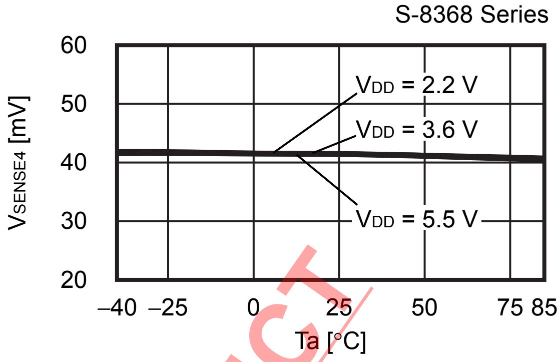
S-8368 Series



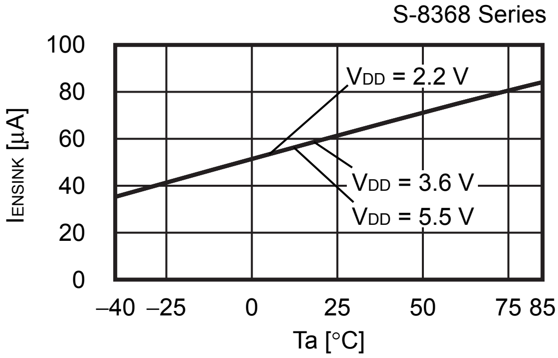
2. 17 VSENSE pin voltage during short-circuit protection operation (V_{SENSE3}) vs. Temperature (Ta)



2. 18 VSENSE pin voltage for short-circuit protection release (V_{SENSE4}) vs. Temperature (Ta)



2. 19 EN pin sink current during short-circuit detection (I_{ENSINK}) vs. Temperature (Ta)

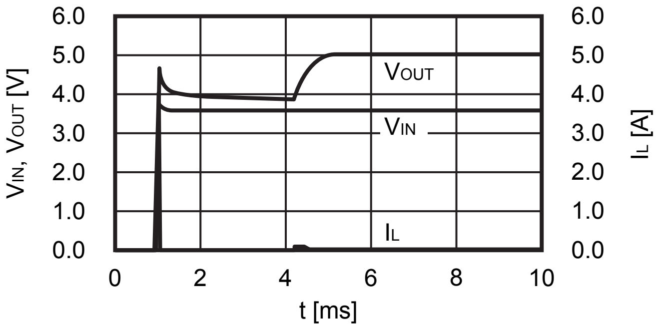


3. Examples of Transient Response Characteristics

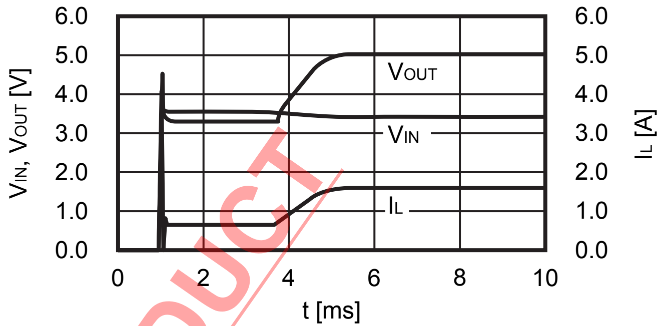
Unless otherwise specified, the used parts are those in condition 1 of "**Table 14 External Parts Examples**".

3. 1 Power-on ($V_{OUT(S)}$ = 5.0 V, V_{IN} = 0 V → 3.6 V, Ta = +25°C)

3. 1. 1 I_{OUT} = 1 mA

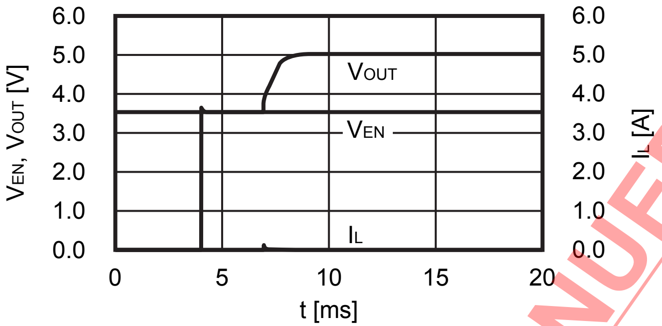


3. 1. 2 I_{OUT} = 1000 mA

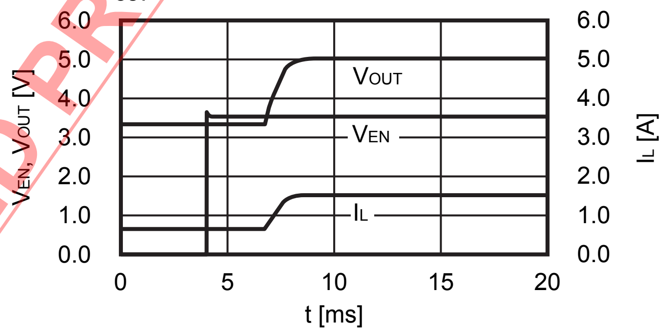


3. 2 Power-off pin response ($V_{OUT(S)}$ = 5.0 V, V_{IN} = 3.6 V, V_{EN} = 0 V → 3.6 V, Ta = +25°C)

3. 2. 1 I_{OUT} = 1 mA

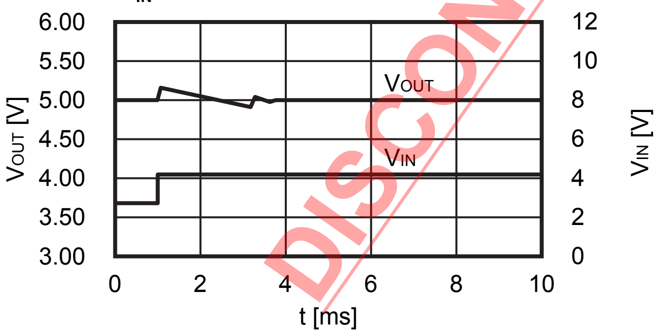


3. 2. 2 I_{OUT} = 1000 mA

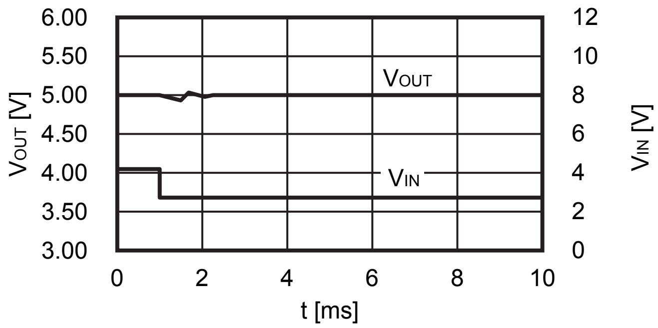


3. 3 Power supply voltage fluctuation ($V_{OUT(S)}$ = 5.0 V, I_{OUT} = 1 mA, Ta = +25°C)

3. 3. 1 V_{IN} = 2.7 V → 4.2 V

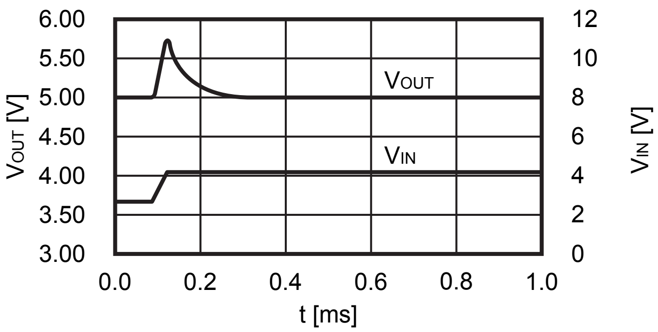


3. 3. 2 V_{IN} = 4.2 V → 2.7 V

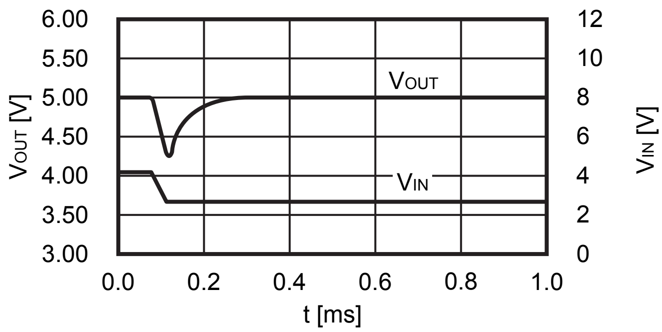


3. 4 Power supply voltage fluctuation (V_{OUT} = 5.0 V, I_{OUT} = 1000 mA, Ta = +25°C)

3. 4. 1 V_{IN} = 2.7 V → 4.2 V

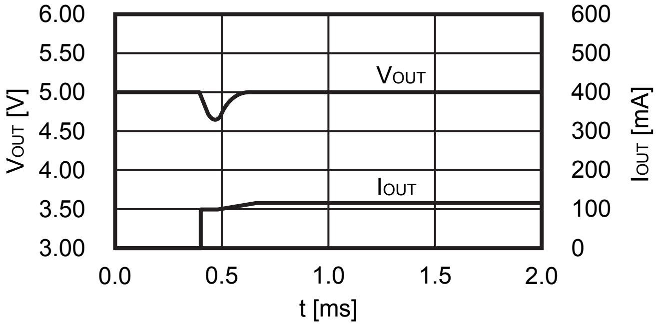


3. 4. 2 V_{IN} = 4.2 V → 2.7 V

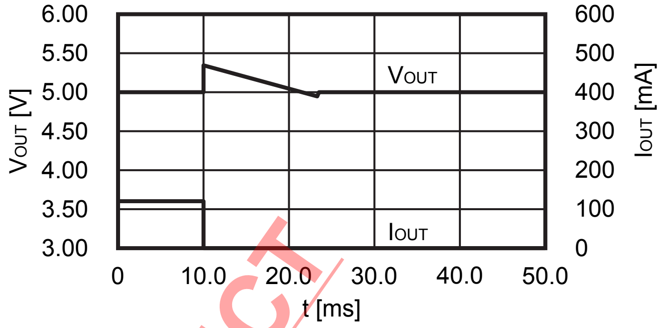


3. 5 Load fluctuation (V_{OUT} = 5.0 V, V_{IN} = 3.6 V, I_{OUT} = 0.1 mA → 100 mA → 0.1 mA, Ta = +25°C)

3. 5. 1 I_{OUT} = 0.1 mA → 100 mA

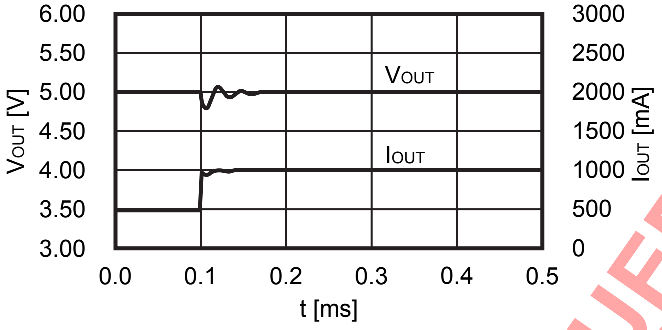


3. 5. 2 I_{OUT} = 100 mA → 0.1 mA

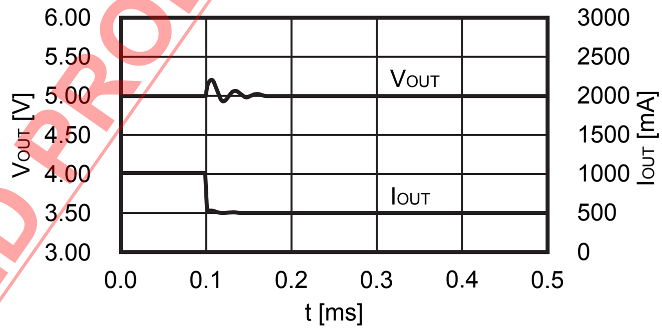


3. 6 Load fluctuation (V_{OUT} = 5.0 V, V_{IN} = 3.6 V, I_{OUT} = 500 mA → 1000 mA → 500 mA, Ta = +25°C)

3. 6. 1 I_{OUT} = 500 mA → 1000 mA

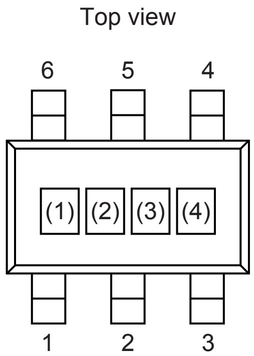


3. 6. 2 I_{OUT} = 1000 mA → 500 mA



■ Marking Specification

1. SOT-23-6



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

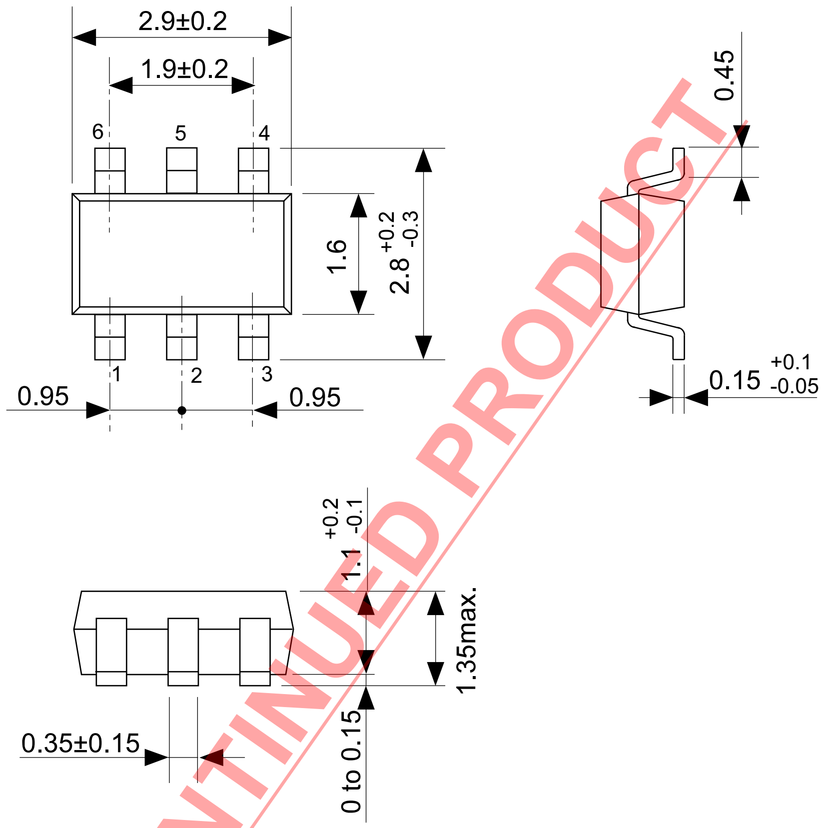
Product Name vs. Product Code

1. 1 S-8367 Series

Product Name	Product Code		
	(1)	(2)	(3)
S-8367A21I-M6T1U2	3	Y	B

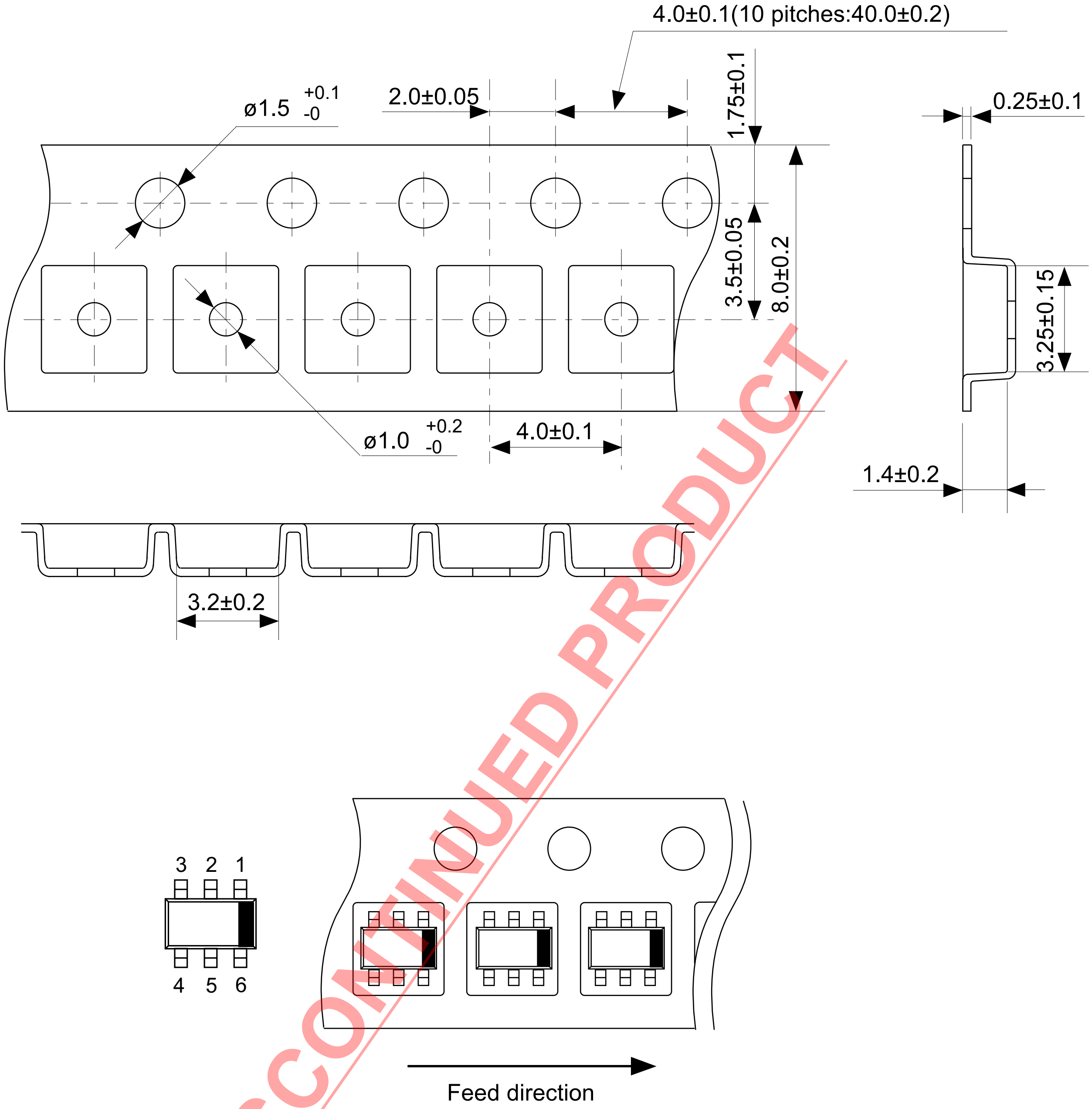
1. 2 S-8368 Series

Product Name	Product Code		
	(1)	(2)	(3)
S-8368A21I-M6T1U2	3	Y	S



No. MP006-A-P-SD-2.0

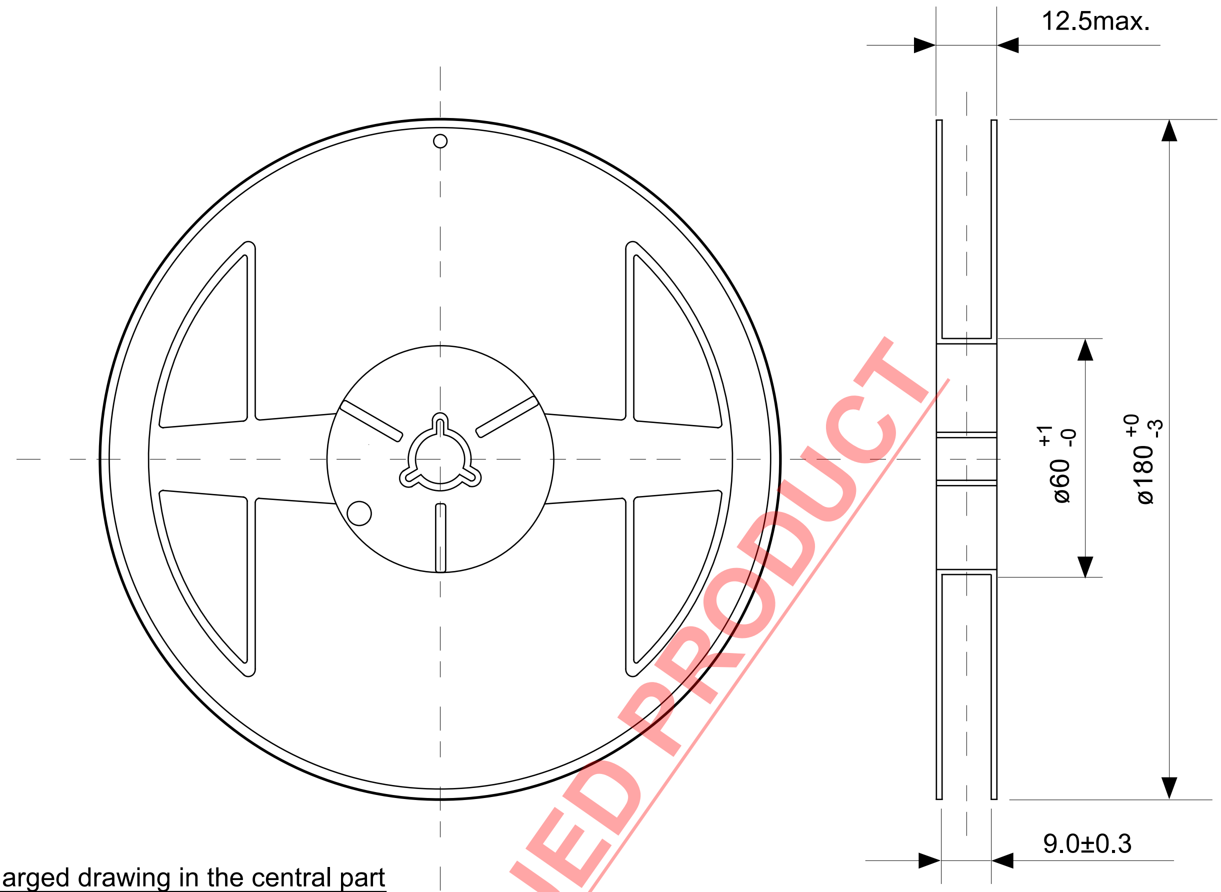
TITLE	SOT236-A-PKG Dimensions
No.	MP006-A-P-SD-2.0
SCALE	
UNIT	mm
Seiko Instruments Inc.	



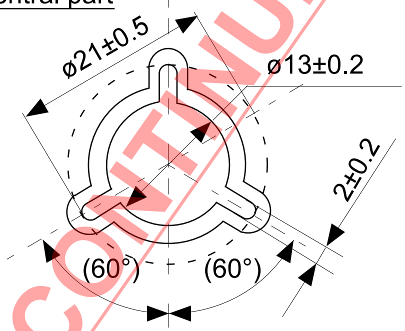
No. MP006-A-C-SD-3.1

TITLE	SOT236-A-Carrier Tape
No.	MP006-A-C-SD-3.1
SCALE	
UNIT	mm

Seiko Instruments Inc.



Enlarged drawing in the central part



No. MP006-A-R-SD-2.1

TITLE	SOT236-A-Reel		
No.	MP006-A-R-SD-2.1		
SCALE		QTY	3,000
UNIT	mm		

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