PWM Control & PWM/PFM Control High-Frequency Step-Down Switching Regulator Controllers

S-8540/8541 Series

The S-8540/8541 Series is a family of CMOS step-down switching regulator controllers with PWM control (S-8540) and PWM/PFM switchover control (S-8541). These devices consist of a reference voltage source, oscillation circuit, an error amplifier, phase compensation circuit, PWM control circuit, current limit circuit. A high efficiency and large current switching regulator is realized with the help of small external components due to the high oscillation frequency, 300 kHz and 600 kHz.

The S-8540 provides low-ripple voltage, high efficiency, and excellent transient characteristics which come form the PMW control circuit capable of varying the duty ratio linearly from 0% to 100%, the optimized error amplifier, and the phase compensation circuit.

The S-8541 operates under PWM control when the duty ratio is 29% or higher and operates under PFM control when the duty ratio is less than 29% to ensure high efficiency over all load range.

These controllers serve as ideal main power supply units for portable devices due to the high oscillation frequencies together with the small 8-pin MSOP package.

■ Features

- Oscillation frequency: 600 kHz (A & B series), 300 kHz (C & D series)
- Output voltage: 1.5 V to 6.0 V in steps of 0.1 V (A & C series)
  Variable (Feed back) type is available.
- Output voltage precision: ±2.0%
- External components: A transistor, a coil, a diode, and capacitors.
- Built-in PWM/PFM switchover control circuit(S-8541)
  Duty ratio: 29% (PFM control)
  29 to 100% (PWM control)
- Current limit circuit: Current is set by an external resistor RSENSE.
- Soft-start: Time is set by an capacitor CSS and a resistor RSS.
- Power-off function
- Small package: 8-pin MSOP

■ Package

- 8-pin MSOP (Package drawing code: FN008-A)

■ Applications

- Power supplies for PDAs, electric organizers, and portable devices.
- Power supplies for audio equipment such as portable CD players and headphone stereos.
- Main or sub power supplies for notebook computers and peripheral equipment.

■ Block Diagram

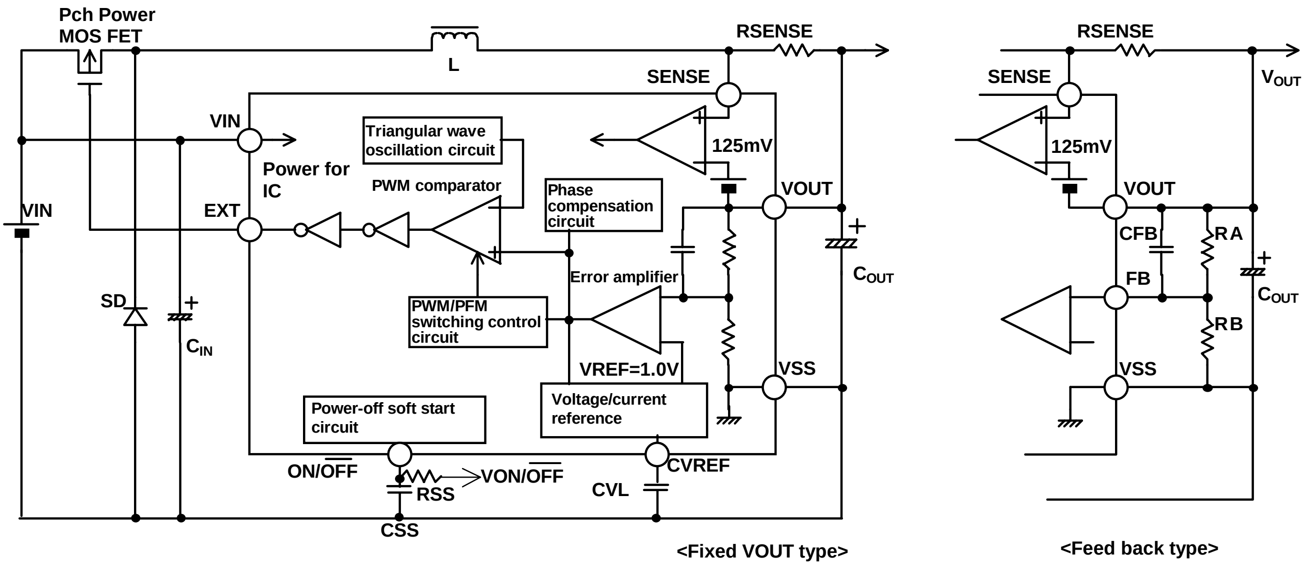


Figure 1 Block diagram

■ Selection Guide

1. Product Name

S-854X X XX FN - XXX - T2

- T2: Tape specifications.
- XXX: Product name abbreviation.
- FN: Package name abbreviation (8-pin MSOP).
- XX: Output voltage (1.5 to 6.0 V), 00: Feed back type
- X: A: Fixed output voltage, fosc=600 kHz
  B: Feed back type, fosc=600kHz
  C: Fixed output voltage, fosc=300 kHz
  D: Feed back type, fosc=300 kHz
- 854X: 0: PWM control
  1: PWM/PFM switchover control

2. Product List (as of November 1, 2000)

2-1 A, B Series (oscillation frequency: 600 kHz)

Output Voltage (V)	S-8540XXXFN Series	S-8541XXXFN Series
1.8 V	S-8540A18FN-IAD-T2	S-8541A18FN-IGD-T2
2.5 V	S-8540A25FN-IAK-T2	S-8541A25FN-IGK-T2
3.3 V	S-8540A33FN-IAS-T2	S-8541A33FN-IGS-T2
Feed back (1.5 to 6.0)	S-8540B00FN-IMA-T2	S-8541B00FN-IMD-T2

2.2 C,D Series (oscillation frequency: 300 kHz)

Output Voltage (V)	S-8540XXXFN Series	S-8541XXXFN Series
1.8	S-8540C18FN-ICD-T2	S-8541C18FN-IID-T2
2.5	S-8540C25FN-ICK-T2	S-8541C25FN-IIK-T2
3.3	S-8540C33FN-ICS-T2	S-8541C33FN-IIS-T2
Feed back (1.5 to 6.0)	S-8540D00FN-IMB-T2	S-8541D00FN-IME-T2

When another output voltage product is needed, please contact SII sales office.

■ Pin Assignment

8-pin MSOP
Top view

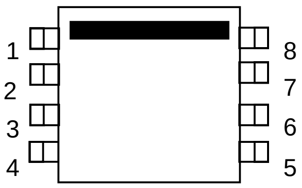


Figure 2

Pin No.	Pin Name	Function
1	VSS	GND pin
2	EXT	Connection pin for external transistor
3	VIN	IC power supply pin
4	CVREF	Bypass capacitor connection pin for reference voltage source
5	ON/$\overline{\text{OFF}}$	Power-off pin Soft-start capacitor connection pin • Normal operation (Step-down operation) • All circuit halts (No step-down operation)
6	NC (FB)	NC for fixed output voltage type (FB for feed back type)
7	VOUT	Output voltage pin
8	SENSE	Current limit detection pin

■ Absolute Maximum Ratings

(Ta = 25°C, unless otherwise specified)

Item	Symbol	Ratings	Units
VIN pin voltage	V_{IN}	12	V
Other pin voltage	–	-0.3 to V_{IN}+0.3	V
EXT pin current	I_{EXT}	±100	mA
Power dissipation	P_D	300	mW
Operating temperature range	T_{opr}	-40 to 85	°C
Storage temperature range	T_{stg}	-40 to 125	°C

Note: Although the IC contains protection circuit against static electricity, excessive static electricity or voltage which exceeds the limit of the protection circuit should not be applied to.

■ Electrical Characteristics

1. S-8540/41A, C

(Ta = 25 °C, unless otherwise specified)

Parameter	Symbol	Conditions		Min.	Typ.	Max.	Units	Circuit
Output voltage	V_{OUT}	$V_{IN} = V_{OUT} \times 1.5$, $I_{OUT} = 120mA$		$V_{OUT} \times 0.98$	V_{OUT}	$V_{OUT} \times 1.02$	V	2
Input voltage	V_{IN}	–		2.5	–	10.0	V	1
Current consumption 1	I_{SS1}	$V_{IN} = V_{OUT} \times 1.5$ 100% duty ratio	S-8540/41AXX	–	180	300	μA	1
			S-8540/41CXX	–	140	240		
Current consumption during power off	I_{SSS}	Power-off pin = 0V, $V_{OUT} = V_{OUT}(S) \times 0.95$		–	–	1.0	μA	1
EXT pin output current	I_{EXTH}	V_{IN}=10V, V_{EXT}= V_{IN}-0.2V		-32	-48	–	mA	1
	I_{EXTL}	V_{IN}=10V, V_{EXT}= 0.2V		45	66	–	mA	1
Line regulation	ΔV_{OUT1}	$V_{OUT}\times1.1 \leq V_{IN} \leq 10V$, I_{OUT}120mA		–	30	60	mV	2
Load regulation	ΔV_{OUT2}	$V_{IN}=V_{OUT}\times1.5$, $10\mu A \leq I_{OUT} \leq 150mA$		–	30	60	mV	2
Output voltage temperature coefficient	$\frac{\Delta V_{OUT}}{\Delta Ta \bullet V_{OUT}}$	$V_{IN}=V_{OUT}(S)\times1.5$, I_{OUT}120mA, $-40°C \leq Ta \leq 85°C$		–	±100	–	ppm/°C	2
Oscillation frequency	fosc	Measure waveform at the EXT pin.	S-8540/41AXX	510	600	690	kHz	2
			S-8540/41CXX	255	300	345		
Maximum duty ratio	MaxDuty	Measure waveform at the EXT pin.		100	–	–	%	2
PWM/PFM-control switch duty ratio *1	PFM Duty	$V_{IN} = V_{OUT}(S)$ - 1.5 V, No load		19	29	39	%	2
Current limit detection voltage	V_{SENSE}	See I_{SS1}. Measure waveform at the EXT pin.		100	125	150	mV	1
SENSE pin input current	I_{SENSE}	See I_{SS1}. V_{SENSE}= V_{IN} -0.1 V		6.7	11.2	16.8	μA	1
Power-Off pin input voltage	V_{SH}	See V_{OUT}. Judge $V_{OUT} \times 0.98$.		2.3	–	–	V	2
	V_{SL}	See I_{SS1}. Judge CVREF pin "L".		–	–	0.3	V	1
Power-Off pin input leakage current	I_{SH}	See I_{SS1}. Power-off pin = Output voltage		–	–	0.1	μA	1
	I_{SL}	See I_{SS1}. Power-off pin = 0 V		–	–	-0.1	μA	1
Soft-Start time	T_{SS}	Time until VOUT reaches 90% or higher of the setting		7.0	12.0	17.0	ms	2
Efficiency	EFFI	–		–	90	–	%	2

Condition: Recommended parts are used unless otherwise specified. $V_{IN}=V_{OUT}\times1.5$(V), I_{OUT}=120(mA) (When $V_{OUT} \leq 1.6$ V, then V_{IN} = 2.5 V)

*1: Applied to the S-8541 series only

External components

Coil (L):	Sumida CDRH6D28-100
Diode (SD):	Panasonic MA2Q737 (Schottky diode)
Output capacitor (COUT):	Nichicon F93 (16 V, 47 μF, tantalum)
Input capacitor (CIN):	Nichicon F93 (16 V, 47 μF, tantalum)
Transistor (PSW):	Toshiba 2SA1213
Base resistor (Rb):	100mΩ
Base capacitor (Cb):	2200pF
CVL:	1.0μF
CSS:	0.047μF
RSS:	220kΩ
RSENSE:	100mΩ

Note: Line regulation and load regulation may change greatly due to GND wiring when V_{IN} is high.
In the S-8540 series (PWM control), a state in which the duty ratio 0% continues for several clocks may occur when the input voltage is high and the output current is low. In this case, the operation changes to the pseudo PFM mode, but the ripple voltage hardly increases.

2. S-8540/41B,D

(Ta=25°C,unless otherwise specified)

Parameter	Symbol	Conditions		Min.	Typ.	Max.	Units	Circuit
Output voltage *1	V_{OUT}	V_{IN} = 4.5 V I_{OUT} = 120mA		2.940	3.0	3.060	V	4
Input voltage	V_{IN}	–		2.5	–	10.0	V	3
Current consumption 1	I_{SS1}	V_{IN} = 4.5 V 100% duty ratio	S-8540/41B00	–	180	300	μA	3
			S-8540/41D00	–	140	240		
Current consumption during power off	I_{SSS}	Power-off pin = 0V V_{OUT} = V_{OUT}(S) × 0.95		–	–	1.0	μA	3
EXT pin output current	I_{EXTH}	V_{IN}=10V, V_{EXT}= V_{IN}-0.2 V		-32	-48	–	mA	3
	I_{EXTL}	V_{IN}=10V, V_{EXT}= 0.2 V		45	66	–	mA	3
Line regulation	ΔV_{OUT1}	3.3 ≤ V_{IN} ≤ 10V, I_{OUT}120mA		–	30	60	mV	4
Load regulation	ΔV_{OUT2}	10μA ≤ I_{OUT} ≤ 150mA		–	30	60	mV	4
Output voltage temperature coefficient	$\frac{\Delta V_{OUT}}{\Delta Ta \bullet V_{OUT}}$	V_{IN}=V_{OUT}(S)×1.5, I_{OUT}120mA -40°C ≤ Ta ≤ 85°C		–	±100	–	ppm/°C	4
Oscillation frequency	fosc	Measure waveform at the EXT pin.	S-8540/41B00	510	600	690	kHz	4
			S-8540/41D00	255	300	345		
Maximum duty ratio	MaxDuty	Measure waveform at the EXT pin.		100	–	–	%	4
PWM/PFM-control switch duty ratio *2	PFM Duty	V_{IN} = V_{OUT}(S) × 1.5 V, No load		19	29	39	%	4
Current limit detection voltage	V_{SENSE}	See I_{SS1}. Measure waveform at the EXT pin.		100	125	150	mV	3
SENSE pin input current	I_{SENSE}	See I_{SS1}. V_{SENSE}= V_{IN} -0.1 V		6.7	11.2	16.8	μA	3
Power-Off pin input voltage	V_{SH}	See V_{OUT}. Judge V_{OUT} × 0.98.		2.3	–	–	V	4
	V_{SL}	See I_{SS1}. Judge CVREF pin "L".		–	–	0.3	V	3
Power-Off pin input leakage current	I_{SH}	See I_{SS1}. Power-off pin = Output voltage		–	–	0.1	μA	3
	I_{SL}	See I_{SS1}. Power-off pin = 0 V		–	–	-0.1	μA	3
Soft-Start time	T_{SS}	Time until VOUT reaches 90% or higher of the setting		7.0	12.0	17.0	ms	4
Efficiency	EFFI	–		–	90	–	%	4

Condition: Connect recommended parts unless otherwise specified. V_{IN}=V_{OUT}×1.5(V), I_{OUT}=120(mA)
*1: The typical value (set output voltage value) is V_{OUT} = 1+RFB1/RFB2=3.0(V).
*2: S-8541 series only

External components

Coil (L):	Sumida CDRH6D28-100
Diode (SD):	Panasonic MA2Q737 (Schottky diode)
Output capacitor (COUT):	Nichicon F93 (16 V, 47 μF, tantalum)
Input capacitor (CIN):	Nichicon F93 (16 V, 47 μF, tantalum)
Transistor (PSW):	Toshiba 2SA1213
Base resistor (Rb):	100mΩ
Base capacitor (Cb):	2200pF
CVL:	1.0μF
CSS:	0.047μF
RSS:	220kΩ
RSENSE:	100mΩ
RA:	200kΩ
RB:	100kΩ
CFB:	50pF

Note: Line regulation and load regulation may change greatly due to GND wiring when V_{IN} is high.
In the S-8540 series (PWM control), a state in which the duty ratio 0% continues for several clocks may occur when the input voltage is high and the output current is low. In this case, the operation changes to the pseudo PFM mode, but the ripple voltage hardly increases.

■ Measurement Circuits

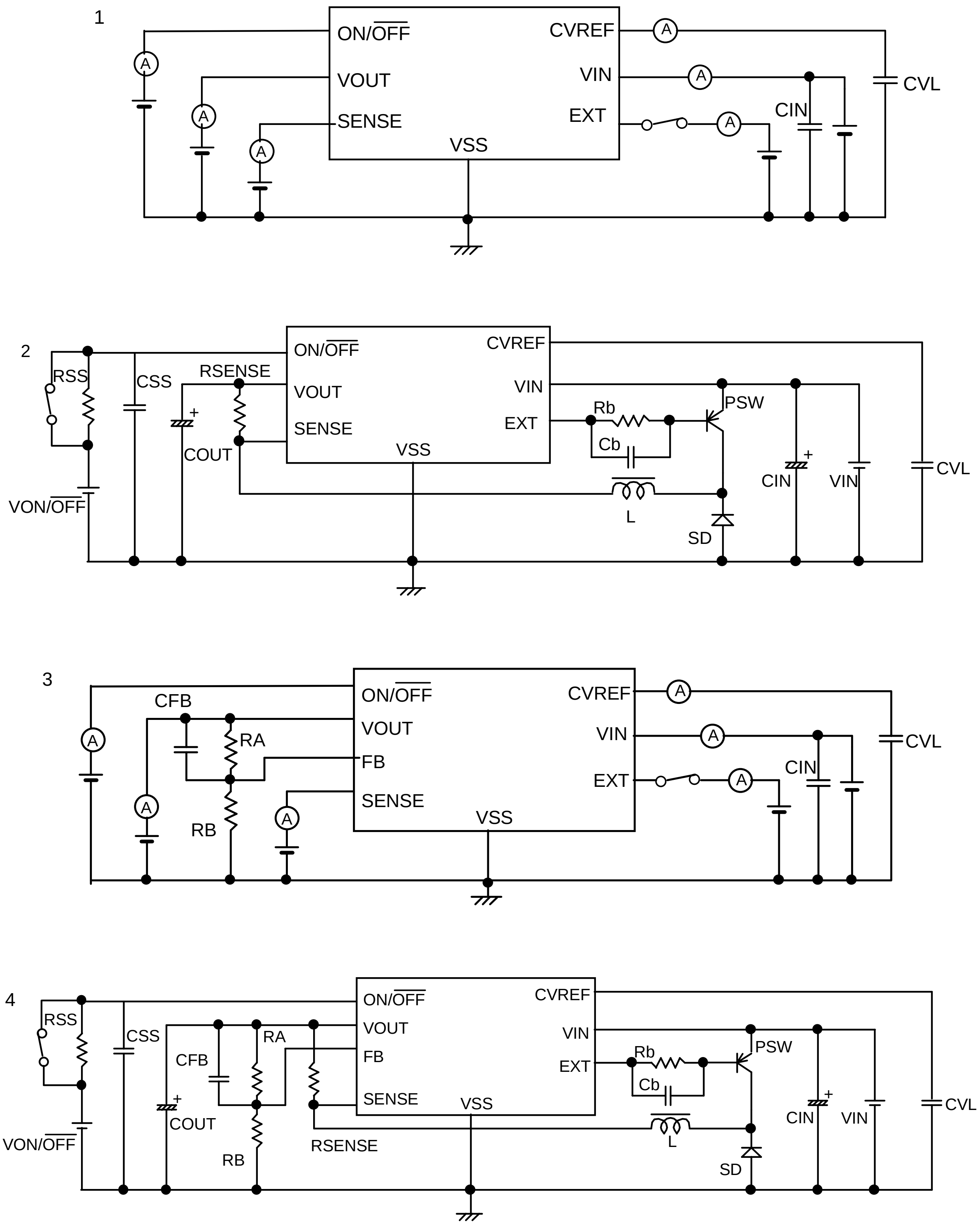


Figure 3

■ Operation

1. Step-down DC-DC converter

1.1 PWM Control (S-8540 Series)

The S-8540 series consists of pulse width modulation (PWM) DC/DC converters. In conventional pulse frequency modulation (PFM) DC/DC converters, pulses are skipped when they operate at low output load current, causing the variation in the ripple frequency and the increase in the ripple voltage of the output voltage both of which constitute inherent drawbacks to those converters.

In the S-8540 series the pulse width varies in the range from 0% to 100% according to the load current, yet ripple voltage produced by the switching can easily be removed by a filter since the switching frequency is always constant. These converters thus provide a low-ripple voltage over wide range of input voltage and load current.

1.2 PWM/PFM Switchover Control (S-8541 Series)

The S-8541 series consists of DC/DC converters capable of automatic switching between the pulse width modulation (PWM) and the pulse frequency modulation (PFM) according to the load current and is characterized by its low current consumption.

In a region of high output load current, the S-8541 operates under PWM control where the pulse width duty varies from 29% to 100% to realize low ripple power source.

In a region of low output load current, the converter is switched to PFM control where pulses having fixed width and the duty of 29% are skipped depending on the load current, and are sent to the switching transistor. The oscillation circuit thus enters intermittent oscillation, the current consumption is reduced and efficiency lowering at low load is avoided. For output load current especially in the region of 100 μA, a high efficiency DC/DC converter can be realized.

2. Power-Off Pin (ON/$\overline{\text{OFF}}$ Pin)

This pin deactivates and activates the step-down operation. When the power-off pin is set to "L", the voltage of the EXT pin goes to V_{IN} level to shut off the switching transistor. All the internal circuits stop, and substantial saving in current consumption is achieved.

The power-off pin is configured as shown in the figure 4. Since pull-up or pull-down is not performed internally, operation where the power-off pin is in a floating state should be avoided. Application of voltage of 0.3V to 1.8V to the pin should also be avoided lest the current consumption increases. When the power-off pin is not used, it should be connected to the VIN pin.

Power-Off Pin	CR Oscillation Circuit	Output Voltage
"H"	Active	Set value
"L"	Non-active	OPEN

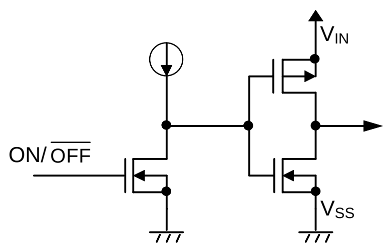


Figure 4

3. Soft-start Function

The S-8540/8541 series 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 power-off pin is set to "H".

The soft-start function of this IC, however, can not suppress rush current to the load completely.
(See figure 5. The rush current is affected by the input voltage and the load. Please evaluate the rush current under the actual test condition.)

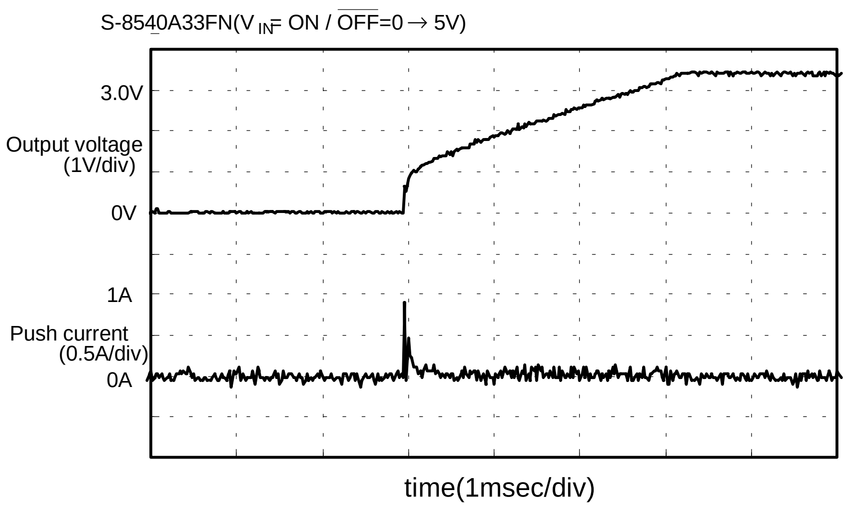


Figure 5 Wave form of Output Voltage and Rush Current at Soft-start

The soft-start function of the IC is achieved by raising internal reference voltage gradually, which is caused by the raising of power-off pin voltage through RC components (RSS and CSS) connected to power-off pin.

A soft-start time (TSS) is changed by RSS, CSS and the input voltage $V_{ON/\overline{OFF}}$ to RSS.

T_{SS} is calculated from the following formula:

$$T_{SS\,[ms]}=R_{[k\Omega]}\times C_{[\mu F]}\times \ln(V_{ON/\overline{OFF}}\ [V]/(V_{ON/\overline{OFF}}\ [V]-1.8))$$

Example : When R_{SS}=220 kΩ, C_{SS}=0.047 µF, $V_{ON/\overline{OFF}}$ =2.7 V , then T_{SS}=11.4 ms

4. Current Limit Circuit

The S-8540/41 series contains a current limit circuit.

The current limit circuit is designed to prevent thermal destruction of external transistors due to overload or magnetic saturation of the coil.

The current limit circuit can be enabled by inserting a sense resistor (R_{SENSE}) between the external coil and the output pin VOUT, and connecting the node for the sense resistor and the coil to the SENSE pin.

A current limit comparator in the IC is used to check whether the voltage between the SENSE pin and VOUT pin reaches the current limit detection voltage (V_{SENSE}=125mV(typ.)). The current flowing through the external transistor is limited by turning it off during the left time of the oscillation period after detection. The transistor is turned on again at the next clock and current limit detection resumes. If the overcurrent state still persists, the current limit circuit operates again, and the process is repeated. If the overcurrent state is eliminated, the normal operation resumes. Slight overshoot occurs in the output voltage when the overcurrent state is eliminated.

I_{Limit} (current limit setting value) is calculated by the following formula:

$$I_{Limit}\text{ (current limit setting value)} = \frac{\text{Vsense}(= 125\text{ mV})}{\text{Rsense}}$$

If the change with time of the current flowing through the sense resistor is higher than the response speed of the current limit comparator in the IC, the actual current limit value becomes higher than the I_{Limit} (current limit setting value) calculated by the above formula. When the voltage difference between VIN and VOUT is large, the actual current limit value increases since the change with time of the current flowing through the sense resistor becomes large.

Input voltage vs. peak current in the overcurrent state

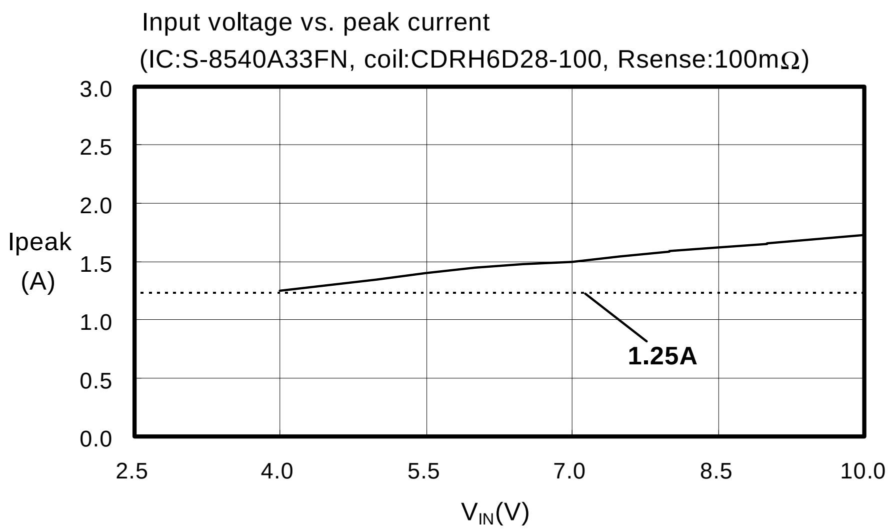


Figure 6 Ipeak change by input voltage

When the output voltage is approximate 1.0V or less, the load short-circuit protection does not work, since the current limit circuit does not operate.

When the current limit circuit is not used, remove the sense resistor and connect the SENSE pin to the VSS or VOUT pin.

5. 100% Duty Cycle

The S-8540/8541 series operates up to the maximum duty cycle of 100%. The switching transistor is kept on continuously to supply current to the load, when the input voltage falls below the preset output voltage value. The output voltage in this case is equal to the subtraction of lowering causes by DC resistance of the coil and on resistance of the switching FET from the input voltage.

Even when the duty cycle is 100%, the current limit circuit works when overcurrent flows.

■ Selection of Series Products and Associated External Components

1. Selecting a product

The S-8540/41 series is classified into eight types according to the way of control (PWM and PWM/PFM switching), the oscillation frequencies, and output voltage settings (fixed and feed back). Please select the type that suits your needs best by taking the advantage described below into account.

(1) Control method:

Two different control methods are available: PWM control (S-8540 Series) and PWM/PFM switching control (S-8541 Series).

(2) Oscillation frequencies:

Two oscillation frequencies -- 600 kHz (A & B Series) and 300 kHz (C & D Series) -- are available.

Because of their high oscillation frequency, the products in the A and B Series allow the use of small size inductors since the peak current decreases when the same load current flows. In addition, they can also be used with small output capacitors. These outstanding features make the A & B series ideal for downsized devices.

On the other hand, the C & D series, having lower oscillation frequency, are characterized by small self-consumption current and excellent efficiency under light load.

(3) Output voltage setting:

Two different types are available: fixed output (A & C series) and feed back type (B & D series).

The table below provides a rough guide for selecting a product depending on the requirements of the application. Choose the product that has the best score (○).

	S-8540				S-8541			
	A	B	C	D	A	B	C	D
The set output voltage is fixed (1.5 to 6.0 V)	☆		☆		☆		☆	
Set an output voltage freely (1.5 to 6.0 V)		☆		☆		☆		☆
The efficiency at light load (less than 10mA) is important.					○	○	○	○
The efficiency at 100mA or more is important.			○	○			○	○
Low-ripple voltage is important.	○	○			○	○		
Use of small external parts is Important.	⊙	⊙			⊙	⊙		

The symbol "☆" denotes an indispensable condition, while the symbol "○" indicates that the corresponding series has superiority in that aspect. The symbol "⊙" indicates particularly high score.

2. 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 Ipk 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 Ipk 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.

When the inductance is large in an S-8540/41 series product, the output voltage may grow unstable in some cases, depending on the conditions of the input voltage, output voltage, and the load current. Perform sufficient evaluation under the actual condition and decide an optimum inductance.
In many applications, an inductance of 10 µH for A/B series and 22 µH for C/D series will yield the best characteristics of the S-8540/41 series 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 equation in non-continuous operation mode:

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

Where fosc is the oscillation frequency and L is the inductance value of the inductor.

3. Diode

The diode should meet the following conditions:
- The forward voltage is low (Schottky barrier diode is recommended).
- The switching speed is high (50 ns max.).
- The reverse breakdown voltage is higher than V_{IN}.
- The current rating is larger than I_{PK}.

4. Capacitors

4.1 Input/output capacitors (C_{IN}, C_{OUT})

The capacitor inserted in the input side (C_{IN}) serves to reduce the power impedance and to average the input current for better efficiency. The C_{IN} value 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 side capacitor. A tantalum electrolytic capacitor is recommended since the unstable area widens when a capacitor with a large ESR, such as an aluminum electrolytic capacitor, or a capacitor with a small ESR, such as a ceramic capacitor, is chosen. The range of the capacitance should generally be 47 µF to 100 µF.

4.2 Internal power source stabilization capacitor (CVL)

The main circuits of the IC work on an internal power source connected to the CVREF pin. The CVL is a bypass capacitor for stabilizing the internal power source. CVL should be a 1µF ceramic capacitor and should be wired in a short distance and at a low impedance.

5. External Switching Transistors

The S-8540/41 series can work with an enhancement (Pch) MOSFET or a bipolar (PNP) transistor as an external switching transistor.

5.1 Enhancement MOSFET

The EXT pin of the S-8540/41 series can directly drive the Pch power MOSFET with a gate capacity of approximate 1200 pF.
When a Pch power MOSFET is chosen, efficiency will be 2 to 3% higher than that achieved by a PNP 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 a Pch power MOSFET are the threshold voltage, breakdown voltage between gate and source, breakdown voltage between drain and source, total gate capacity, on-resistance, and the current ratings.

The EXT pin swings from voltage V_{IN} to V_{SS}. When the input voltage is low, a MOS FET with a low threshold voltage has to be used so that the MOSFET will turn on as required. When, conversely, the input voltage is high, select a MOSFET whose gate-source breakdown voltage is higher than the input voltage by at least several volts.

Immediately after the power is turned on, or the power is turned off (that is, when the step-down operation is terminated), the input voltage is applied across the drain and the source of the MOSFET. The transistor therefore needs to have drain-source breakdown voltage that is also several volts higher than the input voltage.

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

The power loss for charging and discharging the gate capacity by switching operation will affect the efficiency at low load current region more when the total gate capacity becomes larger and the input voltage becomes higher. If the efficiency at low load is a matter of concern, select a MOSFET with a small total gate capacity.

In regions where the load current is high, the efficiency is affected by power loss caused by the on-resistance of the MOSFET. If the efficiency under heavy load is particularly important in the application, choose a MOSFET 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}.

5.2 PNP Bipolar Transistor

Figure 7 shows a circuit diagram using Toshiba 2SA1213-Y for the bipolar transistor (PNP). Using a bipolar transistor, the driving capacity for increasing the output current is determined by the h_{FE} value and the Rb value.

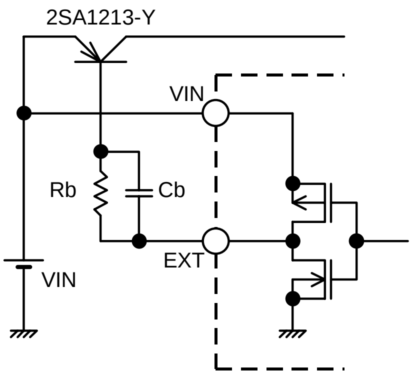


Figure 7

The Rb value is given by the following equation:

$$Rb = \frac{V_{IN} - 0.7}{Ib} - \frac{0.4}{\left|I_{EXTL}\right|}$$

Calculate the necessary base current Ib using the h_{FE} value of the bipolar transistor from the relation, Ib = I_{PK}/h_{FE}, and select a smaller value for Rb which is calculated from the above equation.

A small Rb value will certainly contribute to increase the output current, but it will also decrease the efficiency. Determine the optimum value through experiment since the base current flows as pulses and voltage drop may takes place due to the wiring resistance and so on.

In addition, if speed-up capacitor Cb is inserted in parallel with resistance Rb, as shown in figure 7, the switching loss will be reduced, leading to a higher efficiency.

Select a Cb value by using the following equation :

$$Cb \leq \frac{1}{2\pi \times Rb \times fosc \times 0.7}$$

Adjust the optimum Cb value, however, through experiment since the optimum Cb value differs depending upon the characteristics of the bipolar transistor.

■ Standard Circuits

(1) Fixed output voltage (Pch MOSFET)

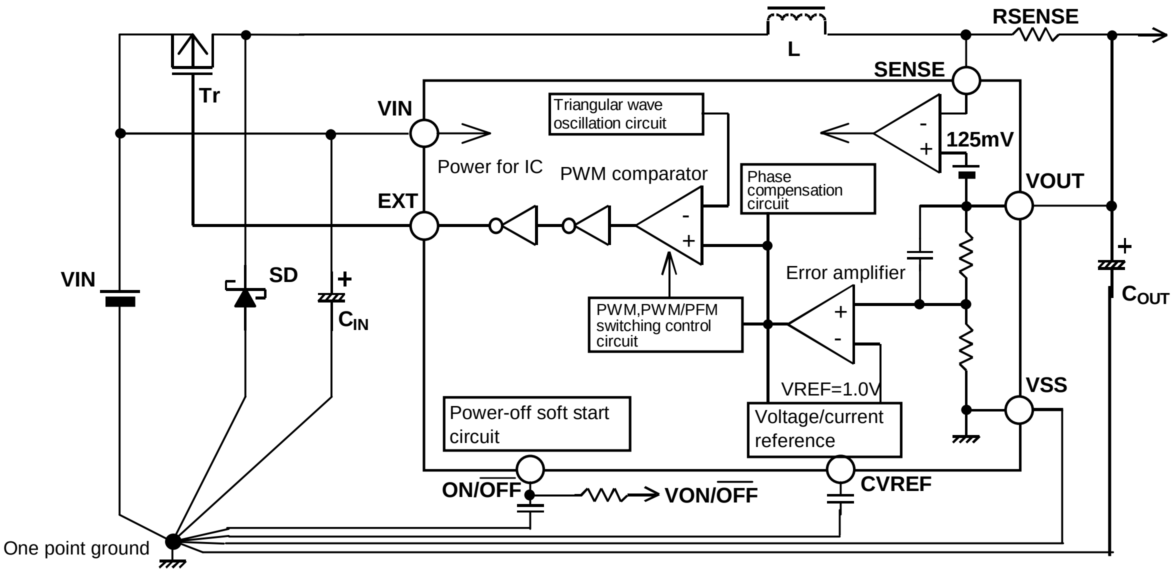


Figure 8 Fixed output voltage

(2) Feed back type (Pch MOSFET)

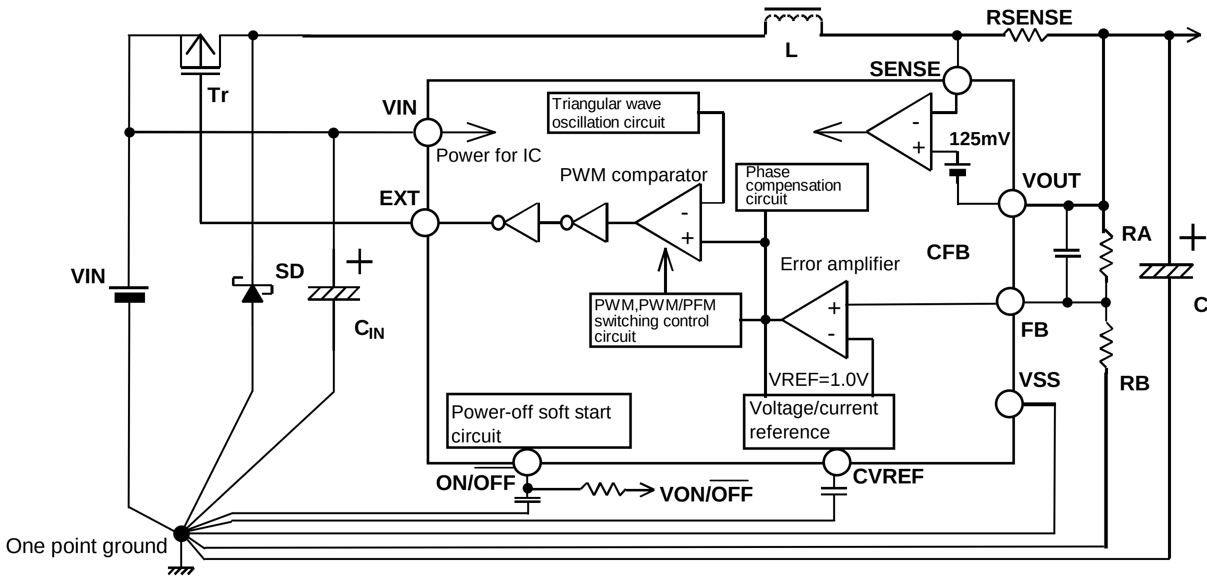


Figure 9 External setting output voltage

Output voltage adjustment

The output voltage can be adjusted or changed in the output voltage setting range (1.5 to 6.0 V) by adding external resistors (RA, RB) and a capacitor (CFB) in the S-8540/41B00AFN and S-8540/41D00AFN series. Temperature gradient can be given by inserting a thermistor in series to RA and RB.

RA+RB must be equal to or less than 2MΩ and the ratio of RA to RB should be set so that the FB pin is 1.0 V. Add a capacitor (CFB) in parallel to the external resistor (RA) to prevent unstable operation like output oscillation.

Set the CFB so that f = 1/(2×πCFB×RA) is 0.1 to 20 kHz (normally 10 kHz).

Example: When VOUT=3.0 V, RA=200kΩ, RB=100kΩ, then CFB=100pF

The precision of output voltage (V_{OUT}) determined by the resistors (RA, RB) is affected by the precision of the voltage at the FB pin (1 V±2.0%), the precision of external resistors RA and RB, current input to the FB pin, and IC power supply voltage V_{DD}.
Suppose that the FB pin input current is 0 nA, and that the maximum absolute values of the external resistors RA and RB are RAmax and Rbmax, and the minimum absolute values of the external resistors RA and RB are RAmin and RBmin, and that the output voltage shift due to the V_{DD} voltage dependency is ΔV, the minimum value V_{OUTmin} and maximum value V_{OUTmax} of the output voltage V_{OUT} variation is calculated by the following formula:

$$V_{OUTmin} = (1+\frac{RAmin}{RBmax})\times 0.98-\Delta V \quad [V]$$

$$V_{OUTmin} = (1+\frac{RAmax}{RBmin})\times 1.02+\Delta V \quad [V]$$

The precision of the output voltage V_{OUT} cannot be made lower than the precision of the IC output voltage without adjustment of external resistors RA and RB. The lower the RA/RB, the less it is affected by the absolute value precision of the external resistors RA and RB. The lower the RA and RB, the less it is affected by the FB pin input current.
To suppress the influence of FB pin input current on the variation of output voltage V_{OUT}, the external resistor RB value must be made sufficiently lower than the input impedance of the FB pin, 1V/50nA=20MΩmax.
Waste current flows through external resistors RA and RB. When it is not a negligible value with respect to load current in actual use, the efficiency decreases. The RA and RB values of the external resistors must therefore be made sufficiently high.
Evaluation of the influence of the noise is needed in the actual condition If the RA and RB values of resistors are high (1MΩ or higher) since they are susceptible to external noise.
The output voltage V_{OUT} precision and the waste current are in a trade-off relation. They must be considered according to application requests.

■ Precautions

- Install the external capacitors, diode, coil, and other peripheral components as close to the IC as possible, and make a one-point grounding.
  When the input voltage is 9 to 10 V, V_{OUT} may vary largely according to the grounding method.
  When it is difficult to make one-point grounding, use two grounds: one for VIN, CIN, and SD GND, and the other for VOUT, CVREF, and IC GND.
- A switching regulator produces ripple voltage and spike noise, which are largely dictated by the coil and the capacitors in use. When designing a circuit, check them in under actual condition.
- If the input voltage is high and 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.
- If the input power supply voltage is lower than 1.0 V, the IC operation is unstable and the external switch may be turned on.
  If input power supply voltage is 10.0 V or higher, the circuit operation is unstable and the IC may be damaged.
  The input voltage must be in the standard range (2.5 to 10.0 V).
  The current limit circuit of the IC limits current by detecting a voltage difference of external resistor R_{SENSE}. In choosing the components, make sure that overcurrent will not surpass the allowable dissipation of the switching transistor and the inductor.
- Make sure that dissipation of the switching transistor will not surpass the allowable power dissipation of the package. (especially at high temperature)

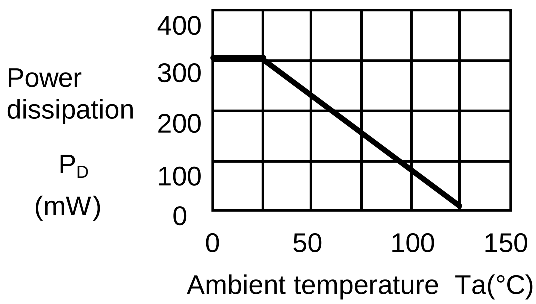
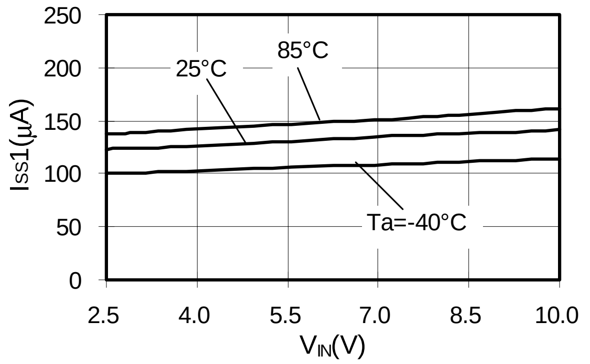


Figure 10 8-pin MSOP Package Power Dissipation in Free Air

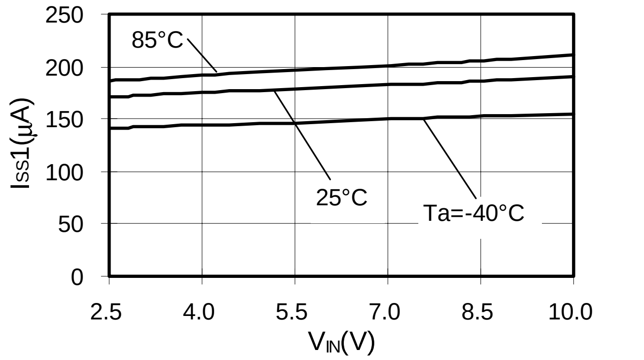
- Seiko Instruments Inc. shall bear no responsibility for any patent infringement by a product that includes an IC manufactured by Seiko Instruments Inc. in relation to the method of using the IC in that product, the product specifications, or the destination country.

■ Characteristics of Major Parameters (Typical values)

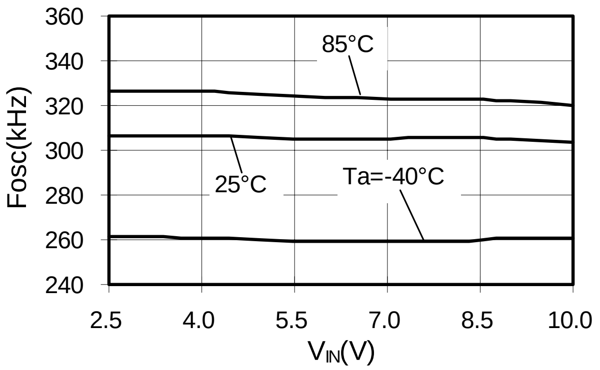
(1) I_{SS1} — V_{IN} S-8540/41(300kHz)



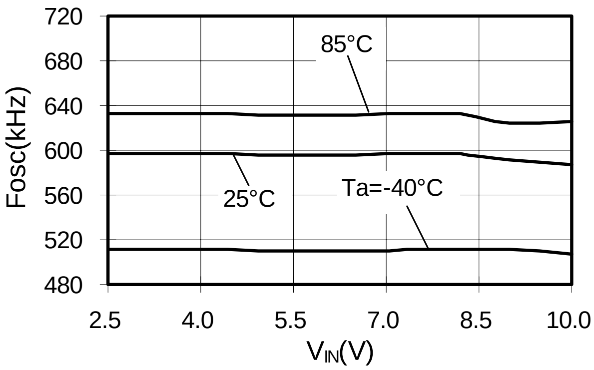
(2) I_{SS1} — V_{IN} S-8540/41(600kHz)



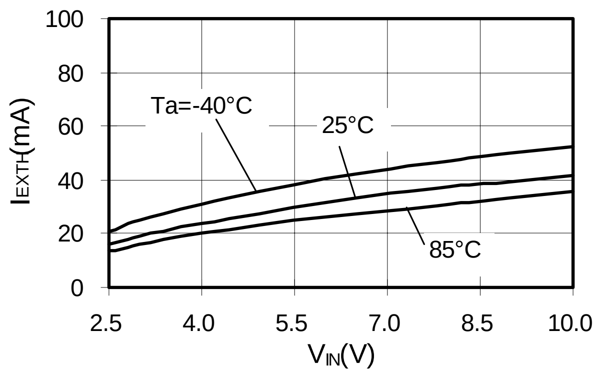
(3) Fosc — V_{IN} S-8540/41(300kHz)



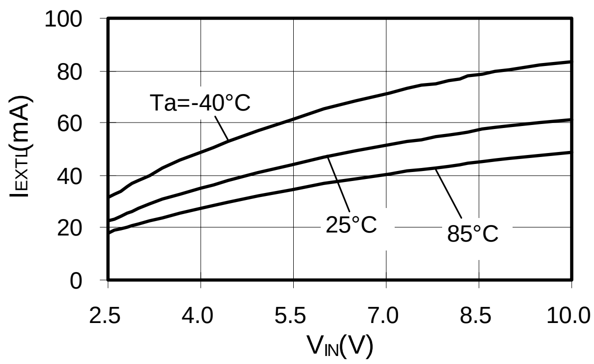
(4) Fosc — V_{IN} S-8540/41(600kHz)



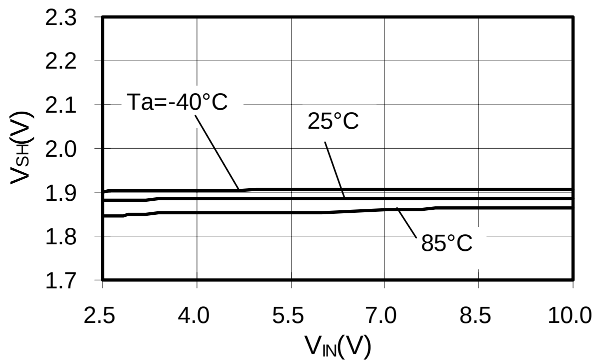
(5) I_{EXTH} — V_{IN} S-8540/41



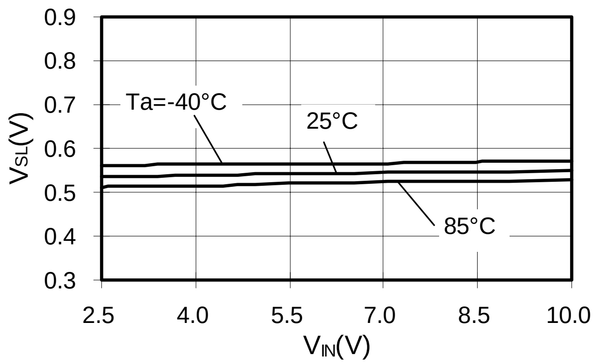
(6) I_{EXTL} — V_{IN} S-8540/41



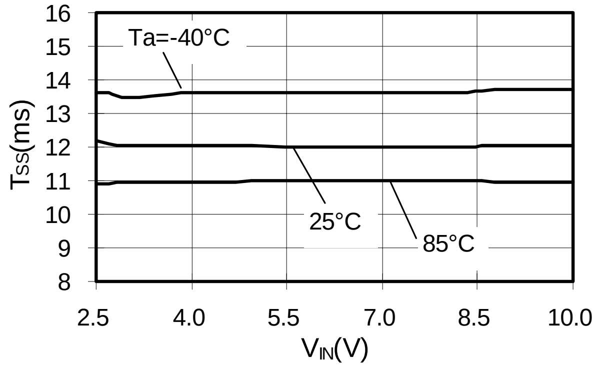
(7) V_{SH} — V_{IN} S-8540/41



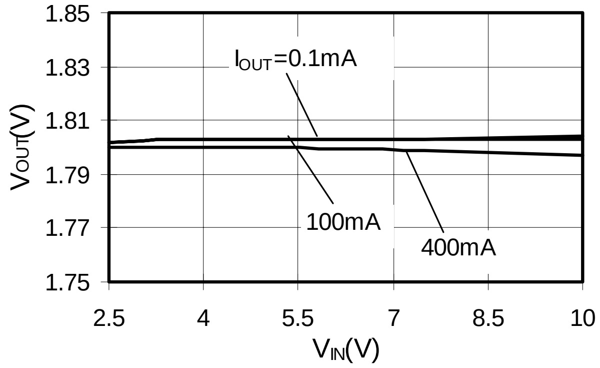
(8) V_{SL} — V_{IN} S-8540/41



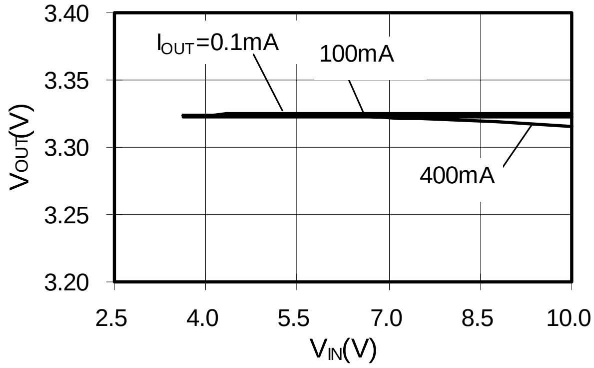
(9) T_{SS} — V_{IN}



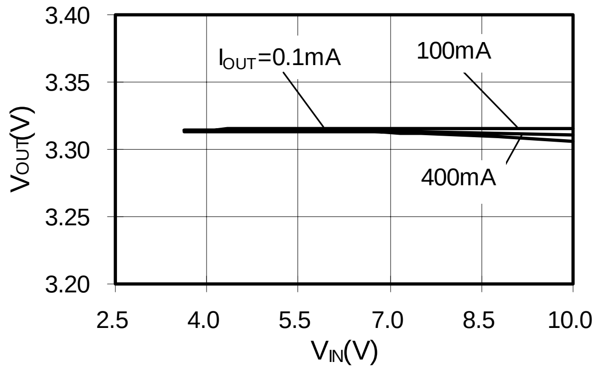
(10) V_{OUT} — V_{IN} 1.8V PWM/PFM 600kHz



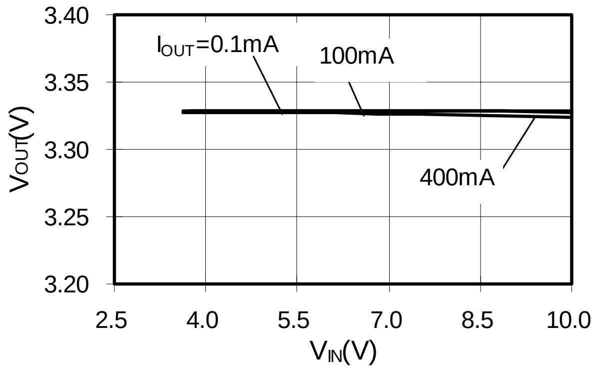
(11) V_{OUT} — V_{IN} 3.3V PWM/PFM 600kHz



(12) V_{OUT} — V_{IN} 3.3V PWM/PFM 600kHz



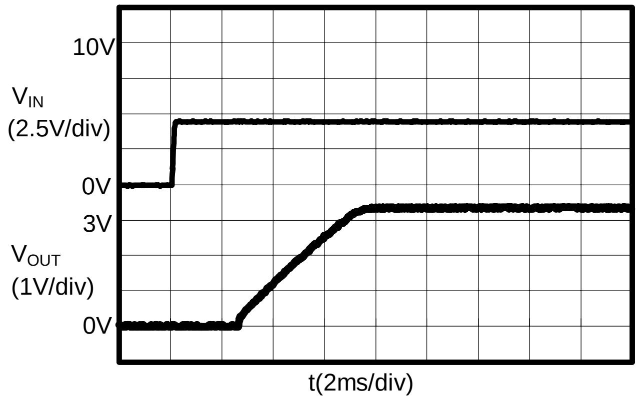
(13) V_{OUT} — V_{IN} 3.3V PWM/PFM 300kHz



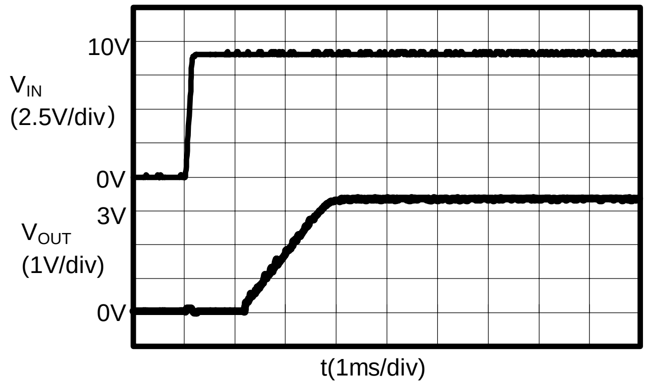
■ Transient Response Characteristics

1. Power-On(V_{IN};0V→ 4.95V or 0V→ 2.7V, 0V→ 10V I_{OUT};No Load)

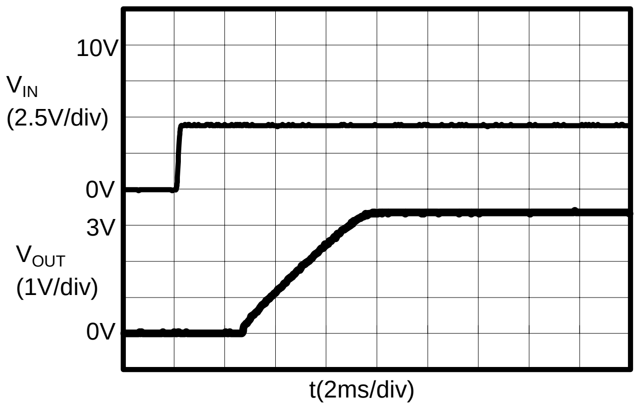
(1) S-8540A33FN(V_{IN};0V→ 4.95V)



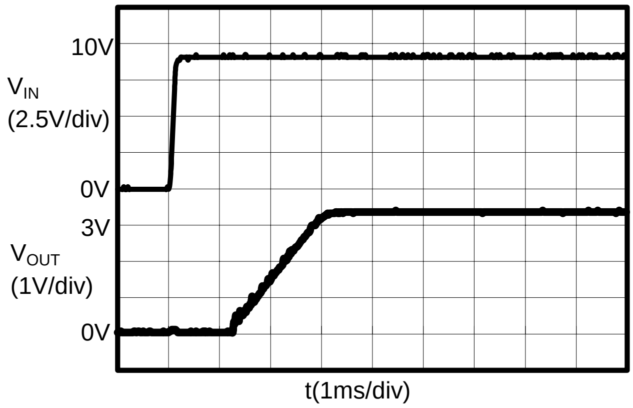
(2) S-8540A33FN(V_{IN};0V→ 10V)



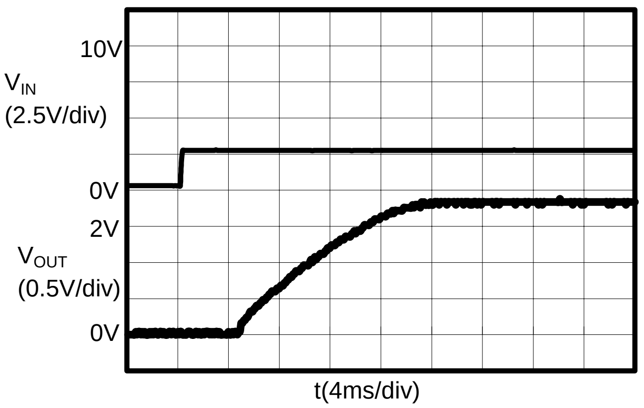
(3) S-8540C33FN(V_{IN};0V→ 4.95V)



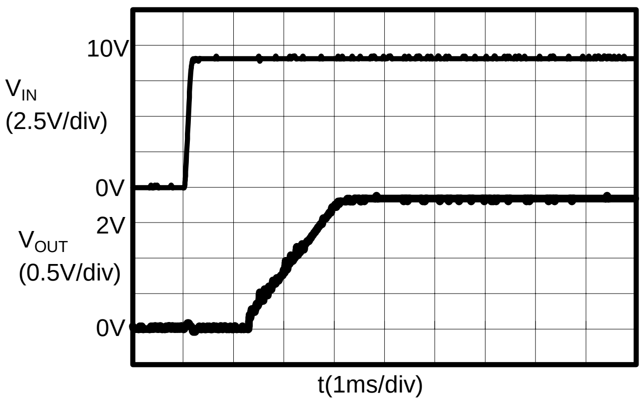
(4) S-8540C33FN(V_{IN};0V→ 10V)



(5) S-8540A18FN(V_{IN};0V→ 2.7V)

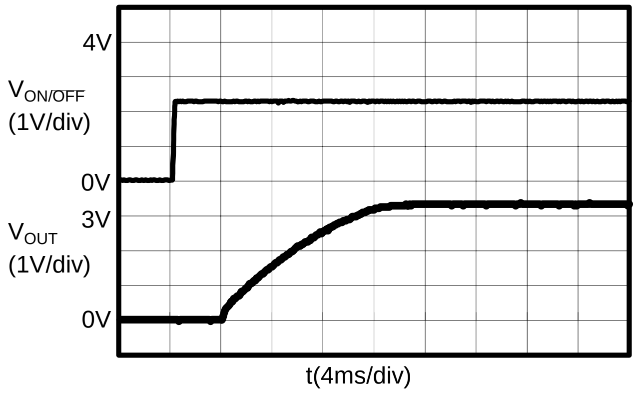


(6) S-8540A18FN(V_{IN};0V→ 10V)

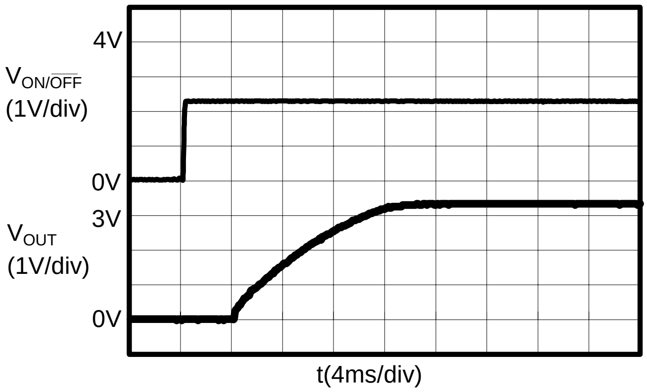


2.Power-Off Terminal Response (ON/$\overline{\text{OFF}}$;0V→ 2.5V I_{OUT};No Load)

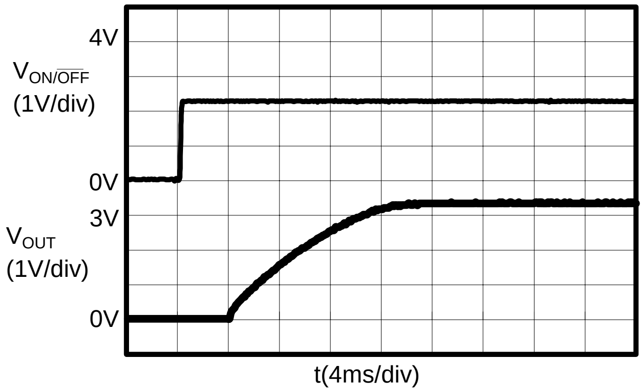
(1) S-8540A33FN(V_{IN}; 4.95V)



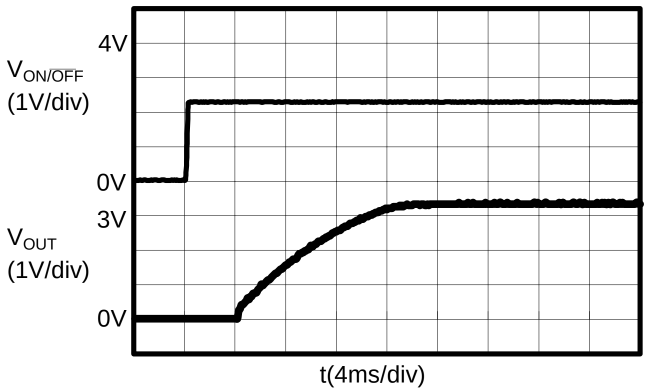
(2) S-8540A33FN(V_{IN}; 10V)



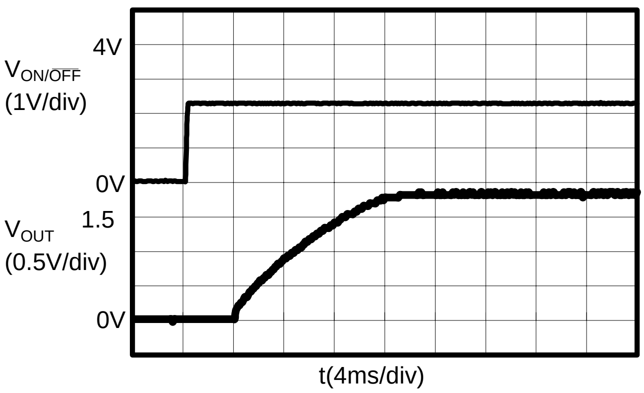
(3) S-8540C33FN(V_{IN}; 4.95V)



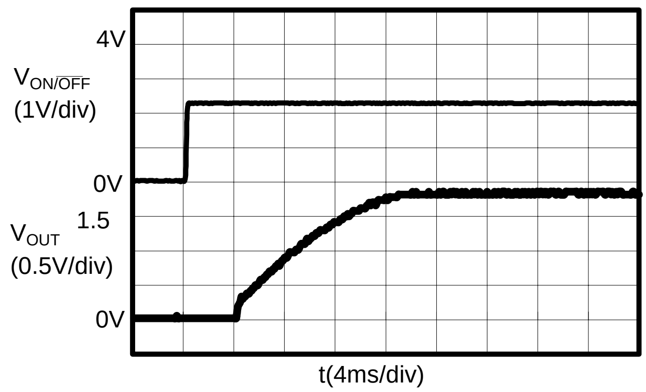
(4) S-8540C33FN(V_{IN}; 10V)



(5) S-8540A18FN(V_{IN}; 4.95V)

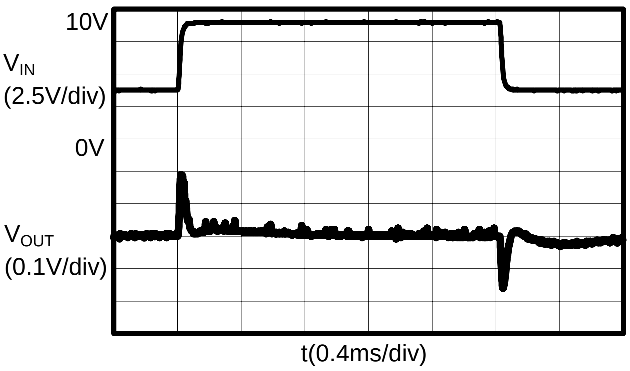


(6) S-8540A18FN(V_{IN}; 10V)

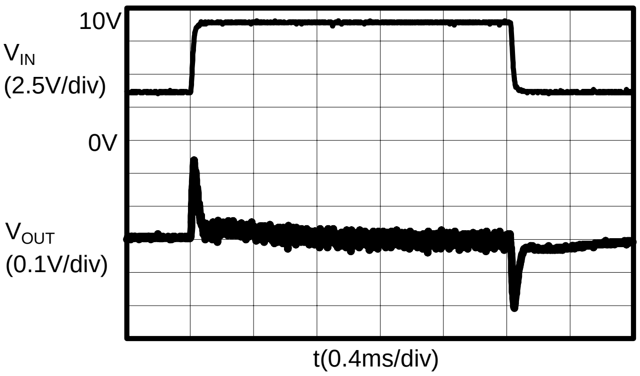


3.Supply Voltage Variation (V_{IN};3.6V→ 9.0V→ 3.6V)

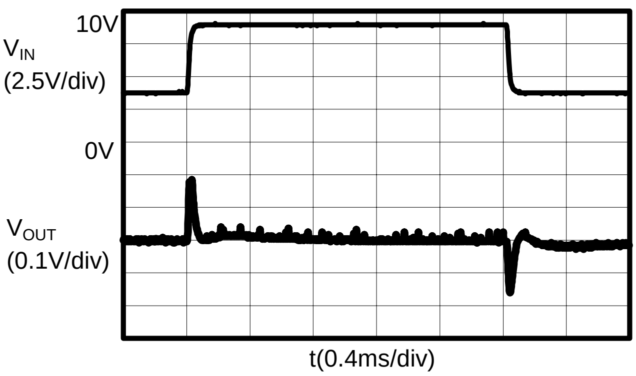
(1) S-8540A33FN(I_{OUT};10mA)



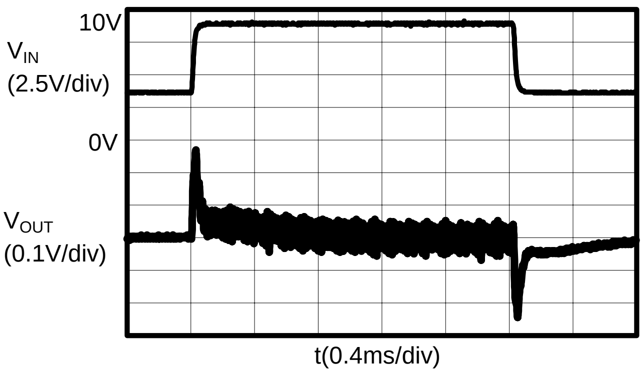
(2) S-8540A33FN(I_{OUT};500mA)



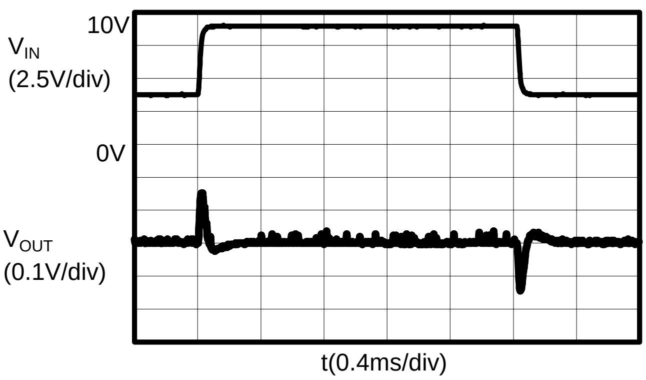
(3) S-8540C33FN(I_{OUT};10mA)



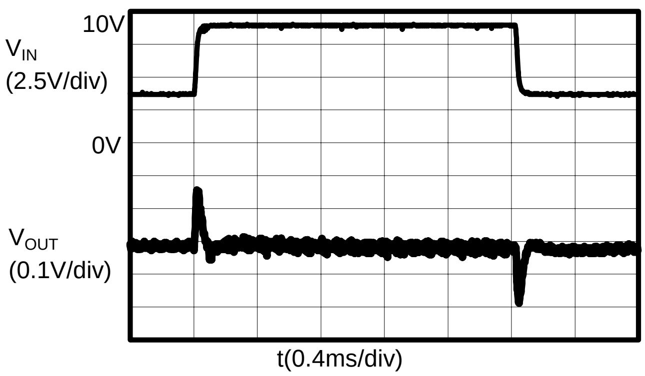
(4) S-8540C33FN(I_{OUT};500mA)



(5) S-8540B18AFT(I_{OUT};10mA)

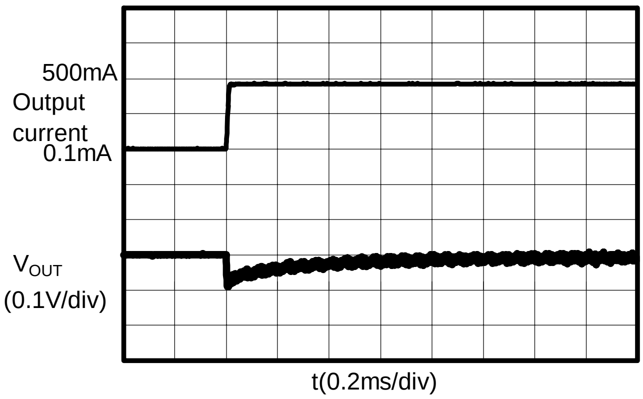


(6) S-8540B18AFT(I_{OUT};500mA)

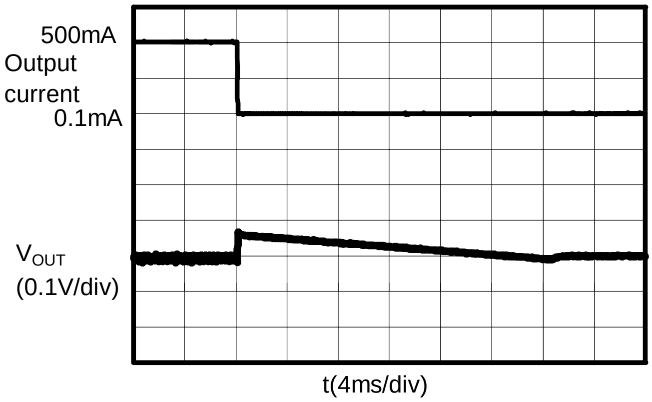


4.Load Variation (V_{IN};2.7V or 5.0V or 7.5V, I_{OUT};0.1mA $\rightarrow$ 500mA, 500mA $\rightarrow$ 0.1mA)

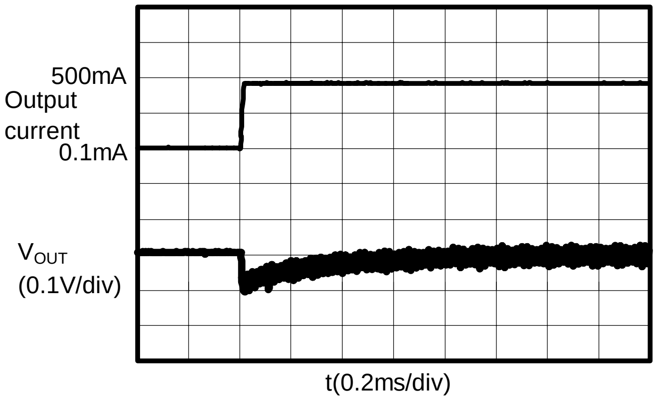
(1) S-8540A33FN(V_{IN};4.95V)



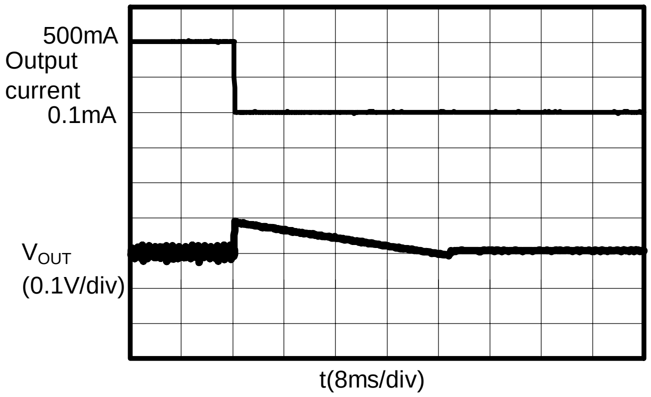
(2) S-8540A33FN(V_{IN};4.95V)



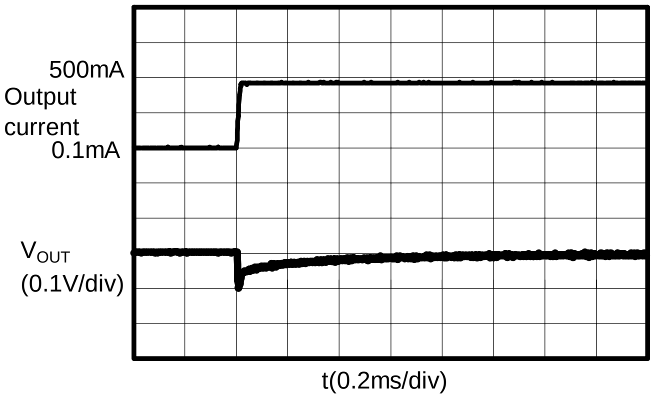
(3) S-8540C33FN(V_{IN};4.95V)



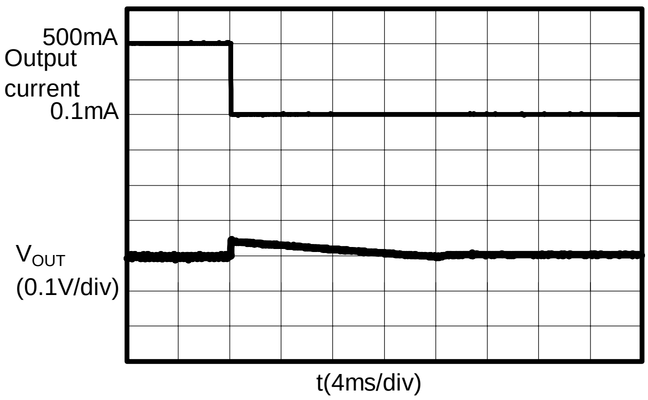
(4) S-8540C33FN(V_{IN};4.95V)



(5) S-8540A18FN(V_{IN};2.7V)



(6) S-8540A18FN(V_{IN};2.7V)



■ 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 show typical values

1. External components list for efficiency vs output current characteristics

Small and thin application using 1.3mm or less tall components (Maximum load current : 0.9A)

No.	Product Name	Output Voltage	Modulation	fosc	Inductor	Transistor	Diode	Output Capacitor
(1)	S-8540A33FN	3.3 V	PWM	600kHz	LDR655312T-4R7	CPH6301	RB491D	F920J476MB×2
(2)	S-8541A33FN	↑	PWM/PFM	↑	↑	↑	↑	↑
(3)	S-8540A25FN	2.5V	PWM	↑	↑	↑	↑	↑
(4)	S-8541A25FN	↑	PWM/PFM	↑	↑	↑	↑	↑
(5)	S-8540A18FN	1.8	PWM	↑	↑	↑	↑	↑
(6)	S-8541A18FN	↑	PWM/PFM	↑	↑	↑	↑	↑

High efficiency application using 3.0mm or less tall components (Maximum load current : 1.0A)

No.	Product Name	Output Voltage	Modulation	fosc	Inductor	Transistor	Diode	Output Capacitor
(7)	S-8540C33FN	3.3 V	PWM	300kHz	CDRH6D28-220	CPH6301	RB491D	F931A476MN×1
(8)	S-8541C33FN	↑	PWM/PFM	↑	↑	↑	↑	↑
(9)	S-8540C25FN	2.5V	PWM	↑	↑	↑	↑	↑
(10)	S-8541C25FN	↑	PWM/PFM	↑	↑	↑	↑	↑
(11)	S-8541C18FN	1.8	PWM	↑	↑	↑	↑	↑
(12)	S-8541C18FN	↑	PWM/PFM	↑	↑	↑	↑	↑

2. External components list for ripple voltage vs output current characteristics

No.	Product Name	Output Voltage	Modulation	fosc	Inductor	Transistor	Diode	Output Capacitor
(13)	S-8540A33FN	3.3 V	PWM	600kHz	LDR655312T-4R7	CPH6301	RB491D	F920J476MB×2
(14)	S-8541A33FN	↑	PWM/PFM	↑	↑	↑	↑	↑
(15)	S-8540A18FN	1.8V	PWM	↑	↑	↑	↑	↑
(16)	S-8541A18FN	↑	PWM/PFM	↑	↑	↑	↑	↑
(17)	S-8540C33FN	3.3 V	PWM	300kHz	CDRH6D28-220	CPH6301	RB491D	F931A476MN×1
(18)	S-8541C33FN	↑	PWM/PFM	↑	↑	↑	↑	↑
(19)	S-8540C18FN	1.8V	PWM	↑	↑	↑	↑	↑
(20)	S-8541C18FN	↑	PWM/PFM	↑	↑	↑	↑	↑

Performance Data

Component	Product Name	Manufacturer	L-Value	DC Resistance	Maximum Current	Size (LxWxH)
Inductor	LDR655312T-4R7*	TDK	4.7μH	0.19Ω	0.9A	6.5x5.3x1.25
	CDRH6D28-220	Sumida	22.0μH	0.128Ω	1.2A	7.0x7.0x3.0x
Diode	RB491D	Rohm	Forward current 1.0A at VF=0.45V, Vrm=25V			3.0x3.1x1.3
Output Capacity (tantalum electrolytic)	F920J476MB	Nichicon	47μF, 6.3V			3.6x3.0x1.2
	F931A476MC	Nichicon	47μF, 10.0V			6.2x3.4x2.7
Transistor (MOSFET)	CPH6301	Sanyo	Vdss=20V max., Vgss=10V max., ID =3.0A max., Ciss=360pF, Ron=110mΩ			2.9x2.8x0.9

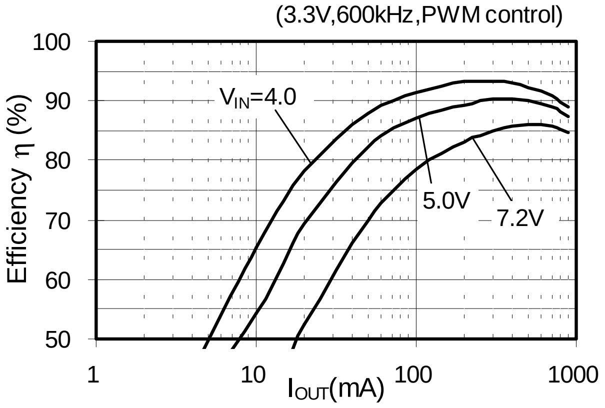
Note:

* : Inductor LDR655312T-4R7 is a new product. Please contact the following department for detail.

TDK: Business Promotion Department
Power Electronics Products Division
Electronics Components Business Group
Tel: +81-3-5201-7206 Fax : +81-3-5201-7207

1. Efficiency η — Output current I_{OUT} Characteristics

(1) S-8540A33FN



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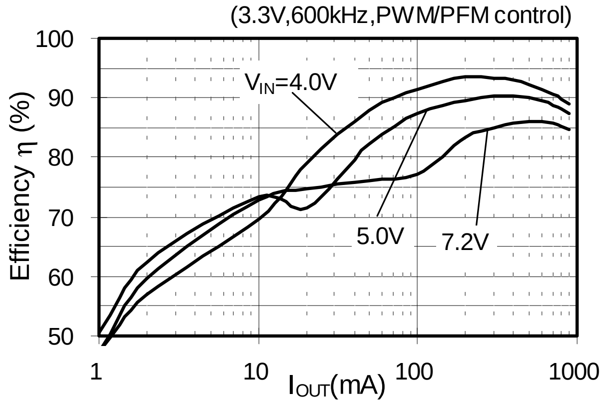

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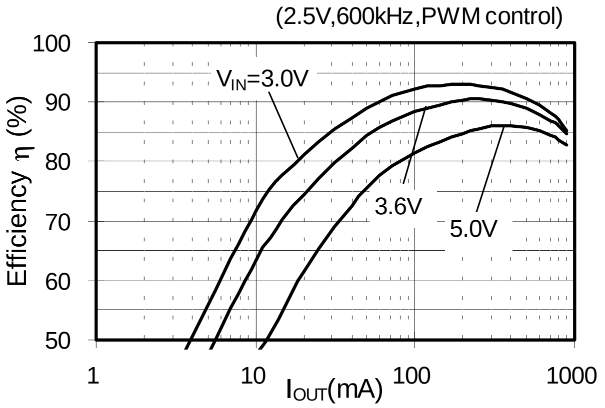

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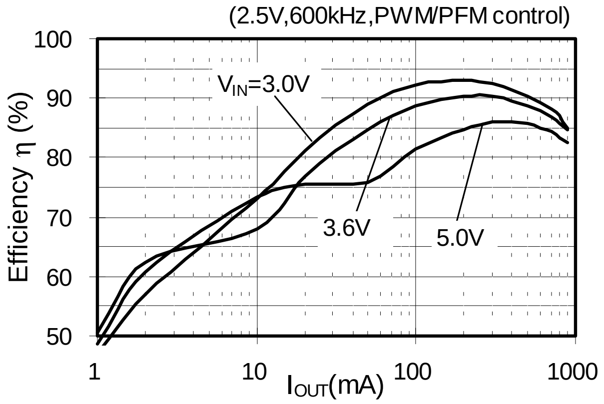

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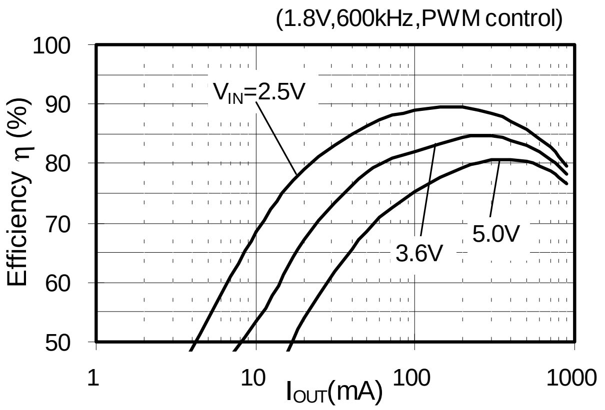

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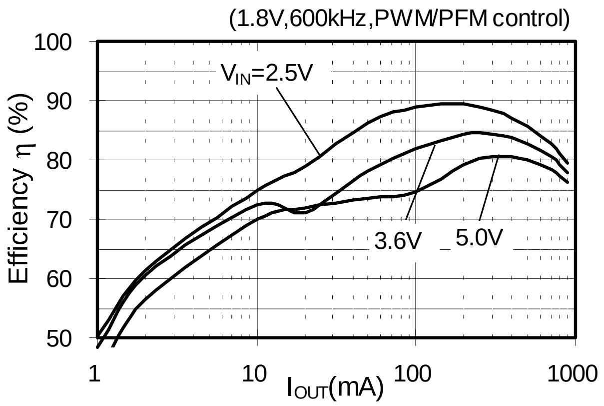

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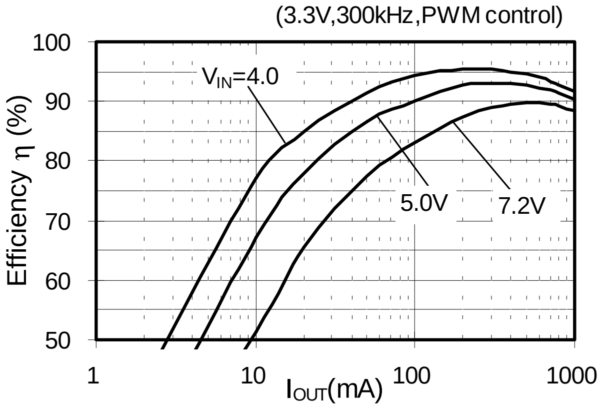

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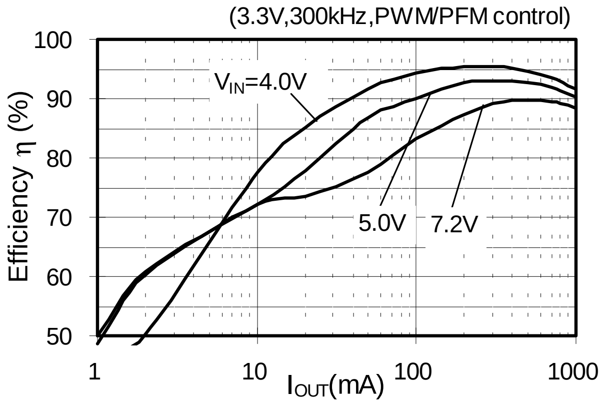

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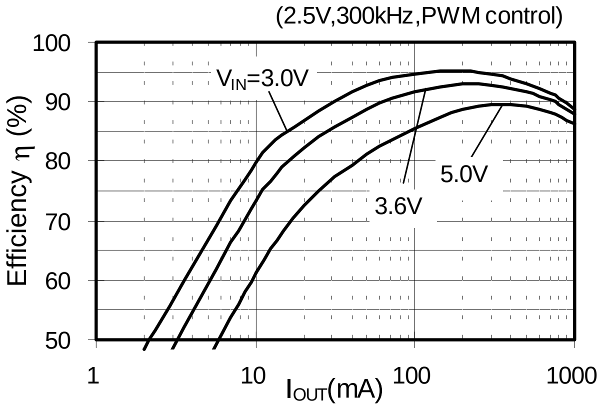

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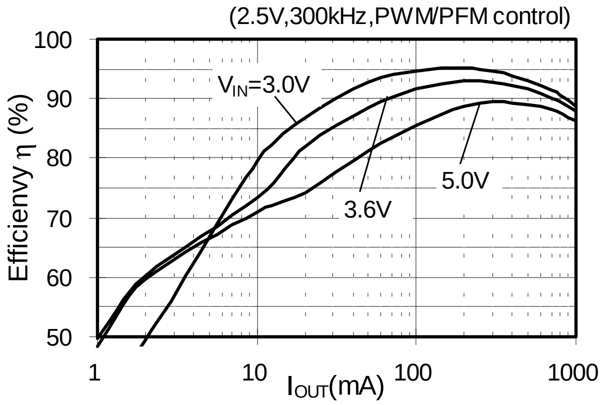

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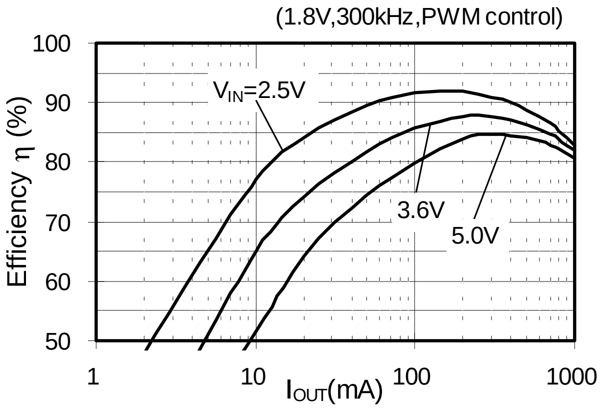

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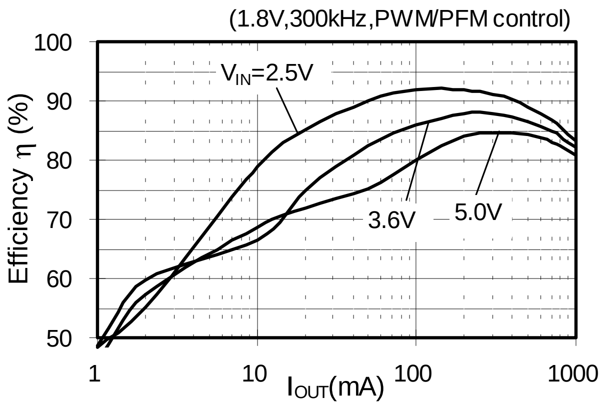
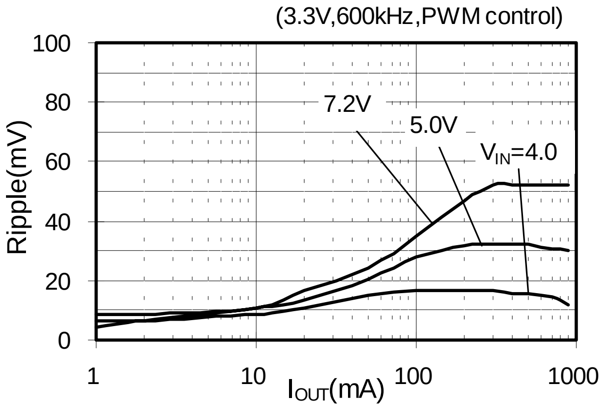


2. Ripple— Output current I_{OUT} Characteristics

(13) S-8540A33FN



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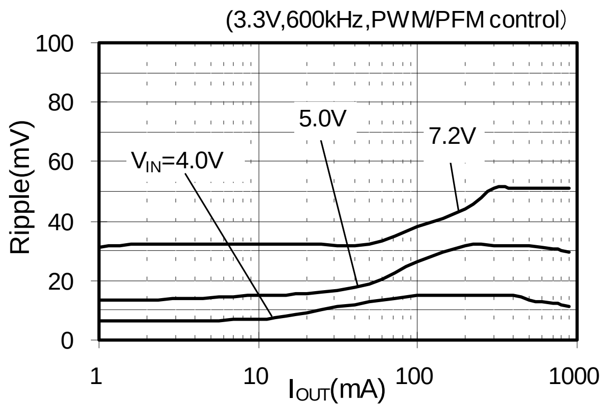

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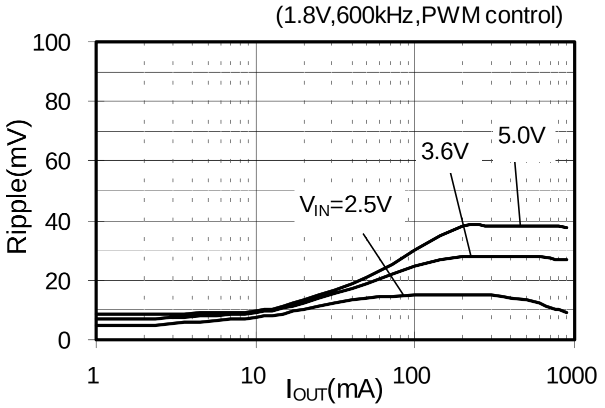

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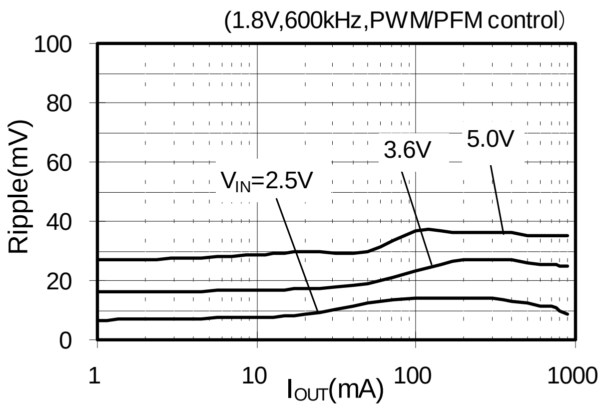

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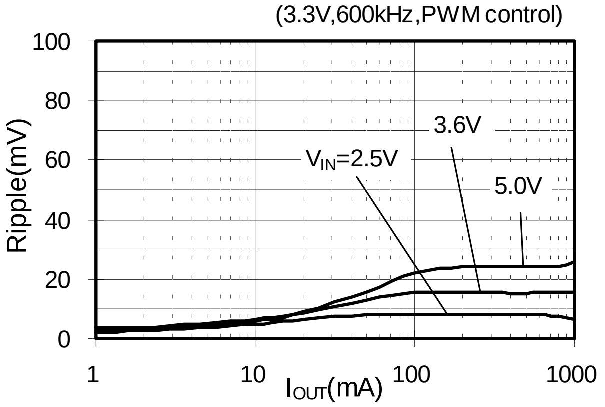

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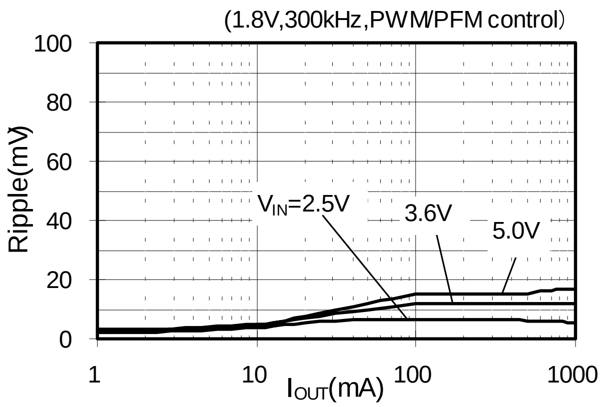

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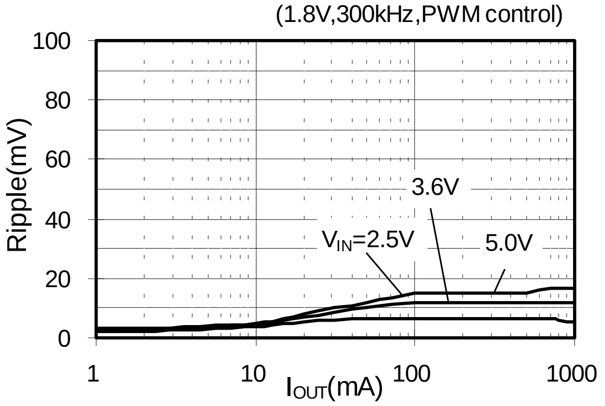
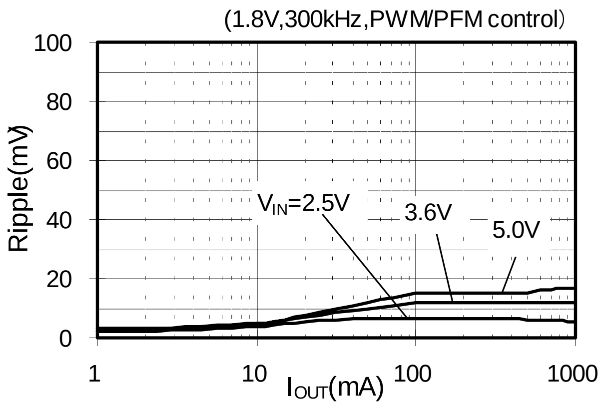


(20).S-8541C18FN

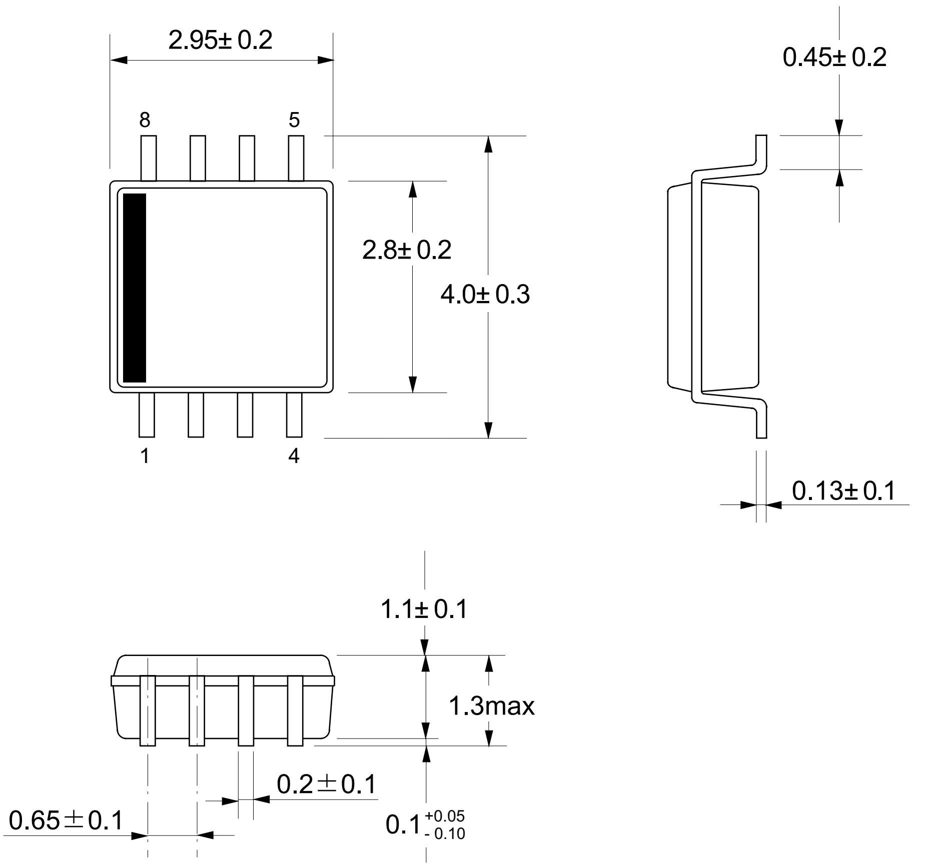


■ 8-pin MSOP

FN008-A 990531

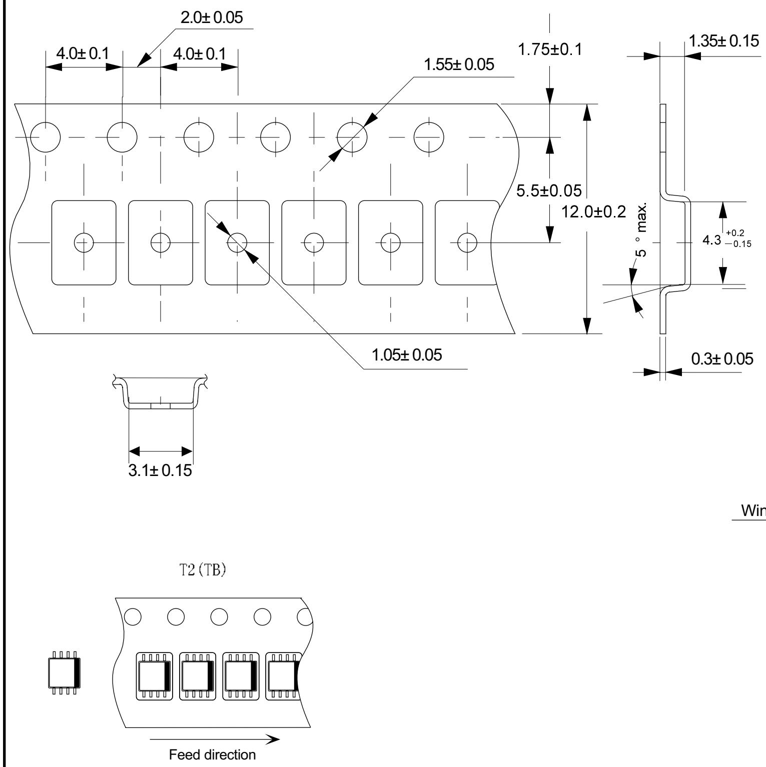
●Dimensions

Unit:mm



No.：FN008−A−P−SD−1.0

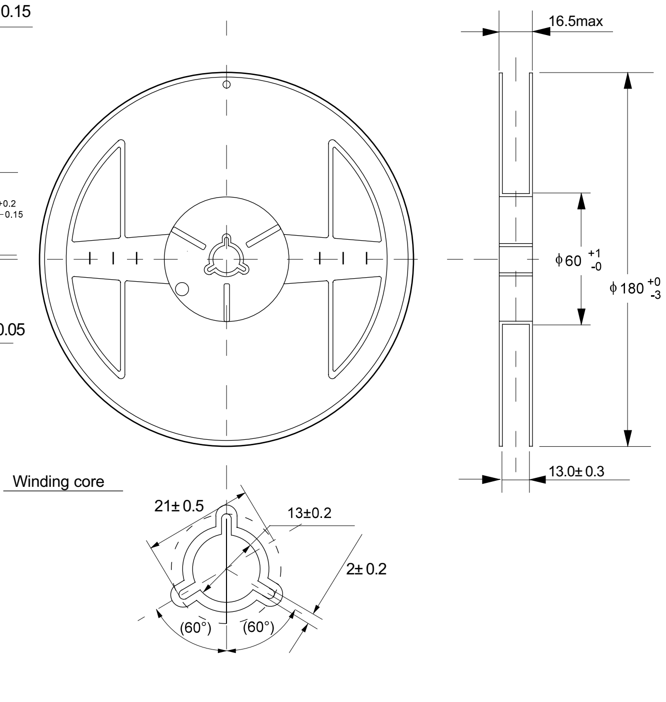
●Taping Specifications



No.：FN008−A−C−SD−1.0

●Reel Specifications

1 reel holds 3000 ICs.



No.：FN008−A−R−SD−1.0