1-coil PWM Control Step-up-and-down Switching Regulator Controller

S-8460

The S-8460 is a PWM control step-up and step-down switching regulator-controller consisting of an automatic-selection control circuit for step-up and step-down, a reference voltage source, an oscillation circuit, an error amplifier, a phase compensation CMOS circuit, etc. The automatic-selection control circuit for step-up and step-down in PWM control realizes a high performance step-up and step-down switching regulator operating on one coil. Adopting N-channel power MOS transistors for external switches, in addition, enables high efficiency and high output current.

The S-8460 provides low-ripple output, high-efficiency and excellent transient characteristics which come from the PWM control circuit capable of varying the duty ratio linearly from 0%, the optimized error amplifier and the phase compensation circuit.

■ Features

- High-efficiency is achieved from one coil by automatic-selection control circuit.
- N-channel power MOS configuration for external switches realizes high-efficiency.
- Synchronous rectification at step-down operation
- Input voltage : 2.2 V to 18.0 V
- Variable output voltage

  Output voltage range : 2.5 V to 6.0 V
- Automatic-recovery overload protection circuit
- Oscillation frequency : 300 kHz
- Soft-start function set by an external capacitor Css
- Power-off function

■ Applicatios

- Power source for portable devices such as PDAs, electronic organizers, cellular phones.
- Main or local power source for notebook PCs and peripherals
- Constant voltage source for cameras, video equipment and communication devices.
- Available from 2 dry battery cells and 1 lithium cell to AC adapter.

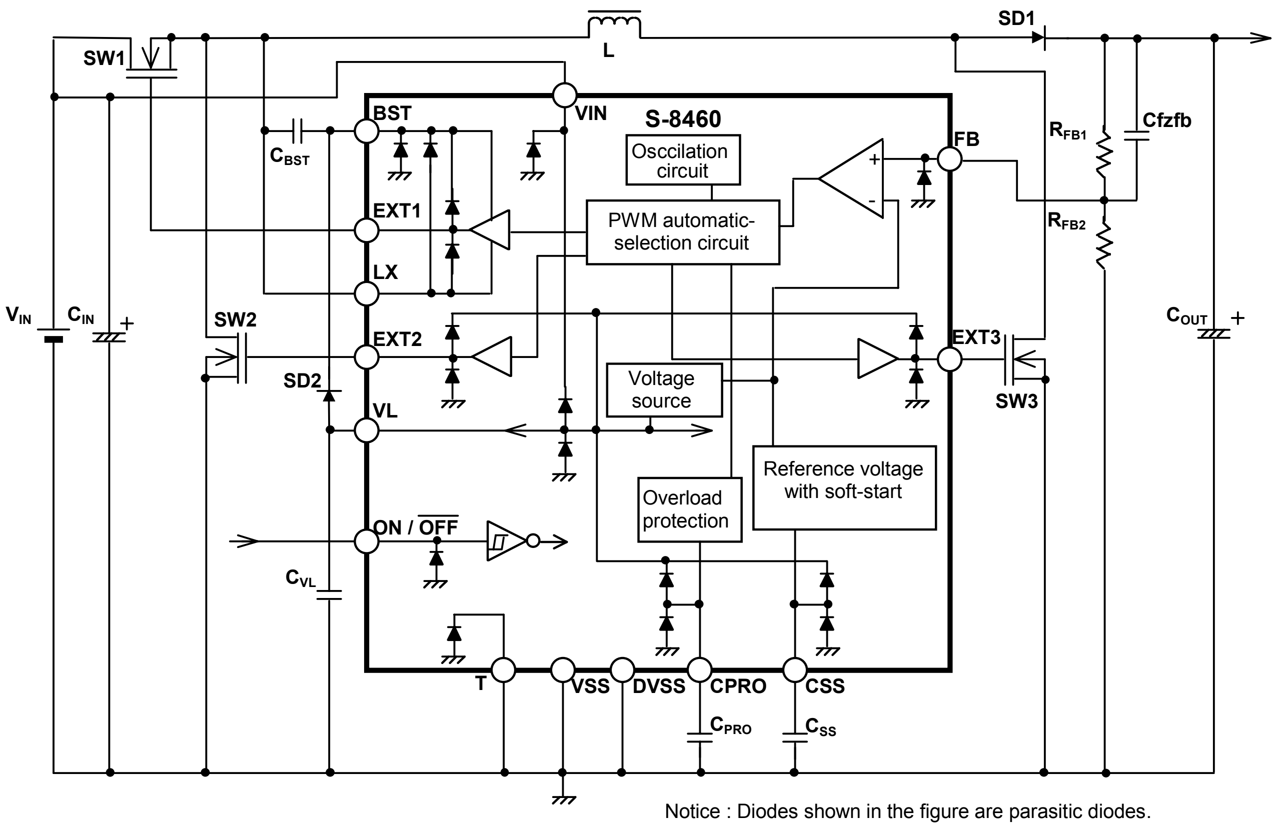
■ Package

- 16-Pin TSSOP (Package drawing code : FT016-A)

■ Product Name

S-8460B00AFT-TB

■ Block Diagram



Notice : Diodes shown in the figure are parasitic diodes.

Figure 1 Block Diagram

■ Pin Configuration

16-pin TSSOP
Top View

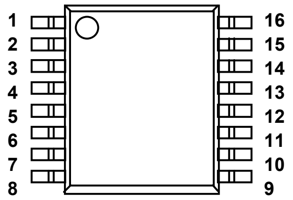


Figure 2

Table 1

Pin No.	Name	Description
1	VIN	IC Power supply pin
2	VL	Power supply for boost *1
3	ON/ $\overline{OFF}$	Power-off pin "H" : Normal operation (Step-up and -down) "L" : Halt (No step-up and -down)
4	VSS	GND pin *2
5	CSS	Capacitor connection for soft-start time
6	CPRO	Capacitor connection for protection time
7	T	Test pin, should be connected to GND
8	NC	No connection *3
9	FB	FB pin
10	NC	No connection *3
11	EXT3	External transistor driving pin 3
12	DVSS	Digital GND pin *2
13	EXT2	External transistor driving pin 2
14	LX	Connection pin for coil
15	EXT1	External transistor driving pin 1
16	BST	Boost capacitor connection for SW1 driving

***1.** No use except boosting this IC is allowed.
***2.** VSS pin and DVSS pin are internally short-circuited.
***3.** NC pin is electrically open. Connection of this pin to VIN or VSS is allowed.

■ Absolute Maximum Ratings

Table 2 (Ta=25°C unless otherwise specified)

Parameter	Symbol	Ratings	Unit
VIN pin voltage	V_{IN}	V_{SS}–0.3 to V_{SS}+20	V
FB pin voltage	V_{FB}	V_{SS}–0.3 to V_{SS}+20	V
ON/$\overline{\text{OFF}}$ pin voltage	$V_{ON/\overline{OFF}}$	V_{SS}–0.3 to V_{SS}+20	V
CSS pin voltage	V_{CSS}	V_{SS}–0.3 to V_{SS}+7	V
CPRO pin voltage	V_{PRO}	V_{SS}–0.3 to V_{ss}+7	V
BST pin voltage	V_{BST}	V_{SS}–0.3 to V_{SS}+25	V
BST pin — LX pin voltage	V_{BST} — V_{LX}	–0.3 to +7	V
LX pin voltage	V_{LX}	V_{SS}–3 to V_{SS}+20	V
EXT1 pin voltage	V_{EXT1}	V_{Lx}–0.3 to V_{BST} +0.3	V
EXT2,3 pin voltage	$V_{EXT2,3}$	V_{SS}–0.3 to V_{SS}+7	V
EXT1,2,3 pin current	$I_{EXT1,2,3}$	±100	mA
LX pin current	I_{LX}	±100	mA
BST pin current	I_{BST}	±100	mA
VL pin voltage *1	V_L	V_{SS}–0.3 to V_{SS}+7	V
VL pin current *1	I_{VL}	±100	mA
T pin voltage *2	V_T	V_{SS}–0.3 to V_{SS}+20	V
Power dissipation	P_D	400	mW
Operating temperature rage	T_{opr}	–40 to + 85	°C
Storage temperature range	T_{stg}	–40 to + 125	°C

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.

***1.** Only capacitor C_{VL} and Schottky diode D2 can be connected to this pin.
***2.** T pin should be connected to GND.

■ Electrical Characteristics

Table 3

(Unless otherwise specified : V_{IN}=5.0 V, I_{OUT}=66 mA, output voltage is set to 3.3 V, Ta=25°C)

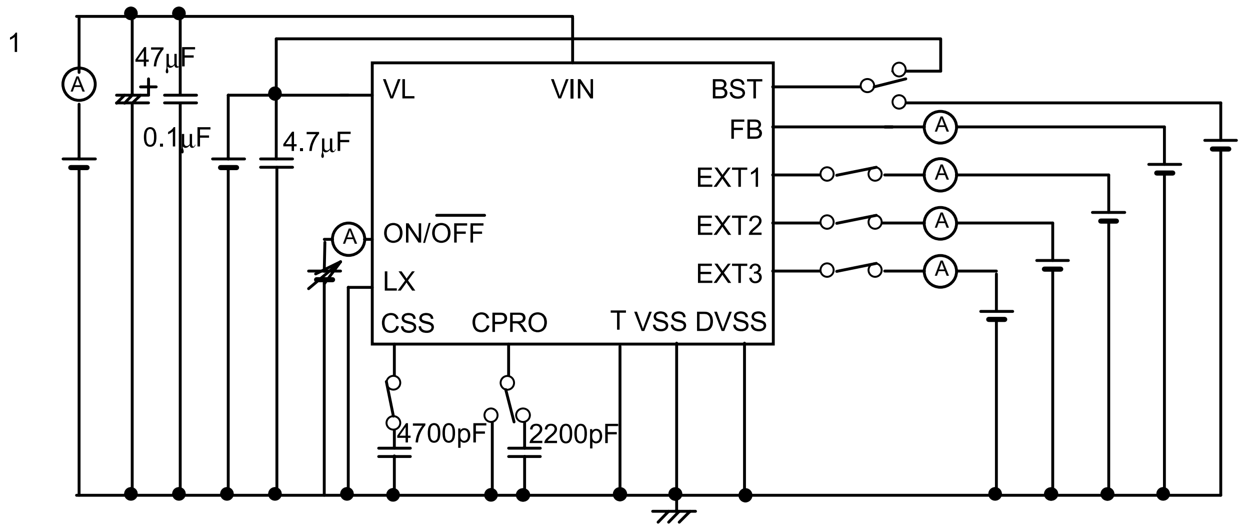
Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit	Test Circuit
Output voltage at step-down	V_{OUTD}	V_{IN}=4.95 V	3.234	3.3	3.366	V	2
Output voltage at step-up	V_{OUTU}	V_{IN}=2.64 V	3.234	3.3	3.366	V	2
Input voltage	V_{IN}	—	2.2	—	18.0	V	2
Current consumption 1	I_{SS1}	No external parts, V_{OUT}=3.3 V×0.95 V (Step-up mode at MaxDuty)	—	900	1380	μA	1
Current consumption 2	I_{SS2}	No external parts, V_{OUT}=3.3 V+0.5 V(Step-down mode at 0% Duty)	—	75	150	μA	1
Current consumption at power-off	I_{SSS}	$V_{ON/\overline{OFF}}$=0 V	—	0.5	2.0	μA	1
VL pin output voltage	V_L	The same condition as I_{SS2}	4.32	4.50	4.68	V	1
EXT1,2,3pin output current	$I_{EXT1,2,3H}$	V_{VL} =4.5 V, $V_{EXT1,2,3}$= V_{VL}–0.2	30	40	—	mA	1
	$I_{EXT1,2,3L}$	$V_{EXT1,2,3}$= 0.2 V	40	60	—	mA	1
Line regulation	ΔV_{OUT1}	V_{IN} = 2.2 V to 18.0 V	—	V_{OUTD} ×1.0%	V_{OUTD} ×2.0%	V	2
Load regulation	ΔV_{OUT2}	I_{OUT}= 10 μA to 1.25 × 66 mA V_{IN}=4.95 V	—	V_{OUTD} ×1.0%	V_{OUTD} ×2.0%	V	2
Temperature coefficient for output voltage	$\frac{\Delta V_{OUT}}{\Delta Ta \bullet V_{OUT}}$	Ta=–40°C to + 85°C	—	±100	—	ppm/°C	—
Oscillation frequency	fosc	The same condition as I_{SS1}, judged by wave form at EXT3 pin.	255	300	345	kHz	1
Maximum duty	MaxDuty	The same condition as I_{SS1}, judged by wave form at EXT3 pin.	70	78	85	%	1
FB pin input current	I_{FB}	The same condition as I_{SS2}	—	0.0	0.1	μA	1
ON/$\overline{OFF}$ pin input voltage	V_{SH}	The same condition as I_{SS2}, judged by voltage output at VL pin.	1.6	—	—	V	1
	V_{SL}	The same condition as I_{SS2}, judged by voltage output at VL pin.	—	—	0.4	V	1
ON/$\overline{OFF}$ pin input leak current	I_{SH}	The same condition as I_{SS1}, $V_{ON/\overline{OFF}}$=V_{IN}	–0.1	—	0.1	μA	1
	I_{SL}	The same condition as I_{SS1}, $V_{ON/\overline{OFF}}$=0 V	–0.1	—	0.1	μA	1
Soft-start time	T_{SS}	The same condition as I_{SS1}, time for EXT3 pin to start is measured.	6.0	12.0	24.0	ms	1
Integration time of protection circuit	T_{PRO}	The same condition as I_{SS1}, CSS pin: OPEN, C_{PRO}:2200 pF, repeat time of CPRO pin is measured.	1.25	2.5	5.0	ms	1
Efficiency at step-down	EFFI1	V_{IN}=4.95 V, I_{OUT}=200 mA to 600 mA	—	87	—	%	2
Efficiency at step-up	EFFI2	V_{IN}=2.64 V, I_{OUT}=50 mA to 400 mA	—	83	—	%	2

Details for external parts

Coil:	Sumida Electric Co., Ltd.	CDRH104R (22 μH)
Diode:	Panasonic	MA2Q737 (Schottky)
	Rohm Corporation	RB411D (Schottky)
Capacitor:	Nichicon Corporation	F93 (16 V, 47 μF, tantalum)×4
Transistor:	Fairchild Semiconductor Corporation	FDN337N × 3
C_{VL}:	4.7 μF (Ceramic)	
C_{SS}:	4700 pF	
C_{PRO}:	2200 pF	
C_{BST}:	0.1 μF	
	R_{FB1}: 230 kΩ, R_{FB2}: 100 kΩ, Cfzfb: 330 pF	

■ Measurement Circuits

1



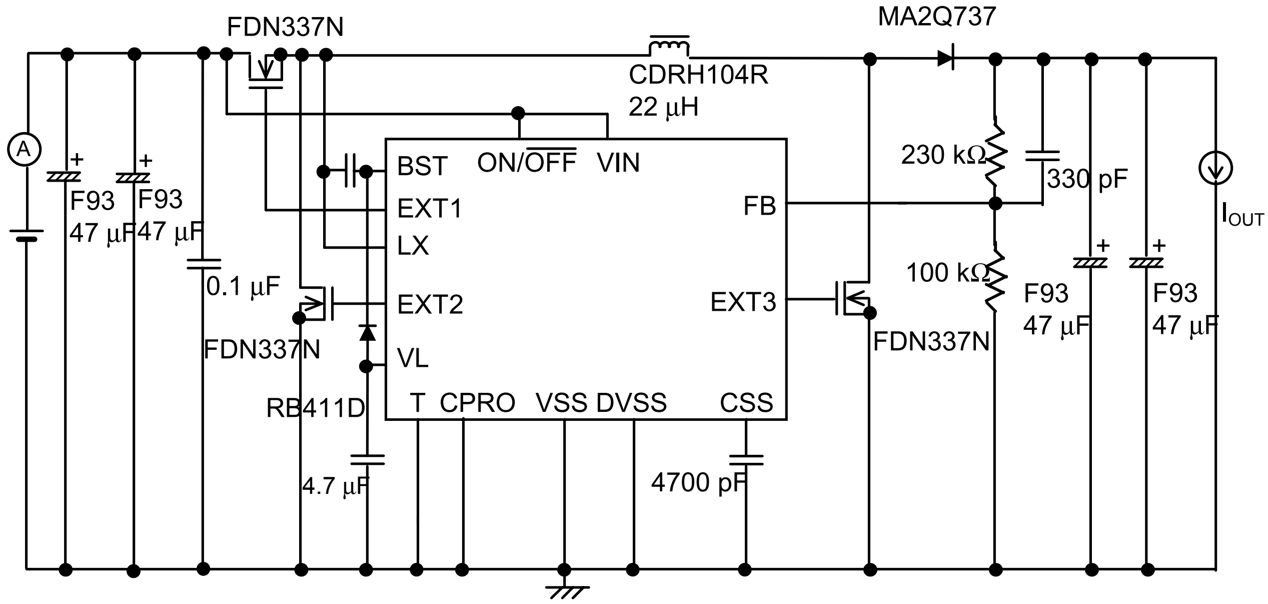


Figure 3

■ Operation

1. Step-up-and-down DC-DC converter

1.1 Basic operation

The S-8460 automatically selects step-up operation or step-down operation to hold the output voltage constant according to input voltage V_{IN}, output voltage V_{OUT} and output current I_{OUT}. A high-efficient power supply can be constructed using the S-8460, since the S-8460 works as a switching regurator for both step-up and step-down operation.

Figure 4 shows the block diagrm of the S-8460. Internal circuits operate on the voltage V_L generated internally except pre-driver circuit for EXT1 and ON/$\overline{\text{OFF}}$ circuit. When the input voltage V_{IN} is 4.5 V or more, the voltage is down converted to 4.5 V to generate the internal voltage V_L, and when V_{IN} is lower than 4.5 V, the internal voltage is set to V_{IN}. The output voltage of the pre-driver circuit for EXT1 lies between the BST pin voltage V_{BST} and the LX pin voltage V_{LX} where the BST pin voltage V_{BST} is normally V_{LX} plus V_L. The gate to souce voltages for all external power MOS transistors, SW1 to SW3, thus become V_L, which drives these external power MOS transistors.

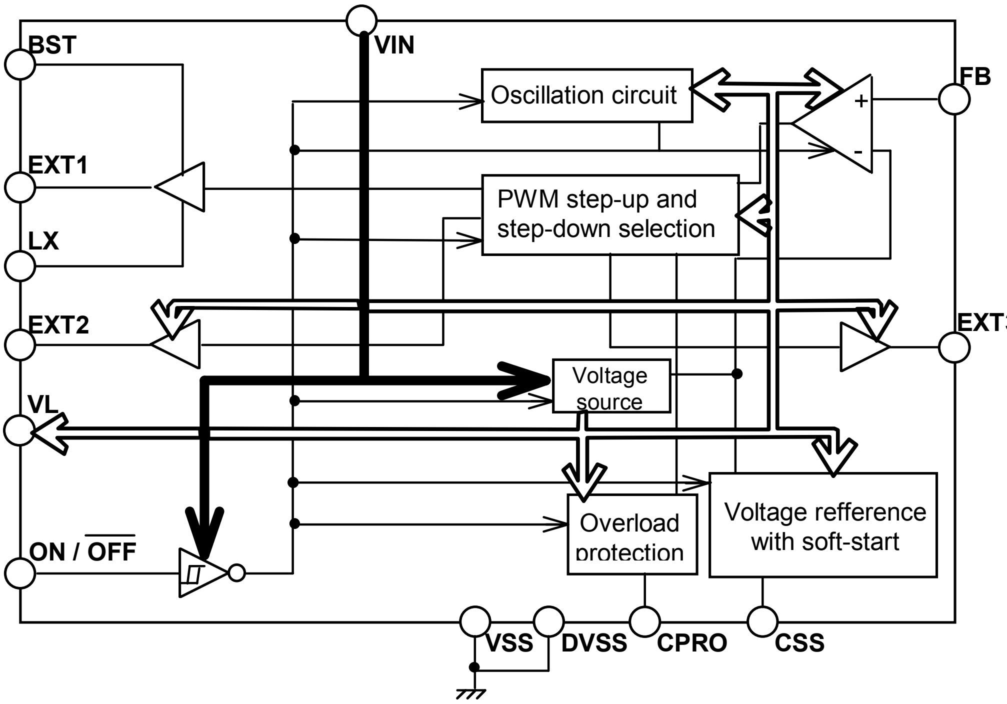


Figure 4

1.2 Step-up operation

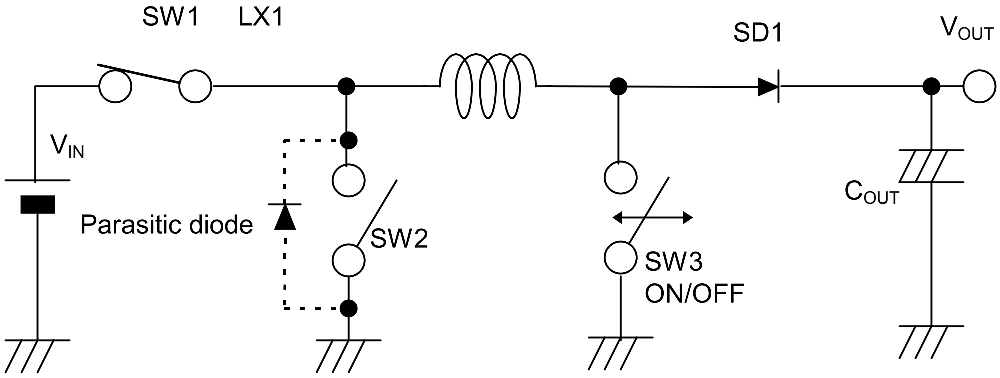


Figure 5

Step-up operaion is carried out by setting SW1:ON, SW2:OFF, and toggling the SW3. The voltage V_{IN}+V_L is needed at the BST pin to turn the SW1 on to maintain this state. For this purpose the capacitor C_{BST} is charged to V_L by the switch combination SW1:OFF, SW2:ON for approximate 200ns just after the SW3 is turned off, and the BST pin is then bootstrapped to V_{IN}+V_L by SW1:ON, SW2:OFF.

The SW2 is tuned on after the SW1 is tured off and the SW1 is turned on after the SW2 is turned off to avoid the large current to flow between V_{IN} and V_{SS} if the SW1 and the SW2 are turned on simultaneously. When the two switches, SW1 and SW2, are turned off, current flows to V_{OUT} through the parasitic diode of the SW2. In some MOS transistors current is not allowed to flow through the parasitic diode. Then a Schottky diode must be connected parallel to the MOS tramsistor.

1.3 Step-down operation

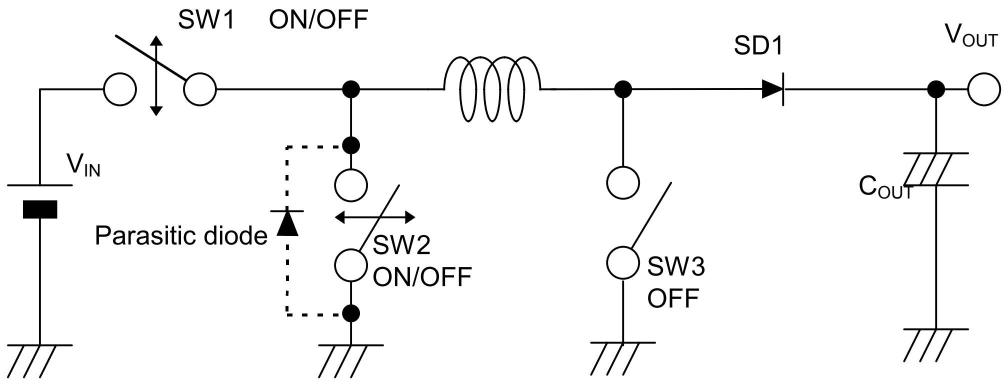


Figure 6

Step-down operation is carried out by synchronous switching of SW1 and SW2, and keeping SW3 open. The BST pin voltage is kept at V_{IN}+V_L, since the switches, SW1 and SW2, repeat toggling in each period in step-down operation.

1.4 Control sequence

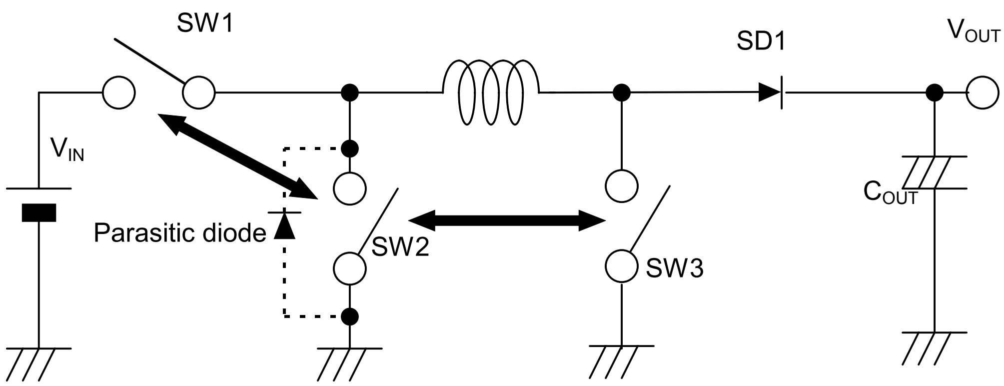


Figure 7

If the switches, SW1 and SW2, are turned on simultaneously, V_{IN} and V_{SS} are short-circuited and large useless current flows. And if the switches, SW2 and SW3, are turned on simultaneously, the energy stored in the coil flows to V_{SS} and is wasted. The S-8460 thus controls the switches in such a way that in operations involving SW1 and SW2, and involving SW2 and SW3 both transistors are turned off simultaneously to avoid useless current flowing due to simultaneous turn-on of the switches.

1.5 Step-up and step-down selection control

The S-8460 automatically selects operation between step-up and step-down to maintain a constant output voltage according to the relation which holds among input voltage V_{IN}, output voltage V_{OUT} and output current I_{OUT}. Simple relations that step-up operation works when input voltage ≤ output voltage and that step-down operation works when input voltage ≥ output voltage do not hold. Step-up operation emerges when the output voltage is kept constant by step-up operation, and step-down operation emerges when the output voltage is kept constant by step-down operation according to the relation among input voltage V_{IN}, output voltage V_{OUT} and output current I_{OUT}.

Figure 8 shows the turning point between step-up operation and step-down schematically for the case when the output voltage is 3.3 V. In the area where the two slant lines are crossing and noted by "Step-up and -down" the S-8460 shows step-up operation or step-down operation. Not that step-up operation and step-down operation appear alternately in this area, but that one of the two operations is selected and stable operation is carried out. The voltage for the turning point between step-up and step-down varies slightly due to external parts and mounting conditions.

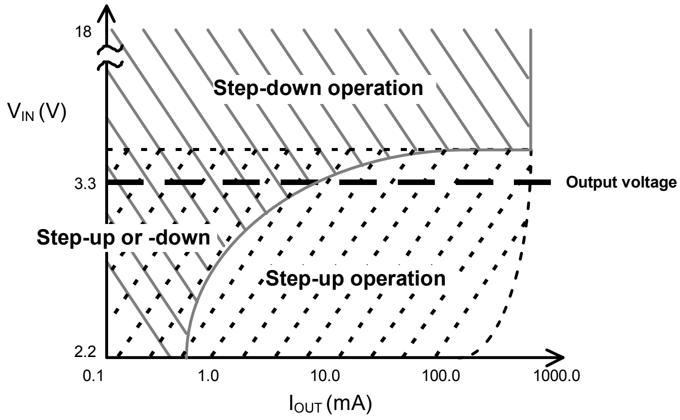


Figure 8 Graphic scheme for automatic selection of step-up and step-down for V_{OUT}=3.3V

1.6 PWM control

The S-8460 is a pulse width modulation (PWM) control DC/DC converters. In conventional pulse frequency modulation (PFM) DC/DC converters, pulses are skipped when the convertors operate at light load, and caused variation in the ripple frequency and increase in the ripple voltage of the output both of which constitute inherent drawbacks to those converters.

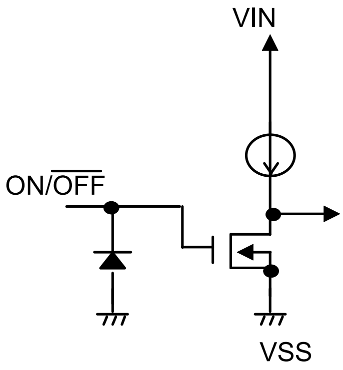
In the S-8460 the pulse width varies in the range from 0 to 100% in step-down operation and 0 to 78% in step-up according to the load, yet ripple voltage produced by the switching can easily be removed by a filter since the switching frequency is always constant. The converter thus provides a low-ripple voltage over wide range of input voltage and load current.

2. Internal circuits

ON/$\overline{\text{OFF}}$ pin (Power-off pin)

When the ON/$\overline{\text{OFF}}$ pin is set to "L", the EXT1 pin voltage becomes eqaul to the L_X voltage and the pin voltage of the EXT2 and EXT3 becomes V_{SS} level to turn the power MOS transistors off as well as the S-8460 stops all the internal circuit and suppresses the current consumption down to 0.5 µA approximately. At the same time the internal voltage, the CSS pin and CPRO pin become V_{SS} level. Electrical isolation between power input side V_{IN} and output side V_{OUT} is thus possible when the S-8460 is in halt state.

The ON/$\overline{\text{OFF}}$ pin is constructed as shown in the figure 9. Since pull-up or pull-down is not performed internally, operation where the ON/$\overline{\text{OFF}}$ pin is in a floating state should be avoided. When the ON/$\overline{\text{OFF}}$ pin is not used, it should be connected to the VIN pin.



ON/$\overline{\text{OFF}}$ pin	CR oscillation circuit	All EXT pin voltage	Output voltage
"H"	Active	—	Set value
"L"	Non-active	V_{SS}	Open

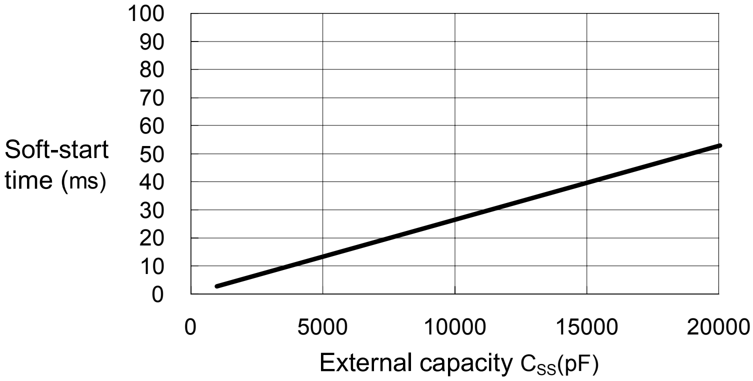
Figure 9

3. Soft-start function

The S-8460 has a built-in soft-start circuit. This circuit enables the output voltage to rise gradually over the specified soft-start time to suppress the overshooting of the output voltage and the rush current from the power source when the power is switched on or the ON/$\overline{\text{OFF}}$ pin is set to "H".

The soft-start time T_{SS} is determined by an external capacitor C_{SS}. The time needed for V_{OUT} to reach 95% of the setting value of the output volltage is approximetaly expressed by the following equatuion.

$$T_{SS}(\text{ms})=0.0026\times C_{SS}\ (\text{pF})$$



The value for C_{SS} should be selected to give enough margin to the soft-start time against the power supply rise time. If the soft-start time is short, possibilty for output overshoot, input current rush and malfunction of the IC increases.

4. Overload protection Circuit

The S-8460 contains a built-in overload protection circuit. When the output voltage falls because of an overload despite the step-up operation or step-down, the S-8460 enters the step-up operation and holds the maximum duty step-up operation. If this maximum duty state lasts longer than the overload detection time T_{PRO}, the overload protection circuit will hold the pins EXT1 to EXT3 at "L" to protect the switching transistors and the inductor. When the overload protection circuit works, the output voltage rises slowly since a soft-start is carried out in the reference voltage circuit in the IC to rise the reference voltage slowly from 0 V. If the load is still heavy at this time and the maximum duty step-up operation lasts longer than the overload detection time T_{PRO}, the overload protection circuit will work again. Reapeat of this process leads to an operation of intermittent mode. If the overload is removed, the S-8460 goes back to the normal operation.

The overload detection time T_{PRO} which is measured from the beginning of the maximum duty operation to the instant at which pin voltage of the EXT1 to EXT3 is held "L" to protect switching transistors and the inductor is determined by the external capacitor C_{PRO}, and is expressed by the following equation.

$$T_{PRO}(ms)=0.0011\times C_{PRO}(pF)$$

■ Selection of Extarnal parts

1. Inductor

The inductance value greatly affects the maximum output current I_{OUT} and the efficiency η.

As the Inductance is reduced gradually, the peak current I_{PK} increases, and the output current I_{OUT} reaches the maximum at a certain Inductance value. As the Inductance is made even smaller, I_{OUT} begins to decrease since the current drivability of the switching transistor becomes insufficient.

Conversely, as the Inductance is increased, the loss in the switching transistor due to I_{PK} decreases, and the efficiency reaches the maximum at a certain Inductance value. As the Inductance is made even larger, the efficiency degrades since the loss due to the series resistance of the inductor increases. In many applications, an inductance of 22 μH will yield the best characteristics of the S-8460 in a well balanced manner.

When choosing an inductor, attention to its allowable current should be paid since the current over the allowable value will cause magnetic saturation in the inductor, leading to a marked decline in efficiency.

An inductor should therefore be selected so as not the peak current I_{PK} to surpass its allowable current. The peak current I_{PK} is represented by the following equations in step-up operation and in step-down operation. Comparing each calculation result for step-up and step-down, larger value should be taken as the I_{PK}. Adding some margin to the obtained result, an inductor with the alowerble current can be thus chosen.

Continuous mode at step-up operation

$$I_{PK}=\frac{V_{OUT}+V_F}{V_{IN}}\times I_{OUT}+\frac{(V_{OUT}+V_F-V_{IN})\times V_{IN}}{2\times(V_{OUT}+V_F)\times fosc\times L}$$

Continuous mode at step-down operation

$$I_{PK}=I_{OUT}+\frac{V_{OUT}\times(V_{IN}-V_{OUT})}{2\times fosc\times L\times V_{IN}}$$

where fosc (=300 kHz) is the oscillation frequency, L is the inductance of the inductor, and V_F is the diode forword voltage (≅0.4 V).

2. Capacitors

2.1 Input and output capacitors (C_{IN}, C_{OUT})

A capacitor inserted in the input side (C_{IN}) serves to reduce the power impedance and to average the input current to give better efficiency. The capacitor should have low ESR (Equivalent Series Resistance) and large capacitance which should be selected according to the impedance of the power supply. It should be 47 to 100 μF, although the actual value depends on the impedance of the power source used and load current value.

For the output side capacitor (C_{OUT}), select a large capacitance with low ESR (Equivalent Series Resistance) to smoothen the ripple voltage. When the input voltage is extremely high or the load current is extremely large, the output voltage may become unstable. In this case the unstable area will become narrow by selecting a large capacitance for an output capacitor. A tantalum electrolyte capacitor is recommended since the unstable area widens when a capacitor with a large ESR, such as an aluminum electrolyte capacitor, or a capacitor with a small ESR, such as a ceramic capacitor, is chosen.

In selecting input and output capacitors sufficient evaluation is needed in actual application environment.

2.2 Internal power source stabilization capacitor (C_{VL})

The main circuits of the IC work on an internal power source connected to the VL pin. The C_{VL} is a bypass capacitor for stabilizing the internal power source. C_{VL} is a 4.7 µF ceramic capacitor and should be wired in a short distance and at a low impedance.

3. External Switching Transistors

Enhancement N-channel MOSFETs are reccomennded to use with the S-8460 for the extarnal switching transistors. The SW1 is drived by the bootstrapped voltage. If a bipolar transistor is used for the SW1, the transisitor does not turn on since the charge in the capacitor C_{BST} for bootstrap is discharged.

3.1 Enhancement MOSFET

The gate driving pins EXT1 to EXT3 of the S-8460 can directly drive an N-cannel power MOSFET with a gate capacitance of approximate 1000 pF.

When an Nchannel power MOSFET is chosen, efficiency will be 2 to 3% higher than that achieved by a PNP or an NPN bipolar transistor since the MOSFET switching speed is faster than that of the bipolar transistor and power loss due to the base current is avoided.

The important parameters in selecting an N-channel power MOSFET are threshold voltage, breakdown voltage between gate and source, breakdown voltage between drain and source, total gate capacitance, on-resistance, and the current rating.

Voltage swing of the EXT2 and EXT3 is between VL and VSS. The EXT1 pin voltage swings between V_L and V_{SS} since the LX pin voltage becomes V_{SS} when the SW2 is on and swings between V_L+V_{IN} and VIN since the LX pin voltage becomes V_{IN} when the SW2 is off. The gate to source breakdown voltage of the transistors should be at least some volts higher than VL voltage since the maximum voltage applied between gate and source of each transistor is V_L. On the other hand when the input voltage V_{IN} is lower than 4.5 V, the threshold voltage of MOSFETs should be low enough to turn on completely at low input voltage since the V_L voltage becomes V_{IN} voltage.

Immediately after the power is turned on, or the power-off state at which the step-up and -down operation is terminated, the input voltage or output voltage is applied across the drain and the source of the MOSFETs. The transistors therefore need to have drain to source breakdown voltage that is also several volts higher than the input voltage or output voltage.

The total gate capacitance and the on-resistance affect the efficiency.

The larger the total gate capacitance becomes and the higher the input voltage becomes, the more the power loss for charging and discharging the gate capacitance by switching operation increases, and affects the efficiency at low load current region. If the efficiency at low load is important, select MOSFETs with a small total gate capacitance.

In regions where the load current is high, the efficiency is affected by power loss caused by the on-resistance of the MOSFETs. If the efficiency under heavy load is particularly important in the application, choose MOSFETs having on-resistance as low as possible.

As for the current rating, select a MOSFET whose maximum continuous drain current rating is higher than the peak current I_{PK}.

If the external N-channel MOSFETs have much different characteristics (input capacitance, Vth, etc.) among them, they turn on at the same time to let a short-circuit current flow and reduce efficiency. If a MOSFET with a large input capacitance is used, switching loss increases and efficiency decreases. If such a MOSFET is used at several hundreds of mA or more, the loss at the MOSFET increases and may exceed the power dissipation of the MOSFET. In selecting N-channel MOSFETs, enough performance evaluation under the actual condition is indespensible.

For reference, efficiency data using Sanyo CPH6401, CPH3403 and FTS2001, Siliconix Si2302DS, and Fairchild FDN335N is attatched in this document. Please see "Reference Data".

In some MOSFETs current flow through the parasitic diode is not allowed . In this case, a Schottky diode must be connected in parallel to the MOSFET. The Schottky diode must have a low forward voltage, a high switching speed, a reverse-direction withstand voltage higher than the input/output voltage, and a current rating higher than I_{PK}.

4. Output voltage adjustment

The output voltage can be set and adjusted in the output voltage setting range (2.5 to 6.0 V) by adding external resistors R_{FB1} and R_{FB2} and a capacitor Cfzfb in the S-8460. Temperature gradient can be added by inserting a thermistor in series to R_{FB1} and R_{FB2}.

The output voltage is set as $(R_{FB1}+R_{FB2})/R_{FB2}$, since the FB pin voltage is kept 1.0 V. $R_{FB1}+R_{FB2}$ must be smaller than 2 MΩ. A capacitor Cfzfb should be added in parallel to the resistor R_{FB1} to avoid unstable operation like output oscillation.

Set the Cfzfb so that $f = 1/(2 \times \pi \times \mathrm{Cfzfb} \times R_{FB1})$ is equal to 2 kHz.

Example: When V_{OUT}=3.3 V, R_{FB1}=200 kΩ, R_{FB2}=100 kΩ, then Cfzfb=330 pF is recommended.

The precision of output voltage V_{OUT} determined by the resistors R_{FB1} and R_{FB2} is affected by the precision of the voltage at the FB pin (1 V ± 2.0%) as well as the precision of external resistors R_{FB1} and R_{FB2}, and IC power supply voltage V_{IN}.

Waste current flows through external resistors R_{FB1} and R_{FB2}. When it is not a negligible value with respect to load current in actual use, the efficiency decreases. The values of the external resistors must therefore be made large.

When the R_{FB1} and R_{FB2} values are high, 1 MΩ or higher, evaluation of the influence of the noise is needed in the actual condition since the resistors become susceptible to external noise.

5. Diode

Diode should meet the following requirements:

- The forward voltage is low (Schottky barrier diode is recommended).
- The switching speed is high (50 ns).
- The current rating is larger than I_{PK}
- The reverse breakdown voltage is higher than V_{IN} or V_{OUT} for SD1.
- The reverse breakdown voltage is higher than V_{IN} for SD2.2.

■ Standard Circuits

● N-channel MOSFETs are used for SW1 to SW3

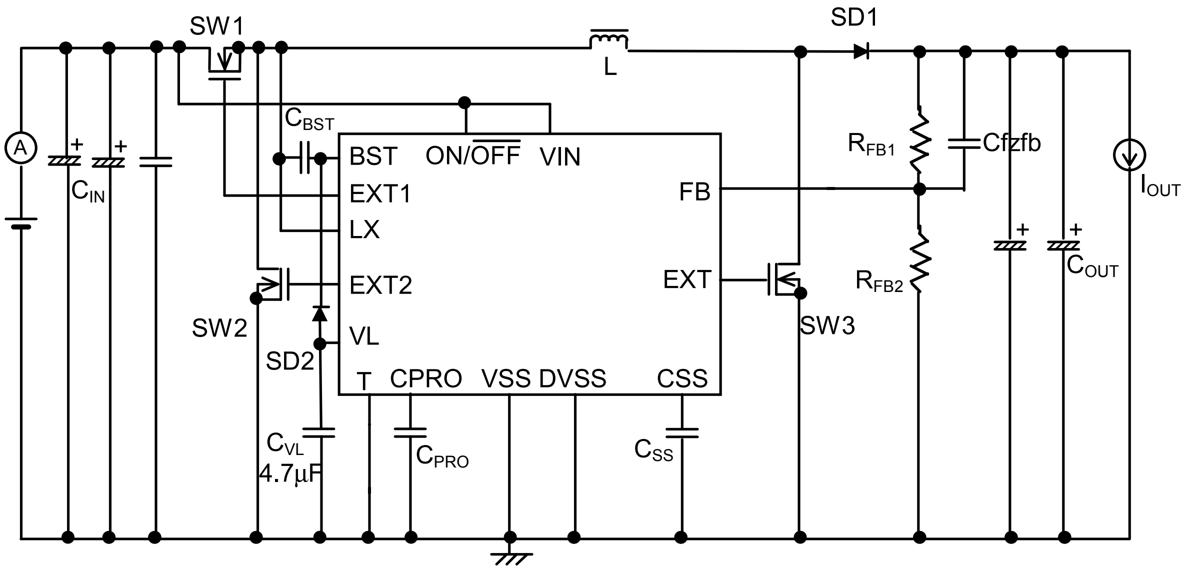


Figure 10

■ Precautions

- Install the external capacitors, diode, coil, and other peripheral components as close to the IC as possible, and make a one-point grounding.
- Normally the SW1 and SW2 do not turn on at the same time. If external N-channel MOSFETs have much different characteristics (input capacitance, Vth, etc.) among them, however, they may turn on at the same time, and short-circuit current flows. Select transistors with similar characteristics.
- A switching regulator produces ripple voltage and spike noise, which are largely affected by the coil and the capacitors in use. When designing a circuit, check these characteristics under the actual condition.
- When the input voltage is high and the output current is low, pulses with a low duty ratio may appear, and then the 0% duty ratio continues for several clocks. In this case the operation changes to the pseudo pulse frequency modulation (PFM) mode, but the ripple voltage hardly increases.
- According to the input voltage and the load condition the oscillatio frequency of the EXT1 to EXT3 may become an integer fraction of 300 kHz.

- No parts other than a capacitor C_{VL} and a schottky diode SD2 can be connected to the VL pin.
- A 4.7-µF ceramic capacitor should be connected to the VL pin.
- The overload protection circuit of the IC starts working by detecting the time for maximum duty. In choosing the components, make sure that the overcurrent caused by load short-circuiting will not exceed the power dissipation of the switching transistors, diodes, and the inductor.
- The oscillation frequency of the EXT1 and EXT2 may vary in some voltage range and load condition depending on input voltage.
- If the VOUT pin is short-circuited to VSS, the protection circuit starts to operate before the integral protection time T_{PRO} passes.
- When the temperature is high and the load is 0 to about 1µA, the voltage of the EXT1 to EXT3 pins is held "L" and the output voltage VOUT increases. The operation returns to normal when the load of 1µA or more is attached.
- Make sure that dissipation of the switching transistor especially at high temperature will not surpass the power dissipation of the package.
- Do not apply an electrostatic discharge to this IC that exceeds the performance ratings of the built-in electrostatic protection circuit.
- Seiko Instruments Inc. shall bear no responsibility for any patent infringement by a product that includes an IC manufactured by Seiko Instruments Inc. in relation to the method of using the IC in that product, the product specifications, or the destination country.

■ Package Power Dissipation

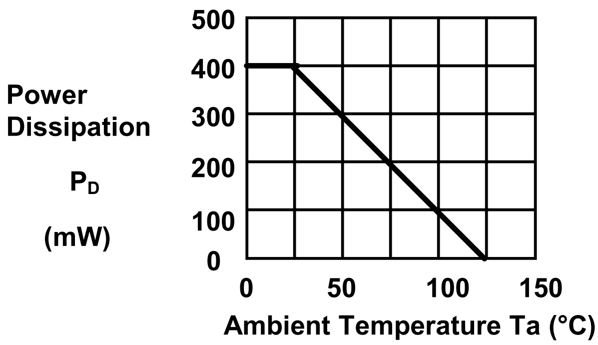
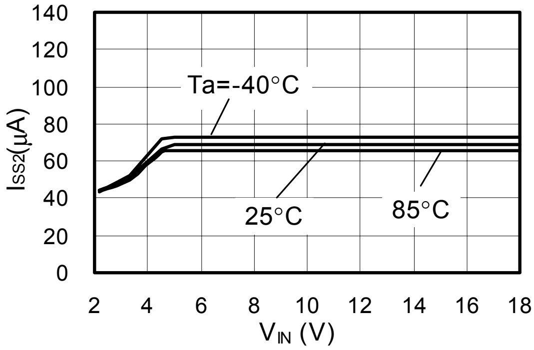


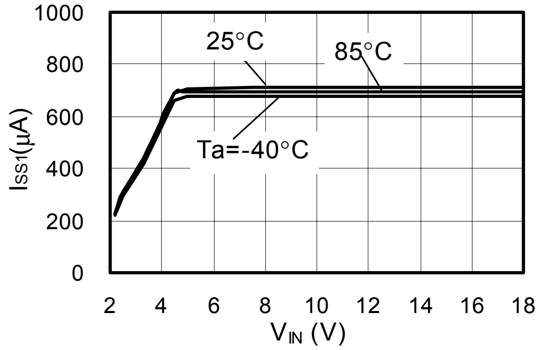
Figure 11 16-Pin TSSOP package power dissipation in free air

■ Typical Characteristeics of Major Parameters

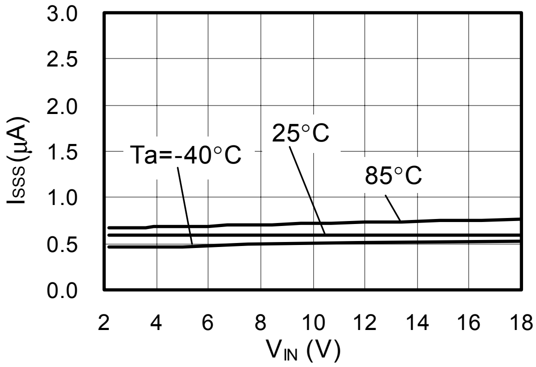
(1) I_{SS2}—V_{IN}



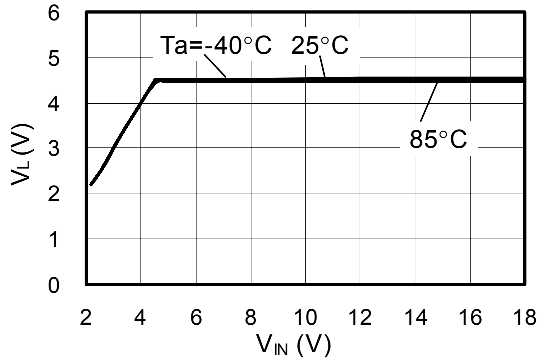
(2) I_{SS1}—V_{IN}



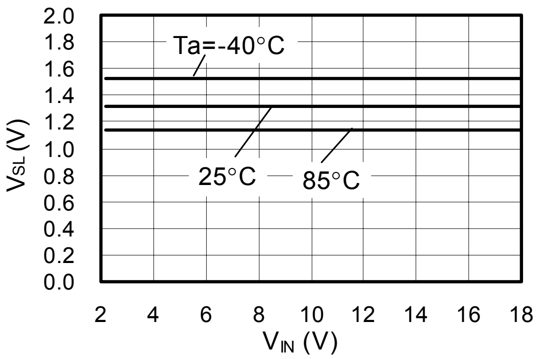
(3) I_{SSS}—V_{IN}



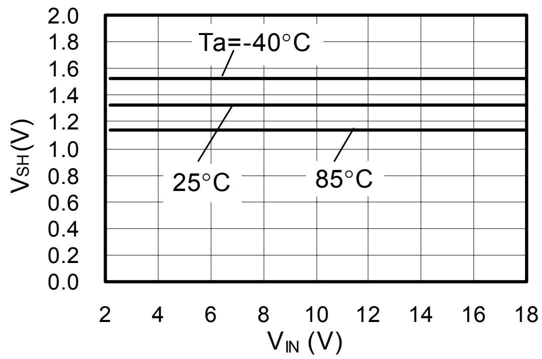
(4) V_L—V_{IN}



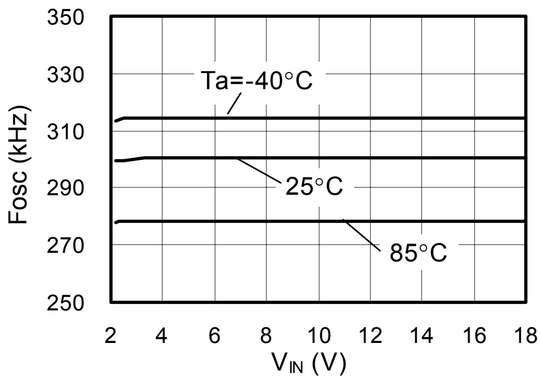
(5) V_{SH}—V_{IN}



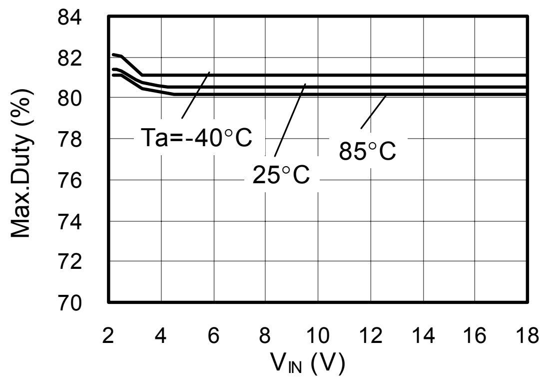
(6) V_{SL}—V_{IN}



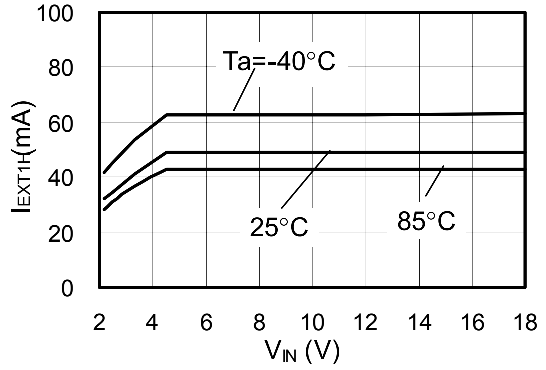
(7) Fosc —V_{IN}



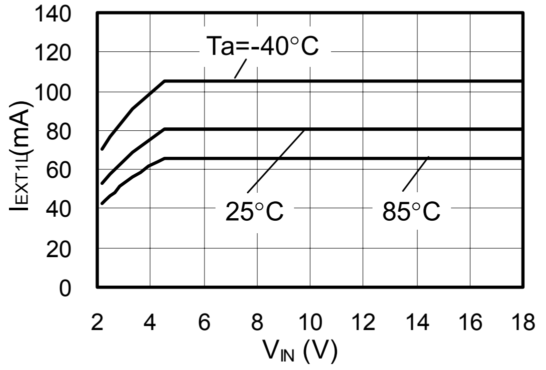
(8) Max.Duty —V_{IN}



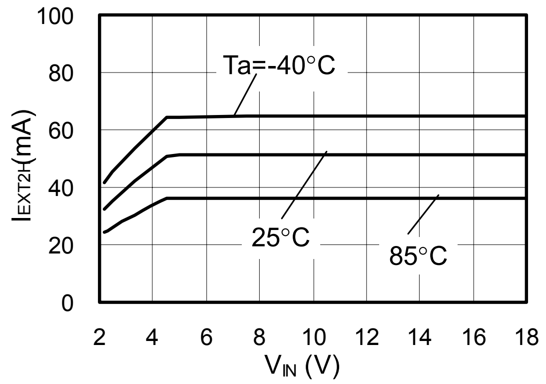
(9) I_{EXTH1H} — V_{IN}



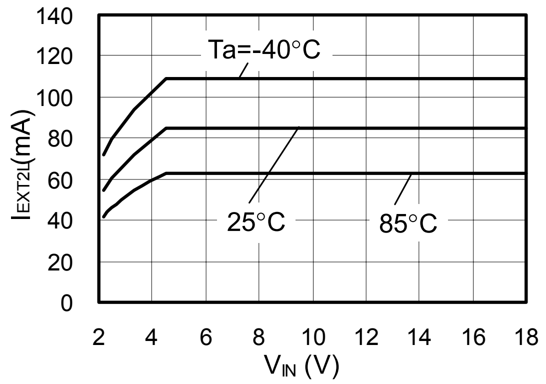
(10) I_{EXT1L} — V_{IN}



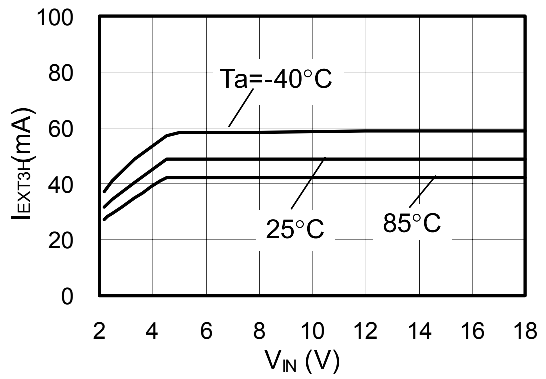
(11) I_{EXTH2H} — V_{IN}



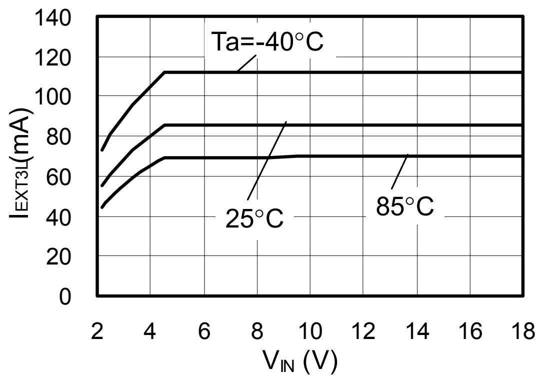
(12) I_{EXT2L} — V_{IN}



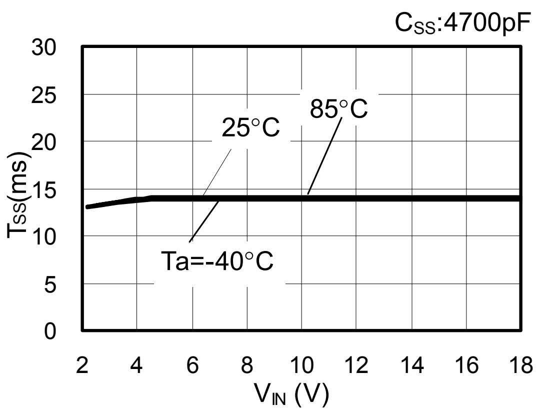
(13) I_{EXTH3H} — V_{IN}



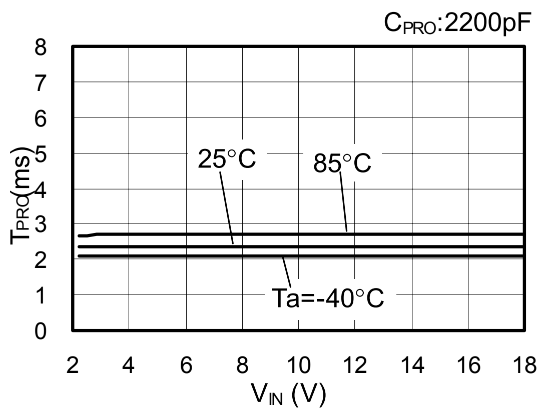
(14) I_{EXT3L} — V_{IN}



(15) T_{SS} — V_{IN}



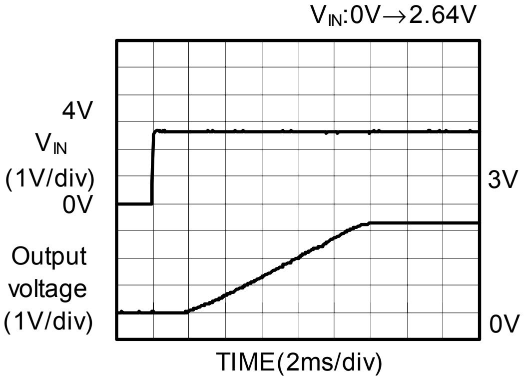
(16) T_{PRO} — V_{IN}



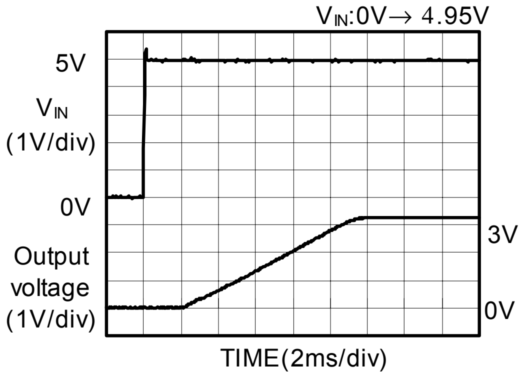
■ Typical Characteristics for Transient Response

1. Response to power on (V_{IN}: 0V → 2.64V or 4.95 V or 18.0 V I_{OUT}: no load) V_{OUT}: 3.3 V, C_{SS}: 4700 pF

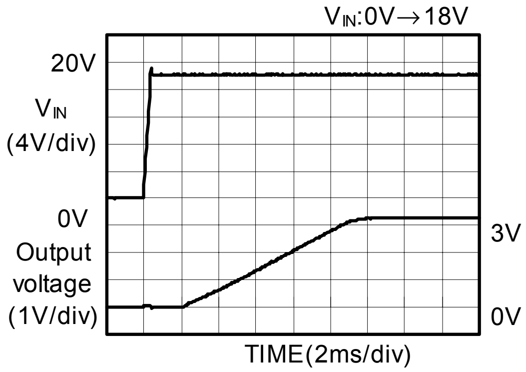
(1) S-8460B00AFT



(2) S-8460B00AFT

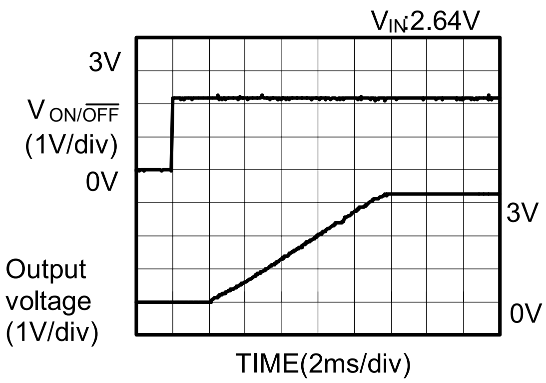


(3) S-8460B00AFT

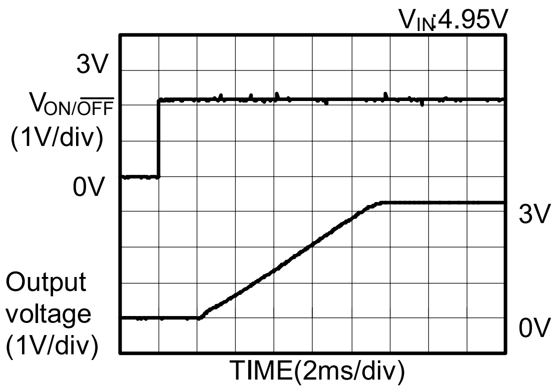


2. Responce to power -off pin ($V_{ON/\overline{OFF}}$: 0 V → 2.2 V I_{OUT} : no load) V_{OUT}: 3.3 V, C_{SS}: 4700 pF

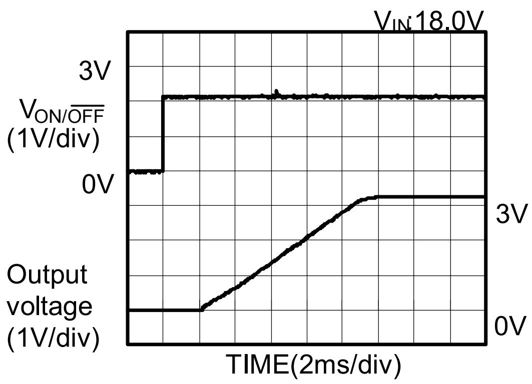
(1) S-8460B00AFT



(2) S-8460B00AFT

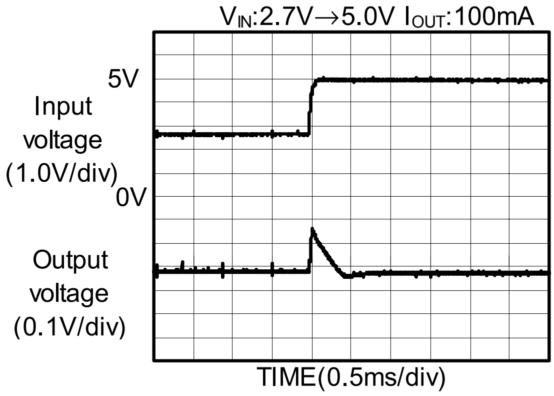


(3) S-8460B00AFT

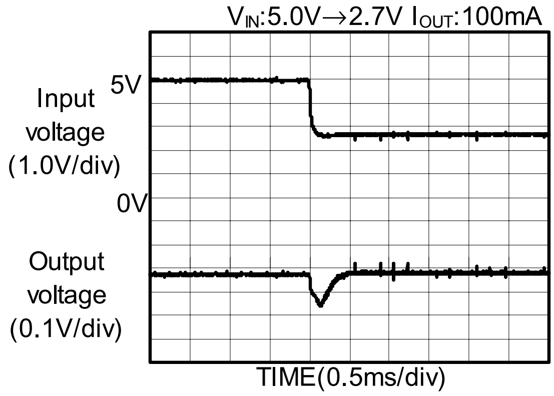


3. Response to power voltage shift
(V_{IN}: 2.7 V → 5.0 V,5.0 V → 2.7 V,2.2 V → 18.0 V → 2.2 V I_{OUT}: 100 mA) V_{OUT}: 3.3V

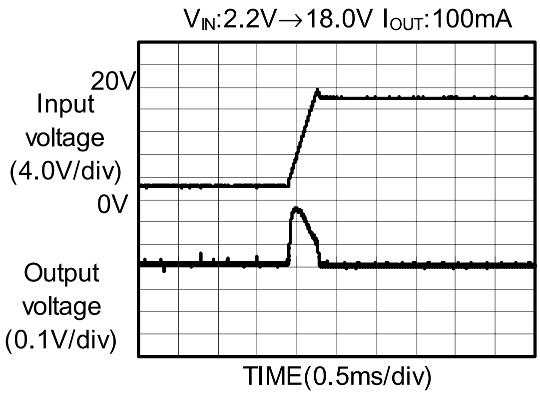
(1) S-8460B00AFT



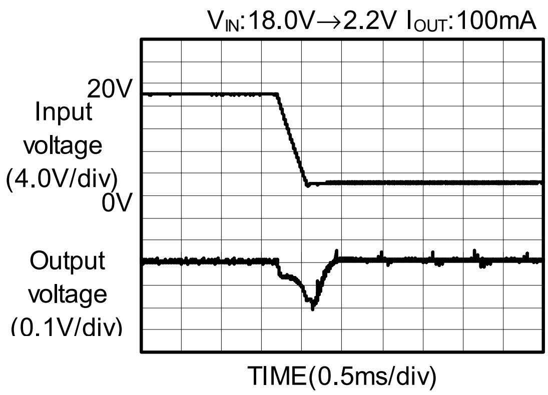
(2) S-8460B00AFT



(3) S-8460B00AFT

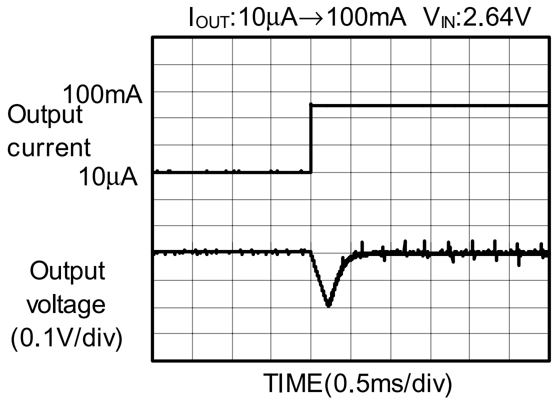


(4) S-8460B00AFT

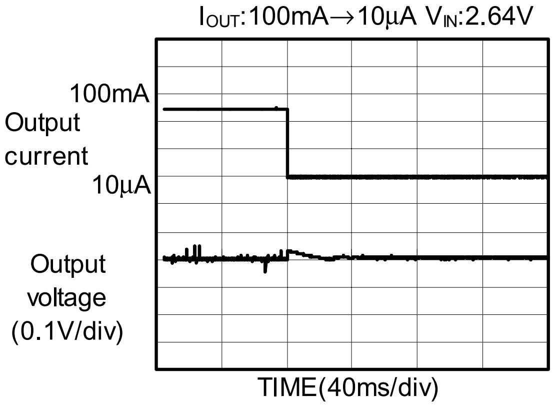


4. Response to load shift (I_{OUT}: 10 µA → 100 mA, 100 mA → 10 µA, V_{IN}: 2.64 V, 4.95 V, 18.0 V) V_{OUT}: 3.3V

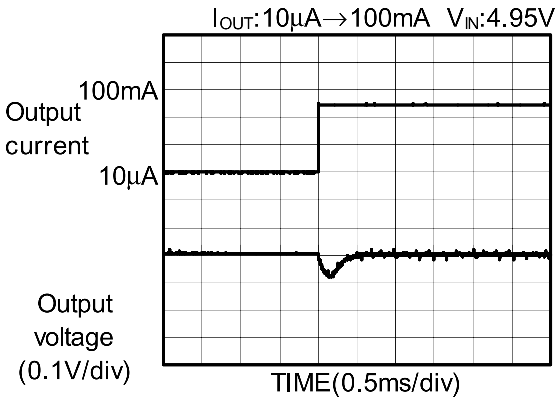
(1) S-8460B00AFT



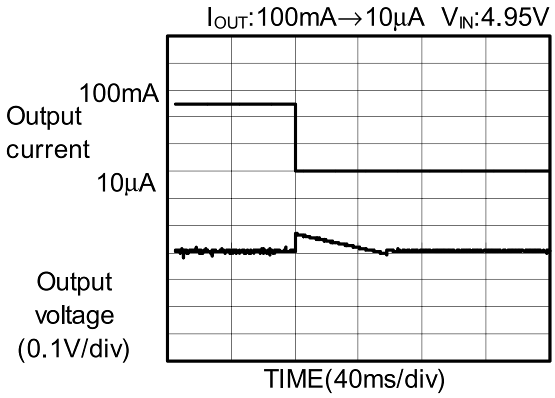
(2) S-8460B00AFT



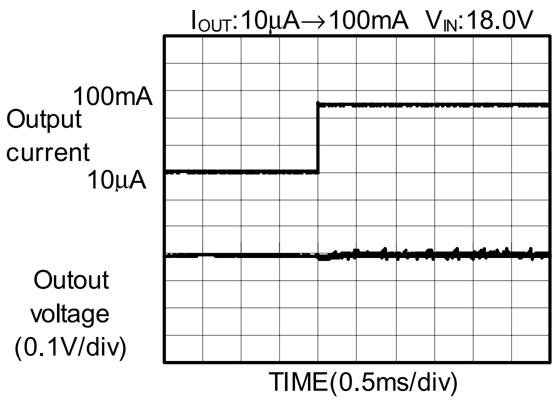
(3) S-8460B00AFT



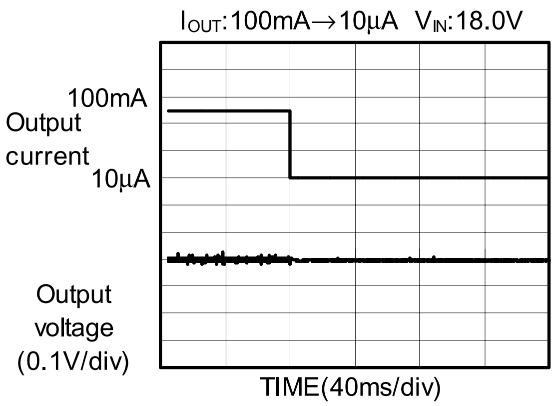
(4) S-8460B00AFT



(5) S-8460B00AFT



(6) S-8460B00AFT



■ Reference data

Reference data are intended for use in selecting peripheral components to the IC. The information therefore provides characteristic data in which external components are selected with a view of wide variety of IC applications. All data shows typical value.

External components list for efficiency-output voltage, efficiency-input voltage, output voltage-output current, and output voltage-input voltage characteristics

Table 4

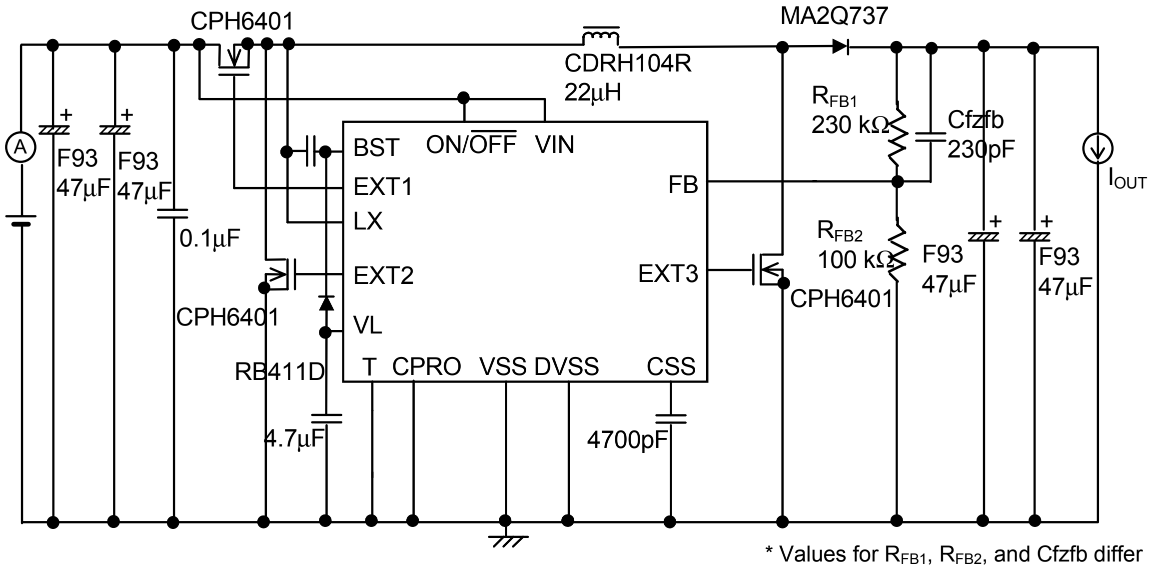
No.	Product Name	Output Voltage	Transistor	Diode	Inductor	Output Capacitor	Input Capacitor
(1)	S-8460B00AFT	3.3 V*1	CPH6401	MA2Q737	CDRH104R/22 μH	47 μF×2	47 μF×2, 0.1 μF
(2)	↑	↑	FTS2001	↑	↑	↑	↑
(3)	↑	↑	CPH3403	↑	↑	↑	↑
(4)	↑	↑	↑	D1FH3	↑	↑	↑
(5)	↑	↑	Si2302DS	↑	↑	↑	↑
(6)	↑	↑	FDN335N	↑	↑	↑	↑
(7)	↑	↑	CPH6401	MA2Q737	CDRH104R/10 μH	↑	↑
(8)	↑	↑	↑	↑	CDRH104R/47 μH	↑	↑
(9)	↑	2.5 V*2	↑	↑	CDRH104R/22 μH	↑	↑
(10)	↑	↑	CPH3403	D1FH3	↑	↑	↑
(11)	↑	↑	CPH6401	MA2Q737	CDRH104R/10 μH	↑	↑
(12)	↑	↑	↑	↑	CDRH104R/47 μH	↑	↑
(13)	↑	5.0 V*2	↑	↑	CDRH104R/22 μH	↑	↑
(14)	↑	↑	CPH3403	D1FH3	↑	↑	↑
(15)	↑	↑	CPH6401	MA2Q737	CDRH104R/10 μH	↑	↑
(16)	↑	↑	↑	↑	CDRH104R/47 μH	↑	↑
(17)	↑	3.3 V*1	↑	↑	CDRH104R/22 μH	↑	↑
(18)	↑	↑	FTS2001	↑	↑	↑	↑
(19)	↑	↑	CPH3403	↑	↑	↑	↑
(20)	↑	↑	↑	D1FH3	↑	↑	↑
(21)	↑	↑	Si2302DS	↑	↑	↑	↑
(22)	↑	↑	FDN335N	↑	↑	↑	↑
(23)	↑	↑	CPH6401	MA2Q737	CDRH104R/10 μH	↑	↑
(24)	↑	↑	↑	↑	CDRH104R/47 μH	↑	↑
(25),(28)	↑	3.3 V*1	↑	↑	CDRH104R/22 μH	↑	↑
(26),(29)	↑	2.5 V*2	↑	↑	CDRH104R/22 μH	↑	↑
(27),(30)	↑	5.0 V*2	↑	↑	CDRH104R/22 μH	↑	↑

*1 External parts: R_{FB1}=230 kΩ, R_{FB2}=100 kΩ, Cfzfb=330 pF

*2 External parts: R_{FB1}=150 kΩ, R_{FB2}=100 kΩ, Cfzfb=470 pF

*3 External parts: R_{FB1}=400 kΩ, R_{FB2}=100 kΩ, Cfzfb=220 pF

■ Test circuit



* Values for R_{FB1}, R_{FB2}, and Cfzfb differ according to the ouput

Figure 12

External components list for ripple data

Table 5

No.	Product Name	Output Voltage	Transistor Nch	Diode SD1	Inductor	Output Capacitor	Input Capacitor
(31)	S-8460B00AFT	3.3 V*1	CPH6401	MA2Q737	CDRH104R/22 μH	47 μF×2	47 μF×2, 0.1 μF
(32)	↑	↑	↑	↑	CDRH104R/10 μH	↑	↑
(33)	↑	↑	↑	↑	CDRH104R/47 μH	↑	↑
(34)	↑	2.5 V*2	↑	↑	CDRH104R/22 μH	↑	↑
(35)	↑	5.0 V*3	↑	↑	CDRH104R/22 μH	↑	↑

***1.** External parts: R_{FB1}=230 kΩ, R_{FB2}=100 kΩ, Cfzfb=330 pF
***2.** External parts: R_{FB1}=150 kΩ, R_{FB2}=100 kΩ, Cfzfb=470 pF
***3.** External parts: R_{FB1}=400 kΩ, R_{FB2}=100 kΩ, Cfzfb=220 pF

Performance data for components

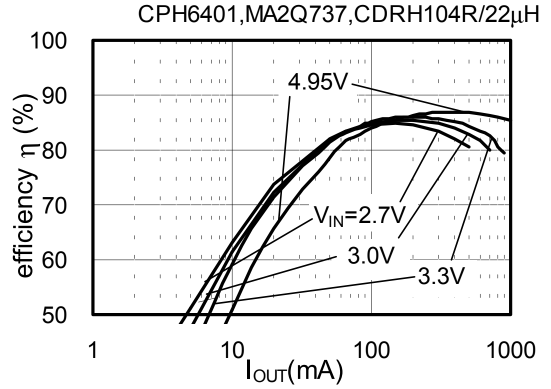
Table 6

Component	Product Name	Manufacturer	Performance				
			L	DC resist.	Max. current	Diameter	Hight
Inductor	CDRH104R	Sumida Electronic Co. Ltd.	47 μH	0.095 Ω	2.1 A	13.5 mm max.	4.0 mm max.
			22 μH	0.054 Ω	2.9 A		
			10 μH	0.026 Ω	4.4 A		
Diode	MA2Q737	Panasonic	Forward current 2.0 A @V_F=0.5 V				
	D1FH3	Shin Dengen Electric Manufacturing Co., Ltd.	Forward current 1.0 A @V_F=0.3 V				
Output Capacity	F93	Nichicon Corporation					
External Transistor (N-channel MOSFET)	CPH6401	Sanyo Electric Co., Ltd.	V_{GS} 12 V max. , I_D 4 A max. , V_{th} 0.4 V min. , C_{iss} 300 pF typ. R_{on} 0.105 Ω max.(V_{gs}=2.5 V) , CPH6				
	CPH3403	Sanyo Electric Co., Ltd.	V_{GS} 12 V max. , I_D 2.2 A max. , V_{th} 0.4 V min. , C_{iss} 170 pF typ. R_{on} 0.220 Ω max.(V_{gs}=2.5 V) , CPH3				
	FTS2001	Sanyo Electric Co., Ltd.	V_{GS} 10 V max. , I_D 5A max. , V_{th} 0.4 V min. , C_{iss} 750 pF typ. R_{on} 0.046 Ω max.(V_{gs}=2.5V) , TSSOP-8				
	Si2302DS	Vishay Siliconix	V_{GS} 8 V max. , I_D 2.8 A max. , V_{th} 0.65 V min. , R_{on} 0.115 Ω max.(V_{gs}=2.5 V) , SOT-23				
	FDN335N	Fairchild Semiconductor Corporation	V_{GS} 8 V max. , I_D 1.7 A max. , V_{th} 0.4 V min. , C_{iss} 310 pF typ. R_{on} 0.100 Ω max.(V_{gs}=2.5 V) , Super SOT-3				

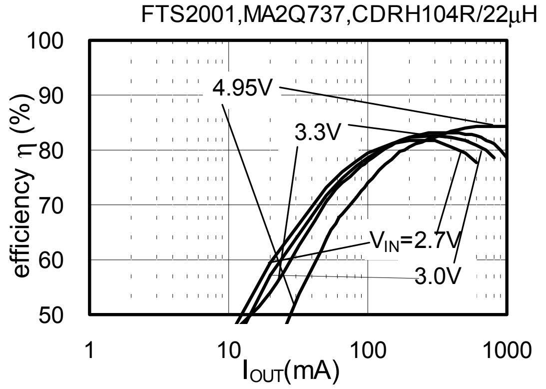
Super SOT-3 is a trademark of Fairchild Semiconductor Corporation.

1.Effficiency η — Output current I_{OUT} characteristics

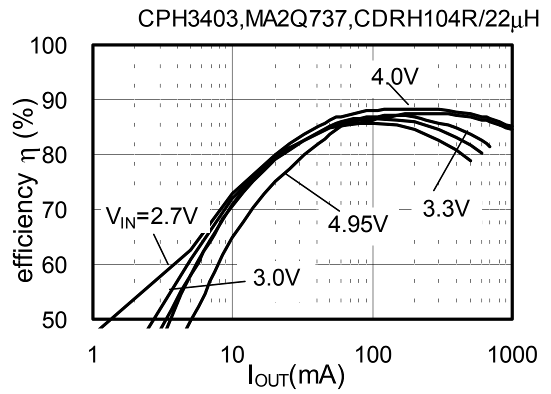
(1) S-8460B00AFT(V_{OUT}=3.3 V)



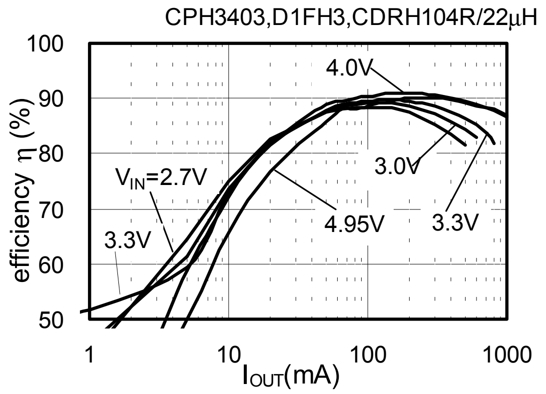
(2) S-8460B00AFT(V_{OUT}=3.3 V)



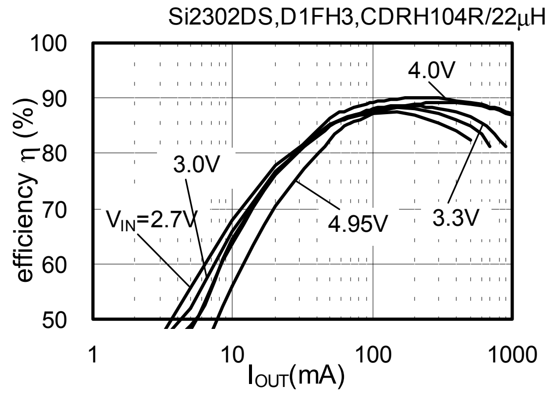
(3) S-8460B00AFT(V_{OUT}=3.3 V)



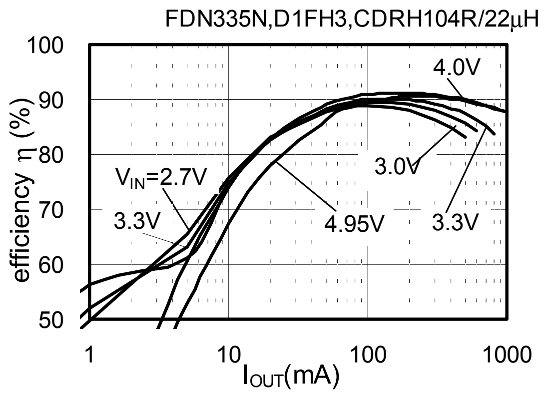
(4) S-8460B00AFT(V_{OUT}=3.3 V)



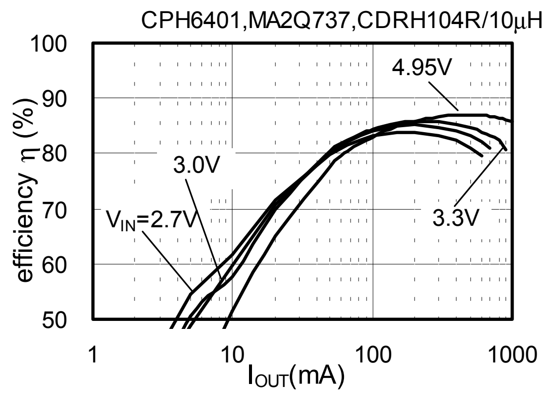
(5) S-8460B00AFT(V_{OUT}=3.3 V)



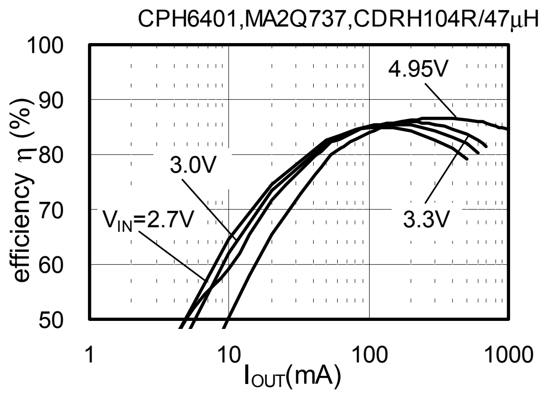
(6) S-8460B00AFT(V_{OUT}=3.3 V)



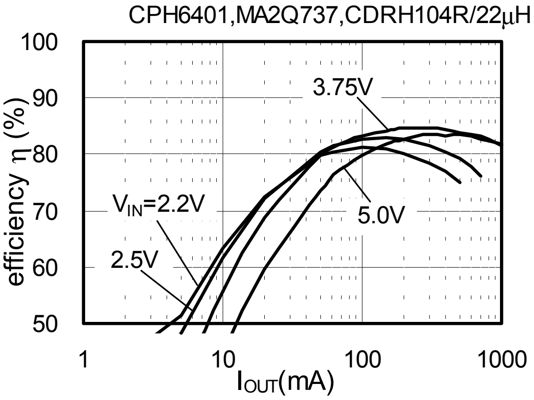
(7) S-8460B00AFT(V_{OUT}=3.3 V)



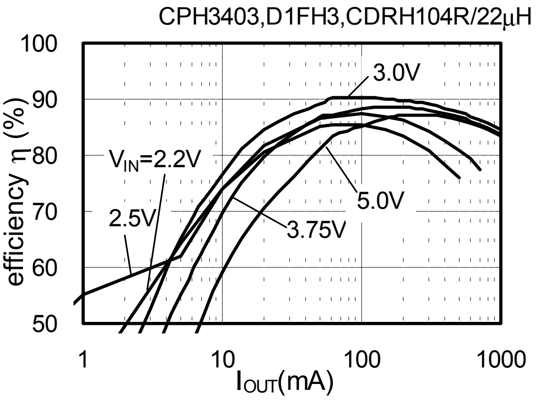
(8) S-8460B00AFT(V_{OUT}=3.3 V)



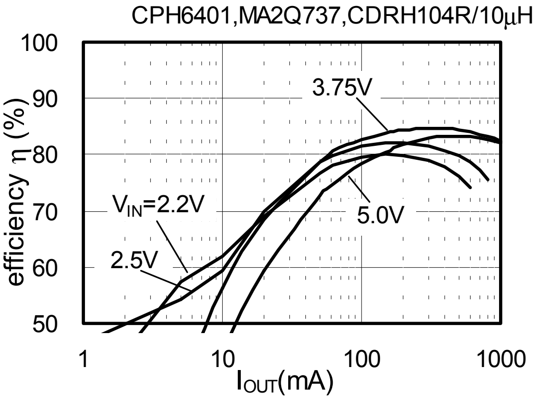
(9) S-8460B00AFT(V_{OUT}=2.5 V)



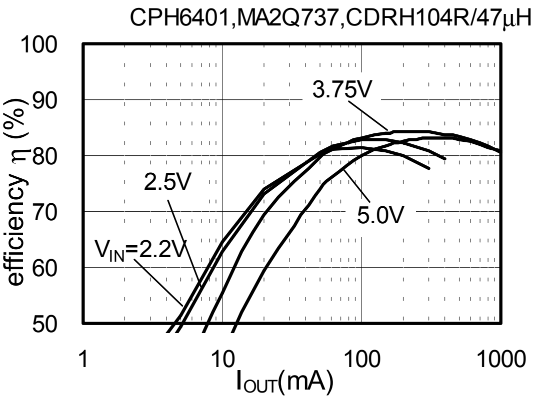
(10) S-8460B00AFT(V_{OUT}=2.5 V)



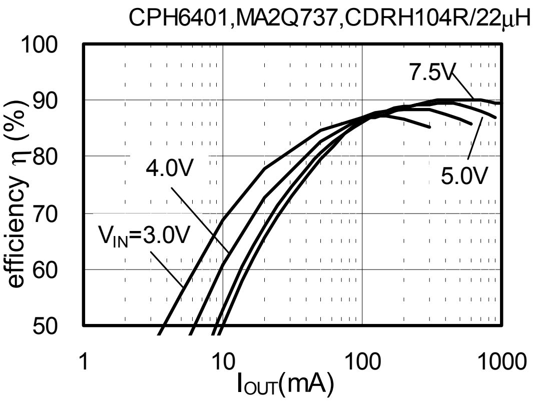
(11) S-8460B00AFT(V_{OUT}=2.5 V)



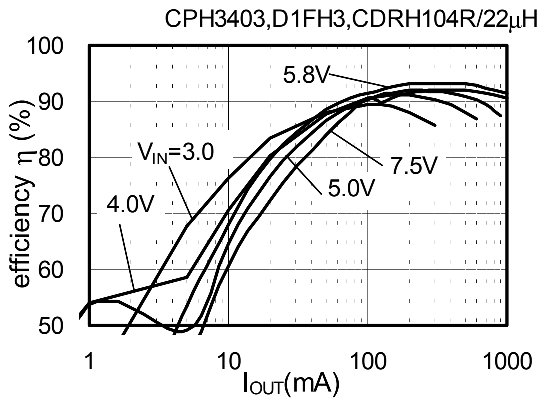
(12) S-8460B00AFT(V_{OUT}=2.5 V)



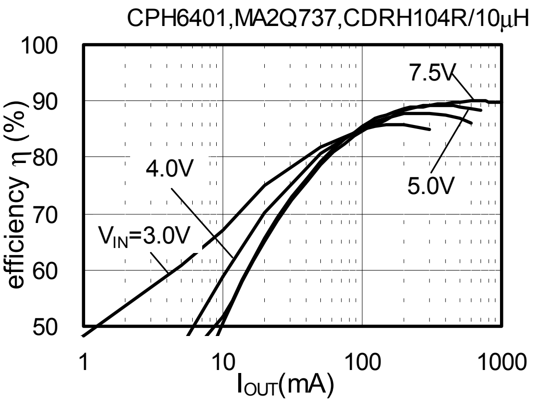
(13) S-8460B00AFT(V_{OUT}=5.0 V)



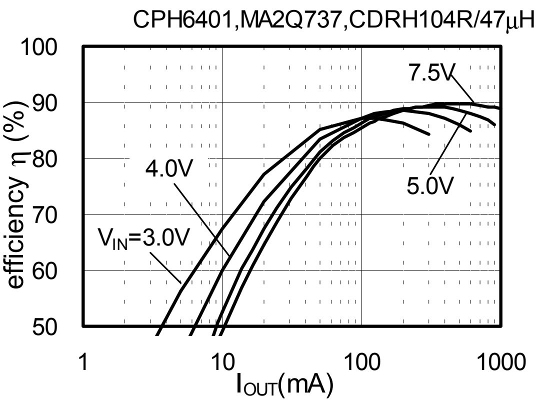
(14) S-8460B00AFT(V_{OUT}=5.0 V)



(15) S-8460B00AFT(V_{OUT}=2.5 V)

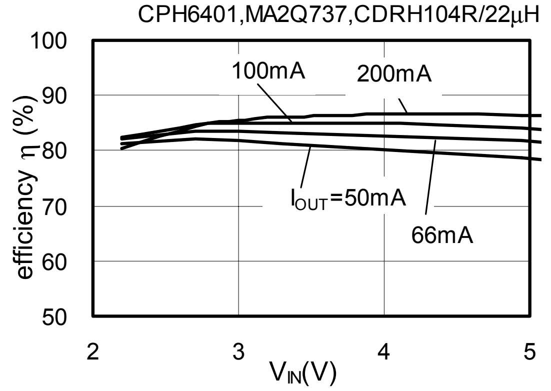


(16) S-8460B00AFT(V_{OUT}=2.5 V)

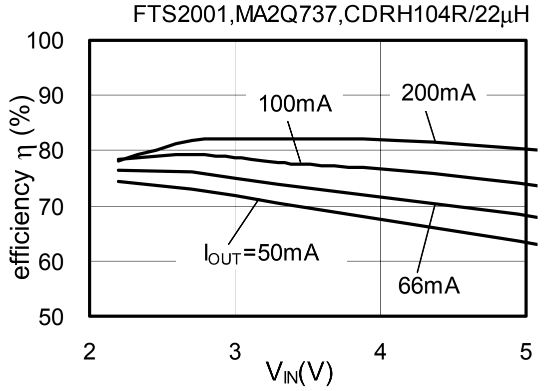


2.Efficiency η —Input voltage V_{IN} characteristics

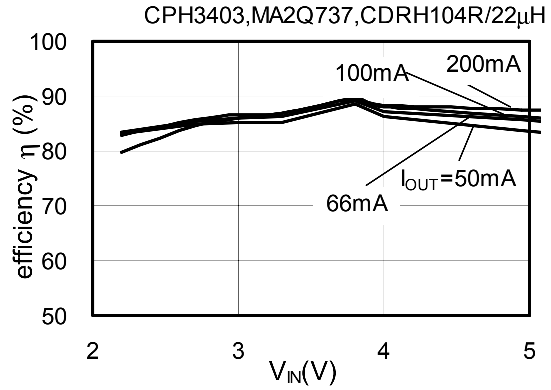
(17) S-8460B00AFT(V_{OUT}=3.3 V)



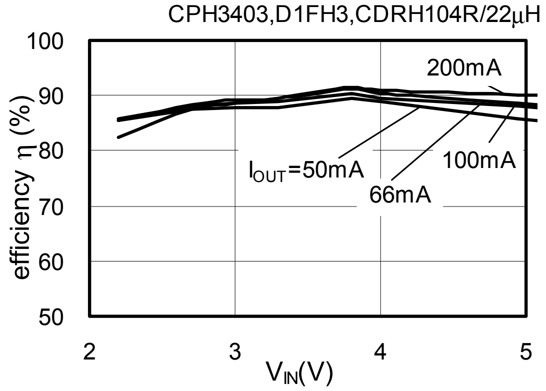
(18) S-8460B00AFT(V_{OUT}=3.3 V)



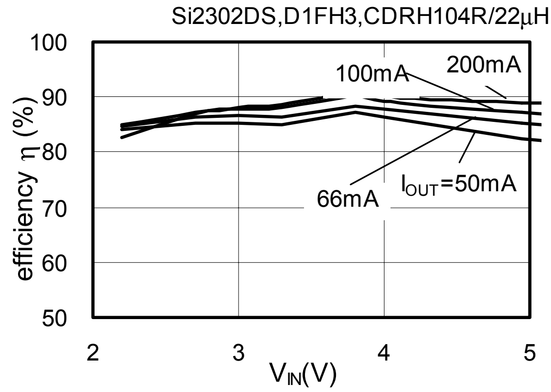
(19) S-8460B00AFT(V_{OUT}=3.3 V)



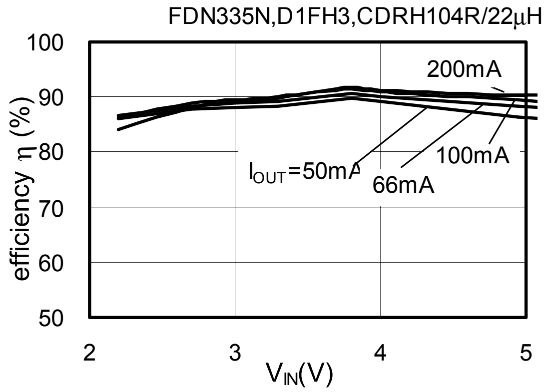
(20) S-8460B00AFT(V_{OUT}=3.3 V)



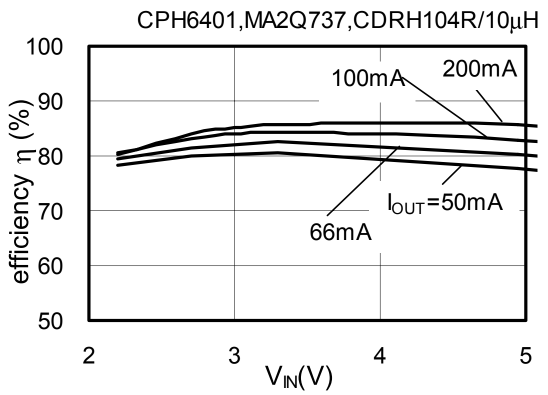
(21) S-8460B00AFT(V_{OUT}=3.3 V)



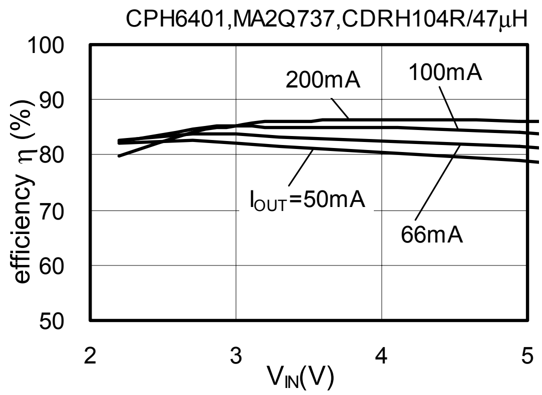
(22) S-8460B00AFT(V_{OUT}=3.3 V)



(23) S-8460B00AFT(V_{OUT}=3.3 V)

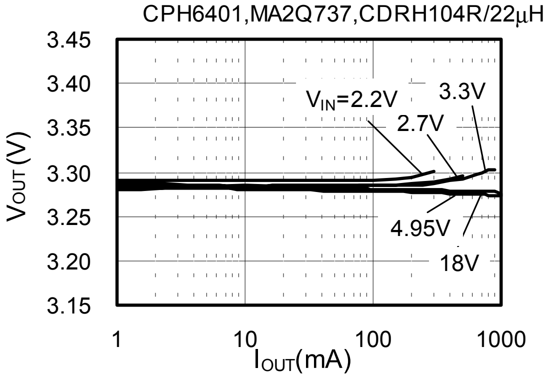


(24) S-8460B00AFT(V_{OUT}=3.3 V)

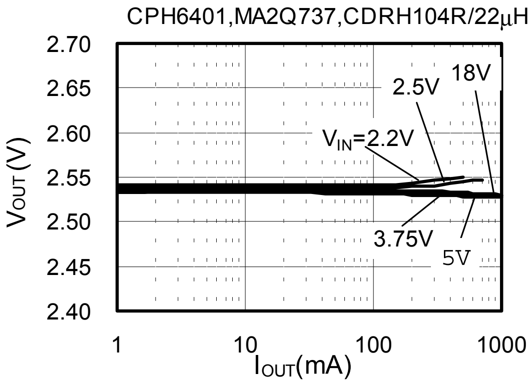


3.Output voltage V_{OUT}—Output current I_{OUT} characteristics

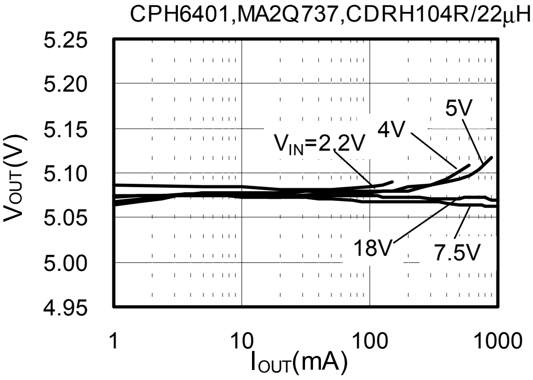
(25) S-8460B00AFT(V_{OUT}=3.3 V)



(26) S-8460B00AFT(V_{OUT}=2.5 V)

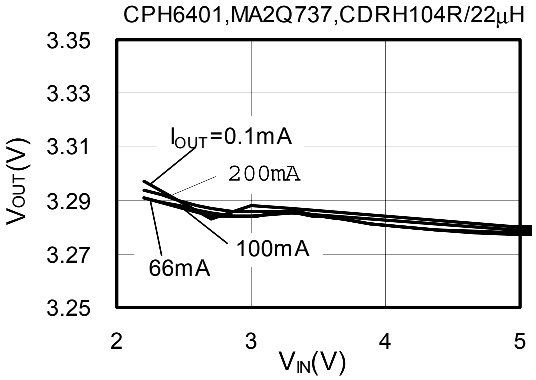


(27) S-8460B00AFT(V_{OUT}=5.0 V)

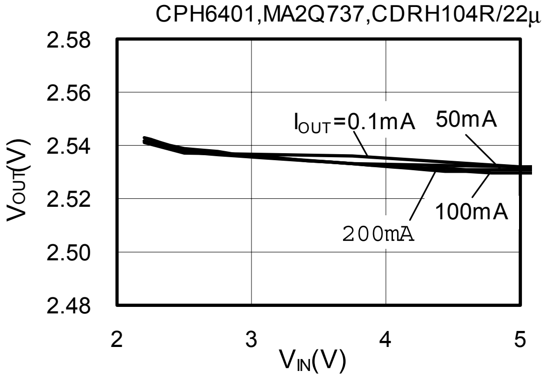


4.Output voltage —Input voltage characteristics

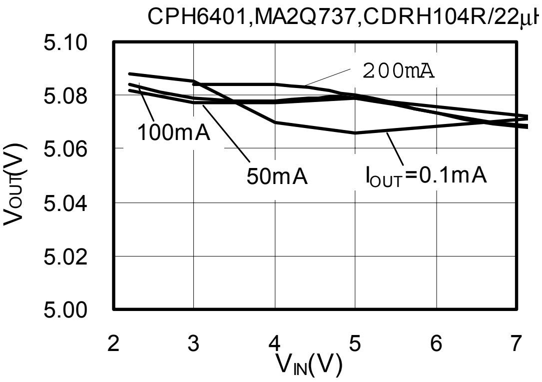
(28) S-8460B00AFT(V_{OUT}=3.3 V)



(29) S-8460B00AFT(V_{OUT}=2.5 V)

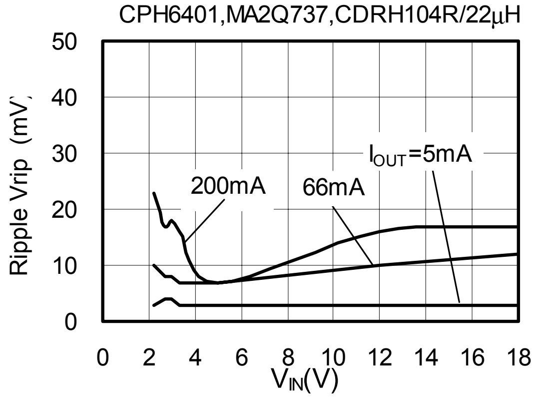


(30) S-8460B00AFT(V_{OUT}=5.0 V)

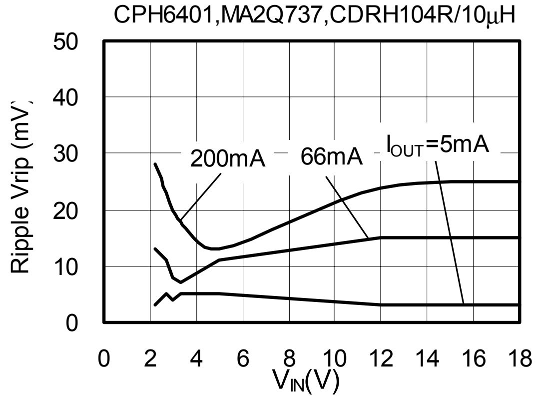


5.Ripple voltage characteristics

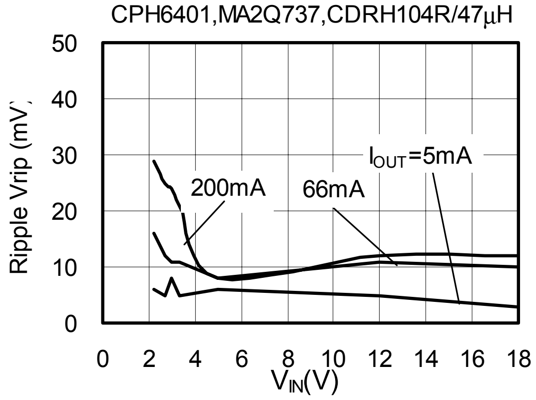
(31) S-8460B00AFT(V_{OUT}=3.3 V)



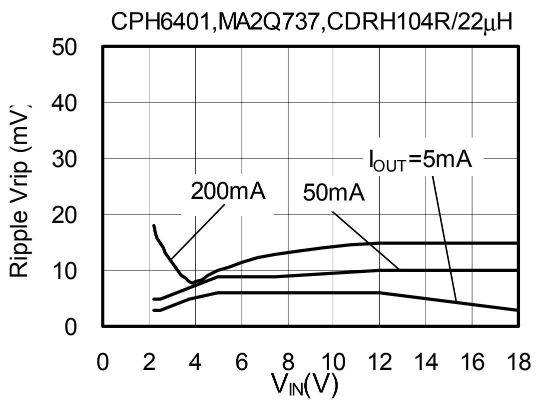
(32) S-8460B00AFT(V_{OUT}=3.3 V)



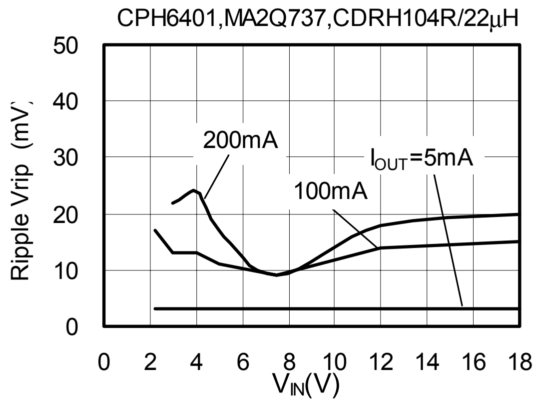
(33) S-8460B00AFT(V_{OUT}=3.3 V)



(34) S-8460B00AFT(V_{OUT}=2.5 V)



(35) S-8460B00AFT(V_{OUT}=5.0 V)

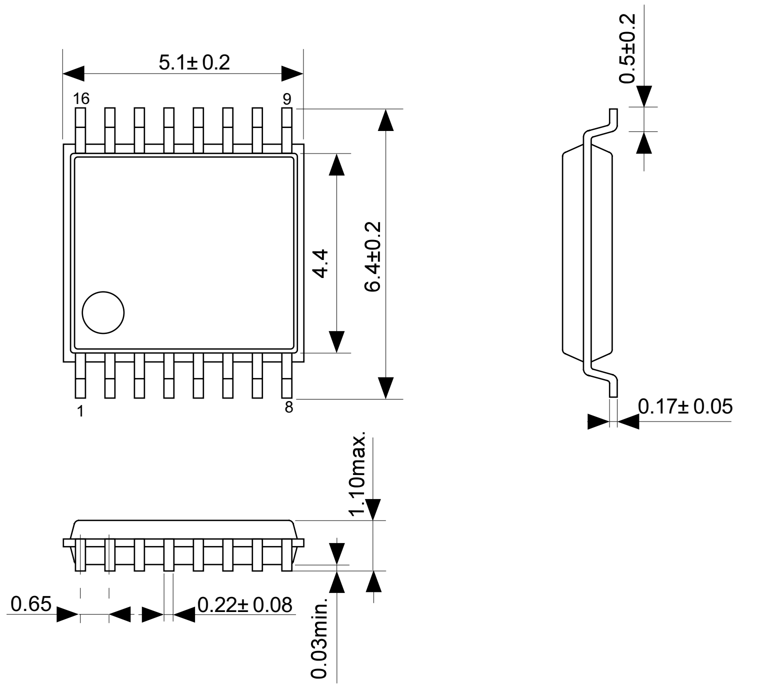


■ 16-Pin TSSOP

FT016-A **Rev.1.0** 020107

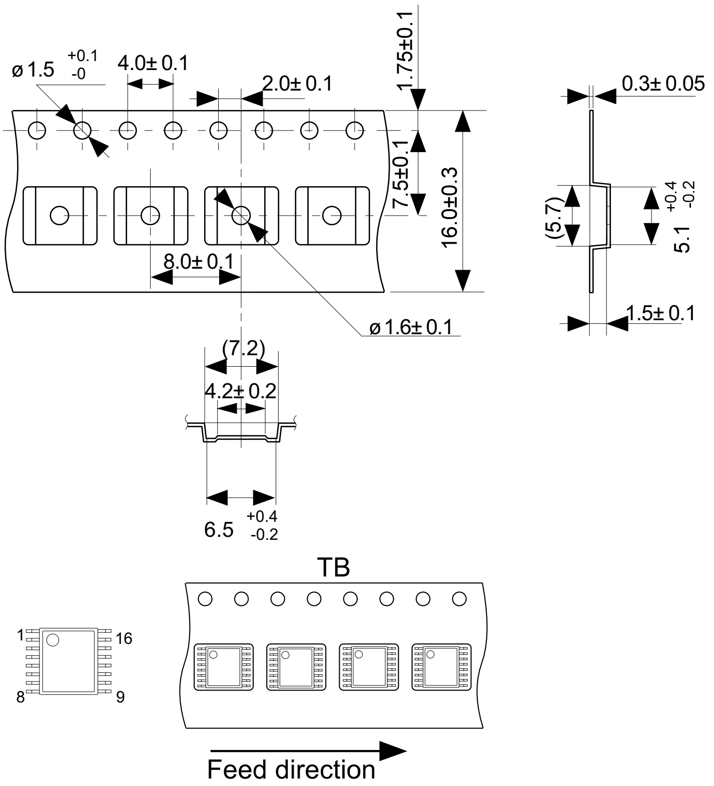
Unit:mm

● Dimensions



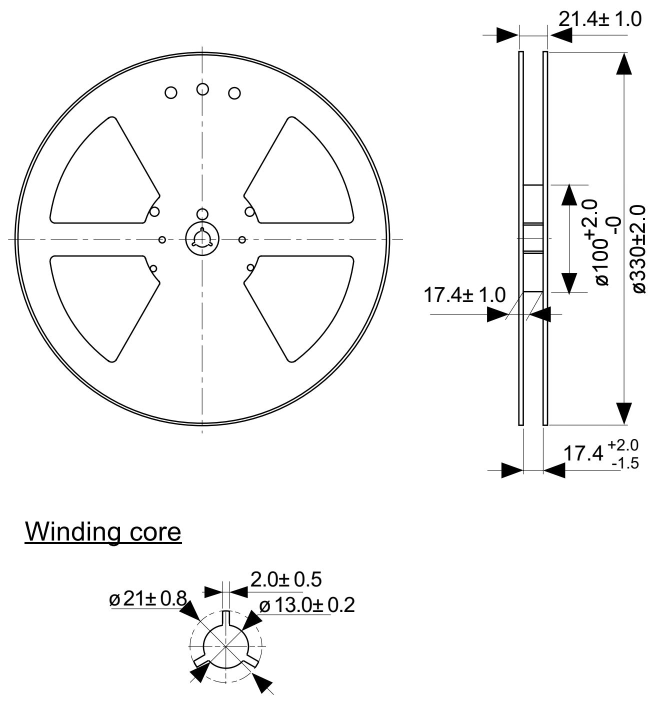
No. : FT016-A-P-SD-1.0

● Taping Specifications



No. : FT016-A-C-SD-1.0

● Reel Specifications



No.:FT016-A-R-SD-1.0